Integrating BIM and Energy Performance for Sustainable Residential Buildings

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Abstract - *The Construction sector is the largest consumer of energy as buildings demand energy in their life cycle right from its construction to demolition. Therefore, it is important for the stakeholders to be concerned about the sustainability and energy performance of proposed building projects. Assessment of the energy associated with the production of construction materials, transportation and construction of buildings help in reducing the use of energy. BIM provides detailed digital representation of buildings that can be integrated with various energy modelling approaches to achieve a sustainable design and assessment of energy consumption. Analyzing the energy consumption of the building components at the conceptual and design stage is helpful in selection of the most suitable design alternative that will lead to an energy-efficient building. This paper focuses on the use of BIM sustainability design tools to achieve energy efficiency in residential buildings. Using Revit Architecture, energy demand will be estimated for a building. The effect of passive design techniques (planning and orientation, natural ventilation etc.) and material selection on building energy demand will be analyzed for the Warangal (Telangana State, India) region. The study will be helpful to make energy related decisions that have impact on the building energy consumption.*

Key Words: Revit Architecture, Sustainability, Energy Consumption, Solar Analysis, Green Buildings.

1. INTRODUCTION

Climate change and greenhouse gas emissions are the most critical environmental issues for mankind [1]. The construction sector globally is having an increase in both emissions and energy use and a lower rate of energy-efficient investment growth. Concrete actions are the need of the hour to control these emissions and deliver a low-carbon, sustainable built environment [2].

As per UN Environment Programme, building construction and operations accounted for the largest share of both global energy use (36%) and energy-related CO_2 emissions (39%) in 2018. In the industrial sector, the most energy intensive industries were iron and steel, which accounted for 15.05 % of the industrial energy use followed by construction for 2.12 % [3].

The building sector contributes for about one-third of the total global energy usage through construction, operation and demolition [4].

Considering the energy-usage requirements of buildings, reduction of energy use mainly depends on the material used for the building's main components and façade [5]. The term 'building energy efficiency' refers to the reduction in energy usage levels while maintaining a comfortable environment. The practice of energy efficiency leads to saving a significant amount of consumed energy [6]. Adopting energy efficient buildings is a key factor to achieve sustainability [7].

BIM is helpful in designing more efficient buildings by integrating Building Energy Modelling (BEM) at the design stage [8]. The key benefit of BIM during the design phase is allowing the project team to make any changes to the project at any time [9]. BIM provides support for the design process which helps in decreasing the carbon footprint of our buildings.

Efficiency of a project is dependent on the adequate care and attention in the planning stage. For a sustainable building, there should be enough awareness about the materials, orientation, heat losses, renewable energies and insulation. Keeping these factors as a baseline, building planning in BIM can help evaluate whether the building design will meet energy regulations or certifications, such as LEED, ASHRAE, and GRIHA etc. But BIM has the potential to go beyond the design stage by modelling control of the building in actual operation [10].

This present study is focused on decreasing the energy emitted by a residential building through adopting various building materials in the planning stage and conducting an energy analysis on the residential building. Building performance simulation was conducted on the case study using REVIT Architecture, Insight 360 and Green Building Studio and various aspects such as thermal performance of walls, insulation materials etc. were analyzed to ensure the energy efficiency of the building. Different factors such as envelope design, heating and cooling loads, lighting, materials, and structural orientation, can be integrated by using BIM and different configurations can be determined to choose the most cost-effective design.

2. METHODOLOGY

In this study, a single-story residential building (Built up Area-725 ft^2 / 67.35 m^2) located in Warangal, Telangana was simulated. Warangal is located in semi-arid region with hot and dry type of climate (Average high of 102^o F in summers and a low of 62^o F in winters). The 3-D model of the building is created using Revit Architecture 2020 with the help of 2-D AutoCAD plans available and the model is further analyzed for energy analysis by Autodesk Insight. Autodesk Insight 360 is building performance analysis tool of Revit useful for Energy analysis, lighting analysis and solar analysis. Green Building Studio is a cloud-based service by Autodesk to carry out Energy analysis and to access the models and results of the analyzed projects are obtained in the form of EUI (Energy Usage Intensity) and Energy Cost.

The annual and monthly operational energy consumption, energy cost, and heating and cooling loads were analyzed. Based on R-values (i.e., thermal resistance) of different combinations of materials, thermal properties of building components are affected that in turn impacts the calculation of annual energy consumption. Later, solar path analysis was carried out to find out the impact of the sun on building energy requirements. This data along with climatic data of Warangal was used to determine how BIM can be used to reduce the energy demand of the building through optimum use of solar energy.

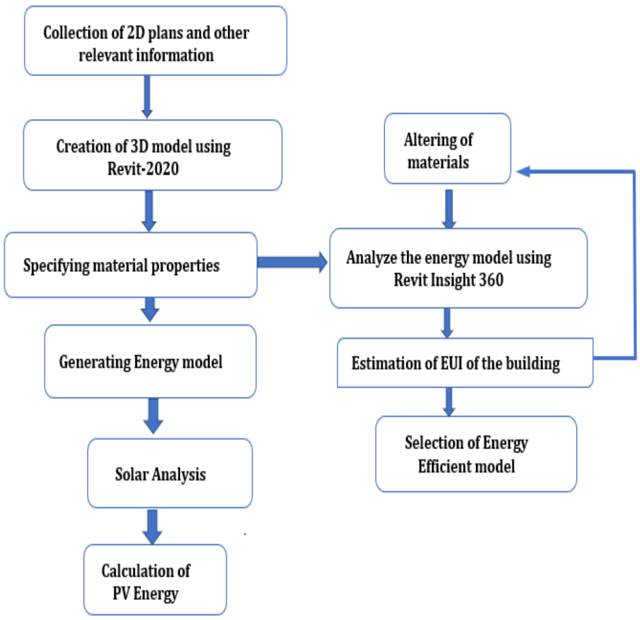


Fig – 1: Methodology

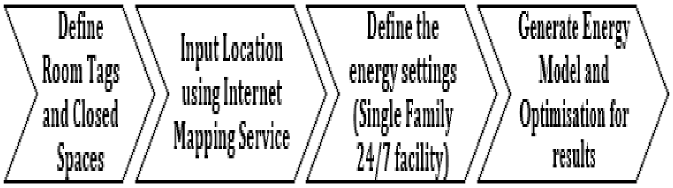


Fig – 2 : Process Flowchart

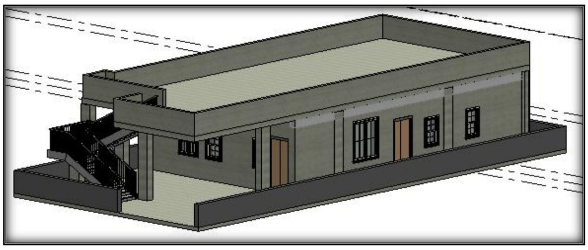


Fig -3: 3D Model of the Project

3. RESULTS AND DISCUSSION

The Energy Analysis results were obtained from Autodesk Insight 360 website. The results show the Energy Assessment Model, EUI (Energy Usage intensity) and different combinations of important criteria including Building Orientation, Window wall ratio (WWR), Window Shades, Window Glass, Wall and Roof Construction properties. By toggling among the different given alternatives, the value of energy cost in USD/m²/ year can be varied and the most efficient model can be selected. Insights gives the results in USD/m^2/year which is the cost of energy per unit of area for a year and the prices for KWh usage of electricity are considered as per the location by applying standard conversion rates. Figure 4 shows the 3D model from Autodesk Insights and the colors are just for differentiating various components of the energy model.

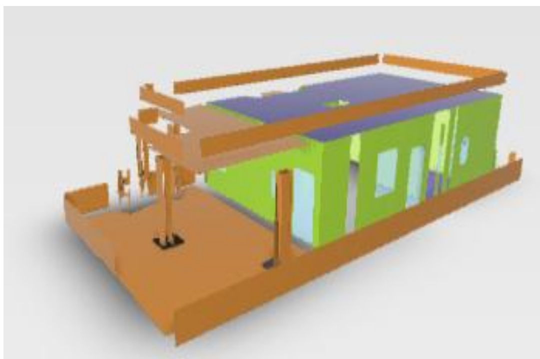
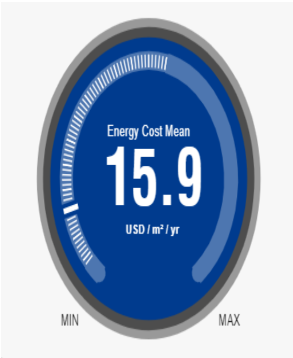
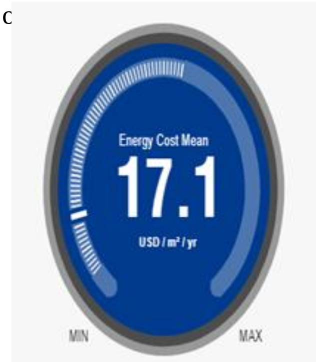


Fig – 4: 3D Model from Insights Website





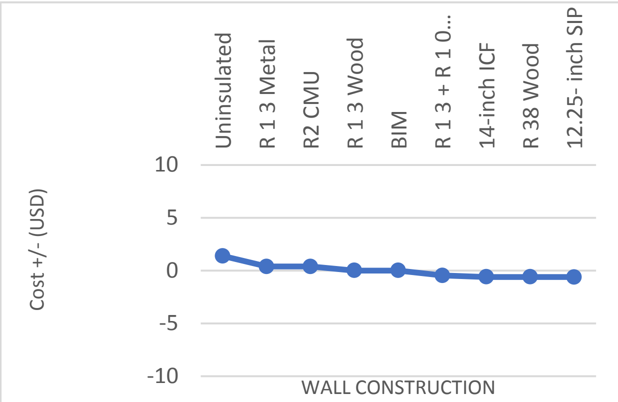
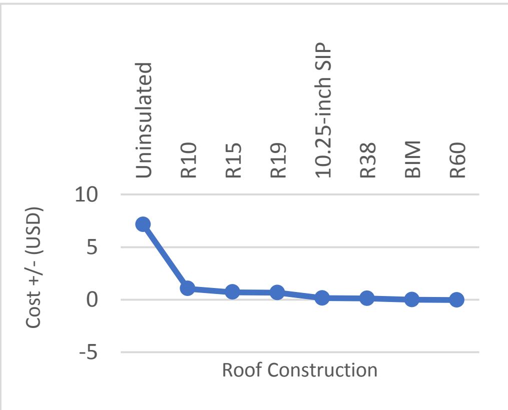


Fig – 5: Wall Construction (R2 CMU vs Uninsulated)



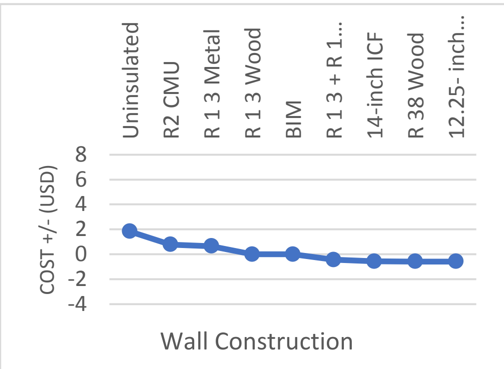
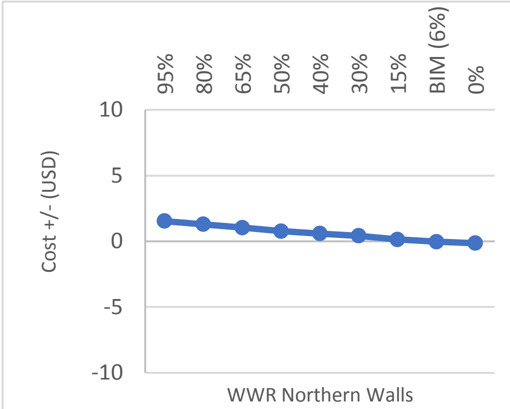


Fig- 6: Energy Cost vs. Different Criteria



Green Building Studio provides 248 run base alternatives for the model analyzed for any energy usage reduction, the building envelope materials play a significant role compared to other aspects. Hence, alternatives with varying envelope materials were selected as mentioned in Table 1.

Table -1: Specifications of materials for alternatives

	Alternative 1	Alternative 2	Alternative 3
Energy Use Intensity (KBtu/sq. ft/year)	128	176	129
Energy Use Intensity (KWh/sq.m/year)	403.7	555.1	406.9
Annual Energy Cost	$499	$591	$499
Lifecycle Cost	$6791	$8043	$6801
Total Annual Energy (Electric KWh)	8661	9632	8648

Alternative No.	Description
Alternative 1	Exterior Walls- SIP Wall 12.25 inch (U value: 0.03 W/ m²-K) Interior walls- Uninsulated interior wall (U value: 0.41 W/ m²-K) Roof – R20 over Roof Deck - Cool Roof (U value: 0.04 W/ m²-K) Floor- Concrete Cast in Place Windows- Double Glazed Doors- Solid Core wood
Alternative 2	Exterior Walls- R2 CMU (8"concrete wall with ½"polyurethane board) (U value : 0.21 W/ m²-K) Interior walls- Uninsulated interior wall (U value: 0.41W/ m²-K) Roof – R20 over Roof Deck - Cool Roof (U value: 0.04 W/ m²-K) Floor- Concrete Cast in Place Windows- Double Glazed Doors- Solid Core wood
Alternative 3	Exterior Walls- Insulated Concrete Foam wall 14 inch(U value: 0.03 W/ m²-K) Interior walls- Uninsulated interior wall (U value: 0.41 W/ m²-K) Roof – R20 over Roof Deck - Cool Roof (U value: 0.04 W/ m²-K) Floor- Concrete Cast in Place Windows- Double Glazed Doors- Solid Core wood

3.1 Solar Energy Analysis

Solar Analysis has been carried out for a period of one year for the roof area of 123 m² using Revit.
Coverage area is taken as 70%.
For the panel of 16.0% efficiency: $2.86/Installed Watt
Electricity cost: $0.15/ KWh
Annual PV Energy Production: 17673 KWh
Building Energy Offset: 52% of 33936 KWh/year
Savings per year: $ 2651
Payback period: 12.1 years

4. CONCLUSIONS

Building orientation and material properties plays an important role in the operational energy demand of a building. In this study, an atempt was made by the integration of BIM into sustainable designing of buildings to reduce operation energy cost. The materials to be selected for Energy Efficiency are based on important parameters like U (Thermal Transmittance) & R(Insulation Value). Among the analysed material alternatives, Alternative 1 has the least Energy Usage Intensity i.e., 128 KBtu/sq. ft/year and hence can be selected as the efficient one. The conducted solar analysis gives the potential energy savings of $2651/ yr, when photovoltaic panels were adopted. This study proves to be helpful to designers as it helps in decision making over the choice of materials which will help in operational energy demand reduction for creating an energy-efficient buildings.

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