

## Energy audit: types, scope, methodology and report structure

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### ABSTRACT

The objective of this paper is to study various methods adopted during the energy audit. Many countries are focusing on energy, not only enhancing the tenable power generation sources but also on utilizing the power more proficiently for economic utilization. The energy audit is an important parameter for all the developing and developed countries and they focus on energy efficiency, energy quality, and energy intensity. In the industrial, residential, and commercial sectors the top operating expense is found to be are material, machine, manpower, and energy. Identification of the energy-consuming sector is the prior attention to look for the energy-saving potential and quality improvement. Implementation of an energy audit can enhance the efficiency, quality of power, reduce the tariff of bills, and reduces the wastage of energy. The need for energy audits, different types of energy audits, various types of software used, and the energy audit report structure were presented in this paper.

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## 1. INTRODUCTION

Nowadays, the world is suffering from many problems that cause major harm to all mankind. The major problems are climate change and pollution. These problems are done by the human to generate energy from fossil fuel. The generation of energy is very expensive hence the conservation of energy is very important. The electrical system having a long-wired networking system, various safety devices are installed in the system, and the variable load is connected to the system. The ultimate loads are heating, ventilation, and air conditioning (HVAC) system, fans, pump, computers, lightening system, blowers, compressor, and many other heavy machines are connected in this electrical system which perverts the performance and the efficiency due to the several reasons such as aging of the device, aging of the wires used, dust factor, humidity, and various other factors [1]. This results in loss of electrical energy and it is converted into heat energy which reduces the system efficiency and increases power consumption. It is possible to reduce the losses through the modus operandi energy auditing which helps to find the performance of the whole electrical system. If there are any leakages they will be observed and fixed. Thus the modus operandi auditing activity will help the electrical and electronic devices last for a long time [2]. An energy audit consists of various jobs that can be carried out, which depends on the type of energy audit and the purpose of the energy audit facility. The energy audit can start with a review of the electricity bill which shows energy consumption. The energy audit has been carried out by various researchers in different ways for the energy consumption has been presented in [3], and it states that energy audit in the residential house and the

provided recommendation for the energy can be used in proper utilization, which can also reduce the tariff in their electricity bill. The renewable energy integration and energy audit for historic buildings have been looked forward to the hybrid system which is proposed after only when all the renewable choices for energy consumption is considered and also the other factors that are their impacts, their possible outputs, and the money that could be gained by making this incentive schemes.

The energy audit in the industrial site and the author benchmark with the energy factory model, for each action energy-saving potential, has been calculated by using the factory model. Reference [4] analyzes the programs on energy auditing practices and Ecuadorian policies. Now what exactly the energy audit is, it is an investigation of energy in a particular area or building, to decide from where and how the energy will be utilized and depends upon the utilization auditor makes different strategies for energy consumption. The whole investigation process will reduce energy consumption without affecting the work of his devices or its equipment and maintain the comfort level. Consumer behavior can be considered as a vital factor that affecting energy consumption, in addition to the age of building and climate factor. Data gathered from the local weather station helps to design the model of the thermal power structure of the buildings, whether a large number of variables can affect the energy consumption whether increase and decrease. Good energy management starts with energy-saving, it would be done by using the adequate rating of devices, by using high-efficiency devices, and change of habits which cause huge wastages of energy audit [5].

The energy audit is essential to reduce electrical billing and to decrease energy wastages. Governments must take some steps to make energy audits compulsory for industrial buildings at certain frequencies [6]. In [7] recommended that electrical energy is the most important part of private as well as in government. An energy audit is an effective tool to find out the energy consumption of a building and helps to obtain the best solution. Detailed auditing was carried out to find out the construction material, overall energy consumption, HVAC load, lightening system load, and thermal images to provide information about the temperature distribution and gives an idea about the heat or air leak from or into the building. Modifications can be done by using the payback method. Regular energy auditing will show the electrical energy consumption and wastage of electrical energy, it also helps in suggesting the new energy-saving opportunities and it is reviewed in reference [8]. The reduction in electrical energy shows the reduction of carbon emission. In [9] presents that India is the fifth largest producer of electrical energy in the world. Despite such accomplishments, the hole amongst requests and supply of electrical energy is expanding each year and power division is profoundly capital escalated. An energy audit is a compelling instrument for distinguishing and examining a complete energy administration program. This approach could be valuable for an industry infighting fundamental energy cost and raps a few different advantages like enhanced creation, higher profit, better quality, and the most essential fulfillment of heading towards contributing to the world's energy-saving.

Energy audit and planning for both existing and new-to-construct buildings have been of expanding enthusiasm amid the most recent years because of developing ecological concerns. The mix of auxiliary coating draft sealing drapes for windows, protection of floors, and supplanting of the evaporator with a gathering one would cost around 90,000 £ that could be amortized inside eight years [10]. In [11] presents the national and local experiences, issues of energy-efficiency audits. They are the key means for recognizable proof and execution of practical energy-efficiency openings in industrial offices. Such evaluations can be important for helping undertakings in taking activities to meet energy power lessening focuses on the 12th five-year plan and besides China's worldwide sense of duty regarding the reduction of the nation's carbon force by 40% to 45% from 2005 levels by 2020. In [12] presents the energy audit of irrigation network outcomes and suggests the connection between water and energy in water distribution systems. The yearly energy funds coming about because of the utilization of another control framework when contrasted with current tasks may be (25,931.8 MJ, equal to 7.20 MWh year 1), a substantial value for a small irrigation system. Moreover, another indicator (I63) that gauges the energy scattered in water system facilities has been characterized. The study and analysis of electrical power consumption of various electrical and electronic appliances through the energy audit has been presented in [13]. Energy audit finds out the energy-saving mechanisms and increases the responsiveness of energy conservation among society. The factor that affects the benefits and cost of an energy audit has been discussed in reference [14], and also surveys on 1750 houses out of which only 550 house owners have an audit of their houses.

The remainder of this work is organized as follows: The description and need for energy audit have been presented in Section 2. Section 3 presents the different types of energy audits. Softwares used for energy audit and the energy audit report structure have been described in Sections 4 and 5. Finally, the contributions with concluding remarks are described in Section 6.

## 2. ENERGY AUDIT

Energy has the highest potential for cost reduction, and thus the energy audit becomes a crucial exercise [15]. An energy audit helps us to understand how the energy is used in the industry and helps in identifying areas where the waste of energy can occur and where the scope for improvement exists. The requirements that must be fulfilled for an energy audit are [16, 17]:

- Measured up-to-date energy consumption data
- A detailed review of the energy consumption profile
- Provide life-cycle cost rather than the simple payback period

The audit should provide a clear picture of energy consumption and energy opportunities for improvements. The international standards ISO 50002:2014 specifies the process required for carrying out an energy audit. It specifies the principles, common process, and deliverables for an energy audit. European standards for energy audit BS EN 16247 deal with commercial, industrial, non-commercial, and public sector organizations, excluding individual private dwellings [18, 19]. According to the Bureau of Energy Efficiency (BEE), the consumer shall have its first energy audit conducted with the one and half year notification issued by the government. The time interval for conduct and completion of energy audit shall be 3 years with effect from the date of submission of the previous energy audit report by the energy auditors to the management of designated consumers.

### 2.1. Need for energy audit

The energy demand is increasing day-by-day. To fulfill this demand, we need to use more fossil fuels. Fossil fuel generates energy as well as pollution, which is harmful to mankind [20]. The pollution and emission checking calculators are available on the internet and they are used to help in measuring the pollution level and emission level in the environment. An energy audit will reduce the environmental effect directly or indirectly [21]. The functions of the energy audit are,

- an energy audit can reduce energy consumption
- an energy audit can reduce the energy bill and save the money
- an energy audit can improve the comfort level
- an energy audit can reduce the carbon footprints
- an energy audit can reduce unnecessary waste and pollution

The energy audit is the great and most valuable step to save energy consumption and save money. It may seem that an organization's energy audit provides a point of reference for managing the consumption of energy and also it provides a better plan for the essential use of energy in an organization [22].

## 3. TYPES OF ENERGY AUDIT

The energy audit provides the best solution to reduce energy bills and energy consumption whether it is a commercial or non-commercial sector [23]. The type of energy audit that needs to be performed depends on,

- to what extent the penetration and depth required for the final inspection are
- the industry used: its function and type
- the size of the audit and the desired amount reached.

There can be three types of energy audits [24], and they are walk-through energy audits, target energy audits, and detailed energy audits.

### 3.1. Walk through energy audit

It is defined as the simple surveying audit in which the auditor only investigates the energy consumption of an organization and in this type of energy audit no major steps will be taken for consuming energy, it is also known as a preliminary audit. It is the first step of auditing and it is the simplest and quickest type of audit. And is focused on the major energy consumption area [25]. The walk-through energy audit is completed in the lesser time of span. The auditor will find the energy consumption area and developed the full list of the energy-saving measures [26]. The walkthrough audit is completed by the certified energy manager or certified auditor or professional engineer. Walkthrough energy audit details are not sufficient for searching for an energy-saving solution. The auditor can take action in less time with great accuracy and profitability. From this type of energy audit, the auditor gets all the details of an organization which is further needed for a detailed energy audit [27, 28]. The scope of the walkthrough energy audit are:

- In an organization to establish the consumption of energy.
- Minimal interview with the concerned person in the organization.
- The only major problem area will be covered during this type of auditing.

- To find out the most likely ways to reduce consumption and improve the efficiency measurements (and the easiest of interest) [29].
- To find out the improvements and savings (special/low cost).

### 3.2. Targeted energy audit

The target energy audit starts with the finding of the walk-through energy audit. This type of audit provides a detailed analysis of a specific project. This energy audit approach differs depending upon the structure type whether it is a commercial structure, residential, or industrial structure, but in all the structures more detailed information and data are needed [30, 31]. The outcomes are the recommendations regarding the actions to be taken. A clear and brief energy report should be submitted including the action plan “how to improve energy efficiency”. The scope of a target energy audit are:

- To establish the energy consumption in the organization.
- Minimal interview with the concerned person in the organization.
- Only the targeted area will be covered during this audit.
- To find out the most likely ways to improve the efficiency measurements and to reduce the consumption (and the easiest of interest) [32].
- To find out the improvements and savings (special/low cost) [33].

### 3.3. Detailed energy audit

This audit is also known as an investment-grade or comprehensive energy audit. In the detailed energy, the audit may need a complete analysis of possible capital-intensive modifications, including modeling and simulation. The detailed energy audit may need the collection of data over a long period for high accuracy and provide detailed energy consumption reports and detailed saving reports so that it becomes easy for the contractors to understand what exactly the measures to install [34]. The detailed energy audit has been carried out in three phases [35], i.e., pre-audit phase, audit phase, and post-audit phase, and it is depicted in Figure 1

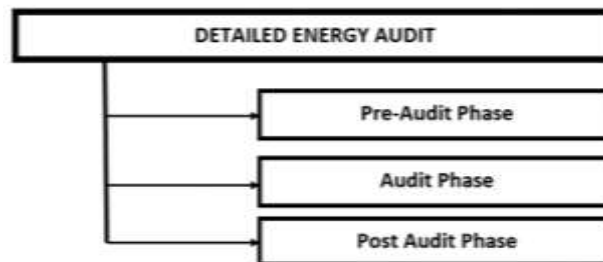


Figure 1. Types of detailed energy audit

#### 3.3.1. Pre-audit phase

A pre-audit phase is the first phase or first step of a comprehensive energy audit. In the pre-audit phase, the energy auditor organizes and plans for the energy audit. In this phase, a formal interview is conducted with the chief executive officer (CEO), plant manager, energy manager, and production manager. In this phase, a brief meeting is also conducted with all the heads and the concerned person [36]. During the pre-audit phase, the energy auditor or accredited energy auditor intends to take the following measure:

- Discusses with the site manager about the aim of the comprehensive energy audit
- Explains the meaning of the comprehensive energy audit and data needed during the audit phase
- Analyzes the major area of energy consumption
- Obtains the site drawings such as a single line diagram of the electrical circuit, building layout, HVAC system.

The outcomes of this phase should help to finalize the audit team, the expectation of the management from the comprehensive energy audit, and to plan the whole comprehensive energy audit within a period.

#### 3.3.2. Audit phase

An audit phase is the second phase or second step of a comprehensive energy audit. The audit phase depends upon the nature and complexity of the site. In this phase, the audit can take days, weeks, or a month,

as well as non-working hours and nights, are also included; to ensure that nothing is overlooked completely in the audit [37]. The following information has been collected during the audit phase:

- Collect the information about the source of the energy supply
- Collect the energy bills to find out the tariff data and electrical energy cost
- Collect the load sector data
- Review of present energy management procedure and training program
- Energy flow diagram

The outcomes of the collected data are:

- Preparing process flow diagram and energy, and material balance.
- Identification of Energy Conservation (ENCON) opportunities.
- Energy conservation options and recommendations.
- Energy-saving and payback period.
- Technical and feasibility report.
- Implementation plan for energy-saving measures and projects for the third phase (post-audit phase).

**3.3.3. Post audit phase**

For the evaluation of a capital budgeting decision, a set of procedures must require after the fact. The plan of action for the post-audit phase is implementation and follow-up [38]. The result is to assist and implement ENCON recommendation measures ad monitor the performance.

**4. SOFTWARE USED FOR ENERGY AUDITING**

Various types of software used for energy auditing are presented in Table 1.

Table 1. Various types of software are used for energy auditing

Software	Remarks
Simprosys	Simprosys software is helpful for mass transfer, design projects, courses in unit operation, heat, and mass balance calculation. It is not freeware software [39].
Road pollution	Road pollution software is helpful for the installation of road lighting and the assessment of the environmental impact due to light pollution [40].
MATLAB	MATLAB is an advanced simulation software where any job such as automation, lighting, layouts, engineering, and mathematics functions can be performed [41, 42].
Piping System Fluid Flow	Piping system fluid flow can be used for accurate simulation of network performance before a network design or modified a network [43].
IH A T	Indoor humidity assessment tool (IHAT) software is used to check the humidity level in a building, which includes the use of an energy recovery ventilation (ERV) system [40].
eQUEST	Energy Quick energy simulation (eQUEST) software is a user-friendly and freeware tool that is used to predict energy use, building layout, HVAC requirement, hourly weather data, and energy cost [21].
DIALux	DIALux is used for advanced lighting study and energy efficiency measures for roads, areas, buildings, and offices [40].
TREAT	TREAT stands for targeted retrofit energy analysis tool. It is a comprehensive energy analysis and building modeling software [40].
Energy Analysis Software	This software unpretentiously called energy analysis software is backed by an Italian start-up. This software consists of 4 independent modules and they need to buy separately [40].
OptiMiser	It is modular software built on a proprietary platform. The software is customizable in terms of data collection, reporting, and data exchange [40].
Easy Audit	Easy Audit doesn't require internet access. It is designed for use on tablets with a stylus but runs on any computer or device that runs MS Excel [40].
SnapCount	It is a lighting and energy retrofit software [40].
PSAT	The pumping system assessment tool (PSAT) is used for the measurement of pump efficiency and pressure drops [44].
SSAT	Steam system assessment tool (SSAT) is used to measure the performance of the steam system [45].

**5. ENERGY AUDIT REPORT STRUCTURE**

The mandatory idea of energy audit requires building up guidelines for energy auditing methods as well as calls for the standardization of energy audit reports. The directives are fundamentally governed by the structure of the report of the energy audit [46]. The energy audit reports are required to highlight the details of energy consumption, energy costs, major energy consumption area, performance of various types of equipment, and suggested energy-saving method of energy conservation, installation cost, and their payback period. Each report may include the following sections:

- *Title Page*: The title page is the first page of the energy audit report. It contains the title of the energy audit report, auditor name, client name, logo, and submission date.
- *Table of Content (TOC)*: The table of content is the second page of the energy audit report. The TOC is an organized list of chapters, tables, graphs, and figures. A clear, concise, and well-formatted TOC is the first indicator of a good energy audit report.
- *Acknowledgment*: The page acknowledgment is added to the report immediately after the TOC. Acknowledgment enables one to thank all those people who helped in carrying out the energy audit [25].
- *Auditor Firm and Audit Team Details and Certification*: This page contains details of the auditor firm, audit team, and certification.
- *Executive Summary*: This section summarizes the long report in such a way that a reader can rapidly become familiar with the report without having read it all.
- *Introduction to the Energy Audit and Methodology*: The action of introducing to the energy audit and methodology.
- *Description of the Plant / Establishment*: This page contains a description of the plant.
- *Energy Consumption Profile and Evaluation of Energy Management System*: This page contains the energy consumption profile and evaluation of the energy management system.
- *Equipment / Systems Specific Section Reports*: This page consists of the equipment/systems-specific section reports.
- *Summary of recommendations and action plan*: This page consists of the conclusion of the overall report or summary of recommendations and action plans.
- *References Page*: References page is the last page of the energy audit report that has been written in the American Psychological Association (APA) created the style which is a standardized method of the document and citing the source [26].

## 6. CONCLUSIONS

This paper presents various types, scopes, and methods that are required for the energy audit, software, tools, report structure, and professionals and fields of an energy audit. There are different strategies and methods from which one can save energy essentially. Alongside a given structure of such an audit, a few imperative undertakings are underlined to achieve a successful energy audit. The energy audit techniques can be extended as required in different periods of the energy program, with the utilization of each succeeding stage yielding more data on energy use and more open doors for raising energy effectiveness. This paper is much helpful for an energy auditor and an energy manager. Energy auditing involves various professional fields such as engineering, agriculture, management, economics, financial analysis, operation research, public relations, and environmental engineering. Various software and tools are used in energy auditing for measurement and diagnostics are also analyzed in this paper. The identification of energy-consuming sectors is the prior attention to look for energy-saving potential and quality improvement. Implementation of an energy audit which can improve the efficiency, quality of the power, and reduces the tariff of bills and wastages of energy.

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