Amrita Sai Institute of Science & Technology

Autonomous

Department of EEE

ENERGY AUDIT, CONSERVATION & MANAGEMENT

UNIT-I

Basic Principles of Energy Audit and management

Prepared by

K.SABARINATH

ASSISTANT PROFESSOR

ENERGY AUDITING

Energy Audit

An energy audit is an assessment of ho w much energy a home consumes and the development of a plan to make the home more energy efficient. An energy audit cannot only reveal ways to help conserve precious energy; it can also save you significant amounts of money by maximizing energy efficiency in your household. During an audit, an expert examines the building for energy leakages (such as air leaks) as well as ways to maximize energy usage (such as with more efficient lighting and heating/cooling systems).

Definition of Energy Audit

An energy audit is a review of current energy costs so that a company can achieve savings. An audit is conducted by a company's in-house personnel or by a professional energy audit firm. If an audit firm does the audit, they either charge a flat fee or ask that you pay them a percentage of the savings achieved. The three types of energy audit are a preliminary audit, the general audit and an investment grade audit, according to Gard Analytics.

Definition

An **energy audit** is an inspection, survey and analysis of energy flows for energy conservation in a building, processor system to reduce the amount of energy input into the system without negatively affecting the output(s).

History

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

Principle

When the object of study is an occupied building then reducing energy consumption while maintaining or improving human comfort, health and safety are of primary concern. Beyond simply identifying the sources of energy use, an energy audit seeks to prioritize the energy uses according to the greatest to least cost effective opportunities for energy savings.

Home energy audit

A home energy audit is a service where the energy efficiency of a house is evaluated by a person using professional equipment (such as blo wer doors and infrared cameras), with the aim to suggest the best ways to improve energy efficiency in heating and cooling the house.

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

A home energy audit may include a written report estimating energy use given local climate criteria, thermostat settings, roof overhang, and solar orientation. This could show energy use for a given time period, say a year, and the impact of any suggested improvements per year. The accuracy of energy estimates are greatly improved when the homeowner's billing history is available showing the quantities of electricity, natural gas, fuel oil, or other energy sources consumed over a one or two-year period. A home energy audit is often used to identify cost effective ways to improve the comfort and efficiency of buildings. In addition, homes may qualify for energy efficiency grants from central government.

Industrial energy audits

Increasingly in the last several decades, industrial energy audits have exploded as the demand to lower increasingly expensive energy costs and move towards a sustainable future have made energy audits greatly important. Their importance is magnified since energy spending is a major expense to industrial companies (energy spending accounts for ~ 10 % of the average manufacturer's expenses). This growing trend should only continue as energy costs continue to rise.

While the overall concept is similar to a home or residential energy audit, industrial energy audits require a different skill set. Weatherproofing and insulating a house are the main focus of residential energy audits. For industrial applications, weatherproofing and insulating often are minor concerns. In industrial energy audits, it is the HVAC, lighting, and production equipment that use the most energy.

Concept

Energy Concepts specializes in Energy Audits and Energy Star certifications in the East Texas area. We are proud to announce our most recent partnership in the Home Performance with Energy Star program.

If you are considering building a ne w home, Energy Concepts can provide the expertise to help design your new home’s energy efficiency. For existing home purchases, an energy audit can provide you with a detailed analysis showing you potential problems with your future home.

Types of Audits

The Audit Process

In general, a typical audit includes the following sequential steps:

- Scheduling an opening conference to discuss the audit objectives, timing, and report format and distribution.
- Assessing the soundness of the internal controls or business systems and operations.
- Testing the internal controls to ensure proper operation.
- Discussing with management all preliminary observations.
- Discussing with management the draft audit report and their responses, if available, prior to release of the final audit report.
- Following up on critical issues raised in audit reports to determine if they have been successfully resolved.

Audits

Types of Audits and Reviews:

1. Financial Audits
2. Operational Audits

3. Department Reviews
4. Information Systems Audits
5. Integrated Audits
6. Investigative Audits or Reviews
7. Follow-up Audits

Financial Audit

A historically oriented, independent evaluation performed for the purpose of attesting to the fairness, accuracy, and reliability of financial data. CS ULB's external auditors, KP M G, perform this type of review. CS ULB's Director of Financial Reporting coordinates the work of these auditors on our campus.

Operational Audit

A future-oriented, systematic, and independent evaluation of organizational activities. Financial data may be used, but the primary sources of evidence are the operational policies and achievements related to organizational objectives. Internal controls and efficiencies may be evaluated during this type of review.

Department Review

A current period analysis of administrative functions, to evaluate the adequacy of controls, safeguarding of assets, efficient use of resources, compliance with related laws, regulations and University policy and integrity of financial information.

Informationon Systems (IS) Audit

There are three basic kinds of IS Audits that may be performed:

1. **General Controls Review**

   A review of the controls which govern the development, operation, maintenance, and security of application systems in a particular environment. This type of audit might involve reviewing a data center, an operating system, a security software tool, or processes and procedures (such as the procedure for controlling production program changes), etc.

2. **Application Controls Review**

   A review of controls for a specific application system. This would involve an examination of the controls over the input, processing, and output of system data. Data communications issues, program and data security, system change control, and data quality issues are also considered.

3. **System Development Review**

   A review of the development of a new application system. This involves an evaluation of the development process as well as the product. Consideration is also given to the general controls over a new application, particularly if a new operating environment or technical platform will be used.

Integrated Audit

This is a combination of an operational audit, department review, and IS audit application controls review. This type of review allows for a very comprehensive examination of a functional operation within the University.

Investigative Audit

This is an audit that takes place as a result of a report of unusual or suspicious activity on the part of an individual or a department. It is usually focused on specific aspects of the work of a department or individual. All members of the campus community are invited to report suspicions of improper activity to the Director of Internal Auditing Services on a confidential basis. Her direct number is 562-985-4818.

Follow-up Audit

These are audits conducted approximately six months after an internal or external audit report has been issued. They are designed to evaluate corrective action that has been taken on the audit issues reported in the original report. When these follow-up audits are done on external auditors' reports, the results of the follow-up may be reported to those external auditors.

Types of energy audit

The term energy audit is commonly used to describe a broad spectrum of energy studies ranging from a quick walk-through of a facility to identify major problem areas to a comprehensive analysis of the implications of alternative energy efficiency measures sufficient to satisfy the financial criteria of sophisticated investors. Numerous audit procedures have been developed for non-residential (tertiary) buildings. Audit is required to identify the most efficient and cost- effective Energy Conservation Opportunities (ECOs) or Measures (ECMs). Energy conservation opportunities (or measures) can consist in more efficient use or of partial or global replacement of the existing installation.
When looking to the existing audit methodologies developed in IEA-ECBCS Annex 11, by ASHRAE and by Krarti (2000), it appears that the main issues of an audit process are:

- The analysis of building and utility data, including study of the installed equipment and analysis of energy bills;
- The survey of the real operating conditions;
- The understanding of the building behaviour and of the interactions with weather, occupancy and operating schedules;
- The selection and the evaluation of energy conservation measures;
- The estimation of energy saving potential;
- The identification of customer concerns and needs.

Common types/levels of energy audits are distinguished below, although the actual tasks performed and level of effort may vary with the consultant providing services under these broad headings. The only way to ensure that a proposed audit will meet your specific needs is to spell out those requirements in a detailed scope of work. Taking the time to prepare a formal solicitation will also assure the building owner of receiving competitive and comparable proposals.

Generally, four levels of analysis can be outlined (ASHRAE):

- **Level 0** – Benchmarking: This first analysis consists in a preliminary Whole Building Energy Use (WBEU) analysis based on the analysis of the historic utility use and costs and the comparison of the performances of the buildings to those of similar buildings. This benchmarking of the studied installation allows determining if further analysis is required;

- **Level I** – Walk-through audit: Preliminary analysis made to assess building energy efficiency to identify not only simple and lo w-cost improvements but also a list of energy conservation measures (EC Ms, or energy conservation opportunities, ECOs) to orient the future detailed audit. This inspection is based on visual verifications, study of installed equipment and operating data and detailed analysis of recorded energy consumption collected during the benchmarking phase;

- **Level II** – Detailed/General energy audit: Based on the results of the pre-audit, this type of energy audit consists in energy use survey in order to provide a comprehensive analysis of the studied installation, a more detailed analysis of the facility, a breakdown of the energy use and a first quantitative evaluation of the ECOs/EC Ms selected to correct the defects or improve the existing installation. This level of analysis is can involve advanced on-site measurements and sophisticated computer based simulation tools to evaluate precisely the selected energy retrofits;

- **Level III –** Investment- Grade audit: Detailed Analysis of Capital-Intensive Modifications focusing on potential costly ECOs requiring rigorous engineering study.

Benchmarking

The impossibility of describing all possible situations that might be encountered during an audit means that it is necessary to find a way of describing what constitutes good, average and bad energy performance across a range of situations. The aim of benchmarking is to answer this question. Benchmarking mainly consists in comparing the measured consumption with reference consumption of other similar buildings or generated by simulation tools to identify excessive or unacceptable running costs. As mentioned before, benchmarking is also necessary to identify buildings presenting interesting energy saving potential. An important issue in benchmarking is the use of performance indexes to characterize the building.

These indexes can be:

- Comfort indexes, comparing the actual comfort conditions to the comfort requirements;
- Energy indexes, consisting in energy demands divided by heated/conditioned area, allowing comparison with reference values of the indexes coming from regulation or similar buildings;
- Energy demands, directly compared to "reference" energy demands generated by means of simulation tools.

Walk-through or Preliminary Energy Audit (PEA)

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

Typically, only major problem areas will be covered during this type of audit. Corrective measures are briefly described, and quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided. A list of energy conservation measures (EC Ms, or energy conservation opportunities, ECOs) requiring further consideration is also provided. This level of detail, while not sufficient for reaching a final decision on implementing proposed measure, is adequate to prioritize energy-efficiency projects and to determine the need for a more detailed audit.

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

Approach to Preliminary Energy Audit (PEA)

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

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

Normally the results of the audit would depend on:-

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

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

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

    b. Conduct plant walkthrough/visual inspection
    - Material/energy flow through plant
    - Major functional departments
    - Any installed instruments, including utility meters
    - Energy report procedures
    - Production and operational reporting procedures
    - Conservation opportunities
4. Analyze data
    a. Develop data base
    - Historical data for all energy suppliers

- Time frame basis
- Other related data
- Process flow sheets
- Energy-consuming equipment inventory

b. Evaluate-data
- Energy use-consumption, cost and schedules
- Energy consumption indices
- Plant operations
- Energy savings potential
- Plant energy management program
- Preliminary Energy Audit

5. Develop action plan
- Conservation opportunities for immediate implementation
- Projects for further study
- Refinement of corporate energy
- Resources for detailed energy audit
  - Systems for test
  - Instrumentation: portable and fixed
  - Manpower requirements
  - Time frame

6. Implementation
- Implementation identified low cost/no cost projects
- Perform detailed audit

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

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

Detailed Energy Audit (DEA)

This would be a comprehensive energy study using portable energy monitoring instruments. The essential part of this audit is carrying out various measurements and analyses covering individually every significant energy consuming plant item/processes, to determine their efficiencies and loss of energy at that point, and potential energy savings.

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

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

Measurements are critical in any serious effort to conserve energy. Apart from helping to quantify energy consumption, measurements also provide a means to monitor equipment performance and check equipment condition. Examples of measurements and instrument types are:

1. Flo w/ Velocity: Orifice plate, Picot tube, Ventura tube, Turbine meter, Vortex shedding flow meter
2. Temperature: Thermometers - Bimetallic, Resistance etc., Thermocouple, Radiation pyrometer.
3. Pressure: Bourdon gauge Diaphragm gauge, Manometers
4. Stack Gas Analysis: Or satapparatus, Oxygen analyzers, Carbon dioxide analyzers, Carbon monoxide analyzers.
5. Heat flow: Thermography equipment
6. Electrical: Multimeter, Ammeter, Wattmeter, Power Factor meter, Light meter
7. Stream Trap Testing: Stethoscope, Ultrasonic Detector

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

Long term approach
These are still short term solutions. The opportunities for improving the efficiency of energy use in the long term, however, lie in applying techniques and technologies of conservation to ne w plants. Proper attention to the efficient use of energy at the design stage is vitally important.

General audit

The general audit (alternatively called a mini-audit, site energy audit or detailed energy audit or complete site energy audit) expands on the preliminary audit described above by collecting more detailed information about facility operation and by performing a more detailed evaluation of energy conservation measures. Utility bills are collected for a 12 to 36 month period to allow the auditor to evaluate the facility's energy demand rate structures and energy usage profiles. If interval meter data is available, the detailed energy profiles that such data makes possible will typically be analyzed for signs of energy waste. Additional metering of specific energy- consuming systems is often performed to supplement utility data. In-depth interviews with facility operating personnel are conducted to provide a better understanding of major energy consuming systems and to gain insight into short and longer term energy consumption patterns. This type of audit will be able to identify all energy-conservation measures appropriate for the facility, given its operating parameters. A detailed financial analysis is performed for each measure based on detailed implementation cost estimates; site-specific operating cost savings, and the customer's investment criteria. Sufficient detail is provided to justify project implementation.

Investment-grade audit
In most corporate settings, upgrades to a facility's energy infrastructure must compete for

capital funding with non-energy-related investments. Both energy and non-energy investments are rated on a single set of financial criteria that generally stress the expected return on investment (ROI). The projected operating savings from the implementation of energy projects must be developed such that they provide a high level of confidence. In fact, investors often demand guaranteed savings. The investment-grade audit expands on the detailed audit described above and relies on a complete engineering study in order to detail technical and economical issues necessary to justify the investment related to the transformations.

Simulation-based energy audit procedure for non-residential buildings

A complete audit procedure, very similar to the ones proposed by AS HRAE and Krarti (2000), has been proposed in the frame of the AUDITAC and HARMO NAC projects to help in the implementation of the EPB ("Energy Performance of Buildings") directive in Europe and to fit to the current European market.

The following procedure proposes to make an intensive use of modern BES tools at each step of the audit process, from benchmarking to detailed audit and financial study:

- Benchmarking stage: While normalization is required to allow comparison between data recorded on the studied installation and reference values deduced from case studies or statistics. The use of simulation models, to perform a code-compliant simulation of the installation under study, allows assessing directly the studied installation, without any normalization needed. Indeed, applying a simulation-based benchmarking tool allows an individual normalization and allows avoiding size and climate normalization.
- Preliminary audit stage: Global monthly consumptions are generally insufficient to allow an accurate understanding of the building's behaviour. Even if the analysis of the energy bills does not allow identifying with accuracy the different energy consumers present in the facility, the consumption records can be used to calibrate building and system simulation models. To assess the existing system and to simulate correctly the building's thermal behaviour, the simulation model has to be calibrated on the studied installation. The iterations needed to perform the calibration of the model can also be fully integrated in the audit process and help in identifying required measurements and critical issues.
- Detailed audit stage: At this stage, on-site measurements, sub-metering and monitoring data are used to refine the calibration of the BES tool. Extensive attention is given to understanding not only the operating characteristics of all energy consuming systems, but also situations that cause load profile variations on short and longer term bases (e.g. daily, weekly, monthly, annual). When the calibration criteria is satisf ied, the savings related to the selected ECOs/EC Ms can be quantified.
- Investment-grade audit stage: At this stage, the results provided by the calibrated BES tool can be used to assess the selected ECOs/EC Ms and orient the detailed engineering study.

Specific audit techniques

Infrared thermography audit

The advent of high resolution thermography has enabled inspectors to identify potential issues within the building envelope by taking a thermal image of the various surfaces of a building. For purposes of an energy audit, the thermographer will analyze the patterns within the surface temperatures to identify heat transfer through convection, radiation, or conduction. It is important to note that the thermography ONLY identifies SURFACE temperatures, and analysis must be applied to determine the reasons for the patterns within the surface temperatures. Thermal analysis of a home generally costs between 300 and 600 dollars.

For those who cannot afford a thermal inspection, it is possible to get a general feel for the heat loss with a non contact infrared thermometer and several sheets of reflective insulation. The method involves measuring the temperatures on the inside surfaces of several exterior walls to establish baseline temperatures. After this, reflective barrier insulation is taped securely to the walls in 8-foot (2.4 m) by 1.5-foot (0.46 m) strips and the temperatures are measured in the center of the insulated areas at 1 hour intervals for 12 hours (The reflective barrier is pulled away from the wall to measure the temperature in the center of the area which it has covered.). The best manner in which to do this is when the temperature differential (Delta T) between the inside and outside of the structure is at least 40 degrees. A well insulated wall will commonly change approximately 1 degree per hour if the difference between external and internal temperatures is an average of 40 degrees. A poorly insulated wall can drop as much as 10 degrees in an hour.

Pollution audits

With increases in carbon dioxide emissions or other greenhouse gases, pollution audits are now a prominent factor in most energy audits. Implementing energy efficient technologies help prevent utility generated pollution.

Online pollution and emission calculators can help approximate the emissions of other prominent air pollutants in addition to carbon dioxide.

Pollution audits generally take electricity and heating fuel consumption numbers over a two year period and provide approximations for carbon dioxide, VOCs, nitrous oxides, carbon monoxide, sulfur dioxide, mercury, cadmium, lead, mercury compounds, cadmium compounds and lead compounds.

ENERGY INDEX

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

Units and conversion factors.

General

1 short ton (ton) = 2000 lb
1 metric ton (tonne) = 1000 kg
1 ton = 0.907185 tonne
1 barrel = 42 U.S. gallons = 159.0 liters
1 barrel of crude oil ~ 0.136 tonne
1 square mile = 640 acres = 2.590 km^2
1 hectare = 10^{-2} km^2 = 2.471 acres

Energy units

1 calorie (thermochemical) = 4.184 J
1 calorie (15 °C) = 4.1858 J
1 calorie (IT) = 4.1868 J
1 calorie (mean) = 4.1900 J
1 Btu = 251.9958 calories
1 Btu (thermochemical) = 1054.35 J
1 Btu (59 °F) = 1054.80 J
1 Btu (IT) = 1055.06 J
1 Btu (mean) = 1055.87 J
1 kilowatt-hour (kWh) = 3.6 x 10^6 J
1 kilowatt-hour (kWh) = 3412 Btu
1 electron-volt = 1.6022 x 10^{-19} J

Large-scale units

1 quad = 10^9 MBtu = 10^{15} Btu
1 exajoule (EJ) = 10^{18} J

Assumed efficiency in electricity generation
(for calculating "primary energy")

Source	DOE/EIA	OECD/IEA
nuclear power	0.320	0.33
hydroelectric	0.332[a]	1.00
biomass	0.332[a]	
wind and solar	0.332[a]	1.00
geothermal	0.163	0.10

a. Set equal to efficiency for fossil fuels.

Heat content of fuels

	MBtu[a]	GJ[a]
Nominal equivalents:		
1 barrel of crude oil	5.80	6.12
1 tonne of crude oil	39.68	41.87
1 short ton of coal	25.18	26.57
1000 ft^3 of natural gas	1.000	1.055

1 terawatt-year (TWyr) = 8.76 x 10^{12} kWh

	Quad[a]	EJ
1 quad	1.000	1.055
1 EJ	0.948	1.000
1 TWyr (100% effic)	29.89	31.54
1 TWyr (33 % effic)	90.6	95.6
10^9 tonne coal equiv	27.76	29.29
10^9 barrel oil equiv	5.80	6.12
10^9 tonne oil equiv[b]	39.68	41.87
10^9 tonne oil equiv[c]	42.43	44.77

a. Based on IT Btu.
b. As used by OECD/IEA (Ref. 4).
c. As used in Ref. 6.

Unit s of power

1 watt (W) = 1 J/sec
1 horsepower = 746 W
10^6 bbl of crude oil/day ~ 2.12 quad/yr

Average for U.S., 1995:		
1 bbl petroleum prod	5.358	5.653
1 ton coal	20.852	22.000
1000 ft^3 of natural gas	1.028	1.085
1 bbl petroleum products:		
propane	3.836	4.047
aviation gasoline	5.048	5.326
motor gasoline	5.253	5.542
distillate fuel oil	5.825	6.146
residual fuel oil	6.287	6.633
Other:		
1 cord dry wood[b]	21.5	22.7
1 tonne ^{235}U[c]	8 x 10^7	8 x 10^7

a. 1 MBtu = 10^6 Btu (IT); 1 GJ = 10^9 J
b. 1 cord of dry wood = 1.25 ton
c. Ignoring n-capture in ^{235}U and ^{238}U.

Example 1: An office block uses $40X10^3$ gallons of fuel oil per year for heating purposes. The calorific value is $175\ X10^3$ Btu/gal. The fuel consumption may be expressed in litres or m^3.

$40X10^3$ gal = 40 $X10^3$4.545 litres = $182X10^3$ litres = 182 m^3
the calorific value may be quoted as 10^3 J/L
$175X10^3$ Btu/gal = $175X10^3$ X0.2321 $X10^3$ J/L = $40600X10^3$ J/L = $40.6X10^9$ J/L
The total theoretical heat available becomes:

(a) $40X10^3$ gal X $175X10^3$ Btu/gal = $7.00X10^9$ Btu/year
(b) (b) $182X10^3$ L X $40600X10^3$ J/L = $7.39X10^{12}$ J/year
(c) 182 m^3 X 40.6 $X10^9$ J/L = 7.39 $X10^{12}$ J/year

Example 2:

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

Energy type	**Consumption**	**Energy**	**Energy (J)**	**Energy (Wh)**
Oil	$10X10^3$ gal	$1.775X10^9$ Btu	$1.872X10^{12}$	$0.520X10^9$
Gas	$5X10^3$ therm	$5X10^3$ therm	$0.526X10^{12}$	$0.146X10^9$
Electricity	$995X10^3$ KWh	$995X10^3$ KWh	$0.358X10^{12}$	$0.995X10^9$
		Total	$2.754X10^{12}$	$1.661X10^9$

Note: Calorific value of oil: 18.3X10 Btu/lb; Density of fuel: 9.7 lb/gal

Percentage Energy Balance:

Energy Form	**Percentage**
Oil	67.9
Gas	19.1
Electricity	13.0
Total	100.0

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

Example 3:
If the company in Example 2 produces 100 $X10^3$ tons of a particular product, calculate the energy indices.
Oil energy index: $0.520X10^9$ Wh/$100X10^9$ = $5.20X10^3$ Wh/ton of product
Gas energy index: $0.146X10^9$ Wh/$100X10^9$ = $1.46X10^3$ Wh/ton of product
Electricity energy index: $0.995X10^9$ Wh/$100X10^9$ = $9.95X10^3$ Wh/ton of product
Total energy index: $1.661X10^9$ Wh/$100X10^9$ = $16.61X10^3$ Wh/ton of product

COST IN DEX

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

Example 1:

Table below shows energy costs for a company using coke, gas and electricity. This company produces $15X10^3$ tons per year. Calculate cost indices.

Energy Type	Consumption	Costs
Coke	$1.5X10^3$ (tons)	$108.0X10^3$
Gas	$18\ X10^3$ (therms)	$3.6X10^3$
Electricity	$1\ X10^9$ (Wh)	$22.5X10^3$
	Total	$134.1X10^3$

Coke cost index = $108.0\ X10^3/15\ X10^3$ (tons) = 7.2/ton
Gas cost index = $3.6\ X10^3/15\ X10^3$ (tons) = 0.2/ton
Electricity cost index = $22.5\ X10^3/15\ X10^3$ (tons) = 1.5/ton
Total cost index = $134.1\ X10^3/15\ X10^3$ (tons) = 8.9/ton

REPRESENTATION OF ENERGY CONSUMPTION

Several methods of representing energy flows and energy consumption are available and these may be graphical or tabular. Most popular among them are Pie chart and the Sankey diagram.

Pie Chart

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

A **pie chart** (or a **circle graph)** is a circular chart divided into sectors, illustrating proportion. In a pie chart, the arc length of each sector (and consequently its central angle and area), is proportional to the quantity it represents. When angles are measured with 1 turn as unit then a number of percent is identified with the same number of centiturns. Together, the sectors create a full disk. It is named for its resemblance to a pie which has been sliced. The sizes of the sectors are calculated by converting between percentage and degrees or by the use of a percentage protractor. The earliest known pie chart is generally credited to William Playfair's Statistical Breviary of 1801.

The pie chart is perhaps the most widely used statistical chart in the business world and the mass media. However, it has been criticized, and some recommend avoiding it, pointing out in particular that it is difficult to compare different sections of a given pie chart, or to compare data across different pie charts. Pie charts can be an effective way of displaying information in some cases, in particular if the intent is to compare the size of a slice with the whole pie, rather than comparing the slices among them. Pie charts work particularly well when the slices represent 25 to 50 % of the data, but in general, other plots such as the bar chart or the dot plot, or non- graphical methods such as tables, may be more adapted for representing certain information.

Example

The following example chart is based on preliminary results of the election for the European Parliament in 2004. The table lists the number of seats allocated to each party group, along with the derived percentage of the total that they each make up. The value in the last column, the derived central angle of each sector, is found by multiplying the percentage by 360°.

Group	Seats	Percent (%)	Central angle (°)
EUL	39	5.3	19.2
PES	200	27.3	98.4
EF A	42	5.7	20.7
EDD	15	2.0	7.4
ELDR	67	9.2	33.0
EPP	276	37.7	135.7
UEN	27	3.7	13.3
Other	66	9.0	32.5
Total	732	99.9*	360.2*

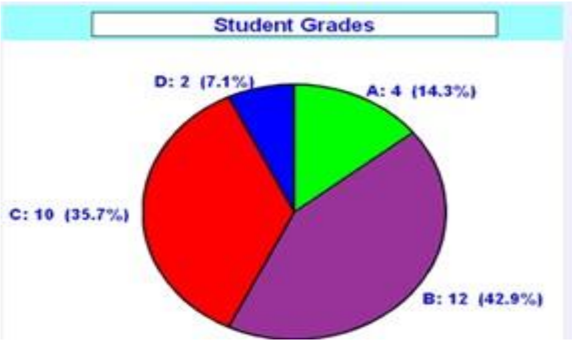
*Because of rounding, these totals do not add up to 100 and 360.

The size of each central angle is proportional to the size of the corresponding quantity, here the number of seats. Since the sum of the central angles has to be 360°, the central angle for a quantity that is a fraction *Q* of the total is 360*Q* degrees. In the example, the central angle for the largest group (European People's Party (EPP) is 135.7° because 0.377 times 360, rounded to one decimal place(s), equals 135.7.

Example: Student Grades
Here is how many students got each grade in the recent test:

A	B	C	D
4	12	10	2

And here is the pie chart:



Pie Chart - A special chart that uses "pie slices" to show relative sizes of data.
Imagine you just did a survey of your friends to find which kind of movie they liked best.
Here are the results:

Table: Favorite Type of Movie				
Comedy	**Action**	**Romance**	**Drama**	**SciFi**
4	5	6	1	4

You could show that by this pie chart:

It is a really good way to show relative sizes: it is easy to see which movie types are most liked, and which are least liked, at a glance.
You can create graphs like that using our Data Graphs (Bar, Line and Pie) page. Ho w to Make Them Yourself
First, put your data into a table (like above), then add up all the values to get a total:

Comedy	**Action**	**Romance**	**Drama**	**SciFi**	**TOTAL**
4	5	6	1	4	**20**

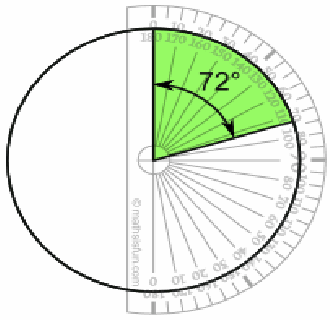
Next, divide each value by the total and multiply by 100 to get a percent:

Comedy	**Action**	**Romance**	**Drama**	**SciFi**	**TOTAL**
4	5	6	1	4	**20**
4/20 = **20%**	5/20 = **25%**	6/20 = **30%**	1/20 = **5%**	4/20 = **20%**	**100%**

No w you need to figure out ho w many degrees for each "pie slice" (correctly called a sector). A Full Circle has 360 degrees, so we do this calculation:

Comedy	**Action**	**Romance**	**Drama**	**SciFi**	**TOTAL**
4	5	6	1	4	**20**
4/20 = **20%**	5/20 = **25%**	6/20 = **30%**	1/20 = **5%**	4/20 = **20%**	**100%**
4/20 × 360° = **72°**	5/20 × 360° = **90°**	6/20 × 360° = **108°**	1/20 × 360° = **18°**	4/20 × 60° = **72°**	**360°**

Now you are ready to start drawing!
Draw a circle.
Then use your protractor to measure the degrees of each sector.



Sankey Diagram

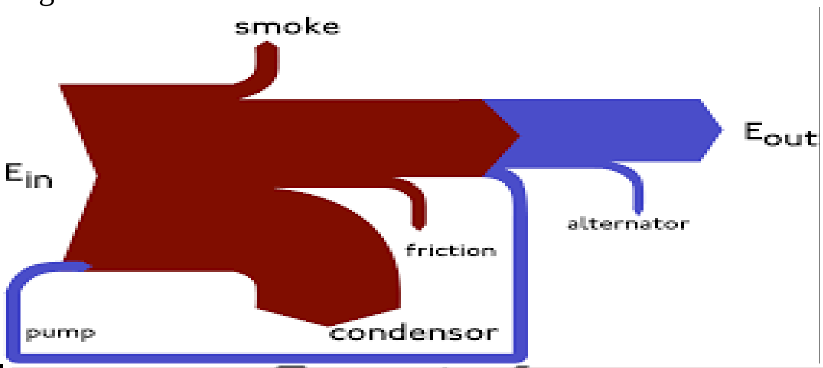
Sankey diagrams is a specific type of flow diagram, in which the width of the arrows is shown proportionally to the flow quantity. They are typically used to visualize energy or material or cost transfers between processes.

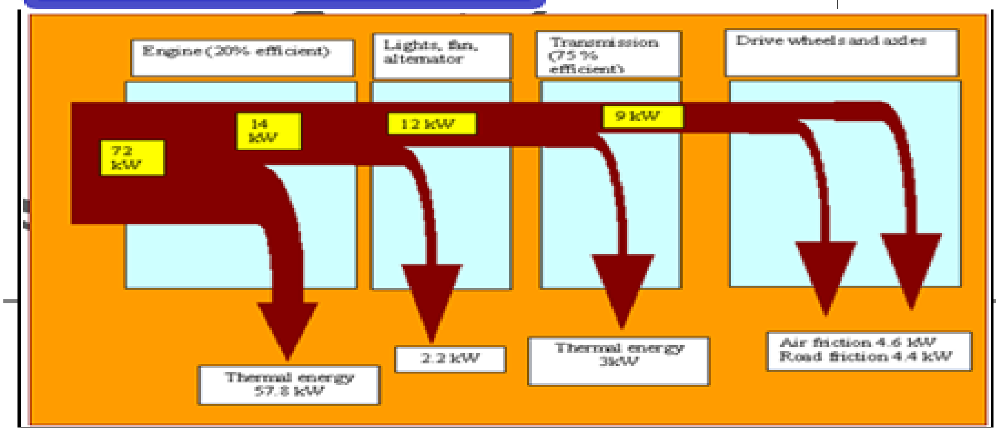
Applications

They are also commonly used to visualize the energy accounts or material flow accounts on a regional or national level. Sankey diagrams put a visual emphasis on the major transfers or flows within a system. They are helpful in locating dominant contributions to an overall flow. Often, Sankey diagrams show conserved quantities within defined system boundaries, typically energy or mass, but they can also be used to show flows of non-conserved quantities such as energy. Sankey Diagrams drop their arrows when energy is being used.

One of the most famous Sankey diagrams is Charles Minard's Map of Napolean's Russian Campaign of 1812. It is a flow map, overlaying a Sankey diagram onto a geographical map. It was created in 1869.

Sankey diagrams are named after Irish Captain Matthew Henry Phineas Riall Sankey, who used this type of diagram in 1898 in a publication on the energy efficiency of a steam engine While the first charts in black and white were merely used to display one type of flow (e.g. steam), using colors for different types of flows has added more degrees of freedom to Sankey diagrams.

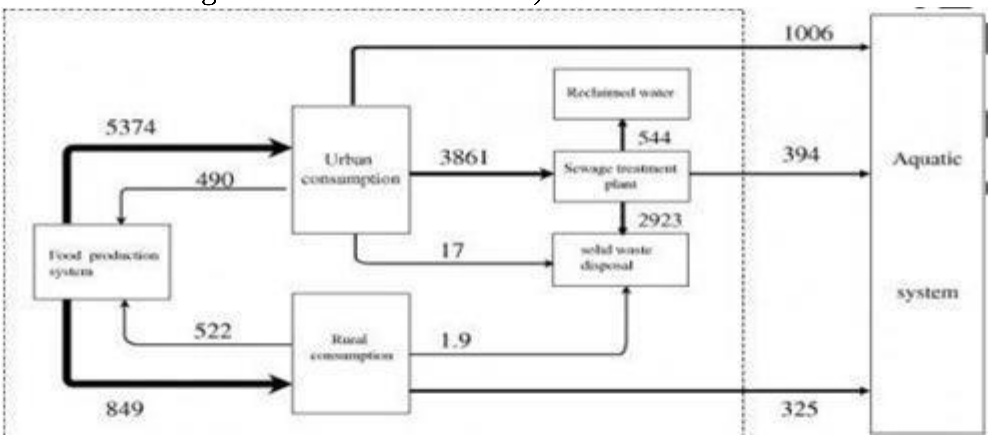




Show it with Sankey Diagrams

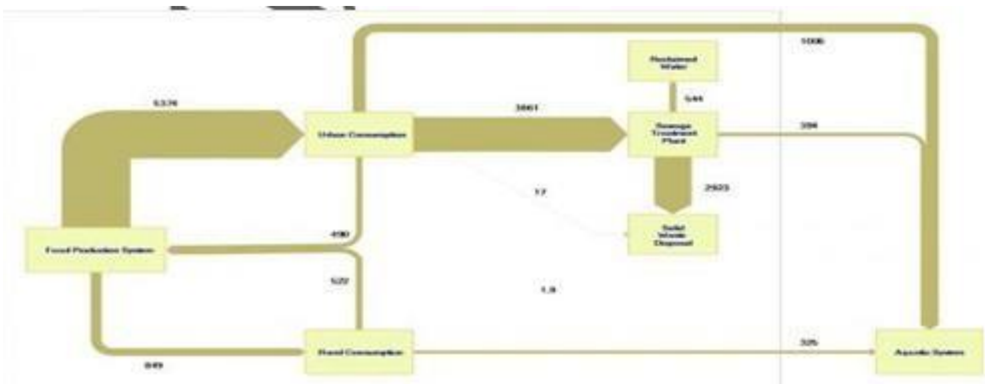
Phosporus in the natural environment and the food chain has been a topic of several posts on my blog. So it didn't come as a surprise to find yet another diagram on phoshphorus flows over at Nels's MFA Diagram blog (one of the blogs I follow closely, see blogroll).

MF A diagrams has their focus on the nodes and the build-up of stocks. Sometimes they get a touch of Sankey diagram with the arro ws having different magnitudes. The MF A diagram belo w is for phosphorous flo ws in China 2008 (original source: Min Qiao, Yuan- Ming Zheng, Yong- Guan Zhu, 2011. Material flo w analysis of phosphorus through food consumption in t wo megacities in northern China). Values are in tonnes.



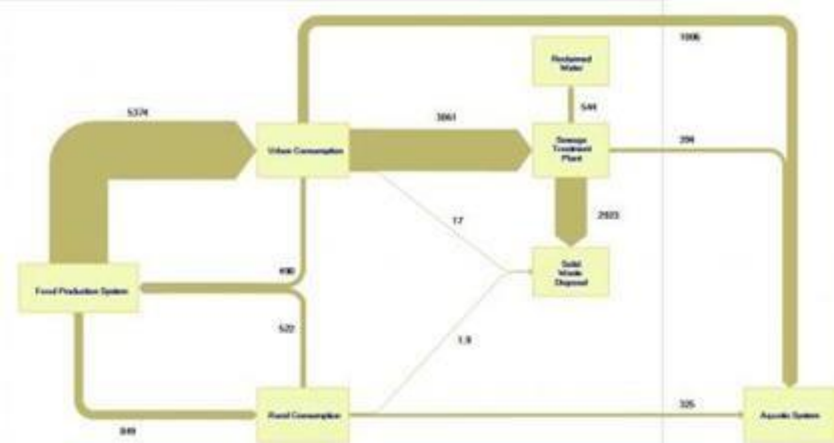
We can detect arrows with three different brush widths (my guess is 1px, 2px and 4 px), each standing for a value range into which the actual flow quantity falls. This may, ho wever, bes somewhat misleading when having a quick glance at the diagram.

I quickly "translated" the above diagram to a Sankey diagram with flo w values being actually to scale.



Here it is quite clear where the major phosphorus flows are located (from food production via urban consumption to se wage treatment plant and solid waste disposal: 2923 out of 5374 tons end up here). The other flo ws are comparatively small, with the phoshporous flow going directly to the aquatic system worth a mention. Two small flo ws in the center of the diagram are negligible, they are in fact so tiny in comparison to the major flows that they even don't show up (or just as a hairline) here.

I have therefore added a minimum width of 1 px for small flows so that the annual 17 tons from urban consumption and the 1.9 tons from rural consumption to the solid waste disposal are at least visible (albeit not to scale with the other flows any more).

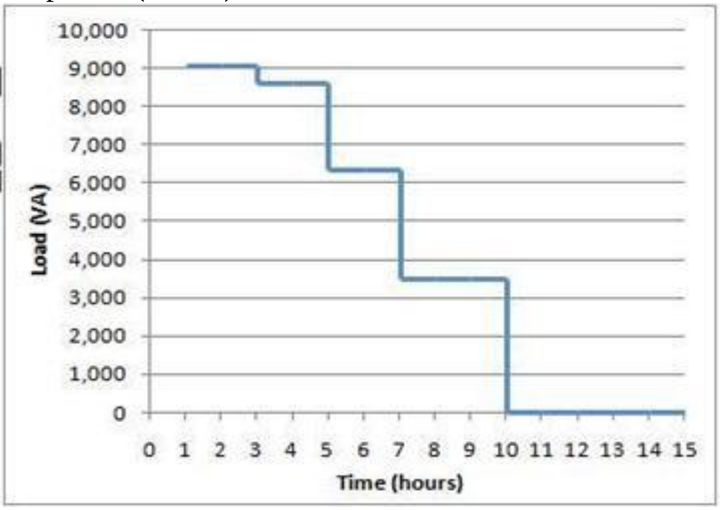


Load Profiles

Introduction

The energy load profile (hereafter referred to as simply "load profile") is an estimate of the total energy demanded from a power system or sub-system over a specific period of time (e.g. hours, days, etc). The load profile is essentially a two-dimensional chart showing the instantaneous load (in Volt-Amperes) over time, and represents a convenient way to visualize how the system loads changes with respect to time.

Note that it is distinct from the electrical load schedule - the load profile incorporates a time dimension and therefore estimates the energy demand (in kWh) instead of just the instantaneous load / power (in kW).



Why do the calculation?

Estimating the energy demand is important for the sizing of energy storage devices, e.g. batteries, as the required capacity of such energy storage devices depends on the total amount of energy that will be drawn by the loads. This calculation is also useful for energy efficiency applications, where it is important to make estimates of the total energy use in a system.

When to do the calculation?

A load profile needs to be constructed whenever the sizing of energy storage devices (e.g. batteries) is required. The calculation can be done once preliminary load information is available.

Calculation Methodology

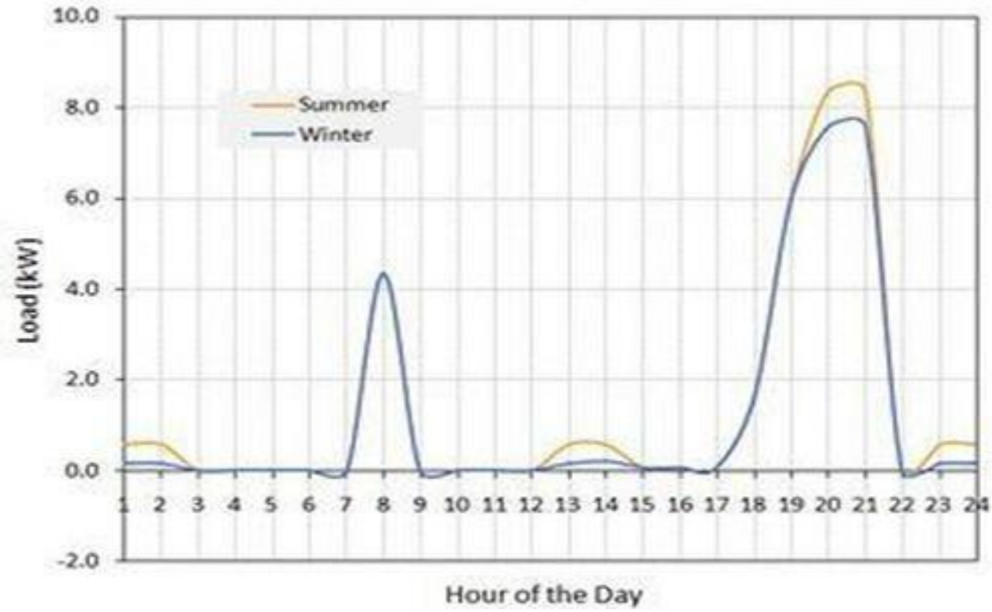
There are two distinct methods for constructing a load profile:

1) **Autonomy** method is the traditional method used for backup power applications, e.g. UP S systems. In this method, the instantaneous loads are displayed over an autonomy time, which is the period of time that the loads need to be supported by a backup power system in the event of a power supply interruption.

2) **24 Hour Profile** method displays the average or expected instantaneous loads over a 24 hour period. This method is more commonly associated with standalone power system applications, e.g. solar systems, or energy efficiency applications.

Both methods share the same three general steps, but with some differences in the details:

- Step 1: Prepare the load list
- Step 2: Construct the load profile
- Step 3: Calculate the design load and design energy demand



Step 1: Prepare the Load List

The first step is to transform the collected loads into a load list. It is similar in form to the electrical load schedule, but is a little simplified for the purpose of constructing a load profile. For instance, instead of categorizing loads by their load duty (continuous, intermittent or standby), it is assumed that all loads are operating continuously.

However, a key difference of this load list is the time period associated with each load item:

In the **autonomy method**, the associated time period is called the "autonomy" and is the number of hours that the load needs to be supported during a power supply interruption. Some loads may only be required to ride through brief interruptions or have enough autonomy to shut down safely, while some critical systems may need to operate for as long as possible (up to several days).

In the **24 hour profile** method, the associated time period is represented in terms of “ON" and “OFF " times. These are the times in the day (in hours and minutes) that the load is expected to be s witched on and then later turned off. For loads that operate continuously, the ON and OFF time would be 0:00 and 23:59 respectively. A load item may need to be entered in twice if it is expected to start and stop more than once a day.

Calculating the Consumed Load VA

For this calculation, we are interested in the consumed apparent power of the loads (in VA). For each load, this can be calculated as follows:

$$S_l = \frac{P_l}{\cos\phi \times \eta}$$

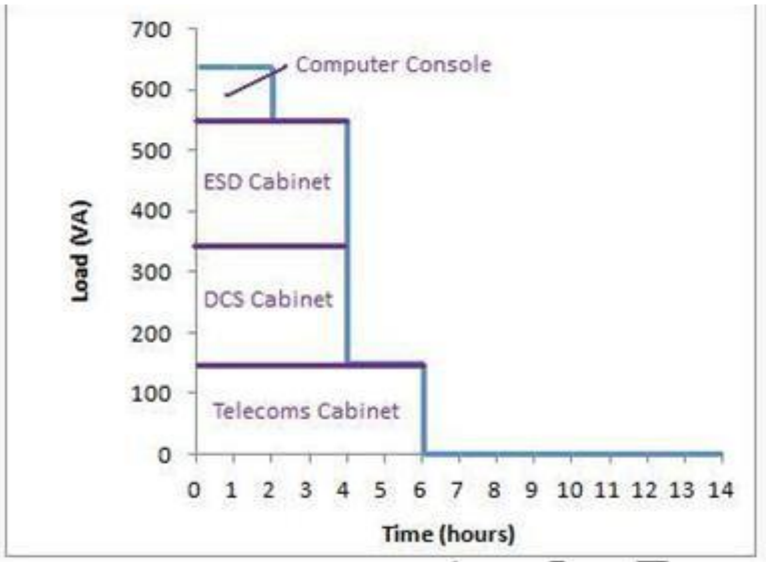
Where S_l is the consumed load apparent power (VA) P_l is the consumed load power (W)

$\cos\varphi$ is the load power factor (pu)

η is the load efficiency (pu)

Step 2: Construct t he Load Profile

The load profile is constructed from the load list and is essentially a chart that sho ws the distribution of the loads over time. The construction of the load profile will be explained by a simple example:



Load profile constructed for this example

Suppose the following loads were identified based on the Autonomy Method:

Description	Load (VA)	Autonomy (h)
DCS Cabinet	200	4
ESD Cabinet	200	4
Telecommunications Cabinet	150	6
Computer Console	90	2

The load profile is constructed by stacking "energy rectangles" on top of each other. An energy rectangle has the load VA as the height and the autonomy time as the width and its area is a visual representation of the load's total energy. For example, the DCS Cabinet has an energy rectangle of height 200 (VA) and width 4 (hours). The load profile is created by stacking the widest rectangles first, e.g. in this example it is the Telecommunications Cabinet that is stacked first.

For the 24 Hour method, energy rectangles are constructed with the periods of time that a load is energized (i.e. the time difference between the ON and OFF times).

Step 3: Calculate Design Load and Energy Demand

Design Load

The design load is the instantaneous load for which the power conversion, distribution and protection devices should be rated, e.g. rectifiers, inverters, cables, fuses, circuit breakers, etc. The design can be calculated as follows:

$$S_d = S_p(1 + k_g)(1 + k_c)$$

Where S_d is the design load apparent power (VA)

S_p is the peak load apparent power, derived from the load profile (VA)

k_g is a contingency for future load growth (%)

k_c is a design margin (%)

It is common to make considerations for future load growth (typically somewhere between 5 and 20%), to allow future loads to be supported. If no future loads are expected, then this contingency can be ignored. A design margin is used to account for any potential inaccuracies in estimating the loads, less-than-optimum operating conditions due to improper maintenance, etc. Typically, a design margin of 10 % to 15 % is recommended, but this may also depend on Client preferences.

Example: From our simple example above, the peak load apparent power is 640VA. Given a future growth contingency of 10 % and a design margin of 10 %, the design load is: VA

Design Energy Demand

The design energy demand is used for sizing energy storage devices. From the load profile, the total energy (in terms of VAh) can be computed by finding the area underneath the load profile curve (i.e. integrating instantaneous power with respect to time over the autonomy or 24h period). The design energy demand (or design VAh) can then be calculated by the following equation:

Where E_d is the design energy demand

(VAh) is the total load energy, which is the area under the load profile

(VAh) is a contingency for future load growth as defined above

(%) is a design contingency as defined above (%)

Example: From our simple example above, the total load energy from the load profile is 2,680VAh. Given a future growth contingency of 10 % and a design margin of 10 %, the design energy demand is:

$$E_d = 2,680 \times (1 + 0.1)(1 + 0.1) = 3,242.8 \text{ Vah}$$

Energy Conservation Schemes

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

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

(a) **Short term**: These measures usually involve changes in operating practices resulting in little or no capital expenditure.

(b) **Medium term:** Lo w-cost modifications and improvements to existing equipment where the pay-back period is less than two years and often under one year.

(c) **Long term:** Modifications involving high capital costs and which frequently involve the implementation of new techniques and new technologies.

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

Short- term energy conservation schemes

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

(a) Furnace efficiencies: Greater emphasis should be placed on minimum excess combustion air. Oxygen levels of flue gases should be continually monitored and compared with target values. Oil burners must be cleaned and maintained regularly.

(b) Heat exchangers: In the case of heat where useful heat is transferred from product streams to feed streams, careful monitoring of performance should be carried out to determine optimum cleaning cycles. Frequency of cleaning will generally increase as a result, with consequent improved heat recovery.

(c) Good housekeeping: Doors and windows should be kept closed as much as possible during the heating season. Wear natural light is sufficient, do not use artificial light. Avoid excessive ventilation during the heating season. Encourage staff to wear clothing appropriate to the temperature of the working areas.

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

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

Medium -term energy conservation schemes

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

(a) Insulation: Improving insulation to prevent cold air leaking into the building and also, improving insulation thickness was determined at a time when fuel oil was **Rs 6** per tone and, consequently, at present fuel oil prices, optimum thicknesses have increased appreciably. In addition, in older plants lagging may have deteriorated to varying degrees. For an outlay of **Rs25000,** savings of **Rs60000** per annum were achieved.

In all oil refinery the lagging on the process steam system was up rated to new optimum thicknesses and the **Rs20000** invested in the project was recouped within a year

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

(c) Replacing air compressors

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

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

In one instance 10000 Kg/h of condensate was recovered for an investment of **Rs10000;** the pay-back time was less than six months.

(f) Burners: The control and amount of atomizing stream is important and often in furnaces and boilers the amount of atomizing steam is far in excess of design.
In a hospital two fuel oil-fired boilers were examined and in some instances it was found that 1 kg steam/kg fuel oil was being utilized. The oil burners were replaced and the atomizing steam requirements are no w 0.1 kg steam/kg fuel oil. The pay-back for an outlay of **Rs12000** was ten months.

(g) Electrical Power Savings: Considerable savings may be made by adjusting the electrical power factor correction.

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

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

Long-term energy conservation schemes

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

(a) Heater modifications: The installation of heating tubes and air pre-heaters to extract more heat from furnace flue gases.

(b) Improved Insulation: Additional lagging of heated storage tanks. This type of project often comes within the medium-term group.

(c) Heat recovery: improved heat recovery in the processing areas by additional heat exchange schemes.

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

The ABCs of Energy Conservation Schemes can be used as a checklist to identify the areas of deficiency and adopt the right approach for energy savings.

A	**B**	**C**
Adjustable frequency drives Ambient air reset controls Analysis of audit results	Balancing energy Blow-down controllers Break-even analysis	Co-generation Chiller optimization Copper fins in cooling/ heating
D	**E**	**F**
Demand control Delay monitoring and avoidance DDC management systems	Economizer control Efficient equipment selection Energy audit and analysis	Fenestration techniques Filter loading control Fan efficiency optimization
G	**H**	**I**
Glazing systems for heat gain Gas cooling General housekeeping	Heat energy tacking Heat recovery methods High efficiency criteria	Insulation Infiltration control Inspections
J	**K**	**L**
Job-task analysis Joint sealing and testing Justify retrofits	Kettle heat control kWh and kW reduction keg temperature control	Lighting Load calculation/shedding Life-cycle cost analysis
M`	**N**	**O**
Ma intenance Metering Monitoring	Non conventional methods Novel technologies Natural gas use	Occupancy sensors Optimization Over-rating avoidance

P	Q	R
Peak demand shaving Power factor corrections Pay-back period	Quality	Retrofits Return air systems Rate of return
S	**T**	**U**
Solar energy Steam traps Selection criteria	Time of day Thermostat settings Temperature control	U-values Utilities Utility meter close to site
V	**W**	**X,Y,Z**
Variable air volume boxes Variable supply air set point Voltage selection	water conservation waste heat recovery water treatment	XTMR losses Yearly cost and savings Zone controls

Measurements in energy audits

A home energy audit can help you find some surprising ways to save energy and money.

Conserving energy at home is a great idea for many reasons. It cuts down on energy costs, and because most of the energy we use comes from fossil fuels, using less is beneficial for the environment, too.

In many ways, saving energy can be pretty simple. You can find dozens of different ways to conserve — such as turning down your thermostat in the winter, putting a blanket on your water heater or switching to more efficient light bulbs. But most homes are so inefficient that even after you've done all the easy home improvements, there are still dozens of ways to save money and energy. How do you identify them all and then decide which to do first?

Unfortunately, the improvements that save you the most energy over time tend to be expensive. Before you spend hundreds — or even thousands — of dollars on home improvements, such as buying a new furnace, installing insulation or putting in new windows, it's nice to know how much energy they'll actually save. Just as important, you'll want to know how long these home energy upgrades will take to pay for themselves and start saving you money.
These questions aren't just for older homes — ne w homes often have significant energy problems, says Ken Riead of Hathmore Technologies in Independence, Mo. Riead is a home energy rater (one type of certification for home energy auditors). He trains other energy raters and has been working in the field of energy efficiency and renewable energy since the 1970s.

"New houses typically aren't as solidly constructed as older houses," Riead says. "New homes can leak more air, causing health and comfort problems, and the quality of the wood and other building components can be poor. Insulation is often very sloppily installed and, in many cases, missing entirely."

A home energy audit can help, he explains. "Most homeowners aren't knowledgeable about ho w to look for these problems, nor ho w to properly correct them. Unless your home is an Energy Star home or has undergone energy testing, you will likely experience high energy bills and comfort problems, so it is well worth having an energy audit performed," Riead says

Principles of energy management

Improving energy efficiency is, in part, a technical pursuit with a scientific basis. However, although some aspects are undeniably highly specialised, the essential science should be familiar to most readers (perhaps dimly) from their school days and where BS EN 16001 (section 3.4.2) calls for the energy manager to be appropriately qualified. I read this as meaning that a basic grasp of physics and chemistry would be expected.

This chapter reviews some of the fundamental scientific concepts needed for the job, and other more specific topics are introduced in individual chapters where they may be helpful.

Energy and power

In BS EN16001 energy is defined as "electricity, fuel, steam, heat, compressed air and other like media" (your physics teacher probably defined it more rigorously as "capacity to do work" but the real-world definition is better for our purposes). When we buy or use energy it may be billed or reported in a variety of units of measurement, but all have their equivalents in kilowatt hours (kWh) which is how most practitioners commonly express energy consumption.

Some of the conversion factors are given in the following table:

Energy source	Measured units	To get kWh multiply by	Notes
Electricity	kWh	1	
Natural gas	m3	10.7	*1*
Natural gas	hundred cu ft	30.3	*1*
Natural gas	kWh	1	*1*
Natural gas	Therm	29.31	*1*
Diesel or 35-second gas oil	Litre	10.6	
Heavy fuel oil	Litre	11.4	
Propane	Tone	13,780	
Propane	Kg	13.78	
Coal	Tone	9,000	*2*
Coal	Kg	9	*2*
Steam	Tone	630	*3*

"Power" has a quite specific meaning: it is the rate at which energy is delivered, commonly expressed in watts (W) or kilowatts (kW), although horsepower (HP) will also come to mind in some contexts. Because both are measures of power, there is a conversion factor between the two: 1 HP is equal to 0.746 kW.

The energy used by a piece of equipment running at fixed power for a certain time is the time multiplied by the power. A 3 kW heater running for two hours will use 3 x 2 = 6 kWh. A 55 HP diesel engine running flat out for two hours will deliver 55 x 0.746 x 2 =
82.06 kWh

Power factor

In an electrical circuit, power is calculated by multiplying voltage and current together. In the case of mains power, where the current alternates, this relationship holds true at any given instant, so the *instantaneous* power will vary as the voltage and current continuously vary through the cycle. However, in order to deliver the maximum useful power, the current and voltage must be exactly in step. If they are not – for example if the load characteristics make the current waveform lag slightly behind the voltage waveform
– then throughout the cycle either the voltage will coincide with a current that is less than it would have been, or the current coincides with a voltage that is lower than it would have been had they been in step. Indeed, there will be four occasions in each cycle when the instantaneous power is zero (two when the current is zero and two when the voltage is zero). The result: less power will be developed for a given current. The *power factor* is the ratio between delivered useful power and what it would have been with perfect synchronisation of current and voltage.
Poor power factor means that a higher-than-necessary current must be drawn in order to deliver the required useful power. This increases the load on supply cables and switchgear, increases line losses, and (depending on the tariff) can impose higher supply- capacity and maximum-demand charges.

Efficiency

This is another word that has quite a narrow meaning in the context of energy management, where it refers to the ratio between useful energy output and energy input. Examples might be the useful heat output from a boiler, divided by the amount of fuel put in; or the work done by a car engine relative to diesel consumed. Take the earlier example of the engine which delivered 82.06 kWh over two hours. If it used 25 litres of fuel in the process, how efficient was it? From Table xxx we see that 25 litres of diesel **co**ntain 25 x 10.6 = 265 kWh. So the efficiency of the engine was 82.06 / 265 = 30.9% In common parlance "efficiency" is often used interchangeably with "efficacy" or "effectiveness". If the occupants of a building tell one that its heating system is efficient, they usually mean that it keeps them warm, not that the boilers are well tuned and properly controlled to minimize standing losses. Beware also when promoting "efficiency savings" as this term has connotations of downsizing and redundancies.

Energy balance

Most people talk about "consuming" energy (be it in the form of gas, oil, electricity, heat, compressed air or steam) but purists would argue that we don't consume it: merely convert it from one form to another. Nobody seriously argues that we stop using the term "consume" but the point about conversion is important in a way. In the engine example, we used 265 kWh of chemical energy in the diesel fuel to generate about 82 kWh of useful mechanical work. But as energy cannot be destroyed, where did the missing 183 kWh go? It came out as heat in the exhaust and cooling system. There is an overall balance between what goes in and what comes out. We will encounter a similar argument when we discuss combustion efficiency in a later chapter.

Heat and temperature

Heat is one manifestation of energy. A flow of heat can be expressed in energy units (such as kWh). You can meter, buy, or use a quantity of it. The engine in the earlier example produced it by converting chemical fuel energy. Ten tonnes of steel at 300C contains twice as much heat as five tonnes at 300C.

Temperature, by contrast, is just a measure of how hot something is. You cannot buy or use temperature; it is not a form of energy. You can see how different heat and temperature are if you think about taking some ice from the freezer and adding heat to it. At first, starting from a temperature of -15C (say), its temperature rises as it absorbs the heat. When it reaches melting point, it continues to absorb heat as it turns to water.
During this process its temperature stays constant at 0℃ but its heat content continues increasing (if you completely stop adding heat, the ice-water mix does not change). Once it is all melted, the liquid water continues to absorb heat and its temperature starts climbing again until it reaches the boiling point, whereupon the temperature again stops rising while the water evaporates. Only when there is no more liquid left can the water, now as vapour, start to increase in temperature (and become what is called 'superheated'). With a few odd exceptions that don't go through a liquid phase, as you add heat to any solid its temperature rises unevenly, remaining on plateaux while it is melting or vaporising, following the same trajectory back down as it first condenses to liquid and then solidifies when heat is removed from it. Common physical manifestations of this are
(a) Your drink with ice in it starts to warm abruptly once all the ice has melted
(b) Boiling a pan of water rapidly does not raise its temperature.

One finicky point you will need to know. When engineers and scientists talk about temperature *differences* they use a unit of measurement called a kelvin represented by a capital K. One kelvin is numerically equal to a one-degree difference between two temperatures in celsius (centigrade degree in the old nomenclature); when it is 19°C indoors and 5°C outside, the temperature difference is 14K.

Monitoring energy consumption

To manage energy successfully you need to measure how much you use, and that means taking your own meter readings rather than relying on figures provided by the utility companies. How frequently you get your meters read depends on your circumstances.EN16001 section 3.5.1 places an obligation on the organization to monitor, measure and record significant energy consumption 'at defined intervals'. My usual guidance is to consider a weekly regime as the best starting point. Monthly monitoring, which has historically been the norm, is too blunt an instrument for major users while fine-grained data (30-minute intervals or less) brings attendant problems of data overload and difficulties in interpretation and analysis. EN16001 also calls for 'energy factors' to be recorded as well. By this it means weather data, usually in the form of degree-day figures (also discussed later), production statistics, and the like -- what in normal energy management terminology would have been called 'driving factors'. When we come to discuss understanding patterns of energy consumption the value of this data will become clear but suffice it to say, for now, that both consumption and driving-factor information need to be synchronised and collected at intervals to match your required interval of assessment and reporting.

ENERGY METERING TECHNOLOGIES

Many readers will be happy to make do with existing metering, but some may need to install additional meters in order to separate out significant energy uses, or to measure flows of product. To get the best accuracy it is important to choose an appropriate measurement technology, but cost is always an issue. Fortunately, EN16001 does not lay down accuracy standards. Section 3.5.1 merely stipulates that accuracy and repeatability should be 'appropriate' and for routine energy management the requirement is actually quite relaxed, since you will mainly be interested in changes and trends.

Electricity meters

Modern electricity meters are solid-state electronic devices which are either directly connected in the supply cabling or (usually) where the measured current exceeds 100 amps indirectly through current transformers (CTs). A CT typically consists of a ring of magnetic material through which the power cable passes, the load current inducing a voltage in a secondary winding. It is this voltage which is sensed by the meter. The advantage of indirect connection is that the meter can be mounted in a convenient location remote from the power cable, where it may be easier to read; and multiple meters can be marshalled together.

For the sake of accuracy, CTs should be matched to the current they will be measuring. On a three-phase supply one CT per phase is needed and care must be taken that all are properly connected: having one disconnected will reduce the measurement by one-third, while one connect the wrong way around will reduce the measurement by two-thirds. Such faults may go undetected for years, giving incorrect results and ultimately causing embarrassment. More advanced meters nowadays include on-board diagnostics which aid

Correct commissioning and prevent these problems; they can also report power quality, harmonics, power factor and other parameters.

Where it is not possible to disconnect the power cable to thread it through the CT, split-core types can be used which clip over the cable. There are even flexible types where space is limited.

FLOW METERS

There are numerous technologies available for measuring gas, steam, compressed air, oil and other fluids but even knowing what liquid or gas is being measured, other questions will have a bearing on the choice of metering technique:

- What is the expected temperature range?
- What is the maximum expected pressure?
- What maximum and minimum flow rates need to be accommodated?
- What is the maximum acceptable pressure drop?
- In some cases, how much straight pipe is there upstream and downstream?
- In some cases, is electrical power available?
- If measuring a liquid, what is its viscosity? Is the viscosity likely to vary significantly?
- What is the state of the measured liquid (dust, dirt, bubbles, etc.)?

This is definitely a case where advice from a consultant (or metering supplier with a wide product range) will be invaluable. But for now here is some very general guidance for the more common applications.

Firstly for **gas** supplies, turbine meters would be the usual choice for large meters (pipe sizes of 200mm and over). Otherwise rotary positive displacement or bellows types would normally be used. The latter are limited to low-pressure applications.

For **oil**, a positive-displacement type of meter would be the typical choice.

For **compressed air** submeters, turbine meters are unsuitable because they are easily damaged by sudden pressure fluctuations, and entrained dust or water droplets. Orifice plates are a robust solution where the flow rate is constant; otherwise either thermal-mass or vortex meters should be employed. Both of the latter impose relatively low pressure drop, making them attractive for retrofit applications. Pressure and temperature correction is likely to be needed.

For **steam** the best candidates are likely to be vortex meters and variable-area orifice meters such as the Spirax Gilflo, unless the flow rate is unlikely to vary, in which case a fixed orifice might be an option. Pressure and temperature correction are definitely required in all cases.

For **water** and other clean liquids, positive-displacement and multi-jet meters are acceptable. Vortex and orifice meters are more tolerant of suspended contaminants but the latter are only accurate over a narrow range of flow rates. Electromagnetic meters may also be considered, as long as the fluid is conductive.

Check list for top management

Seven Principles for Effective Energy Management

Rising energy costs have again made energy management a priority for facilities managers. Many new energy-saving technologies are available, such as automated management systems, but they do not, in themselves, guarantee a successful energy program. Facility managers should keep the following principles in mind as they consider "new" approaches to energy management.

1. Without knowing how, when and where energy is used, there is no way to gauge the relative importance of energy management projects. Identifying and tracking energy use patterns is the first step in any energy program.
2. More energy savings may be obtained by simply controlling a system's use (e.g., lighting) than by installing more efficient components (e.g., T-8 lamps and electronic ballasts).
3. Most successful energy management programs are found in the best managed and maintained facilities, not in those with the greatest quantity of technological equipment.
4. Good maintenance practices and good energy management go hand in hand. Some of the highest rates of return on energy conservation are generated simply by performing maintenance.
5. Preventive maintenance is still critical, and reactive maintenance (waiting for a crisis to occur) is still foolish, despite funding limitations. It is easy to ignore preventive maintenance when systems are new, calibrations are

precise, seals are tight, and heat-exchanger surfaces are clean. As systems age, these and other items need care. No amount of technology will obviate the need for regular care or compensate for its absence.

6. Maintenance and energy management serve different purposes. One cannot be substituted for the other. For example, cleaning light-fixture lenses and re lamping them is good maintenance; installing more efficient lamps and ballasts is good energy management. These distinctions must be remembered when budgets are being prepared.
7. Automated energy management systems cannot compensate for poor HVAC system design. If heating and cooling loads are incorrectly estimated or equipment is inappropriate, automation cannot wring more performance out of system components than they were designed to provide.

With the passage of time, the cost of energy has shot up to a great extent. This change has resulted in making energy management a priority for all the facility managers and commercial building owners.

Nowadays, a number of cutting-edge technologies are being exploited in the field including the latest automated management systems. These technologies when used in conjunction with certain principles of energy management exhibit potentials to create a successful energy program which is quite efficient. The basic principles of energy management so employed are as follows:

1. **Identification and tracking of Energy Pattern:** The first step of any program is identifying and tracking the energy pattern of that program. If we do not have the knowledge of when and where the energy is used, then there is no way to estimate the relative importance of any Energy Management Project.
2. **Controlled energy system's use:** To obtain more amount of energy saving, it is not important to install more and more efficient components like electronic ballasts or T-8 lamps, etc. Instead, what is more important is that we must keep a check on the system's use and ensure that the resources are aptly used.
3. **Properly maintained and managed facilities:** A program with effectively maintained and managed facilities is the only program that offers effectual Energy Management. The quantity of technological equipment has nothing to do with the success of energy management program.
4. **Good Maintenance practices:** To attain the highest rates of return on Energy Conservation, it is important to keep in mind the maintenance practices in the program. We know that Great Maintenance and Successful Energy Management go hand in hand, so simply by performing maintenance, we can achieve success in any energy management programs.
5. **Preventive and Reactive Maintenance:** Despite the funding limitations, we know that waiting for any crisis to take place is a waste of time, i.e., reactive maintenance is imprudence. On the contrary, preventive maintenance is critical for the program's success. It can be ignored when systems are new, heat exchange systems are clean, seals are tight and calibrations are precise. However, as the system ages, these items need care or preventive maintenance.

6. **Distinction between Maintenance and energy Management:** One should know the clear distinction between Maintenance and Energy Management. Cleaning and fixing of equipment for better use come under good maintenance while installation of more efficient equipment comes under good energy management. Both of these serve different purposes. It is very important to remember their difference whenever a budget is being prepared for any program.
7. **Automated Energy Management Systems:** Even the most overrated technologies of automated energy management systems cannot recompense for a poor HVAC system design. No automation can bring more performance out of any system components if heating and cooling of loads is incorrectly calculated or if the set of equipment is inappropriate.

Thus, to create an effective **energy management program**, it is imperative to keep these basic principles of energy management in mind. Furthermore, the global scenario is changing at a rapid phase. Hence, it demands for innovative as well as effective energy management solutions every single day. So, organizations are hiring professionals to take care of this. These professionals have in-depth knowledge of the technicalities, economics, legal requirements and entrepreneurial concepts of the energy sector and so they are paid well.