Energy Audit Along with Energy Saving Implementations for HVAC Systems

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Abstract: **The main objective of this work involves performance of energy audit at a retail store. The focus is on energy and power saving ideas on Heat Ventilation & Air Conditioning (HVAC) systems. Energy audit includes monitoring of daily energy consumptions from different electronic devices and gives the scope for energy savings ideas and implementations at workplace. The other objective is to find any possible energy saving implementations for the energy audit. As a result, we have developed an idea regarding set temperature controlling sensor module.So that the temperature of HVAC remains same regardless how much temperature change we make through remote or controller. This helps us in saving the compressor's work, amount of usage of refrigerant, power consumption and the most important advantage is human safety.**

Index Terms: **HVAC, energy audit, energy saving implementations.**

I. INTRODUCTION

Energy is of many types like primary and secondary energy. The key primary and the secondary energy sources are shown in Figure1.

Matteo Dongellini et al. [1] has carried out preliminary energy audit on eight big industrial buildings of a car manufacturing company in Bologna State. They developed a model to estimate various energy effects on primary energy consumption in the buildings and performance of HVAC systems.

Malkiat Singh et al. [2] has developed a basic model for load management in industries and explained an example of lighting in the industries.

Primary sources are principally regenerated in industrial utilities into secondary energy sources. For instance, coal, oil or gas regenerates into steam and electricity. Across the world, commercialized fuels are predominant supplies not only for economic production but also for several household works of general population. Anupama Gupta et al. [3] has focused on various rules of management of energy i.e. auditing and various processes involved in saving of energy and cost analysis. S.U.Kulkarni [4] has concentrated on energy management related to small and medium industries. They considered an industrial unit and have done energy audit analysis related to lighting and harmonic. P.Kiranmai et al. [5] has discussed usage of energy in a standard manner. According to him and energy auditing is one effective program. Study mainly related to aspects of energy economics, money saving on electricity amounts and emissions of the green house.

M. S. Sujatha et al. [6] has developed a modern method to overcome under frequency load shedding problems by the implementation of "ANFIS" controller to calculate quantity of load shed. JianZhang. [7] They clearly mentioned how energy can be saved by using various latest energy audit and energy management methods. Tarun B Patel. [8] they focused mainly on small companies' energy auditing, process of audit and how it should be carried out in companies. AhilaC.P. [9] they have considered a ladies hostel and have done energy auditing for that particular hostel and made calculations related to Power consumption, cost analysis and other facilities like water. Shashank Shrivastava. [10] has carried out energy audit in a particular industry and improved the efficiency. To improve efficiency, they collected data of pumps, water, and lighting. They removed losses in it.

Figure 1 represents various stages involved in energy generation. In the initial stages various sources of energy available are identified, and then from the earth crust energy sources are extracted. This is materialized by using various methods. In the next stage processing or preparation takes place. Finally, it is converted into energy.
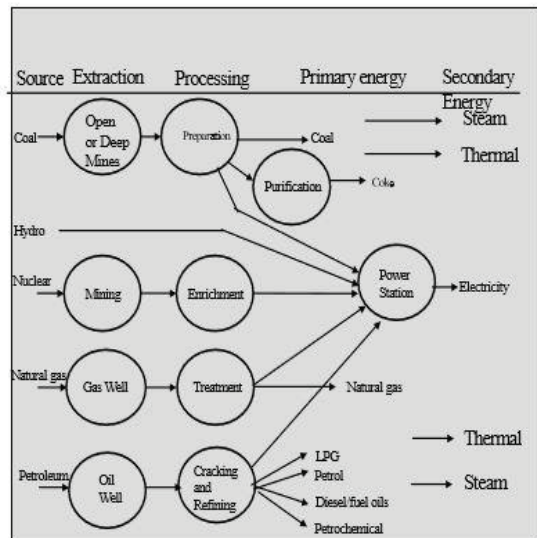

Figure 1.   Various sources

(Source: BP2018, Statistical Review of World Energy)

Figure 2 represents about energy consumption taking place around the world. It also shows a particular type like

oil, natural gas, nuclear energy, hydroelectricity, and coal utilization globally.
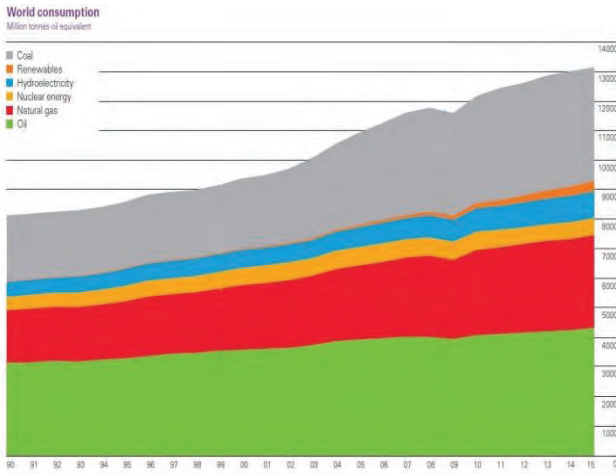

Figure 2. Global Primary Energy Consumption
(Source: BP2018, Statistical Review of World Energy)

The pollutants which damage the atmosphere are (SO2), (NOX), (CO) and (CFC) etc. In chemical and fertilizers industries poisonous gases which are emitted will damage the Environment. The Input and output of process is shown in figure 3.
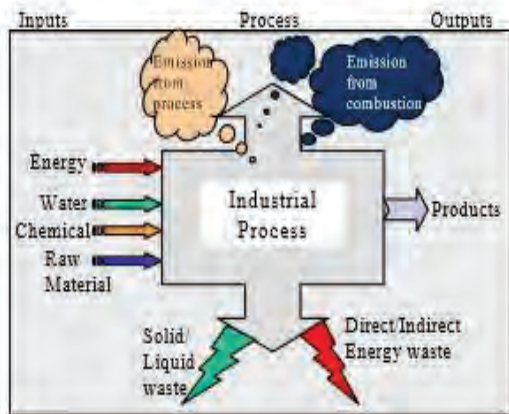

Figure 3. Input and Output of Process.
(Source: researchgate.net)

Figure 3 shows the various input parameters taken and finally the products which we obtain. The principle pollutants made by industrial, domestic and traffic sources are sulfur dioxide, N oxides, material, CO, ozone, hydrocarbons, benzene, 1, 3-butadiene, poisonous organic small pollutants, lead, and significant metals.Human activities and combustion of fossil fuels have created the blanket of greenhouse gases (water vapor, carbonic acid gas, methane, ozone etc.) round the earth thicker.

II. ENERGY CONSERVATION

Promotion of energy potency can contribute to energy conservation is thus an integral part of energy conservation promotional policies. Energy potency is usually viewed as a resource possibility like coal, oil, or fossil fuel.

Energy conservation protects the resources and reduces pollution as an example, replacement of ancient lightweight bulbs with Compact Fluorescent Lamps (CFLs). It means that one uses solely 1/4th of the energy to lightweight an area. Pollution levels conjointly scale back by an equivalent quantity. Figure 4 is the best example of energy conservation. In this figure one can see the difference in Co_2 emission by using 60W Incandescent lamp and 15W fluorescent lamp.

Figure 4. Energy Conservation Example.
(Source: researchgate.net)

The commercial sector accounts for a 40% of worldwide primary energy demand and around constant share of carbonic acid gas emissions. The advantages of energy conservation for varied players are shown in Figure 5.
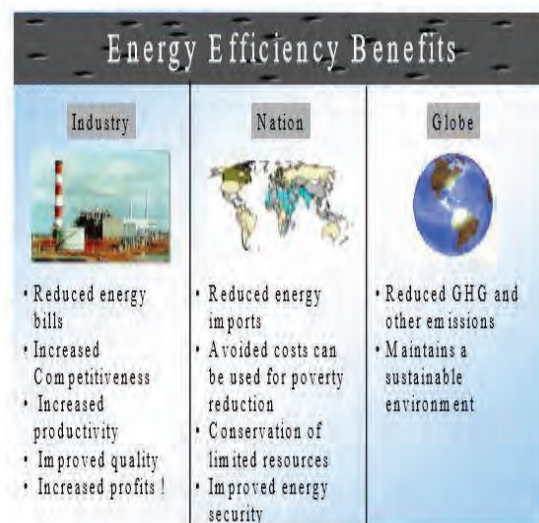

Figure 5. Energy Efficiency Benefits.
(Source: Energy Auditing and Demand Side Management (10EE842))

III. ENERGY MANAGEMENT AND AUDIT

To appreciate and maintain optimum energy acquisition and utilization, throughout the organization, to scale back energy costs / waste whereas not moving production.

Energy audit is that the key to a scientific approach for decision-making at intervals is the house of energy management. Energy Audit will facilitate to grasp loads of (some word is missing) regarding the ways in which energy and fuel are used in any trade. First objective of energy audit is to see ways that to cut back energy consumption per unit of product output or to lower in operation prices.

Energy audit provides a "benchmark" (Reference point) for managing energy within the organization and additionally provides the premise for designing a more practical use of energy throughout the organization.

The sort of energy audit to be performed depends on perform and kind of business, depth to that final audit is required.

Preliminary energy audit is a quick process to identify the problems. It uses existing, or simply obtained knowledge.

Phase I (Pre-Audit Phase)

The engineer will perform the following activities: discuss economic aspects related to the audit, analyze the foremost energy consumption knowledge with the relevant personnel, get web site drawings wherever required and instruments needed for finishing audit.

Phase II (Audit Phase)

The data to be obtained in this phase will contain energy consumption based on a kind of energy, instrumental and material information, development of compressed gas and steam, usage of co-generation systems, energy management procedures and awareness programs.

The audit team ought to collect the subsequent baseline data: nowadays, to be at the forefront of any trade it's imperative to own a correct energy management system established. Strain to be sooner than your competitors include constant work towards eliminating waste, increasing potency and up fight. The energy audit could be a valuable partner on the road to achieve energy potency. Several corporations merely pay their bills and place up with the high prices of energy. However, increasing range of corporations understands the importance of understanding energy consumption and begins operating to eliminate inessential prices.

These savings will then be reinvested back in potency with the prospect to continuous improvement that successively results in improved economic and environmental results.

IV. TEN STEP METHODOLOGY

Table I represents the methodology of auditing. The auditing is divided into three phases. In first phase works related to plan and organize. In the second phase works related to data gathering and drawing process flow diagrams and energy diagrams. Finally, in the third phase post auditing will be done. In this phase, works carried out related to preparing schedule, action plan and follow-up.

TABLE I.
METHODOLOGY OF AUDITING

Step No.	Plan of Action	Purpose/Results
Step1	**Phase I:** Plan and organize, Walk through Audit and Informal Interview with Energy Manager, Production/Plant Manager.	(1) Resource planning, (2) Establish/organize an Energy audit team. (3) Organize Instruments & time frame. (4) Macro Data Collection (5) Familiar with all activities. (6) Fresh observation & Evaluation of present operation and practices.
Step2	Conduct of brief meeting / awareness program with all divisional heads and persons concerned (2-3 hrs.).	(1) Building up cooperation. (2) Issue questionnaire for each department. (3) Orientation, awareness creation.
Step3	**Phase II:** Primary data gathering, Process Flow Diagram, & Energy Utility Diagram.	(1) Historic data analysis, Baseline data collection. (2) Prepare process flow charts. (3) All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution). (4) Design, operating data and schedule. (5) Yearly Energy Bill and energy consumption shape.
Step4	Conduct survey and monitoring.	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.
Step5	Conduct of detailed trials /experiments for selected energy guzzlers.	Trials/Experiments: (1) 24 hours power monitoring. (2) Load variations trends in pumps, fan compressors etc. (3) Boiler/Efficiency trials for (4 – 8 hours). (4) Furnace Efficiency trials Equipment's Performance experiments etc.
Step6	Analysis of energy use.	Energy and Material balance & energy loss/waste analysis.
Step7	Identification and development of Energy Conservation (ENCON) opportunities.	Identification& Consolidation ENCON measures: (1) Conceive, develop, and refine ideas. (2) Review the previous ideas suggested by unit personal. (3) Review the previous ideas. (4) Use various techniques. (5) Contact contractors for new idea.
Step8	Cost benefits analysis.	(1) Assess technical feasibility, economic viability and prioritization of ENCON options for implementation. (2) Pick up Value projects. (3) Take measures.

Step9	Reporting & Presentation to the Top Management.	Give Presentation to Management.
Step10	**Phase III: Post Audit Phase** Implementation and Follow-up.	Related to ENCON (1) Action plan, Schedule for starting. (2) Follow-up and regular review.

V. ENERGY SAVING IMPLEMENTATIONS

Energy saving implementations based on the energy audit for HVAC systems involves arrangement of sensor module between the HVAC indoor and outdoor unit. With this module, one can control the set temperatures, shut down the compressor and can break the signal coming from the indoor unit of HVAC. This entire sensor module has three main units:

1. Input Unit
2. Data Controller Unit
3. Operating Unit

Technology (Microcontroller ESP 32)
ESP32 is a series of low-cost, low-power system on a chip micro and controllers with integrated Wi-Fi and dual-mode Bluetooth.
Figure 6 represents the type of microcontroller used in energy auditing process. The micro controller used here is ESP32 type.

Figure 6.   ESP32 Microcontroller.
(Source: Calcutta Electronics.com)

Arduino software (IDE): The Arduino IDE employs the program argued to convert the potential code into a document in number representation system writing that is loaded into the Arduino board by a loader program in the board's firmware. The details and coding part of Arduino software sample is shown in Figure 7.It is less expensive software and easy conversion tool which is used by mainly electrical and mechanical engineers in industries, specially industries related to energy systems there are very limited companies which are developing this software in India.
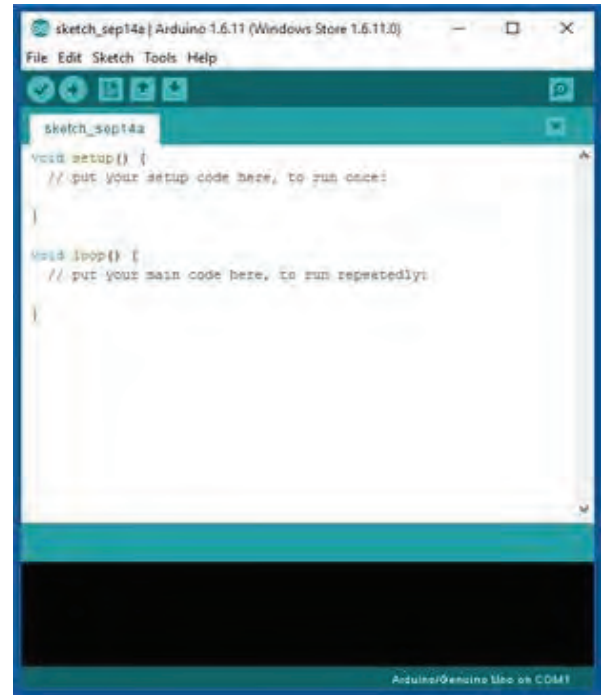

Figure 7.   Arduino IDE Coding.
(Source: researchgate.net)

Eagle Software: EAGLE stands for simply Applicable Graphical Layout Editor and is developed by CAD Soft pc GmbH.Schematics area unit keep in files with SCH extension, elements area unit outlined in device libraries with LBR extension. Figure 8 represents the Eagle software details related to a circuit design. This software is mainly used in Energy saving processes for developing circuit design.
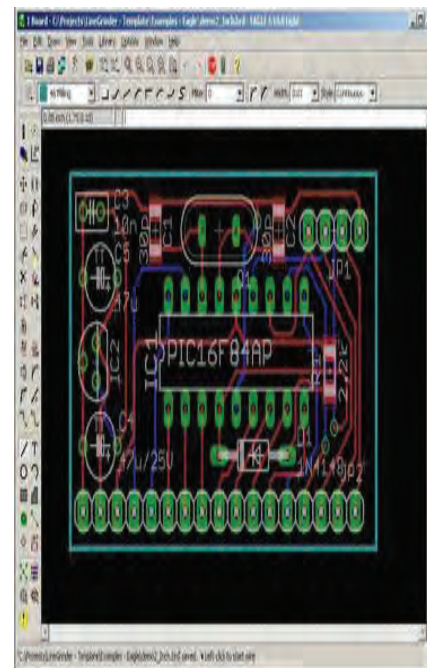

Figure 8.   Eagle Software for Circuit Design
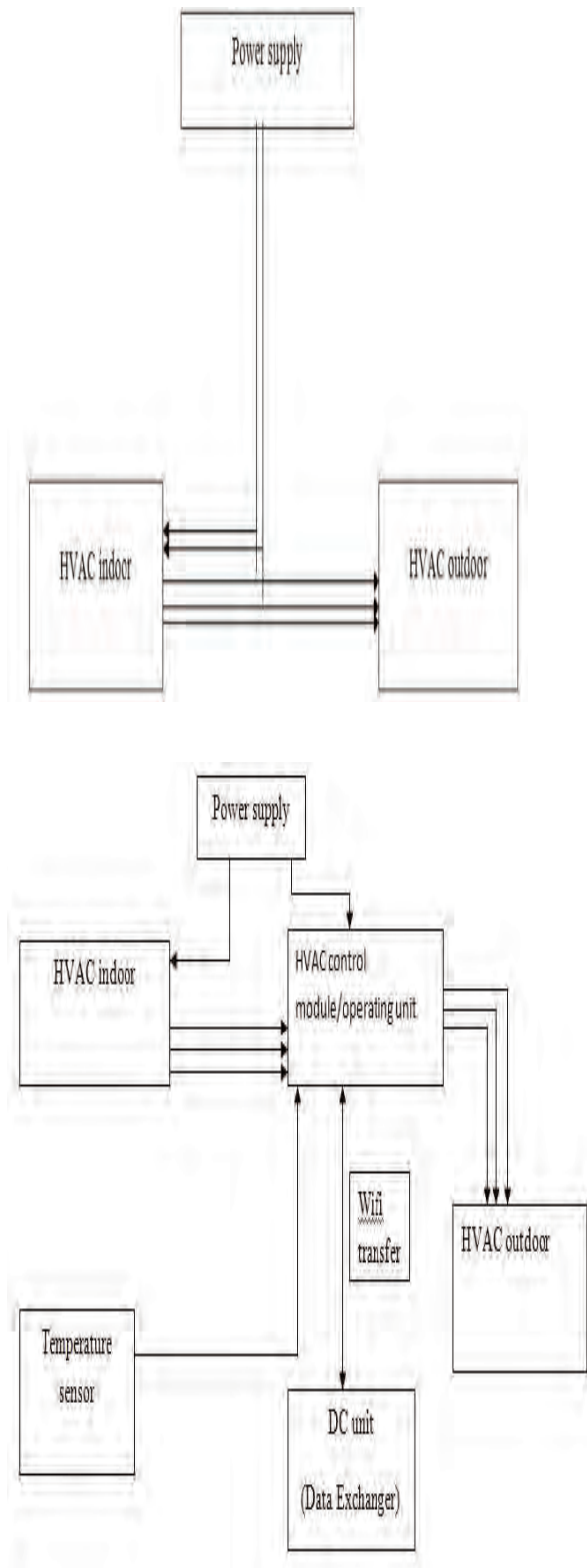
Block diagrams: without Module and with Module

Figure 9 represents the block diagrams related to, with module and without module.

The figure clearly shows how the process takes place with the installation of module and without the installation of module.

VI. RESULTS

Table II represents the energy audit report without using module in it and, have taken weekly readings at different times of a day and noted down the energy consumed at a particular time of a day by using energy meter readings.

TABLE II.

ENERGY AUDIT REPORT WITHOUT MODULE UNIT

Days Count/Time	Set Temperature of AC unit in 0c			Ton of Refrigeration			Energy Meter Readings in KW-h
	AC1	AC2	AC3	AC1	AC2	AC3	
1/11.30 am	22	24	21	9.5	9.5	9.5	9636.11
2/1.45 pm	21	22	20	9.5	9.5	9.5	9661.63
3/12.30 pm	21	22	22	9.5	9.5	9.5	9667.63
4/4.30 pm	22	19	21	9.5	9.5	9.5	9702.25
5/7.00 pm	23	19	23	9.5	9.5	9.5	9736.63
6/2.10 pm	21	22	20	9.5	9.5	9.5	9764.92
7/2.45 pm	23	21	22	9.5	9.5	9.5	9789.37

For a week readings, the difference in energy meter readings for the first and the last is approximately 153 units.

Let, per unit is cost Rs.10 → For 153 units 1530 per week.

Table III represents the energy audit report by using module in it, and have taken weekly readings at different times of a day and noted down the energy consumed at a particular time of a day by using energy meter readings in this case the set temperature is constant.

TABLE III.

ENERGY AUDIT REPORT WITH MODULE UNIT

Days (Count/ Time)	Set (T)	Set Temperature of AC unit in 0c			Ton of Refrigeration			Energy Meter Readings in KW-h
		AC 1	AC 2	AC 3	AC 1	AC 2	AC 3	
1/11.30 am	24	22	24	21	9.5	9.5	9.5	9837.14
2/1.45 pm	24	21	22	20	9.5	9.5	9.5	9847.4
3/12.30 pm	24	22	21	22	9.5	9.5	9.5	9859.95
4/4.30 pm	24	22	19	21	9.5	9.5	9.5	9871.63
5/7.00 pm	24	23	19	23	9.5	9.5	9.5	9881.45
6/2.10 pm	24	21	22	20	9.5	9.5	9.5	9891.94
7/2.45 pm	24	23	21	22	9.5	9.5	9.5	9905.56

For a week readings, the difference in energy meter readings for the first and the last is approximately 69 units.

Let, per unit is cost Rs.10 → For 69 units, Rs.690 per week.

Total Savings/Week = Rs.1530 – Rs.690 = Rs.840/week

Figure 9.   Block Diagrams with Module and without Module

VII. CONCLUSIONS

Energy auditing is done mainly for energy saving purposes.

(1) By the installation of module unit, we can save large amount of energy consumption.
(2) The number of units per week can be reduced by using module
(3) The working life of refrigerant can be improved.
(4) The environment can be emission free.
(5) Percentage of usage of refrigerant reduces.

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