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ASSESSING THE ENERGY CONSUMPTION OF NET- ZERO BUILDING WITH THE LIFE CYCLE COST AND ENERGY: AN EMPIRICAL ANALYSIS

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Abstract

The energy used to maintain the internal temperature of buildings and provide partial heating and cooling in buildings constitutes a large part of the energy demand. Therefore, minimizing energy losses and using energy more efficiently is required to decrease energy requirements. Building Information Modeling (BIM) and Energy Assessment (E.A.) tools in the construction process have helped select suitable building materials and significantly reduced energy consumption. In this study, the performance of the building was analyzed in a Green Building Studio (GBS) with alternative materials for optimizing energy performance. Furthermore, life cycle cost, energy use, fuel use, and Energy Use Intensity (EUI) of building components such as, wall, roof, and HVAC, were also analyzed. Building energy modelling, also known as building energy simulation, has developed rapidly in recent years and plays a crucial role in building lifecycle analysis. However, although computer technologies have greatly advanced in recent years and help engineers improve work efficiency, Wall, Roof, HVAC, the design process is still very time-consuming. Optimized results show a better alternative design of building performance, minimizing fuel, electricity, and life cycle costs. The study aims to find an alternative new material for sustainable design in energy-efficient buildings.

Keywords: Sustainable Design, Energy Life Cycle Cost, Building Components, Alternative Design, Building Information Modeling

1. Introduction

Buildings account for 36% of global energy consumption and 39% of energy-related CO_2 emissions.. Reducing construction-related environmental impacts and ensuring that buildings are energy-efficient are indeed necessary for meeting global climate agreements. Global energy needs for buildings are increasing 1.3% per year; electricity needs for cooling and heating the building is the most-utilized energy source in commercial and residential buildings and is expected to increase twice than now due to population growth and the necessary standards of living. Accordingly, buildings are referred to as "primary commercial space" for main reasons- building processes such as lighting, heating, cooling, and ventilation which are responsible for a significant proportion of energy-related greenhouse gas emissions[1].

They are climate zone, type of building, normal development and the status of modern technologies which determine the various properties and capabilities of building materials[2]. By intelligent selection of external walls, ceilings, door materials, window materials and floor areas, and a limited room structure with significant effects, the energy requirement for heating or cooling a room can be significantly reduced. Results from the studies on building life cycle cost on energy consumption show that the Operational stage in conventional buildings accounts for around 80 to 90 % of total energy consumption. Still, the visualized energy is about 10 to 20 %[3].

Based on the keyword "Building Energy Analysis" data was downloaded from the Scopus database. The total number of 2280 removed unrelated data and duplicate data ; finally, The total data retrieved was 1875. The researcher used an R to find keywords, authors, and country-based relationships, which are represented in figure 1 [4]. Lifecycle cost, life cycle assessment, and Energy Efficiency research are most relevant to building energy analysis, represented in the author's keywords of 1875 articles. USA, China, Italy, and Korea contribute to building energy analysis. India needs to research more on lifecycle cost, life cycle assessment and energy analysis.

The current paper discusses the current situation of the sustainable strategy of existing buildings in improving energy efficiency. "Autodesk Revit 2020[5]" and "Green Building Studio"[6] were employed in selecting the optimal alternative building materials that would improve building performance and reduce energy consumption over the life of buildings. Meteorological data and building material properties were used as inputs in the analysis and conversion phases to determine the best scenario for the most critical construction features.

This study optimizes wall material, roof material, and HVAC with the framework. Life cycle cost analysis is used to quantify building envelopes' construction and operational impacts. This study's optimization problem is a multi-dimensional single-objective type that minimizes the sum of life cycle costs over 25 years for building materials and operational energy.

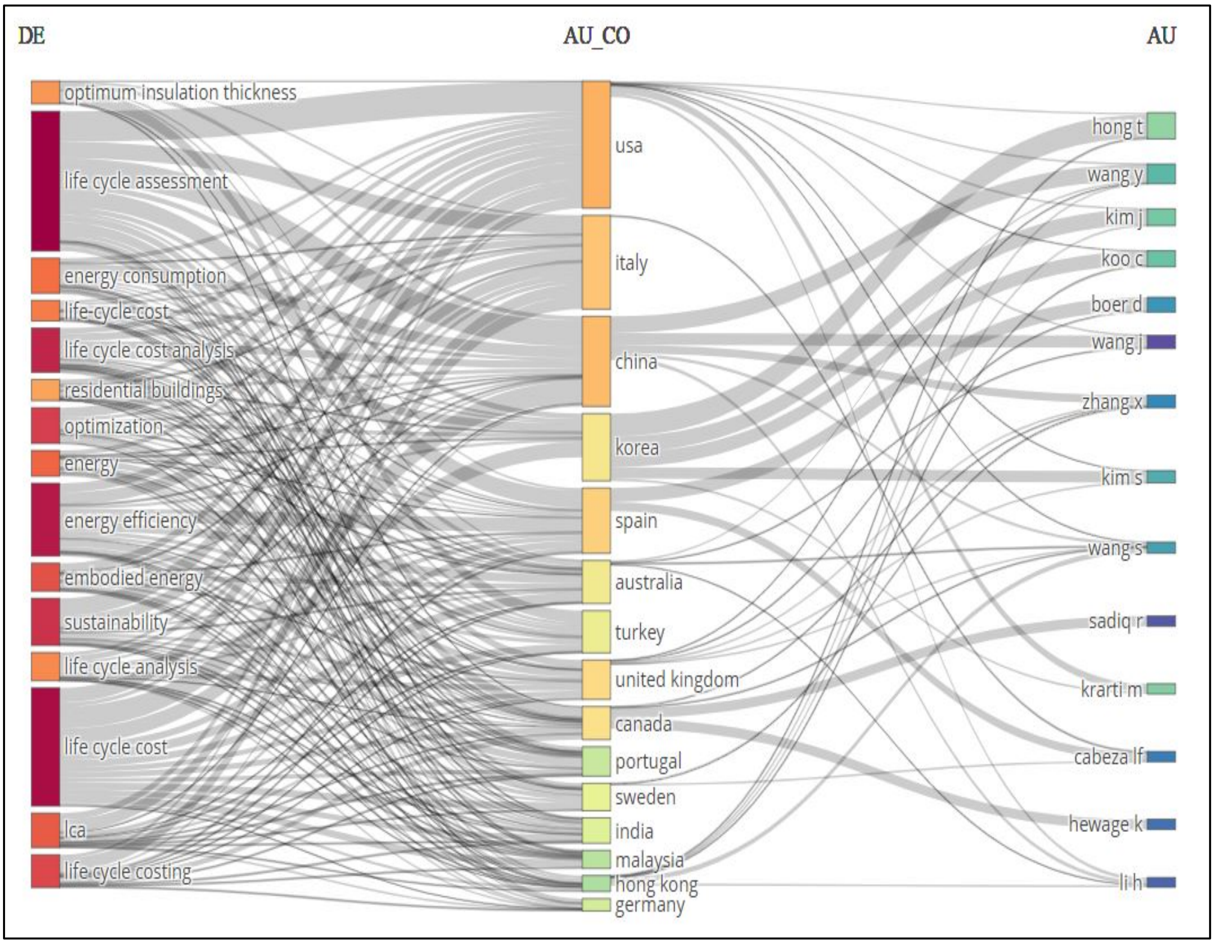

Figure 1 Contribution of author, keywords, and country contribution

3. Work Flow

A building design is outlined with a specific material in Revit 2020 in 2D and 3D. From being in 2D, inputs such as location and spacing were created to convert into an energy model. This Revit file is converted into a gbXML file for Green Building Studio file format, using a green building studio analysis and energy performance building. Using different materials while modelling, the examined building was analyzed with other materials to compare the energy consumption. Building components that have the most significant impact on energy dissipation, such as wall, roof, and HVAC, were identified and examined as shown in figure 2.

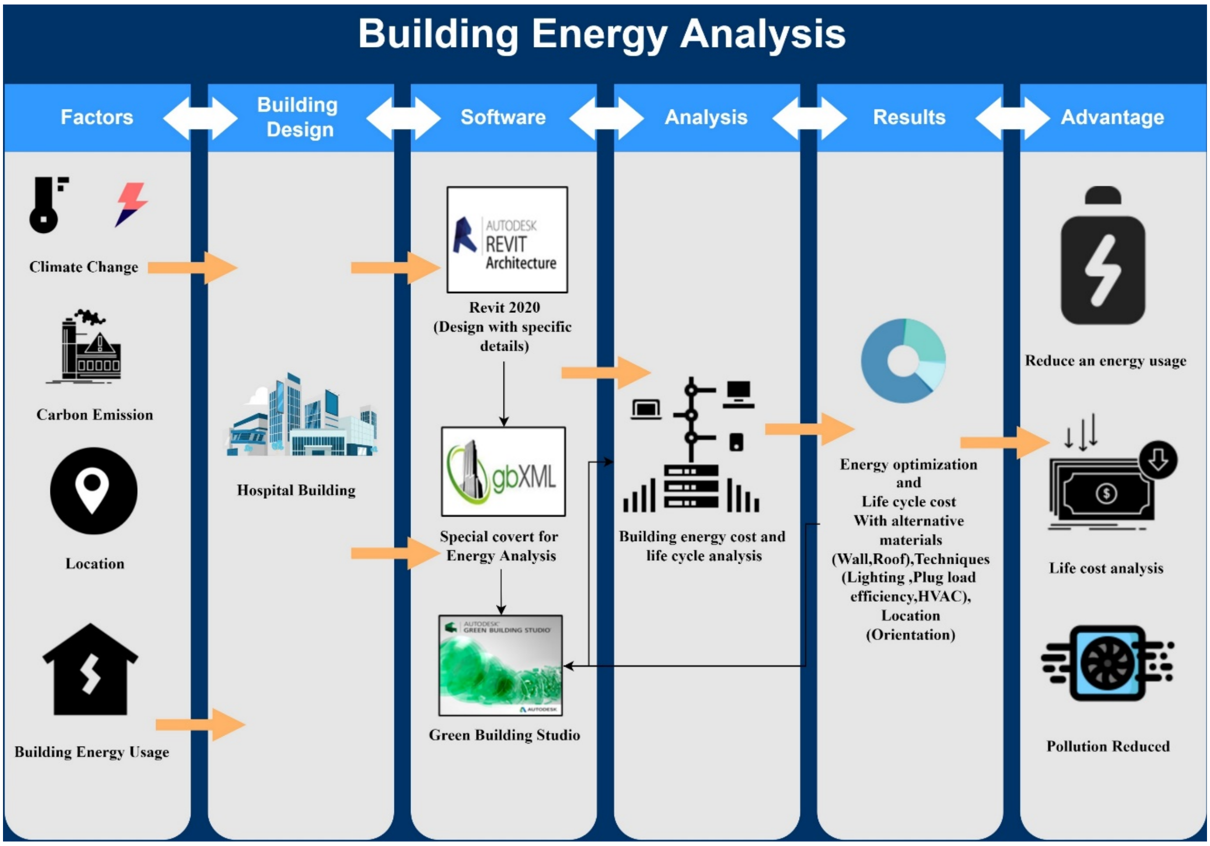

Figure 2 Methodology

3.1 Design

The Design building are a coordinates are Latitude: 13.0827; Longitude: 80.2707, Zone: Tropical, Climate: semi-arid. After location selection, design a Health care centre in a selected location building shown in 3D are Figures 3. Model converted into energy model with a space show Figure 4 analysis thermal and properties of conventional Materials used in Building design.

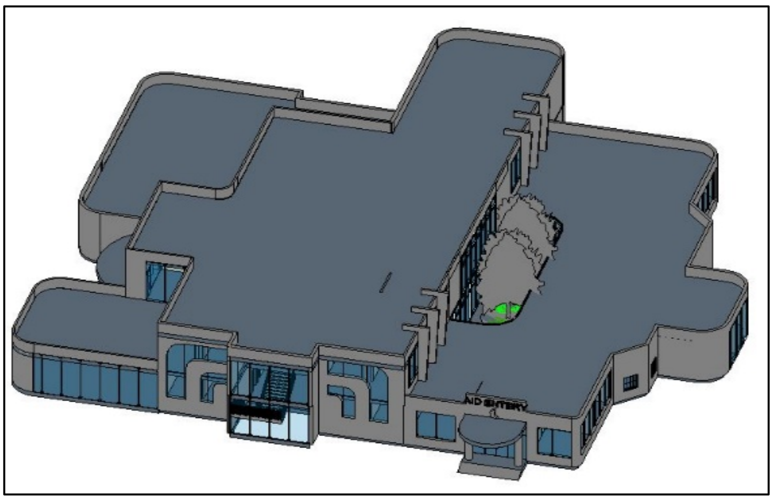

Figure 3 3D Model of health care center

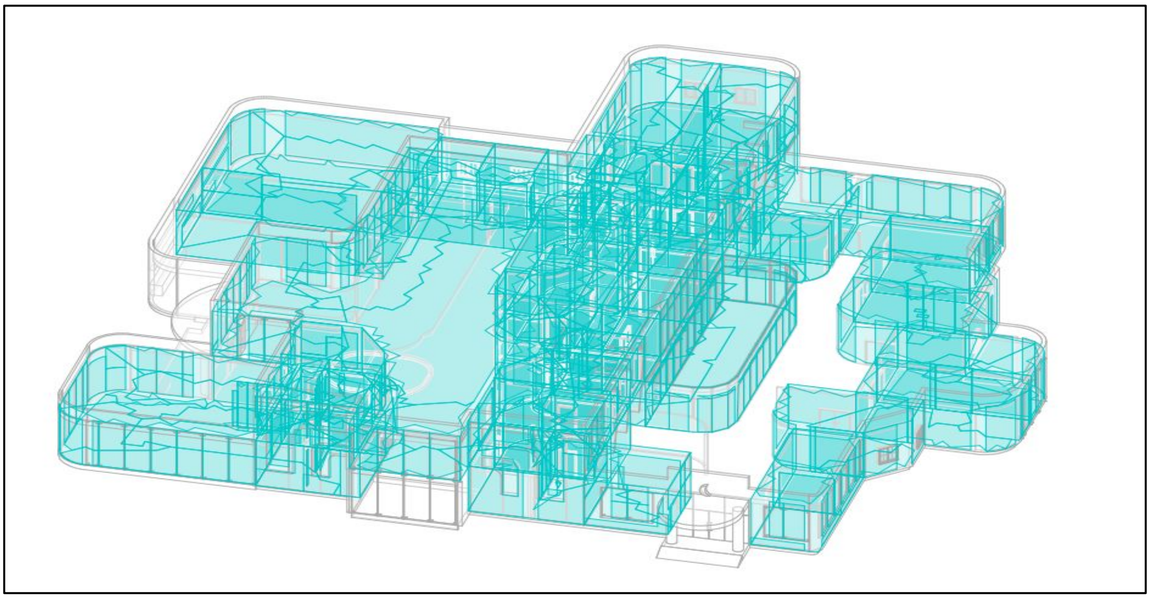

Figure 4 Energy Model

3.2 Software Analysis

3.2.2 Alternative Wall Materials

Walls play an important role in conserving A.C. energy costs when reducing a building's energy usage. Choosing a suitable wall material significantly reduces your A.C.'s energy usage[7]. Removing and replacing exterior non-structural infill brick panels and installing additional insulation materials between the new brick panels and interior concrete masonry unit walls will be examined in this study Figure 8 shows the life cycle of electrical energy (kilowatts), fuel life cycle energy (M.J.), energy intensity (EUI) (M.J. / m² / year). There are eight alternative wall materials in the Green Building Studio: Building without an insulating wall, R13 metal wall, R38 wooden wall, R2 CMU building wall, R13 metal building wall, R13 wooden building wall, SIP 12.25 inch building wall, 14 inch ICF building wall as in table 3 with the production results shown. 14-inch wall construction ICF is an important alternative finding compared to the similarity of wall materials shown in Figure 5.

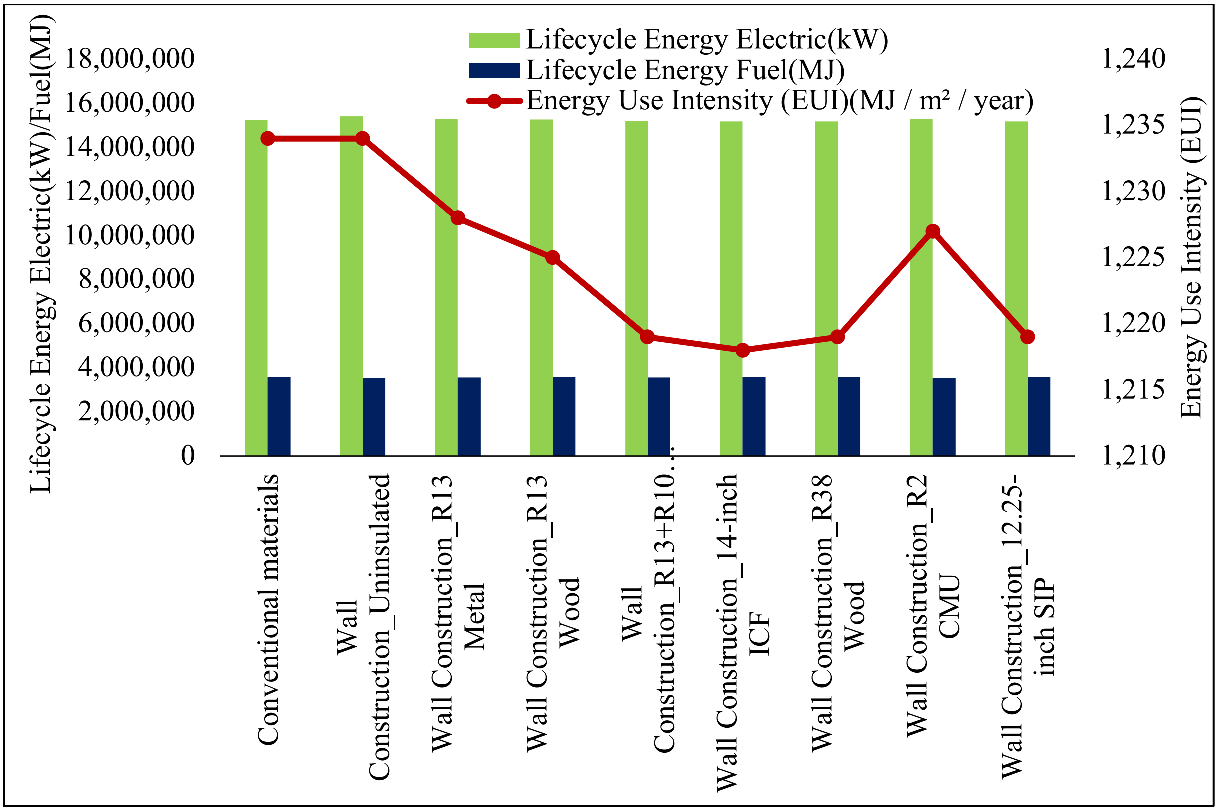

Figure 5 Comparison of alternative design in Wall Materials

3.2.4 Alternative Roof Materials

Alternative roofing strategies, such as green roofs and cool roofs, reduce the impact of urban heat islands and boost a building's energy efficiency[8]. On the other hand, cool roofs and pavements reduce summer urban heat islands by enhancing indoor air quality and comfort[9]. Compared to traditional black roofing materials, the cooling, evaporative, and efficiency advantages of white roofing materials make it an excellent choice. In the Green Building Studio, seven roof replacement materials are insulated roof structure, R38 roof structure, 10.25-inch SIP roof structure, R15 roof structure, R10 roof structure, R60 roof structure, and R19 roof structure displayed in the design results table. The figure shows the life cycle of electrical energy (kilowatts), fuel life cycle energy (M.J.), energy intensity (EUI) (M.J. / m² / year)[10]. Construction Roof_R38, Construction Roof_R60, Construction Roof_10.25 inch SIP are important alternative results compared to conventional wall materials, which are shown in Figures 6.

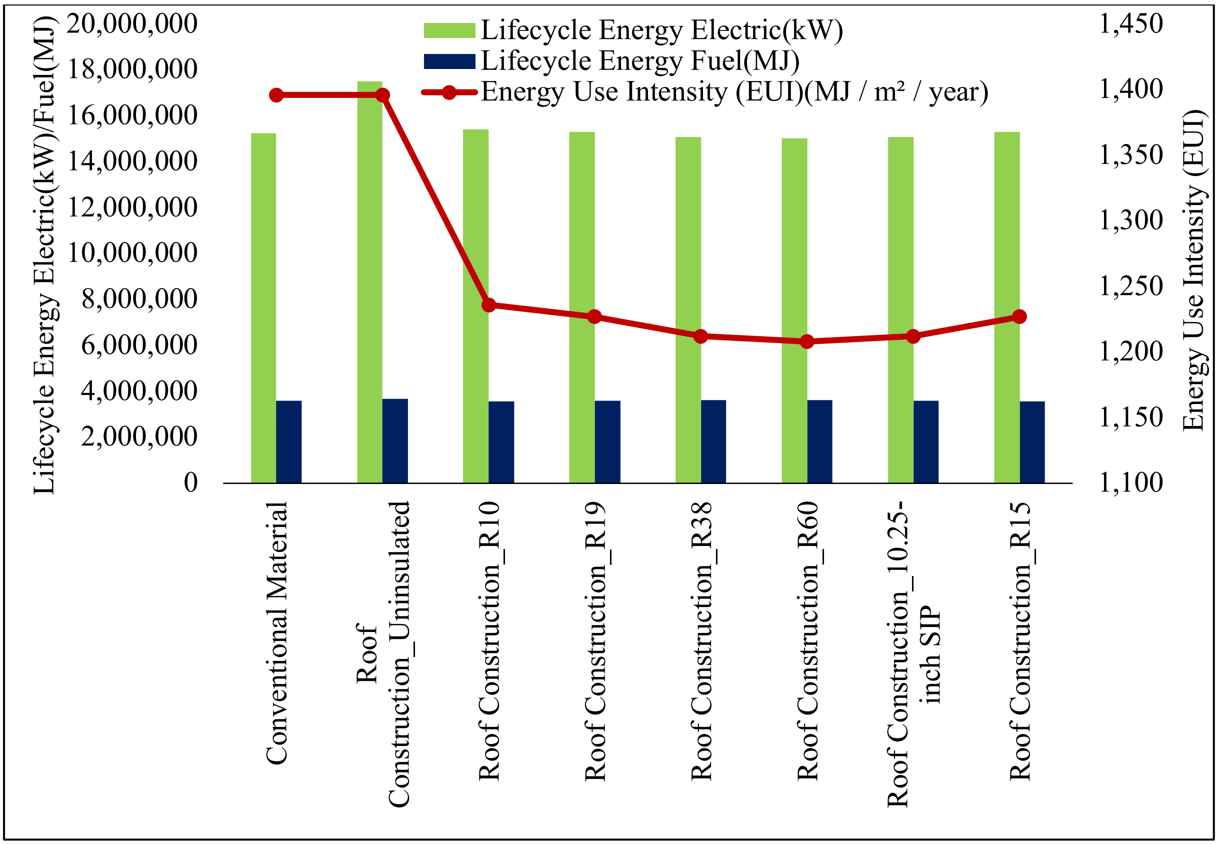

Figure 6 Comparison of alternative design in Roof materials

3.2.5 Heating, ventilating, and air-conditioning (HVAC)

Energy is wasted in the buildings because of poor thermal performance and low HVAC system efficiency[11]. The main purpose of HVAC deployment is to improve indoor air quality, acceptable thermal comfort, and control of cooling and heating temperature in commercial and residential buildings. VAV, types HVAC_ASHRAE centrifuge station P, type HVAC_ ASHRAE package system, types HVAC_High Eff. Heat pumps, types HVAC_ASHRAE Heat pumps, types of high-efficiency HVAC. A.C. terminal package ,. HVAC_ high-performance types. Encapsulation system, HVAC_ASHRAE VAV types. The figure shows the life cycle of electrical energy (kilowatts), fuel life cycle energy (M.J.), energy intensity (EUI) (M.J. / m² / year). HVAC_ high-performance types. Compared to conventional methods, VAV has lower energy costs and energy intensity (EUI) than traditional methods in Figure 7.

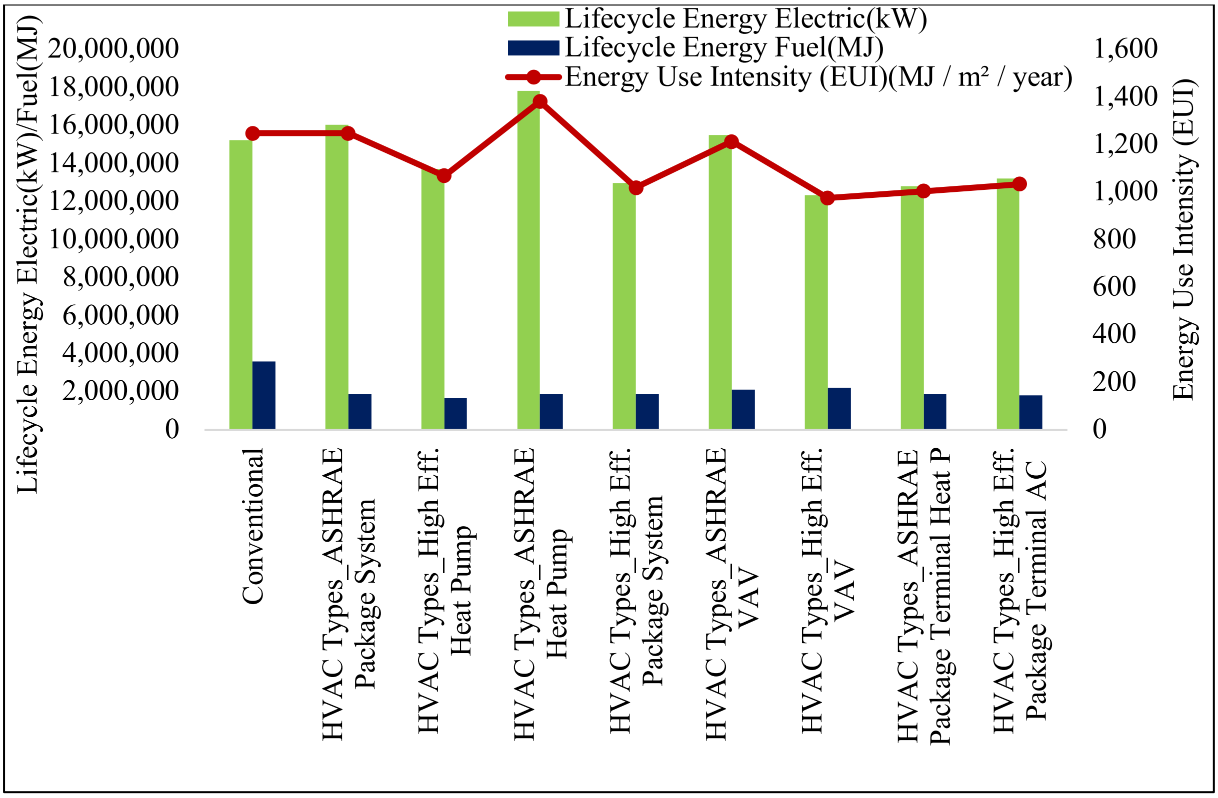

Figure 7 Comparison of Alternative Design in HVAC

4. Discussion of the findings

This study estimates the energy efficiency and life cycle cost analysis of the parameters and components in a Green Studio Building[12]. According to the chosen analysis method, a preliminary evaluation of each building parameter is performed before conducting full energy and cost analysis of recommended parameters in wall, roof and orientation, as well as the efficiency of plug load and lighting as well as HVAC by highly optimized model from an above analysis . The following fhighlights the main variation and the improvement of using suggested parameters comparing suggested Alternative wall material, alternative roof material, and alternative HVAC.

5. Conclusion

In this analysis, to reduce the total life-cycle cost (including operational energy costs) of a hospital building used as a benchmark. Building information modeling **(**BIM) tools evaluate the energy efficiency and life cycle costs of an existing building with Revit 2020 and Green Building Studio, considering study variables including work efficiency, orientation, wall, roof, HVAC, plug load, and lighting efficiency, all of which are components of the building envelope. In this Research paper, the recommended parameters are evaluated against the standard design parameters, which significantly impact operational energy consumption by improving the energy life cycle, fuel consumption, and reducing energy costs. In optimum alternative design with minimum energy cost and use of electric and fuel are Wall Construction_14-inch ICF, Plug Load Efficiency 0.6 W/sf, Lighting Efficiency_0.3 W/sf, Roof Construction_R38, HVAC Types_High Eff. VAV, Building Orientation (Degrees)_315. In the change of alternative design, wall materials with an initial design show the lowest difference, 6% other alternative roof materials with an initial design show 15%.

REFERENCE

[1] P. Moran, J. O'Connell, and J. Goggins, "Sustainable energy efficiency retrofits as residenial buildings move towards nearly zero energy building (NZEB) standards," *Energy Build*, vol. 211, p. 109816, Mar. 2020, doi: 10.1016/J.ENBUILD.2020.109816.

[2] S. O. Ajayi, L. O. Oyedele, and O. M. Ilori, "Changing significance of embodied energy: A comparative study of material specifications and building energy sources," *Journal of Building Engineering*, vol. 23, pp. 324–333, May 2019, doi: 10.1016/J.JOBE.2019.02.008.

[3] P. Rathnasiri and S. Jayasena, "Green building information modelling technology adoption for existing buildings in Sri Lanka. Facilities management perspective," *https://doi.org/10.1080/17508975.2019.1632782*, 2019, doi: 10.1080/17508975.2019.1632782.

[4] G. Nakkeeran and L. Krishnaraj, "Prediction of cement mortar strength by replacement of hydrated lime using RSM and ANN," *Asian Journal of Civil Engineering*, vol. 1, pp. 1–10, Jan. 2023, doi: 10.1007/S42107-023-00577-6/TABLES/5.

[5] B. Ozarisoy and H. Altan, "Low-energy design strategies for retrofitting existing residential buildings in Cyprus," *Proceedings of the Institution of Civil Engineers: Engineering Sustainability*, vol. 172, no. 5, pp. 241–255, May 2018, doi: 10.1680/JENSU.17.00061.

[6] J. Shen, B. Krietemeyer, A. Bartosh, Z. Gao, and J. Zhang, "Green Design Studio: A modular-based approach for high-performance building design," *Build Simul*, vol. 14, no. 2, pp. 241–268, Apr. 2021, doi: 10.1007/S12273-020-0728-9.

[7] M. Marwan, "The effect of wall material on energy cost reduction in building," *Case Studies in Thermal Engineering*, vol. 17, p. 100573, Feb. 2020, doi: 10.1016/J.CSITE.2019.100573.

[8] R. William, A. Goodwell, M. Richardson, P. V. V. Le, P. Kumar, and A. S. Stillwell, "An environmental cost-benefit analysis of alternative green roofing strategies," *Ecol Eng*, vol. 95, pp. 1–9, Oct. 2016, doi: 10.1016/J.ECOLENG.2016.06.091.

[9] Y. Anand *et al.*, "Comparative Thermal Analysis of Different Cool Roof Materials for Minimizing Building Energy Consumption," *Journal of Engineering (United Kingdom)*, vol. 2014, 2014, doi: 10.1155/2014/685640.

[10] J. Park, J. Park, J. Kim, and J. Kim, "Building information modelling based energy performance assessment system: An assessment of the Energy Performance Index in Korea," *Construction Innovation*, vol. 12, no. 3, pp. 335–354, 2012, doi: 10.1108/14714171211244587/FULL/HTML.

[11] M. Elhelw, "Analysis of energy management for heating, ventilating and air-conditioning systems," *Alexandria Engineering Journal*, vol. 55, no. 2, pp. 811–818, Jun. 2016, doi: 10.1016/J.AEJ.2016.01.034.

[12] V. Pereira, J. Santos, F. Leite, and P. Escórcio, "Using BIM to improve building energy efficiency – A scientometric and systematic review," *Energy Build*, vol. 250, Nov. 2021, doi: 10.1016/j.enbuild.2021.111292.