

# ENERGY EFFICIENT SMART CLASSROOMS WITH WI-FI CONTROL

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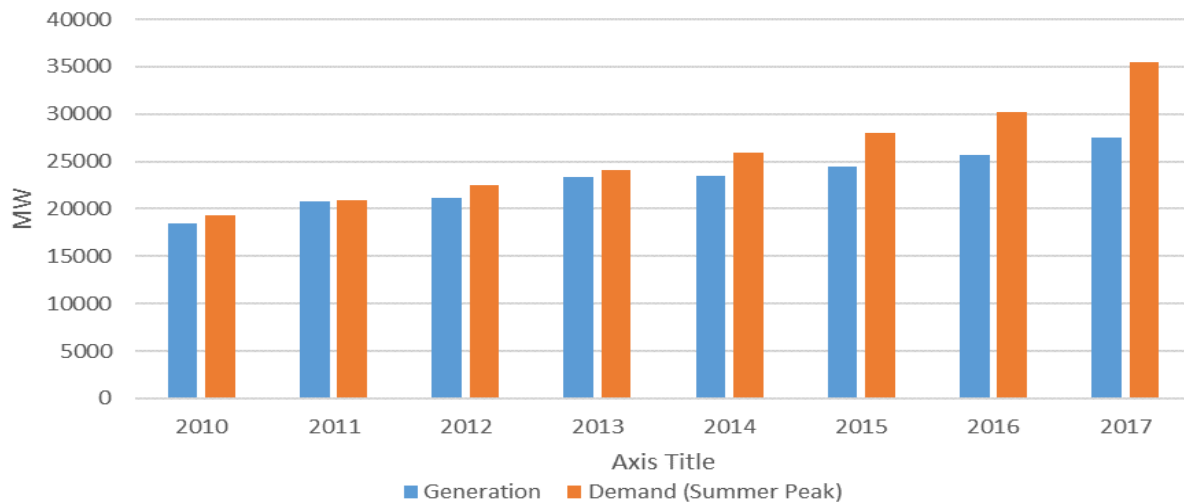
**Abstract** – Our country, Pakistan, is facing an energy crisis and poor economy. The need of the time is to develop a solution which promotes a better lifestyle and less burden on the economy. This paper represents the design and implementation of an automated classroom that not only uses smart algorithms but based on the ECOs (Energy Conversion Opportunities) of an energy audit it reduces the energy consumption without affecting the performance of system and then make a priority list of these opportunities to optimize the energy consumption. A prototype comprising of a smart central unit which monitors occupants, their location and their preference trends using Passive Infrared motion sensors and automated switching that control lighting and heating, and an Android application that monitors and controls the smart system has been implemented. The prototype has been tested in two identical environments; one classroom was treated as an experimental group and the other as the control group. The results show that the ‘smart’ classroom with integrated algorithms and control architecture smartly distributes the available energy and keeps the classroom in optimal conditions. It proves to be significantly effective in saving energy. Thus it has been concluded that with this approach we can save energy and money that was previously wasted and efficiently consume energy considering our country’s limited energy resources.

**Index Terms** – Passive Infrared Module, Android Application, Energy Auditing, Smart Classroom.

## 1. INTRODUCTION

Energy is considered to be life line of any economy and most vital instrument of socioeconomic development of a country. There has been an enormous increase in the demand of energy and this demand is not being met. The major reason behind Pakistan’s poor power generation is the exponentially increasing demand for power. Pakistan is currently facing a huge energy crisis. This energy crisis has seriously hampered the economic growth and our development progress.

According to statistics the peak electricity demand in Pakistan is 21,835MW while total generation capacity varies between 17523MW in summer to 14640MW in winter. As a result, the supply-demand gap also varies between 3500-4310 MW. In 2008, availability of power in Pakistan fell short of the population's needs by 15%.



**Fig. 1.1 Electricity Supply vs. Demand 2010 – 2017 [1]**

At present the supply-demand gap is filled through planned power cuts, also called load-shedding. In cities, these scheduled power cuts last for 6-8 hours, while in rural areas the figure goes above 12.

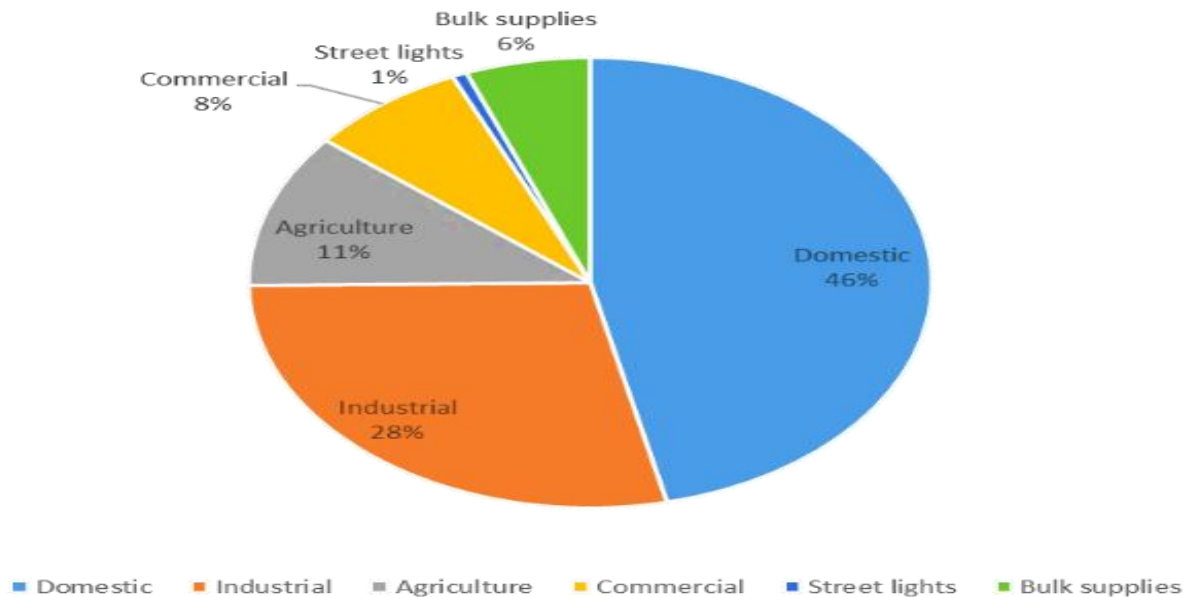
Overall the load shedding has created a negative impact on the economy of Pakistan. In NEPRA State of Industry Report 2013, NEPRA estimated that the energy crisis and frequent load shedding are responsible for 2 to 3 percent reduction in the annual GDP of Pakistan. It is estimated that, due to power shortages in the industrial sector alone, the loss was over \$3.8 billion in 2009 that is approximately 2.5 percent of the gross domestic product (GDP).

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pg. 17

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**Fig. 1.2 Energy Consumption by Sector [2]**

Pakistan's energy saving potential is estimated at 2,250 MW [3] which is about half of the country's total power shortfall. Energy can be saved effectively by proper management of electricity distribution for electronic devices based on the activities of the users. [4]

According to Consumer Rights Commission of Pakistan (CRCP) survey, lighting and space cooling are two major electrical end using categories amongst households in Pakistan. Bulbs and tube lights are generally used for lighting, whereas fans, air coolers and air conditioners are used for space cooling. These two basic electrical appliances account for two third of the total household electricity consumption. Similar trends are observed in offices and commercial sectors. According to a report by European Commission, energy smart homes can reduce energy consumption by up to 30%. Also a recent study published by McKinsey and Company states that IOT based energy management system can cut energy use by 20% in offices and 10-20% in factories.

**Table- 1.1 Potential Energy Conservation Areas**

Conservation Areas	Saving Potential
Overall lighting potential	29%
High efficiency lighting	72%
Fluorescent Tube Ballasts	83%
Lamp fixtures	50%
Air conditioners	18%
Fan	5%
Computer	2%

The smart classroom is a part of the solution towards this goal. Smart class room is actually interconnectivity of devices that helps to administrators and policymakers [24]. It aims towards developing an energy-efficient power distribution system. The idea is to audit for the energy that is being consumed by the occupants of the room. In an energy audit, audit methods data is collected about the building. Then a survey of the building and overall breakdown of the consumption is done. After analysis and careful observation of the collected data, a report is made which includes different strategies to reduce energy cost. This information is used to implement the 'smart' energy usage technology to manage and save energy in the class room environment.

The 'smart' system monitors the energy being consumed by electrical outlets and autonomously makes decisions according to its sensory input [23] and smart algorithms to minimize energy being consumed in an optimum manner. An Android application is also developed which acts as a manual override. This system, applied to a conventional class room, acts as an experiment and any sort of changes are compared against another class room with identical conditions which acts as the control group. Both classrooms have electric meters installed for recording electricity usage. One classroom is equipped with our solution and the other continues to run as it is. The energy consumption of both the classrooms are reviewed continually. The end result is an affordable prototype of a scalable smart energy distribution and monitoring system which is autonomous in making smart decisions in real-time.

The paper is organized into sections as follows. Section II comprises the compilation of the literature review of the home automation and smart lighting, while Section III deals with the methodology followed during the course of the project including the hardware modules Passive Infrared technology for occupancy and thermal detection and the algorithm for machine learning and for the linking of data with the Internet of Things. In Section IV, discusses the results drawn from the comparison of the project in terms of the energy saved and concludes the paper.

## 2. RELATED WORK

### 2.1 Energy Auditing

Developments and innovations in technology help to solve energy crises by using different renewable energy sources [26]. Energy audit provides results in reduction energy billing for which suitable preventive and cost effective maintenance and quality control programs are essential leading to enhanced production and economic utility activities. Depending upon the type of functions different types of energy audit are performed [5].

Energy audit estimates energy input for different processes, collection of previous data on production levels and total energy consumption. It is a detailed energy audit action plan to be followed effectively in the industry. It provides a complete model of energy use of the existing facility and all energy conservation measures are identified. The building model is calibrated against actual data to provide a baseline against which to compute operating savings for proposed measures.

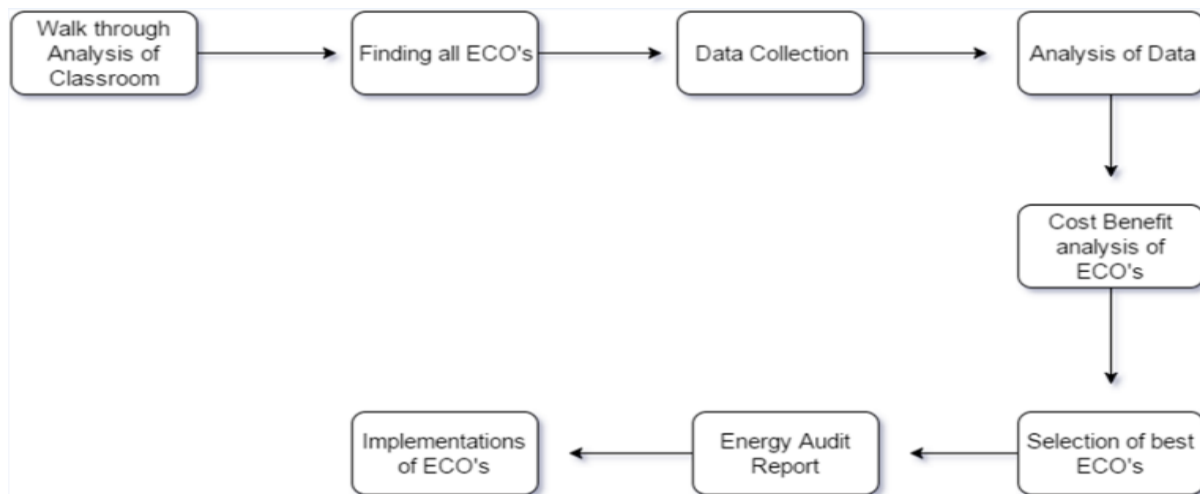
On a basic level energy auditing of a system can be divided into two stages

#### 2.1.1 Walk through Analysis

In walk through analysis a simple audit report is made depending upon the historical data about the building. First characteristics of building and historical energy bills are collected. Then after some observation a list of some obvious energy conservation opportunities is made.

#### 2.1.2 Detailed Energy Audit

Detailed energy audit gives an accurate estimate of overall energy flow and cost. In detailed energy audit a complete survey of the building is performed. Then a breakdown of overall energy consumption is performed. According to this data energy saving potential are identified.



**Fig. 2.1 Procedure of Energy Audit**

Researching several energy audits methods, a number of problems have come into notice. One of main problem lies with the method of calculating total energy cost savings: whether to use the average cost of energy or break the cost down into energy and demand cost parts. Other problems are instances where energy and demand savings associated with specific energy efficiency measures are not fully realized or maybe more research should go into determining the actual savings potential.

### 2.2 Occupancy and Thermal Detection

Home Automation or any other type of automation for a specified location requires an arrangement of sensors to give input and feedback to the system that automates it. Occupancy sensors and detection systems are a preferred choice because they are affordable, scalable and most importantly accurate in their readings [6]. Agarwal et al. has used a switch door in pairing with an infrared motion sensor to monitor occupancy in an office building. However, his work differs due to the type of the wireless networking i.e. ZigBee. IoT applications are also helpful for

controlling different home appliances for example computers, telephones, television and many others that help to improve home and energy management [27].

Smart thermostat is also a popular option available in the market which controls a home's heating and cooling. It is connected to the Internet and can be controlled by other Internet-connected devices e.g. smartphones [7]. These smart thermostats can gradually adjust the schedule, maintaining energy savings and comfort. The Nest Learning Thermostat is a self-learning Wi-Fi-enabled thermostat that optimizes heating and cooling of homes and businesses to conserve energy [8]. The shortcoming of this technology is that it only caters for heating and cooling whereas in this paper, the focus is on integrated network that controls lighting and heating.

Most frequently used sensor for detecting people is PIR, passive infrared sensors. PIR are sensitive to sunlight, therefore to avoid any sunlight pyro electric sensors of high sensitivity are used. PIR detectors have a problem. There are not much more efficient when it comes to detect crawling or slowly moving people. A PIR sensor-based indoor location aware system that estimates the resident's location for location-based intelligent services in the smart home [9]. In order to enhance the location accuracy, it is also necessary to enhance the method of processing the PIR sensors using more advanced techniques such as probabilistic theories and soft computing.

Some comparisons between the occupancy sensors locally available are as follows:

**Table-2.1 Comparison of Various Locally Available Sensor for Motion Detection Module**

	<b>Omron D6T-44L Thermal Sensor</b>	<b>PIR sensor</b>	<b>Ultrasonic sensors</b>	<b>Dual occupancy sensors</b>
<b>Size</b>	14mm x 18mm	20mm x38mm	110x55mm	
<b>Detects</b>	Detects thermal radiation	Detects change in infra-red radiation. cannot detect stationary or slow moving body <sup>1</sup>	Detects the changes in ultrasonic frequency caused by a moving person	
<b>Sensitivity</b>	Highly sensitive	Standard Sensitive	More sensitive, but can perceive noise as data too	Combines PIR and ultrasonic. Reduces false activation chances.
<b>Coverage</b>	Measures the temperature of an entire area contactlessly.	Covers the targets in line of sight	Do not require a direct line of sight. Can detect people behind obstacles.	
<b>Range</b>	5-6 meters	10 meters	15 meters	
<b>Area</b>		300-1000 sq. ft.	275-2000 sq. ft.	2500 sq. ft.
<b>Price</b>	Rs. 5251 <sup>2</sup>	Rs. 500-700 per module piece	Rs. 800	

**Table-2.2 Comparison of Various Locally Available Sensor for Motion Detection Module**

	<b>TMP006 Infrared Thermopile Contactless Temperature Sensor</b>	<b>Infrared Thermometer MLX90614</b>	<b>Murata IRA-E700 Series<sup>4</sup></b>	<b>Futurlec</b>	<b>Panasonic PIR AMN series</b>	<b>Schneider occupancy sensors</b>
<b>Size</b>		13x10mm	4.7x4.7x2.4mm	28x38mm		100x60mm
<b>Range</b>		1m		5-7 m	5m	7m
<b>FOV</b>	180	70 – 90	45 degrees	120	100 degrees	360 – 90
<b>Price</b>	Rs. 400	Rs. 2000	Rs. 400-500	Rs. 500-700	Rs. 2000	21000Rs.

**Table-2.3 Comparison of Omron Thermal Sensor and Pir Sensor for Motion Detection Module**

<b>Omron</b>	<b>PIR</b>
Caters for stationary human presence	Detects only a moving body
Detects temperature too	Does not detect temperature
Divides area into grids. Specifies area where the heated body is located.	No such features.
FOV is limited to 45 degrees	More than 100
Extremely pricey	Affordable
Limited to 5-6 meters.	Up to 10 meters in the forward direction
Unavailable locally	Available locally



Occupancy monitoring is a complicated deal especially for rooms which have large number of occupants (e.g. classrooms), because it heavily affects control strategies and impacts environmental conditions. A number of researches have been done on wireless network systems with algorithms that estimate the number of people in classrooms and develop people counting algorithm which run in real-time. This approach is becoming popular and several monitoring systems have been designed [10] and are already on the market, for instance IBM TRIRIGA R Energy Optimization [11] and Siemens Desigo [12].

Good results can be achieved by video cameras streaming. This process is very reliable in counting task. On the other hand, it requires a lot of computational efforts. People detection is another technique used in crowded most areas. This process is based on using occupancy models. There is another solution that uses ceiling top down view. Cameras can be installed on the ceiling to count number people. Counting people through this method uses a single wide-angle camera. This method uses movements of people.

A novel algorithm to detect the occupancy of mostly static-rooms. It elaborates images, instead of video, to reduce the overhead of computation and network traffic [13]. The algorithm reaches a good accuracy in mostly-static occupancy context. Work has also been done on sensor mobile applications and services. Motion sensors are used to monitor and recognize human activities. Data of these sensors is further used to perform required tasks. Watching TV walking etc. can be easily detected with fairly high accuracy [14]. There is variety of sensors including Bluetooth, Wi-Fi Detectors, and GPS. These sensors enable to implement system with accuracy and providing rich context of information. These sensors can provide information about human status tracking, social net-working, and location based services. All these sensors are available in mobile and mobile battery life puts constraint that how long can these be used. Problem of power management of mobile has been well explored. Survey has been done on how to reduce power consumption of mobile phones. Dynamic frequency voltage scaling is one solution to reduce power [15].

### 2.3 Switching and Wireless Networking

TRIACs and Relays are the most common AC switching devices. A TRIAC is three terminal electronic component that can conduct current in either direction when triggered. [16][17] Whereas most of the relays use an electromagnet to operate switch mechanically [18]. TRIACs and relays have one thing in common, both require small current to get triggered.

A table given below shows comparison of TRIACs with relays:

**Table-2.4 Triacs & Relays Comparison**

TRIACs	Relays
Solid state device	Electromechanical
Silent	Noisy
No mechanical wear out	There are chances of mechanical wear out
Need snubber circuit	Need no snubber

TRIACs were opted over relays for their better Peak Gate Current, Peak Gate Voltage, Peak Gate Power, Storage Temperature, and Operating Junction Temperature. TRIAC BT16 was selected in the end as it had more power rating. It has a high immunity to dv/dt. It minimizes snubber networks protection due to high immunity. It has a high range of temperature it can withstand. It is also safer to use especially in conditions where AC current and high power is used. Wireless networks can easily be used in implementing a monitoring system. A lot of wireless networks are available in the market [19]. For example, wireless data transfer through Wi-Fi module can be used to check energy consumption. Wireless sensors network provides the basic tool for monitoring data. Wireless networks can be implemented using several available technologies. Wireless networks consist mainly of two nodes.

### 2.4 Sensor Nodes

Wireless sensor nodes model used for Monitoring is called W24TH model [20]. This model reduces energy losses during idle state. CPU used in this model is 32-bit Architecture (NXPJN5148).

### 2.5 Camera Nodes

The camera nodes are Android platforms or development platforms with external camera. They communicate with a Wi-Fi module. [21] By connecting “things” in the real world — such as cars, buildings, and industrial equipment Internet of Things (IoT) promises to revolutionize how we live and work. By 2025, organizations that adopt IoT extensively will be at least 10% more profitable than competitors that don't.

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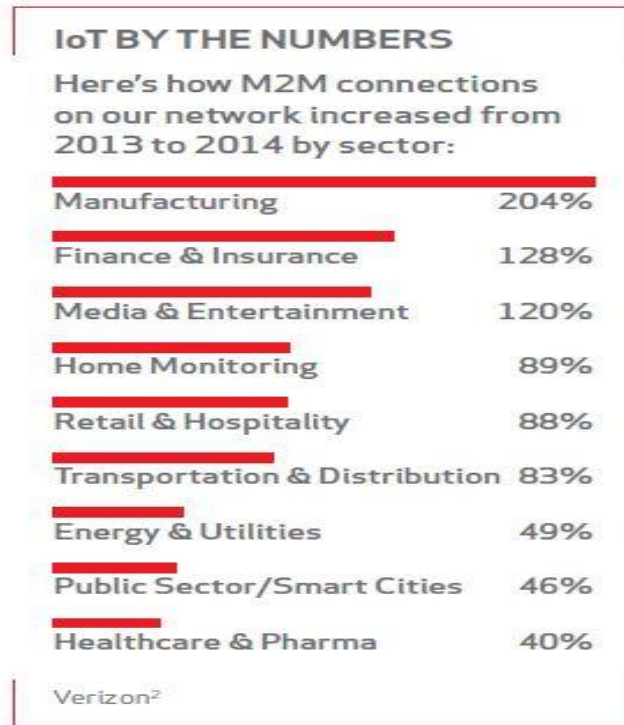
pg. 21

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Table-2.5 IoT Statistics from 2013 - 2014 [13]



In the report the McKinsey Global Institute puts the value of Smart systems in home and offices at the combined valuation of 500 billion dollars by the year 2025 [22].

Home: A wide range of IoT devices and applications are emerging for use in the home, including connected thermostats, smart appliances, and self-guided vacuum cleaners. As these devices evolve, we expect that the greatest economic impact from the Internet of Things in the home will be in chore automation, which we estimate can cut 100 hours of labor per year for the typical household. That could be worth nearly \$135 billion globally in 2025. The next-largest impact would come from energy management (up to \$110 billion per year), followed by security, which would have an impact of more than \$20 billion per year, based on injuries and deaths avoided. In total, we estimate that IoT applications in the home could have an economic impact of \$200 billion to \$350 billion per year in 2025.

### 3. MATERIALS AND METHODOLOGY

The smart system was applied to a conventional class room which acted as an experiment and any sort of changes was compared against another class room with identical conditions which acted as the control group.

#### 3.1 Energy Audit and Data Logging

In energy audit, to calculate the energy usage of light and fans in a classroom, a measure of the total and instantaneous energy usage in a classroom was required. For this purpose, HXE-12 was chosen, which is a single phase meter smart meter. Using this meter, the overall energy usage between any interval and the amount of energy being used by each electrical components of the classroom was monitored accurately. To maintain an accurate record of data, readings of the smart meters HXE-12 were taken each day at a specific time to make a full energy usage report. From these meters, the maximum energy usage of each month and the previous month was also noted. The walk through analysis of the energy auditing included:

Table-3.1 Building's Characteristics And Classroom Construction

<b>Building ID</b>	<b>Mechatronics Department</b>
<b>Date of Audit</b>	13/4/2016
<b>City</b>	Rawalpindi
<b>State/Province</b>	Punjab
<b>Zip/Post</b>	45200
<b>Latitude</b>	33°37'19.56"
<b>Longitude</b>	72°57'35.64"
<b>Year of Construction</b>	1999

Area of the Classroom	49 x 32ft
Height of Classroom	14ft
No of windows	4
Area of a windows	6x6ft
Construction of Walls	6 inch heavy weight concert with 2 inch Insulation
Construction of Roof	6 inch heavy weight concert
Floor No	1st Floor

**Table-3.2 Energy Allocation to End Use**

S. No.	End Use	Appliances
1	Heating	Heaters
2	Cooling	Fans, Air Conditioners
3	Lighting	Tube lights
4	Multimedia	Projector

**Table-3.3 Equipment Wise Analysis of Classroom**

Category	Tube lights	Fans	Projector
Power (W)	46	58	190
No.	10	6	1
hr./day	6	6	6
day/yr.	260	260	260
Total Power (Kwh)	717.6	542.88	296.4

**Table-3.4 Overall Classroom Schedule**

Days	Hours Open	Hours Closed	Peak no. of occupants	Average no. of occupants
Mon	0800-1600	-	45	40
Tue	0800-1600	-	45	40
Wed	0800-1600	-	45	40
Thu	0800-1600	-	45	40
Fri	0800-1600	-	45	40
Sat	-	0000-2400	0	0
Sun	-	0000-2400	0	0

The data of the smart meters was used to conduct a trend analysis of energy usage. The analysis included energy usage changes on different days, the energy being used by different component and which electrical equipment consumed the maximum amount of energy. From all this, the ECOs were deduced for the smart classroom. The ECOs provided the data about which electrical component saves the maximum energy with minimum expenses. Then according to this data, the best solution to save energy usage was finalized.

First a simple report for energy usage of classroom was made. In this report, the energy usage of lights and fans were roughly calculated. The wattage and number of all electrical equipment in the classroom were known, so a rough estimate of energy usage by each component and total energy usage was made easily.

For detailed analysis, many different factors which affects the energy usage of classroom were kept in consideration. For example, to calculate the cooling load the amount of heat is being transfer by sun through the glass is assumed and the number of students in the class is being assumed who affect the cooling load. For heating, the amount of energy being lost through doors and windows is also assumed.

### 3.2 PIR Sensors

To devise a system that could monitor the human presence in a classroom a wide variety of sensors were studied e.g. Passive infrared sensors, thermal sensors etc. The advantages and the disadvantages were studied and compared. In the end Passive Infrared Motion Sensor model HC-SR501 was chosen for its range, its sensitivity and its price. It

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pg. 23

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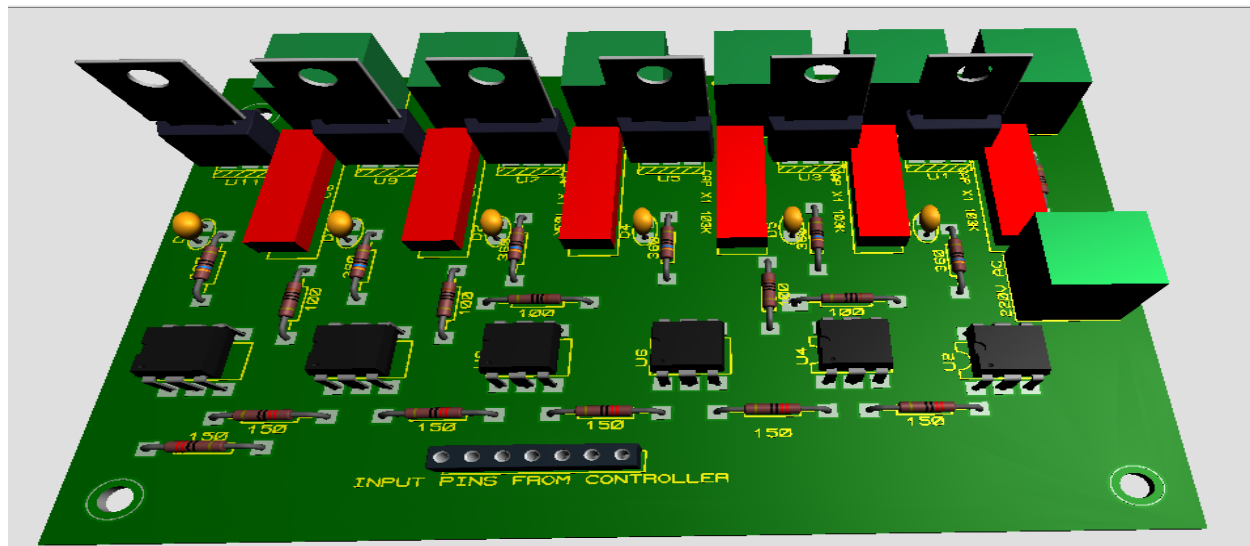
was selected for its function to detect Infrared radiations from the surroundings and produce a high output. In case if no kind of infrared radiation detected, during the time delay, the output stayed low.

### 3.2.1 Algorithm

When a person entered the classroom, entering the focal vision of the sensor, the output from the sensor went high. It remained high even if a second person entered after the first. The output remained high until the no further movement was detected from inside the room. The system was designed into an arrangement of a set of three, each one at an angle of 120 degrees to the next. This technique was the most effective as the FOV of the PIR sensors used was 110 degrees which created an overlapping field of vision and with a blind spot for a few degrees the arrangement covered a 360 angle of area. The system was housed on a plastic dome with the sensors mounted at the 120 degrees-apart arrangement and mounted on the ceiling. The lights installed were grouped together in sections. Each individual sensor gave feedback when a person entered the section being monitored by each sensor. The algorithm was designed in such a way that the group of lights which turn on overhead provide maximum light to the occupant without wasting any energy. The sensor showed a high output for the range of 11 meters which covered the area from the front door to the back door of the class room. To cover the worst-case scenario, only one candidate was asked to sit in various places at different distance on the seats across the room to check the response of the sensor. All results were positive. The next phase after the testing was to integrate the sensor with the electrical switch through the Wi-Fi-module. The high output from the PIR sensor successfully sent a signal to the switching circuit through the Wi-Fi module connected to it which in turn turned the light on.

### 3.3 Switching

Smart switches are implemented in automation so that it turns on and off automatically when required. The switching element used in the circuit was TRIAC. It controlled nine devices that were connected at the output. Opto-couplers were used in the circuit to separate two different types of signals namely AC and DC. When used to control reactive (inductive or capacitive) loads, care must be taken to ensure that the TRIAC turns off correctly at the end of each half-cycle of the AC in the main circuit. Snubber circuit is used with TRIACs to avoid the unnecessary switching. Snubber circuit is simply RC circuit with resistor and capacitor connected in parallel. Turn-ons are caused by internal capacitive currents flowing into the gate as a consequence of a high  $dv/dt$ . Resistor and capacitors are connected in between gate and the terminal the output terminal. It provided low impedance path to output terminal and avoided false triggering. Resistor of snubber circuit helped leakage current draw out of the TRIAC.



**Fig. 3.1 PCB design of Switching Circuits**

The problem faced with the flickering of bulb. Bulb flickered even when there was no gate current. The problem was solved by using capacitor of a very low value in order to increase  $dv/dt$ . Using capacitors of low values removed this problem. 5 volts GPIO will trigger TRIACs in our case. Boards implemented in the classrooms will be replaced by these smart switches. Acrylic sheet casing was used as an enclosing for the circuit.

### 3.4 Wi-Fi Module

The smart switching circuit is already completed and works great. It uses the ESP8266 module which is currently the most advance technology for connecting to a Wi-Fi network. The smart switch contains this chip and can control any electrical appliances connected to it by the switching circuitry which is housed inside the switch. When anything

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pg. 24

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is plugged to this switch it is made available online and can be assigned its nature i.e. fan, light, air conditioner etc. Connecting a number of appliances creates a network of things which is then controlled smartly. Light and temperature sensors are also connected for sensing the conditions of the room or the office. ESP8266 is developed by the Espressif Systems and is currently the industry standard for Wi-Fi modules. In our project we are using it to control the switching circuitry over Wi-Fi. TCP/IP communication is being used for this purpose. The GPIO pins of the ESP8266 module are given tags in HTML and when a tag is accessed, the pin respective to that tag is turned ON or OFF. The module is initiated in Access Point mode and the user connects his/her device to the module. The SSID and the Password of the router to which the module is later connected is entered in this stage. The module is then restarted and it connects to its respective router. This step is performed to ensure that the module only connects to the specific router to which we want it to connect in a setting where multiple routers are present. After connecting with the router, the module is assigned an IP address by its router. To access our tags for switching appliances, we need to know this IP address. As the routers distribute IP addresses to the connecting devices randomly, so this step needs a workaround. We need to ensure that our module always receives a pre-assigned IP address. For this we can use the MAC Address of our module from its configuration file and then setup our router to assign only a specific IP address to device with that MAC address. After confirming that our module always gets assigned the pre-determined IP address, we can use that IP address in our smartphone application or the desktop computers to access the tags of our module. Finally, after connecting the module to the router, we can switch the appliances by accessing tags of IP address of our module. The tag for turning the appliances ON and OFF are different. Since the switching circuit can control nine different appliances, so a total of 18 different tag are assigned to each IP address. For controlling the module through the smartphone application we've made buttons with for each connected electric device. When these buttons are pressed in the app, a redirect request is sent to its respective tag over the Wi-Fi. This turns the device ON or OFF through the smartphone application.

## 4. RESULTS AND CONCLUSIONS

### 4.1 Energy Audit Report

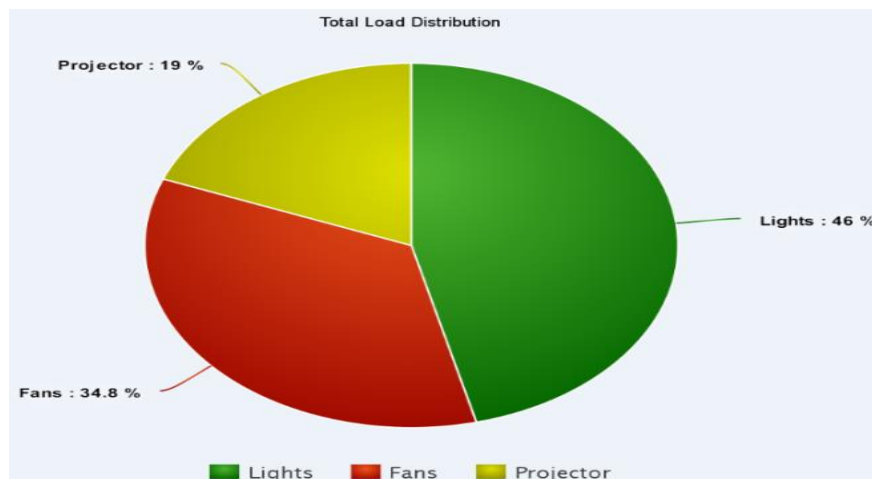
The Energy Audit for the target classroom was completed with a detailed report covering the trend of energy consumption of the classroom, the heating and cooling load, and the recommendation made after the energy analysis report calculations for high consumption.

### 4.2 Equipment Wise Analysis of Classroom

With the help of smart meter HXE-12 we collected the data of energy consumption by each device. Then the annual energy and percentage of energy consumption was calculated [23].

**Table-4.1 Analysis of Classroom**

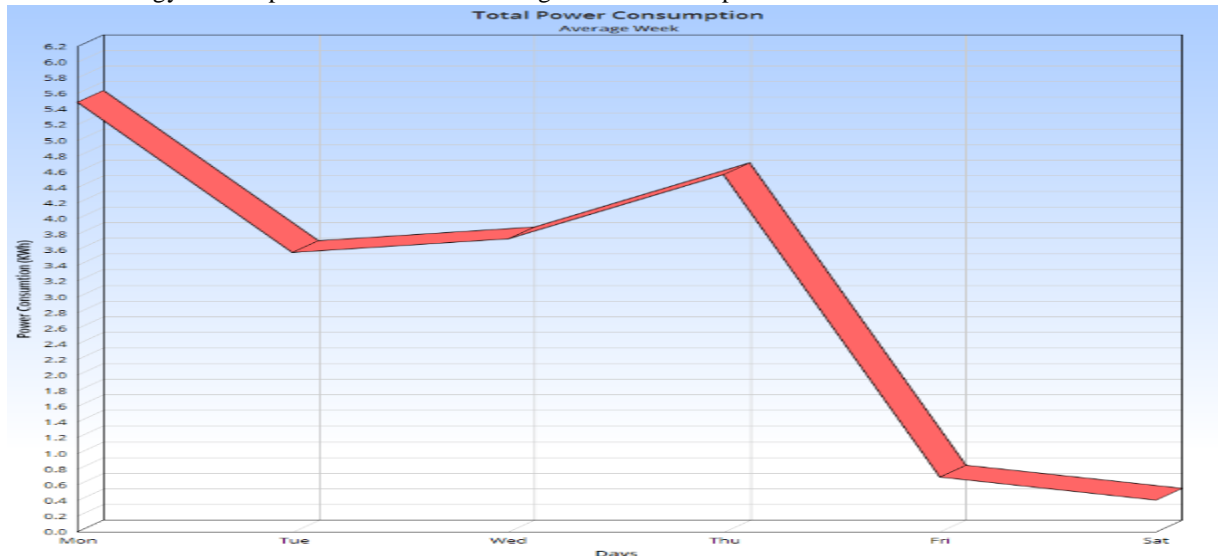
Category	Power (W)	Qty	Hrs/day	Days/yr	Total power (Kwh)
Tube lights	46	10	6	260	717.6
Fans	58	6	6	260	542.88
Projector	190	1	6	260	296.4
Total					1556.88



**Fig. 4.1 Percentage of Energy Usage**

### 4.3 Trend of Energy Consumption

Trend of energy consumption for classroom during the month of April is shown below.



**Fig. 4.2 Trend of Energy usage**

From the analysis of the data collected from hxc-12 meters, it is obvious that energy consumption is lot higher on Monday and Thursday. So it is recommended that schedule of class should be made in such a way that energy consumption is equal on all working days. We can also conclude that almost half of the energy is being used for the lighting of classroom. So it is recommended to use SMD tube lights. This will result in significant reduction of energy usage.

### 4.4 Wi-Fi Networking

To ensure that the control of the switching of the devices of the classroom is not misused, Mac Binding is implemented which ensures the highest level of security. Due to this no third party, can control the circuits or have access to them. The application is accessible to only a few individuals with the Mac Addresses previously approved by the administrator. This prevents any misuse of the system.

## CONCLUSIONS

In this study, we focused on two things. First was the energy auditing; the energy audit of the target classroom was done. This included the heating load and cooling load of the room. Based on the energy audit report, recommendations were made which contributed in optimizing the energy consumption of the classroom. Smart meters were installed to monitor the energy consumption of two classrooms. The readings of the smart meters by the end of the interim proved that smart classrooms were more efficient in using electricity.

Secondly, the classroom was automated to detect human occupancy and integration of the hardware and the software was successful. Also, the smart switchboards were installed in place of the traditional switch circuits as smart switches (part of Internet of things) are able to manage the energy efficiency, due to its low energy consumption and to manage the devices connected to it [25]. The Wi-Fi module created a network of communication for all smart modules installed in the classroom. Lastly, an Android Application was developed which allowed exclusive group of people to monitor energy consumption and control the automation of the classroom.

The Energy Efficient Smart Classroom included smart switchboards which networked via Wi-Fi and were fabricated keeping in mind a functional aesthetic design, an Android Application which is based on a fragmented user design which allows better interfacing, and a technique was used to ensure the Application was exclusive: Mac Binding does not allow intruding devices to acquire the ability take the control of the automation.

The results showed that this approach saved energy in an easier and cheaper way. The prototype was made scalable which makes it easier for it to be implemented in another classroom or the whole building with somewhat similar setup.

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