Civil Engineering and Architecture 11(4): 1776-1794, 2023
DOI: 10.13189/cea.2023.110410 http://www.hrpub.org

Energy Consumption of Composite Structure in Various Regions in India: A BIM Approach

Arun Kumar B[1], Daniel C[1,*], Amudhan V[1], Sandya Devarajan[2], Tahara R M K[3], Arunraj E[4], Arun Solomon A[5]

[1] Department of Civil Engineering, Hindustan Institute of Technology and Science, Padur, India
[2]Lupiter Technologies LLP, Chennai, India
[3]Department of Civil Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, Selangor, Malaysia
[4]Department of Civil Engineering, Karunya Institute of Technology and Sciences, Coimbatore, India
[5]Department of Civil Engineering, GMR Institute of Technology, Rajam, India

Received January 13, 2023; Revised February 21, 2023; Accepted April 7, 2023

Cite This Paper in the Following Citation Styles

(a): *[1] Arun kumar B, Daniel C, Amudhan V, Sandya Devarajan, Tahara R M K, Arunraj E, Arun Solomon A , "Energy Consumption of Composite Structure in Various Regions in India: A BIM Approach," Civil Engineering and Architecture, Vol. 11, No. 4, pp. 1776 - 1794, 2023. DOI: 10.13189/cea.2023.110410.*

(b): *Arun kumar B, Daniel C, Amudhan V, Sandya Devarajan, Tahara R M K, Arunraj E, Arun Solomon A (2023). Energy Consumption of Composite Structure in Various Regions in India: A BIM Approach. Civil Engineering and Architecture, 11(4), 1776 - 1794. DOI: 10.13189/cea.2023.110410.*

Abstract Energy - efficient building design has become an important factor to be considered in Architecture, Engineering and Construction (AEC) industry to develop sustainable structures as a result of other environmental issues and the ongoing rise in global warming. The necessity of the hour is to predict the building's energy use and use an appropriate energy-saving solution and construction design. Commercial buildings are a significant energy consumer and a primary factor of CO_2 emissions during the course of their existence. As a developing country, the practice on energy efficient building in India is not as much as in developed countries. In the present study, a commercial composite building located in five regions in India with different climatic conditions assist its energy consumption using Building Information Modelling (BIM) tools. Modelling of the structure is developed using Autodesk Revit Architecture. ETABS is used to analyze the structural stability of the proposed composite commercial building. Further for energy analysis, Autodesk Green Building Studio (GBS) and Autodesk Insight are used. From the GBS results, commercial building which is located in Dispur, Assam has less EUI 863.8 MJ/m^2/year compared with other four regions of India. The building in the Assam region is further examined using Autodesk Insight to determine the various design strategies with regard to Energy Use Intensity (EUI). The EUI for the Assam region has been shown to vary by a significant amount due to small variations in design strategies. Through energy analysis, the cost of energy could be significantly decreased by using BIM, which helps implement better design alternatives prior to building construction by optimizing yearly energy budget when compared to conventional techniques.

Keywords Building Information Modeling (BIM), Energy Analysis, Energy Use Intensity, Energy Cost, Greenhouse Gas Emission, Composite Commercial Building

1. Introduction

The most recent IPCC (Intergovernmental Panel on Climate Change) AR6 (sixth Assessment Report), buildings were shown to be the primary source of energy consumption and greenhouse gas emissions worldwide. Due to global warming, these have a harmful influence on the environment and communities. It is not unexpected that the building sector now began to respond to the increasing demand for energy-efficient structures. A case study of domestic small-scale building, which is located in United

Kingdom, is modelled using Autodesk Revit and exported to Green Building Studio (GBS) via gbXML format to change the orientation of the existing building. Savings of $878 over a 30-year period are possible by turning the orientation of building to 180^o [1]. Water conservation, energy efficiency, sustainable material sourcing, industrial growth, recycling, waste management, climate change, transportation systems, and biodiversity are all aspects of sustainable development. In order to determine the financial impact and Cost-Benefit Ratio (CBR), Ahmed and Ghadge conducted an analysis of a hotel building that takes into account a number of factors, including sun-path, location, orientation, heating and cooling loads, thermal properties of materials, ventilation, and daylighting [2].

The commercial building located in vadodara city, Gujarat, India was modelled using Autodesk Revit architecture for the energy analysis (EUI and energy cost) that is evaluated using Autodesk Insight, using different design strategies (Window Wall Ratio, operating schedule, lighting efficiency, plug load efficiency, orientation and HVAC) with respect to Energy Use Intensity (EUI) and energy cost based on ASHRAE 90.1 standards. As Window Wall Ratio (WWR) increases, EUI and energy cost also increase. With a minor increase in operating schedule, lighting efficiency, plug load efficiency of building both EUI and energy cost increase drastically and huge amount of energy and cost can be saved [3].

A G+6 Residential building located in Kolhapur was modelled by Jadhav using BIM tools, to view the realistic model of the structure before the construction and easy to reduce the construction wastage cost. The materials take off and cash flow was also studied. The clash deduction before and after construction is evaluated [4].

A small building with living room and bathroom is modelled by Rania and Neveen. The energy plus software is utilized to estimate the annual energy consumption. Different orientations are analyzed and it is found that southern faced houses result in lower energy consumption [5]. Using BIM to assess the sustainability performance of green office buildings, green building model and conventional building are modelled in Bangalore. 15% of energy is saved and 21% of carbon is reduced in green building compared to conventional building. 4.7% energy cost is saved and 38.6% carbon is reduced in green building compared to existing design by Anju [6]. Similarly, a multi - family residential building in Afghanistan is modelled by Yarramsetty and the orientation of the building changed to 315 ^{o}from the actual orientation results in cost saving of $1393 in its life cycle span of building [7].

Abdullah and Cross compared the Vasari/GBS and Sefaira energy analysis software results are compared with actual annual utility data of Research laboratory building located in Tacoma, Washington. Vasari/GBS energy analysis results are 63% higher than actual value due to advanced lighting and HVAC system, Safaira provides comparable energy values which are 1% slightly higher than actual building energy consumption [8]. A survey was conducted by Salman among the Architecture, Engineering and Construction (AEC) people to find leading software for energy analysis. Based on the survey. The Virtual Environment (VE) software appears to be most versatile and powerful software [9].

Shivsharan analyzed a G+9 residential building at Vakola, Maharashtra, energy analysis is carried out using Autodesk GBS. To integrate the BIM energy analysis in predicating the energy consumption of the building and to avoid the wastage of energy [10]. An educational building at University of Kirkuk, Iraq was modelled with Autodesk Revit and energy analysis done using Autodesk GBS. In correct direction, insulating materials are exposed to solar radiation. Arrangements of rooms (warehouses, bathrooms, toilets and stairs) to the direction of sun light can reduce the operational cost of the building [11]. A residential building with a normal brick wall and air-filled wall is modelled and GBS is used to perform the energy analysis. Air filled wall reduces the energy consumption up to $110 when compared with normal brick walls [12].

Autodesk Insight energy analysis tool suggested few materials to be used to reduce the energy consumption in study of uninsulated materials. Thermal comfort of building is improved by reducing the heat gain of the building envelope [13]. Jorge evaluated a two-story residential building evaluated in five different locations using Autodesk Insight. The lighting efficiency, plug-load efficiency, and HVAC systems are considered in the study. Higher the efficiency of lighting and applications, the lower the electric demand. In addition, type of climate and thermal characteristics of materials used in building envelope significantly affect the energetic performance [14].

Farah analyzed Autodesk Insight and Autodesk GBS for Diyala University building, Iraq. The daylight in a building with 29 lamps worth 6500 ID is reduced. Using of Photovoltaic (PV) panels 44% of annual energy consumption is obtained [15]. Autodesk Insight 360 and green building studio cloud-based service are used to find the energy performance of a multi-story residential building. In design stage the changes can be altered to various configurations to optimize the maximum energy consumption, which is suggested by Abhilash [16].

Nalamwar analyzed a building orientation in Nagpur on the solar radiation, annual cooling and total energy load calculated. In 0 degree cooling load, there are a minimum of 14643.15 KWh and maximum of 14934.84KWh orientation of 60 degree respectively [17]. To find optimum WWR of an office building which is assumed to be located in three different cities of Iran. The optimum WWR, solar heat gain, cooling load, heating load and lighting consumption are studied. From the results 20 - 100% maximum and minimum energy consumption in Bushehr and Shiraz and 16 - 25% in Tabriz [18]. Building orientation and window-glazing (Visual Transmittance, Solar Gain Heat Coefficient and U - Factor) are the major reason for Heating, Ventilation and Air-Conditioning system in buildings. Based on the location of the building and climatic conditions, the window glazing affects the energy usage [19]. By using Inter Building Effect (IBE), the residential building annual cost is reduced. For a walk - in clinic, both internal and external factors (orientation, WWR, wall and roof materials and HVAC system) are examined to assess the effect on annual cost [20].

Based on Saudi vision 2030 existing unsustainable residential buildings are energy retrofitted. By altering Eight Energy Efficiency Measures (EEMs), cooling set point temperature, using energy efficient appliances, replacing conventional lights with more efficient lights, applying window shading, improving glazing type, improving air tightness, using more efficient air conditioning system, and adding envelope insulation. Maximum 56.9% and 58.5% energy consumption can be reduced in a villa and apartment respectively for a year [21]. Energy retrofit for a residential building in Saudi Arabia (KSA) envelope energy conservation measures which included wall insulation, roof insulation, window area, window glazing, window shading, thermal mass, and location (Riyadh, Jeddah, Dhahran, Tabuk and Abha) are altered to find the optimal energy consumption [22 - 24].

Effective parameters of energy consumption are altered in a multi-story residential building and 16.30% of energy use intensity for a period of 30 – years is optimized by BIM tools [25].

In a case study of double story bungalow house in Malaysia, the walls are reverse brick veneer, windows to double glazed timber frame, doors to Glass sliding door and ceiling as plaster insulation. The indoor temperature as 23 - 27℃ has an annual energy consumption reduced from 17,600 kWh to 12,580 kWh, which makes a building sustainability building and reduces the operational energy [26].

Janata Bank building in Bangladesh is modeled using Autodesk Revit 2017 to optimize the energy systems. High insulated materials with low thermal conductivity, high performance glass, green roof and WWR less than 30% were considered in the analysis. The electricity consumption reduced by 9% and annual carbon dioxide emission reduced from 14 tons per year to 3 tons per year [27]. Energy analysis for a five-storey office commercial construction in Boston. Providing acoustic ceiling tile and gypsum wallboard tile instead of no ceiling 19.48% energy consumption is reduced. Use of concrete wall, brick and window wall increase energy consumption in 5.25% and 13.02% respectively. Double-glazed with aluminum frames, simple glazed with timber frames and half of windows increase in energy consumption 3.73%, 7.12% and 2.44% respectively when compared to total double glazed timber. Timber floors increase in energy consumption 1.34% when compared with concrete floors [28].

Energy use and emission percentage of Baghdad international airport terminal building is modeled and energy analysis is carried out. Solar panels fixed in different locations of the building to reduce the energy use. PV panels reduced 45%, 13%, 23% of energy consumed. In addition, by using double glazing and foam material the CO_2 emission is reduced and energy is saved [29].

Composite column technologies are wildly used in tall buildings and commercial structure, composite column is unbending, cost effective, etc. composite column are made up of two different materials. For composite building structural analysis Etabs is most advanced software that has been used nowadays [30]. Saleem and shrivastava studied G+15- story building with similar base plan and same floor height, three geometric forms of rectangular, triangular and a plus shape are validated to find the maximum story displacement, maximum story shear and maximum story moment [31]. S. S. Charantimath compared RCC structures with composite structures for tall structures and found that composite structures are the best solution when compared with RCC structures [32].

2. Methodology

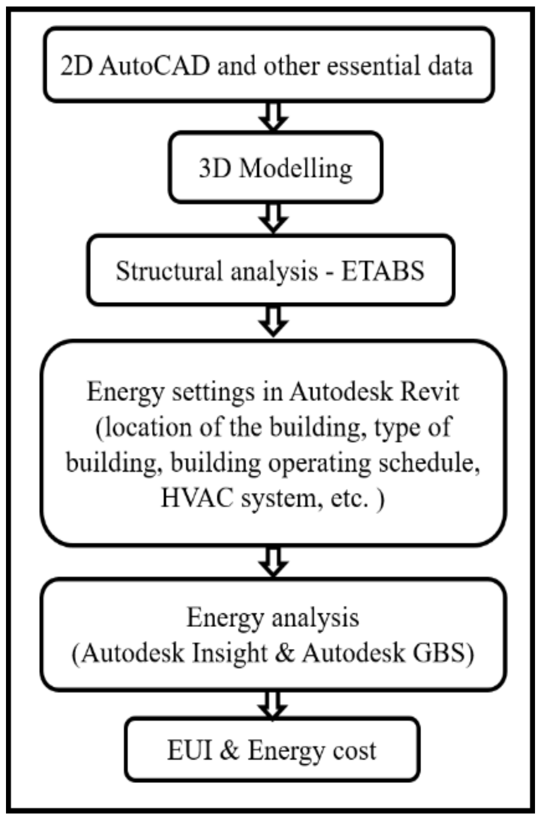


Figure 1. Flowchart of Energy analysis

The research methodology utilized for the present study is presented as a flowchart, as shown in Figure 1. In various sections of the article, the explanation of research methods is explained. The methods are modified to calculate the planned commercial building's energy usage, which is spread throughout five different regions of India.

When a commercial building is 3D modelled using Autodesk Revit Architecture and Autodesk Revit Structure, it is taken into account for energy usage. ETABS is used to do the structural analysis in order to examine the structural stability of commercial composite structures. Additionally, Autodesk Green Building Studio (GBS) and Autodesk Insight are used for energy analysis.

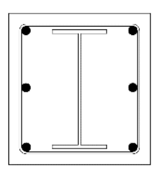
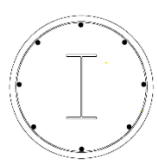
3. Linear Static Analysis of Composite Commercial Building Using ETABS

In reality, composite columns combine the two traditional approaches of steel and concrete construction. To put it another way, they are made of both steel and concrete. The composite column is a very efficient companion for the building and bridal constructions because of the exterior and interior behaviors of the structural steel and concrete materials. It is also sufficiently squashy, cost-effective, and unbending. Regarding the construction sector, composite column construction has sufficiently revolutionized the industry. The design process does not take the staircase into account. The basic information of the proposed composite commercial building is tabulated in table 1. To avoid the conditions of eccentricity, the beams are resting centrally on the column. In ETABS, this is accomplished automatically. The M40 grade of concrete, ISWB550 (I-Section), and Fe415 grade of steel for composite column structural elements are tabulated in table 2.

Table 1. Fundamental facts about the composite commercial building

Building parameters	**Specifications**
Region	Northern region – Delhi, north eastern region – Assam, eastern region - west Bengal, western region – Gujarat, southern region - Tamil Nadu.
Type of structure	Frame structure (composite column, RCC beams and RCC slabs)
Structure and wall construction	Composite (steel and RCC) framed building, interior brick masonry, and exterior glass panels
Duration of service	60 – 80 years
Number of floors	Five floors with two basements
Building height	Ground +28 m, Ground −10 m
Story height	5 m (Basement 1, Basement 2 and 3rd floor - Theatre)
	3.5 m (Ground, 1st, 2nd, 4th and 5th floor)
Floor area	5080 m^2
No. of shops	63 shops and with 2 theatres capacity of 150 seats each
No. of offices	1 office – with capacity of 150 employee and 4-conference room.

Table 2. Specification of composite column

S.No	**Shape of Column**	**Size (mm)**	**Cross Section**	**Reinforcement detailing**	**Total (Nos)**
1	Rectangular column	650 x 700		1 Nos – ISWB550 (I-section) 6 Nos – 20 mm# 10mm# @ 150mm C/C	104
2	Circular column	1200 dia		1 Nos – ISWB550 (I-section) 8 Nos – 20 mm# 10mm# @ 150mm C/C	8

Element of the Fe415 grade of steel and concrete of M40 grade are utilized to construct beam element. There is no design for the footing. Fixed supports are used to allocate supports. Dead load, live load, and wind load are considered as per IS 875. The factor of safety 1.2 applied along with dead, live and wind load is considered for load combination. Figure 2 represents the 3D model of the proposed composite commercial building in ETABS.

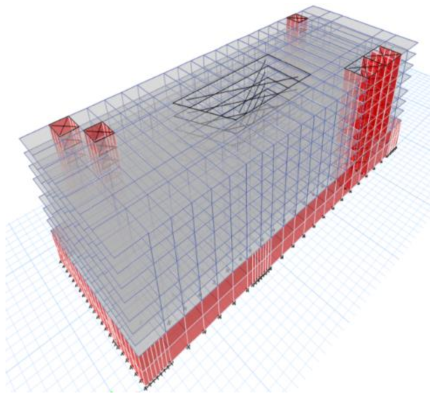


Figure 2. Composite commercial building model in ETABS

4. Modelling Composite Commercial Building

BIM is a collection of integrated regulations, processes, and technologies that are used to manage the vital project and building design data. Revit architecture is a specialist programme for 3D modelling with many capabilities that support BIM processes. The three-dimensional model of the proposed composite commercial building modelled for energy analysis as shown in Figure 3.

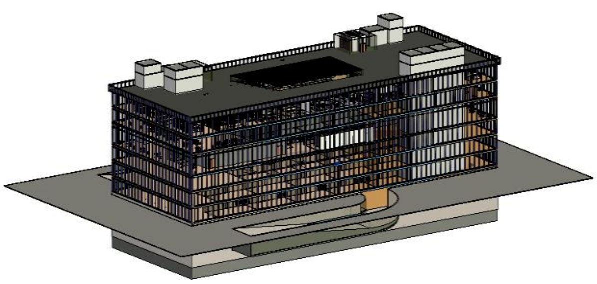


Figure 3. 3D view of the composite commercial building in Autodesk Revit 2021

The commercial building's component parts' U (thermal resistance) and SHGC (solar heat gain coefficient) values are as follows. The roofs are made of lightweight concrete (U - 1.2750 W/(m^2.K)). Exterior lightweight concrete block walls are utilized (U-0.8108 W/(m^2.K)), as are internal framed partition walls with 34 inch gypsum board (U-1.4733 W/(m^2.K)), ceilings made of lightweight concrete (U-1.3610 W/(m^2.K)), passive flooring (U-2.9582 W/(m^2.K)), and metal doors (U-3.7021 W/(m^2.K)). Utilized are sizable double-glazed windows with U-values of 2.9214 W/(m^2.K) and 0.13 SHGC. Large windows with single glazed panes of glass (U-3.6898 W/(m^2.K), SHGC-0.86) or double glazed panes (U-3.1956 W/(m^2.K), SHGC-0.13).

Rendering is a cloud based advantage of virtually infinite computing power and has the ability to quickly create a photorealistic image, and high-resolution images of a building before the construction. Figure 4 represents the rendered view of the proposed composite commercial building.

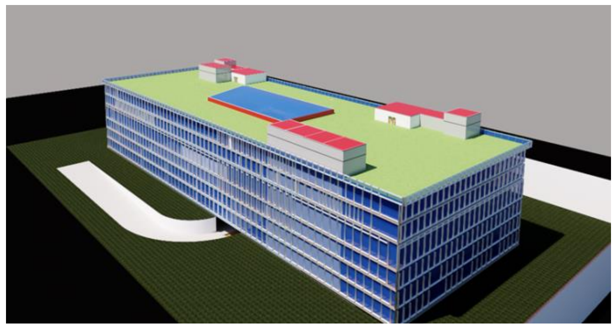


Figure 4. 3D Rendering view – Autodesk cloud rendering

4.1. Energy Simulation in Autodesk Revit

After the 3D model has been created, tools for energy simulation and optimization are used as illustrated in figure 5. The "Analyze" panel of Autodesk Revit building's geographic location is selected using an "Internet Mapping Service". The proposed composite commercial building's project address is as illustrated in figure 6.

Geographically, India is divided into five regions: the Northern region, the Northeastern region, the Eastern region, the Western region, and the Southern region. From each region, one major city is selected for this case study: Delhi, Dispur (Assam), Kolkata (West Bengal), Gandhinagar (Gujarat), and Chennai (Tamil Nadu).

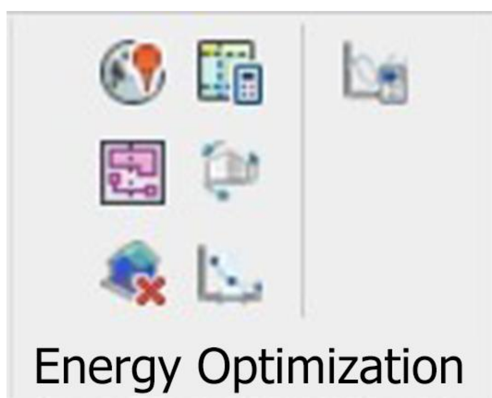


Figure 5. Energy optimization in Autodesk Revit 2021

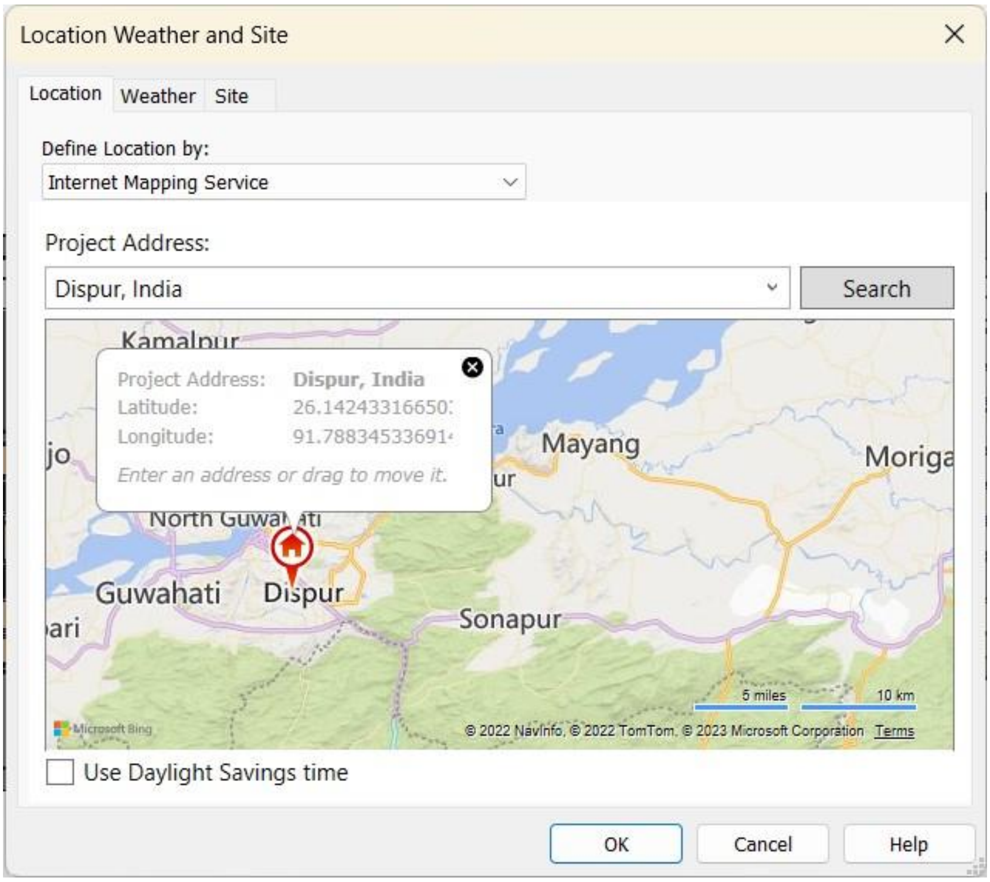


Figure 6. Defining geographical location of building in Revit

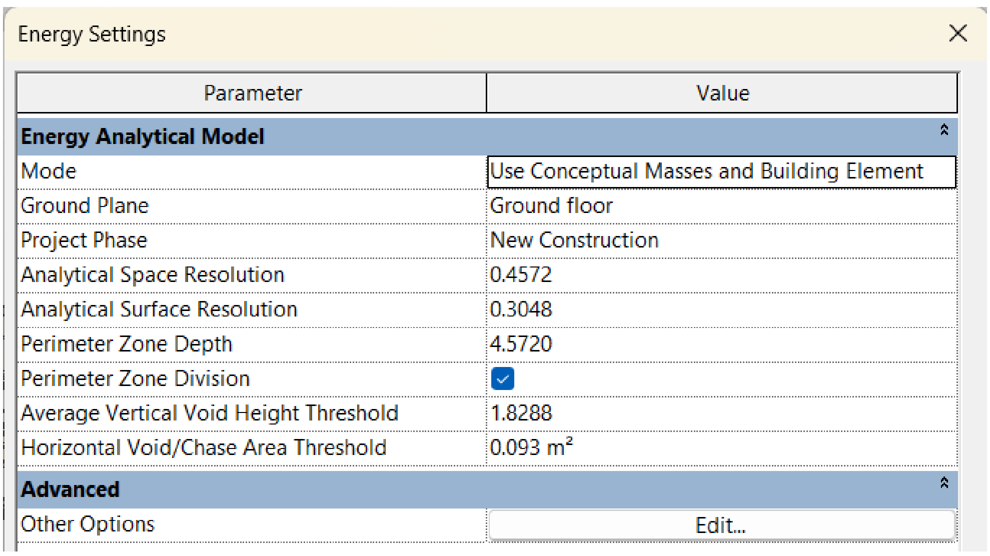


Figure 7. Energy setting in Revit

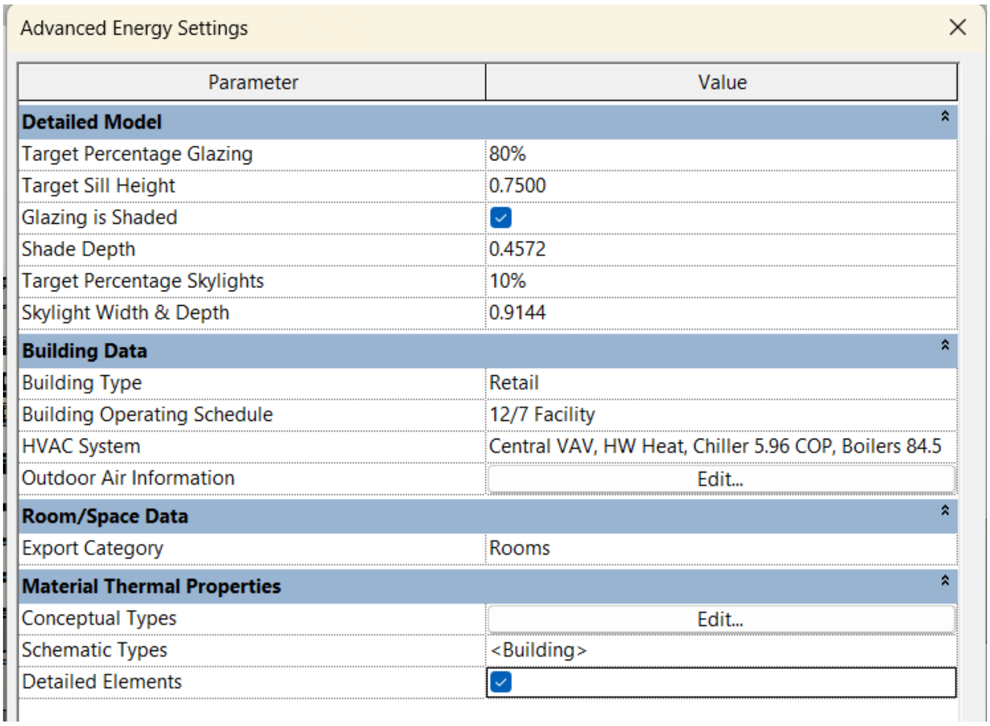


Figure 8. Advanced energy settings in Revit

After the building has been positioned in five regions, the nearest weather station and details about the project site area are discovered. The following step is "energy setting," which is shown in figure 7 and describes the parameters to produce the energy analytical model. In "advanced energy setup," shown in figure 8, building data can be selected, such as building type, building operating schedule, HVAC system, etc.

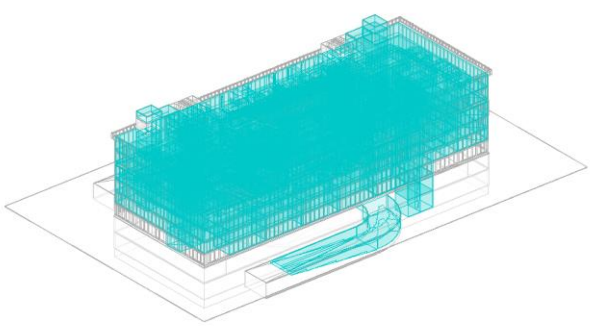


Figure 9. 3D energy model in Revit

The "conceptual types" option is given as lightweight construction for all the exterior and interior wall. High mass construction used for underground exterior wall and lightweight construction are used for floors under the "advance energy setting," where some values are assumed to modify specific construction components. After adding all the energy parameters into the application, the creation of an energy analysis model as well as design possibilities are examined utilizing the "create" option. The "optimize" option in Revit 2021 is then used to generate an energy model so that insight and the green building studio may get data on energy and environmental performance. Figure 9 displays the final three-dimensional energy model that was produced by the entire procedure.

5. Energy Analysis Using Autodesk Green Building Studio (GBS)

Green Building Studio is a web-based simulation engine for comprehensive building energy analysis, allowing users to examine the environmental implications of building components at the design stage. GBS can be used to assess the analyses of water efficiency, costs, and energy. It powers the DOE-2 simulation engine-based BIM Based Energy/Sustainability.

Integrating energy analysis tools into every Autodesk product, the legible way by GBS, which functions as the back end of DOE 2. Since it can analyze any gbXML file. GBS requires an Autodesk subscription to fully explore its potential. It cannot be installed on a host PC as it is cloud-based. The benefit is that it is accessible from any location with an internet connection.

Data such the Project Name, Building Type, Schedule, Project Type, Project Location, Time Zone, Currency, Weather Station, HVAC system, and Utility Information (Electric Cost $ 0.1 / kWh and Fuel Cost $ 6.65 / Therm) need to be updated in order to build a new project to do energy analysis. After project creation, an energy analysis file in gbXML format is to be uploaded. The project details are tabulated in table 3 and also depicted in figure 10.

Table 3. Project details

S.No	Building type	Schedule	Location	Time zone	Currency
1	Retail	12/7	Dispur	IST	USD
2	Retail	12/7	Chennai	IST	USD
3	Retail	12/7	Delhi	IST	USD
4	Retail	12/7	Gujarat	IST	USD
5	Retail	12/7	Kolkata	IST	USD

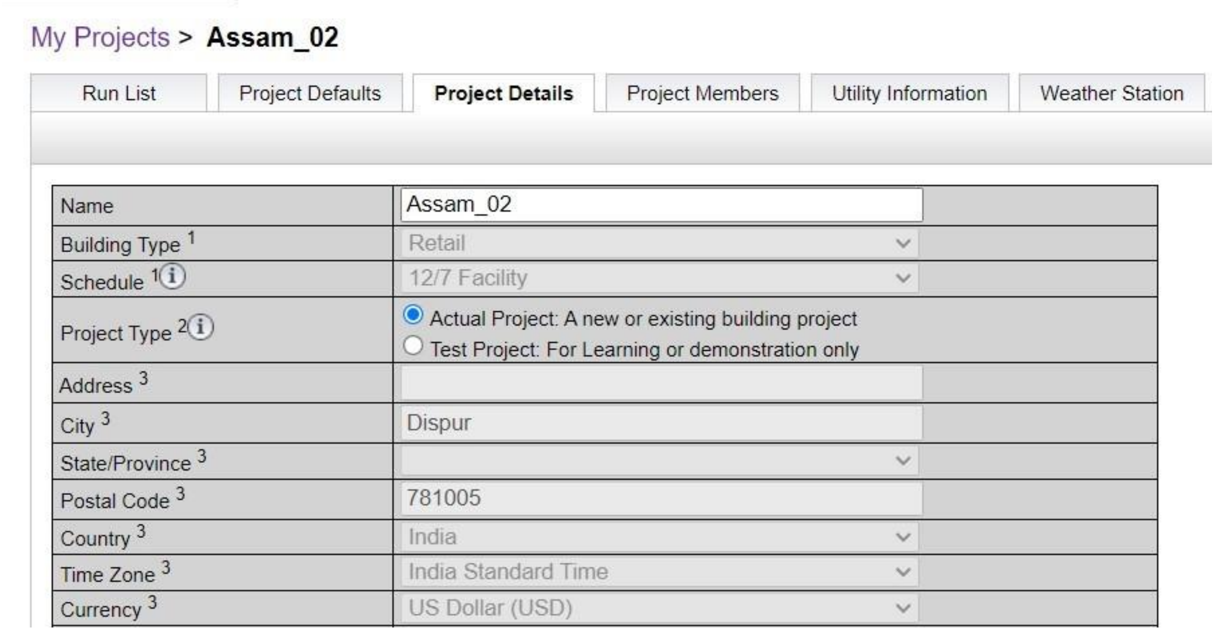


Figure 10. Project Details in GBS - Assam

6. Energy Analysis of Assam Region Building in Autodesk Insight

By coordinating energy, lighting, and solar studies, a cloud-based energy analysis method called Autodesk Insight is used to improve the energy and ecological assessment across the whole life cycle.

After creating the model for the proposed composite commercial building in Revit 2021, an energy analysis is conducted. Building characteristics and appropriate structural data are supplied as inputs. Energy simulation is carried out using Autodesk Insight, a built-in feature in Revit, which also produces an energy model of the building. The MEP details are not considered in this study. Autodesk Insight presents the outcomes of the energy analysis process in the form of EUI and energy cost based on the energy settings (inputs) of the project. Using the graphical data and the current energy rate for each constituent separately. According to GBS results, the energy consumed by commercial buildings in Assam is comparatively lower when compared to buildings in other regions.

The first step after login into the Autodesk Insight Application is to specify the utility rates, which are 0.10 USD for electricity per kWh and 2.35 USD for gas per cubic metre. The building in the Assam region's energy model in Autodesk Insight is depicted in Figure 11.

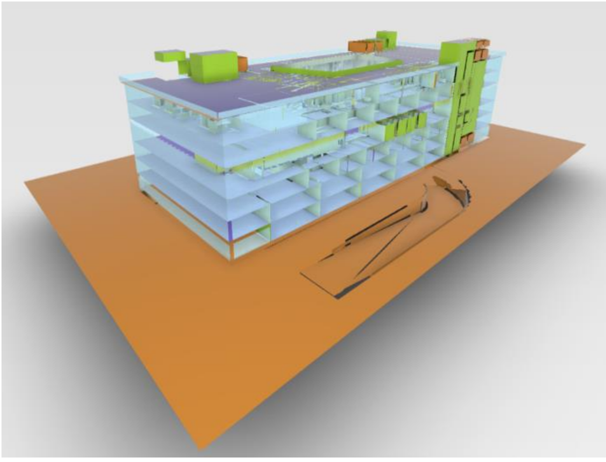


Figure 11. Energy model in Autodesk insight - Assam

7. Results and Discussion

7.1. Static Analysis of Composite Structure Using ETABS

Following from the ETABS static structural analysis for the proposed composite commercial building maximum story displacement, maximum story shear (in kN), maximum story moment (kN-m) along x axis and y axis are studied as show in the figure 12,13,14.

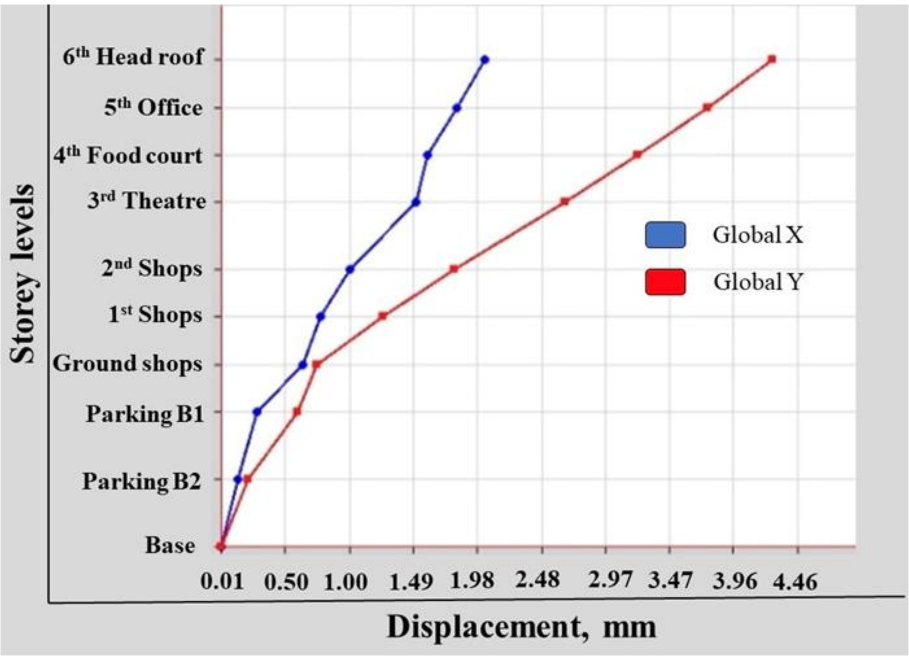


Figure 12. Story displacement

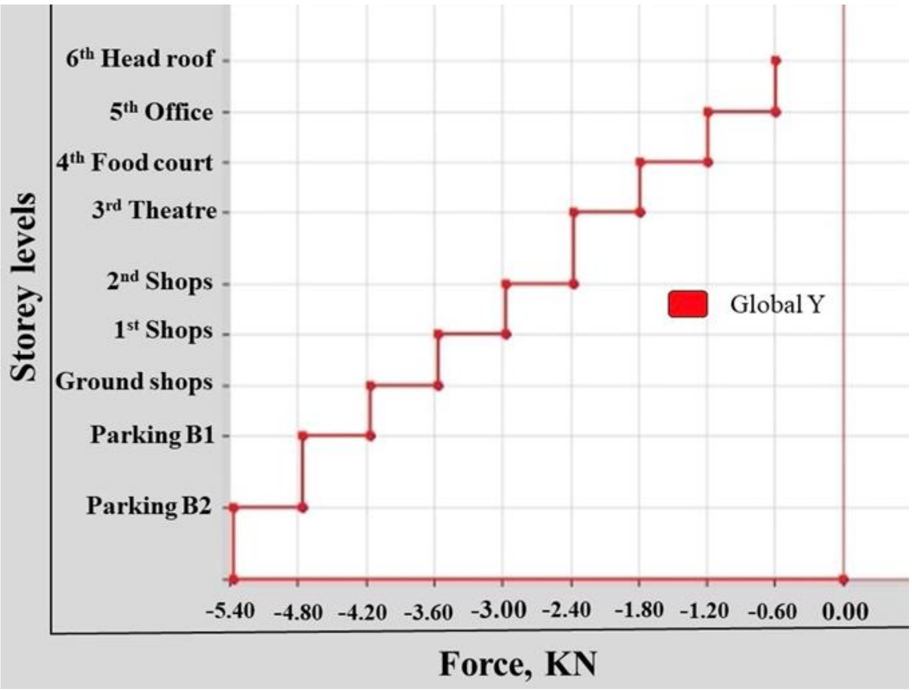


Figure 13. Story shear

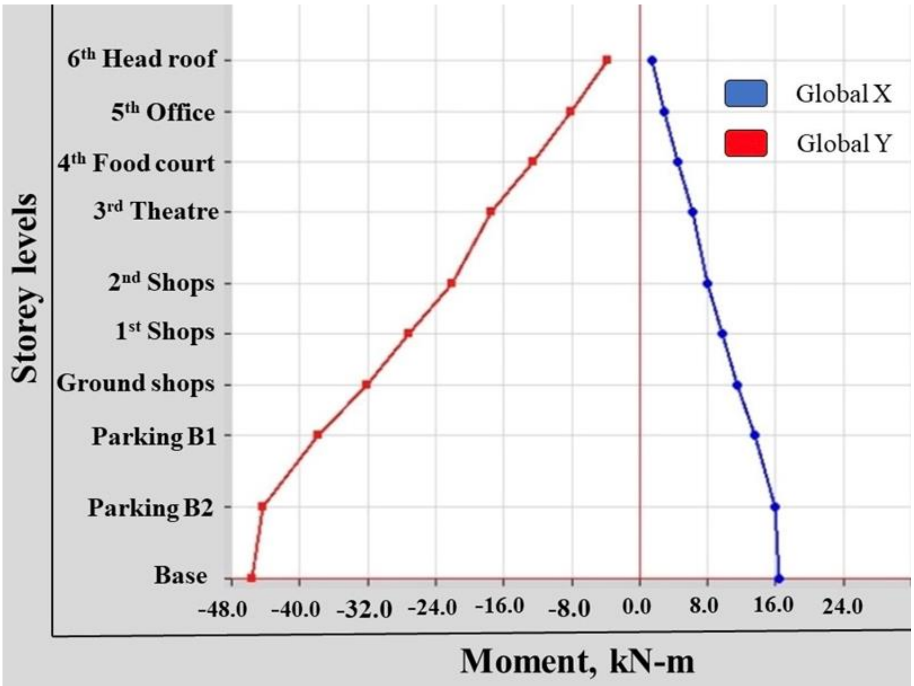


Figure 14. Story overturning moment

Maximum displacement along the x-axis is 2.05mm and y-axis is 4.3mm at roof level of the building, which is 28m from the ground level. Maximum shear along global y axis is 5.36 KN at the base. Overturning Moment is minimum in roof floor 3.83 KN-m and maximum in base floor 45.6 KN-m along global y axis. Along the global x axis is minimum in 1.38 KN-m at the roof floor and maximum at base 16.3 KN-m.

7.2. Optimization of EUI Using Autodesk Green Building Studio (GBS)

The results of the five region are extracted in pictorial form, North-eastern region - Dispur, Assam results are depicted in Figures 15, 16 and 17.

			Total Annual Cost [1]			Total Annual Er	
Energy Use Intensity (MJ/m²/year)	Electric Cost (/kWh)	Fuel Cost (/MJ)	Electric	Fuel	Energy	Electric (kWh)	Fuel (MJ)
--	$0.10	$0.06	--	--	--	--	--
863.8	$0.10	$0.06	$432,858	$130,224	$563,082	4,328,580	2,066,108

Figure 15. Simulated Base Run results in the Green Building Studio software

1 Base Run

Energy, Carbon and Cost Summary	
Annual Energy Cost	$563,110
Lifecycle Cost	$7,669,552
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	103.0 Mg
Large SUV Equivalent	10.3 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	864 MJ / m² / year
Electric	4,328,580 kWh
Fuel	2,066,108 MJ
Annual Peak Demand	1,085.1 kW
Lifecycle Energy	
Electric	129,857,400 kW
Fuel	61,983,240 MJ
Assumptions	

Figure 16. Energy, Carbon & Cost Summary

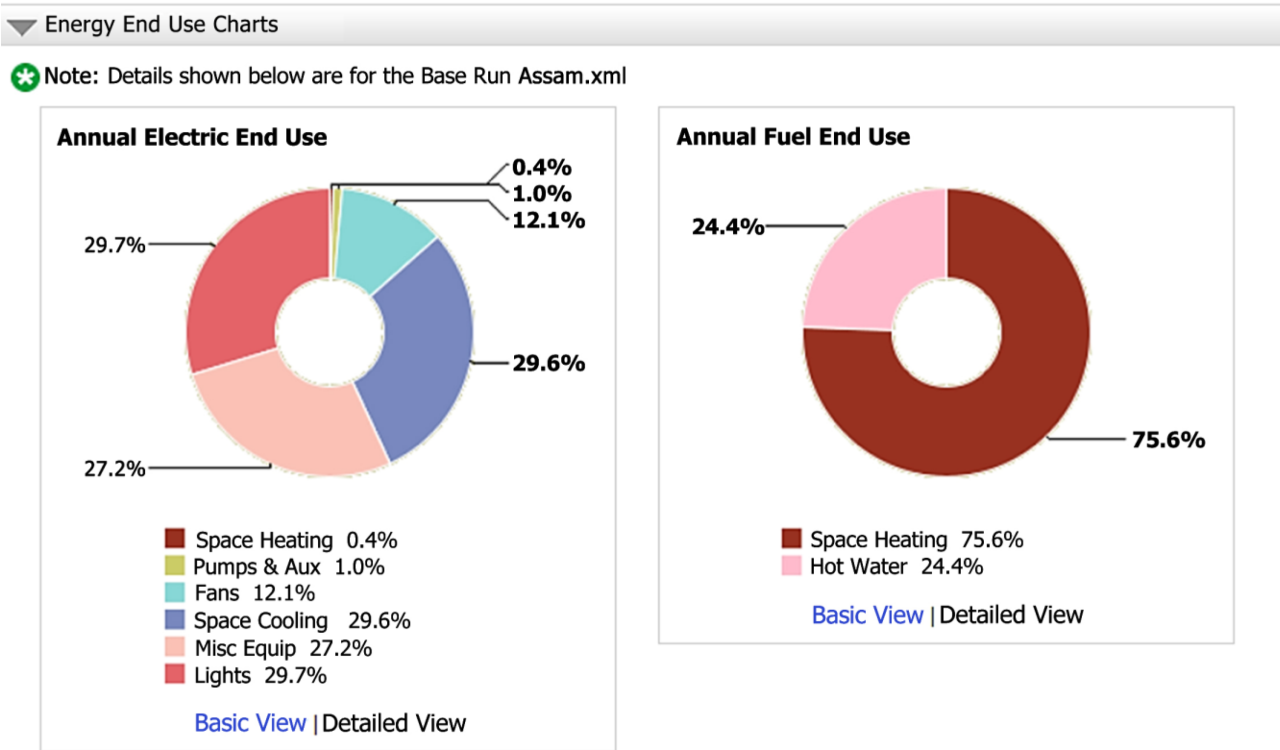


Figure 17. Energy End Use Charts

From the GBS results, when the proposed commercial building is located in Dispur, Assam consumes less amount of energy in terms of EUI when compared with other four region buildings. From the table 4 and figure 18 the Energy use intensity of commercial building which is located in Dispur, Assam consumes 863.8 MJ/m^{2}year which is 2.8% lesser when compared to the EUI 888.4 MJ/m^{2}year of the same commercial building which is located in Gandhinagar, Gujarat with same material properties.

Energy use intensity of the Assam region building is comparatively less but the fuel consumption and annual CO_2 emission are high when compared with other regional buildings. The life cycle energy cost and CO_2 emission for all five regions of the India are tabulated in table 5, Assam building emits 103.0 Mg of CO_2 annually, buildings that are environmentally friendly and energy efficient are the primary goals of this study. Since the Assam building consumes less energy, further study is carried out in Autodesk Insight only for the Assam region building to reduce the CO_2 emission and to find the alternative materials to reduce the energy consumption.

From the table 6 annual electric end use chart, it is obvious that the majority of the energy is used for cooling applications, lighting and Misc. equipments. The proposed commercial building is fully covered with glass panels, by using optimum glass materials that direct heat radiation from the sunlight is reduced. Therefore, the energy used for cooling system can be reduced. The usage of glass panels can allow the sun light to enter into the building and therefore the lighting energy is also reduced during day time.

The energy consumption and carbon emissions for the proposed composite commercial building can be estimated using the BIM tool prior to construction. Multiple models can be created and analyzed throughout the design phase to pick the most suitable design but energy concept cannot be applicable to all buildings.

Table 4. Simulated Base Run results in the Green Building Studio software

S.No.	City	Energy use intensity MJ/m ²/year	Total annual cost			Total annual energy	
			Electric in $	Fuel in $	Energy in $	Electric (kWh)	Fuel (MJ)
1	Dispur, Assam	863.8	4,32,858	1,30,224	5,63,082	43,28,580	20,66,108
2	Delhi	866.1	4,55,861	80,871	5,36,732	45,58,610	12,83,081
3	Kolkata, West Bengal	882.2	4,80,991	44,700	5,25,691	48,09,907	7,09,204
4	Gandhinagar, Gujarat	888.4	4,84,631	44,318	5,28,950	48,46,313	7,03,148
5	Chennai, Tamil Nadu.	883.8	4,96,453	11,671	5,08,124	49,64,531	1,85,176

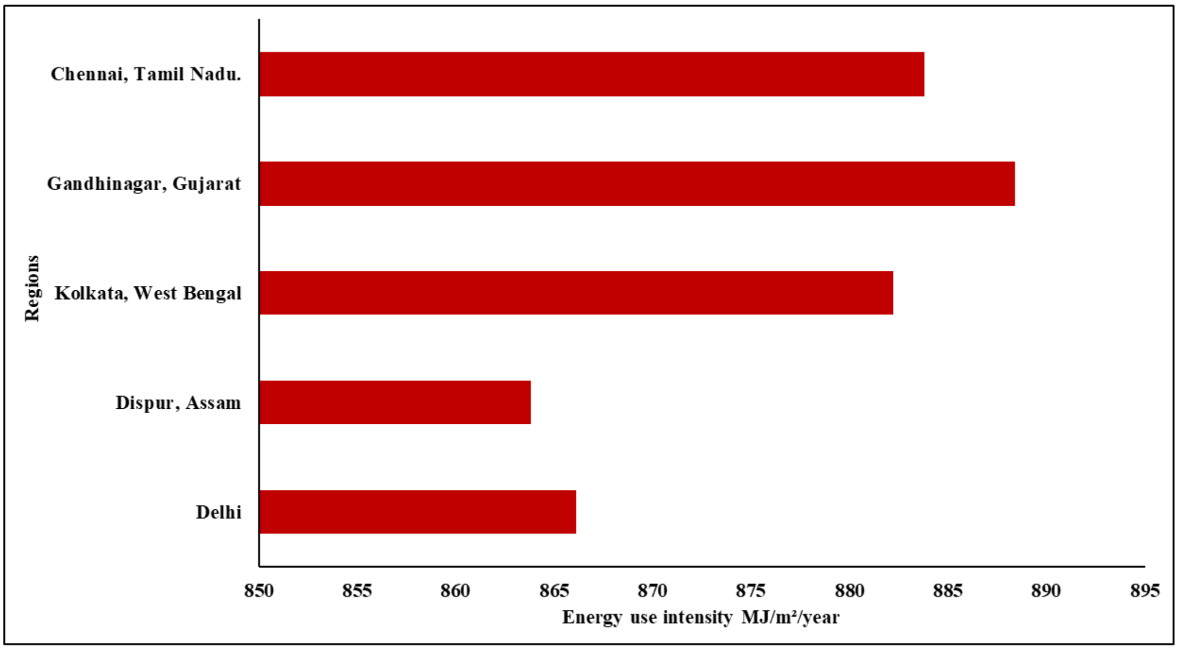


Figure 18. Energy use intensity for different regions

Table 5. Energy, Carbon & Cost Summary

S.No.	City	Lifecycle Energy		Lifecycle cost in $	Annual CO_2 emissions	
		Electric kW	fuel MJ		onsite fuel	Large SUV equivalent
1	Dispur, Assam	12,98,57,400	6,19,83,240	76,69,552	103.0 Mg	10.3 SUVs/Year
2	Delhi	13,67,58,300	3,84,92,430	73,10,521	64.0 Mg	6.4 SUVs/Year
3	Kolkata, West Bengal	14,42,97,210	2,12,76,105	71,60,038	35.4 Mg	3.5 SUVs/Year
4	Gandhinagar, Gujarat	14,53,89,390	2,10,94,428	72,04,423	35.1 Mg	3.5 SUVs/Year
5	Chennai, Tamil Nadu.	14,89,35,930	55,55,277	69,20,689	9.2 Mg	0.9 SUVs/Year

Table 6. Annual electric end use

S.No	Specifications	Dispur, Assam	Delhi	Kolkata, West Bengal	Gandhinagar, Gujarat	Chennai, Tamil Nadu.
1	Space Heating	0.4%	0.2%	0.1%	0.1%	0%
2	Pumps & Aux	1.0%	0.5%	0.5%	0.5%	0.5%
3	Fans	12.1%	12.2%	12.3%	12.5%	12.4%
4	Space Cooling	29.6%	33.1%	36.0%	36.1%	39.4%
5	Misc. Equip.	27.2%	25.8%	24.4%	24.3%	21.8%
6	Lights	29.7%	28.2%	26.8%	26.6%	25.9%

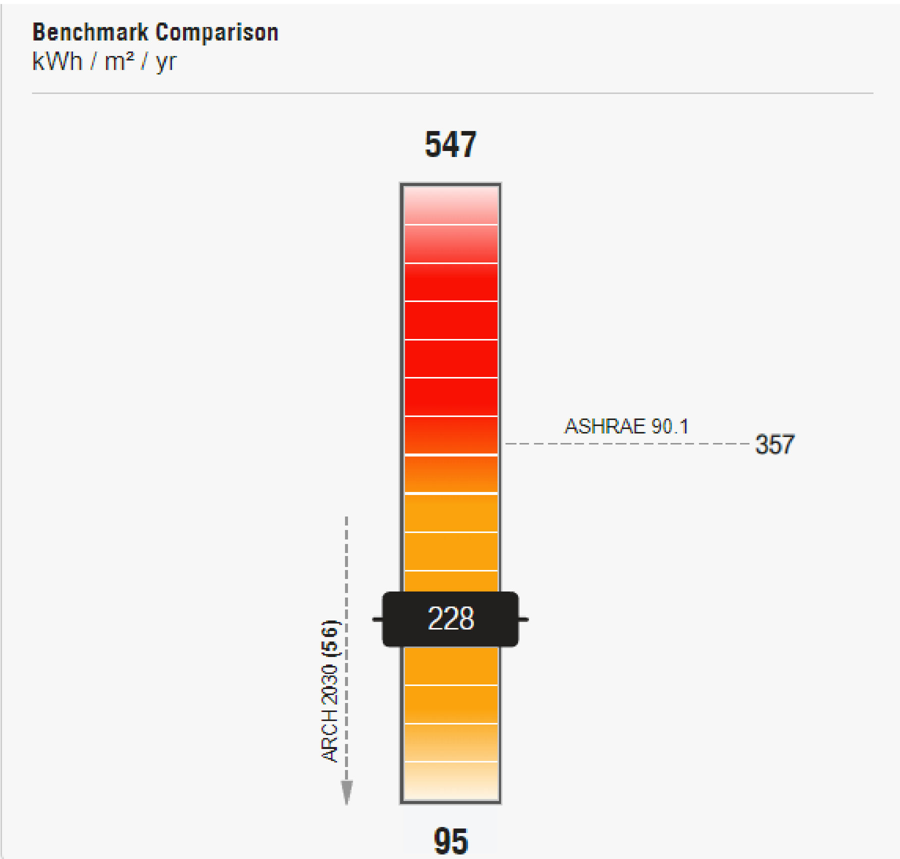


Figure 19. Benchmark comparison of Assam region building in terms of EUI

7.3. Optimization of EUI Using Autodesk Insight

Based on the project's energy parameters, a benchmark comparison between the building's energy usage (measured in kWh/m^2/year) and ASHRAE 90.1 and ARCH 2030 requirements is generated. The building's total gross floor area is divided by its annual energy consumption to get the building's energy usage intensity.

In terms of energy cost and EUI, benchmark comparisons indicate the minimal requirements outlined in ASHRAE 90.1. The EUI in the present case study commercial building is observed to be 228 kWh/m^2/year, which is within the allowable range, as shown in Figure 19. Consequently, the structure is energy-efficient.

Numerous design factors, including window wall ratio, operating schedule, building orientation, HVAC system, window shades, lighting efficiency, window glass type, wall and roof construction, and plug load efficiency, are available in the insight energy report to measure the building's energy consumption. However, these methods can be employed to reduce energy usage if the building is not energy-efficient or if energy costs are too high.

Alterations in a small design criterion in Autodesk Insight will result in a significant change in energy consumption in terms of EUI and energy cost. This allows for the creation of the most suitable energy building model with a decrease in the building's energy consumption. Additionally, with Autodesk Insight, many energy models may be compared to choose the optimal one for planning a structure before construction.

Various design strategies are shown pictorially in the energy report suggested by Autodesk Insight operating schedule, building orientation, HVAC, window shades, window glass type, etc.

7.3.1. Operating Schedule

The operation schedule gives information on the typical hours of use by building occupants when performing an energy analysis. The type of building and the intended purpose of the structure have a drastically effect on the schedule. For illustration, a school building typically operates for 8 to 10 hours per day, five to six days per week, but a hospital or residential structure operates around-the-clock. As part of the case study, Figure 20 depicted the building's working schedule with respect to EUI.

7.3.2. Building Orientation

Building orientation denotes the building's rotation around a center line in a clockwise direction. This aids in receiving the least amount of radiation, which reduces the building's heat gain and amount of air conditioning used. Through enhancing the use of sunshine and ventilation, it reduces energy loads. Building orientation is determined by the sun's path and the wind's direction, which vary according to local climate conditions. Building orientation in relation to EUI is shown in figure 21.

7.3.3. Heating, Ventilation, and Air Conditioning System

The region, location and type of the structure's climatic circumstances have the most impact on the HVAC system's efficiency. Internal temperatures are influenced by the exterior environment through a building's design and operation. Therefore, HVAC systems deliver thermal comfort and acceptable requirements of indoor air quality through the appropriate regulation of temperature, humidity, airflow and air filtration. Figure 22 illustrates the building HVAC system in relation to EUI.

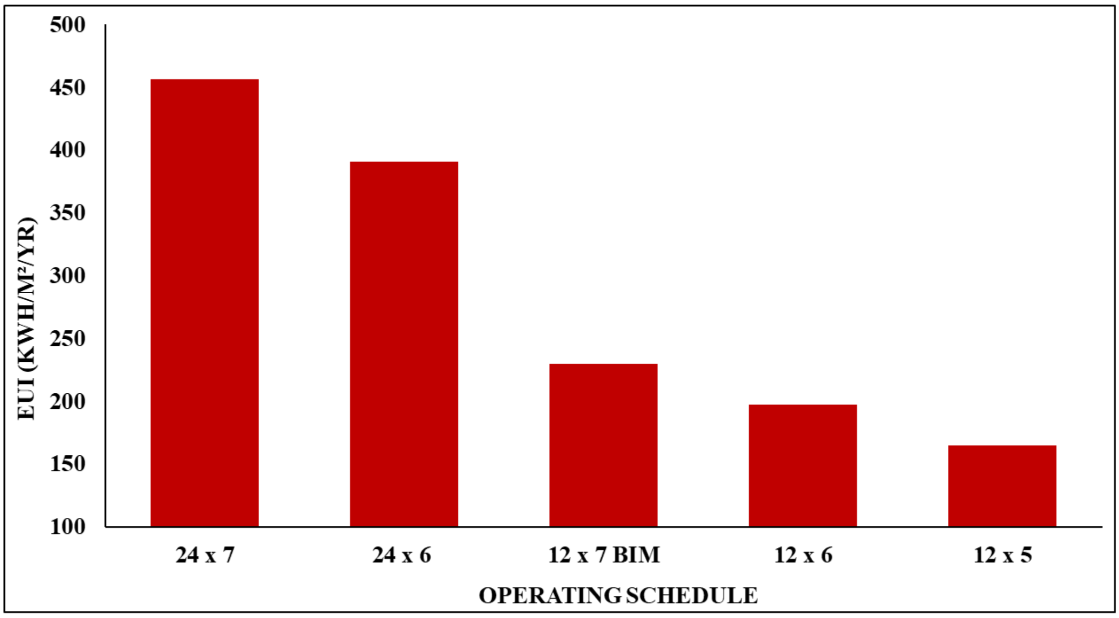


Figure 20. Operating schedule

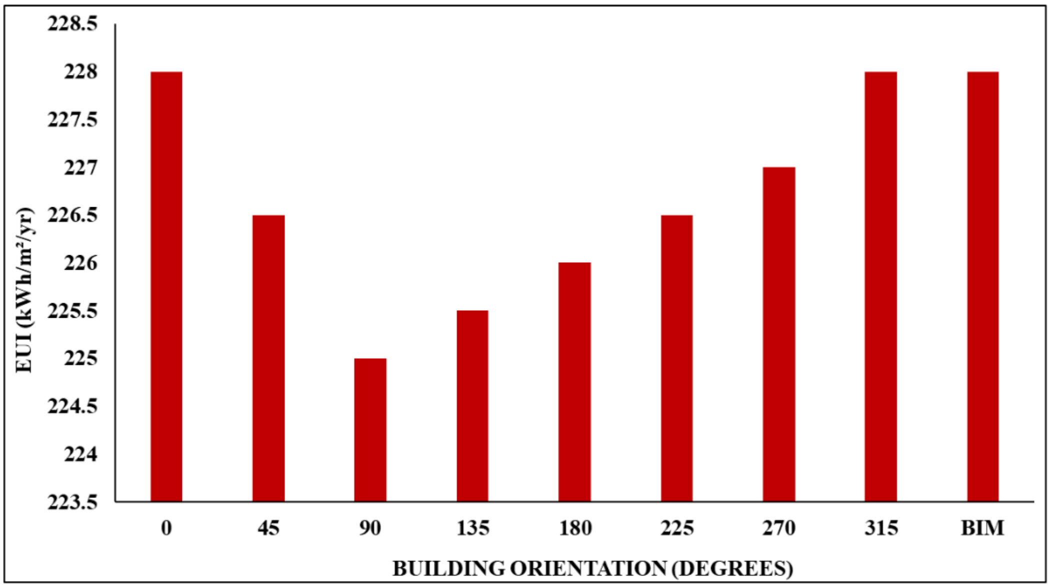


Figure 21. Building orientation

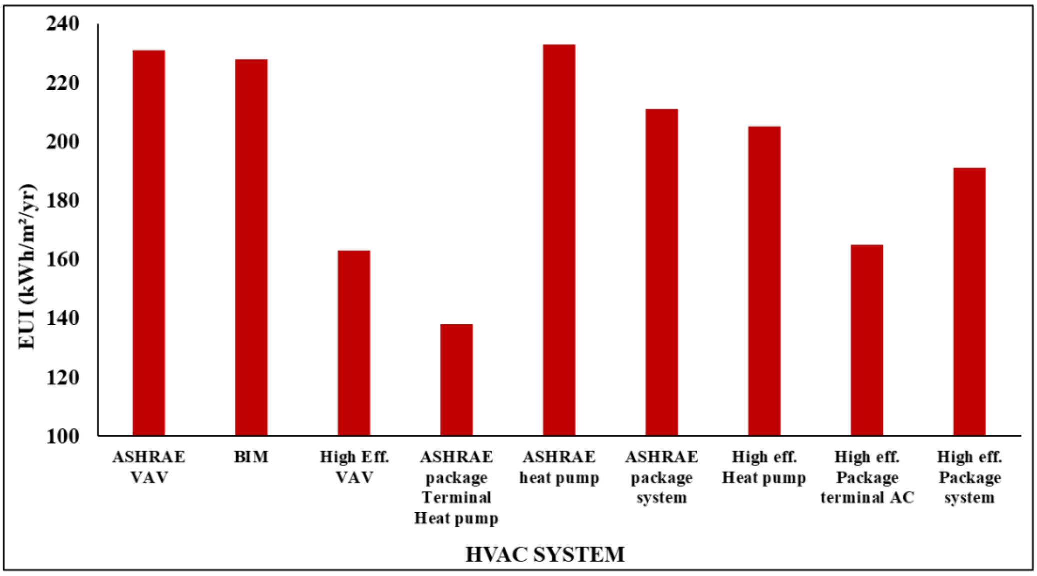


Figure 22. Heating, Ventilation, & Air Conditioning System

7.3.4. Window Shades

The direct sun light through windows will affect the cooling efficiency of the structure. To reduce the structure direct heating window shades should be provided, which reduces energy consumption for heating and cooling. The influence depends on the size of the windows and the amount of daylight. In the present study, commercial building window shades with relation to EUI are depicted in figure 23.

7.3.5. Window Glass Type

The selection of glass type is essential since the current study in construction is on reducing energy use, costs associated with energy usage, and raw material costs. Glass properties have a significant influence in reducing the amount of natural sunshine and warmth caused by direct sunlight within the building, thereby lowering the cost of cooling and electricity. Low solar heat gain coefficient glazing is preferable when ideal orientation or external shading is not attainable. Figure 24 illustrates the building window glass type in the present study with respect to EUI.

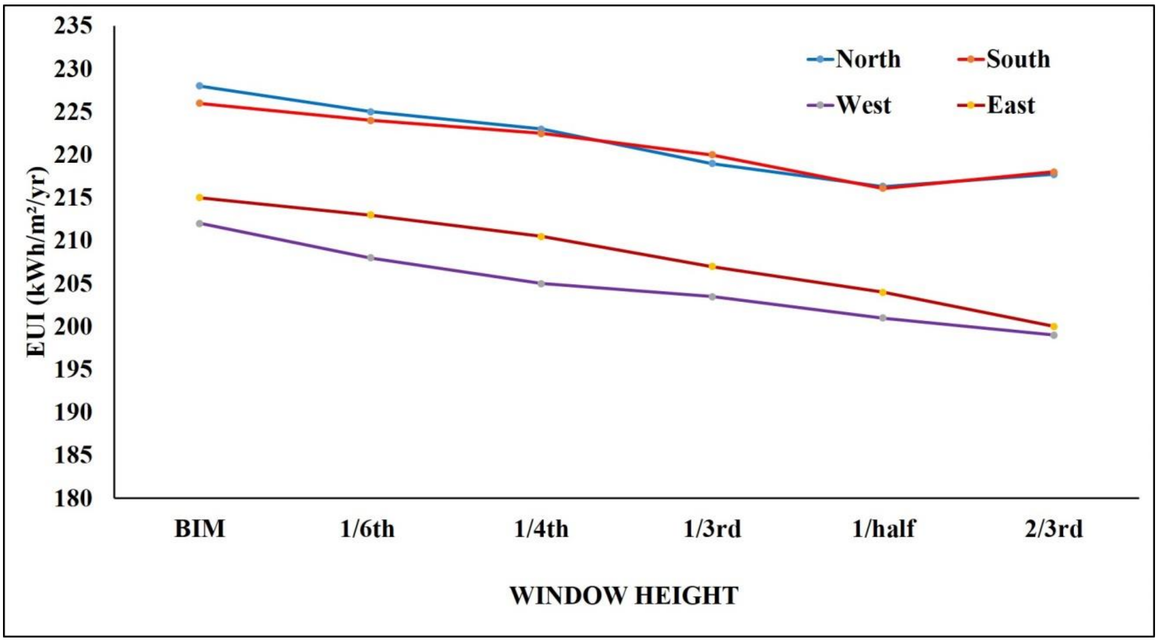


Figure 23. Window shades

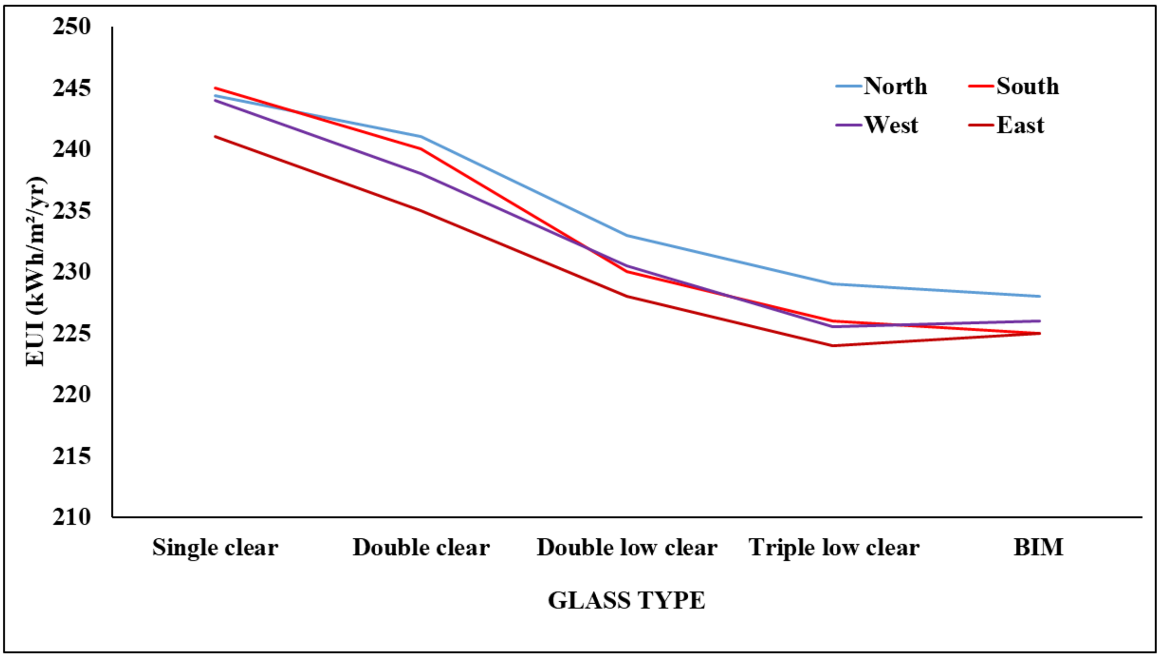


Figure 24. Window glass type

8. Conclusions

In this article, various studies were incorporated for estimating energy analysis and to assess the factors that influence the structure's energy, which includes the location, building envelope, building component, tenant occupancy, building orientation, building scale, and structure. The proposed composite commercial building model underwent static analysis to ascertain its structural stability for a better understanding of the proposed commercial building. The analyzed structures have a maximum displacement of 4.3 mm along the Y-axis, which meets within the limitations established by the Indian Standard codal provisions. Energy analysis is carried out for the five different regions by using the Autodesk Green Building studio. From the GBS results, commercial buildings in Dispur, Assam region consume less energy of 863.8 MJ/m^2/year EUI as compared to the other four regions of India. Since the climatic condition in Assam - North Eastern region is between 24^o C to 33^o C which is comparatively less when compared to the other regions of the India. The annual carbon emission is 103.0 Mg which is comparatively higher than the other four regions.

With the utilization of Autodesk Insight, it can be understood that the energy consumption at operational phase can be reduced which has a direct impact on reduction of life cycle carbon emission. From the Autodesk Insight, the annual energy consumption of the Assam commercial building is $228 KWh/m^2/yr. When it comes to the design strategies, the operating schedule is changed to 12 hours and 5 days a week, and the energy consumption is reduced, but in the present study, the commercial building needs to be operated for 12 hours a day and throughout a week. In the orientation analysis of the building, it is concluded, that by rotating the building at the interval of 45 ° from 0 ° to 360 °, the amount of EUI and energy cost is slightly varying when the building is rotated to 90 °. On behalf of using HVAC system, it is benefited to use ASHRAE package terminal heat pump (APTHP) to reduce both EUI and energy cost in the building. In window shades analysis as the window height is decreasing, EUI and energy cost also are slightly increased in all directions. The exterior part of the building has been covered by triple low-clear glass material. The proposed study cannot be generalized to all commercial structures in India, This is one of the BIM technology-based strategies that may be used to cut carbon emissions and improve the composite commercial building's yearly energy budget.

REFERENCES

[1] Abanda, F. H., and L. Byers. "An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling)." Energy, vol. 97, 2016, pp. 517-527. DOI: 10.1016/j.energy.2015.12.135

[2] Khan, Ahmed, and Anil Nivrati Ghadg. "Building information modelling (BIM) based sustainability analysis for a construction project." Proceedings of Sustainable Infrastructure Development & Management (SIDM), 2019. https://doi.org/10.2139/ssrn.3366799

[3] Mahiwal, Sharda G., Manas Kumar Bhoi, and Naimish Bhatt. "Evaluation of energy use intensity (EUI) and energy cost of commercial building in India using BIM technology." Asian Journal of Civil Engineering, vol. 22, no. 5, 2021, pp. 877-894. DOI: 10.1007/s42107-021-00352-5

[4] Jadhav, Gayatri Dhananjay, Madhav Bhalchandra Kumthekar, and Jyoti Suresh Magdum. "Building information modeling (BIM) a new approach towards project management." International Journal of Engineering Research & Technology, vol. 10, no. 1, 2017, pp. 143-148. http://www.ripublication.com/irph/ ijert_spl17/ijertv10n1spl_24.pdf.

[5] Ashmawy, Rania E., and N. Y. Azmy. "Buildings Orientation and Its Impact on the Energy Consumption." The Academic Research Community Publication, vol. 2, no. 3, pp. 35-49, 2018. https://doi.org/10.21625/archive.v2i3.3 44.

[6] Ebrahim, Anju, Abhaykumar S. Wayal, and M. Cook. "BIM based building performance analysis of a green office building." International Journal of Science Engineering and Technology, vol. 8, no. 8, 2019, pp. 566-573. https://www.ijstr.org/ (IJSTR©2019)

[7] Yarramsetty, Subbarao, M. Sayed Rohullah, and M. V. N. Sivakumar. "An investigation on energy consumption in residential building with different orientation: A BIM approach." Asian Journal of Civil Engineering, vol. 21, no. 2, 2020, pp. 253-266. https://doi.org/10.1007/ s42107-019-00189-z.

[8] Abdullah, Abul, Ben Cross, and A. Aksamija. "Whole building energy analysis: A comparative study of different simulation tools and applications in architectural design." ACEEE Summer Study on Energy Efficiency in Buildings. 2014.https://www.aceee.org/2022-buildings-summer-study

[9] Azhar, Salman, and Justin Brown. "BIM for sustainability analyses." International Journal of Construction Education and Research, vol. 5, no. 4, 2009, pp. 276-292. DOI: 10.1080/15578770903355657

[10] Shivsharan, A. S., D. R. Vaidya, and R. D. Shinde. "3D Modeling and energy analysis of a residential building using BIM tools." Int. Res. J. Eng. Tech, vol. 4, no. 7, 2017, pp. 629-636. https://irjet.net/archives/V4/i7/IRJET- V4I7111.pdf.

[11] Ali Shoshan, Anas Attellah, and Qubad Sabah Haseeb. "Analysis and reduction of energy consumption in educational buildings: A case study in the college of education for pure sciences at the University of Kirkuk." International Journal of Civil Engineering and Technology, vol. 10, no. 3, pp. 768-778, 2019. https://iaeme.com/Home/article_id/IJCIET_10_03_074

[12] Pathan, G., et al. "Comparative study of energy analysis on residential building in Revit Software." International Journal of Advance Research and Innovative Ideas in Education, vol. 5, no. 2, 2019, pp. 1182-1189. www.ijariie.com

[13] Maurya, Amit, et al. "Sustainable Building Design: Energy Analysis of a Residential Building using Autodesk Revit." 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM). IEEE, 2021. DOI: 10.1109/ICIEM51511.2021.9445376

[14] González, Jorge, et al. "BIM and BEM Methodologies Integration in Energy-Efficient Buildings Using Experimental Design." Buildings, vol. 11, no. 10, 2021, pp. 491. https://doi.org/10.3390/ buildings11100491

[15] Taha, Farah Faaq, Wadhah Amer Hatem, and Nidal Adnan Jasim. "Effectivity of BIM technology in using green energy strategies for construction projects." Asian Journal of Civil Engineering, vol. 21, no. 6, 2020, pp. 995-1003. https://doi.org/10.1007/s42107-020-00256-w.

[16] Jangalve, Abhilash, et al. "Energy analysis of residential building using BIM." International Journal of Emerging Engineering Technology and Science, vol. 108, 2017, pp.15-19. http://www.ijeets.org

[17] Nalamwar, Mahesh R., D. K. Parbat, and D. P. Singh. "Optimum building orientation study for Central India by simulation." Int. J. Theor. Appl. Res. Mech. Eng, vol. 5,

2018, pp. 25-27. http://irdindia.in/journal_ijtarme

[18] Shaeri, Jalil, et al. "The optimum window-to-wall ratio in office buildings for hot–humid, hot–dry, and cold climates in Iran." Environments, vol. 6, no. 4, 2019, pp. 45. DOI: 10.3390/environments6040045

[19] Siddhartha, Maya Yeshwanth Pai, and Y. Pai. "Effect of building orientation and window glazing on the energy consumption of HVAC system of an office building for different climate zones." International Journal of Engineering Research, vol. 4, no. 9, 2015, pp. 838-843. https://doi. org/10.17577/ijertv4is090754.

[20] Singh, Premjeet, and Ayan Sadhu. "Multicomponent energy assessment of buildings using building information modeling." Sustainable Cities and Society, vol. 49, 2019, 101603. https://doi.org/10.1016/j.scs.2019.101603.

[21] Ahmed, Wahhaj, and Muhammad Asif. "BIM-based techno-economic assessment of energy retrofitting residential buildings in hot humid climate." Energy and Buildings, vol. 227, 2020, 110406. https://doi.org/10.1016/j.enbuild.2020.110406

[22] Alaidroos, Alaa, and Moncef Krarti. "Optimal design of residential building envelope systems in the Kingdom of Saudi Arabia." Energy and Buildings, vol. 86, 2015, pp. 104-117. http://dx.doi.org/10.1016/j.enbuild.2014.09.083

[23] Krarti, Moncef, Kankana Dubey, and Nicholas Howarth. "Evaluation of building energy efficiency investment options for the Kingdom of Saudi Arabia." Energy, vol. 134, 2017, pp. 595-610. DOI: 10.1016/j.energy.2017.05.084

[24] Ghabra, Noura, Lucelia Rodrigues, and Philip Oldfield. "The impact of the building envelope on the energy efficiency of residential tall buildings in Saudi Arabia." International Journal of Low-Carbon Technologies, vol. 12, no. 4, 2017, pp. 411-419. DOI: 10.1093/ijlct/ctx005

[25] Amani, N., and A. A. Reza Soroush. "Effective energy consumption parameters in residential buildings using Building Information Modeling." Global Journal of Environmental Science and Management, vol. 6, no. 4, 2020, pp. 467-480. DOI: 10.22034/gjesm.2020.04.04.

[26] Shoubi, Mojtaba Valinejad, et al. "Reducing the operational energy demand in buildings using building information modeling tools and sustainability approaches." Ain Shams Engineering Journal, vol. 6, no. 1, 2015, pp. 41-55. http://dx.doi.org/10.1016/j.asej.2014.09.006

[27] Hasan, Md Rakibul, Md Saidul Islam, and Jhumana Akter. "Energy performance analysis of an office building using BIM: a case study." Journal of System and Management Sciences, vol. 7, no. 3, 2017, pp. 34-53. https://doi. org/10.1016/j.enbuild.2017.10.

[28] Lung, L. "Using BIM to simulate the energy consumption and reduce its cost." International Journal of Innovation, Management and Technology, vol. 10, no. 1, 2019. DOI: 10.18178/ijimt.2019.10.1.830

[29] Kareem, Fatima M., Abbas M. Abd, and Raquim N. Zahawi. "Utilize BIM Technology for Achieving Sustainable Terminal Building of Airport." IOP Conference Series: Earth and Environmental Science, vol. 856, no. 1. IOP Publishing, 2021. DOI: 10.1088/1755-1315/856/1/012053

[30] Abbas, Hajer Satih, et al. "Analysis or Design of Composite Column by Using Etabs Software." Webology, vol. 19, no. 1, 2022. http://www.webology.org

[31] Saleem, Hatim, and L. P. Shrivastava. "A Comparative Study on high rise building for various geometrical shapes subjected to wind load of RCC & composite structure using ETABS." IRJET, vol. 6, no. 12, 2019, pp. 1553-1558. www.irjet.net

[32] Charantimath, S. S., Swapnil B. Cholekar, and M. Birje Manjunath. "Comparative Study on Structural Parameter of RCC and Composite Building." Civil and Environmental Research, vol. 6, no. 6, 2014, pp. 2224-5790. www.iiste.org