ENERGY AUDIT

Brief Overview of Theory & Practice of Energy Audits

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Abstract

A review of the published literature on the theory and practice of performing an Energy Audit was conducted. The purpose of this review was to assess relevant information on conducting an energy audit as a tool in the movement to a carbon net zero environment. This research is part of the overall Kenson Group Carbon Net Zero Capability Portfolio that positions Kenson as a viable provider in this area.

An Energy Audit is a process of checking the way energy is used in a building and identifying areas where wastage can be minimized or eradicated.

All businesses and homes can benefit from conducting an energy audit as it will save money spent on electricity and it will promote energy conservation which is a major contributing factor in the battle against climate change. It is an inexpensive process that requires little to no expertise.

The following steps are important for a successful energy audit:

1. Collect building and utility data and analyze
2. Conduct a walk-through survey
3. Develop a baseline for energy use
4. Conduct evaluation of energy saving methods

Examples of published literature where energy audits were conducted were a factory in Ireland and a university in India. As a result of their Energy Audits, the Irish factory was able to reduce its annual energy use by 53,579kWh providing a cost saving of 11.5% per annum. The Indian University on the other hand managed an energy reduction of 77,221.88kWh giving an overall cost reduction target of 26.3% per annum.

In Trinidad and Tobago, the electrical bill is statistically the largest of all utility bills with the average being TT$1500 and the upper about TT$3000 and the lower being TT$600. Despite Trinidad's electricity being highly subsidized due to our production of fossil fuels, every citizen can benefit from reducing their electricity bill. These subsequent reductions can be achieved by conducting an energy audit to your personal household. This audit will provide you with your relevant energy use to which you can then implement conservation methods to reduce your monthly energy consumption.

It can be seen from the literature review the importance of Energy Auditing in the movement to achieving Carbon Net Zero. It provides a foundation of physical data on energy use that can then be analyzed to make the decision of implementing measures of reducing this subsequent energy. By partaking in this reduction, it helps in the overall battle against carbon emission as the less energy being used proportionally means less energy needed to be made.

1.0 Introduction & Background

One of the main objectives of organizations is to cut on costs and increase profit margin. On average, office buildings in the U.S have an annual expenditure of US$1.34 per square footage on electricity and US$0.18 per square footage on natural gas. Energy represents about 19% of total expenditures for a typical office building thus proving the significance of energy operational costs and why it deserves management attention. Energy conservation is the primary way of reducing this number in a cost-effective way.

In Trinidad and Tobago, the average household in 2015 had an electricity consumption bill of 2100kWh. However, electricity in Trinidad is highly subsidized with prices varying from TT$ 0.35 per KWH for households to TT$0.36 per KWH for businesses or roughly US$0.05 per KWH.

This high subsidization subsequently results in nonchalant behavior to energy use and thus an increase in demand for electricity resulting in greater emissions.

A vital part of energy conservation and efficiency is energy auditing. An energy audit is an investigation of all facets of an organization's historical and current energy use with the objective of identifying and quantifying areas of energy wastage within the organization's activities. An energy audit will provide the organization with a baseline foundation for improvements coupled with a comprehensive and systematic method for cost effective efficiency gains. This can provide significant savings without the need for significant capital investment as well as have the long-term benefit of reducing carbon emissions due to a lower demand for energy thus moving towards Carbon Neutrality.

2.0 Research Methodology

This research methodology consists of two parts. Firstly, a breakdown of the steps on how to conduct an Energy Audit will be explained in detail followed by two case studies exhibiting the benefits and savings that can be achieved after an audit.

To perform an energy audit the following steps are needed:

Step 1: Building and Utility Data Analysis

The main purpose of this step is to evaluate the characteristics of the energy systems and the patterns of energy use for the building. The building characteristics can be collected from the architectural/ mechanical/electrical drawings and/or from discussions with building operators. The energy use patterns can be obtained from a compilation of utility bills over several years. Analysis of the historical variation of the utility bills allows the energy auditor to determine any seasonal and weather effects on the building energy usage. Some of the tasks that can be performed in this step are presented below:

- Collect at least 3 years of records of utility data [*to identify a historical energy use pattern*]
- Identify the fuel types used (electricity, natural gas, oil, etc.) [*to determine the fuel type that accounts for the largest energy use*]
- Determine the patterns of fuel use by fuel type [*to identify the peak demand for energy use by fuel type*]
- Understand utility rate structure (energy and demand rates) [*to evaluate if the building is penalized for peak demand and if cheaper fuel can be purchased*]
- Analyze the effect of weather on fuel consumption
- Perform utility energy use analysis by building type and size (building signature can be determined including energy use per unit area [*to compare against typical indices*]

Step 2: Walk-Through Survey

This step should identify potential energy savings measures. The results of this step are important since they determine if the building warrants any further energy auditing work. Some of the tasks involved in this step are

- Identify the customer's concerns and needs
- Check the current operating and maintenance procedures
- Determine the existing operating conditions of major energy use equipment (lighting, HVAC systems, motors, etc.)
- Estimate the occupancy, equipment, and lighting (energy use density and hours of operation)

Step 3: Baseline for Building Energy Use

The main purpose of this step is to develop a base-case model that represents the existing energy use and operating conditions for the building. This model will be used as a reference to estimate the energy savings due to appropriately selected energy conservation measures. The major tasks to be performed during this step are

- Obtain and review architectural, mechanical, electrical, and control drawings
- Inspect, test, and evaluate building equipment for efficiency, performance, and reliability
- Obtain all occupancy and operating schedules for equipment (including lighting and HVAC systems)
- Develop a baseline model for building energy use
- Calibrate the baseline model using the utility data and/or metered data

Step 4: Evaluation of Energy-Saving Measures

In this step, a list of cost-effective energy conservation measures is determined using both energy savings and economic analysis. To achieve this goal, the following tasks are recommended:

- Prepare a comprehensive list of energy conservation measures (using the information collected in the walk-through survey)
- Determine the energy savings due to the various energy conservation measures pertinent to the building by using the baseline energy use simulation model developed in Step 3
- Estimate the initial costs required to implement the energy conservation measures
- Evaluate the cost-effectiveness of each energy conservation measure using an economic analysis method (simple payback or life-cycle cost analysis)

Below is a diagram that explains the relevant steps in conducting and Energy Audit

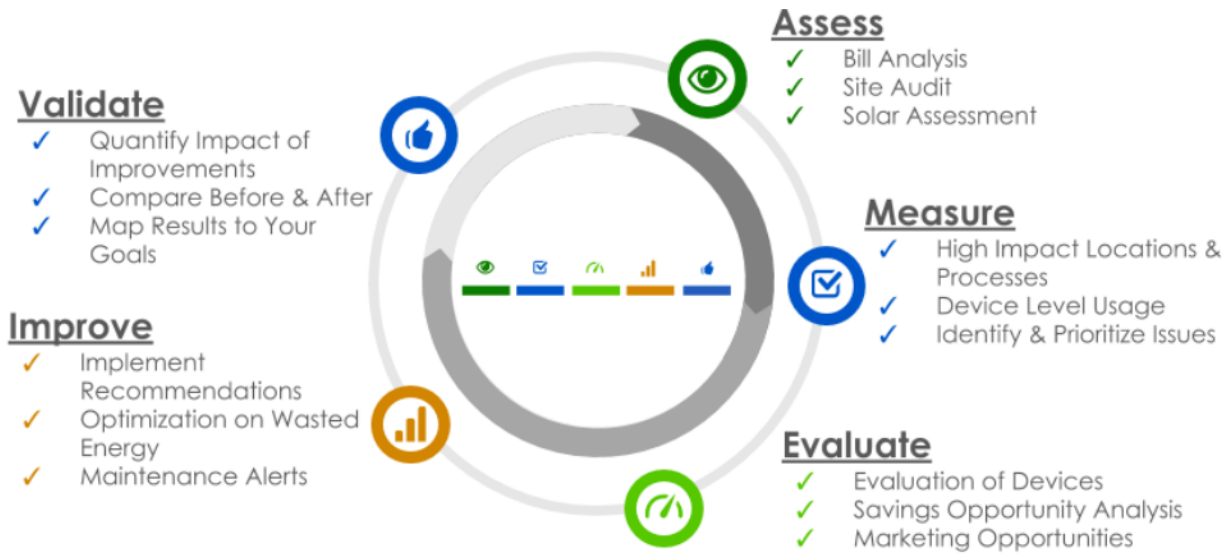

Figure 1 Diagram showing the Steps of Conducting an Energy Audit

3.0 Practical Examples

3.1 Case Study 1

This first study takes place in Limerick Ireland. A consultant, Maz Ali was appointed to review and identify areas of reducing energy consumption in a gel and toner manufacturing factory to minimize the factory's emissions. The site's occupancy has been reduced to just three units to be

audited as part of the business has been sold off. There is a total of 25 staff members that currently work in the client's factory which operates between the times of 7:30am to 4pm daily 5 days a week. Two main sources of energy used on site are:

- Electricity
- Natural Gas

Electricity is utilized mainly for the production purposes while natural gas is used for thermal oil heating and space heating.

The tables below will show the Energy Usage and annual costing regarding to the energy data given by the client.

3.1.1 Energy Consumption and Cost Analysis

Table 1 Cost Break Down for Client Energy Usage at €0.16/kWh

Consumption Date	Consumption kWh		Max Demand kW	Cost €
	Day Units	Night Units		
Mar 08	50,013	14,443	336	10,019
Apr 08	47,323	15,897	307	9,676
May 08	39,564	14,162	277	8,641
Jun 08	39,154	12,646	294	8,405
Jul 08	43,280	11,281	305	8,892
Aug 08	35,219	10,115	284	7,800
Sep 08	36,737	10,485	319	7,983
Oct 08	27,787	8,870	-	6,401
Nov 08	35,440	11,375	-	7,791
TOTAL	**354,517**	**109,274**		**75,608**

The above consumption is attributed, based on sub-meters reading, to the different areas of the factory as follows on an annual basis.

3.1.2 Natural Gas Consumption

The total gas consumption by the factories was calculated to be 295,584kWh. The annual gas expenditure worked out to be **€14,744** with the cost of gas estimating to be **€0.04/kWh.**

3.1.3 Energy Management

Currently there is an existing Energy Management program system on site that monitors the monthly gas and electricity meter readings and the energy consumption against production. However, only a simplistic energy management program will be needed to ensure an effective monitoring of energy consumption and cost. The following improvements can be made to the existing program to further enhance its effectiveness:

- Have weekly meter readings to ensure any anomalies are quickly identified at an early stage to eliminate any energy wastage.
- Information on energy consumption should be circulated to all the critical departments.
- One person should be nominated to be responsible for all energy matters on site

Table 2 Recommendations for Energy Reduction and the Energy Saved

T12 Fluorescent Tubes – 1.6" Fluorescent Tubes
T5 Fluorescent Tubes – 0.6" Fluorescent Tubes

Recommendations	Investment Cost Category	Payback Period/year	Predicted Annual Savings		Annual CO_2 Emissions Savings/Tonne
			Energy/kWh	Cost/€	
Reduce Maximum Import Capacity on the electricity contract from the existing level of 800 kVa to 400 kVa	Low Cost	0.3	-	6,500	-
Eliminate poor factor charges	Low Cost	1.5	-	500	-
The gas supply to the smallest factory, Unit 12 should be changed	Low Cost	-	-	1,500	-

to Small Business User (less gas being sent therefore less gas wastages)					
Operate the Vacudest 400 machine during the nighttime tariff	Low Cost	-	-	3,000	-
Install PIR controllers for the lighting control in the locker room, toilet, canteen and entrance area of unit 12	Low Cost	1	1,534	250	1.2
Replace the existing 100W (Y12) fluorescent tubes in unit 13 main area by T5 tubes to save 50% energy use for lighting in this area	Medium	2	4,908	800	3.8
The lights in the storage areas, mixing room and toilet, locker room of unit 13 should be controlled by PIR switches	Medium	1	6,135	1000	4.7
Install PIR controllers to control lighting in the corridor and relevant individual offices in unit 14	Medium	1	1,534	250	1.2
Install Thermostatic Radiator Valves on the radiators in unit 13	High	1.5	33,333	1,500	8.6
The hot room temperature in unit 12	Low	0.5	6,135	1,000	4.7

should be controlled at optimum level and the existing temperature of over 39C is considered excessive					
TOTAL			**53,579**	**16,300**	**24.2**

3.2 Case Study 2

The next case study of energy audits was conducted in India at a University institute. The audit begun by breaking down the equipment that required electrical load and how many of them existed within the building. This was done for all 7 departmental buildings.

An example of how the tables were laid out is shown below:

Table 3 Equipment Present at Facility and the Subsequent Load Used

Equipment	Rating of the Equipment (W)	Number of Equipment	Power (W)	Energy Consumption per month (kWh)
Fan	70	27	1890	15.12
Tube Light T12	40	120	4800	38.4
CFL	18	19	342	2.73
2 by 2 CFL	36	3	108	0.864
Printer	250	5	1250	10
Xerox	250	1	250	168
AC	1500	14	21000	8
System LCD System CRT	250 350	37 11	9250 3850	74 30.8

By doing this the total amount of each equipment and its energy usage was able to be calculated and energy savings calculations were then able to be conducted.

3.2.1 Energy Savings Calculations

Energy Savings by replacing the T12 tube lights with higher efficient T5 tube lights is as follows:

Total No. of T12 tube lights = 1522
Total Power consumption = 1522 x 40W
= 60,880W
Total Daily Energy Consumption = power consumption x operating hours
= 60.88kW x 8hours
= **487.04 kWh**

Total No of T5 tube lights = 1522
Total Power Consumption = 1522 x 28W
= 42.61kW
Total energy consumption = power consumption x operating hours
= 42.61kW x 8hours
= **340.88kW**

Daily Energy Saved = 487.04kW – 340.88kW
= **146.16kW**
Percent Saved Daily = $\frac{146.16}{487.04}$ x 100
= 30%

Other energy saving methods that were implemented are:

1. Changing CFL to LED – **23.86kWh saved daily**
2. Replacing normal fan to energy efficient fan – **34.32kWh saved daily**
3. Changing CRT computer to LCD computer – **14.4kWh saved daily**
4. Replacing Window AC to Split AC – **76kWh saved daily**

In total by implementing these measures **294.74kWh** would be saved daily. Using the assumption that there are 262 working days in a year the total annual energy savings would be **77,221.88kWh.**

4.0 Analysis and Discussion

The chosen literature discussed how an energy audit can be conducted and how its findings can be beneficial for companies to be able to pinpoint where they can reduce their energy usage and subsequently save on their monthly bills. In the first case study taking part in Ireland on a gel and toner manufacturing factory it was found that their energy usage before the implementation of an energy management system was roughly 463,791kWh annually. This translated to annual cost north of €75,000. By implementing a refined energy management system annual energy usage dropped to 410,212kWh providing a total energy saving of 53,579kWh giving a 11.5% reduction. These savings were achieved through implementing measures such as:

- Reducing maximum import capacity
- Eliminating poor factor charges
- Changing the gas supply to less busy plant to a small business user
- Operating the Vacudest machine only at night
- Installing a PIR controller
- Replacing T12 fluorescent bulbs with T5 tubes
- Installing thermostatic radiator valves
- Controlling hot room temperature at optimum level

For case study 2 similar findings were achieved. This study was conducted on a university in India. The audit began by selecting all equipment that requires an electrical load and counting how many of each were present. For example, the T12 fluorescent lamp, using its factory power rating the amount of load used by the lamps was calculated. This figure was then used in conjunction with its time of use to distinguish its daily energy use of 487.04kWh. Next using the same time of use from before daily energy usage was calculated but for the more efficient T5 fluorescent lamp giving 340.88kWh. As it was seen daily energy savings of 146.16kWh was achieved with this change. The following were also implemented to add to these energy savings:

- Changing CFL to LED – **23.86kWh saved daily**
- Replacing normal fan to energy efficient fan – **34.32kWh saved daily**
- Changing CRT computer to LCD computer – **14.4kWh saved daily**
- Replacing Window AC to Split AC – **76kWh saved daily**

A Total of 77,221.88kWh was able to be saved annually providing an overall energy difference of 26.3%. Kenson has begun the movement of changing all inefficient incandescent bulbs to LEDs

and Fluorescent tubes wherever necessary throughout the head office and the Kenson school. The findings of energy and cost savings will be reflected in the Implementation Plan.

5.0 Conclusion & Recommendations

Energy auditing is the process of checking how energy is used and how to identify areas in which waste can be minimized if not eradicated. An energy audit consists of several tasks which can be carried out depending on the type of audit being performed and the function of the audited facility. It follows 4 generic steps:

1. Collect building and utility data and analyze
2. Conduct a walk-through survey
3. Develop a baseline for energy use
4. Conduct evaluation of energy saving methods

The two chosen literature case studies applied these steps to carry out their audit on their factory and university respectively. After conducting the audit and being able to see where the majority of their energy usage lies, they then implemented energy conservation techniques and subsequently achieved annual reductions of 53,579kWh and 77,221.88kWh respectively.

Energy Auditing is often the first step in practicing energy conservation. It provides the relevant data for an organization to see where energy use could be reduced and potentially save on annual costs.

Kenson has implemented energy conservation into the company's facilities in numerous ways, however, it is understood that for those who would like to conduct their own energy audits at home, it can be quite confusing on where to start. Here are some simple steps to follow:

I. Look at your most recent utility bill and determine how much you would like to see it reduced
II. Start small; you and family members should get into the habit of turning off lights, fans and AC units when leaving a room.
III. Start with affordable changes: exchange old incandescent bulbs for higher efficient LEDs, buy door sweeps for air-conditioned rooms.
IV. Further alterations would be to remove old window AC units and move to the more efficient split units. Additionally changing older electronics in household with newer more efficient ones can also aid in energy conservation.

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