Technical Guide
Energy Audit, Types & Equipment Required

(June 2023)

Small and Medium Enterprises Development Authority

Ministry of Industries & Production
Government of Pakistan

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2 Introduction to SMEDA

The Small and Medium Enterprises Development Authority (SMEDA) was established in October 1998 with an objective to provide fresh impetus to the economy through development of Small and Medium Enterprises (SMEs).

With a mission "to assist in Employment Generation and Value Addition to the national income, through development of SME sectors, by helping increase the number, scale and competitiveness of SMEs", SMEDA has carried out 'sectoral research' to identify Policy, Access to Finance, Business Development Services, strategic initiatives and institutional collaboration & networking initiatives.

Preparation and dissemination of prefeasibility studies in key areas of investment has been a successful hallmark of SME facilitation by SMEDA.

Concurrent to the prefeasibility studies, a broad spectrum of Business Development Services is also offered to the SMEs by SMEDA. These services include identification of experts and consultants and delivery of need-based capacity building programs of different types in addition to business guidance through help desk services.

2.1 Industry Support Program

In order to enhance competitiveness of SMEs and achieve operational excellence, SMEDA established an Industry Support Cell (ISC) for provision of foreign technical support and knowledge transfer in collaboration with International Development Organizations. SMEDA's Industry Support

Program (ISP) initially launched with Japan International Cooperation Agency (JICA) and actively engaged in reducing energy inefficiencies and improving production and quality of products with the support of Japanese Experts. Later on, similar activities with other international partner organizations like German Corporation for International Cooperation (GIZ), Training and Development Centers of the Bavarian Employers' Association (bfz), Germany, and United Nations Industrial Development Organization (UNIDO) were also successfully implemented.

3 Introduction

Energy is one of the major inputs for the economic development of any country. The energy sector assumes a critical importance in view of the ever-increasing energy needs requiring huge investments to meet them.

3.1 What is Energy?

The universe is composed of matter in different forms, and all forms of matter contain energy. The different forms of energy on Earth originate from the Sun — the ultimate energy source. Plants capture light energy from the Sun, and, via the process of photosynthesis, convert it into chemical energy. This stored energy from plants can be harnessed in many ways. For example, eating plant products as food provides energy for our body to function, and burning wood or coal (fossilized plants) generates heat and electricity. Thus, Energy is defined as the ability to do work. Work is done when a force applied to an object causes the object to move against an opposing force. For example, work is done when a table is pushed across a room against the resistance from the floor.

3.1.1 What are the types of energy?

Energy can be classified into several types based on the following criteria:

1. Primary and Secondary energy
2. Commercial and Non-commercial energy
3. Renewable and Non-Renewable energy

3.1.1.1 Primary and Secondary Energy

Primary energy sources are those that are either found or stored in nature. Common primary energy sources are coal, oil, natural gas, and biomass (such as wood). Other primary energy sources include nuclear energy from radioactive substances, thermal energy from the earth's interior, and potential energy due to the earth's gravity.

Primary energy sources are mostly converted in industrial utilities into secondary energy sources; for example, coal, oil, or gas converted into steam and electricity. Primary energy can also be used directly. Some energy sources have non-energy uses; for example, coal or natural gas can be used as a feedstock in fertilizer plants.

3.1.1.2 Commercial Energy and Non-Commercial Energy

Commercial Energy

Energy sources that are available on the market for a price are known as commercial energy. Most important forms of commercial energy are electricity, coal, and refined-petroleum products. Commercial energy forms the basis of industrial, agricultural, transport, and commercial development in the modern world. In industrialized countries, commercialized fuels are the predominant source not only for economic production, but also for many household tasks of the general population.

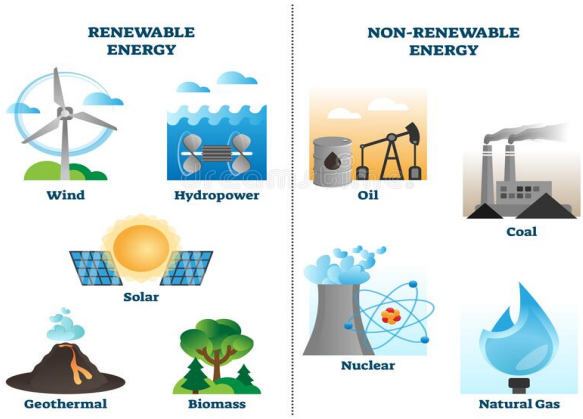
Non-Commercial Energy

Energy sources that are not available on the market at a price are classified as non-commercial energy. Non-commercial energy sources include such fuels as firewood, cattle dung, and agricultural waste, which are traditionally gathered and not bought at a set price especially in rural households. These are also called traditional fuels. Noncommercial energy is often ignored in energy accounting.

Examples: Firewood and agro-waste in rural areas; solar energy for water heating, fish, and fruits; animal power for transport, threshing, lifting water for irrigation, and crushing sugarcane; wind energy for lifting water and electricity generation.

3.1.1.3 Renewable and Non-Renewable Energy

Renewable energy is energy obtained from sources that are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power, and hydroelectric power as shown in following figure. The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants. Non-renewable energy includes conventional fossil fuels such as coal, oil, and gas, which are likely to be depleted over time**.**



Renewable and Non-Renewable Energy

3.2 What is Energy Mix?

The term “energy mix” refers to the combination of the various primary energy sources used to meet energy needs. It includes fossil fuels (oil, natural gas and coal), nuclear energy and the many sources of renewable energy (wood and other bio-energies, hydro, wind, solar and geothermal). These primary energy sources are used, for example, for generating power, providing fuel for transportation, and for heating and cooling of residential and industrial buildings.

The composition of the energy mix varies greatly from one industry to other. The most common types of energy mix under use of any company include:

- Electricity
- Diesel
- Gas
- Others (if any)

3.3 What is Energy Audit?

Energy Audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursuing comprehensive energy management program. Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency (EE) with cost benefit analysis and an action plan to reduce energy consumption."

The main focused areas of energy audit are as follows:

- Electrical System
- Lighting System
- Compressed Air System
- Mechanical System
- Thermal System
- Cooling Towers/Chillers
- Boilers

3.3.1 Why is it needed?

In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labor and materials. Among these, energy is the component which is manageable easily for cost savings. Energy Audit will help to understand more about the ways energy and fuel are used in any industry and help in identifying the areas where waste can occur and where scope for improvement exists.

The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programs which are vital for production and utility activities. Such an audit program will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc.

In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a “bench-mark” (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

In general, the objectives of Energy Audit are listed as follows:

1. Conduct a simple Walk-Through audit or observation of the energy consumption of electrical appliances within the building/industry.
2. Review and analyze energy usage history to create a baseline for which savings can be measured in the audited building/industry.
3. Determine what can be done to reduce energy consumption throughout the building/industry and what options are available for system improvements if funding is available.
4. Identify and evaluate measures that could improve the environmental performance of the buildings/industries and provide recommendations

4 ENERGY AUDIT TYPES

The type of industrial energy audit conducted depends on the function, size, and type of the industry, the depth to which the audit is needed, and the potential and magnitude of energy savings and cost reduction desired. Based on these criteria, an industrial energy audit can be classified into three types:

1. Preliminary Audit (walk-through audit) -Tier 1 Audit.
2. Detailed Audit (diagnostic audit) -Tier 2 Audit.
3. Precise subsystem audit -Tier 3 Audit.

4.1 Preliminary Audit

It is also known as Tier 1 / Level 1 audit. In a preliminary energy audit, readily available data are mostly used for a simple analysis of energy use and performance of the plant. This type of audit does not require a lot of measurement and data collection. These audits take a relatively short time, and the results are more general, providing common opportunities for energy efficiency. The economic

analysis is typically limited to calculation of the simple payback period, or the time required paying back the initial capital investment through realized energy savings.

Preliminary energy audit is a relatively quick exercise to:

- Establish energy consumption in the organization
- Estimate the scope for saving
- Identify the most likely and the easiest areas for attention
- Identify immediately no or low cost improvements/ savings
- Set a 'reference point'
- Identify areas for more detailed study/measurement
- Preliminary energy audit uses existing or easily obtained data

4.2 Detailed Audit (Diagnostic audit)

It is also known as Tier 2 / Level 2 audit and requires more detailed data and information. Measurements and a data inventory are usually conducted and different energy systems like pump, fan, compressed air, steam, process heating, etc. are assessed in detail. Hence, the time required for this type of audit is longer than that of preliminary audits. The results of these audits are more comprehensive and useful since they give a more accurate picture of the energy performance of the plant and more specific recommendation for improvements.

This type of audit considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost. In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use is then compared to utility bill charges. Detailed energy auditing is carried out in three phases:

- Phase I - Pre-Audit Phase
- Phase II - Audit Phase
- Phase III - Post Audit Phase

4.3 Precise Subsystem Audit

It is also known as Tier 3 / Level 3 audit. Type 3 audits are detailed audits of specific subsystems, with additional data gathering and measurement to provide a higher level of accuracy. Audits of this type are typically focused on a process or subsystem level, such as for HVAC, building management systems, compressed air or lighting, rather than a whole site.

These type of audits involve onsite measurements to monitor energy data over a period long enough to capture the various operating conditions and relevant variables, in order to be able to quantify costs and benefits to a level sufficient to meet the site's capital expenditure process requirements.

5 ENERGY AUDIT PHASES

There are generally three phases to an Energy Audit, depending on the complexity and detail required by the client:

1. Investigation Phase
2. Monitoring Phase
3. Analysis & Reporting Phase

5.1 Investigation Phase

This phase encompasses obtaining all relevant data concerning:

- Historical energy consumption for the past 1 to 2 years
- Tariffs and related energy supply contracts
- Floor areas, staff numbers, production levels
- Occupancy / operational hours
- Industry energy use/cost benchmark levels
- Sub electrical and gas metering equipment
- After-hours air conditioning usage
- Mechanical plant configuration (e.g., chiller plant rated cooling capacity, pump and fan motor kW ratings and efficiency), as installed drawings, electrical single line drawings, operational & maintenance manuals
- Lighting configuration (i.e., Lamp number & fitting type, Wattage, ballast type), condition and controls
- Compressed air system (if present) including rating, presence of air leaks, hours of usage
- Steam and hot water boilers
- Building Management Systems and control strategies
- Building envelope, shading, orientation, insulation levels
- Energy management process and policy information
- Asset management plan, if any.

5.2 Monitoring Phase

This phase involves obtaining detailed information pertaining to the overall site as well as the major energy use categories. The operation of key plant and equipment is inspected, and measurement of a range of parameters, is undertaken where appropriate, including:

- Electrical & gas load profiles
- Internal temperature/humidity
- Ventilation rate
- Light levels
- Boiler flue gas combustion analysis.

Feedback is also obtained from maintenance staff on issues concerning building and plant operation and maintenance which could well be impacting on energy efficiency as well as occupant comfort.

5.3 Analysis and Reporting Phase

This phase involves:

- Determination of overall energy efficiency
- Determination of the greenhouse gas emission index
- Life cycle cost analysis of various energy saving measures
- Tariff analysis
- Peak demand management including evaluation of power factor correction
- Written and if required, verbal report on findings.

6 EQUIPMENT REQUIRED FOR ENERGY AUDIT

6.1 Three-Phase Power Analyzer

Three phase power analyzer is used to measure and record real time Energy Consumption, analysis of electrical load, demand control, harmonics and transient measurement. This equipment is installed without disturbing the mains supply.

6.2 Digital Clamp Meter

This is a handy tool and it is used to measure the current flowing through any conductor. When the conductor is placed under the clamp then the meter shows the current flowing through that conductor.

6.3 Digital Multimeter

This equipment is used for the measurement of voltage, current, resistance, continuity and some other purposes.

6.4 Luxmeter/ Luminometer

It is used for the measurement of illumination level inside any confined space, room or anywhere.

6.5 Infrared Thermometer

It is used for measuring temperatures from a distance using infrared technology.

6.6 Thermocouple Thermometer

Thermocouple thermometers are versatile and accurate industrial temperature measurement devices that use either built-in thermocouples or input from external thermocouples. A thermocouple senses temperature by using two conductors of dissimilar metals joined together at one end. When conductors are exposed to a thermal gradient, they generate a voltage. The difference in the voltages produced by dissimilar metals corresponds to temperature.

6.7 Flue Gas Analyzer

It is used for optimizing the combustion efficiency by measuring/monitoring the oxygen and CO levels in flue gas of boilers, furnaces etc. and calculation of CO2 percentage in excess air level and efficiency.

6.8 Thermal Imager

It is used to get the thermal readings of an object which can be seen as a thermal image and temperature on different points can be observed will using that thermal image.

6.9 Insulation Resistance Meter

Insulation resistance measurement is done using an IR tester. This is a portable tool that is more or less an ohmmeter with a built-in generator that is used to produce a high DC voltage.

6.10 Earth Resistance Meter

Earth resistance meters test the resistance of soil to the passage of electric current to determine the adequacy of the grounding of an electrical system by ensuring an adequately large path for fault currents, an indispensable component of a safe, properly functioning electrical system.

6.11 Digital Tachometer

It is used to measure and indicate the speed of the rotating object.

6.12 Gas Leak Detector

It is used to detect gas leaks. Gas verification and gas leak location can be carried out on gas pipes and installations both indoors and outdoors using this device.

6.13 Differential Pressure Meter

It is used for the measurement of differential pressure.

6.14 Digital Ultrasonic Flow Meter

It is used for the measurement of flow of liquids through pipelines of various sizes through ultrasonic sensors mounted on the pipelines.

6.15 Non-Contact Voltage Detector

A non-contact voltage tester is the safest way to make sure the power is off without touching any wires. The tester will light up and/or make noise when it comes close to a hot (live) wire, even one that's covered in plastic insulation.

6.16 Moisture Meter

It is used to measure the moisture content in surfaces and materials.

6.17 Phase Sequence Meter

A phase sequence meter or indicator can be a wall or panel mount or handheld instrument which determines the phase sequence of three phase supply systems. The display of these meters indicates the order of phase sequence to which their terminals are designed.

6.18 Pressure Sensor

A pressure sensor is a device for pressure measurement of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed.

6.19 Pressure Data Logger

It is used to measure and store the pressure signals that a system puts out via a pressure sensor. Then this data can be plotted to analyse the pressure trend of a machine or a compressor.

7 CONCLUSION

With the continuous rise of per unit cost of , production cost has risen up. Energy Audit has become a key feature for any building , business or industry owner who wants to remain competitive. Public and private sector need to carry out Energy Audit because we all know that saving one unit of electricity is far more easy than producing it.