# ENERGY AUDIT AND MITIGATION MEASURES

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***Abstract: Improving energy-efficiency is typically seen as a key strategy to reduce greenhouse gas emissions, especially in the short and medium term. Unlocking the global industrial energy efficiency potential isconsidered as a cost effective means of reducing global fossil fuelconsumption, mitigating greenhouse gas emission, improving energysupply security and ensuring a sustainable industrial development. In order to reduce energy consumptions for sustainable and energy-efficient manufacturing, continuous energy audit and process tracking of industrial machines are essential. It is the most comprehensive approach to improve an existing system's energy efficiency. The adoption of many measures on energy efficiency which are technically feasible and economically viable may significantly contribute for energy saving and cost reduction and ultimately reduction in emission of greenhouse gases.***

***Keywords: Energy efficiency, energy audit,greenhouse gas, energy consumption***

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## 1. Introduction

Energy is an indispensable factor for the social and economic development of societies. The usage level of electricity is an indication of the economic prosperity of nations. The importance of energy efficiency was first realized following the two oil crises of the 1970s. The world has trimmed its energy budget by utilizing higher efficiencies, while still growing economically, and has realized the importance of protecting the environment. Consequently, in addition to the development of conventional energy resources, exploitation of non-conventional energy resources and energy conservation has become inevitable [3]. The concentration of greenhouse gases (GHG) from manufacturing factory activities, vehicle emissions, as well as the service and sales sectors has increased significantly. Greenhouse gases have an adverse environmental impact. Increasing energy efficiency is an important strategy for reducing greenhouse gas emissions. Energy research institutes and governmental energy departments in various nations are all committed to developing methods for assessing energy efficiency; these can be used as references for policy-making [8].Since GHG emissions are recognized to come primarily from energy consumption, climate change is a growing global concern. To minimize the environmental impact of GHG (such as global climate change and global warming), the United Nations Framework Convention on Climate Change (UNFCCC) initiated efforts in Rio de Janeiro in 1992 to consider strategies for reducing GHG emissions. In December 1997, the third conference of parties (COP-3) of the UNFCCC was held in Kyoto in Japan and resulted in the so-called Kyoto Protocol in which the developed countries committed themselves to reducing emissions of carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$) by 6–8% compared with 1990 emission levels in the period 2008–2012. Therefore, energy research organizations and governments are actively engaged in developing methods of assessing energyefficiency [5].Improving energy efficiency in energy-intensive industry is thus becoming increasingly important. From an industrial perspective, improved energy efficiency is recognized as providing a number of direct economic benefits, apart from indirect benefits such as increased competitiveness and higher productivity [14]. Industrial energy efficiency can be improved by various means, including management, technology, policy, and regulatory strategies [12].

Presently, energy auditing is becoming more popular to cut down electricity bill and reduce the recurring expenditures. Energy auditing will not only save money but it also improves the quality of electrical energy supply. The most of the saving is possible without any investment, just by modifications and proper tuning without affecting the manufacturing processes in industries [6].

Energy audit is an inspection, survey and analysis of energy flows for energy conservation to reduce the amount of energy input into the systemwithout negatively affecting the output. It is the key for decision-making in the area of energy management. Hence it is a reliable and systematic approach in the industrial sector that helps any organization to analyze its energy use and discover areas where energy use can be reduced and waste can occur, plan and practice feasible energy conservation methods that will enhance their energy efficiency, serve to identify all the energy streams in a facility, quantify energy usage, in an attempt to balancethe total energy input with its use[1]. Moreover, the audit can eliminate the barriers of energy efficiency [11]. Some of these barriers are external, such as the lack of interest by consumers or investorsorlack of knowledge about the impacts on and from suppliers and customers [7].

Energy audits have three objectives: (1) assisting energy users to establish energy audit systems; (2) assisting energy users to implement energy management and set energy saving goals; (3) providing on-site energy audit and guidance, technology and information services related to energy saving.

## 2. Energy Audit

A typical audit includes two components. One is an energy accounting audit which examines an enterprise's energy consumption level and composition on an annual basis, energy flows, energy measurement and statistics, energy management procedures, the performance of all major energy-consuming equipment, energy intensity relative to products and production, levels and flows of raw material consumption, as well as energy costs. Another component is an energy-saving opportunity assessment, which identifies the areas for efficiency improvement based on the examination of an enterprise's energy system and energy use. Detailed energy audits are also performed – usually under the request of a government agency to ensure the quality of energy audits performed by enterprises or for verifying actual energy savings from enterprises'

implementation of energy-efficiency projects. These types of special audits focus more on examining the enterprises' annual energy use and energy data reporting and less on assessing enterprises' opportunities for efficiency improvement [4].

There can be three types of energy audit.

- Preliminary energy audit
- General energy audit
- Detailed energy audit

The preliminary energy audit alternatively called a simple audit screening audit or walk through audit, is the simplest and quickest type of audit. It is carried out in a limited span of times and it focuses on major energy supplies and demands. It aims at taking steps which are necessary for implementation of energy conservation program in an establishment. Typically, only major problems area will be uncovered during this type of audit, corrective measures are briefly described and quick estimates of implementation cost, potential operating cost savings and simple payback periods are provided.

The general energy audit is also called a mini audit or site energy audit or complete site energy audit. It expands on the preliminary audit by collecting more detailed information about facility operation and performing a more detailed evaluation of energy conservation measures identified. Utility bills are collected for a 12 to 36 months period to allow the auditor to evaluate the facility energy/demand rate structure and energy usage profiles. A detailed financial analysis is performed for each measures based on detailed implementation cost estimates, site specific operating cost savings and the customer's investment criteria. Sufficient detail is provided to justify project implementation.

Detailed energy audit is also called comprehensive audit or investment grader audit. It expands on the general energy audit. It covers estimation of energy input for different processes, collection of past data on production levels and specific energy consumption. It is a comprehensive energy audit action plan to be followed effectively by the industry. Thus, the scope of this audit is to formulate a detailed plan on the basis of quantitative and control evaluation, to evolve detailed engineering for options to reduce total energy costs, consumption for the product manufactured [13].

Energy audit process involves the following basic steps:

(a) First, the energy audit group holds a meeting todetermine the audit date.

(b) The Bureau of Energy of the Ministry of EconomicsAffairs (2004) is requested to issue an official auditnotice to energy users.

(c) Before on-site energy audit (roughly 1 month before),the energy audit group conducts a pre-visit requestinginformation from the energy user and this informationis used to plan the on-site energy audit.

On-site energy audit is performed as follows:

(i) Initially, an energy audit meeting is held tointroduce energy audit targets and the membersof the audit group. The energy user explains theirmanufacturing process and the main energy-consumingequipment, and provides operation andmaintenance records for review by the auditors.

(ii) Following the audit meeting, the energy user takesthe auditors to their manufacturing plant for anon-site audit. The auditors discuss the mainenergy-consuming equipment with representativesof the energy user or equipment operators.

(iii) Auditors review the operating manual and equipmentspecifications for the energy-consumingequipment against energy user-provided operationand maintenance records and check for abnormalities.

(iv) Measurement equipment such as IRthermal analyzer, ultrasonic flow meter, illumination meter, and so on are used to test the major energyconsumingequipment or manufacturing processes,and organize the results of testing and analysis.

(v) Subsequent to the facility inspection, the auditorsmeet again with the facility staff to review thepreliminary findings and the recommendationsbeing considered.

(e) After the on-site audit, the results and recommendationsare combined to produce the on-site energy auditreport.

(f) A database containing energy-saving recommendationsand energy consumption data for use bythe government in developing energy policy and for useby other energy users as a referenceis established[5].

3. Energy efficiency

Among the ways to improve energy efficiency in motor systems, the replacement of a low efficient motor for a high efficient one is recommended. Before the determination of energy saving, it is necessary to know the real values of load and efficiency from each motor. The mathematical model used for estimating the motor load has presented a correlation coefficient of 99.3% with real motors curves. From real measured current(IR), nominal current(IN) given by manufacturer and no load current (I0), measured or given by manufacturer, the real load(g) is determined by (1) $\Upsilon = 1 + \frac{1}{\alpha}\ln\frac{I_o}{I_N}$ (1)

Where $\alpha = -\ln\frac{I_o}{I_N}$ (2)

The efficiency is the relation between output power and input power, including energy losses. Thus real efficiency is given by $\eta_L = \frac{P_{out}}{P_{in}} = \frac{0.746 P_{HP} \Upsilon}{P_R}$ (3)

Where $P_{HP}$ is the nominal output power (HP); $P_R$ is the real input power (HP); HP = 746W; γ is the rated load (%); and $\eta_L$ is the low efficiency (%). The improvement in energy efficiency (IEE) indicates the percent of energy saved after the replacement of the low efficiency motor ($\eta_L$) for a high efficiency motor or premium efficiency motor (η) and is calculated as follows:

$IEE = \left(1 - \frac{\eta_L}{\eta}\right) X\ 100\%$ (4) [2]

4. Case studies

In a work conducted by Kokate et al., it is suggested that solar dryer could be used for pre conditioning that is de-humidification and pre heating in the plastic manufacturing process. Solar dryer reduced conventional energy consumption during plastic processing. Hence about 20 to 25 % energy saving potential can be achieved in actual industrial process. Cost benefit analysis showed that adaptation of solar energy dryer for plastic process industry lead to economic production of plastic goods.

The electrical energy audit conducted by Deepak et al., resulted in annual cost savings of Rs 3.49 lakh with investment of Rs 1.67 lakhs and overall pay back period of 6 months. This was achieved by supply voltage of 230 V for lighting and reducing contract demand to 600 kVA from 750kVA.

Table 1: Areas with potential for energy savings

| Industry | Areas | Energy efficiency measures recommended |
|---|---|---|
| Iron and Steel | Electric arc furnace | Adopt high efficiency furnace |
| | Air flow control | Using variable frequency control, such as Variable Voltage Variable Frequency (VVVF) to control air flow in dust collection equipment could achieve savings of 3.4kWh/ton of production |
| | Waste heat recycling | Recycle waste heat from heating furnaces to save fuel |
| | Air pre heater | Use an air pre heater to heat air entering the furnace to achieve 15% savings in thermal energy |
| | Improve heat pattern | Design a heating profile, improve the operating temperature and save fuel according to product specifications |
| Chemical | Air compressor efficiency | Maintenance and leak control could achieve 20 to 30% energy savings |
| | Recycling waste heat from boilers | Add equipment for recycling waste heat and lowering boiler exhaust temperature |
| | Recycle waste heat from steam | Add a heat exchanger and recycle waste heat from cooling water |
| | Improve efficiency of equipments | Improve efficiency by adding inverters to the cooling tower, pump and electric fan |
| Cement | Recycle waste heat | Recycle waste heat to achieve 35% electricity savings |
| | Cement mills | Use high efficiency dust collection bags and grinding aids for cement mills |
| | Secondary fuel | Waste tires and organic solvents can be used |
| | Auxiliary fuel | Use petroleum coke as an auxiliary fuel and use waste oils as fuel |
| Pulp and paper | Motors | Upgrade to high efficiency motors |
| | Cooling tower, pumps and electric fans | Add inverters to cooling towers, pumps and electric fans |
| | Increase boiler efficiency | Control discharge oxygen concentration of boiler and prevent discharge temperature from exceeding designed specifications |
| | Recycling cooling water | Increase the rate of recycling cooling water, preferably to exceed 80% |
| | Steam line insulation | Enhance steam line insulation and avoid unnecessary heat loss |
| | Pulping systems | Adopt medium and high concentration pulping system to achieve 10% electricity savings |
| Textiles | Thermal oil boilers | Add inverters to blowers to save electricity |
| | Motors | Add inverter to motors to save electricity |
| | Dying machine and spinning frames | Use high speed machines and high speed frames to save on fuel oils and electricity |
| Electric | Air conditioning cleaning systems | Optimize clean room air flow, reduce use of cooling water under low load and increase cold outlet temperature |
| | Cooling water systems | Improve water quality and prevent scaling, increase electricity power factor, modify pipelines and add inverters to electric fans |
| | Air compressor systems | Lower the pressure settings of air compressors and upgrade air compressors |

The methodology adopted by Hassouneh for energy audit of a building in Jordan was visual inspection and data collection, observations on the existing condition of the facility, equipments and quantification, identification/verification of energy consumption and other parameters by measurements and potential energy saving opportunities. It was found that installing double glass rather than single one reduced heat loss through building, and around 60% of heat loss in the building occurred through standard, single pane windows. Once the double glazing has been installed, heating costs should decrease by around 10–12%. Installing dimmers in the rooms and other facilities which needa variable luminance in several periods of the day, potential saving which varied from 10% to 60% depending on the user.
Similarly areas with potential for energy savings in various industries are listed in Table 1.

## 5. Conclusions

Energy accounts for40–60% of the total production cost. Energy users should observe theregulations promulgated by the central authority such as conducting an energy audit, as well as setting an energy conservation target and action plan. However, industry usually focuses on production and still has a strong need for assistance in regard to adopting and carrying out energy saving measures. Increased energy utilization efficiency is necessary for industry to obtain the desired results of energy audits. The status can be compared among different countries to achieve the common aim of reducing greenhouse gas emissions. Forests are crucial in the global carbon (C)cycle. Tree growth provides an important means of capturing and storing atmospheric $CO_2$ in biomass. Plants have the following $CO_2$ absorbing capability: tree plantations (10.09tC/ha/yr) < coconut (4.78tC/ha/yr) < brush land (4.29tC/ha/yr) < natural forest (0.92tC/ha/yr). It was also observed that effective public policies are also needed to reduce industrial energy consumption along with emission reduction.

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