Lecture 5: Energy Audits and Surveys

5.1 Introduction.

Before any energy-saving measures can be undertaken within an organization, it is first necessary to collect comprehensive energy data through an auditing process. Before any energy 'problems' can be treated it is first necessary to determine the current state of a facility's or organization's energy consumption and thus diagnose any problems that exist. In order to do this, an energy audit must be undertaken and analysis performed on the data collected.

An energy audit is a feasibility study to establish and quantify the cost of the various energy inputs to, and flows within, a facility or organization over a given period. The overall aim of an energy audit is to identify viable and cost-effective energy measures which will reduce operating costs.

Energy audits can take a variety of forms, but the process usually involves collecting data from energy invoices and meters, and undertaking surveys of plant, equipment and buildings, as well as collecting information from managers and other staff. The auditing process should identify ways to enhance an organization's operating efficiency and decrease its maintenance costs. In addition, the process should help to resolve any occupant-comfort problem which may exist.

An energy audit should be viewed as the 'foundation' on which any future energy management programme is built.

Energy-management programs involve the continual monitoring and targeting of energy consumption. Before targets can be set, or effective monitoring undertaken, it is important to establish:

- baseline energy consumption;
- patterns of operation and the work practices used;
- the condition of the organization's buildings, plant and equipment; and
- *Energy-management opportunities*, which will result in energy cost reductions.

This information can only be obtained by carrying out a full energy audit of an organization's facilities.

An energy audit should identify those issues which need immediate direct action, as well as those which require further detailed investigation. It should also produce data which can be used to justify future capital investment, and raise, within the organization, general awareness of energy conservation matters. The financial benefits afforded to an organization by an energy audit are both direct and indirect. The direct benefits are fairly obvious; energy cost savings can be achieved by reducing consumption, or simply by changing tariff or fuel type. The indirect benefits are much less obvious; reduced maintenance costs will arise from improved plant utilization and reduced operating hours. Also, improved plant utilization may result in the elimination of excess plant capacity and ultimately reduce capital expenditure.

The auditing process should identify *energy-management opportunities*, which when implemented will result in financial benefit to an organization. The magnitude of these financial benefits is not necessarily dependent on the level of capital investment. In many situations, major cost savings can be achieved through the implementation of 'no cost' or low cost measures, such as:

- Changing an energy tariff;
- Rescheduling production activities to take advantage of preferential tariffs;
- Adjusting existing controls so that plant operation matches the actual requirements of the building or manufacturing process;
- Implementing good housekeeping policies, in which staff are encouraged to avoid energy-wasteful practices and
- Investing in small capital items such as thermostats and time switches.

Although much can be achieved through low cost measures, it is sometimes necessary to undertake more capital-intensive measures, such as replacing worn-out plant or installing a building management system (BMS).

Read about Building management systems here; Why Building Management Systems?

- https://www.eeekenya.com/why-building-management-systems/ and
- https://www.researchgate.net/publication/276273243_HEURISTIC_VIEW_ON_INTELLIGENT_BUILDING_DESIGNS_AS_A_MEANS_TO_SAVE_ENERGY

5.2 Types of Energy Audit

They are broadly classified into:

1. *Preliminary,*
2. *Targeted And*
3. *Comprehensive Audits*

Each type is distinguished by the level of detail involved and the depth of the analysis undertaken. It is important to select the appropriate audit type for the facility concerned.

Comprehensive audits

These involve detailed energy surveys of plant, equipment and the fabric of buildings, which is a time-consuming and expensive process. They therefore should not be undertaken lightly. It is often better to focus detailed surveys on problem areas highlighted by a preliminary energy audit, otherwise much time and money can be wasted. By carrying out a preliminary audit and methodically applying a range of simple analysis techniques it is often possible to identify major energy problems without the need for expensive and detailed energy surveys. These audits provide detailed data on the energy inputs to, and energy flows within, a facility or organization. They should produce detailed energy project implementation plans. Such audits involve detailed energy surveys and may involve the use of complex energy simulation computer software.

Preliminary energy audits

These seek to establish the quantity and cost of each form of energy used in a facility or in an organization. They are relatively quick and are designed to determine a project's potential; more detailed energy audits and surveys can always be undertaken later if so required. Preliminary audits are primarily concerned with obtaining data from energy invoices and meter readings for a given period, which often corresponds to the most recent financial year. Because such audits are primarily concerned with gathering data from bills and invoices, it is sometimes helpful to think of preliminary audits as being ***financial energy audits.***

Targeted energy audits

These often result from preliminary audits. They provide data and detailed analysis on specific targeted projects. For example, an organization may target its lighting installation or boilers with

a view to upgrading these items of equipment. Targeted audits therefore involve detailed surveys of the target subjects and analysis of the energy flows and costs associated with the targets. They should make recommendations regarding action to be taken.

Although in-house staff can carry out audits, they are generally undertaken by either specialist energy consultants or energy service companies. Energy service companies make their money through performance contracts, which guarantee organization's energy cost savings in return for negotiated fees. To energy service companies the main interest lies not in the audit itself, but in installing and managing the plant in accordance with their recommendations.

Some companies may even arrange the finance for such projects. When using an energy service company it is thus important to remember that they have a vested interest in the outcome of any energy audit and that they may not be totally impartial. ***By contrast, energy consultants are independent and therefore should provide objective advice.***

Some of the energy audit firms in Kenya are listed in this page below;

Energy Auditors Firms In Kenya

https://www.eeekenya.com/energy-auditors/

5.2.1 Audit Costs

Energy audits can be expensive undertakings. The more complex the audit, the higher the costs involved. It is therefore important to select the appropriate level of audit for any particular application.

Audit costs are affected by the complexity of the facility under consideration. For example, complex facilities such as hospitals or universities are more costly to audit than, say, schools. The age of the facility may also affect the cost. For example, if a mechanical system is complex and the 'as built' drawings are out of date or not available, then the energy auditors may have to produce schematic drawings.

This can be very time consuming and obviously greatly increases the audit costs. Given the cost involved, it is important that organizations assist their auditors by preparing in advance for the audit and providing the auditing team with as much relevant information as possible.

Energy bills, fuel invoices, meter readings and operational notes should all be collected, together with any relevant system or building drawings. Organizations should also inform their management team that an energy audit is being undertaken and arrange for the auditors to meet with key managers and other relevant staff.

5.3 Why is Energy Wasted?

- Poorly designed buildings and installations. Buildings may be poorly insulated resulting in high space-heating costs, or mechanical ventilation ducts may be undersized so that fan power consumption is high.
- Inadequate control systems. Heating systems may be installed without any optimum start control.
- Poor control settings. Time clock controllers may be incorrectly set so that buildings are heated when not in use.
- Inefficient plant operation, often arising from the use of old or out-of-date technology, a situation often made worse by poor maintenance practices.
- Poor operating and working practices. Lights are often left on in buildings when they should be switched off.

Although the reasons for energy waste are multifactorial, some of the main reasons areas follows:

- Building designers do not pay energy bills. The design process is closely allied to the construction process, and designers usually select low capital cost solutions, which often result in higher operating costs. This situation is made worse by the fact that the budgets for constructing a facility and running it are usually completely separate.
- Energy consumption is taken for granted. Most building occupants and users do not pay energy bills. They are concerned with their own personal comfort and are not particularly interested in how much energy is consumed in achieving a comfortable environment.
- Most organizations do not have a culture of energy efficiency.
- In many countries the cost of energy is low in comparison with labour costs.

The above list demonstrates that much energy wastage arises from poor strategic and operational management, and also a lack of an energy-saving culture amongst staff.

Energy can often be saved at no capital expense simply by improving maintenance procedures and instigating good work practices. This is often referred to as 'good housekeeping' and involves simple measures such as encouraging personnel to switch off lights when they are not required. Initiating good maintenance procedures is also important. It has been estimated that energy bills for organizations can be reduced by approximately 20% through the use of good energy-management practices. It is therefore important that the human and management aspects of energy consumption are investigated in any energy audit. Without a supportive management culture it is difficult to make lasting energy savings in any organization.

5.4 Preliminary Energy Audits

Preliminary audits seek to quantify and cost each form of energy input to a facility or organization over a period of time. They should also identify where the energy is being used within the organization. The main processes involved in such an audit are:

- Collecting data
- Analyzing data
- Presenting data
- Establishing priorities and making recommendations

At the start of any audit process it is important to gather preliminary data about the geographic location of the particular facility concerned, together with any relevant distinguishing features such as its altitude and orientation. Local weather data and degree day data covering the audit period should also be collected. These data will act as a benchmark reference against which the facility's energy consumption can be measured. With manufacturing facilities it will also be necessary to collect data concerning the production output during the audit period, since this will have a considerable impact on energy consumption.

Probably the single most important source of energy data is the energy invoice. It is therefore very important that the audit team has all the relevant energy invoices for the selected audit period. By compiling data from invoices it is possible to build up a clear picture of the pattern of energy consumption and the associated costs to a facility of the various energy inputs. In addition, the

total amount spent on energy can be determined from the invoices, thus indicating the upper limit which can ultimately be saved through energy-management measures.

When collecting data from fuel and energy invoices it is important to ensure that copies of all utility invoices for the audit period are collected rather than simply those for which payments were made during the audit period. It is also important to collect all the invoices or delivery notes relating to oil, solid fuel or liquid petroleum gas for the audit period. Due to the time lag between delivery and consumption, it may also be necessary to include deliveries which occurred before the start of the audit period. In addition, it is essential that all the metering and supply points are identified from the invoices, to account for all the energy inputs.

Any estimated meter readings should be identified, since these can result in misleading data. In order to overcome the problems associated with estimated readings, additional invoices should be collected which cover the same months as the estimated invoice, but for years prior to the audit period. These 'real' data can then be compared with the estimated data, to establish realistic data for the audit period.

If invoice data are inadequate or unavailable, then it will be necessary to approach the utility companies or fuel suppliers for assistance.

Preliminary analysis of energy invoices can often be very useful in identifying any anomalies which require further investigation. If a relatively small building on a site consumes as much gas as one of its much larger neighbours, then it would appear that something is wrong.

Further investigation can then be undertaken, which might reveal that the high gas consumption is due to the heating plant in the small building operating at night-time when the building is empty.

Given that the gathering of information from invoices is crucial to the auditing process, it is important that energy invoices be understood.

Exercise 5.1

Collect sample KPLC electricity invoice or receipt and analyze the information contained in them. If possible for commercial, residential and industrial consumers.

5.4.1 Site Records

In larger more complex facilities, especially those which employ an energy manager, it is often the case that site energy records are kept. These can be an important source of information to an audit team and can be used to corroborate data collected from energy invoices. In particular, records of sub-meter readings can be particularly useful, since they give detailed information about energy flows.

5.4.2 Data Analysis

For a preliminary energy audit, analysis should be limited to those techniques which enable the auditor to determine:

- How much energy is being consumed;
- What type of energy is being consumed;
- The performance of the facility compared with other similar facilities; and
- The characteristic performance of the building.

When all the energy data have been gathered and analyzed, they need to be compared against various 'yardsticks' for similar facilities.

Homework 5.1

Identify at least three data analysis techniques used in energy audits.

5.5 Comprehensive Energy Audits

The analysis techniques used for comprehensive energy audits are essentially much the same as those used for preliminary audits, but the level of detail is much greater. Comprehensive audits require detailed energy surveys to be undertaken, and they often require the installation of additional sub-metering in order to determine accurately component energy flows.

5.5.1 Portable and Temporary Sub-metering

It may be evident from the outset of an auditing project that the installation of additional sub-metering will yield much useful information about the energy flows within a facility. For example, by placing sub-meters on the energy input side and heat meters on the output side, it is possible to determine the efficiency of individual plant items. Sub-metering should also highlight any

imbalances between the consumption recorded by main meters and the total recorded by the sub-meters. If additional submeters are deemed necessary, then the additional cost can usually be justified for items of plant or areas with high loads, particularly in situations where little information exists on current energy consumption.

The process of assessing a facility for additional sub-metering can also highlight shortcomings in the facility's existing metering provision. For example, several buildings may be served off a single electricity meter. In such a situation, it may be worth considering the installation of permanent sub-meters, since these would support any future energy-management programme.

Permanent metering should also be considered when it is less expensive than the cost of hiring, installing and removing temporary metering equipment.

The installation of permanent or temporary meters is invasive and involves the shutting off of energy supplies, which in many circumstances is unsatisfactory. Instead, it is worth considering the use of portable non-invasive metering.

5.5.2 Estimating Energy Use

In many situations it is either impractical or prohibitively expensive to install comprehensive sub-metering and so it is necessary to estimate the energy consumption of various items of plant and equipment. Accurate estimation of equipment energy consumption can be a difficult process and one which relies on skill and judgement. Nevertheless, it is relatively easy to establish an upper limit for energy consumption by using Eqn 5.1.

$$Annual\ energy\ consumption(kWh) = \frac{Q_{out}}{\eta} \times T_h \qquad 5.1$$

Where Q_{out} is the plant power output (kW), η is the efficiency of the plant and T_h is the number of operating hours per year.

While Eqn (5.1) may give an upper limit on plant energy consumption it does not provide the actual operating energy consumption. This problem can be overcome by monitoring the actual plant energy consumption for a short period of time, using meters, and then multiplying the average measured load by the annual operating time. In the case of electrical equipment this can be a relatively simple process since the current can be measured using a portable clamp-on meter.

Space heating energy consumption can be estimated using the heat loss and degree day methods ***(beyond scope of this lecture).***

5.6 Energy Surveys

Energy surveys are an integral part of the auditing process. They enable the auditors to understand the energy flows within facilities and to identify energy wastage. Surveys can be comprehensive, looking in depth at all aspects of a facility's energy consumption, or targeted, in which case they only cover certain specific issues. The main objectives of any energy survey should be to:

- Determine the energy performance of a facility, or in the case of a targeted survey, targeted items of plant and equipment.
- Identify and quantify the principal energy flows.
- Identify and quantify achievable energy cost savings.
- Produce costed recommendations to achieve energy cost savings.
- Make recommendations on the future energy management of the facility.

Energy surveys, with the exception of specifically targeted surveys, should cover all aspects relating to a facility's or organization's energy consumption. This will involve detailed surveys of:

- The management and operation characteristics of a facility or organization.
- The energy supply to an organization's various facilities.
- The energy use within a facility.
- The plant and equipment within a facility.
- The fabric of the organization's buildings.

5.6.1 Management and Operating Characteristics

The management culture within an organization can have a great influence on energy consumption. It is therefore important to determine the management structure and practices relating to energy procurement and consumption.

In particular, it is important to identify cost centres clearly, where the managers accountable for operating costs can be made individually responsible for energy consumption. Maintenance practices can also have a direct influence on energy consumption, so it is important to establish

the frequency and quality of the maintenance procedures, and to identify new maintenance measures which could improve the energy performance of plant and equipment.

At the auditing stage it is important to survey the operating practices within an organization or facility. Detailed data should be gathered on such factors as:

- The use of a particular space or building.
- The mechanical and electrical services within the building.
- The number and type of occupants. Particular attention should be paid to any special characteristics of occupants. For example, in rooms containing smokers, windows are often opened with the result that space-heating costs are increased.
- The occupancy patterns of building or space.
- The environmental conditions within a space or building. This will include air temperature, dry resultant temperature, and relative humidity and illuminance levels.
- The operating practices of major items of plant and equipment.

5.6.2 Energy Supply

It is important to identify the tariffs and supply contracts under which any organization purchases its energy. This will enable the energy auditing team to establish whether or not a particular organization is purchasing energy at a low price. If an organization is paying a higher than necessary price for its energy, then the auditor should recommend a change of tariff or fuel supplier.

Because electricity tariffs usually include some form of demand charge, it is important that an organization selects the correct electricity tariff to suite its load profile.

Therefore, the audit process should include a survey of the electrical load profile of a facility.

For relatively minor loads it may be sufficient to take meter readings at the beginning and end of a selected period, with intermediate readings taken during the daytime, night-time and at the weekend. This will give a good indication of when electrical energy is being consumed and should assist the auditor in recommending an appropriate tariff. For larger electrical loads, it is important to survey the load profile accurately. This can be achieved by using a portable meter to determine

demand and consumption at 30-minute intervals over a selected period. Any large peaks in load should be identified and further investigations made in order to establish their cause.

With electricity supply, it is important to determine the power factor of a facility. Many items of equipment, such as fluorescent lamps and electric motors, produce a poor power factor (i.e. a decoupling of the current and the voltage so that they become out of phase with each other). This results in higher than expected electricity bills. If poor power factors are found in a facility then it may be worth considering the installation of power factor correction equipment.

5.6.3 Plant and Equipment

Major items of plant, such as boilers and refrigeration chillers, convert energy from one form to another. In doing so energy is wasted. For example, in boilers much of the heat produced by the combustion process can be wasted by allowing it to escape with the flue gases. The more efficient an item of plant, the less energy is wasted. Major items of plant and equipment should therefore be surveyed in order to determine their operating efficiency. It is also important to survey their respective pipe distribution networks since these too can be a major source of energy wastage.

With boilers it is essential that they be 'tuned' so that flue gas heat losses are minimized. This involves sampling the CO_2 or O_2 content of the flue gases and adjusting the burner settings so that excess O_2 is minimized, whilst still ensuring that complete combustion takes place. In addition, it is important to identify whether or not flue gas heat recovery is feasible.

The efficiency of refrigeration plant is measured by its coefficient of performance (COP). The higher the COP, the greater the efficiency of the machine. COP varies with the cooling load and the external air conditions. It is therefore necessary to meter the energy input and output over a period of time, if the average COP is to be identified. Note should be taken of the operating pattern of refrigeration plant and also of how it is controlled, since this will tell the auditor much about the operation of the facility.

In many facilities much energy is wasted from hot water, chilled water and steam distribution pipework because of inadequate or poor quality insulation. Pipework systems should therefore be inspected to establish the quality of the insulation and also to identify any leaks.

Plant surveys should allow for the fact that mechanical equipment has a finite working life and that efficiency often deteriorates badly when plant is old. Therefore one of the important outcomes of such a survey should be a recommendation for the planned replacement of older plant. In many situations it is much more cost-effective to replace old plant, rather than renovate it.

5.6.4 Building Fabric

It is important to note the age, size, shape and orientation of the buildings within a facility, since these are all factors which affect energy consumption. In particular, areas of greatest heat loss should be identified.

When surveying buildings, it should be appreciated that large amounts of heat can be lost by excess ventilation.

Particular attention should therefore be paid to any poorly fitting window and door frames, or to any space where windows and outside doors remain open for any length of time

5.7 Recommendations

The energy auditing process should enable recommendations to be made, which will result in cost savings. Although the precise nature of these recommendations will depend on the particular application in question, they can broadly be classified as follows:

(i) ***Reducing energy costs by tariff negotiation:*** Electricity and gas are supplied either through published tariff s or through negotiated supply contracts. Not all tariffs and supply contracts are suited to every organization and some are better than others. It may therefore be possible to reduce energy costs simply by changing tariff or negotiating a more beneficial supply contract.

(ii) ***Good maintenance and work practices:*** Energy can often be saved at no capital expense simply by ‘good housekeeping’ (i.e. improving maintenance procedures and implementing good work practices).

(iii) ***Retrofitting and tuning systems:*** Energy is often wasted as systems age, because components wear out or become damaged. Also, the controls associated with these systems are often inappropriate or poorly set up with the result that systems

perform inefficiently. Significant energy savings can be achieved through modest capital investment to retrofit t and re-tune inefficient installations.

(iv) ***Capital investment:*** In many situations the poor condition of plant and infrastructure makes refurbishment a futile exercise. Under these circumstances major capital investment is required to replace existing plant. In this case, it is often worthwhile reappraising the situation to determine whether or not an alternative installation might be more appropriate. An existing boiler installation could be replaced by a combined heat and power (CHP) plant, thus reducing the need to buy in electrical power. Such measures usually involve large capital investment and careful financial appraisal is therefore required.

5.8 The Audit Report

The audit process should identify potential energy-management opportunities. Since exploitation of these opportunities often involves capital expenditure, maximum effort should be put into investigating those measures which will yield the greatest cost savings. Those energy-management opportunities which result in lesser savings should be given a low priority.

The final audit report should include:

- A description of the facility, including layout drawings, construction details, hours of operation, equipment lists and any relevant materials and product flows.
- A description of the various utility tariffs or contracts used.
- A presentation of all the energy data gathered, together with any relevant analysis.
- A detailed statement of potential energy-management opportunities, together with supporting cost/benefit analysis calculations.
- An energy management action plan for the future operation of the facility. This may include an implementation schedule for the recommended energy-management opportunities and a programme for the ongoing energy monitoring and targeting of the facility.

Although the audit report should contain detailed technical information, it is important to remember that its primary purpose is to communicate the principal findings of the audit to an organization's senior management, many of whom may have little understanding of energy

matters. It is therefore advisable to include a short executive summary, giving a brief synopsis of the report and highlighting its major findings and recommendations.

Note:

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