ETHIOPIAN ENERGY AUTHORITY

General Procedures for

Energy Auditing

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Abbreviations

LEA	**Licensed Energy Auditors**
CFL	Compact Florescent Lamp
DSM	Demand Side Management
EE	Energy Efficiency
EEA	Ethiopian Energy Authority
ECM	Energy Conservation Measure
ESCO	Energy Service Company
EUD	European Union Delegation
EMP	Energy Management Programme
GHG	Green House Gas Emissions
ISO	International Organization for Standardization
kWh	Kilowatt-hour
LED	Light-emitting Diode
O&M	Operation &Maintenance
SE4All	Sustainable Energy for All
TA	Technical Assistance

1. Introduction

In January 2014, Proclamation no. 810/2013, “The Energy Proclamation” was published creating the Ethiopian Energy Authority (EEA) with the mandate to regulate the electricity sector, and to improve energy efficiency and to carry out energy conservation.

This guidebook provides guidelines for energy auditors regarding the key elements for preparing for an energy audit, conducting an inventory and measuring energy use, analyzing energy bills, benchmarking, analyzing energy use patterns, identifying energy-efficiency opportunities, conducting cost-benefit analysis, preparing energy audit reports, and undertaking post-audit activities. The purpose of this guidebook is to assist energy auditors and engineers in the plant to conduct a well-structured and effective energy audit.

The Energy Audit is an examination process where the energy consumptions of a given facility or building are investigated, the objective is to ensure that the energy is being used in an efficient manner. This involves a detailed assessment of the energy consumptions of the different equipment and components, identifying inefficiencies or potential areas of improvement. Therefore, the Energy Audit is an effective energy management tool that not only identifies and implements measures to enhance the energy savings but also reduces the installation running costs and if well implemented extends the equipment and system life. Furthermore reduced energy consumptions contribute to minimizing generated emissions thus minimizing the environmental impact showing a commitment of the company in terms of sustainability.

Therefore, the energy audit process will range from energy studies to walk-through in the 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 the Client. The procedures when developing an energy audit will be described in the following sections.

2. Scope of Works

The first aspect to consider when undertaking an energy audit is to define the scope of workfor the potential project. This involves the assessment of the available resource for conduction the auditing thus clarifying the budget allocate, the human resources and timescales. This information will help to make a decision regarding:

- The scope of the energy audit such as the potential areas to be audited
- The level of depth of the audit and
  staff involved
- Potential training needs for building managers, O&M staff, etc.

Therefore, it is useful to have a discussion with the Client defining the services and expected outputs from the energy audit.

2.1. Energy Audit Team Selection

The selection of the energy auditing team is a crucial decision as depending on the type of project. It can be formed by electrical engineers, thermal engineers, mechanical engineers, instrumentation specialists, etc. the activity shall be done by trained or certified Energy Auditors.

2.2. Time Frame & Budget

As mentioned previously the available budget allocation, human resources and time scales have to be clearly defined. The budget basically indicates the time allocated for the auditors to undertake the energy audit and measurement instrumentation costs. The final budget normally depends on various aspects such as the building/facility size, quantity of equipment to be inspected, process complexity, level of detail and the scope of works regarding technical and financial analysis.

On the other hand in several occasions the energy audits do not take place as consequence of different type of reasons such as:

- Disruption caused implementing the ECMs
- Excessive data collection and cost
  requirements
- Time frame
- Clients financial constraints

Therefore the aim is to achieve substantial savings but for a defined budget and minimizing the levels of disruption (developing the work for example on the weekends or holiday periods).Nevertheless financial constraints could be mitigated through financing options, government grants, greater participation of the facility/buildings personnel which do not require high technical expertise etc.

3. Types of Energy Audit

The energy audits can be classified on various types depending on the project, scope of the works and resources allocated:

- Walk-Through Energy Audit: this type consists of a short site visit of the facility / building identifying low cost improvement measures. This frequently involves operation and maintenance measures that achieve immediate cost savings. This type of audit could include as well a review of the energy bill with the metered energy usage of the facility or building. Assessing the utility data helps to identify the demand profiles, energy consumption progressions, energy consumption per fuel (electricity & fuel) etc.

- Standard Energy Audit: this audit type has a greater level of depth analyzing specific energy systems, components and operation activities. This could include undertaking some measurements for some of the components. This includes the calculation of the energy baseline for the facility and the evaluation of the potential energy savings for the defined ECMs (energy conservation measures), and as well the cost benefit analysis for the different measures identified.
- Detailed Energy Audit: this is the most comprehensive and time intensive of all three energy audit types. This involves undertaking various energy measurements on selected energy systems or components of the entire facility. Furthermore thermal and energy computer simulation techniques are employed to model the facility/building in order to estimate with a higher level of accuracy the energy savings on an hourly, daily or yearly basis.

4. Data Collection

4.1. Kick of Meeting with Client and Facility/Building Manager

An initial meeting is scheduled between the Energy Auditor and the potential Client and as well the Project Manager of the Facility. The meeting agendas normally focus on:

- The objectives of the energy audit and scope of work. Understanding of the facility rules and regulations.
- Potential existing energy policies, energy targets, etc. defined by the corporation. Previous audits developed (if that is the case)
- Clarification of the roles and responsibilities of project team members and description of scheduled project activities.
- The discussion during this meeting seeks to establish: operating characteristics of the facility, energy system specifications, operating and maintenance procedures, preliminary areas of investigation, unusual operating constraints, anticipated future

plant expansions or changes in product mix, and other concerns related to facility operations.

4.2. Site Tour & Document Review

After the Kick-Off Meeting, a site tour of the facility/building is arranged to observe the various operations first hand, focusing on the major energy consuming systems identified during the interview, including the architectural, lighting and power, mechanical, and energy systems in general. The auditors review all the data/information provided by the client and shall prepare a questionnaire to collect the data from the Client on unit operations and energy usage during the field visits. This will include all the electrical and thermal energy usage. All parameters measured and recorded by the Client will be included as well as all billing data over recent years. Furthermore the auditor will perform direct measurements, using its own measurement equipment if needed. Also, the maintenance procedures and the operating conditions of major equipment are normally examined to determine their energy efficiency. After the undertaking of the kick-off meeting and site tour, available facility documentation will be reviewed with the building managers or corresponding responsible.

4.3. Facility Inspection

After a thorough review of the construction and operating documentation, the major energy consuming processes in the facility are further investigated. Where appropriate, field measurements are collected to substantiate operating parameters.

4.4. Staff Interviews

After the facility inspection, the audit team meets again with the building managers and corresponding facility staff to review preliminary findings and the recommendations being considered. The objective of the audit is to identify projects that have high value to the customer; management input at this juncture helps establish the priorities that form the foundation of the energy audit. In addition, interviews should be scheduled with key representatives designated by the facility as having information relevant to the energy audit. Please note that these representatives may include other stakeholders such as major energy consuming system service and maintenance contractors and utility representatives.

4.5. Utility Analysis

The utility analysis involves a detailed review of energy bills from the previous years (1 to 3 years). This should include all purchased energy agreements, including electricity, gas, fuel oil, liquefied petroleum gas and purchased steam, as well as any energy generated on site by backup systems (diesel generators) or even renewable technologies. The billing data analysis should include energy consumption, energy demand and utility rate structures. Normalize utility data for weather condition changes and facility operation since it is used as a baseline to compute energy conservation measures. The evaluation of the local tariffs for real- time pricing as it will impact the outcome of the ECM analysis.

The information to be collected during the detailed audit includes:

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

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

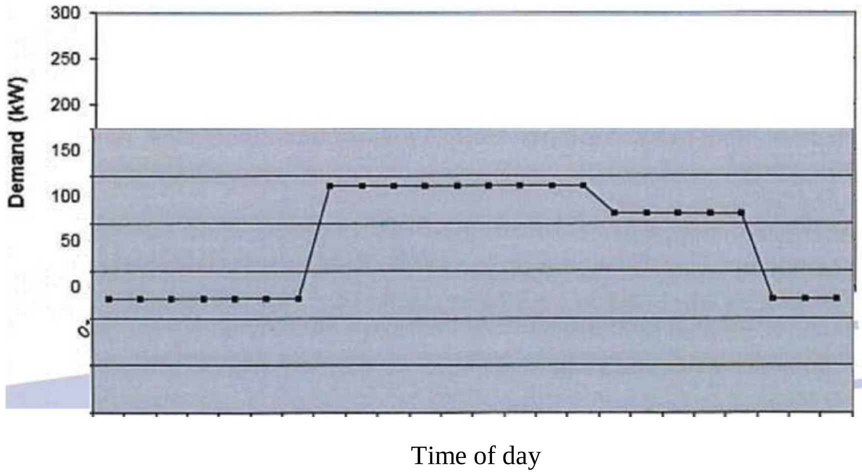
- Technology, processes used and equipment details
- Capacity utilization
- Amount & type of input materials used
- Water consumption
- Fuel consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc…
- Quantity & type of wastes generated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

5. Demand Analysis

5.1. Introduction

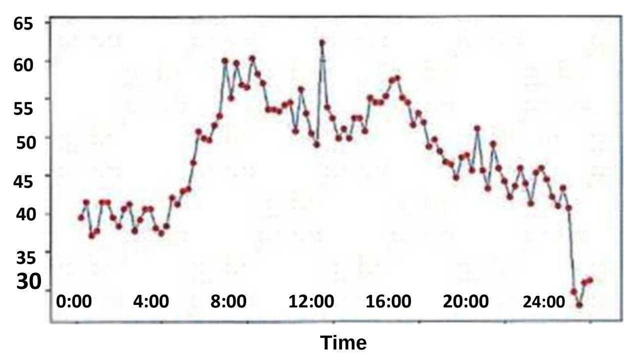
The energy demand profile is a crucial aspect of the electricity bill. The effective demand management offers substantial saving opportunities. The demand profile for a building, facility, or any user of electricity is simply a record of the power supplied at any point in time. Its purpose is to provide detailed information about how the building, or separately metered portion of the building, uses energy. It is, in essence, the "electrical fingerprint" of the facility. To the electrical energy auditor, the demand profile is an extremely useful tool in tracking energy use. The simplest demand profile would be a series of manual utility meter demand readings recorded monthly, daily, or hourly. Monthly demand is shown on the utility bills of monthly billed customers. The particular time interval used will depend on what the information in the demand profile is to be used for.

Figure 5-1 Hourly Demand Profile



The most commonly used form of the demand profile is similar to that illustrated in the figure above. The profile covers a period of approximately 24 hours; lightly more than 24 hours is better than less. The power demand appears on the vertical axis, while the time, in hours, appears on the horizontal axis.

Figure 5-2 15 minute Demand Profile



The figure above shows a 15min interval measurement graph of a power recording from a power analyzer. Readings are generally recorded automatically, less than one minute apart. In some cases, the readings maybe adjusted by the recording instrument to match those that would be taken from the utility meter.
The analysis of the demand profile allows to extract various information such as:

- Peak Demand: The time, magnitude and duration of the peak demand period or periods may be determined.

- Night Load: The demand present at night (or during unoccupied hours) is clearly identified.
- Start-Up: The effect of operation start-up(s) upon demand and the peak demand may be determined.
- Shut-Down: The amount of load turned off at shut-down may be identified. This should equal the start-up increment.
- Weather Effects: The effect of weather conditions upon the demand for electricity can be identified from day to night (with changing temperature), and from season to season by comparing demand profiles in each season.
- Loads that Cycle: The duty cycle of many loads can usually be seen on the demand profile. This can be compared to what is expected.
- Occupancy Effects: Often the occupancy schedule fora facility is reflected in the demand profile; if it is not, this could identify control problems.
- Problem Areas: A short-cycling compressor is usually easy to spot from the demand profile.

The information that may be found in the demand profile is not limited to that mentioned above; these are some of the most obvious items. Profiling not only the facility as a whole, but also departments or sections, will allow the development of detailed knowledge of the building's power consumption habits.

5.2. Demand Profile Interpretation

The demand profile shows the electrical consumption patterns of the given building. Key information may be obtained by reading or interpreting the profile, loads that operate continuously and could be shut down, loads that contribute unnecessarily to the peak demand, or possibly loads that are operating abnormally and require maintenance. Many electrical loads leave behind very distinct fingerprints as they operate. By recognizing the patterns associated with each component, it is possible to identify the contribution of various loads to the overall demand profile. Interpreting a demand profile is not just science; there's a bit of interpretative art involved, too. Good knowledge of the facility, its loads, operational patterns, and the examples in this section should be a good beginning for the development of that art. The following steps are recommended when interpreting a demand profile:

- Listing the electrical loads within a facility
- Study the demand profile and noting of significant events such as: demand changes, repeated demand patterns, flat sections, dips during peak periods minimum demand level, etc.
- Noting the timing during the day of the operational events such as start-ups, shut-downs, coffee breaks, shift changes, etc.

- Opportunities for Savings in the Demand Profile

Often, many opportunities for savings can be found in the Demand Profile. The following are typical examples of savings opportunities:

- A peak demand that is significantly higher than the remainder of the profile for a short amount of time is an opportunity for demand reduction by scheduling.
- A high night load in a facility without night operations presents an opportunity for energy savings through better control or possibly time clocks.
- Loads that cycle on/off frequently during unoccupied periods suggests that possibly they could be shut down completely.
- High demands during breaks or insignificant drops at break times suggests that equipment idling may be costly shutdown could be considered.
- Systems that are not starting up before they are needed and shutting down after the need has past. Even 1/2 hour per day can save a significant amount if the load is high.
- Peak demand periods at start-up times suggest an opportunity for staged startup to avoid the peak. If the billed demand peak is not evident on a typical demand profile, this suggests that the load (or loads) which determine the demand may not be necessary (if they only operate once in a while). Consideration for load scheduling could be allowed. Analysis of the billing history to see if the demand peak is consistent.
- A large load that cycle frequently may result in a higher peak demand and a lower utilization efficiency than a smaller machine running continuously hence consideration for smaller staged units or machines. This may reduce maintenance requirements as the machine start/stop are minimized cycling and wear & tear problems.
- Power Factor Correction Savings Opportunities

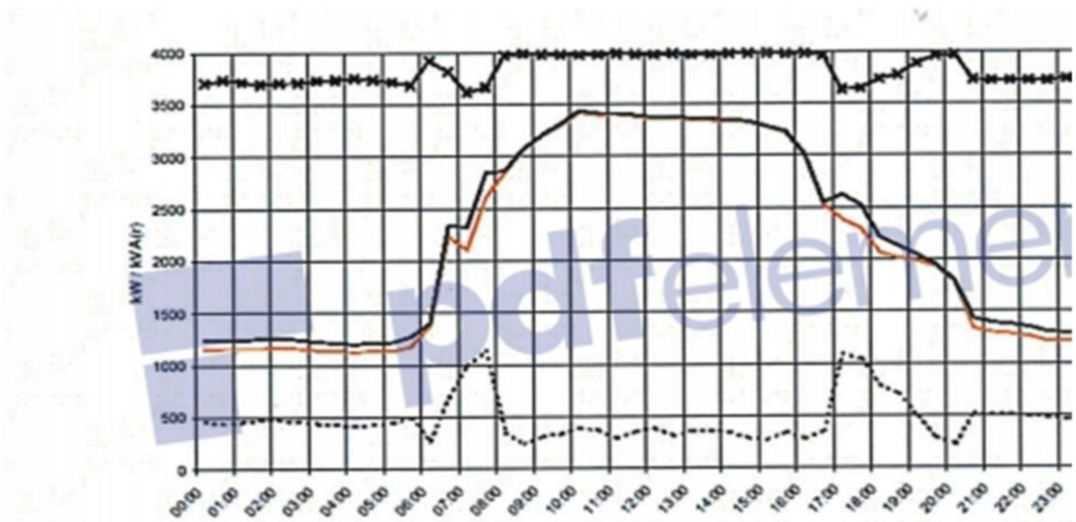
For customers billed on kVA demand there is an opportunity to reduce the peak or maximum kVA demand by increasing the power factor. The application of a capacitor or bank of capacitors it is possible to reduce the kVA demand while maintaining the real power consumption, the kW demand.

- Power factor correction: in practice it is only the on-peak power factor that really is of concern from the perspective of demand costs.
- Correct power factor at service entrance: This can be done with the addition of a fixed capacitor bank provided that the load and power factor are constant. Otherwise a variable bank (one that adjusts itself to the load and power factor) will be required.
- Correct power factor in the distribution system: when large banks of loads are switched as a unit within the distribution system, installing capacitors at the point of switching may be an advantage. This has an added secondary benefit in that it may also free up

current carrying capacity within the distribution system.

- Correct point –of – use factor: when a large number of motors start/stop frequently or are only partly loaded, it may be operationally advantageous to install power factor correction capacitors at the point – of – use (i.e. at the motor). In this manner the correction capacitors are brought on – line with the motor and removed as the motor is stopped.

Figure 5-3 Power Analysis



6. Energy Conservation Measures

6.1. Identification of ECMs

The auditor shall identify measures to reduce Client's consumption of energy and produce energy Efficiency Investment Plan. For each measure identified, the auditor team shall provide:

- Detailed description of the energy efficiency opportunity
- Estimate resulting annual energy savings and associated reduction of GHGs emissions
- Expected implementation duration
- Estimate implementation costs
- Internal Rate of Return (IRR) and a simple payback period

In order to identify the improvement actions for the potential ECMs, calculations should be performed to substantiate the improvement works by quantifying energy savings. The energy audits should clearly elaborate the major facility modifications required with a detailed economic analysis. Nevertheless for minor modifications providing a simple payback should be

Sufficient. Therefore developing a list of the major ECMs for each of the major energy-consuming systems, such as boilers, chillers, envelopes, HVAC, lighting, power and process. Utilizing collected data, finalize a list of ECMs to be reviewed with the facility manager.

6.2. Economic Analysis

The Consultant shall prepare an Energy Efficiency Investment Plan that prioritizes identified measures based on their cost effectiveness. Obviously low cost solutions should be prioritized as the recommended solutions. The Energy Efficiency Investment Plan shall also incorporate the Client's interests, company targets and priorities based on the discussions with Client's internal team.

Based upon a final review of all information and data gathered about the facility, and based on the reactions obtained from the facility personnel at the conclusion of the field survey review, a finalized list of energy conservation measures is developed and reviewed with the facility manager.

Therefore evaluating the effectiveness of a specific ECM, the auditor needs to estimate the payback, net present value or rate of return. Normally simple paybacks calculations can be employed dividing the ECM's capital cost by the annual energy savings to obtain estimate the payback. Nevertheless, for big capital investments where appreciable deviations could take place between the energy cost variations, interest rates, etc. it may be more suitable to utilize calculation methods such as internal rates of return, net present values, etc.

6.3. Identification of Energy Conservation Measures

The most common ECM that could be identified are:

- Fuel substitution: Identifying the appropriate fuel for efficient energy conversion
- Energy generation :Identifying Efficiency opportunities in energy conversion equipment/utility such as captive power generation, steam generation in boilers, thermic fluid heating, optimal loading of DG sets, minimum excess air combustion with boilers/thermic fluid heating, optimizing existing efficiencies, efficient energy conversion equipment, biomass gasifiers, Cogeneration, high efficiency DG sets, etc.
- Energy distribution: Identifying Efficiency opportunities network such as transformers, cables, switchgears and power factor improvement in electrical systems and chilled water, cooling water, hot water, compressed air, Etc.
- Energy usage by processes: This is where the major opportunity for improvement and many of them are hidden. Process analysis is useful tool for process integration measures.

When selecting ECMs, the technical feasibility should address the following issues

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

7. Structure of Audit Report

The auditor after site inspection, ECM's identification, calculations, findings in general and proposed recommendations a final report will be prepared. The report normally includes:

- Description of the facilities and their operation
- Description of the major energy consuming systems
- Detailed description with the identified ECMs, energy saving potential, implementation cost, time of implementation, level of disruption, cost savings and profitability (payback, internal rate of return, etc.).
- Executive summary or final section describing conclusions and recommendations.
- An Annex including data from measurements, calculations in general and photos.

The report is typically presented and reviewed with the responsible which could be the building manager, O&M manager or the client itself. The idea is to explain the process and activities performed that justify the final conclusions and recommendations. This presentation should therefore go through the technical aspects, economic parameters but as well the required capital investments of implementing the different ECMs and the disruption potential caused by each of the measures.

8. ECM Implementation

8.1. ECM Category & Disruption

The auditor according to factors such as cost and complexity for implementation as it was shown in Section 6; the ECMs are classified in three different categories:

- Category |: Involves ECMs that practically require no cost investment and do not cause any disruption to the facility activities or building operation. For example turning off lights when not in use, temperature set points of heating or cooling systems, etc.
- Category II: Involves ECMs that require a low cost capital investment with minor disruption to the facility activities or building operation. For example replacing lights, installing timers etc.
- Category III: Involves ECMs which are highly capital intensive and causing

major disruption to the facility activities or building operation. For example replacement energy systems such as old boilers or chillers with new ones, power factor correction actions in the electrical installations, etc.

8.2. ECM Implementation Planning

The energy audit team should proceed to plan how to implement the ECMs based on the energy audit report and the input provided by the building managers. The planning activities before implementation should take into consideration following aspects:

- Before starting the implementation process discussion of ideas and comments from different staff involved in the ECM implementation activities, as there may be issues or constraints that the audit team has not properly considered or may have overlooked.
- Asses if adequate and sufficient staff resources are available to undertake the work. Otherwise the contracting of the suitable personnel will be needed.
- Identification and definition of the roles and responsibilities for the different staff involved in the implementation process such as building managers, O&M staff, end-users and other personnel.
- Clearly describe the audit objectives and scope to the team involved in the process.
- Preparation of regular meetings for the process monitoring during the ECM implementation process.
- Timing and coordination of the implementation process of the different activities.
- Planning and timing of activities in order to minimize potential disruptions in the facilities or buildings. For example develop the work outside office hours or during holiday periods.

The planning of all the activities will allow the audit team to:

- Reassess or readjust the proposed ECMs, even if necessary the removal of measures or change of criteria based on new factors which had not been considered previously.
- Preparation of a revised final list of ECMs with energy savings, capital cost and remarks on parties involved and specific attentions for implementation;
- Prepare a revised program of ECM implementation, indicating time requirements, constraints to be resolved and time to resolve them.
- Endorsement from the building management of the revised program.

Communication with building managers, end users involved, O&M personnel and the building owner are crucial for the success of ECM implementation process. The close communication and collaboration between the energy team and building/facility management will facilitate, smoothen and make the implementation process more efficient.

8.3. Monitoring of Implementation

In order to ensure the ECM implementation process takes places correctly, the audit team should monitor the development of the works and participation of all the parties involved. The audit team needs to exercise control and adjust procedures from time to time, such as negotiation with end users on permitted working hours or potential conflicts or issues arising during the implementation phase.

8.4. Performance Contracting

The performance contracting is an alternative approach to the implementation of ECMs. This involves that the building management employs a Performance Contracting company which will delivers the required services. The Performance Contractor designs and implements the ECMs at a cost of a certain percentage of the total savings which will result from implementation of these ECMs.

9. Energy Management Programme

The energy auditing process and corresponding implementation of ECMs will produce certain energy savings. Nevertheless maintenance activities are required in the facilities or buildings over time in order to ensure these savings are kept over time. Therefore the building management needs a long term Energy Management Programmed (EMP)

- The building management has to develop an Energy Policy and make sure there is commitment to energy efficiency and energy conservation. The policy has to define the objectives and energy efficiency targets in terms of energy savings, time frames for achievement, allocation of financial resources and staff responsible.
- The building management should train in house experts or contract energy managers to take responsibility for the energy aspects. Furthermore the energy manager should undertake periodic energy audits and define an action plan for the implementation of ECMs.
- Development of a staff awareness training by the energy manager to the employees of the building or facility.
- Regular review of the energy policies and program.

9.1. ISO 50001 - Energy Management Standard

ISO 50001 is a voluntary International Standard developed by the International Organization for Standardization (ISO) to provide organizations an internationally recognized framework to manage and improve their energy performance. The standard addresses following:

- Energy use and consumption

- Measurement, documentation, and reporting of energy use and consumption
- Design and procurement practices for energy-using equipment, systems, and processes
- Development of an energy management plan and other factors affecting energy performance that can be monitored and influenced by the organization.

Therefore ISO 50001 is an energy management standard typically employed for industrial and commercial facilities. The standard focuses on the energy usage aspects and defines the organization for the potential technical and management energy strategies that favor the energy and cost savings and the environmental benefits such as cutting the greenhouse gas emissions (on the short and long term).

As for other ISO management system standards the certification to ISO 50001 is not mandatory. Frequently companies decide to implement the standard solely on the energy costs savings, environmental benefits and company image. Others decide to get certified to it, to show external parties they have implemented an energy management system.

10. Summary for an Energy Audit

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

Table 10-1 Ten Steps Methodology for Detailed Energy Audit:

STEP NO	PLAN OF ACTION	PURPOSE/RESULTS
Step 1	Phase 1-Pre Audit Phase Plan and organize Walk through Audit Informal Interview with energy Manager, Production/Plant Manager	Resource planning, Establish/organize a Energ Audit team Organize Instruments & time frame Macro Data collection (suitable to type of industry.) Familiarization of process/plant activates First hand observation& assessment of f curren level operation and practices
Step 2	Conduct of brief meeting/awareness program with all divisional heads and persons concerned (2-3 hrs.)	Building up cooperation Issue questionnaire for each department Orientation, awareness creation
Step 3	Phase II – Audit Phase Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	Historic data analysis, Baseline data collation Prepare process flow charts All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution. Design, operation data and schedule of operation

		Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step 4	Conduct survey and measurements	Measurements Motor survey, insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.
Step 5	Conduct of detailed trials/experiments for selected energy guzzlers	Trials/Experiments: ▪ 24 hours power monitoring (MD,PF, KWh etc.). ▪ Load variations trends in pumps, fan ▪ Boiler/Efficiency trials for (4-8 hours) ▪ Furnace Efficiency trials Equipments Performance experiments etc
Step 6	Analysis of energy use	Energy and Material balance & energy loss/waste analysis
Step 7	Identification and development of Energy Conservation (ENCON) opportunities	Identification & Consolidation ENCON measures Conceive, develop, and refine ideas Review the previous ideas suggested by unit personal Review the previous ideas suggested by energy audit if any Use brainstorming and value analysis techniques Contact vendors for new/efficient technology
Step 8	Cost benefit analysis	Assess technical feasibility, economic viability and prioritization of ECM options for implementation Select the most promising projects Priorities by low, medium, long term measures
Step 9	Reporting & Presentation to the Top Management	Documentation, Report Presentation to the top Management.
Step 10	Phase III – post Audit phase Implementation and Follow – up	Assist and implement ECM recommendation measures and Monitor the performance Action plan, Schedule for implementation Follow – up and periodic review