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Life Cycle Assessment of an Existing Building Model: Building Energy Simulation

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Abstract: The progress of the study is represented on the design and implementation of technology for sustainable development of buildings using life cycle assessment (LCA). The progress of this study is presented on the design and implementation of technology for sustainable development of buildings using life cycle assessment (LCA). In this particular study, a flexible design and structure is developed to measure the quantity of energy used in different stages of building construction by the help of Revit Architecture. This study also includes the energy efficiency of a building. Out of the three major stages of LCA Study, the embodied energy of building materials is the most important aspect to focus as it contains around 30% – 35% of total building energy, which is not visible. The embodied energy refers to energy consumed during the construction of building, includes mining, manufacturing and transportation of building materials. The other stages include the operational and end of life energy of building. The study explains the theory including its importance and its impact on buildings life cycle. The methodology developed through energy analysis of a building in India, is done to measure the embodied energy used during the construction of these building with proper impact assessments. Other aspect of this study includes parametric study on energy analysis with the help of a software "Green Building Studio" and detailed discussions on insulation details, inclusion of skylight, outdoor air infiltration, iterative process which are based on SP 41 (code for ventilation and day lighting), IS 2440:1975 (Guide for Day lighting of buildings), IS 3362:1977 (Code for practice of natural ventilation of existing buildings), IS 3792: 1978 (Guide for heat insulation of non-industrial buildings) and IS7662.1: 1974 (Recommendation for orientation of buildings part 1- non-industrial buildings).

Index Terms **– BIM, embodied energy, Revit, Green Building Studio**

1. Introduction

Globally, buildings are responsible for over one third of final energy consumption and the greenhouse gas emissions related to the generation of that energy [1]. It has been asserted that it is simpler to save energy than to produce it [2], thus, the importance of ensuring the energy efficiency of buildings for a range of reasons is now well established. This shows the flexibility and consistency of energy analysis performed with BIM-based simulations such as Revit, Insight, and Green Building Studio. These tools were used to study the energy performance and thermal comfort of an existing building to reduce the dependence on the mechanical system of the building through retrofitting strategies. The BIM tools helped the designers to experiment with all possible design alternatives before the execution for the final design solution, which saves money and time while simultaneously contributing to more energy-efficient building design.

1. 1 Performing Energy Analysis

Rapid urbanization has resulted in exploitation of the available energy resources. Greenhouse emissions due to the maximum usage of the mechanical system for active cooling of the building has created greater impact on our fragile ecosystem. This was an eye-opening situation for people all around the world, thus promoting energy-efficient solutions for the buildings. Envelope systems pose a great scope to reduce the energy consumption and consequently improve building efficiency. It is not yet known in what way building

envelope design measures are to be selected and the Energy performance [3] in hot and humid climates.

1.2 REVIT ARCHITECTURE:

The energy analytical model feature in Revit building design software provides tools for fast, flexible creation of models for energy simulation. Autodesk Revit Architecture softwareprovides architects the tools to easily capture and analyses design concepts, and more accurately maintain coordinated andreliable design data through documentation and construction.

Energy analytical models are created to suit different design stage needs, workflows and precision preferences. A model to be created directly from architectural building elements and room/space elements, or manually using conceptual massing.

1.3 GREEN BUILDING STUDIO

Green Building studio is an online software to perform energy analysis of buildings. The analytical building model is imported from Revit architecture. The original Green Building Studio web-based service was first introduced in 2004[4] and by 2007[5] its analysis results had met American Society of Heating, Refrigerating and Air- Conditioning (ASHRAE Standard 140) and were certified by the U.S. Department of Energy [6]. The link between the Revit platform and the Green Building Studio webservice, now an Autodesk product, has been streamlined through a plug-in that enables registered users to access the service directly from their Revit design environment. Various project default settings enable to set spaces, zones, surfaces, Heat Ventilation and Air Conditioning (HVAC) and zones. The nearest weather station appropriate to the location of the building is automatically selected by the software. The advantages of analysis is to improve analysis quality to find potential opportunities for energy savings. It presents analysis results in a highly visual format for easy comparison and interpretation.

2. DETAILS OF THE EXISITNG BUILDING MODEL

The existing building is located in Tambaram, Chennai. The plot area is 2800 sq. ft. The building type is single family residential building constructed ten years ago. The plan of the building, windows and doors orientation are studied. The building location comes under Hot and humid zone according to SP 41[7].

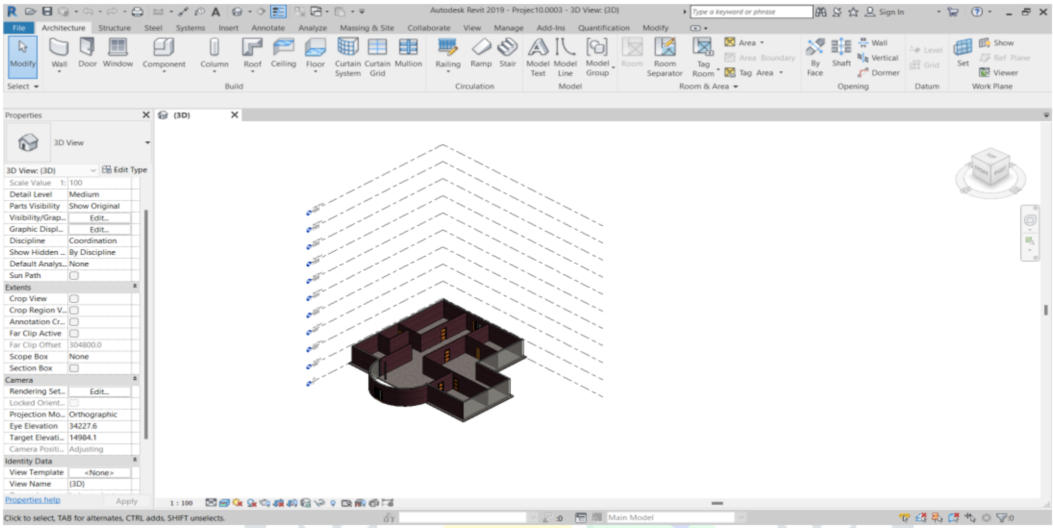

Fig. 1: Plan of the existing building in Kolkata.

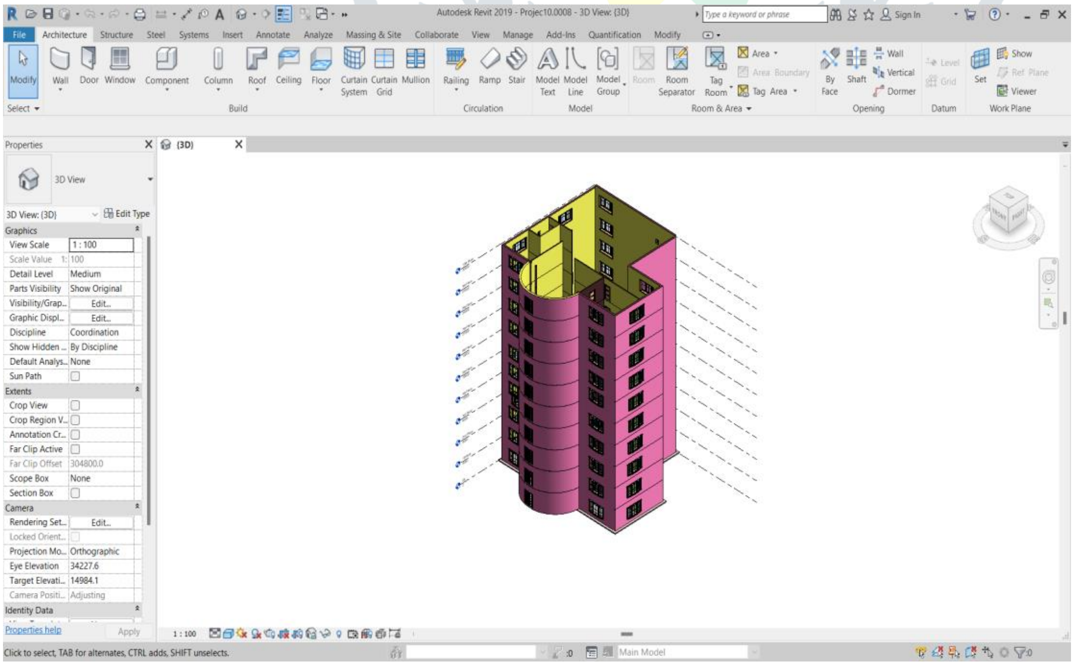

Fig 2: 3d Top view of the existing building

2.1 EXISTING BUILDING MODEL DEVELOPED IN BIM SOFTWARE: REVIT ARCHITECTURE

Revit is 4d- BIM capable with tools to plan and track variousstages in the building's lifecycle, from concept to construction and later demolition. The Revit work environment allows usersto manipulate whole buildings or assemblies (in the project environment) or individual 3D shapes (in the family editor environment). Modeling tools can be used with pre-made solid objects or imported geometric models.

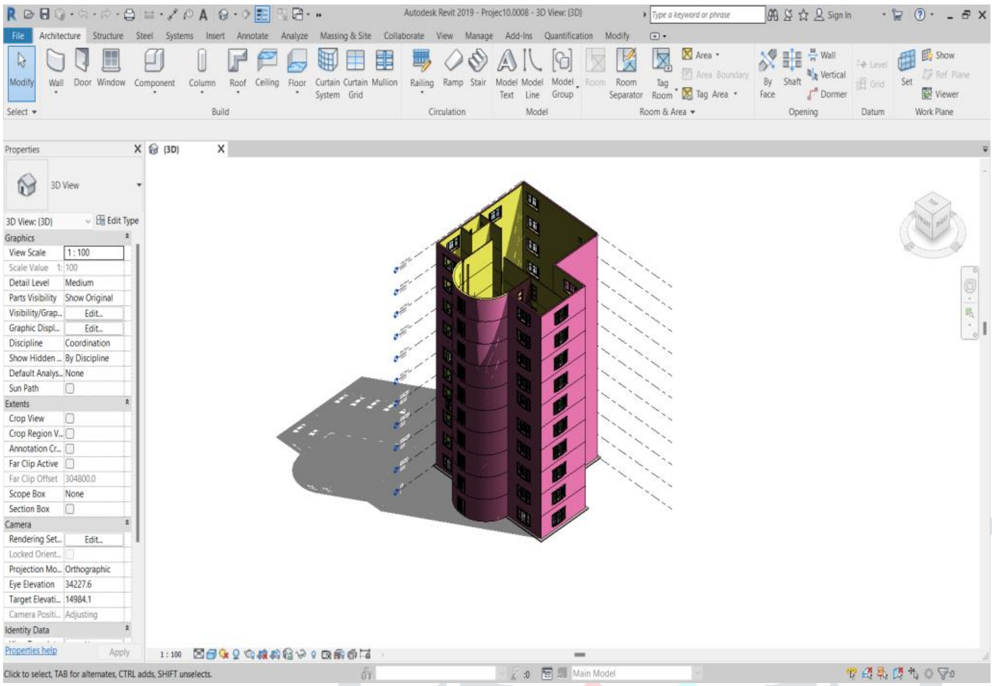

Fig-3: Use of solar analysis of existing building

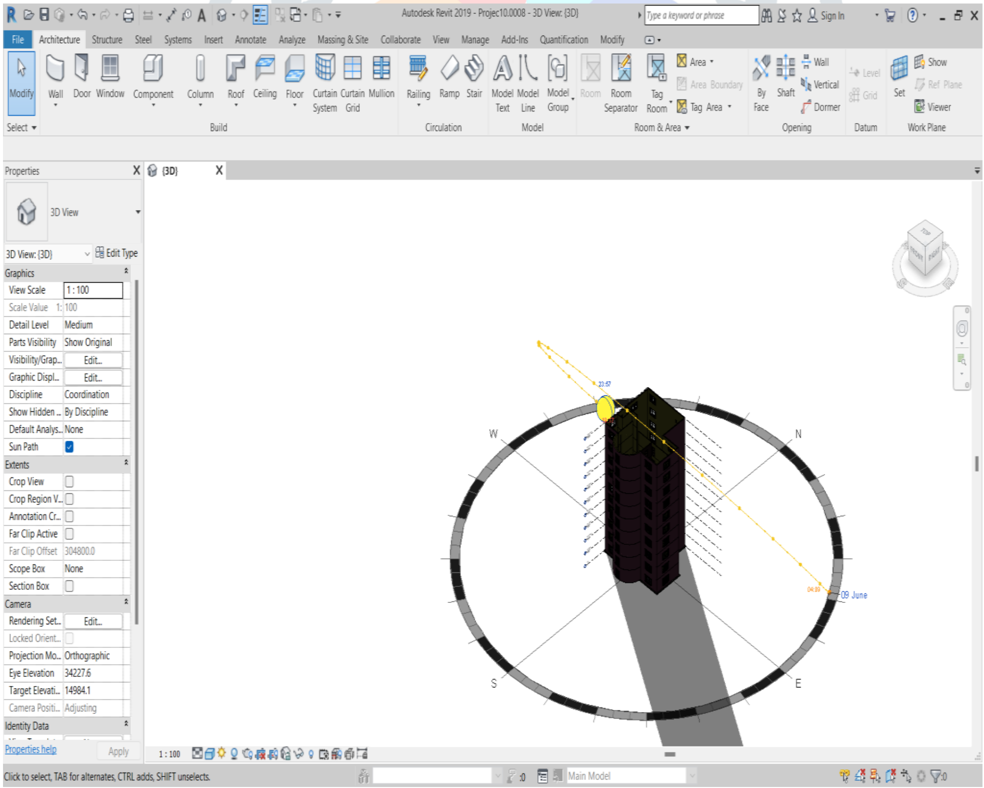

Fig.4. Solar effect time history analysis

The existing building in Tambaram is modelled in Revit architecture in order to create a digital representation of the building and to serve as a input to perform energy analysis in Green building studio.

Although the native Revit BIM data provides considerable “intelligence” relative to more basic CAD data, which consist of dumb shapes and lines, it does not contain the volumetric/zonal data required by building performance analysis tools such as Green Building studio.

2.2 TRANSITION FROM ARCHITECTURAL LOGICAL BASE MODEL

This data must be super imposed on top of the native Revit architectural model. It is usually referred to as the "Analytical Model" because it is the model on which subsequent analysis isbased. The diagram below shows the data objects involved in the transition process from Revit to Green Building studio.

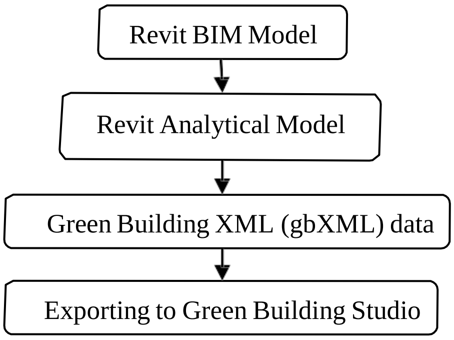

Fig. 4. Flowchart follow steps: Import from Revit to Green building studio transition.

3. ENERGY ANALYIS IN GREEN BUILDING STUDIO

The Autodesk Green Building Studio is modern and web-based service allows users to perform as soon as possible, Green Building Studio gives a report on the amount of energy and electricity consumed per annum by various factors such as area light, external usage, miscellaneous equipment, space cooling, vent fans, pump aux, and hot water. This streamlines the entire analysis process and allows architects to get immediate feedback on their design alternatives making green design more efficient and cost effective.

The output also summarizes the water usage and costs and electricity and fuel cost, calculates an ENERGY STAR score, estimates photovoltaic and wind energy potential, calculates points towards LEED day lighting credit, and estimates natural ventilation potential.

3.1 ENERGY ANALYSIS OF THE LIVE BUILDING WITH EXISTING DATA:

Firstly, the Revit model of the existing building is analyzed in Autodesk Green Building Studio as such with the existing details at the time of construction. Fig 6 shows the Potential energy savings chart which is obtained as output from theanalysis with 90% losses. There is significant loss in wallinsulation, infiltration, roof insulation and plug load efficiency.

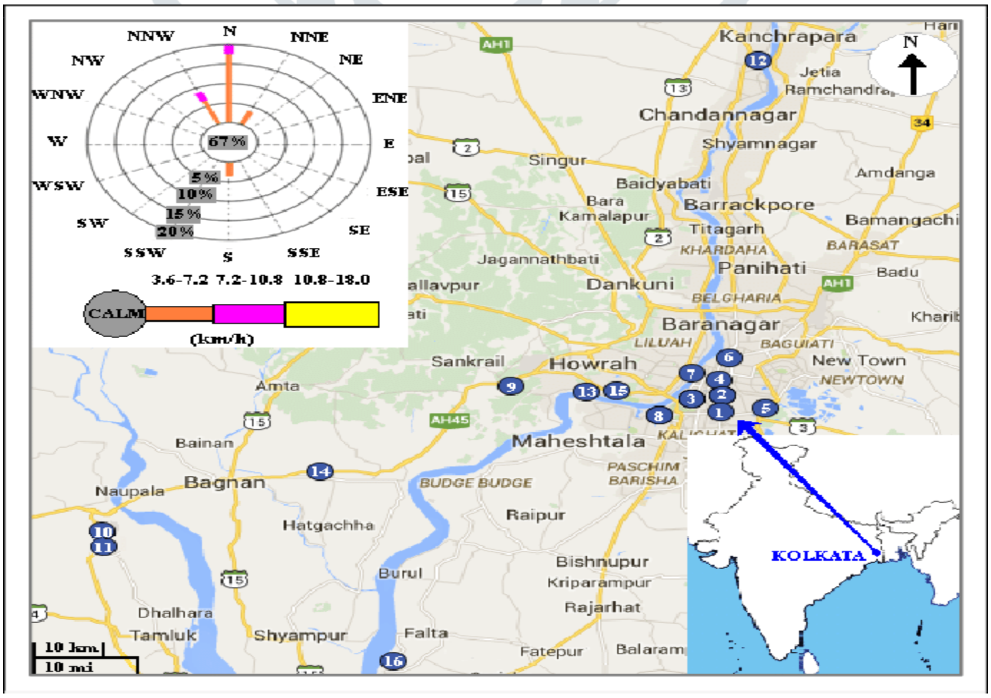

Fig.5: Wind rose data for the existing building in GBS

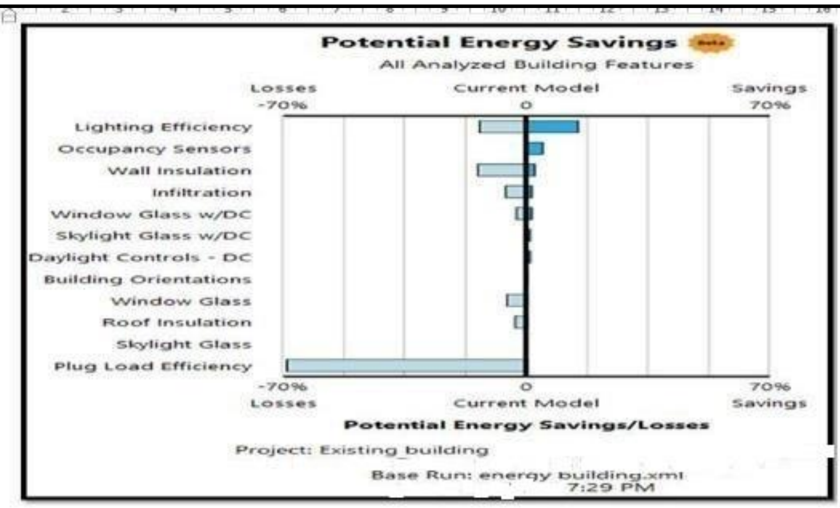

Fig.6: Potential energy savings - base run of existing building analysis

4. PARAMETERS FOR IMPROVING ENERGY EFFICIENCY:

This research work mainly focuses on heat and light efficiency improvement in the existing building. In order to achieve this insulation and skylight parameters are calculated.

4.1 INSULATION ENERGY FORMULA

R-value expresses the resistance to heat transfer. The U- value is the rate of heat transfer per unit area per degree of temperature difference, and is the inverse of the R-value.

The formula has the following form;

$$U = \frac{1}{R} \qquad (3.1)$$

If different cross-sections through a building assembly such as a wall, roof, or floor have different R values, the effective R-value for that surface must be calculated by first calculating the U value of each different cross-section.

4.2 INCLUSION OF A BUILDING SKYLIGHTS

Skylights are designed to bring in natural light, but they also can allow in heat and cold. Skylights that are too large can cause a significant increase in heat during summer months and cold during winter months. Either way, the result is decreased energy efficiency, because more power is required to heat or cool the room. Measuring for the right size skylight will prevent energy efficiency problems.

To keep skylights energy efficient for the homeowner, the industry standard says that a skylight should be approximately 4.75 percent of the floor size of a room where there are many windows and 14.75 percent of the floor size of a room where thereare few windows. Fig 7 shows the skylight area which is included in hall, kitchen and dining area.

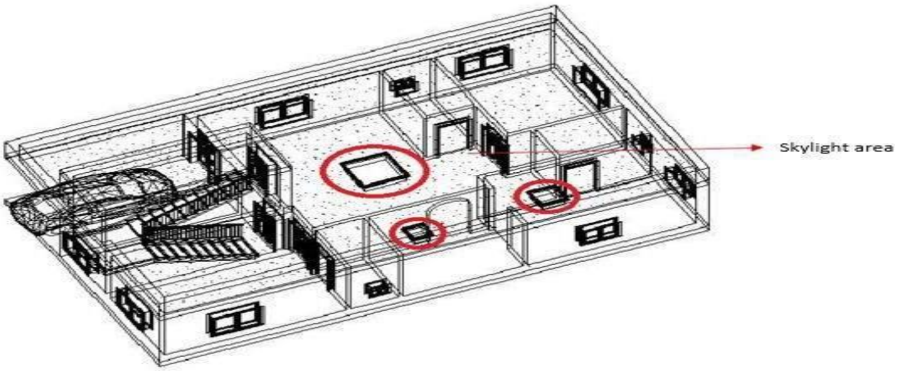

Fig. 7: Skylight area inclusion in subject building.

TABLE 1: SKYLIGHT CALCULATION – MULTIPLICATION FACTOR

Number of windows	Factor of Multiplication
Plenty numbers	Plenty numbers
0.06	0.06
Few numbers and dark	Few numbers and dark

Skylight Area = Area of the room X factor of multiplication (3.1)

Using the above formula,
Here, skylight area is calculated for hall, kitchen and dining area. It allows the daylight to pass in but not the heat. Windows if covered by curtains duringsummer may make the room dark. At that time skylight enables natural day lighting to the building thus eliminating the use of artificial day light during day time.

5. DIFFERENT PART IN GREEN BUILDING STUDIO:

When performing energy simulation using Green Building Studio, building type of the model need to be defined. In order to generate an energy model for simulation, Green Building Studio uses a default value based on building type and project location if a parameter has not been defined in your model.

5.1 DESIGN ALTERNATIVES

The Design Alternative feature allows to modify the base assumptions about your model and then run a simulation that estimates the impact of the modifications on energy efficiency. This feature helps to make significant design decisions quickly. The Design Alternative feature is accessed from My Project tab Run List tab page. `The top portion of the table has standard links to the Run List. The bottom portion of the page has tabs corresponding to the values in the run.

5.2 ITERATIVE PROCESS

The energy analysis in Green Building studio involves iterative process in order to obtain the optimum output in potential energy savings chart. The software comprises of many default options in the Projects default tab for the spaces, zones and opening which differs by material type, thickness and resistance value for insulation. Various options are iteratively analyzed and comparatively optimum result has been taken into account.

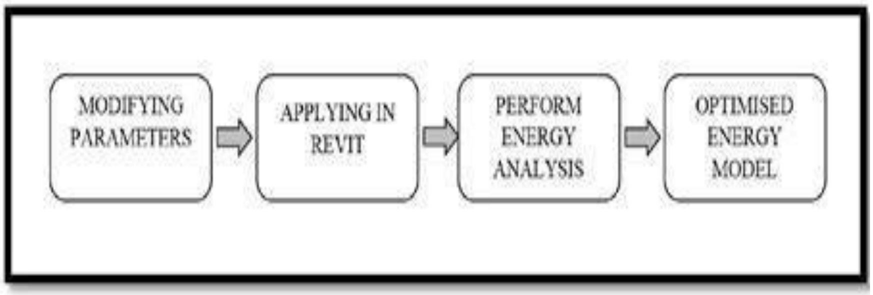

Fig.8: Flowchart representing the iterative analysis process

The first initial analysis had 90 % loss in energy and the following figure shows the analysis made after inclusion of energy efficient parameters with 70% loss in energy. Many trials are run and finally concluded with the minimum loss of 10%. It has been demonstrated that losses reduced substantiallyfrom 90% to 10% thus contributed significant savings in energy.

5.3 OUTDOOR AIR INFILTRATION:

The Outdoor Air value defaults to 15 cfm/person. This value can be edited from the edit menu using Outdoor Air per Person; Outdoor Air per Area; or Air Changes per Hour.
Additional input defaults used in the energy analysis, but not exposed in the Revit or Vasari Energy Settings, are based upon ASHRAE Standards. These defaults can be edited using the Green Building Studio Project Template, Project Default, and Design Alternative features.
These defaults are primarily based upon the ASHRAE 90.1, ASHRAE 90.2, ASHRAE 62.1 and CBECS data, and vary with building type, location, size, and number of floors. For energy settings where ASHRAE baselines do not exist, regional code baselines, or building survey findings are appliedas a reasonable starting point for new construction projects.

6. VARIOUS PARAMETERS USED TO IMPROVE ENERGY EFFICIENCY IN GREEN BUILDING STUDIO

Solar Heat Gain Coefficient (SHGC) is defined as that, fraction of incident solar radiation that actually enters a building through the entire window assembly as heat gain. The SHGC is expressed as a dimensionless number from 0 to 1. A high coefficient signifies high. In the energy analysis SHGC value is 0.27

Visible Light Transmission (VLT) indicates the percentage of visible light that is transmitted through the window. Visible transmission is relatively high for clear glass (about 81% for a single pane) but can be reduced by adding a tint to the body of the glazing, or by applying a colored or reflective film or coating to the surface. In this research VLT is taken as 0.4 based on the default options from green building studio Low emissivity (low e or low thermal emissivity) refers to a surface condition that emits low levels of radiant thermal (heat)energy.

In this project Low E glazing is adopted. Underfloor air distribution systems shall incorporate variable air volume (VAV) units designed to distribute the supply air from under the floor using variable volume boxes or variable volume dampers running out from underfloor, ducted, main trunk lines. The maximum zone size of an underfloor air distribution system shall not exceed 2,360 l/s (5,000 CFM). The domestic hot water system with improved energy efficiency and Package VAV with Underfloor air distribution systems are selected from the drop-down list in Green Building Studio.

VI. RESULTS AND DISCUSSIONS

Energy analysis is most valuable when used early and often enough in a project to take advantage of opportunities to make choices that will reduce a building's energy use. Architecture and engineering teams need to work together to plan and prioritize energy efficiency measures. Potential energy savings chart is meant to make energy efficiency process easier and can be generated easily from energy analysis software Autodesk Green Building Studio.

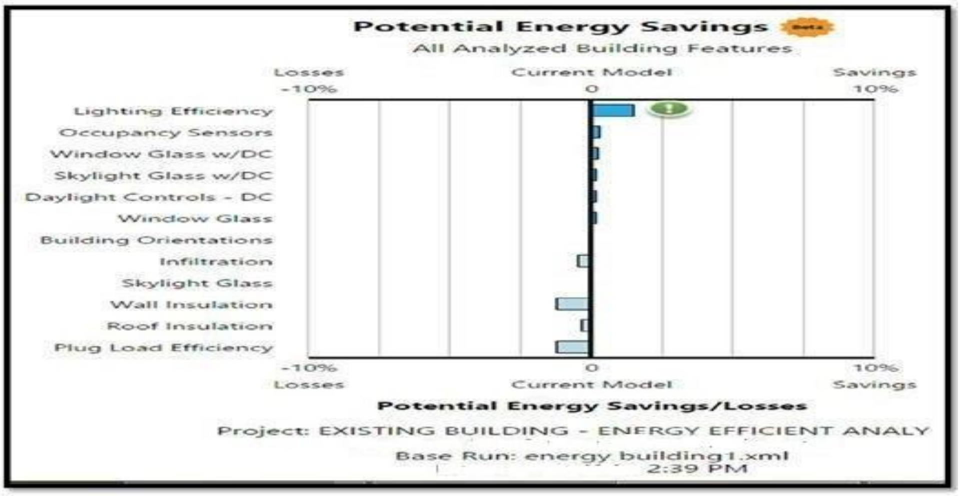

Fig.10: Potential energy savings chart – Optimum model

Wall insulation and Plug load efficiency are important building features affecting energy use (more sensitive). Infiltration and roof insulation are less important to energy use (less sensitive) Lighting efficiency, occupancy sensors, window glass, skylight glass, daylight controls have higher potential for energy savings and infiltration, wall insulation, roof insulation and plug loads have higher potential for energy losses

VI. CONCLUSION

These energy consumption factors can be reduced by using appropriate technology for designing the building envelope, which plays an important role in the consumption of energy in the building. It is concluded from the simulation results that by proper use of shading devices and window glass help in the reduction of energy consumption wherein the roof construction showed less energy benefits. The analysis done during the study highlights the importance of reducing the heat gain through the building envelope and improving the thermal comfort level and energy efficiency in residential buildings. The simulation results show the possible façade design that can efficiently control the amount of insolation, maintain a satisfactory quality of indoor environment, contribute to the reduction in energy demand, and at the same time support and consolidate the architectural vision.

VII. SCOPE FOR FURTHER RESEARCH: FEASIBILITY OF MINIMIZING THE LOSS OF LIGHT AND THERMAL

The application of current industry BIM tools, with enhanced digital workflows in architectural modelling, for the embedding of parameters to the data exchanges for thermal analysis, would provide greater transparency of design intent and address co-ordination issues. Better informed design decisions would be possible that could result in the rapid iterative comparison of design options, greater continuity of project data throughout project phases, and less chance of duplication in design effort to enhance the energy efficiency of residential buildings. There are a number of BIM implementations from around the world that can be used to guide development of Indian BIM use. The energy efficiency provisions of Section J of the Australian building codes could be incorporated in software and rule-based design tools. Associated documented digital workflows, using checking and auditing of digital models, are needed to support the uptake of BIM by industry, with customized Indian object materials.

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