Journal of Building Pathology and Rehabilitation (2022) 7:56
https://doi.org/10.1007/s41024-022-00199-6

RESEARCH ARTICLE

Life cycle assessment for a suburban building located within the vicinity using Revit Architecture

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Received: 23 March 2022 / Revised: 15 May 2022 / Accepted: 20 May 2022 / Published online: 8 June 2022

Abstract
Buildings account for 25% of carbon emissions and 32% of ultimate energy consumption. Urbanization has led to an increase in the requirement for infrastructure in general, which has led to an increase in the demand for housing. Building has a significant influence on the market, community, and the environment, and these issues must be addressed. Building projects that start with the sound design decisions have a far better chance of attaining long-term viability. The environmental consequences of a structure may be reduced through design by as much as 70%. Both the professional and educational groups have welcome to the connections between sustainability and Building Information Modeling (BIM). Construction industry cooperation and productivity are predicted to improve as a result of BIM, which is a mix of technology or organizational solutions that are intended to boost inter-organizational collaboration in building design, construction and maintenance. The increasing of populations is interested in creating ecologically friendly structures that are both high-performing and cost-effective. An approach to analysis a sustainable building that has an energy-efficient orientation and amenities based on the specific location in southern India's subcontinent was presented in the present research. This research work studies a novel approach to implementing an integrated platform for sustainable design in the suburban area.

Keywords BIM · Sustainable design · Energy analysis · Life cycle analysis

1 Introduction

Digitalized technology known as building information modeling (BIM) may be described or characterized as a means of producing, organizing and managing building-related information in an accessible and reusable fashion. BIM has a wide range of useful tools for conducting building behavior analyses, making it easier to examine the sustainability of building design [28]. Conventional LCA devices are still the main technique of measuring embodied energy, and although recent BIM advances have enabled compatibility with energy performance simulation (EPS) devices, current BIM software still requires interoperability with traditional LCA devices. At this phase in the design process, it is common to do an embodied energy assessment since there is less room to investigate unique design options for reducing the building's overall energy use. It is very challenging for designers in the construction business to achieve optimum design due to their extensive workloads and design optimization [34]. Design optimization via the use of BIM may have a substantial impact on attaining sustainable construction [26, 30, 32]. When optimizing for a certain set of performance goals, we're trying to find the best possible solution. With optimization, Geyer believes the solution will be better and the design process will become more efficient. Because of facilities management and building handovers, facility managers are becoming more commonplace later in the building's lifetime. BIM has shown a significant improvement in the design and building process, and it is now beginning to move into facility management as well [8, 23, 35]. Operating and maintaining a facility is more expensive than designing and building it. In order to run their facilities more effectively, construction companies are becoming increasingly interested in the practical expertise of BIM. As a relatively young discipline, BIM in facilities managers lacks a

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wealth of concepts. New construction is the primary target of BIM's facilities management efforts [1, 2]. The BIM facilitates better project and construction process coordination, resulting in higher building efficiency, reduced costs, and shorter design times for projects of all sizes. For those unfamiliar with the symbolism and meanings of the picture, the use of 3D models helps better grasp what we're seeing. These aids in customer and end-user understanding and the development of ways are much more in accordance with their requirements'. An example of a Structure Performance Model (BPM) of a single storey building with a single door, many windows on each wall, a concrete slab, and a roof has been presented by Chung et al. [9]. According to the results, the least amount of energy was used for cooling and heating when the building was oriented at 0° and 180°. Because of this, it is best to face north or south. Using BIM, Shoubi et al. [27] looked at a variety of material combinations to discover new, long-term ways to minimize operational energy use. This technology may also be evaluated at a pre-design or initial design shows the past to find energy-saving methods that surpass the 30% energy-saving requirement above the ASHRAE baseline, as Kim et al. [19] found.

Green Building Studio is utilized in another research to discover energy saving options that meet or surpass the 30% energy saving criterion above the ASHRAE baseline during early design charrette planning [13]. A system for developing sustainable building projects that combines BIM and life cycle assessment tools with a database. It also consists of a minimum of 25% post-consumer and 50% post-industrial materials for at least 90% of the building component and the use of eco-friendly building materials and products (produced from plants gathered within a ten-year cycle or less) for 5% of the total value of all construction materials and components used in the design [18]. An automatic vehicle framework for the integration of optimization techniques, BIM, and LCA has been developed to improve the functioning energy efficiency of building designs adopted while also significantly lowering the difficulties involved with the building's construction in terms of cost and time as reported by Najjar et al. [21] and Imoudu et al. [16]. Another research, by Amani [3], used BIM technology to analyses the energy analyzing of a building by using the effective factors of energy applications. According to the findings, the building may save up to 43.05% of its energy use by applying building information modeling (BIM). Based on the previous literature and the hands-on experience with the energy analysis using Revit software, this paper is planned to draft a building design using the software. In the later part, the drafted model in the Revit -Architecture has been provided with all kinds of specifications such as building materials, HVAV equipment and all other building components that are essential for the building in the suburbs of the study area. The study area selected for this study in the southern part of India with having humid climate. The study area is located in the Vijayawada, Andhra Pradesh, India with location dimensions 16° 20° and 81° 15°. Further the objective of the study is to simulate the building in the Revit Environment to assess the energy consumption of the building towards its life cycle.

2 Role of sustainable design concepts

With the increase of environmental consciousness and action in response to global heat, environmental sustainability will continue to gain popularity in the future. Government programmers, particularly economic incentive schemes, have been created in a number of nations and provinces to promote green building design [6, 33]. There are several methods to measures the sustainability of buildings, including all the elements utilized, the clean energy of the project, the quantity of water used, and the amount of area a structure occupies. For example, the solar panels may be put on the roofs of buildings to provide renewable energy, and concrete can be utilized in place of wood. If you're pursuing a career as a BIM technician, your abilities will be crucial for evaluating the sustainability of architectural components—therefore lowering the environmental effect of the structures.

3 Methodology and steps for simulation

With an integrated design approach, design analysis, material adaptations and system optimization, the building was thoroughly evaluated in this research using designated steps that influence the Revit platform to simulate the uploaded structure. In order to get an idea of how much energy a building would use, Autodesk green building simulation and Revit Architecture are used together. In addition, the software mentioned above is used in this research to create an integrated model as shown in Fig. 1. There has been substantial progress in the capacity to undertake sustainable design at an early stage of a building's existence, to optimize the selections of sustainable building components, and to assess the LCC of alternative design solutions.

4 Study location and observed data

Revit Architecture was used to imitate a traditional Indian bungalow home in Vijayawada, India, which is popular owing to the country's tropical rainy climate. The building

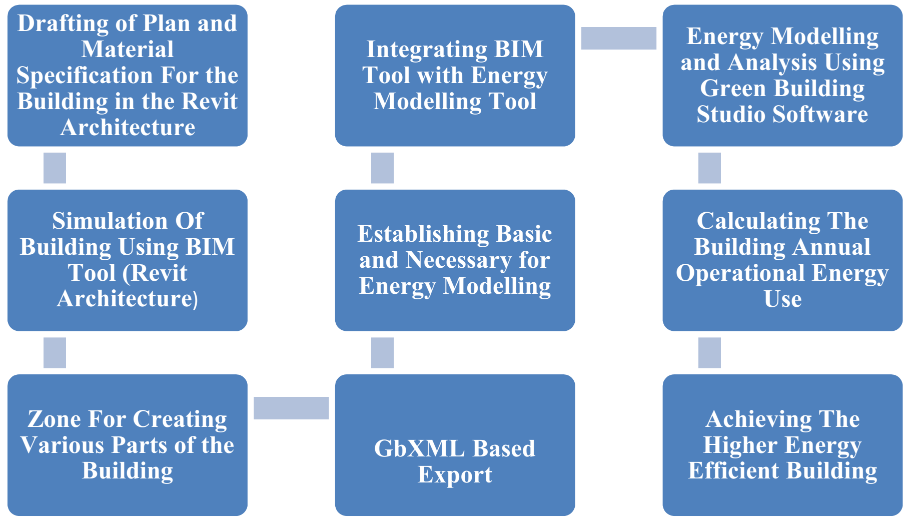

Fig. 1 Flow chart showing the Methodology adopted for this study

Table 1 Shows cases the building details

Building type	Single family type	Building Energy parameters	Values
Total floor area of the building	392 sq. feet	Annual Energy cost	Rs. 29,356
Power supply	24/7	Life cycle cost	Rs. 40,0460
Building location	Vijayawada	Annual electrical energy consumption	7931 kwh
Number of bedrooms	2	Annual peak demand	1.5 kw
Average lighting power Density	1.00 w/ft^2	Energy use intensity	109 kbtu/ft^2/year
Specific fan flow	0.7 cfm/ft^2	Lifecycle electrical energy	237918 kw
Total fan flow	571 cfm	Lifecycle energy fuel	4650 Therms
Total heating capacity	699,993 k Btuh	Natural ventilation hours possible	829 h
Total cooling capacity	− 58,331 tons	Mechanical ventilation hours required	7926 h
Total cooling required	− 58,332 tons	Total fan flow	378 cfm
Total heating required	700,002 kbtuh	Domestic hot water average demand	2616 btu/h
Annual supply fan run time	8760 h		

details are discussed in Table 1 below. Green Building Studio was used to figure out how much energy the home uses on a yearly basis. Figure 1 depicts the technique used in this research, and the procedure will follow it. Selection or adapting drawings blueprints and materials requirements for the building is done in the first stage, and a simulation in the Revit Architecture programmed is run to assess the building's performance [10]. In the Fig. 2 represents that the current study building details layout. Next, Revit Energy Modeling must be used to create different sections of the building. Traditional buildings consume more of the energy resources that necessary and generate a various types of emissions and waste. The solution to overcoming these problems will be to build them green and smart. One of the significant components in the concept of smart green buildings is using renewable energy. Solar energy and wind energy are intermittent sources of energy, so these sources have to be combined with other sources of energy or storage devices. This research represents that the architecture of the proposed green building energy system and a simulation model that allows for the study of advanced control strategies for the green building energy system [12, 24].

The location, kinds and parameters of the energy model must be established in the following phases of the simulation. The file is sent to the Green Building Simulation (GBS) platform for energy modeling and analysis after considering key assumptions. As part of the GBS evaluation, we look at things like the total yearly energy consumption, annual carbon dioxide emissions, and the energy use intensity. There are additional calculations done for other factors such as natural ventilation and solar energy as well as the LEED daylight factor [7]. In Figs. 2 and 3 represents that the building planning construction layout with furniture's. Green building is a recent design philosophy that requires the consideration of resources depletion and waste emissions during its whole life cycle. The design and implementation

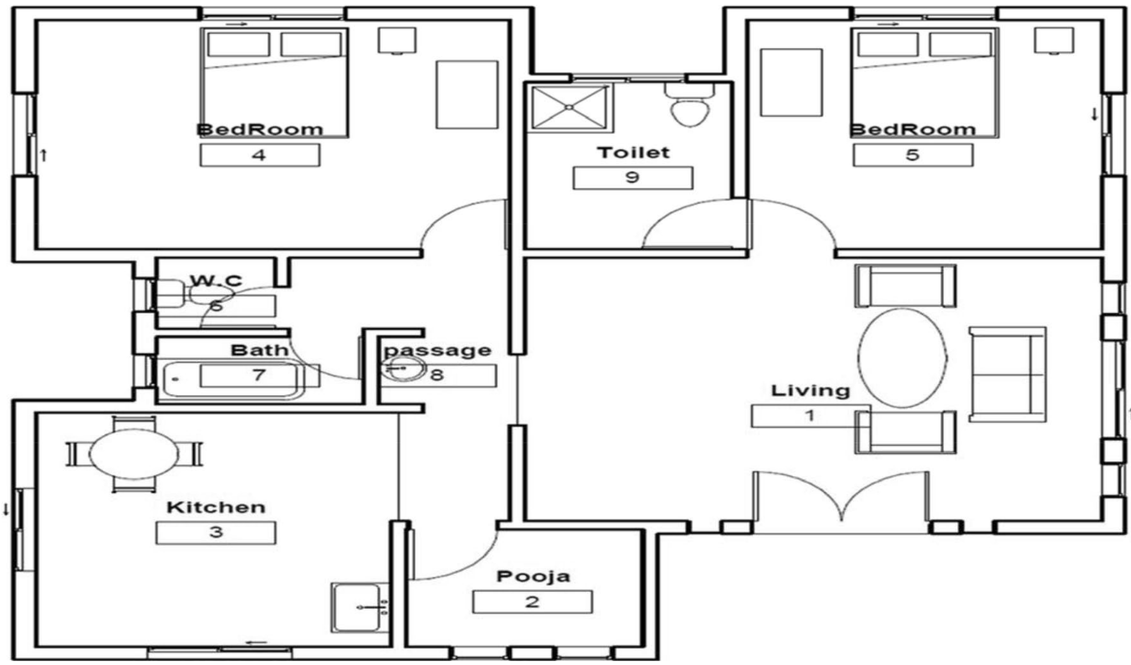

Fig. 2 Depicts the studies of construction layout in the rooms design

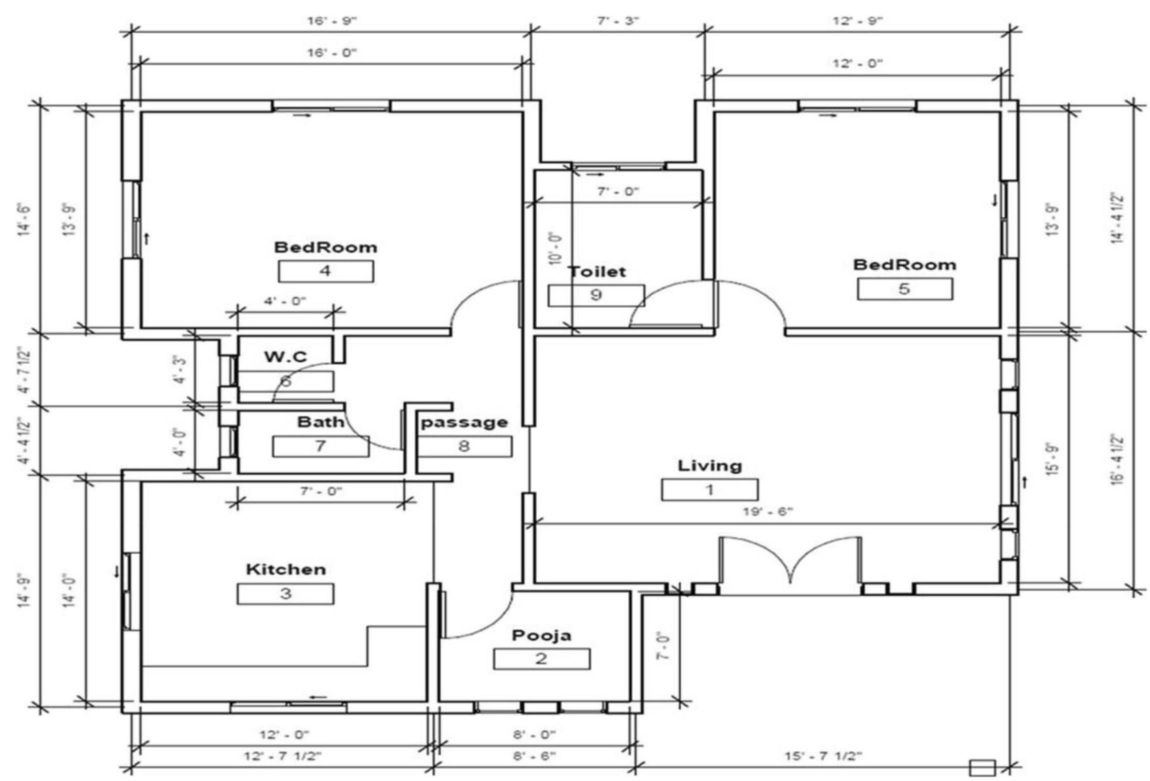

Fig. 3 Planning of the Building with both room types and furniture inside

of the simulation-based optimization system applied for the conceptual design of the green buildings. In the optimization model, variables are mostly envelope-related design parameters such as orientation, building shape, wall type and wall layer. The concept of structured variable is used to describe the hierarchical relationship between the variables. Life-cycle cost and life-cycle environmental impact are two major objective functions that respectively evaluate the economical and environmental performance of a building. The impact categories considered in this research include resource depletions; global warming and acidification are representing in the Fig. 4. They are unified together with the indicator "expanded cumulative energy consumption", which is calculated as the sum of the cumulative energy consumption due to the resource inputs, and the abatement energy consumption due to waste emissions [5, 11].

The system consists of four components: the input and output, the optimizer, the simulation programs, and the data files. The application of green building for different energy sources are represents in the Fig. 4. The genetic algorithm is implemented in the optimizer to solve both single and multi-objective optimization problems. The simulation programs are developed based on the ASHRAE toolkit for building load calculations in order to evaluate objective functions and functional constraints. The system is developed with the object-oriented technology. The case study resulted in multiple Pareto solutions which can help designers to understand the trade-off relationship between reducing environmental impacts and increasing costs due to green design strategies (Fig. 5).

5 Results and discussions

After the analysis all the things, the simulation shows that the building's annual energy cost is around Rs. 29,368, and its life cycle cost is Rs. 4,00,460 for 109 kbtu/ft^2/year of total energy usage and 237,918 kw of life cycle electric energy are the totals. 1 Btu = 1055.06 J. The energy, carbon and cost summary are discussed in the Fig. 6.

Electricity is at the heart of modern economies and it is providing a rising share of energy services. Demand for electricity is set to increase further as a result of rising household incomes, with the electrification of transport and heat, and growing demand for digital connected devices and air conditioning. In Fig. 7 portrays that the information about LEED, photovoltaic, winds energy and ventilation potential. This building's LEED daylight factor is around 2%. Indoor water efficiency costs Rs. 39,354 per year, whereas outside water efficiency costs Rs. 1970 per year. Possibilities for wind power generation. The 747 kilowatt-hours of electricity are generated each year by wind. Overall, this building will need 8755 h of mechanical cooling, with 829 h of natural ventilation being a possibility. As a result, 559 kwh of energy is conserved, saving a total of roughly Rs.1924. The total number of hours needed for mechanical cooling in this building is 7926 [15, 17]. The annual use of energy for electricity production is shown in the Fig. 8. Rising electricity demand was one of the key reasons why global CO_2 emissions from the power sector reached a record high in 2018, yet the commercial availability of a diverse suite of low emissions generation technologies also puts electricity at the vanguard of efforts to combat climate change and pollution. Renewable

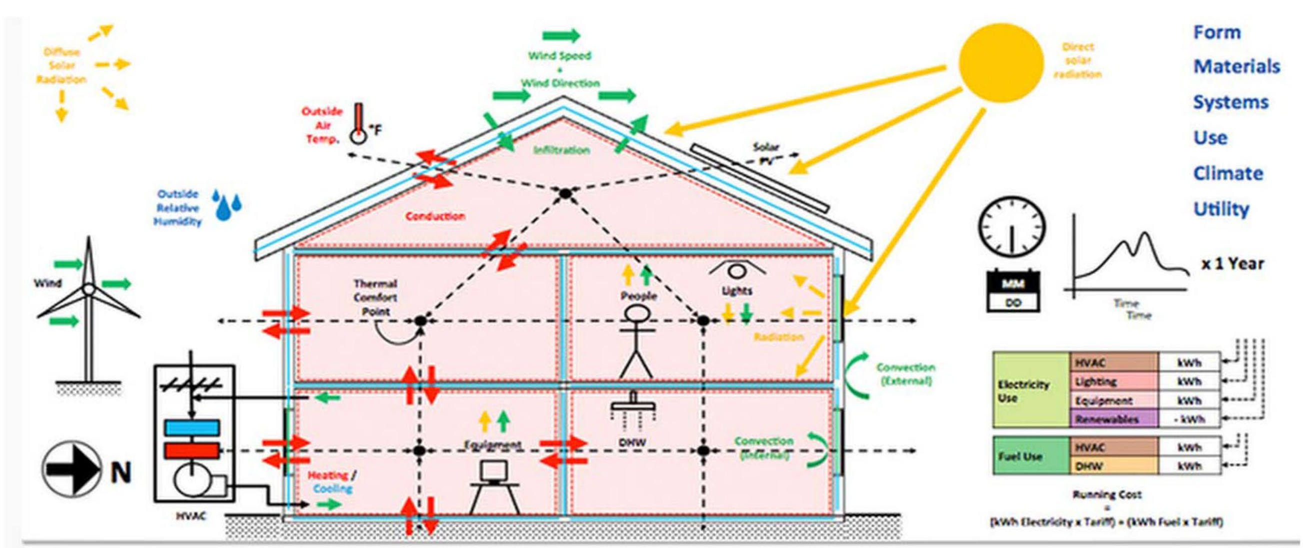

Fig. 4 Green building uses for various energy sources (source: Elements of Green Building elements [31, 32])

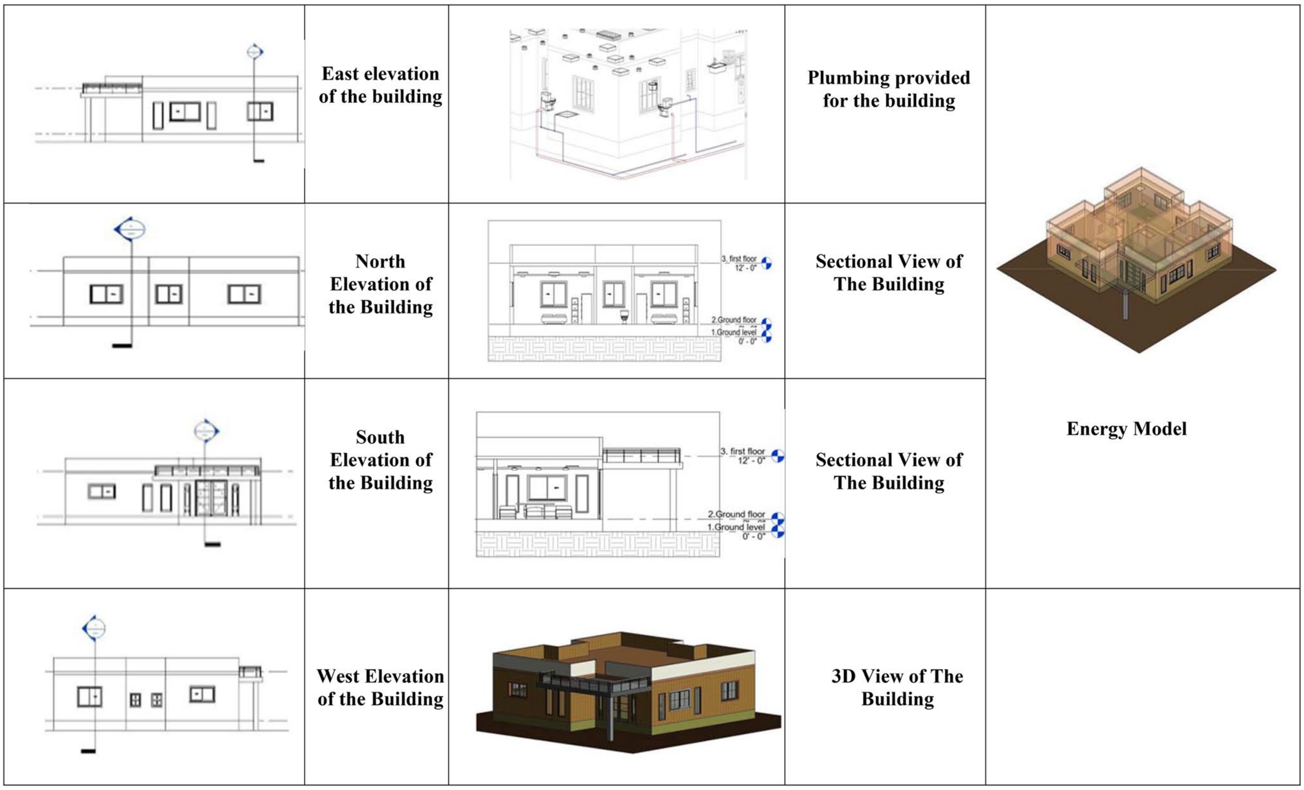

Fig. 5 Elevation, sectional and 3D view of the building

energy also has a major role to play in providing access to electricity for all.

Wind Rose (Jan–Mar): The wind speed in the south-southeast (SSE) direction is greater than in other directions, ranging from 9.9 to 16.5 knots, or 15.6618 to 26.103 km per hour. The wind rose analysis diagram as represents in Fig. 9 of the whole year. Wind Rose (July–September): During the months of July and September, the wind is stronger in the west direction, with an average speed of 26.103 km/h. Wind speeds vary from 3.9 to 5.8 knots, or 6.1 to 9.1 km/h, on around 120 days out of the year, or 33% of the time [4, 14].

Construction work must often be performed under the influence of external factors, including the weather. Contractors must suspend any activity that cannot be completed safely when weather conditions are unfavorable. The life cycle of energy consumptions and cost of the project work is discussed in the Table 2. The weather cannot be predicted with 100% accuracy, and conditions can change in seconds. There are also site-specific conditions that create microclimates, such as terrain features and surrounding constructions. Weather risks can only be managed effectively with the direct measurement of meteorological conditions [29, 31].

Measuring wind direction is also very important since risks change depending on the direction from which the wind blows. In the case of tower cranes, the mechanical loading effects of the wind are determined by speed and direction. Most weather risks in construction are related to the wind, but there are other factors that must be kept under watch [25]. The ultimate outcomes of the construction are replicated and discussed in the Table 3. The graphical representation of weather data is discussed in the Fig. 10. The higher temperatures are dangerous for workers, and they can limit the ability to concentrate. Very low temperature also threatens equipment, since it reduces the loading capacity of many components.

Fog, rain and any other factors that limit visibility should be considered. Construction workers must be fully aware of their surroundings to work safely and low visibility makes accidents more likely. When strong winds occur along with low visibility, the risks are increased. To be useful in construction management, a weather monitoring system must have remote connectivity [20, 22].

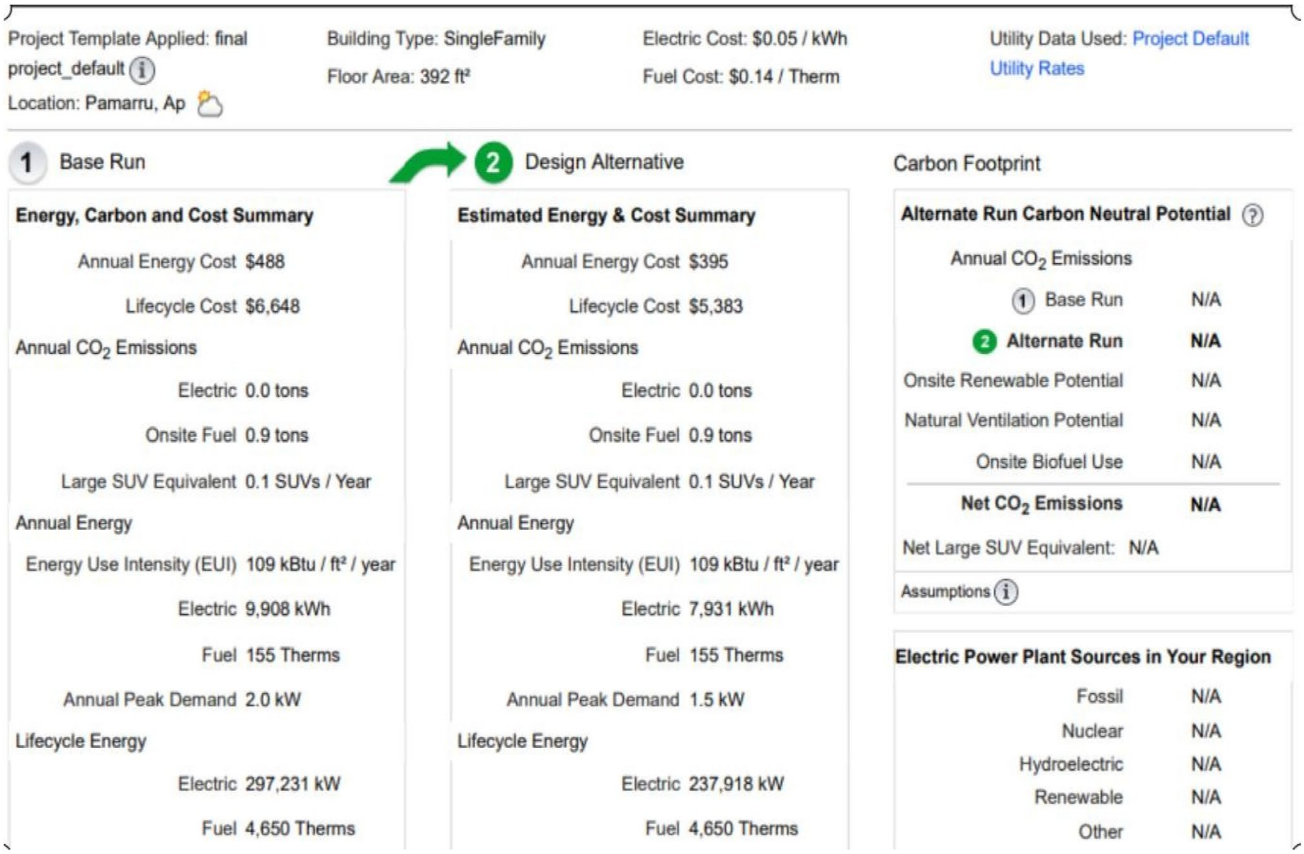

Fig. 6 Energy, carbon and cost summary

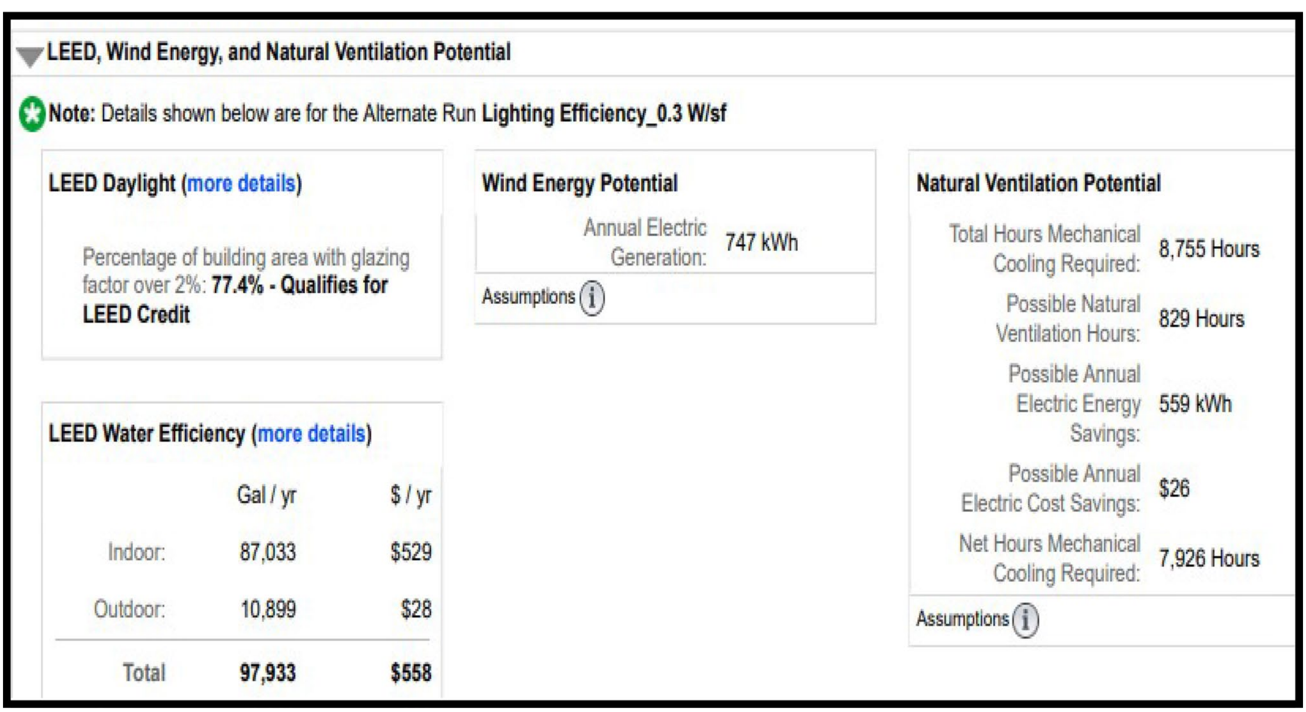

Fig. 7 LEED, photovoltaic, wind energy and natural ventilation potential

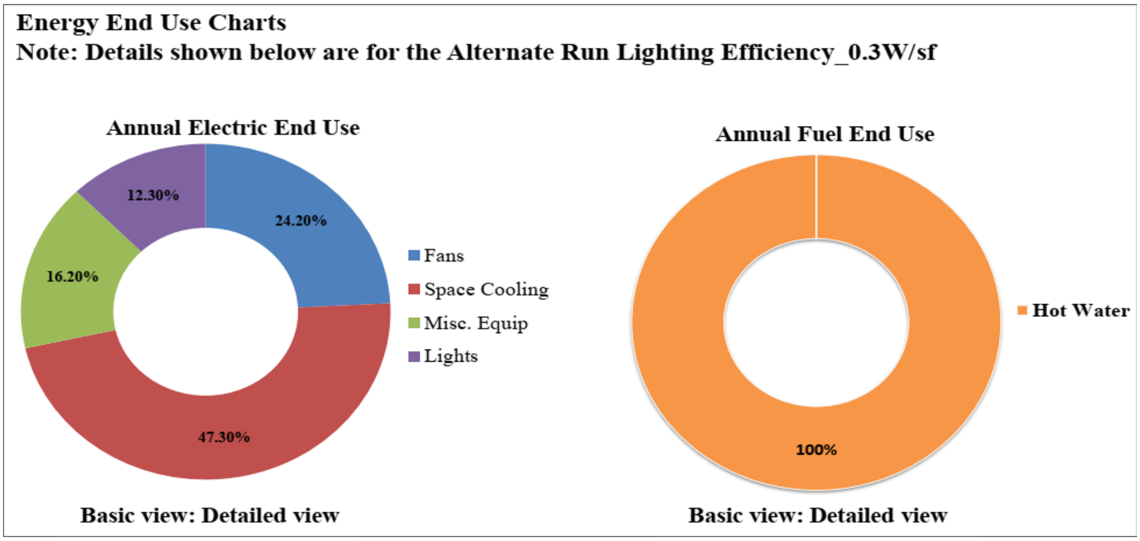

Fig. 8 Energy end use charts

6 Limitations of the study

These research work had utilized the use of BIM technology that is considered to be the need of the hour technology ruling the world, in fact the same software has been utilized to construct the Leishenshan & amp; Huoshenshan hospitals in China. During Covid 19, the project stakeholders had utilized the BIM software to analysis the building design, analysis and management of the project. Keeping in view of the applicability and reliability, the present study had considered few aspects according to the available libraries in the Revit software. Most of the default libraries are proven to be satisfactory and have secured 96% similar results with manual estimation.

7 Conclusion

The yearly energy cost of a structure in the base run is Rs. 36,268; however, the annual energy cost of building constructed using energy-efficient materials is Rs. 29,368; this represents a 19% reduction in the energy costs. A typical building's life cycle cost is Rs. 10,83,360 throughout its 30-year lifespan, but an energy-efficient building's life cycle cost is Rs. 8,81,040 (over the same period), resulting in an 18.67% efficiency in terms of total life cycle cost. In the base run, the annual electrical energy consumption of a building is approximately 9908 kwh, whereas the annual electrical energy consumption of a building after the use of energy efficient materials is 7931 kwh. It has a 19.95% efficiency rating. The consumption of electricity of the building during its life cycle is 297,231 kw, which is reduced to 237,918 kwh by employing energy-efficient materials, which is about 19.95% efficient. The fuel consumption of the building before and after optimization is the same, at 4650 thermal units, which is the same as before and after optimization. During the lifespan of green buildings, BIM might enable data interchange and integration, offer graphical building performance studies, and improve communication and cooperation among diverse stakeholders. A discussion was held on the benefits and limitations of using BIM functionalities for environmental sustainability studies of buildings. A total of four primary BIM functionalities for green studies were identified and thoroughly reviewed: building energy analyses and assessments, carbon pollution analyses, naturally ventilated system analyses, and water consumption analyses.

8 Recommendations

Two limitations of the study methodology must be noted and addressed for future research. The collected papers for scientific analysis were obtained from the databases Web of Science and Scopus; hence, the articles that were unavailable in such databases were not analyzed in the present study. The second relates to the time period of data gathering, such as the number of scientific articles and citations for research conducted between January 1, 2015 and June 30, 2021. In this regard, future research might gather the most recent database information in order to provide the most current findings. As per the existing gaps and limitations at the intersection of the Project lifecycle

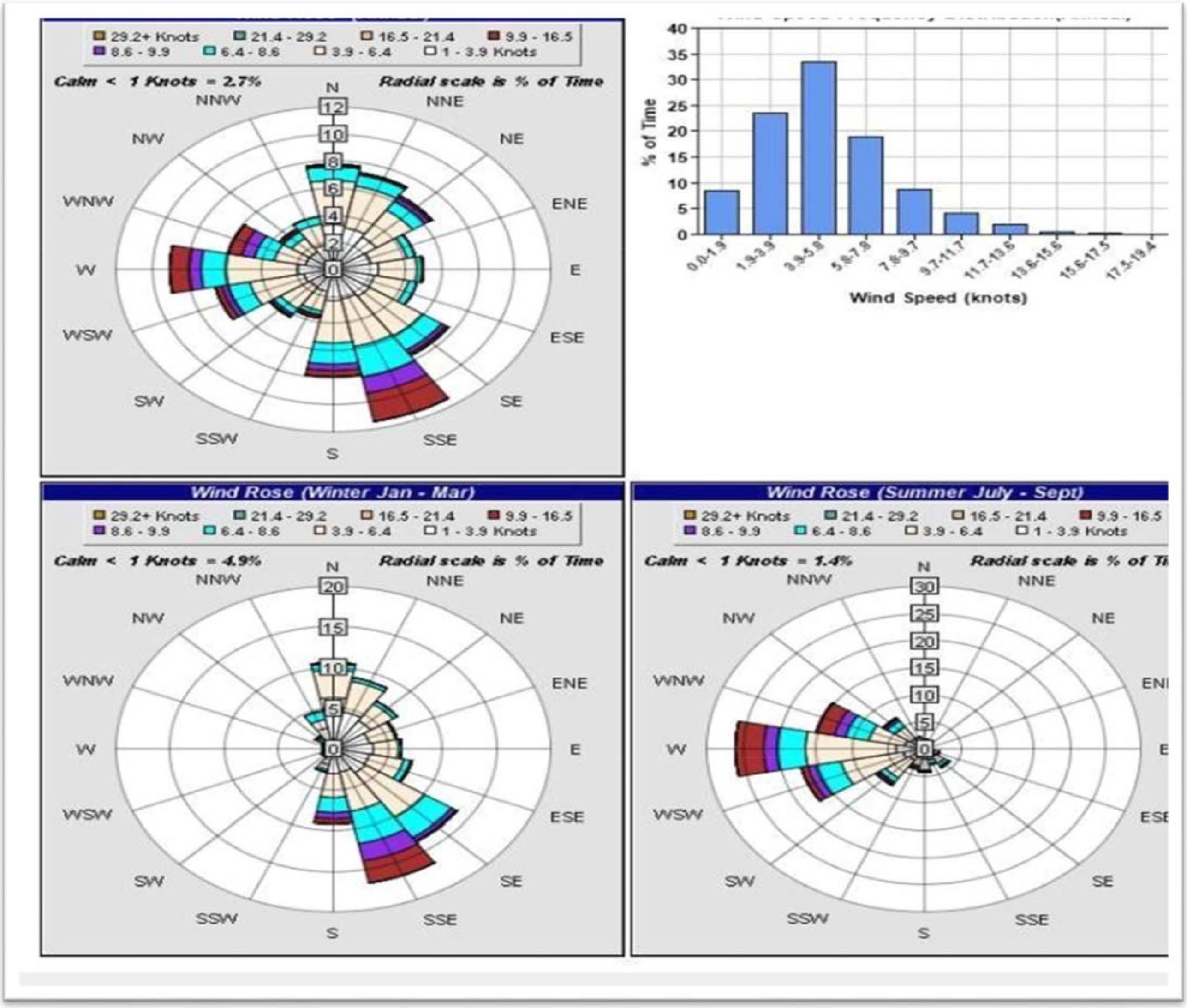

Fig. 9 Wind rose diagram

Table 2 Life cycle of energy consumption and cost of the project work

Life cycle	1 year	10 years	30 years
Life cycle energy consumption	109 kbtu/ft^2/year	1090 kbtu/ft^2/year	3270 kbtu/ft^2/year
Life cycle cost (INR)	Rs. 29,368	Rs. 2,93,680	Rs. 8,81,040

Table 3 Building energy parameters in consumption and cost of various projects

Building energy parameters	Consumption	Cost (INR)
Annual energy	109 kbtu/ft^2/year	Rs. 29,368
Electric	7931 kWh	Rs. 27,762
Fuel	115 Therms	Rs. 1606

and sustainability, additional research is suggested in the following fields: investigating the functionality of BIM in accomplishing economic cohesion, combining BIM with facilities managers and examining the potential of BIM in carbon reduction for accomplishing gross zero emission programmers.

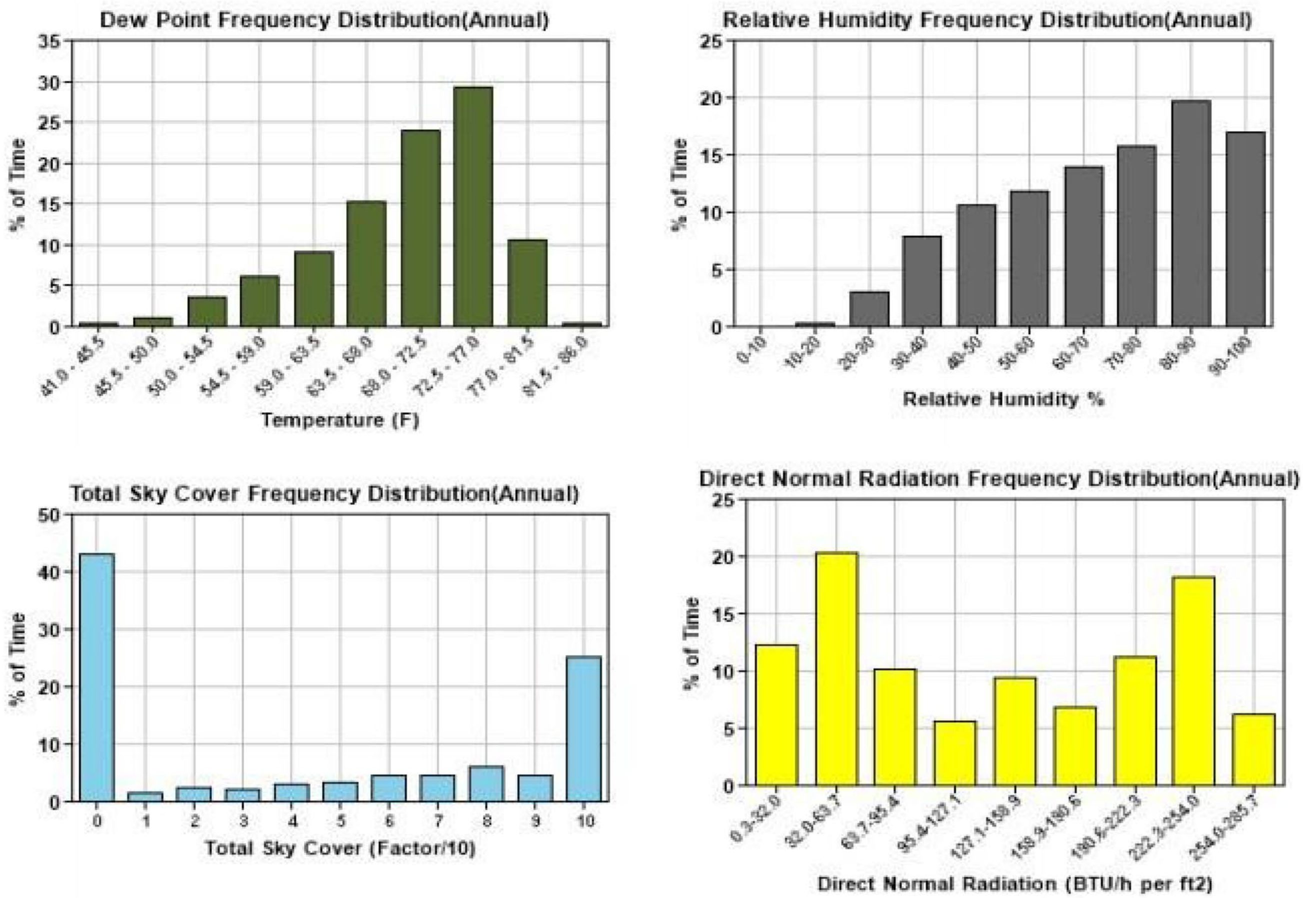

Fig. 10 Graphical representation of the weather data

Funding This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability statement The statements in the paper are properly cited in the manuscript and no additional data is available.

Declaration

Conflict of interest The authors declare no conflict of interest.

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