Energy Auditing: An Overview and Key Issues

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***Abstract*- This study aimed to review the different types of energy audits; the overall auditing process, as well as auditing methodology. A detailed evaluation of the actual performance of a facility's energy is carried out by an energy audit using systems and equipment and results compared with designed performance level or industry best practices. Energy audit is critical because it provides information about current consumption, potential to save energy and help in prioritizing energy use. Major vital issues in the energy audit process are inefficient and inaccurate auditing practices and tools, differing opinions and perceptions among auditors, wrong approaches due to missing or incorrect information, inability to provide client with the "whole picture" afforded by life-cycle costing, and inadequate billing analysis.**

***Index Terms*- energy audit, energy efficiency, facility manager, kick-off, restitution, walk-through,**

I. INTRODUCTION

An energy audit is an inspection, survey and analysis of energy flows for identification of energy savings opportunities in a building, process or system to reduce the amount of energy input into the system, without negatively affecting the output(s) [1]. Energy wastage is cause by inefficient energy use and lack of awareness among users. It is therefore essential to raise awareness among consumers [2]. There are opportunities to realize energy efficiency in all aspects of power systems. On the supply side, more efficient generation and distribution, as well as cleaner energy sources are required. On the demand side, in every segment, some technologies can be applied today to increase efficiency and reduce cost. There are also programmes that effectively coordinate supply and demand [3]. Without awareness, there will be difficulty in sustaining energy efficiency programs.

An Energy audit is conducted to comprehend a building's energy performance so that potentials for improvements can be found [4]. There are multiple reasons why implementing energy audit and improving energy consumption is essential in modern day lives.

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Energy audit tells us about three main things. Firstly, energy audits provided information about current consumption. Secondly, energy saving potential is reveal. Thirdly, energy audits help in prioritizing actions against energy use. Improving energy efficiency will produce a better building with comfortable working environment, more satisfaction and improved productivity [5]. There is a possibility of saving 5-10% of the energy expenditure by implementing improved energy-use behavior [6]. Lack of awareness and failure to fully implement energy efficient technologies in installation has resulted in the higher energy consumption with its accompanying high electricity bills. For the success of energy audit implementation, energy efficiency awareness is necessary, and commitment of top management and involvement of all stakeholders in the organization is a must [7].

II. REASONS FOR CARRYING OUT ENERGY AUDIT

An energy audit is carried out for the following reasons:

- To meet customer and shareholder expectations.
- To identify potential for using alternative energy supply technologies.
- To improve energy performance and minimize the environmental impacts of the organization's operations.
- To inform a strategic plan aimed at minimizing an organization's carbon footprint.
- To identify behavioral change opportunities by evaluating current operations and maintenance practices.
- To provide clear financial information regarding energy savings opportunities to prioritize these items for the organization's decision-making process.
- To comply with corporate social responsibility goals.
- To identify technical opportunities by evaluating significant process energy-using components or utilities, including boilers, refrigeration plant, ventilation systems, building performance and fleet efficiency [1].

III. THE ENERGY EFFICIENCY CYCLE

Energy efficiency needs a structured and persistent approach. An energy management program should follow this cycle, and an Energy Audit is a great way to start. Through an energy audit, one will find many opportunities to bring energy efficiency to an organization. But it is essential to recognize that optimal results cannot be realized unless consumption is automated and regulated. Monitoring is the key to maintaining

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the savings [3]. Figure 1. depicts the four processes of the energy efficiency cycle. It entails the following:

A. *Measure*: Energy audit and metering.
B. *Fix the basics*: Low consumption devices, power quality, and power reliability.
C. *Automate*: Solutions in building management, power management, motor control and lighting control.
D. *Monitor:* Monitoring and consulting services [3]

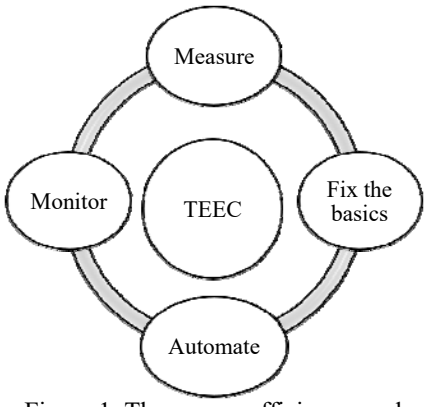

Figure 1. The energy efficiency cycle

IV. TYPES OF ENERGY AUDITS

The first type of audit is known as a walk-through audit. A walk-through or a light audit consists of a relatively brief inspection of the facility to identify maintenance, operation or malfunction device issues and to identify areas which need further evaluation. Some quick-wins can be identified, and some estimated financial computations can be done during this audit [3]. The second type of audit is the comprehensive audit or thorough audit. This involves evaluating the energy consuming systems of the building or plant in detail. It may include performing specific monitoring, metering or testing to identify actual energy consumption and losses [8]. It also consists of an economic evaluation of the identified opportunities, including cost and benefit. Comprehensive audits may be enhanced by adding more comprehensive refinements. Examples would include computer modeling to determine the year-round energy consumption and savings. Additional financial analysis to support investment decisions. This would also involve evaluating risks within the economic calculations. This type of audit may be needed to obtain funding for projects identified and is sometimes known as "investment grade audit" [3]. Information such as code compliance, maintenance schedule development, and equipment inventories are required here.

V. DETERMINING WHICH AUDIT TO SELECT

The decision as to which auditing approach to use is influenced by the following factors:

- Funding available for the audit
- Cost and potential of the Energy Conservation Opportunity (ECO)
- Required accuracy of the audit information
- Type of facility
- Function of facility
- Processes within the facility [3].

Energy audits can be self-assessments conducted by company staff, external reviews obtained through energy service professionals, or a combination of both. Regardless of the form of audit, it is recommended that the audit team represents varied expertise, including process engineers, maintenance experts, systems managers, energy specialists, etc. Support from outside your company can be beneficial and provide an external point of view for the site as well as full-time expertise in many areas.

VI. ENERGY AUDIT ACTIVITIES

An auditor primarily performs four activities. These activities include:

- Understanding the site and gathering the data
- Measuring/Monitoring/Testing
- Assessing the situation, and
- Proposing an action plan

A. Understand the Site and Gather the Data

Rewarding auditors take steps to guarantee that they discern the site and can gather the appropriate data. Employing well-written questionnaires and conducting site visits ensures the auditor has a clear understanding of the operating conditions. Examples of items to review would be the process, including the identification of the main steps and energy requirements, the facilities, and utilities such as compressors, HVAC, Electrical Network, Building Envelope, and so on. Additionally, the review will include the Building Management Systems—such as HVAC control and lighting control as well as the energy awareness and behavior of the people at the site. [8].

B. Measuring/Monitoring/Testing

The second activity involves measuring, monitoring, and testing. To successfully perform this activity, the auditor will need to perform a variety of tests, for example, to verify that a sensor is working correctly [9]. These tests provide vital data about the equipment or information to show if certain types of improvements are feasible. Additionally, if pre-existing data is not available or not sufficient, the auditor may also need to measure and monitor the energy profile and load to identify energy losses [10]. The length, frequency and the number of points to be measured or tested can vary depending on the type of audit and the application to be investigated. It could range from snapshot measurement or a test for a walk-through up to detailed analysis and examination, including monitoring over a significant period for the full type of audit [9]. More substantial buildings and factories contain complex systems. Optimizing the performance of systems such as variable air volume HVAC systems requires continuous monitoring and control

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adjustments. Therefore, large sites and complex systems must be evaluated and treated as a dynamic, not static user of energy. The measuring and monitoring period must take account of this.

C. Assess the Situation

In the third activity, the auditor will assess the situation. This is done by:

- Checking and analyzing all of the data collected
- Looking for Energy Conservation Opportunities which may also involve conducting a study of their feasibility, as well as
- Performing cost-benefit calculations

D. Propose an Action Plan

Finally, the auditor will propose an action plan. The output of the audit is the proposed action plan. An action plan will:

- Provide ways to manage and control power consumption and costs, as well as
- Propose energy saving solutions

VII. PREPARING FOR AUDIT

There are two areas to focus on when preparing for an energy audit:

- Commonly required data
- Planning the audit activities to include the participation of the necessary people from the facility

VIII. ENERGY AUDIT: MAIN STEPS

The appraisal of energy consumption patterns and recognition of energy saving measures are the most vital part of energy management activities, which can be reached via energy audits [11]. The energy audit commonly includes four distinctive components, (and this is especially true if an external company performs the audit) [3]:

- Kick-off meeting
- On-site inspection
- Data analysis, and
- Results restitution

A. Energy Audit: Kick-Off Meeting

Typically, the walk-through or audit begins with a "kick-off meeting." At this meeting, it's an excellent opportunity to have all of the people that are involved around the table. This would typically include the energy manager, facility manager, maintenance supervisor, and the internal or external auditors. Depending on the scope of the audit and the structure of the organization, it might also include the production manager, financial department manager, or other roles [12]. During this meeting, take the time to explain the audit purposes, review the global plan for the audit and go into more details on task plans. It is also during this meeting that you will provide the auditor with the information that has been prepared, as well as giving them the opportunity to ask for more information about processes, energy, and the modernization plan for the facility [12].

B. Energy Audit: On-Site Inspection

This step consists of making visits to the workshop, substation, warehouse, and offices understand the process and how energy is consumed. The maintenance technician responsible for the area being visited should accompany the auditor throughout that part of the audit [10]. The auditor may also have questions for the maintenance supervisor, equipment/area operators, and other facility staff understand the building and the process operation performance problems. Those questions can generally be answered by short interviews, although complex discussions may take longer. A critical success factor while planning the audit is to ensure the necessary people are aware of the audit and available on the day. The auditor will also take measurements during the visits — these measurements may be snapshot measures, or the auditor may leave a temporary meter in place for a few hours or days to record data if required. The on-site inspection should be closed by a wrap-up meeting with the same attendees as the kick-off meeting to announce the first results of the inspection as well as making a final agreement on the deliverable content and a restitution date.

C. Energy Audit: Data Analysis

The next component is data analysis. This step consists of:

- Performing engineering calculations
- Running simulations and tools if necessary
- Contacting solution suppliers to find the cost of the solution and then performing cost-benefit calculations, and
- Writing the deliverables--this will include a presentation and report

D. Energy Audit: Results Restitution

IX. AUDIT REPORT: ENERGY COST ANALYSIS

A vital element of the energy audit is the compilation of a clear and concise report. It needs to convey the depth and breadth of the appraisal carried out, and it should clearly outline the opportunities for improvement [1]. Every audit will culminate with an audit report. At a minimum, the report should include:

- Executive Summary
- Energy Cost Analysis
- Energy Management Recommendations, and a
- The proposition of Energy Action Plan

A. Audit Report: *Executive* Summary

The executive summary is the first thing the reader will see, and it will set the tone for the rest of the report. The abstract should be short, concise and to the point. The executive summary will also list the recommended energy conservation measures and shows the implementation cost as well as

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financial savings amount. This section is intended for readers who only want to see the bottom line.

B. Audit Report: Energy Cost Analysis

Your report will also provide information on the operation of the facility that relates to its energy costs. This could include:

- Energy bill analysis--such as comments on charges and penalties
- Energy consumption breakout, as well as the
- Demand curve

C. Audit Report: Recommendations

The suggestions section lists the areas that were evaluated in the scope of the audit, and contains a discussion of each of the energy management favorable circumstances that have been determined to be cost-effective, and aligned with the financial evaluation criteria collected before the audit. Each energy management recommendation addressed in the executive summary will be described in-depth in this section [12]. Each proposal should summarize the energy demand and cost savings, the implementation cost and the return on investment using the customer's financial criteria. Frequently, a simple payback period is used to evaluate ROI. There should also be a brief narrative detailing the background information regarding the recommended action and an explanation of how it should be implemented at the facility. For each recommendation, the method used to arrive at the savings estimate should be referenced or explained here.

D. Audit Report: Energy Action Plan

The report should suggest an Energy Action Plan. This plan will detail the recommended actions and the implementation schedule. Quick-wins and short paybacks should be implemented first, so savings can be generated rapidly and provide money to pay for high investment solutions. The plan will also propose a monitoring system for following up on the performance and for driving continual improvement.

X. ENERGY AUDIT: NEXT STEPS

The audit is the first step in starting an Energy Management Program. Follow-up actions are necessary to benefit from the audits and drive continuous improvements to the site. These follow-up actions will require you to:

- Validate the energy action plan and the implementation schedule
- Define the energy saving goals
- Implement the action plan
- Establish indicators for measuring the fulfillment of the goals
- Set a baseline and compare the performance over time, as well as
- Seek additional opportunities for continuous improvement [10]

XI. KEY ISSUES IN ENERGY AUDITING

A. Missed Opportunities

The most widespread problem in energy audits as identified by Shapiro [8] is missed opportunities. Shapiro argues that comprehensiveness is widely recognized as a critical feature of all high-quality energy audits. He provides a list of possibilities which he feels should be covered in every energy audit: high-efficiency HVAC, domestic hot water and lighting; lighting power density; lighting controls; wall or roof insulation; motors/drives; HVAC controls; and fenestration opportunities. While we agree that all energy audits should provide clients with a reasonable selection of options for implementation, his study combined results from energy audits of both residential and commercial buildings [8].

B. Equipment and Project Life

This is as a result of overestimated or omitted material and project life. Equipment or project life is so critical to accurate life-cycle cost analysis. Missing or incorrect information regarding project life can lead to poor measure prioritization. It is essential to include projects or equipment life in all NPV, and IRR analysis, calculating it for every measure is recommended.

C. Life-cycle Costing

Failure to provide clients with the "whole picture" afforded by Life-cycle costing. Unlike simple payback, life-cycle costing offers a holistic perspective on potential measures and helps clients and energy auditors make better decisions about which projects to pursue [8]. In an energy audits, in addition to providing simple payback metrics, it is advisable also to calculate the Internal Rate of Return (IRR) and Net Present Value (NPV) for all measures, as well as for the report as a whole. All of these figures are captured in a high-level overview table in the report summary to allow for easier decision making on the part of the client. This information helps clients to make the most effective business case to senior management, for the implementation of the energy-saving measures.

D. Energy Savings Measure Selection

Selecting the wrong measure due to missing or incorrect information can distort the energy audit result. The most common reason that energy auditors do a poor job of identifying and recommending energy-saving measures is due to missing or inaccurate information. For example, one of the most common errors is to suggest an action with a longer payback than the expected life of the project. Other mistakes happen when energy auditors make biased assumptions, do not use life-cycle costing, or underestimate equipment or installation costs.

E. Building Description

Building components poorly described or missing entirely. All energy audits should include a detailed description of all parts of a building. Description and analysis of components for

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commercial and industrial buildings will be different for residential energy audits. HVAC and lighting systems for commercial, institutional and multi-unit residential buildings, offer the best opportunities for energy savings in these building types.

F. Billing Analysis

Inadequate billing analysis for measures and projects can affect the result of the energy audit. The ASHRAE Standard is to study at least one year of monthly energy data [8]. This gives the clients a better understanding of the consumption patterns and energy costs of their buildings. Regression analysis can be run, provided better and further particulars are available on the billing pattern. This will determine the relationships between variables to predict future energy use. Again, it will allow us to correctly understand how the variables that affect energy use, such as weather or occupancy patterns over a particular period, affect energy consumption. This will provide the client with a baseline standard against which to measure energy consumption in subsequent years.

G. Energy Savings Estimation

The overestimation of energy savings is another critical issue. When making energy savings calculations, it is impossible to account for all factors that affect energy savings. However, Shapiro [8] found that over half of the energy audits studied had savings that were twice as high as could be reasonably expected. High energy savings estimates can create unreasonable expectations and may lead to poor prioritization of measures.

XII. CONCLUSION

In this paper, an overview of an energy audit and critical issues were presented. To carry out the energy audit exercise, the auditor should be well trained and certified professional. A poorly trained energy auditor might not be able to come out with proper energy-saving measures.

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