ENERGY EFFICIENCY AND OPTIMIZATION QUANTIFICATION OF ENERGY CONSUMPTION OF BIM MODEL & SMART BUILDINGS.

FINAL YEAR PROJECT UG 2012

By

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This is to certify that the

Final Year Project Titled

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Has been accepted towards the requirement for
the undergraduate degree.

In

CIVIL ENGINEERING

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ABSTRACT:

The process of emergence, innovation and evolution are the only constants in today's world, hence the study focuses on the methods which improve energy efficiency and provide sustainability. So in this process the concept of computer aided designs or computer software as **BIM (Building Information Modeling)** help through and through by making a 3-d model of a building and then by running energy analysis over it, also we have tried to go a little further to cover one aspect of making human life easy and convenient, by transferring or giving the authority to computers or systems, one such example of it is a **smart system or smart building operations using simulation or simulator.**

Now, the question arises what are Smart Buildings? The answer to this question lies in the fact that the building which are **intelligent** itself are termed as **smart buildings**. Which can **sense** and then **acts** or **reacts** upon the prevailing situations are the characteristics of a smart building, and the basic purpose of Smart Home or building is to have a better **control, management and interaction** between the user and the surroundings.

All the above mentioned things, they happen through the development of properly developed logical channels; through the use of simulation or simulators.

So, after running energy analysis of the building on Green Building Studio (GBS), the results were very impressive as it saves a tremendous amount of energy and making building sustainable, and after that; when we run the Smart Building Simulators which were developed on Simulink and by using the same parameters initially set for the building; the results were astonishing; as they bettered the results of GBS and proved to be more energy efficient and sustainable by using **23.5 %** less energy and hence less energy consumptive.

So it can be concluded that Smart Buildings through the aid of simulation are very beneficial, as it caters the need of the hour as: energy efficiency and sustainability.

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LIST OF ABBREVIATIONS:

- **LED:** Light Emitting Diode.
- **CFL :** Compact Fluorescent Light
- **EU :** European Union
- **IBT :** Internet Based Technology
- **HVAC :** Heating, Ventilating & Cooling
- **BAS :** Building Automated System
- **AI :** Artificial Intelligence
- **BIQ :** Building Intelligence Quotient
- **EU :** European Union
- **LEED :** Leadership in Energy & Environmental Design
- **EA :** Energy Analysis
- **MR :** Mass Ratio
- **BIM :** Building Information Modelling
- **IAQ :** Indoor Air Quality
- **Chvac :** Calculate Heating, Ventilating and Cooling Loads
- **BEMS:** Building Energy Managements Systems
- **XML:** Extensible Markup Language

CHAPTER 1

1. INTRODUCTION:

1.1 General:

The process of emergence, innovation and evolution are the only constants in today's world, hence the world is changing drastically; and all of this is being done for the better performance in general and for better living in particular. Construction industry or construction methods are being modified and improved continuously. These revolutions are being made practical for human ease and convenience. So in this process the concept of computer aided designs or computer software as BIM (Building Information Modeling) help through and through.

Keeping this in mind we tried to cover one aspect of making human life easy and convenient, by transferring or giving the authority to computers or systems, one such example of it is a **smart system or smart building using simulation or simulator.**

1.2 SMART Buildings (simulation):

So, what are Smart Buildings or what make the building Smart? The answer to this question lies in the fact that the building which is **intelligent** itself is a smart building. Which can **sense** and then **acts** or **reacts** upon the prevailing situations are the characteristics of a smart building, basically it provides us a platform where we have interaction between the humans and the technology in a manner that can increase the comfort level of the humans and provide convenience to the people. The following are the integral features of the smart building:

- Sensors (sensors ,actuators, switches)
- Simulations that control the entire process using different software as Simulink.
- Action or Reaction of sensors through properly controlled algorithms, functions and simulations.
- Interaction between the user and the technology (BIM modelling)

What do they really do? Basically they are artificially intelligent; which means that they are responsive to inhabitant's actions and make attempts to maximize their comfort by monitoring the environment and prediction of the future occurrence of events and to record such events by the use of a properly developed algorithms, functions and networks and act accordingly with better response while dealing with.

For example: The Air quality and temperature outside or even side the building is sensed and then it can be set or maintained at a certain level in the inside of the building, likewise Lighting is another application which can be controlled and monitored, (HVAC), video surveillance, security and numerous other things can be controlled and monitored by it.

The basic purpose of Smart buildings simulations are to achieve the following:

- **Control**
- **Management**
- **Interaction**

Through the use of different components of a smart building which are hardware, software and a network that can ease out the humans in the best possible manner.

1.3 Global Energy Crisis:

Why do we need smart buildings? During the last years, many researchers focused on the load and demand management because of the depletion of resources and increasing enthalpy. The total energy used in buildings is 32% of the entire energy consumption in the world; In terms of basic energy consumption, buildings accounts for almost 40% in most IEA (International Energy Agency) Countries. Secondly to meet the energy performance and load management is a key issue to achieve the EU Climate and Energy Objectives as the main objectives are to reduce the greenhouse gasses emissions by 20% till the end 2020 as well as 20% energy savings, so in that respect smart building would be very beneficial.

a. Pakistan's Scenario

As far as Pakistan's is concerned its energy crisis are known to all of us, so in this time of need we really need to be thinking on ways to minimize our energy consumption and on sustainable energy development. As our energy resources are on the depleting side and the demand is on the up or rise; where our electricity demand is of almost **22,500 MW** and production is only **15000 MW.** So in this regard we'll have to make our existing energy consuming sources to become sustainable and energy efficient.

Following pie chart will explain to you the electricity production by different sources.

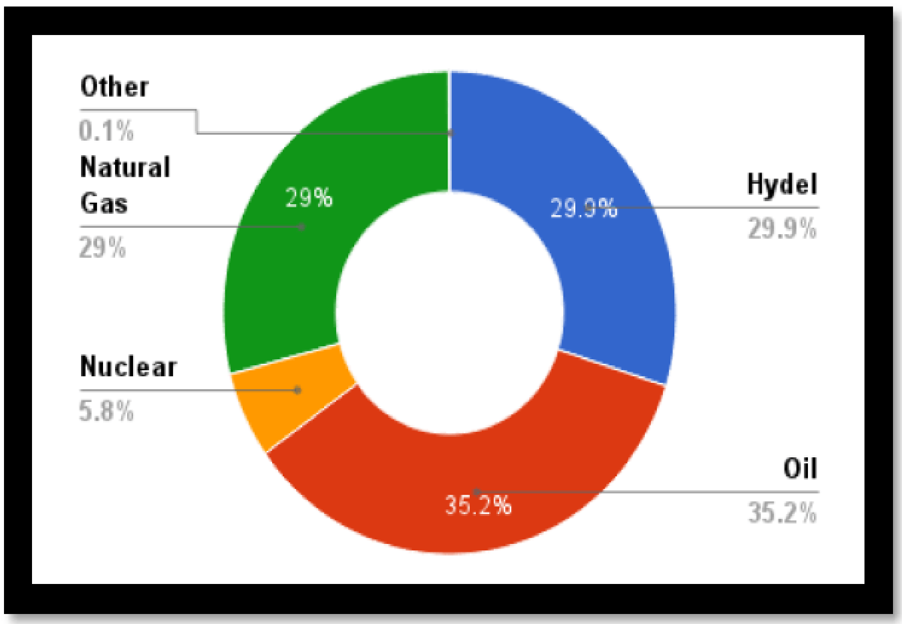


Figure 1: Pakistan's Electricity Generation by Source[7]

Knowing our resources are depleting; so we should be looking for some alternatives by which we can save us and make our world sustainable and energy efficient. One such method is done by making our homes SMART, using simulations or through the aid of specially designed programs, installing special features and making our design sound.

Though; here we'll be restricting ourselves to the use of simulation on our smart system or smart home, hence making it the basis of our thesis, or better say it an objective of our project.

1.4 Objectives:

- The first objective is the development of a 3-D model, through 3D modeling softwares, as (BIM); it is an information source for the geometry, space linkages, quantities and parameters of the entire building and its components, allowing professionals to work on the same platform. BIM is also a platform to provide data for the user.. It is how BIM is used that demonstrates its value as a smart building tool, as it will give us results of its energy consumption and then these results will be compared to other results which are computed using SMART simulators(mat lab's extension: Simulink) as in our case.

- The second objective is the initially the conversion of our house model to a SMART model using mat lab and its extension, (Simulink).
- The next objective is the calculation of Heating Load through Elite HVAC.
- The next objective is to create a model, basically for heating and cooling in specific and catering all the energy consuming aspects in general.
- The development of FUZZY logic, also known as artificial intelligence, which means the machine or automated /automatic systems get to predict the operations or actions of it ,by knowing the habits, sensing and then accordingly performing on it, is our next objective.
- The comparison among the basic energy analysis is done by BIM, and energy analysis done by our own made simulator and the actual energy consumption bills.

Hoping the results of our own made simulator will outclass the results of the BIM model and actual energy consumption of our simple home.

Keeping in mind the development of an industrial solution which will cater the needs of modern construction technology and uphold the concept of going green and sustainability.

For achieving our goal, we will be needing to get to know about the following tools and technologies of smart buildings.

- Sensors and the internet of things (IOT)
- Smart meters and smart grids
- Building information modelling (BIMS)
- Building Energy Management System (BEMS)
- Elite HVAC (Energy Load Analysis)
- Matlab's and its Extension (Simulink).

Following is the block diagram of how a simulator works in smart system.

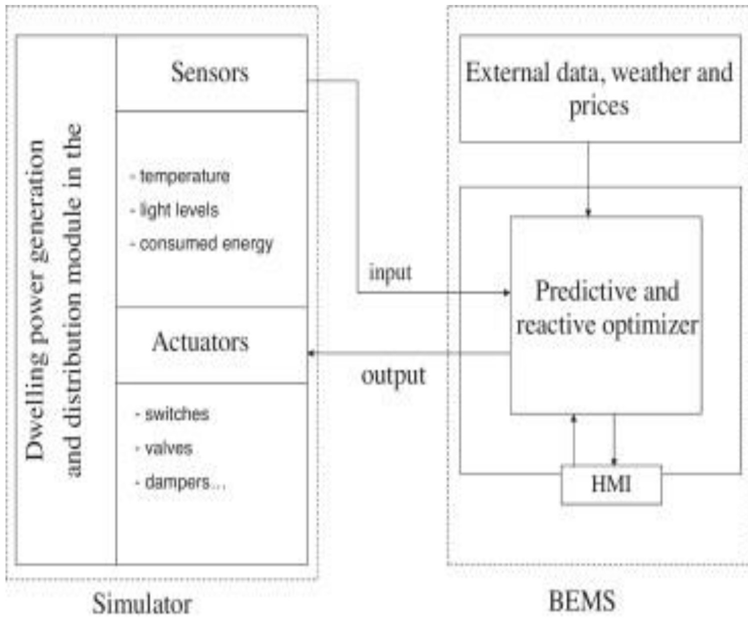


Figure 2- Simulator Working Mechanism.

1.5 <u>Scope:</u>

- 3-d model development and its energy analysis using BIM (Revit).
- Energy Optimization & efficiency of a Smart System.
- Air Conditioner Energy saving Model.
- Room Heater Energy Saving Model.
- Artificial Intelligence concept
- Energy consumption analysis of the above mentioned techniques and of a non-smart home.

1.6 Softwares:

Following is the list of softwares that we have used over the time to complete our project.

- Building Information Modeling (BIM-Revit.)
- Elite HVAC
- Mat lab
- Simulink

The purpose and details of each of the above mentioned software will be provided in the following sections.

CHAPTER 2

2. LITERATURE REVIEW:

2.1 Introduction to Study:

A building in which technology and operations are being used in parallel, for the development of the facility that is productive, in which safety, health, comfort of its inhabitants are of paramount importance is called intelligent or smart building. As all of us know the energy crisis that is going around in the world; so it is now the responsibility of the architects, engineers and the construction managers to develop or make a facility which is efficient in energy and proactive as far as its functions and use are concerned. By applying the technologies that are being used in intelligent buildings, they will not only improve the internal environment and functionality for the inhabitants but also reduce the operational cost. A smart building do have an essential logic that changes with user behaviors or requirements, promising better and improved living with optimizing the control and cost. It also shows the key characteristics of efficiency, sustainability for the benefit of our generation and generations to come.

So now we can easily say that the idea of smart building or intelligent building is the modern

The idea of the Smart Building is the up-to-date solution or innovation of civil engineering for countering the deficiencies of today's world. A smart or intelligent building should cater the needs of the users by varying the environment around and that best suits them. It should also provide numerous ways for communication and efficiency in handling the operations for overall efficiency and betterment.

Benefits of a Smart Buildings are following.

- Shorten preparation period.
- Less connection/fixing stints.
- Enhanced luxury & energy and productivity.
- Better And improved security and safety of the people, records and construction activities
- Less operations and maintenance cost.
- Improved dependability on technical arrangement.
- Better protection of investment throughout the building's life span.

Following are the Factors that play an important role in making building **Energy Efficient** and **Sustainable.**

Construction Development	Environmental Development
▪ Obtaining local construction material.	▪ Optimal use of Day Light.
▪ Efficiently water usage.	▪ Managing best Air Quality.
▪ Landscaping is done efficiently.	▪ Install Air handling components
▪ Materials: Ash bricks, glass and aluminum usage.	▪ Use of LED, CFL lighting.

Table: 1 Comparison b/w C.D & E.D

Managing Water	Managing Waste
▪ Harvested rain water use.	▪ Strategies should be developed for solid waste control.
▪ Use of Re-cycled and treated water for minimal dispose of water.	▪ Entrance Safety: prevention of dust and other external elements from getting into the building.
▪ Water efficient plumbing equipment and fittings.	▪ Grey water use and its handling.
	▪ Non-bio degradable waste should be separated and dealt accordingly.

Table: 2 Comparison b/w C.D & E.D

Smart Building Characteristics	Integrated Building Administration
▪ Energy Efficient Building Services.	▪ Managing Energy
▪ Managing Information.	▪ Monitoring Alarm
▪ Automated Building Systems.	▪ HVAC arrangements
▪ Integrated systems.	▪ Lift management.
▪ Managing Facility.	▪ Control for lighting
▪ Wiring for network design and communication	
▪ IBT & design.	

Table: 3 Comparison b/w C.D & E.D

2.2The Distinctive Features of a Smart Building:

Normally smart buildings are considered to be an automated building; because of the fact that many commercial or money making products are being offered with a remote control device to control a system from remote destination, keeping in mind that there is no intelligence involved in it, and this is what we call automation in a true sense but as far as smart home or building is concerned; they should be called adaptive, intelligent home. Etc.

a) Salient Features:

It responds to its inmate's actions and then making attempt to maximize their luxury or comfort by observing the environment and predicting the occurrence of similar events in the future, all this is done by recording the events and then through the use of AI it tries to act according to the requirement of the user in a much better way.

b) Mechanism:

In dealing with variations or changes Smart building or I would better say Smart system greatly minimize the energy requirements and are fully able to produce maximum results in any circumstance, they even capable enough to warn you in the case of any equipment or sensor malfunction or even when they become faulty, indicating that they need repair. As air quality and temperature is maintained throughout the building environment and if something goes wrong anywhere in the building as far as equipment is concerned; it simply notifies you.

Components/gears of a Smart System include:

- Hardware.
- Software
- Internet of Things IOT (network system.)

The integration of all the above mentioned things make building or home act as a single unit, so in order to choose the best Smart system one should select certain standards to measure the capability of the system normally called quantitative analysis and this whole process is known as Building Intelligence Quotient (BIQ). Numerous parameters are involved in its calculation, some of them includes the subsection of all the measured or observed standards or parameters. For example: Set of all the circumstances that induce changes in the building parameters etc. Normally it is not easy to calculate the BIQ value for a specific building because the provision of the data we need as an input is the biggest challenge to overcome. On the other hand the accuracy is dependent on the AI of a system which in turn gives or provides you better efficiency.

(Eugeny I. Batov, Elsevier B.V.)

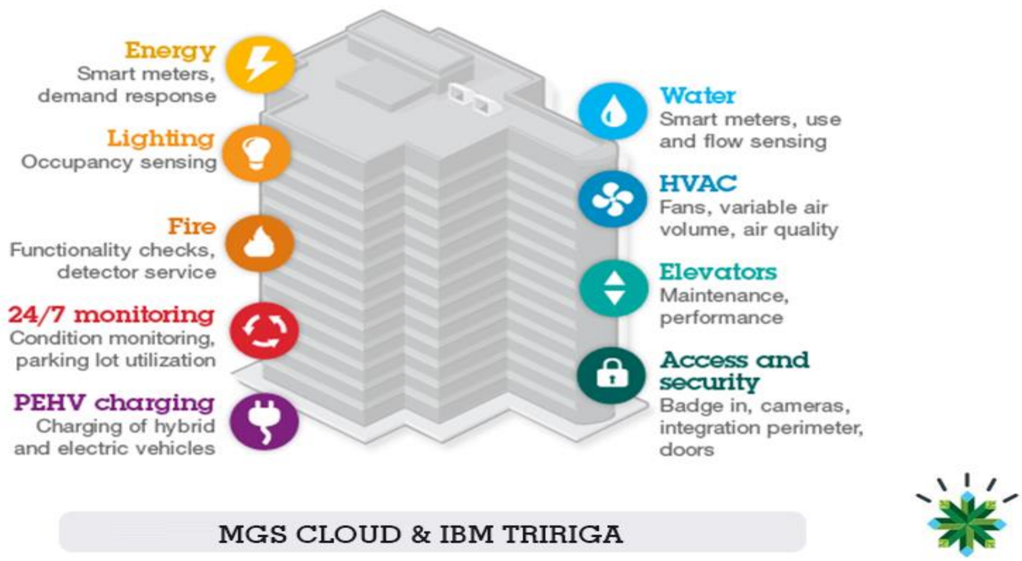


Figure-3 Smart Building Features

2.3 Energy intelligent buildings based on user activity: (A survey)

Basically a survey is done on the study of Building energy and comfort management, covers on Personal activity basis. Intelligent building institute and European intelligent building group gives two separate definitions which focuses on owner benefits and user needs, therefore different modules of smart buildings are listed. Green buildings are environmentally sustainable as well as utilizing balanced resources, services and comforts for different sectors. Survey for different energy consumption rates is taken to compare offices and retail. Portability, behavior and energy usage are the features of inclusion criteria of systems. Survey calculations of plug loads, lights and HVAC and performed on the basis of residential, office, retail and other sectors. Generally various variables of buildings are used in calculating the power saving potential of buildings. Sensors equipped with wireless technology working well to reduce energy wastage to maximum extent. Users have different preferences for lightning usage in different sectors.

(Tuan Anh Nguyen, 5 Sep, 2015)

2.4 3I Buildings: Intelligent, Interactive and Immersive Buildings:

Basically this paper tells us about the above mentioned three key factors of a smart building: This papers tells us about the 3i that are intelligence, interactive and immersive buildings, basically in it a 3d bim model is developed with the help of 3d unity game developing tool and then optimizing algorithms are made (**sensors, actuators, switches, cameras)** and incorporated in the model using servers and LAN which control the thermal comfort and energy consumption,co2 and cov count, space count, user satisfaction level, humidity level, occupancy level, security check and etc. BIM model is very important as it is performs **3 functions: Management, Control, Interaction (user interaction.)**

(António Aguiar Costaa and co, CCC 2015)

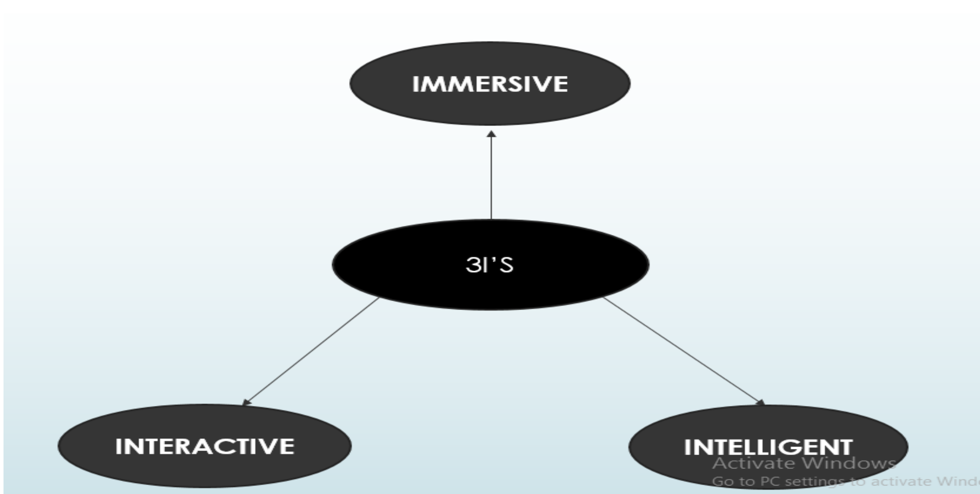


Figure-4 3i's Concept

2.5 Improving energy efficiency via smart building energy management systems: A comparison with policy measures.

The paper is basically a comparison between smart bems using smart grid and regular bems, in this paper mathematical model is developed which is out of scope for us, but a comparison is made and the conclusion is, as smart bems uses **dynamic temperature set point** which enables it perform better in respect of energy efficiency and co2 emission than the simple bem. Numerical and experiments were also performed for buildings in EU, and the results for smart bems are better than the simple bem, hence it should be adopted. As it is more acceptable to environment or climatic conditions hence energy consumption is there. Smart bems also acknowledge the policy measure for energy efficiency.

(Afzal Siddiqui, 2015)

2.6 Indoor air quality and energy management through real-time sensing in commercial buildings:

Energy can be consumed by ventilation when the desirable indoor temperature is equal or lower than the outdoor temperature. Ventilation can help energy consumption of HVAC system of building but at the same time ventilation can deteriorate the indoor environment by letting pollutants like CO, CO2 and NOx etc. which can be harmful for the consumers. Therefore, efficient building energy management system can help in sustaining a desirable level of environment and reducing consumption of energy. Sensors are available to monitor both indoor and outdoor environment but the accuracy in case of nanoparticles which can be more harmful to health is questionable. Progress has occurred in lowering the prices of sensors which is an achievement and can be used in BEMS and can be helpful in conserving energy and preserving environment.

(Prashant Kumara and co, 2015)

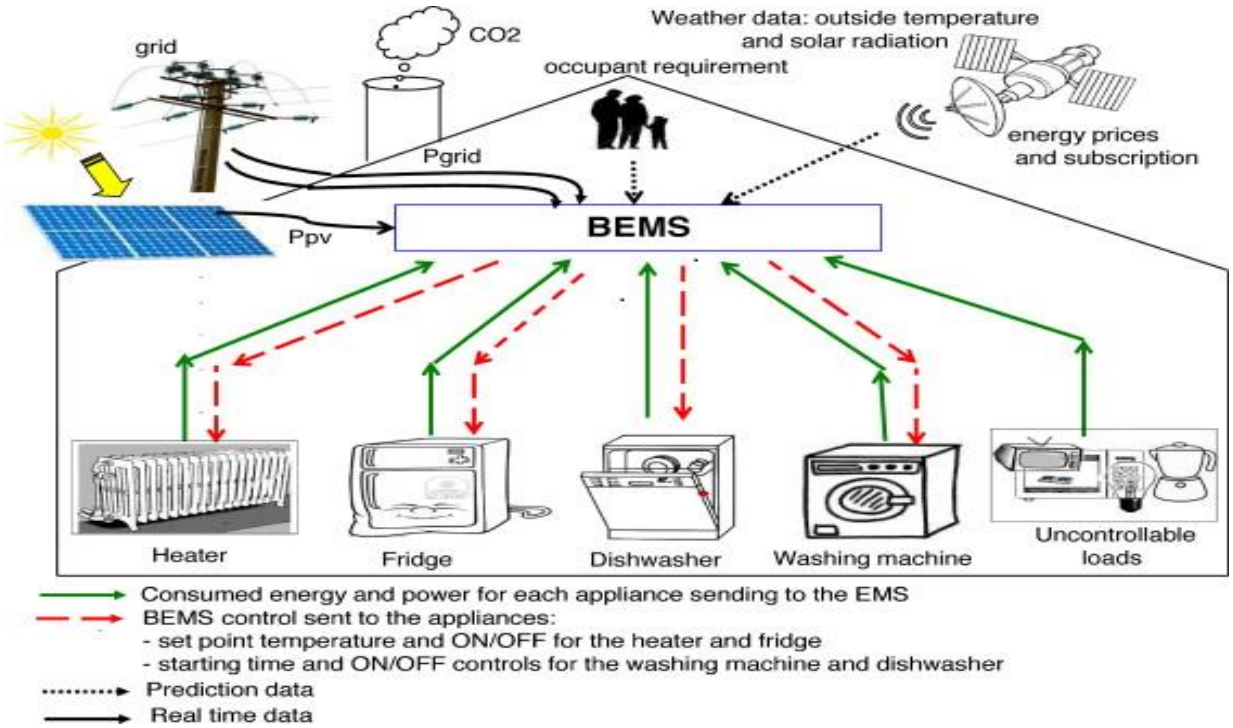


Figure-5 BEMS

2.7 Simulation of building operations for calculating Building intelligence quotient:

A building intelligence quotient formula is formulated to judge the smart buildings intelligence level. Buildings having same functionalities have generally equivalent intelligence potentials. Dynamic modeling is done reproduce the environmental and geometrical features of building. User's activities section includes mobilization of users and simulate inner and outer environment. Simulation is conducted after modeling process in which sensors transmit information to artificial intelligence. All the results concluded in such a process generates inputs of building intelligence quotient formula. It is impossible to get BIQ inputs through analysis.

(Eugeny I. Batova, 2015)

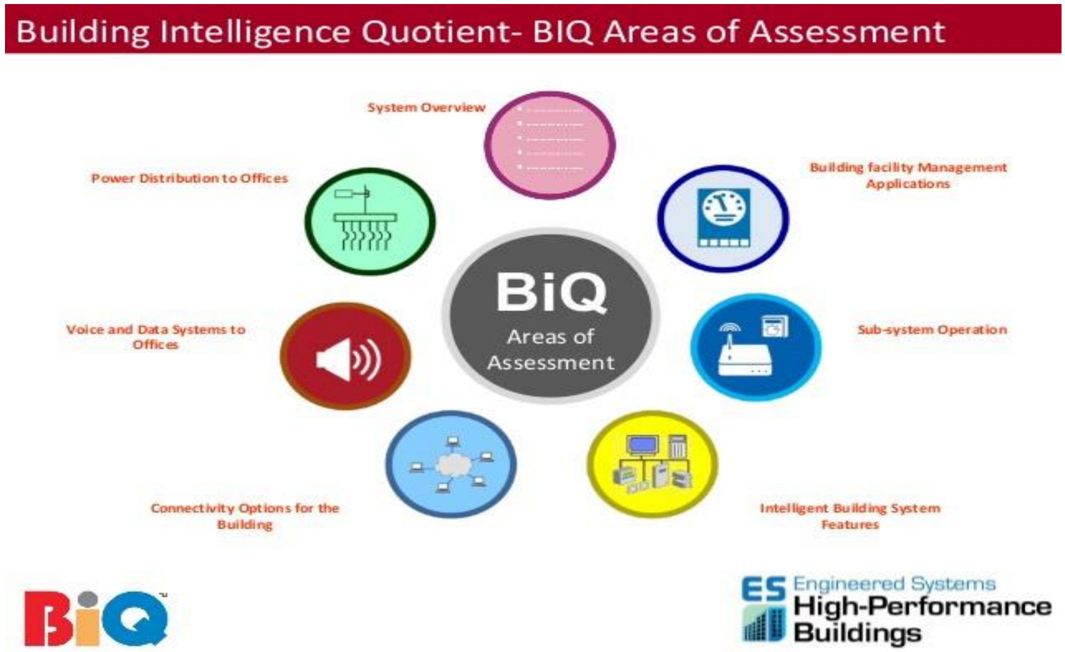


Figure-6 Building Intelligence Quotient

2.8 Intelligent Optimized Control System for Energy and Comfort Management in Efficient and Sustainable Buildings:

The **power optimization** and **comfortable environment** are the two highlighted parameters, which are under the context of smart buildings. Introduction of Multi objective genetic algorithm optimizes through the control system of buildings by ensuring effective energy transmission for various desired comfort preferences. User comfort and energy consumption is a major challenge in the indoor environment. The fuzzy control calculates the power that is actually needed. Different type of graphs describes fuzzy input and output functions. A genetic algorithm performance based on probabilistic approaches using Genetic operations. Pareto optimal graph describes the reverse relationship between energy consumption and comfort level. The user needs pay a major key role in acquiring the desired comfort level.

(Pervez Hameed Shaikh, 2013)

2.9 The Smart Factory: Exploring Adaptive and Flexible Manufacturing Solutions:

The term "smart" can be used in many ways on the performance basis. It may be either a single device or it increase other features implementation. In addition "smart" is also utilized in homes as a higher level of automation. Sustainable manufacturing technologies should be combined with universal technology which in turn enhance the compatibility of emerging technologies, which are the part of study now a days. Another perspective is introduction of innovative ideas in the industrial technology which replace old machinery handling methods and assisted by wireless communication protocols. The terminology Globalized factories refers to centralization of industrial resources which develop self-sufficiency smart factory uses modular platforms which assists companies through flexibility and cost effectiveness. Actually, smart factory is a dynamic phenomenon, which contains automated controls and link industrial and non-industrial features by balancing excessive labor and fewer resources. The vision of smart factories is also applicable in small companies having medium to small enterprises, which caters issues through automation.

(Agnieska radziwon, 2014)

2.10 Dynamic extension of Building Information Model for "smart" buildings:

Role proposed for extension of a static BIM model to advanced dynamic model due to the fact that it was not capable of interpretation and simulation of real-time scenarios during design and operation life of a smart building, because inputs to static model were mainly done manually by applying engineering techniques. The need for a BIQ (building intelligence quotient) as a quantitative measure to mark the best smart buildings with suitable characteristics under given circumstances. Benefits of DM(Dynamic model) to stakeholders such as software developers its use to judge functional(probability of correct and incorrect decisions) and non-functional(performance criteria) aspects of a smart building, designers to choose the best design solution by the aid of BIQ,FM's as they wish to acquire real-time processes for managerial and monitoring perspectives to help deliver better services during the life cycle of smart buildings ,updating of codes and standards are done by analyzing performance on buildings as time passes by because the model acts as a link between the codes followed and its real life performance and to check the credibility of the already present standards. To achieve the objective the dynamic model is retrofitted with topology and geometrical parameters of a building unit under consideration along with scenarios about the environmental changes to achieve simulation of building processes. Dynamic model aided with sensory information makes it up-to-date and capable of generating real-time-monitoring. For incoming and delivery of messages a device known as message broker is used. Large hard drives known as storage devices are used to record trends in performance of the model in regard to environment changes and they can also be used as scenarios for developing other such models in the future.

(Andrey A. Volkova & co)

2.11 Building Information Modelling for Smart Built Environments:

Through 3D computer modelling, BIM is an information repository for the geometry, spatial relationships, quantities and properties of the whole building and its components, allowing architects, engineers and designers to work on the same platform. BIM is also a platform to provide data for the user. It is a way of looking at a building as a system, a method that has been used in manufacturing for decades where interoperability of elements allows for adaptability in processes. It is how BIM is used that demonstrates its value as a smart building tool. Data from sensors can also be analyzed as part of post-occupancy evaluations to inform the design of subsequent buildings and systems. Such information may ultimately be incorporated into 'real-time Building Information Modelling (BIM)', enabling live data to be held in the data structures used to describe building design.

(Jianchao Zhang, 2015)

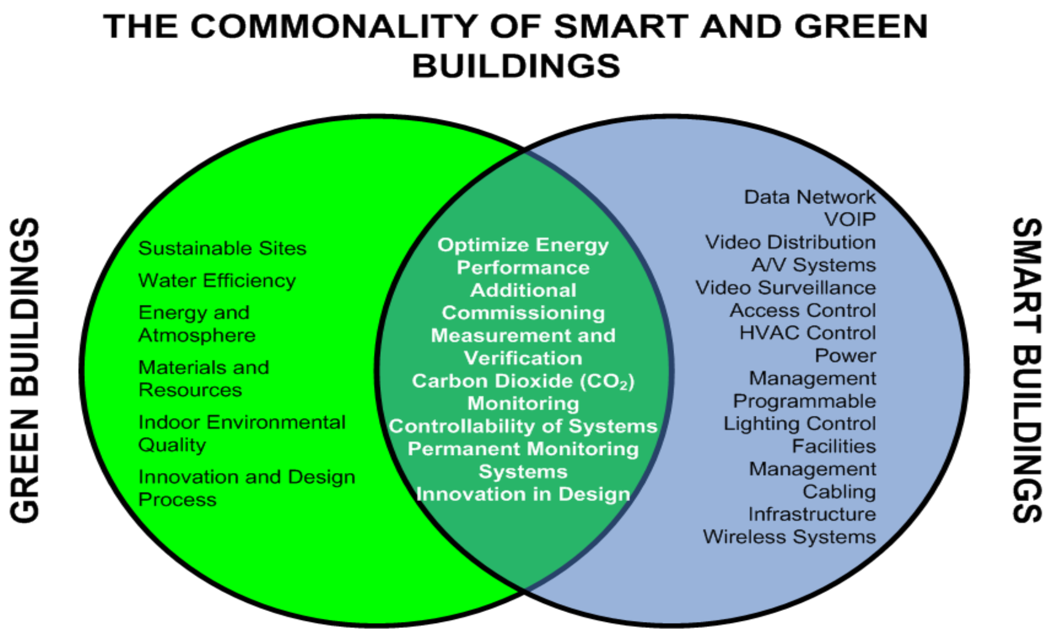


Figure-7 Common Features of a Smart Home and Green Building

2.12 Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings:

Basically it tells us about combining BIM and LEED to make building green, authors elaborate different green building certification but at the same time ranking LEED at the top. BIM is a very versatile software used for analysis, quantity take-offs etc. of a building. It integration with LEED will help to analyze the EA AND MR of the building specifically and all other generally, the model developed is basically a frame work of BIM and LEED combined to analyze and for the rating of the building is done simultaneously. Concept of soft cost is also briefly introduced in it.

(Farzad Jalaei, June, 2015)

2.13 Energy and environmental benefits in public buildings as a result of retrofit actions:

Impacts of retrofitting actions on selected case studies published in the framework of EU Project considering life cycle studies of the retrofitted structures. Study reveals the fact that energy consumption for the buildings in the EU is almost 40% of the total energy demand, besides contributing 40-50% to the output of greenhouse gases, therefore the need arises to work for energy efficient design and sustainability of the existing units.

Past energy and environmental studies on operational phase of buildings are not complete and often misleading and other life cycle phases such as manufacturing of construction materials, production and dismantling of building components are ignored. Numerous attempts to minimize the energy usage during building operation(minimized air leakage, and heat recovery from the) are made but are unsatisfactory to provide good results because they result in lower space heating demand but increases material usage and production energy demand. The six case studies involved are public buildings which are discussed namely.

OLD CITY BREWERY, BRNO (total floor area after the intervention: 2660 m2) retrofitted by new thermal insulation of the surfaces, high-efficiency windows, HVAC systems, condensing gas boilers, and photovoltaic (PV) panels.

Result: primary energy saving of 486 MJ/ (m2 year)

Hol Church, Gol (total floor area after the intervention: 555 m2) . The actions involved replacing rotted timber, installing Rockwool insulation, advanced solar assisted heating systems.

Result: primary energy saving of 443 MJ/ (m2 year)

Plymouth College (total floor area after the intervention: 5794 m2).The retrofitted action was performed by introducing a cavity wall, single glazed windows leading to an overall low values of insulation and installing two wind turbines(with a nominal power of 6 kW each) on the roof of the building that was 21 meter above ground level.

Result: primary energy saving of 24.6 MJ/ (m2 year).

Provehallen, Copenhagen (total floor area after the intervention: 2300 m2).The retrofitting was carried out by a demand controlled natural and mechanical ventilation system. Photo Voltaic (PV) solar collector cooled by a heat pump to increase performance were installed. The site was an old industrial area that was completely reshaped and turned into a modern low energy and multifunctional cultural center.

Result: primary energy saving of 28 MJ/ (m2 year)

Nursing Home, Stuttgart (total floor area after the intervention: 2131 m2).The heating system had an old measurement control system. The retrofit project included many renovation actions, including energy retrofit of structural components, wall insulation with mineral-fiber wool, substitution of old facades with high performance windows, thermal spacers and installation of high performance heating and ventilation systems. Furthermore, a thermal solar plant was installed to provide 32% of the domestic hot water demand. Moreover a PV system with a yearly production of 12.6 kWh/y was used.

RESULT: primary energy saving of 163.6 MJ/ (m2 year)

VGTU main building, Vilnius (total floor area after the intervention: 8484 m2).The retrofitting of the VGTU case study mainly includes renovating old facades and the roof, substituting old wall insulation with higher thermal performance materials, installing highly efficient windows with selective glasses and low thermal conductance, replacing the old heating and ventilation systems with fully automatic ones.

RESULT: primary energy saving of 241 MJ/ (m2 year)

questionnaires provided to the members/participants in order to obtain useful information of the design as well as the applying stage of the retrofit actions. The required information to be filled by the participants include matters such as:

I. innovative and traditional system for heating

II. Photovoltaic (PV) components

III. Ventilation mechanism and systems involved

IV. Ducts and pipes

V. Building materials used for retrofitting function

VI. Production of waste

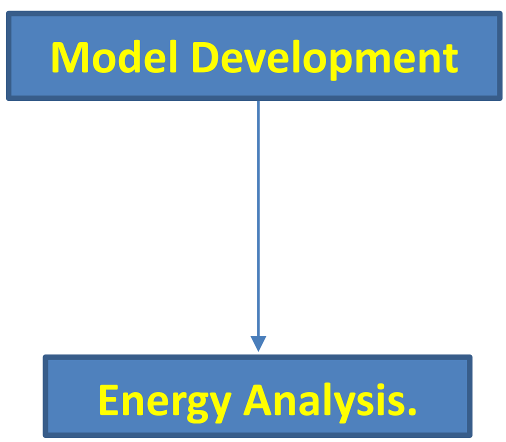
(Fulvio Ardente and co.)

CHAPTER 3

3. METHODOLOGY:

Basically the project is about the quantification of Energy Consumptions of the **REVIT Model and SMART Buildings.** So we started off with the development of 3d-model of a building in Lahore, after that we performed energy analysis over it using **Green Building Studio (GBS),** this was the 1st phase of the methodology, 2nd phase was the development of the Smart Building Simulator; in which we basically **calculated the Building Tonnage** through **ELITE-HVAC** and then development of Smart Building Simulator using the same parameters that were used to perform the Energy Analysis of the building.

3.1 1st Phase:



a) BIM

BIM is the latest technique introduced in construction industry. As a professional involved in construction industry, one must know about the latest techniques and modern innovations beings used in his field. BIM is being adopted in construction industry in developed industries; even UK is going to make it compulsory to use BIM in every project by 2016. So, one going to construction industry must have adequate information about the newest practices and learn to use them. Using BIM in local industry can cause revolution in construction industry as people are worried about their money and design of project. BIM offers them the best solution with its vast area of application that leads to even 7D. By different studies in different projects by professionals it has been seen that BIM has a great hand in reducing costs of the project. One should be familiar with it as it can benefit the people whose stakes are involved. Hence, by looking at its exponential growth, we decided to select BIM as research area.

b) Uses of BIM:

- **Visualization**

In-house 3D renderings can be easily generated with little additional effort.

- **Fabrication/Shop Drawings**

Shop drawings can be easily generated for various building systems, e.g. once the model is complete the sheet metal ductwork shop drawing can be produced quickly.

- **Code Reviews**

For building projects review fire extinguishers and other officials may use these models.

Forensic Analysis

To show graphically the potential failures, leaks, evacuation plans, etc. a building information model can be used.

- **Facilities Management**

BIM can be used by facilities management departments for remodeling, planning of space, and operations of maintenance

- **Cost Estimating**

BIM software(s) have built-in cost estimating features. Material quantities can be easily extracted and changes when any alterations are made in the model.

- **Construction Sequencing**

To create material ordering, fabrication, and delivery schedules for all building components a building information model can be used effectively

- **Conflict and Collision Detection**

BIM models are created, to scale, in 3D space, all major systems can be visually checked for interferences.

c) Benefits of BIM:

BIM covers a vast area. Its advantages are numerous. It has certain limitations as well. But with time, it is being improved for better project delivery. BIM offers a lot assistance to AEC industry. Here, we will restrain ourselves to those aspects which we will adhere the benefits performed through our project.

- **Better visualization of project:**

BIM develops 3D model directly, rather than many 2D views. Hence, it is very effective in being consistent in every view. It can be analyzed at any stage of the project providing accuracy.

- **2D Drawings of any section of the design:**

2D drawings are generated any time required. This removes a lot of errors as it can create these 2D drawings for every design aspect. Comparing these drawings with specification removes a lot of ambiguity.

- **Cost Estimation:**

Cost estimation with is more clear and accurate. Like 2D drawings, cost can be extracted at any stage of the design phase or building phase. The benefit with BIM is that every stake holder involved in the project is kept update about the cost implications related to the project.

- **Emission of errors prior to construction:**

A construction project is a vast project. Different field personals are working in collaboration to complete a project. BIM provides models for all disciplines in time, which can be analyzed and compared to check their consistency. Conflicting points and other problems are easily detected prior to construction and removed.

- **Energy Analysis:**

BIM provides energy analysis over 3D design of the project. It can be carried out more accurately with a 3D design rather than 2D. Changes can be suggested in the early phase. However, carrying out the same work with 2D views takes a lot of time, and is performed at the end which is only a formality.

- **Sustainability:** BIM offers better sustainability options. Various types of analysis tools help generate better alternatives regarding sustainability. It gives a lot of options for choosing different types of results after analysis. These tools create a better and efficient building which is environment friendly and sustainable.

d) BIM and Energy Efficiency:

Building information modeling (BIM) is an integrated process for generating a project's important structural and architectural parts digitally even prior to its construction. The dependable, synchronized data used throughout the BIM process assists engineers, architects, owners and contractors to see, prior to physical building structure, that what design features will the project possess and more significantly, performance characteristics of building. When used on present buildings, we can create the basic model using given information of previously built building using various BIM based modelling software i.e. REVIT and used that model for gathering necessary information needed to conduct energy performance analysis of any existing building. Those BIM based energy performance results can aid us in improving the existing facility and make that building more energy efficient.

With a building information modeling (BIM) concept, any AEC firm can use BIM based energy analysis software to perform analysis on their designs and create different alternatives for greater energy efficiency. Using BIM based results design professionals can quickly and easily provide various alternatives to the clients. Those results include suggestions to improve energy efficiency of the facility and can also provide the conceptual data of energy usage by the building over its whole life cycle. With the simple energy models, design professionals can give the clients different design alternatives, based on cost benefit analysis owners can then choose the suitable design based on their budget and future savings values, hence creating the long lasting and sustainable buildings.

Conducting analyses on the design model is critical; in fact, some studies show that when a design team uses whole building energy analysis, they can save an average of 20 percent on energy use. For retrofit projects, the potential for energy savings is even greater because older buildings tend not to have had any tenant or system improvements over the years. This creates an opportunity for greater reductions in energy consumption—reductions that can be calculated using whole building energy analysis as part of the BIM process.

3.2 METHODOLOGY:

In this section, we are going to discuss that how we are going to carry out our task that is assigned to us.

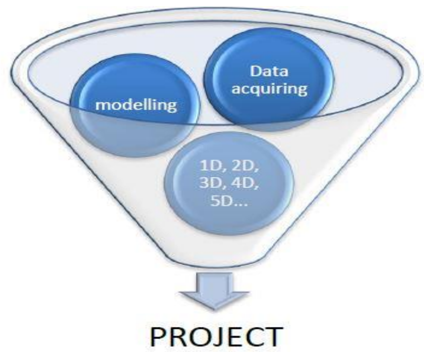


Figure-8 BIM & Revit Modelling.

The following flow chart gives a brief overview of the methodology adopted for the conduction of the project. Each phase of the flow chart has been described in the following lines:

Figure-9 Project's Life

3.3 Software Learning:

Since, the modeling work required use of parametric software which are relatively new and not taught in undergraduate courses. So, all software were self-learned through video tutorials. A sample theoretical project was made in order to have grip on the software before the start of main work. Following Software were learned and used in the project:

- **Autodesk Revit 2013 and 2015**
- **Autodesk Green Building Studio**

- **Site Selection:**

After deciding the specific area of BIM, a site was to be selected to perform the required task and obtain results. A residential Building at Lahore was selected for our case study. We were able to get the necessary data we required for our BIM model development. Hence the double story already constructed residential building at Lahore was selected as the case study. All data required (drawings, specifications, BOQ) were obtained.

- **BIM Model:**

An architectural as planned model was generated through the as planned drawings on Autodesk Revit 2015. Then the energy analysis was performed through Autodesk Green Building Studio.

- **Approach:**

The following is a brief overview, in chronological order, of our approach to develop the BIM model of the residential 2 story's building:

- Development of generic Architecture model.
- Creation of customized Revit families.
- Replacing generic elements with customized families and addition of materials to the generic architectural model.
- Generation of Energy Analysis Report with Green building XML.

3.4 Architectural Model:

Figure-10 Architectural Model

- **Frame Structure:**

Basic frame structure consisting of beams and columns were modelled in the first stage due to the fact that we required a reference for further modelling. The beams and columns were generic i.e. without rebar details. Materials were assigned to the beams and columns after the frame structure was completed.

- **Walls and Shafts:**

As the work progressed we added walls and elevator shafts to the model. The consideration of walls, after the successful creation of basic structure, was due to the fact that the addition of windows and doors require a host family to be placed in. We started with the exterior walls and then moved to interior walls and shafts. The walls used were generic brick walls. Layers and materials were assigned to the walls after the completion of Architectural walls. This was a hectic job as adding a layer would move the wall from its position by a distance equivalent to the thickness of layer added, it would be therefore preferred to assign layers and materials to the walls while drafting them in the model if the wall section detail is available. Structural walls were placed according to the drawings as well.

- **Windows:**

Windows were the next element to be added. They required walls to host them and are easy to place through a drag and drop operation. Window dimensions were assigned according to the specifications provided. Different families were thus used.

- **Curtain walls:**

Curtain walls were placed according to as-planed drawings and the drawings were clear enough to aid us to model the curtain walls. Mullions were provided as per the drawings and Glass Units were used for the curtain walls. Place wall command was used to place curtain walls.

- **Doors:**

Doors like windows also require a host family to be placed. Doors and openings were placed next in the model, again by simple drag and drop operation. Dimensions and material were set as per the specifications

- **Slabs:**

The slabs were expected to be the same on the upper floors and it would have been easier to copy the floor of ground floor onto the upper floors but slab on each floor was slightly different due to difference in dimensions thus each floor's slab had to be modeled separately. Layers with different materials were defined after the model had been completed. Floor by sketch command was used to model slabs.

- **Roof**

Placement of roof is almost the same as placement of a slab in Revit. Layers with different materials were assigned to the roof after the completion of model. Roof by sketch command was used and the boundaries were manually sketched.

- **Stairs**

Adding stairs to the model was more tedious than we imagined. It was partially due to some errors in the drawings and partially due the complex nature of the way the stairs were designed in the planned structure. Spiral stairs were placed inside the building. Both stair by component and stair by sketch command were utilized in this process.

3.5 <u>Energy Analysis:</u>

Energy Analysis was key deliverable for our project. Sustainability and Energy efficient designs were to be proposed. Alternatives were to be suggested after analysis of our project. For the given objectives, following software were used:

- Green Building Studio

Green Building Studio:

Figure-11 GBS

The Revit architectural model was saved in gb.XML format and was exported to Green Building Studio for detailed analysis. Several settings must be defined in the Revit model before it can exported as a gb.XML file. You must log in to Autodesk 360 account to use these settings. Revit gives us two options to create an energy model.

1. By using conceptual mass
2. By using building elements

The energy model was created by using basic building elements. In energy settings, the real life location of the building was selected and the building type was specified e.g. hospital, school, office etc. You can select either ‘rooms’ or ‘spaces’ as export category. Rooms are selected to run energy simulations based on architectural elements of the building. Spaces are selected to run MEP elements based energy simulations. Rooms was selected as our export category. All the floors of the building were divided into rooms. Default thermal properties and systems properties were used since the details were not available. Care must be taken that there are no open spaces left in the building and the building forms a whole closed figure. Open spaces will lead to errors that will not allow the model to be exported as a gb.XML file. All the open spaces were closed and the model was exported to Green Building

Studio. Energy simulations were run on Green Building Studios and detailed reports were created as an output.

a) Results & Analysis:

- **Introduction:**

To learn about BIM tools and applications and know benefits and issues involved in the process a case study was done. Architectural models of Residential building at Lahore, a 2345 ft. square area building with 2 stories.

b) Green Building Studio:

Green building Studio is a cloud based software. Our design which was architectural model was upload which yielded us a lot of results. Alternatives were suggested by the software after analysis.

Input Parameters that were assigned to Green Building Studio are as follows:

1. **Location: Lahore, Pakistan**
2. **Currency: PKR**
3. **Time Zone: Pakistan Standard Time.**
4. **Electricity & Gas Rates. Rs. 11/KWh & Rs. 21.2/therm**
5. **Weather Station: GBS_06M12_12_119245**
6. **Distance from Project: 4.4 miles**

Results are based on number of people using the utilities of the building. Those are summarized in the following tables:

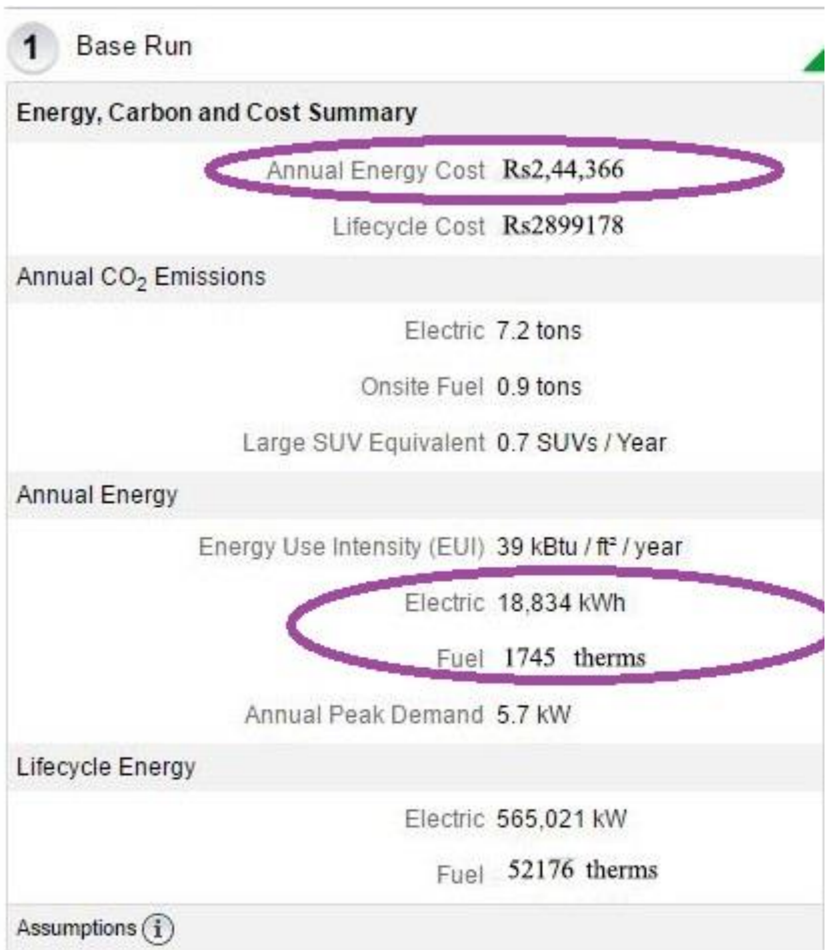
- **Energy Consumption Results:**

Alternatives	Annual Energy Consumption	Life Cycle Energy Consumption(30 years)	Carbon Emission
Base Run	18,834 kWh	565,021 kW	8.1 tons
Double Glass LowE HP Windows	18,149 kWh	544,467 kW	7.7 tons
Continuous Insulated Roof	18,907 kWh	567,208 kW	8.2 tons
Occupancy Sensors	18,055 kWh	541,661 kW	7.9 tons
Orientation 180 degree	18,610 kWh	558,286 kW	8.1 tons

Table: 4 Energy Consumption and Results.

Looking at the summarized tables of the results, one can use the alternatives to improve the efficient design of the project. Using alternatives reduces the carbon emissions by sufficient amount.

- **The below given table is showing values for the annual energy consumption and the units of electricity and fuel energy consumed in units of KWh and Therms.**



1 Base Run

Energy, Carbon and Cost Summary	
Annual Energy Cost	Rs2,44,366
Lifecycle Cost	Rs2899178
Annual CO_2 Emissions	
Electric	7.2 tons
Onsite Fuel	0.9 tons
Large SUV Equivalent	0.7 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	39 kBtu / ft² / year
Electric	18,834 kWh
Fuel	1745 therms
Annual Peak Demand	5.7 kW
Lifecycle Energy	
Electric	565,021 kW
Fuel	52176 therms
Assumptions	

Figure-12- Results of GBS

➢ The graph below is showing the consumption of electricity and fuel energy throughout the year. The consumption of electricity is maximum in the months of May, June and July while the consumption of fuel energy is maximum in the month of December and January.

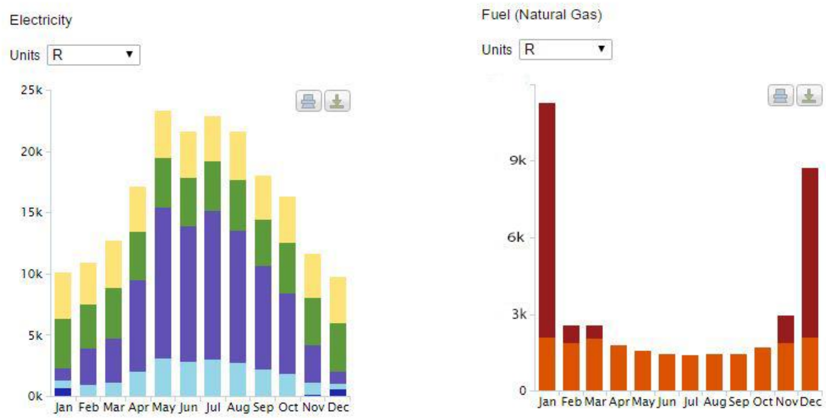


Figure-13 Graphs of GBS

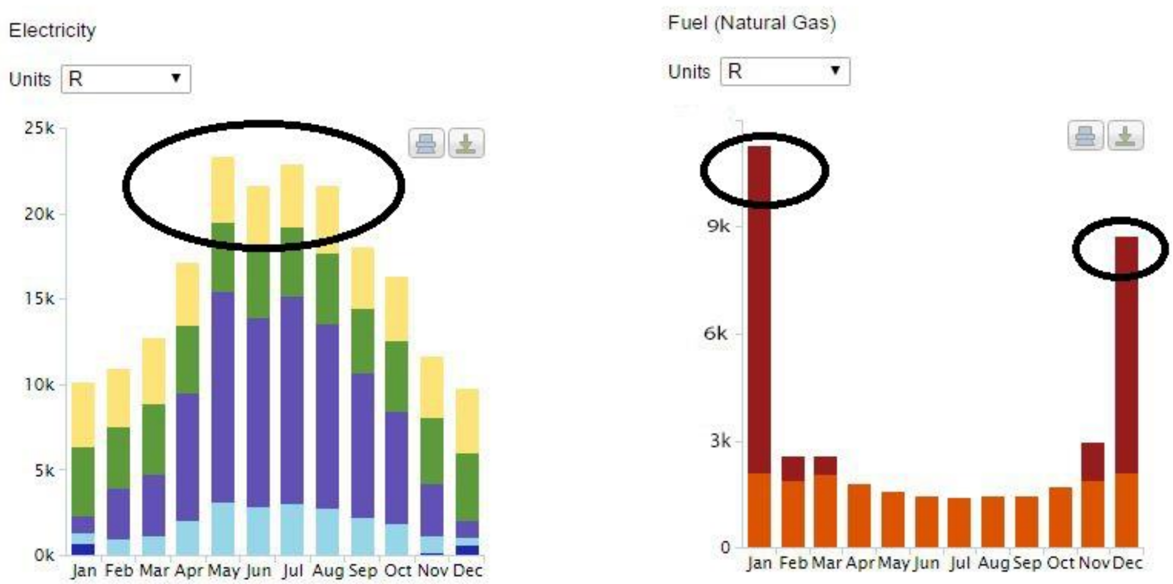


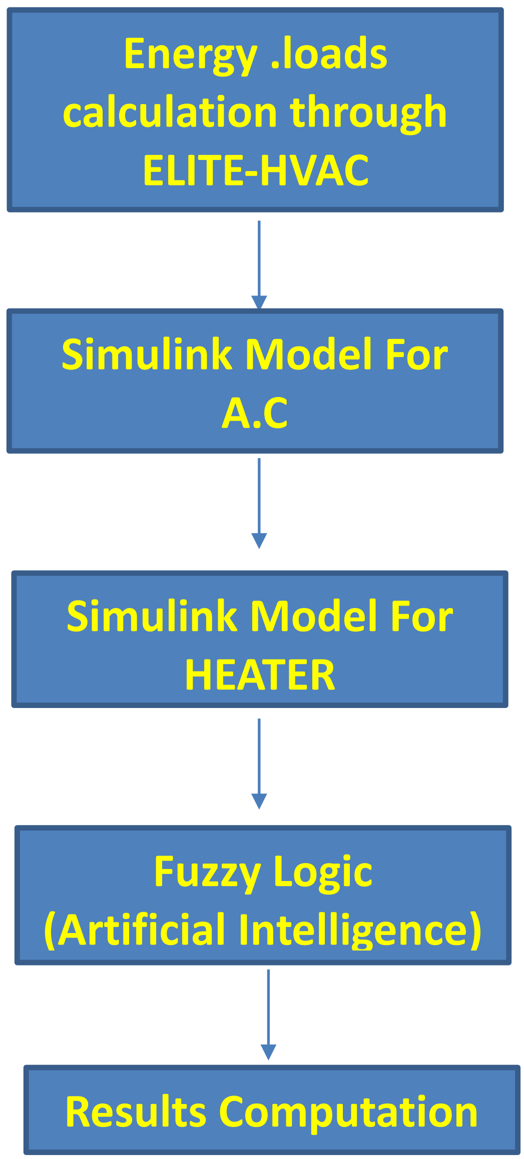
Figure-13 Graphs of GBS

3.6 2nd Phase:

Smart Building Simulation:

Smart Building Simulation is the new thing in, and paving its way up to the top and it provides Energy Efficiency and Sustainablility.

Following is the **METHODOLOGY** of the tasks to be performed.



a) **Smart Building Simulation**

Following are the Softwares that were used to calculate net tonnage of the house first and then to develop a simulator.

3.7 Elite HVAC:

It is basically a commercial and residential software for calculating heating and coolings loads as per ASHRAE codes of fundamentals using either the CLTD(cooling load temperature difference) or RTS(Radiant time series) method. It takes into account the outdoor environment conditions for around 2000 cities worldwide .Options for making slight changes in the weather data as well as plugging new entries for other cities are also available. Inclusive reports list the general project data, thorough room loads, air handler adjusted loads, outdoor air loads, net building loads and building envelope investigation. It Determines Building tonnage and room CFM Requirements, and run-out duct sizes and main duct size. We have adapted CLTD method to calculate the net tonnage required for our house model and proposed a central cooling system. It requires several parameters for performing calculations and to eventually at the end results.

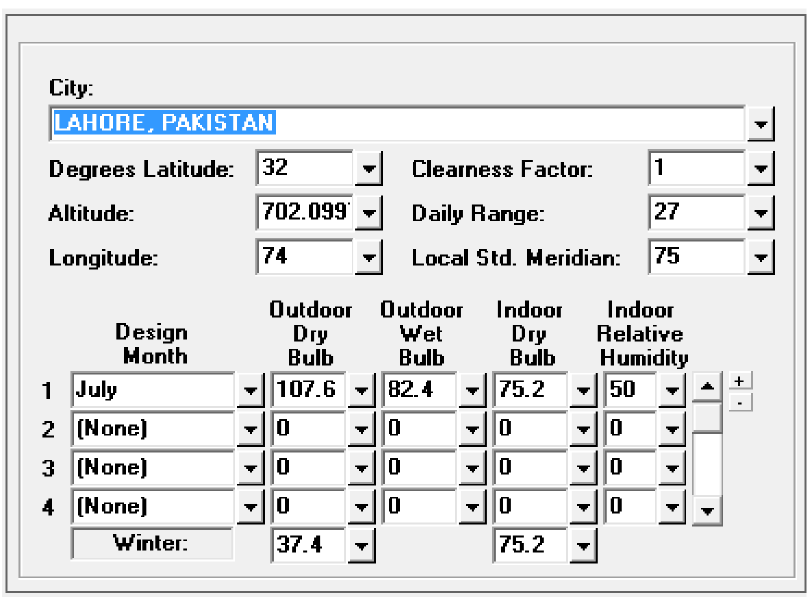


Figure-14 ELITE-HVAC parameters

The climatic conditions for the model are input into the indoor/outdoor design conditions window, which in our case is Lahore, Pakistan. Analysis were run for the month of july as it is the hottest month in this region with temperature rising up to 48 degrees Celsius.

Chvac is extremely simple to use and includes a particular "dropdown" menu to facilitate window for just about each input, together with a listing of selections wherever applicable. The program performs in depth checks on the information you enter and alerts you to any issues that it finds, like a wall having an excessive amount of window space, or if data input in air handler is inappropriate with reference to other features.

Five forms of input data are requested: general project data, outdoor design data, building material data, air handler data, and specific room data. The project data includes the project and consumer name, designer, building gap and shutting hours, internal operational load schedules, and any desired safety factors. The outside input data includes the summer and winter outside style conditions (automatically found for you if a town reference is given) and also the desired ventilation and infiltration rates. The material data includes the definition of master artefact varieties for roofs, walls, partitions, glass sections, and exterior shading. A user outlined material library is out there for saving the information on common material varieties. The air handler knowledge includes the fan and terminal sort, the required heating and cooling offer air temperatures and knowledge for duct heat gains and losses. The room data includes the space name, floor length and dimension, range of individuals, instrumentation watts, lighting watts, and external shading knowledge, and specific roof, wall, partition, floor and glass features. The results in the form of tonnage is then used for modeling by the aid of Simulink. The house model is divided into 3 sections:

- **Bedroom 1 and Bedroom 2**
- **Kitchen and Drawing room**
- **Living room and restroom**

The version of the software used is a demo-version with limited features and calculations are performed on groups of two rooms instead of applying it on the whole model. So the tonnage results of different sections are as below:

➢ Bedroom 1 and Bedroom 2:

Check Figures

Total Air Handler Supply Air (based on a 15° TD):	1,764 CFM
Total Air Handler Vent. Air (1.42% of Supply):	25 CFM
Total Conditioned Air Space:	553 Sq.ft
Supply Air Per Unit Area:	3.1893 CFM/Sq.ft
Area Per Cooling Capacity:	226.4 Sq.ft/Ton
Cooling Capacity Per Area:	0.0044 Tons/Sq.ft
Heating Capacity Per Area:	28.75 Btuh/Sq.ft
Total Heating Required With Outside Air:	15,899 Btuh
Total Cooling Required With Outside Air:	2.44 Tons

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Chvac - Full Commercial HVAC Loads Calculation Program
Elite Software Development
College Station, TX 77845

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Data For Guest Room And Living Room
Page 5

Zone Detailed Loads (At Zone Peak Times)

Load Description	Unit Quan	-SC- CFAC	CLTD SHGF	U.Fac -CLF-	Sen. Gain	Lat. Gain	Htg. Mult.	Htg. Loss
Room 1-Bedroom 1 - Air Handler 1 (Air Handling 2), Zone 4 peaks (sensible) in July at 6pm.								
Roof-1-9-No.Clg-L	280	0.50	38.9	0.300	3,262		11.321	3,170
Wall-1-E-C-D	150	1	41.9	0.300	1,882		11.321	1,698
Wall-2-N-C-D	8	1	26.9	0.300	67		11.321	94
Gls-N-1-90-Tran	48.0	1.000	24	0.810	929		31.374	1,506
0%S-0-WS-Solar	48.0	0.640	40	0.910	1,118			
Lights-Prof=4	333	1.000			1,136			
Equipment-Prof=4	285	1.000			972	0		
People-Prof=2	2.0	1.000			750	1,250		
Sub-total					10,118	1,250		6,468
Safety factors:					+0%	+0%		+0%
Total w/ safety factors:					10,118	1,250		6,468

Table: 5 Tonnage of Br1 and Br2

The net tonnage required for the air handler for Bedroom 1 and Bedroom 2 is 2.44 tons.

➢ Kitchen and Drawing Room:

Check Figures

Total Air Handler Supply Air (based on a 15° TD):	1,899	CFM
Total Air Handler Vent. Air (3.42% of Supply):	65	CFM
Total Conditioned Air Space:	539	Sq.ft
Supply Air Per Unit Area:	3.5259	CFM/Sq.ft
Area Per Cooling Capacity:	246.6	Sq.ft/Ton
Cooling Capacity Per Area:	0.0041	Tons/Sq.ft
Heating Capacity Per Area:	35.95	Btuh/Sq.ft
Total Heating Required With Outside Air:	19,361	Btuh
Total Cooling Required With Outside Air:	2.18	Tons

Note: Due to the system's negative latent gain, tonnage is based solely on sensible gain.

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Final Year Project
Page 5

Zone Detailed Loads (At Zone Peak Times)

Load Description	Unit Quan	-SC- CFAC	CLTD SHGF	U.Fac -CLF-	Sen. Gain	Lat. Gain	Htg. Mult.	Htg. Loss
Room 1-Drawing Room - Air Handler 1 (Air Handling), Zone 0 peaks (sensible) in July at 4pm.								
Roof-1-9-No.Clg-L	324	0.50	37.4	0.300	3,629		11.321	3,668
Wall-1-W-C-D	155	1	27.9	0.300	1,291		11.321	1,749
Wall-2-S-C-D	126	1	28.9	0.300	1,092		11.321	1,429
Gls-S-1-90-Tran	60.0	1.000	26	0.810	1,259		31.374	1,882
0%S-0-WS-Solar	60.0	0.640	72	0.350	968			
Gls-S-1-90-Tran	28.8	1.000	26	0.810	604		31.374	904
0%S-0-WS-Solar	28.8	0.640	72	0.350	464			
Gls-W-1-90-Tran	19.2	1.000	26	0.810	403		31.374	602
0%S-0-WS-Solar	19.2	0.640	215	0.820	2,166			
Lights-Prof=3	692	1.000			2,362			
Equipment-Prof=3	31	1.000			106	0		
People-Prof=3	10.0	1.000			2,450	1,550		
Sub-total					16,795	1,550		10,234
Safety factors:					+0%	+0%		+0%

Table: 6 Tonnage of Kitchen & DR.

The net Tonnage required for second section is 2.18 tons.

➢ **Living room and Restroom:**

Check Figures		
Total Building Supply Air (based on a 15° TD):	1,349	CFM
Total Building Vent. Air (2.59% of Supply):	35	CFM
Total Conditioned Air Space:	662	Sq.ft
Supply Air Per Unit Area:	2.0384	CFM/Sq.ft
Area Per Cooling Capacity:	338.6	Sq.ft/Ton
Cooling Capacity Per Area:	0.0030	Tons/Sq.ft
Heating Capacity Per Area:	21.08	Btuh/Sq.ft
Total Heating Required With Outside Air:	13,954	Btuh
Total Cooling Required With Outside Air:	1.96	Tons

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Air Handler #1 - Air Handling 2 - Summary Loads

Rm No	Description Room Peak Time	Area People Volume	Htg.Loss Htg.CFM CFM/Sqft	Sen.Gain Clg.CFM CFM/Sqft	Lat.Gain S.Exh W.Exh	Htg.O.A. Req.CFM Act.CFM	Clg.O.A. Req.CFM Act.CFM
1	Living Room 6pm July	441 4 4,410	6,917 31 0.07	12,287 879 1.99	3,480 0 0	5/P 20 22	5/P 20 23
	Runout duct size: 2 in. h x 37in. w, Diffusers: 8, CFM/runout: 110, Velocity: 213.8 ft/min, Pressure drop: 0.032 in.wg./100ft						
2	Guest Room 7pm July	221 3 2,210	4,107 19 0.08	6,577 470 2.13	1,875 0 0	5/P 15 13	5/P 15 12
	Runout duct size: 2 in. h x 37in. w, Diffusers: 4, CFM/runout: 118, Velocity: 228.9 ft/min, Pressure drop: 0.036 in.wg./100ft						
	Room Peak Totals: Total Rooms: 2 Unique Rooms: 2	662 7 6,620	11,024 50 0.08	18,864 1,349 2.04	5,355 0 0	 35 35	 35 35
	Main trunk duct size: 2 in. h x 255in. w, Velocity: 381.0 ft/min, Pressure drop: 0.083 in.wg./100ft						

Table: 7 Tonnage of LR. & RR.

The net Tonnage required for third section is 1.96 tons.

a) Net Tonnage for house Model:

Summing the individual tons for all sections of the house it is equal to **6.58** Tons. It is to be noted that these calculations are performed when there is no insulation taken into account either in the walls or in the roof.

b) Insulation Parameter:

If the insulation(Glass fiber 3-4 inches thick) parameter is considered for walls and for roofs and calculations are performed with Elite Chvac, the net tonnage requirement for the house drops down to **6.30** tons and hence more energy efficiency is achieved. Results are shown below:

➢ Bedroom 1 and Bedroom 2:

Check Figures		
Total Building Supply Air (based on a 15° TD):	1,679	CFM
Total Building Vent. Air (1.49% of Supply):	25	CFM
Total Conditioned Air Space:	553	Sq.ft
Supply Air Per Unit Area:	3.0370	CFM/Sq.ft
Area Per Cooling Capacity:	237.7	Sq.ft/Ton
Cooling Capacity Per Area:	0.0042	Tons/Sq.ft
Heating Capacity Per Area:	28.75	Btuh/Sq.ft
Total Heating Required With Outside Air:	15,899	Btuh
Total Cooling Required With Outside Air:	2.33	Tons

Table: 8 Insulated Tonnage of BR-1 & BR-2

➢ Kitchen and Drawing Room:

Check Figures		
Total Building Supply Air (based on a 15° TD):	1,809	CFM
Total Building Vent. Air (3.59% of Supply):	65	CFM
Total Conditioned Air Space:	539	Sq.ft
Supply Air Per Unit Area:	3.3598	CFM/Sq.ft
Area Per Cooling Capacity:	261.4	Sq.ft/Ton
Cooling Capacity Per Area:	0.0038	Tons/Sq.ft
Heating Capacity Per Area:	35.95	Btuh/Sq.ft
Total Heating Required With Outside Air:	19,361	Btuh
Total Cooling Required With Outside Air:	2.06	Tons

Table: 9 Insulated Tonnage of Kitchen and DR.

➢ Living room and Restroom:

Check Figures		
Total Building Supply Air (based on a 15° TD):	1,375	CFM
Total Building Vent. Air (2.55% of Supply):	35	CFM
Total Conditioned Air Space:	501	Sq.ft
Supply Air Per Unit Area:	2.7435	CFM/Sq.ft
Area Per Cooling Capacity:	262.6	Sq.ft/Ton
Cooling Capacity Per Area:	0.0038	Tons/Sq.ft
Heating Capacity Per Area:	24.21	Btuh/Sq.ft
Total Heating Required With Outside Air:	12,131	Btuh
Total Cooling Required With Outside Air:	1.91	Tons

Table: 10 Insulated Tonnage of LR. & RR.

Net Tonnage for House in which Insulation has been installed= 6.3 tons.

3.8 <u>SIMULINK:</u>

Simulink is a Graphical user interface or you can say a block diagram representation for multi-domain simulation and Model-Based style. It supports simulation, automatic code generation, and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is integrated with MATLAB, sanctioning you to include MATLAB algorithms into models and export simulation results to MATLAB for additional analysis. Its capabilities include the model building, model simulation, analysis of the simulation results and its capability to connect with hardware.

It is an extension of MATLAB, which was originally developed for control systems. It can be fully integrated with MATLAB, provides flexibility and points error straightforwardly where it exists rather than creating hindrance in running the programming logic as seen in conventional programming softwares. It has an extensive block library which is not only used for simulation analysis of linear but also for linear systems. Blocks are simply dragged from the library and dropped into the Simulink window .However, modeling a system is not always easy.

For carrying out the simulation the results generated by Elite Chvac served as a pre-requisite for modeling in Simulink. Optimized models for Air-Conditioning and heating system were made in Simulink to conserve energy and ensure user comfort inside the house.

a) The Air-Conditioning Model:

Here is the extensive model for Air-conditioning.

Same logic is implemented on each section except that various parameters such as Section area, thermal resistance of the section, mass flow rate of the air handler unit installed, and mass of air to be cooled are varied for each section. Now a single section (for drawing room and kitchen) is explained separately for understanding.

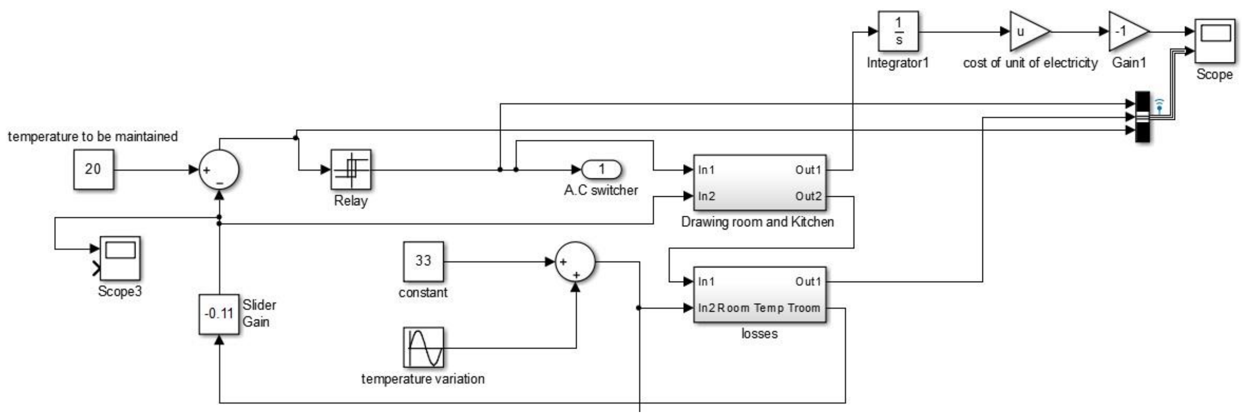


Figure-15 A.C Model.

As it can be seen in the above model a relay system is attached for setting the a.c unit on and off by generating an input of either 0 or 1.The relay system senses and interacts not only with the outside environment but also to how the temperature varies indoor and how the heat energy is transferred inside or outside the room .The two red blocks are pointing the two subsystems which are a.c working mechanism and the feedback losses fed into the system.These two are now expanded to demonstrate their role in the model:

b) A.C working mechanism:

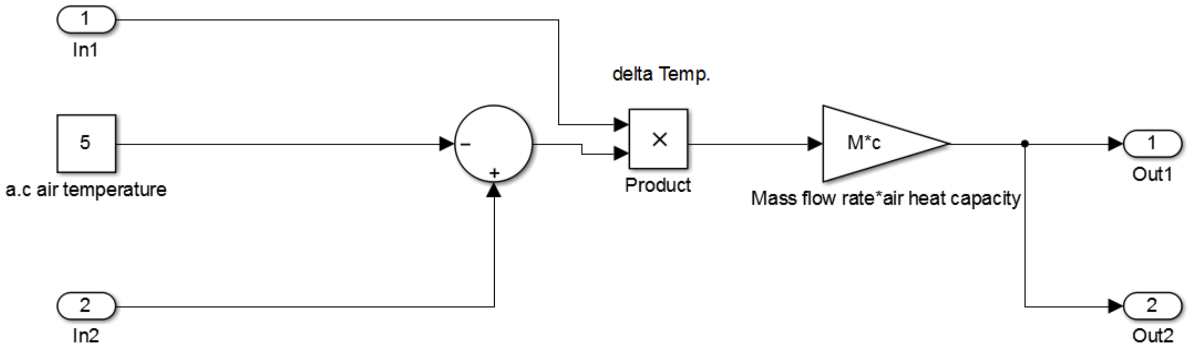


Figure-16 A.C Working Mechanism

The above implemented logic is well explained by the thermodynamic equation of heat transfer.

$$\frac{dQ}{dT} = (Tr - Ta) * M.c$$

- Tr is the room temperature
- Ta is temperature of the a.c air
- M is the mass flow-rate of the air handler unit in units of kg/hr.
- C is the heat capacity of the air at constant pressure in units of J/kg.K.

The input 1 into the system is coming from the relay system. When the temperature of the room rises to 23 degrees Celsius the relay sends an input 1 setting the a.c unit to working position and similarly when the temperature drops to 20 degrees Celsius, the relay generates an input 0, setting the a.c off. And the cycle goes on in accordance to temperature fluctuations. The second input into the system refers to temperature variation.

The output generated is used for two purposes: 1) to calculate the cost of operation of the a.c unit per month .2) It is fed into the losses subsystem.

c) <u>Feedback losses:</u>

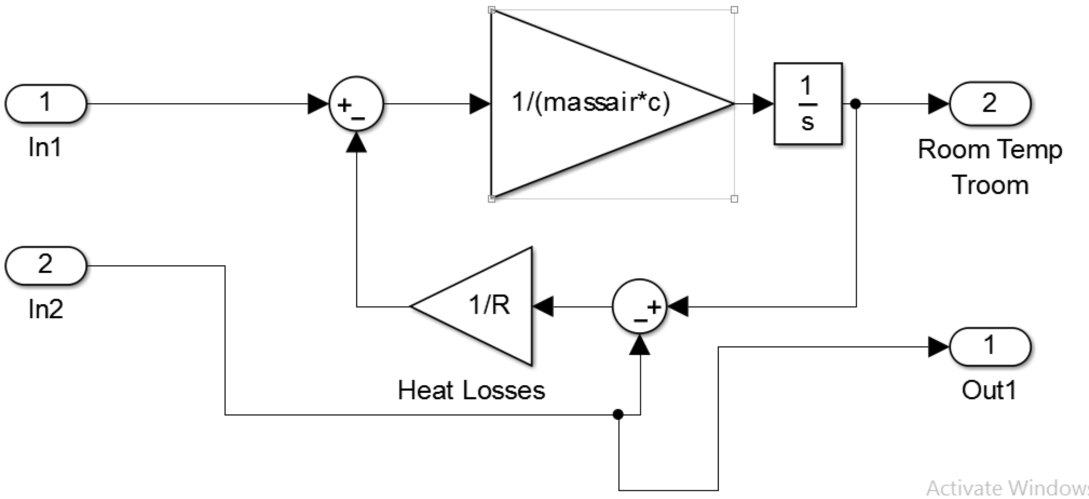


Figure-17 A.C Losses

The Feedback losses subsystem is explained by the following thermodynamic equations:

$$\left(\frac{dT}{dt}\right)=\left(\frac{dQ}{dT}-\frac{dQ}{dT}\text{losses}\right)*\left(\frac{1}{Mair*c}\right)$$

$$\frac{dQ}{dT}\textbf{losses} = \quad (\mathbf{Tr}-\mathbf{To})$$

$\frac{dQ}{dT}$ Is the input in this case which was output generated by the a.c working mechanism system.It is subtracted from $\frac{dQ}{dT}\,losses$, which is the difference in temperature between the room and the outdoor environment. $Mair$ Is the mass of air to be cooled and c is the specific heat of the air. The output generated by this subsystem is in units of temperature.

d) <u>Results:</u>

The results in the form of cost of operation for the month of July and the relay system response with temperature fluctuation are shown by graphs generated by Simulink.

- **Bedroom 1 and Bedroom 2**

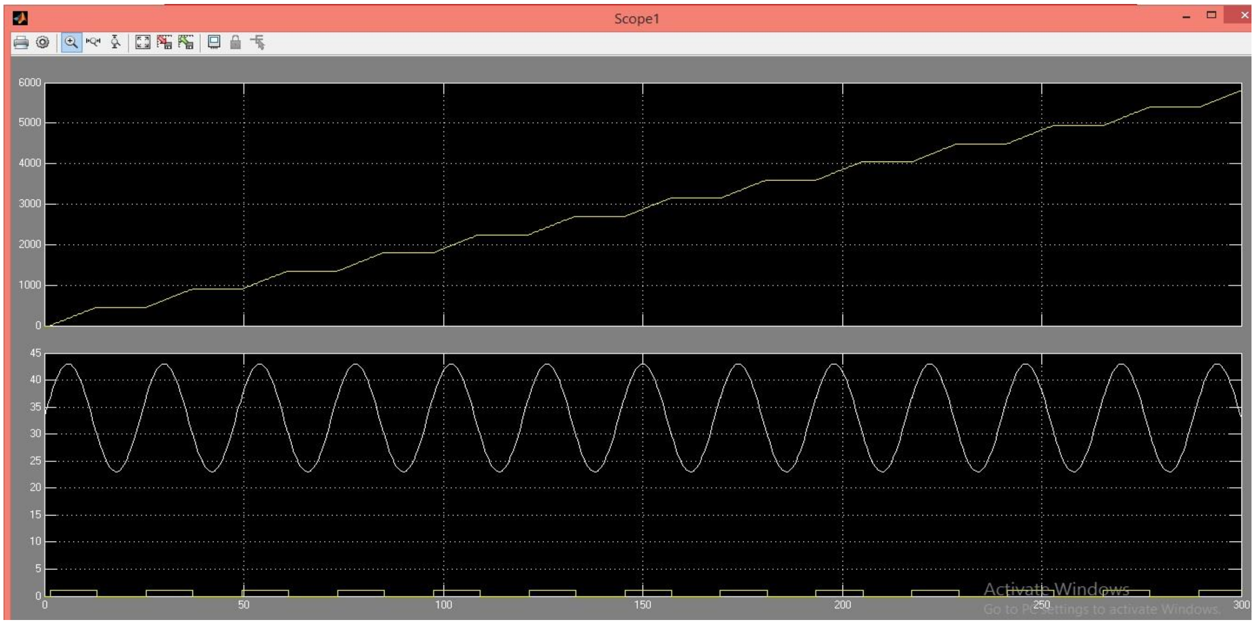


Figure-18 Graph of BR.1 & BR.2

- **Kitchen and Drawing room**

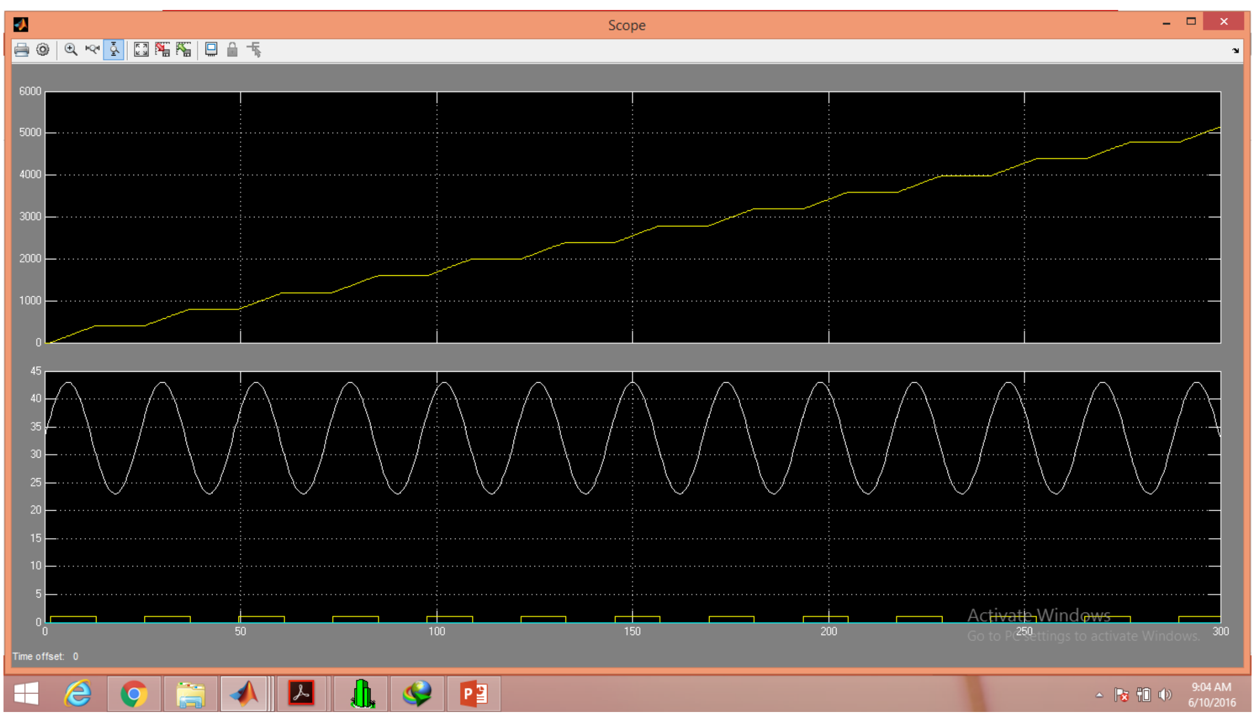


Figure-19 Graph of Kitchen & DR.

- **Living room and Restroom**

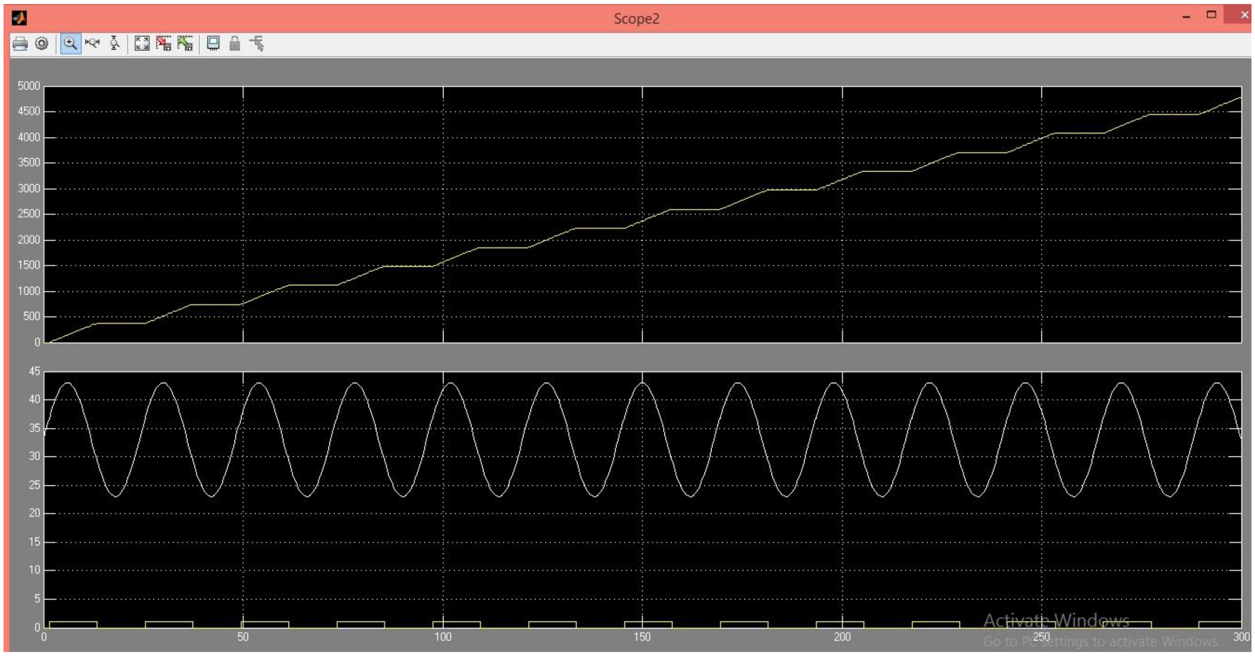


Figure-20 Graph of LR. & RR.

- **Cost of operation for all Rooms => 5100+5800+4700 = 15,600 RS. per month**
- **Total bill for the month of JULY= HVAC + Miscellaneous = 15,600 + 2500 = RS. 18,100**
- **Cost of a unit taken as 11Rs/kwh.**

e) Heating System:

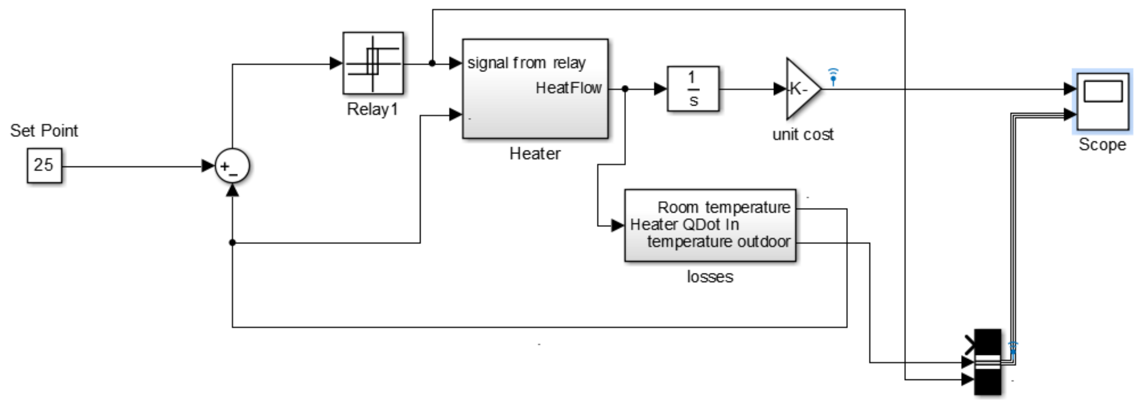


Figure-21 Heating System.

The heating logic is pretty much the same as the a.c logic except the set point and heater air temperature added in the subsystem of heating working mechanism.

f) Heater Working Mechanism:

Logic for a single section:

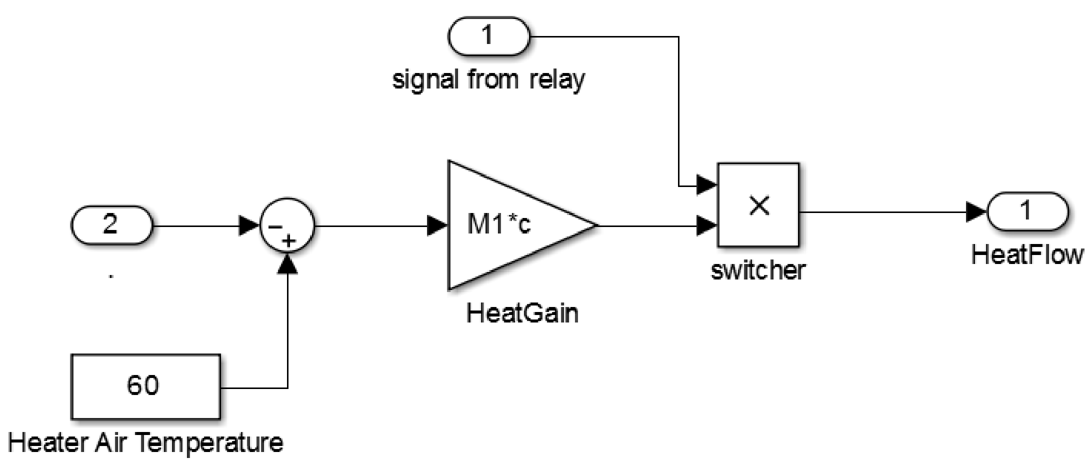


Figure-22 Heater Working Mechanism.

$$\frac{dQ}{dT} = (Tr - Th) * M.c$$

g) <u>Results:</u>

- The results in the form of cost of operation for the month of January and the relay system response with temperature fluctuation are shown by graphs generated by Simulink.

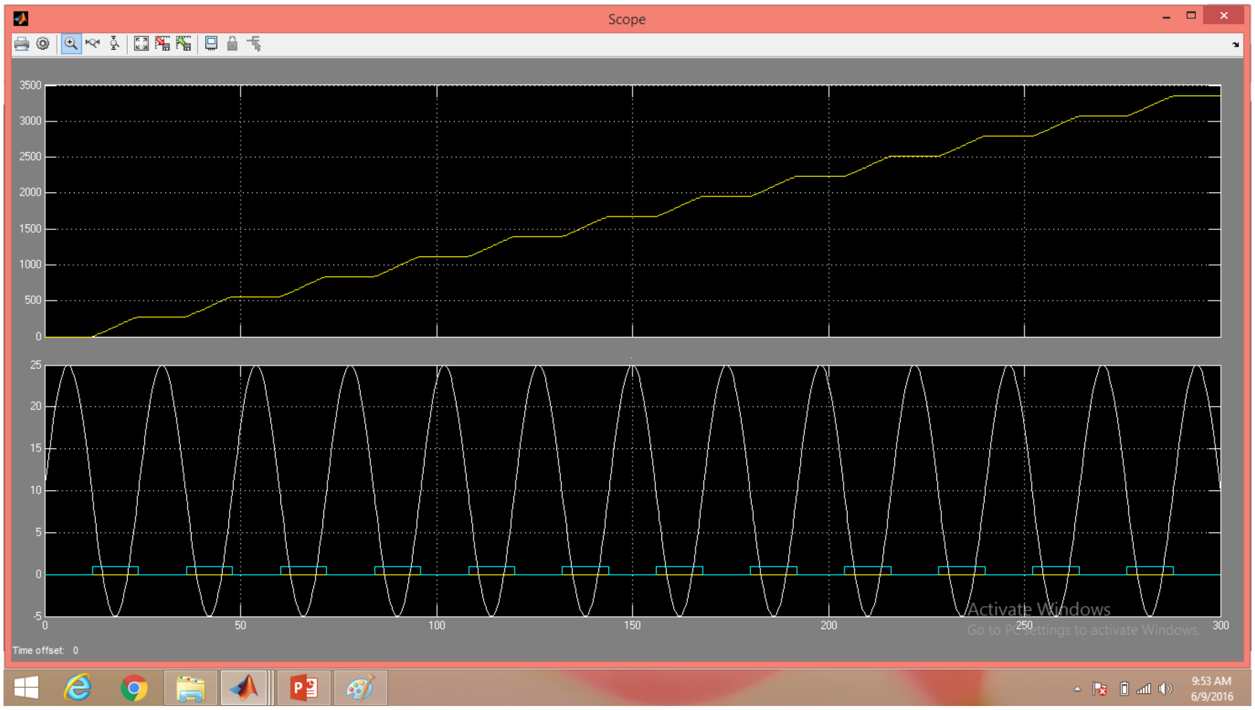


Figure-23 Graph of Heater System.

- **Cost of Operation for all the rooms.=> 3500 + 3000 + 3500 = RS-/ 10,000**
- **Cost of a unit taken as 11Rs/kwh.**

h) Fuzzy Logic:

It is basically a concept of artificial intelligence based on the **degrees of truth**, rather than taking inputs in the form of 0 or 1(Boolean logic) apart from conventional operating systems. *Fuzzy logic* is a form of many-valued *logic* in which the truth values of variables may be any real number between 0 and 1.

It is incorporated in the heating logic to stabilize the set point of the room as to maintain the most desirable indoor conditions for the inhabitants possible.

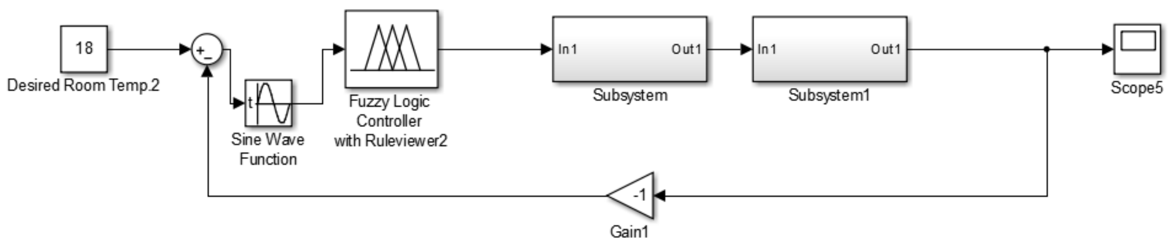


Figure-24 FUZZY Logic

i) Results:

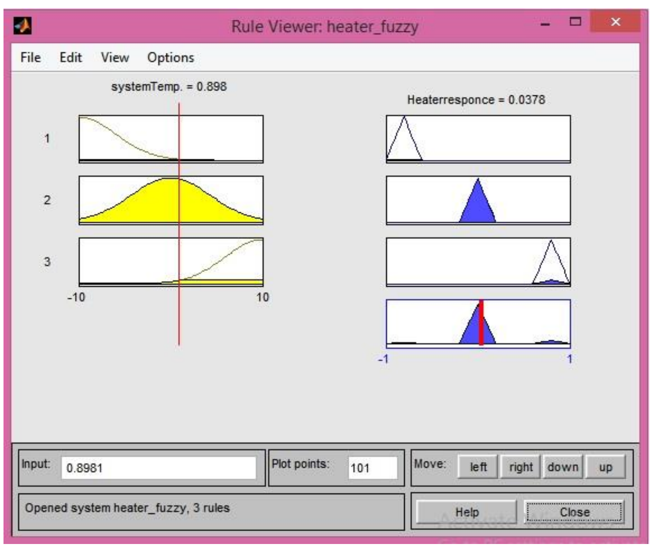


Figure-25 Fuzzy Results.

As the results show the feedback is so adjusted as to keep the indoor temperature to a comfortable level. The peak of the yellow filled function shows the most comfortable condition. The temperature is expected to fluctuate between -10 and +10 of the set point which is 18 degrees as shown in diagram. An error of 0.898 is resulted which accounts to a small value and is normal in such control systems.

CHAPTER 4

4. Results And Analysis:

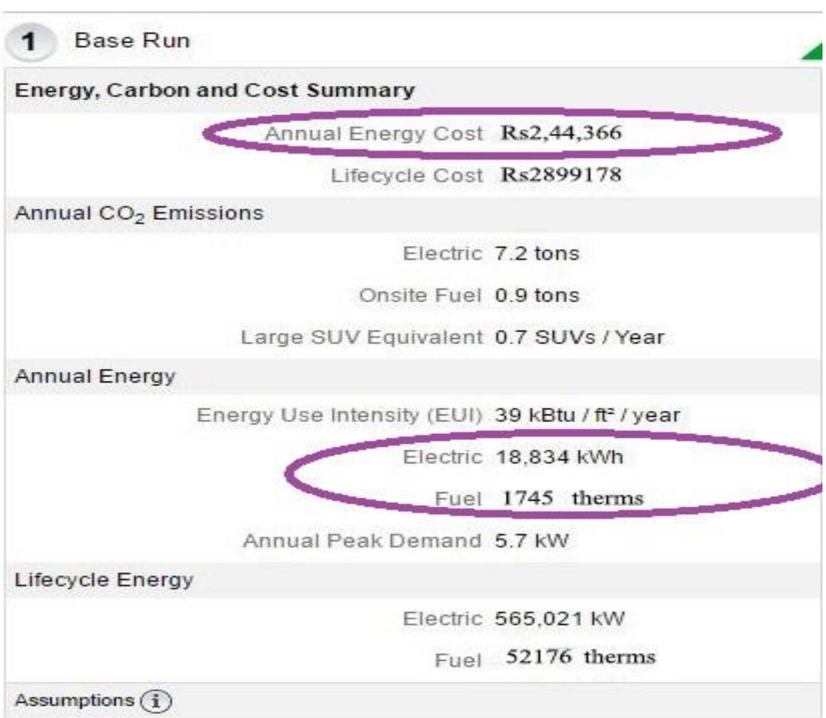
4.1 General:

Basically in this chapter, the results of the analysis that are being performed through **Green Building Studio (GBS)** and through the use **Logically Developed Simulators** will be discussed here.

We'll be using tables and figures to explain the Results.

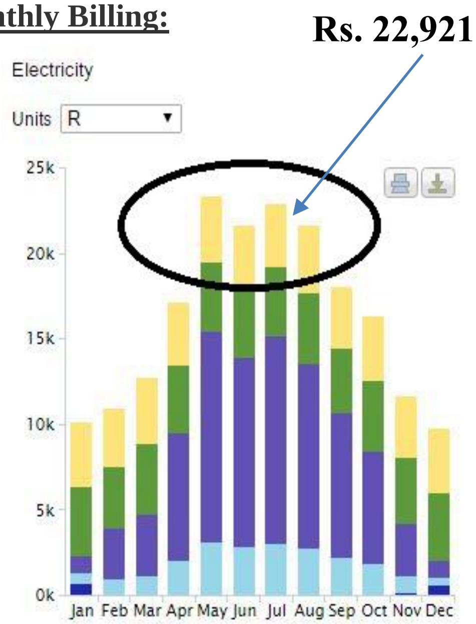
4.2 BIM Model Analysis: Through the use of Green Building Studio **(GBS).**

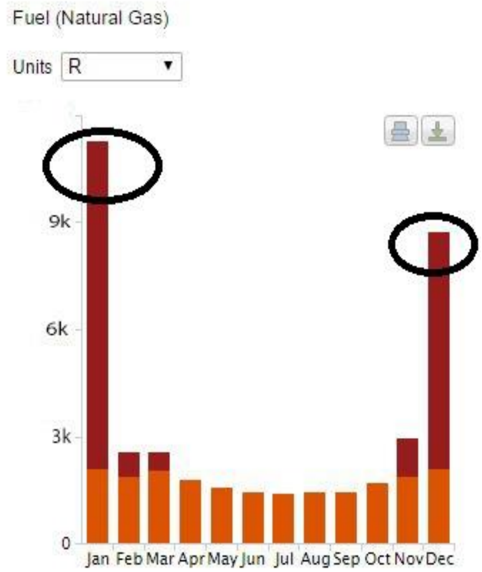
- **Electricity & Gas Rates. Rs. 11/KWh & Rs. 21.2/therm**



This tells us that the Annual Energy Cost of the building will be around RS. 2, 44,366-/

a) **Monthly Billing:**





The maximum Electricity bill will come in the month of July and the cost is around **RS. 22,921-** and for that of Gas the maximum bill will come in the month of January, and it will be off almost RS. **11,000-/.**

4.3 <u>Tonnage Difference:</u> Tonnage Difference of **Non-Insulated & Insulated Building,** through the use of **ELITE-HVAC.**

Without Insulation(tons)	With Insulation(tons)
BR-1 + BR-2 = **2.44 tons**	BR-1 + BR-2 = **2.33 tons**
Kitchen + Drawing Room= **2.18**	Kitchen + Drawing Room= **2.06**
Living Room+ R.Room= **1.96**	Living Room+ R.Room= **1.91**
Total Tonnage= 6.58 tons	**Total Tonnage= 6.3**
Difference= .28 tons b/w the two.	**Percentage diff.= 4.34 %**

Table: 11 Tonnage Comparison of Insulated and non-Insulated.

Percentage Difference = 4.34 %, hence insulated building is more Efficient.

4.4 Smart Building Simulators Results:

Cost of A.C Operation for all the rooms = RS. (5800 + 5100 + 4700)= RS. 15,600 -/

- **Bedroom 1 and Bedroom 2= RS. 5800-/**
- **Kitchen and Drawing room= RS. 5100-/**
- **Living room and restroom= RS. 4700-/**

Cost of Operation for the Building= RS. 15,600 + 2500(miscellaneous) = RS. 18,100-/ july

Keep in mind that all the parameters are same; that have been used for the analysis in GBS, moreover the billing month and is same i.e. JULY.

Cost of a unit taken **as Rs. 11 per KWh.**

4.5 Comparison:

Basically it is a comparison between the Cost of operations that came out using **Green Building Studio (GBS)** and **SMART Building Simulator.**

Energy consumption and its cost GBS (month of July)	Energy consumption and its cost Smart Building Simulator (month of July)
Rs. 22,921	Rs. 18,100

Difference = 22,921 – 18,100 = **Rs 4821**

Percentage difference: (| 22921 – 18,100 | / ((22921 + 18,100)/2)) * 100

=23.50 %

Table: 12 Comparison of Cost b/w GBS and Smart Building Simulator

Clearly a Difference of **23.50 %** is present and hence making Smart Building Simulators more Energy Efficient and a Sustainable solution to our problems.

CHAPTER 5

5. DISCUSSION:

This chapter tells us a about the results that came out, after performing various analysis using the above written Softwares and through developed Simulators. All The results proved to be Energy Efficient and Sustainable; as compared to normal or ordinary construction.

5.1 Energy Efficiency:

Through the use of Smart Building Simulator, they provide us with the most saving and hence are the most Energy Efficient Method, as it caters the need of the hour.

The cost of Energy Consumption for the Month of July, in case of Smart Building Simulator; came out to be RS.-/ 18,100

The cost of Energy Consumption for the Month of July, through the **GBS**; came out to be RS.-/ 22,921.

Clearly it is evident from the **figures** that Smart Buildings are less energy consumptive. And are more efficient.

5.2 Comfort:

The level of Comfort or the ease of use SMART Building provides is immense; and are making lives easier for humans through their Intelligent, Interactive and immersive processes.

CHAPTER 6

6. CONCLUSION:

After the detailed literature review, Reviewing of Softwares, development of Logic and the analysis of results, the study can be concluded by the following main points:

- The values of **cost** for energy consumption of the Smart Building **(RS.18,100)** and Revit Model **(RS.22,921)**
- The total Tonnage **without Insulation** comes out to be **6.58 tons.**
- The total Tonnage **with insulation** comes out to be **6.3 tons**
- Percentage Diff. between the two is = **4.58 %**.
- Smart Buildings through the use of simulation attain maximum control.
- It is the new in thing, which will make its impact slowly but eventually, as the solution to our problems.

CHAPTER 7

7. RECOMMENDATIONS & LIMITATIONS:

7.1 Recommendations:

- As our logic or prototype is complete in some respect, so now the work should be done on its hardware components.
- It should be taken up as an industrial project.
- Further research should be carried out as it caters the need of the hour.

7.2 Limitations:

- The project is a combination of both civil and mechanical engineering.
- Procurement of different softwares was an issue.
- Software incapability to accept input of accurate/realistic schedules for occupancy, electrical lighting use, and equipment use.
- It is very difficult to change the conventional mindset of the people.

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- http://www.mathworks.com/products/simulink/
- http://www.elitesoft.com/web/hvacr/chvacx.html