International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 07 | July 2022 www.irjet.net p-ISSN: 2395-0072

ENERGY EFFICIENT BUILDING FOR INDIAN CLIMATIC ZONE

Kalpesh R. Khairnar[1], Jayashree N. Changade[2].

[1]MTech Student, Department of Civil Engineering, Pimpri Chinchwad College of Engineering Pune, Savitribai Phule Pune University, (INDIA).
[2]Assistant Professor, Department of Civil Engineering, Pimpri Chinchwad College of Engineering, Pune. Savitribai Phule Pune University, (INDIA).

---***---

Abstract - *The design of energy efficient buildings is becoming a need to reduce environment impact. Hence it has become necessary to design or plan the buildings in different forms with different parameters to make it energy efficient. This research report presents quantitative study of energy performance effect due to building morphology in five different climatic zones. Using four building parameters (i.e., relative compactness, orientation; window percentage; sun shading) an optimal building morphology has been suggested for specific Indian climatic zones i.e., Hot and Dry, Warm and Humid, Composite, Cold and Temperate.*

The software to be used for energy Analysis for buildings is ***AUTODESK INSIGHT360*** *software.*

Key Words: **ENERGY EFFICIENT BUILDING, ORIENTATION, OVERHANG SHADE, CLIMATIC ZONES, BUILDING MORPHOLOGY, HEATING AND COOLING LOADS, REVIT, INSIGHT 360**

1. INTRODUCTION

1.1. Description

The building sector makes a significant contribution to total energy consumption. This is one of the reasons why energy efficiency measures in buildings are increasingly being demanded. Worldwide, the issue of energy efficiency has gained relevance in the last decade with the objective of reducing energy consumption that would impact the building performance according to the International Energy Agency (IEA). The growth of new technologies brought many changes in building design and energy analysis process. It is now more crucial than ever to choose from a variety of solutions to increase comfort, cut carbon dioxide emissions, and maximize building profitability. The increasing demand for more energy-efficient buildings led scientists in the world to engage in building energy modeling to implement the strategies that would affect an overall reduction in building energy consumption. Building energy modeling is a process of creating an architectural and energy model through computer software to predict energy consumption and improving building energy performance during occupancy. Comparing the predicted energy consumption to the actual energy consumption can help building owners and operators to detect and diagnose low efficiency or malfunctioning equipment.

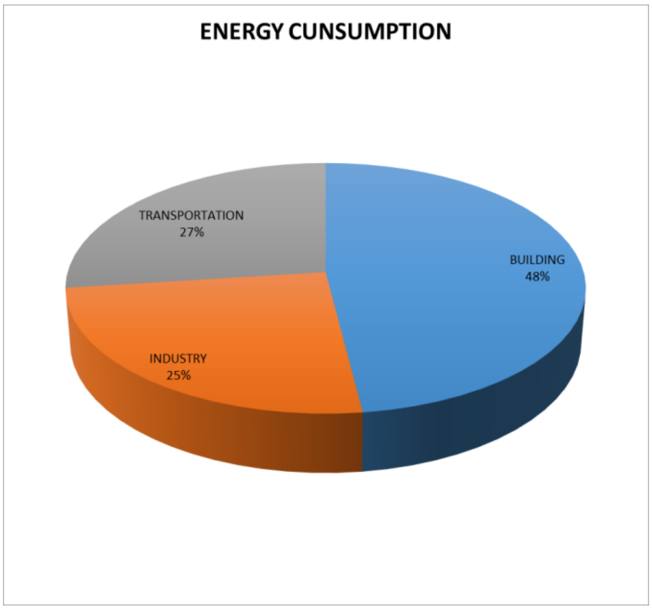


Fig. 1.1. Energy Consumption by Major Sectors

Above figure 1. shows energy consumption by different sectors viz Industries, Buildings, Transportation. From the figure we come to know that buildings consume 48% of energy i.e., it consumes the maximum from all three sectors.

Energy use Scenario in India:

Energy is a prerequisite for economic growth in practically all of India's key industries, including agriculture, manufacturing, transportation, business, and residential. In India, buildings use 29% of the country's total energy, of which 20% are residential and 9% are commercial.

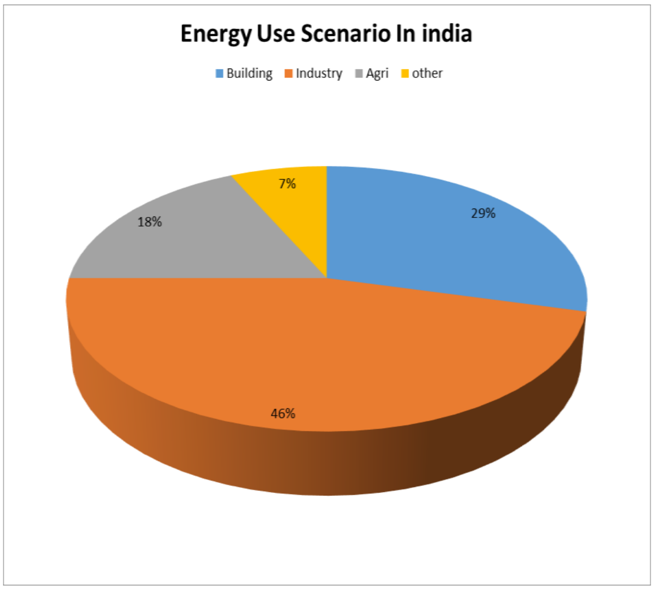


Fig.1.2 Energy Use Scenario in India

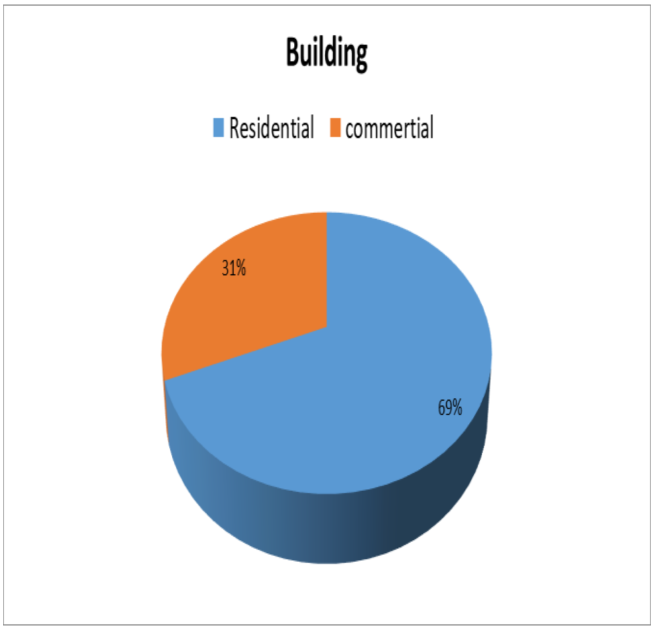


Fig. 1.3. Residential VS. Commercial Building Energy Consumption

1.2 Problem statement

- Heating, ventilation and air conditioning (HVAC) accounts for approximately 40% of building energy consumption, Soo it is important to overcome these drawbacks and to deliver energy efficient building with minimal costs to the client.
- There is not much awareness in construction industry regarding how energy consumption of a building can be reduced and other factors like lack of industrial knowledge, lack of skilled people.
- The engineer also charges for energy efficient building which is much higher to pay for a client.

1.3. Aim

To Analyze Energy Efficiency of Building for Indian Climatic Zones using Simulation Software.

1.4. Objective

1. To identify most influencing architectural parameters.
2. To develop a complex 3D model as per parameters set of building in Revit.
3. To run an energy analytical model in Insight 360 and to get energy consumption results.

2. Literature Survey

- **R.Pacheco, et al. (2012**) this paper discusses about various factors or parameters involved in affecting the internal temperature of the building and the total energy demand of the building to achieve thermal comfort.
- **Werner Pessenlehner et al. (2003)** simple numeric indicators are used by certain energy related building standards to describe geometric compactness of the building.
- **Soojung Kim et al. (2016)** windows play a major role in improving energy efficiency of buildings. in this article 65 different design scenarios are created which are vary by window size, position and orientation.
- **Saboor Shaik et al. (2016)** this paper presents the thermal performance of various single glazing window glasses covered with and without window overhang shading.
- **Ahmed S. Muhaisen et al. (2016)** this paper examines the effect of building proportions and orientations on the thermal performance of housing units.

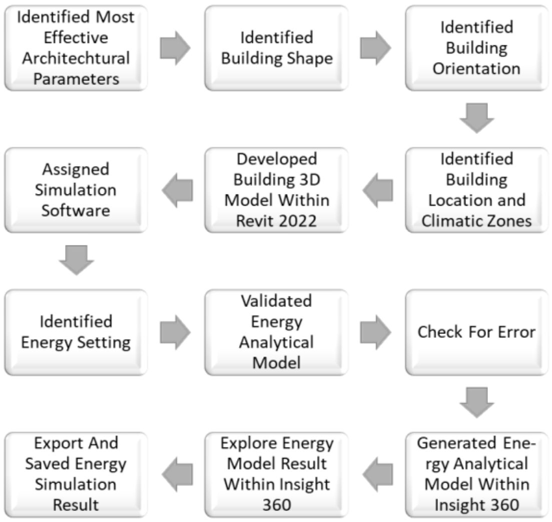
3. METHODOLOGY

3.1 Overview

The research design for the present study involves the following steps:

i) A sample of different building shapes is selected, providing morphological variance;
ii) Different glazing scenarios are generated through variance in glazing area
iii) Orientation;

iv) The resulting set is going to done thermally analyzed via **Autodesk Insight 360**



3.2 Shapes

A modular geometry system was derived based on an elementary cube(5x5x5m): To generate different building shapes, such elements were used. These elements were aggregated in different ways to create 70 morphological variations among which nine were selected on the basis of geometric index and relative compactness. The "relative compactness" (RC) indicator was employed to define compactness. The RC of a shape is derived in that its volume to surface ration is compared to that of the most compact shape with same volume.

According to relative compactness of each building shape they were divided into nine groups 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 1. The shapes of buildings which were having common relative compactness were clubbed into one group among nine above. Then one shape from each group was selected and then analyzed through software (**Autodesk Insight 360**) Analysis.

Following are the examples of different building shapes grouped according to relative compactness among the 70 wooden models.

1. **Relative Compactness (0.6)**

Fig. 3.2.1. Building Shape 1, Relative Index 0.6

2. **Relative Compactness (0.65)**

Fig. 3.2.2. Building Shape 2, Relative Index .65

3. **Relative Compactness (0.7)**

Fig. 3.2.3. Building Shape 3, Relative Index 0.7

4. Relative Compactness (0.75)

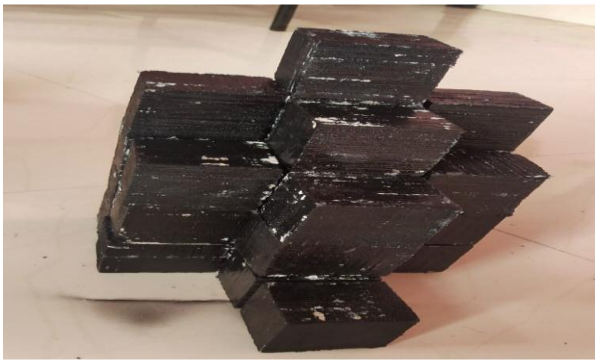


Fig. 3.2.4. Building Shape 4, Relative Index 0.75

4. Relative Compactness (0.8)

Fig. 3.2.5. Building Shape 5, Relative Index 0.8

6. Relative Compactness (0.85)

Fig. 3.2.6. Building Shape 6, Relative Index 0.85

7. Relative Compactness (0.9)

Fig. 3.2.7. Building Shape 7, Relative Index 0.9

8. Relative Compactness (0.95)

Fig. 3.2.8. Building Shape 8, Relative Index 0.95

4.3. TABLE: SHAPE DETAILS

Sr. No.	Name	Exposed Area	Geometrical Index	Relative Index
1	Compact Shape	1125	3	1.0
2	Shape 1	1850	1.824	0.6
3	Shape 2	1725	1.950	0.65
4	Shape 3	1650	2.045	0.7
5	Shape 4	1575	2.142	0.75
6	Shape 5	1400	2.450	0.8
7	Shape 6	1350	2.500	0.85
8	Shape 7	1300	2.596	0.9
9	Shape 8	1200	2.820	0.95

4.4. List of Software's used for building energy simulation

1) OPEN STUDIO
2) ESP-r
3) **AUTODESK INSIGHT 360**
4) eQUEST
5) TRNSYS 18
6) TRANE TRACE 700
7) IDA Indoor Climate and Energy
8) ENERGY PLUS+OPEN STUDIO+TRIMBLE
9) CARRIER HAP
10) IES VE (Integrated Environmental Solutions - Virtual Environment)

About Insight 360

Insight 360 is an energy analysis and thermal load simulation program. based on a user's description of a building from the viewpoint of the physical composition of the building and related mechanical and other systems. It calculates heating and cooling loads necessary to maintain thermal control set points, conditions throughout secondary HVAC system and coil loads, and the energy consumption of primary plant equipment. Simultaneous integration of these -and many other details verify that the Insight 360 simulation performs as would the real building.

Insight 360 is a whole building energy simulation program that engineers, architects, and researchers use to model energy and water use in buildings. Modeling of a building with Insight 360 enables building professionals to the performance optimize the building design to use less energy and water. Each version of Insight 360 is tested extensively before release.

Insight 360 models heating, cooling, lighting, ventilation, other energy flows, and water use. Insight 360 includes many innovative simulation capabilities: time steps less than a half hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, water use, natural ventilation and photovoltaic system.

Key capabilities of Insight 360

AUTODESK® INSIGHT 360™

- Discover a fast, Intuitive Outcome Driven Guide to Better Building Energy &Environment Performance throughout the Building Lifecycle

- Visualize critical performance metrics, benchmarks, factors, ranges, and specs and interact with them to get real-time cause-and-effect feedback that can help you achieve better results.

- Create strong autonomous analytical models using Formlt Pro and Revit to create insights, and see performance data right in the modelling environment.

- Utilizing cutting-edge parallel cloud computing techniques, trusted industry-leading simulation engines for whole building energy, heating, cooling, day lighting, and solar radiation simulation operate to simultaneously represent millions of possible outcomes.

- Organize and share insight with other stakeholders and access anywhere to work towards better outcomes continuously and consistently from early targeting and feasibility all the way through to operation.

3.5 Autodesk Insight 360 Software

Advanced modelling tools are offered by Autodesk Insight 360 in a user-friendly interface. This makes it possible for the entire design team to create cost and energy-efficient designs from conception to completion using the same tools. It is a well-liked tool used by architects, has a straightforward modelling process, makes it simple to quickly change a model's attributes, and takes a decent amount of time to analyze a model.

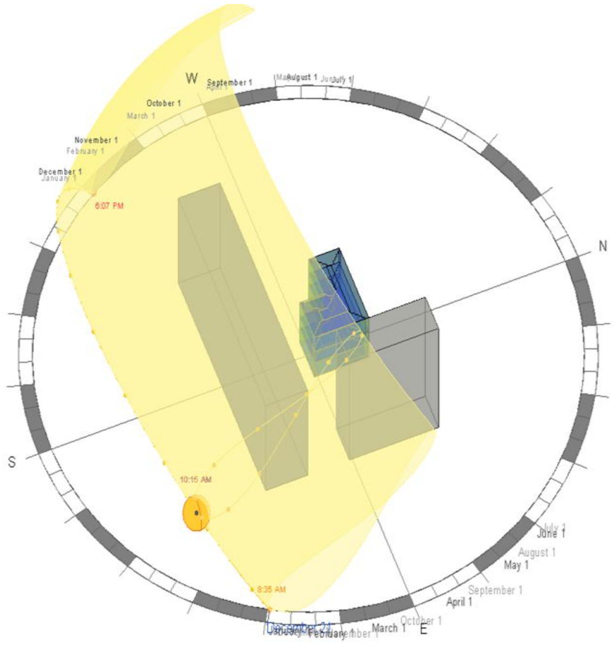


Fig. 3.5.1. Image Shows Payback analysis in Insight 360

The Autodesk Insight 360 procedure starts with creating a three-dimensional shell that represents the building form. This can be done in one of two ways:

1) Building geometry can be imported from 2D CAD floor plan data and then traced over within Autodesk Insight.

360 to create blocks and to partition block up in to zones.
2) 3D-CAD models can be imported from Revit, Micro station, ArchiCAD and Sketchup using gbXML.

For this analysis, we can prepare the building's geometry in Rivet, and then imported the 3D model as surfaces and rooms to Autodesk Insight 360. The analysis then moves forward with the building's envelope being given its allocated thermal properties. a component's constituent substance (concrete wall, slab, glazing wall, etc.).

3.6 Modeling assumptions

For the purpose of the present analysis, several assumptions are made:

a) All the buildings have equivalent material usage, thermal properties and elements;

b) All the buildings are oriented 90° and 180° with the north.

c) Set units as energy

Auto desk Insight 360 calculates the heating and cooling loads based on the admittance procedure, which assume that the fluctuations between the external and internal loads can be presented by the sum of the steady-state component. This method is insensitive to the rapid change in neither temperature nor long-term heat storage.

However, this method has no restrictions on the number of thermal zones or building geometry. The analysis based on the local (outside and inside) mean and the fluctuations in the temperature around this mean, when outside temperature or solar load change the internal air temperature fluctuate in a similar way.

3.7 Analysis Process:

Analysis is going to done on five climate Zones of India

1) Zone I Hot and Dry :-(Jaisalmer)
2) Zone 2 Warm and Humid: - (Chennai)
3) Zone 3 Composite: - (Lucknow)
4) Zone 4 Cold: - (Srinagar)
5) Zone 5 Temperate: - (Bangalore)

The analysis based on the local (outside and inside) mean and the fluctuations in the temperature around this mean, when outside temperature or solar load change the internal air temperature fluctuate in a similar way.

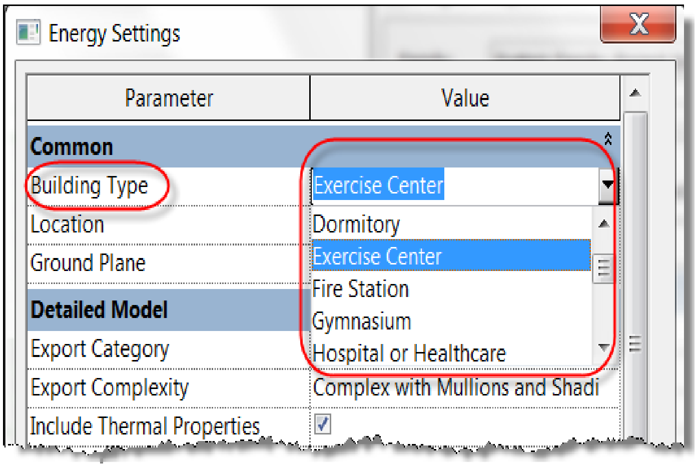
The method used in this study is derived with some considerations and assumptions. The thermal analysis involves examining each of the 9 models in each of the five Zone 1. Hot and Dry Zone 2. Hot and Humid Zone 3. Composite Zone 4. Cold Zone 5. Moderate.

The 9 models analysis required 540 different simulation runs, each of which requires approximately half an hour to complete. For each climate zone, weather data (TMY files) for each city is loaded and the 9 models were tested under equal thermal conditions. That is, the only differences among the runs in the same climate zone are the geometric ratio. Weather data files are imported through AUTODESK INSIGHT 360.

Procedure of Simulation of energy building

A) Creating a building Geometry

- Select Architectural template→ Set out Project Unit as Energy and then create the shape.



- Specifying the Openings.
- Specifying the Location.
- Specifying the Type of Building.
- Generating an analytical model.
- Specifying the Orientation.

B) Visualize

After generating energy model, the building will look like as below.

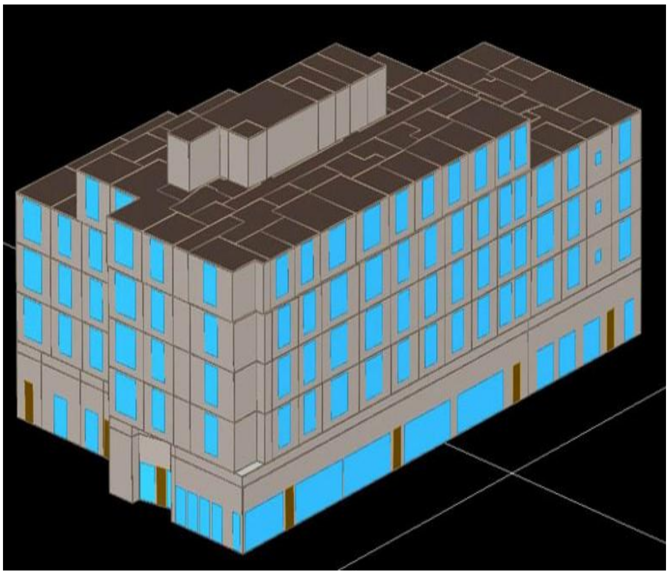
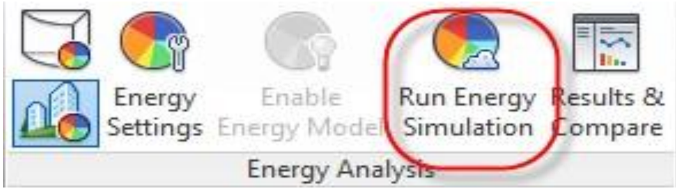
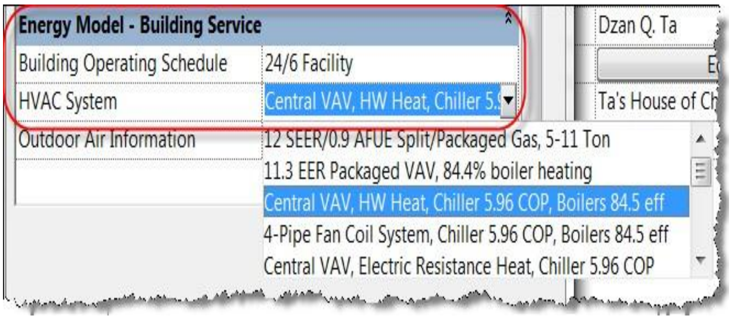


Fig. 3.7.1 Virtual 3D Revit Building Energy Model

C) Run Simulation and Obtaining the Result



- Defining thermal properties of materials.
- Defining Specifying the HVAC system.



- Thermal properties of materials.
- Specifying different space types in our building
- Generating our defined building in detail.

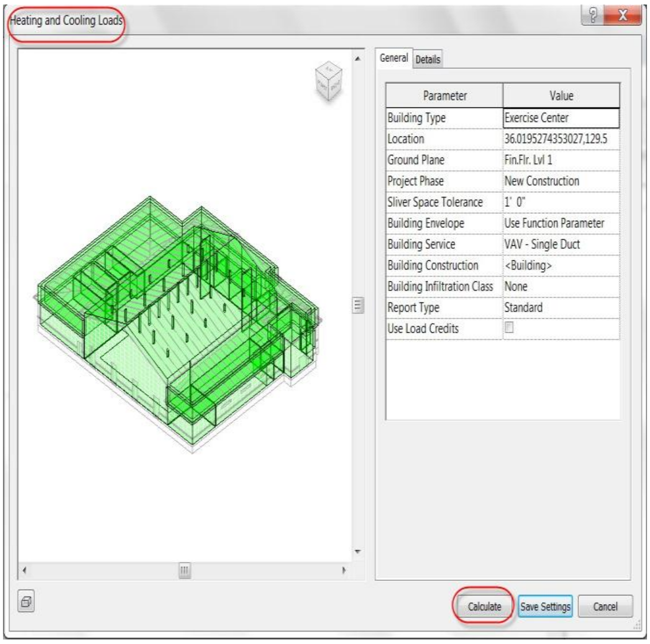
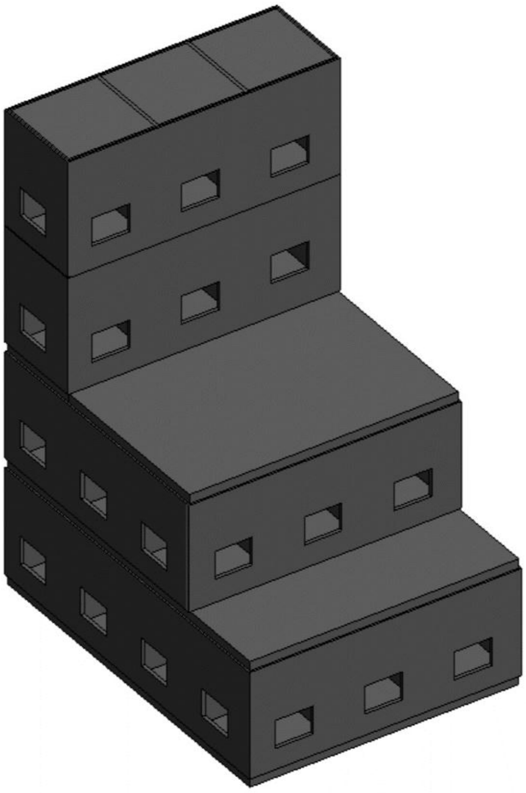
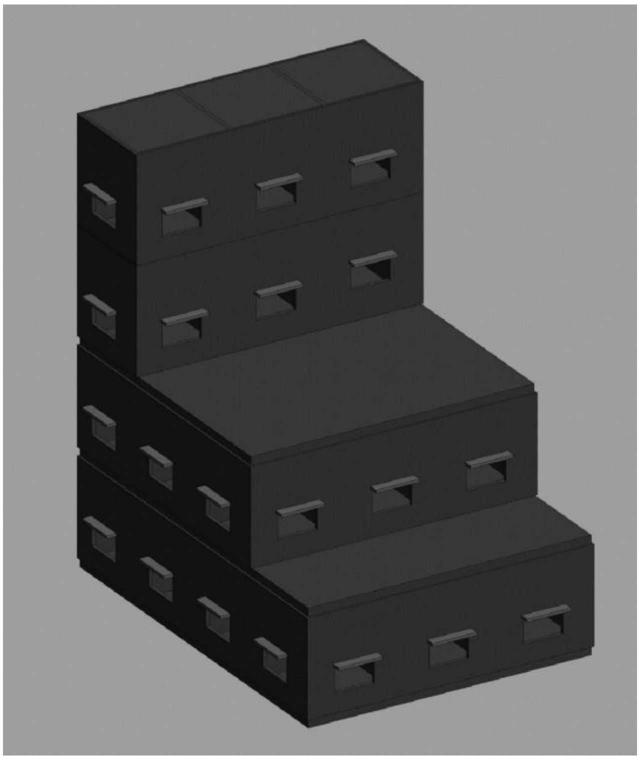


Fig. 3.7.2. Revit Heating and Cooling Load Simulation

BUILDING WITH 10% WINDOWS WITHOUT CHAJJA



BUILDING WITH 10% WINDOWS WITH CHAJJA SIZE 0.5M (20")



5. RESULTS AND DISCUSSION

A role of Insight 360 is to operate simulations of construction performance to optimize power effectiveness as well as to work towards carbon neutrality previously in the design phase.

This idea helps to extend ability before designing high performance buildings. By using Autodesk Revit 2022, the evaluation of power usage can conduct power simulation for conceptual forms and comprehensive architectural designs produced in the software. The output of heating & cooling load and energy consumption are presented in this part.

The control of heating and cooling loads is very significant for facility because it is associated with fuel and electricity consumption. It is well known that by accumulative the thermal mass of a building facility, more heat is stored in the facility structure and the daily maximum temperature is decreased.

The thermal loads are overdue for some hours and this is the way of controlling the temperature of the facility simultaneously. Therefore, heating and cooling analysis for the facility is performed using BIM for designing a better sustainable facility such that, it gets heated and cooled naturally.

Table No. 4.1. Heating & Cooling Loads (In MW.Hr) Hot & Dry Region (Jaisalmer)

Climatic zone	Relative compactness	10%				25%				40%			
		With Chajja		Without Chajja		With Chajja		Without Chajja		With Chajja		Without Chajja	
		90 (E)	180 (S)	90	180	90	180	90	180	90	180	90	180
Hot & Dry	0.6	83.37	79.745	96.38	91.07	93.76	88.67	93.76	88.67	**131.48**	121.84	102.43	95.97
	0.65	81.31	76.62	93.66	86.79	91.26	84.73	91.26	84.73	127.38	114.59	99.76	91.42
	0.7	80.05	74.45	91.77	83.5	89.6	81.81	89.60	81.81	124.23	108.84	97.86	87.93
	0.75	70.79	74.79	78.24	**68.42**	76.99	73.76	76.99	**73.76**	98.95	92.76	82.38	78.30
	0.8	69.57	68.77	76.84	75.8	75.72	74.63	75..72	74.63	97.52	95.88	81.05	79.75
	0.85	72.82	70.51	80.89	77.26	79.72	76.33	79.72	76.33	104.08	96.92	85.75	81.40
	0.9	72.14	71.29	79.23	78.56	78.71	77.51	78.71	77.51	101.95	99.83	84.47	83.02
	0.95	69.44	69.4	76.03	75.92	75.13	75.07	75.13	75.07	95.36	95.18	80.22	80.12
	1	74.89	74.84	81.61	81.59	80.65	80.61	80.65	80.60	101.22	101.17	85.74	85.71

Table No. 4.2. Heating & Cooling Loads (In MW.Hr) Warm & Humid Region (Chennai)

Climatic zone	Relative compactness	10%				25%				40%			
		With Chajja		Without Chajja		With Chajja		Without Chajja		With Chajja		Without Chajja	
		90 (E)	180 (S)	90	180	90	180	90	180	90	180	90	180
Warm & Humid	0.6	95.94	94.08	106.36	103.84	107.02	104.38	**124.15**	120.52	116.25	105.34	122.65	121.54
	0.65	93.44	91.10	103.24	99.79	103.95	100.61	120.11	114.96	112.84	102.51	121.46	116.45
	0.7	91.83	89.11	101.07	96.95	101.87	97.97	117.12	110.83	110.48	101.65	120.75	111.46
	0.75	83.05	81.84	89.07	87.35	89.77	88.13	99.69	97.21	95.62	91.22	101.37	99.26
	0.8	82.17	**81.63**	88.14	84.54	88.95	88.28	98.91	98.12	94.90	92.35	103.15	101.32
	0.85	85.24	84.17	91.64	89.98	92.59	91.02	103.31	100.10	99.14	96.35	106.94	104.76
	0.9	84.95	84.49	91.23	90.62	92.18	91.55	102.068	101.83	98.57	93.65	104.55	106.73
	0.95	82.36	82.26	87.87	87.73	88.74	88.64	97.97	97.78	94.47	**89.96**	100.53	99.62
	1	88.32	88.18	93.82	93.80	94.65	94.60	104.01	103.98	100.36	99.45	109.64	105.72

Table No. 4.3. Heating & Cooling Loads (In MW.Hr) Composite Region (Lucknow)

Climatic zone	Relative compactness	10%				25%				40%			
		With Chajja		Without Chajja		With Chajja		Without Chajja		With Chajja		Without Chajja	
		90	180	90	180	90	180	90	180	90	180	90	180
Composite	0.6	79.97	77.02	91.19	87.49	88.68	85.09	**107.58**	102.43	96.23	86.56	105.36	103.25
	0.65	76.67	74.37	88.66	83.81	86.42	81.76	104.21	97.46	93.70	82.46	103.56	98.22
	0.7	76.68	76.62	86.95	81.18	84.93	79.41	101.77	93.72	92.01	80.01	96.25	95.14
	0.75	68.81	**67.02**	75.40	72.92	74.19	71.80	84.95	81.56	78.92	**73.00**	86.45	85.46
	0.8	67.99	67.47	74.52	73.85	73.44	72.71	84.15	83.29	78.17	75.58	88.24	89.46
	0.85	70.98	69.21	78.08	75.49	77.94	74.84	88.68	84.95	82.20	77.65	89.70	85.95
	0.9	70.43	69.81	77.26	77.44	76.23	75.40	87.57	86.44	81.31	78.32	89.65	87.46
	0.95	68.17	68.14	74.14	74.05	73.24	73.18	83.14	83.01	77.76	78.15	86.36	85.95
	1	73.35	73.32	79.46	79.44	78.47	78.44	89.57	88.06	82.99	80.57	90.94	90.35

Table No. 4.4. Heating & Cooling Loads (In MW.Hr) Cold Region (Srinagar)

Climatic zone	Relative compactness	10%				25%				40%			
		With Chajja		Without Chajja		With Chajja		Without Chajja		With Chajja		Without Chajja	
		90	180	90	180	90	180	90	180	90	180	90	180
Cold	0.6	64.42	62.91	74.13	72.44	71.07	69.09	87.11	84.92	76.53	71.34	**91.66**	86.64
	0.65	63.15	61.20	72.16	69.97	69.49	66.95	84.41	81.56	74.77	69.46	86.25	83.86
	0.7	62.55	61.26	70.98	68.38	68.61	65.61	82.60	79.19	73.75	66.49	83.56	84.22
	0.75	56.59	**55.48**	62.05	60.80	60.37	**58.94**	69.35	67.77	63.68	61.52	71.65	69.86
	0.8	56.79	56.49	62.39	62.14	60.92	60.51	70.26	69.93	64..49	63.42	72.45	71.35
	0.85	59.49	58.42	65.45	64.19	63.92	62.51	72.92	72.17	67.81	63.56	74.11	74.33
	0.9	59.14	58.77	65.07	64.66	63.55	63.06	73.48	72.95	67.37	66.78	75.35	75.48
	0.95	57.67	57.63	62.89	62.82	61.55	61.50	70.30	70.19	64.99	63.03	72.84	72.76
	1	62.20	62.19	67.58	67.61	66.13	66.12	75.13	75.17	69.59	68.34	79.62	78.45

Table No. 5 Heating & Cooling Loads (In MW.Hr) Temperate Region (Bangalore)

Climatic zone	Relative compactness	10%				25%				40%			
		With Chajja		Without Chajja		With Chajja		Without Chajja		With Chajja		Without Chajja	
		90	180	90	180	90	180	90	180	90	180	90	180
Temperate	0.6	71.66	68.54	83.15	78.19	79.29	74.97	97.95	91.01	85.54	76.66	**99.46**	93.02
	0.65	70.31	66.33	81.31	75.01	77.70	72..21	95.56	86.70	83.89	79.12	96.14	87.16
	0.7	69.07	62.03	80.26	72.80	76.89	70.48	94.000	83.48	83.03	73.25	95.11	86.63
	0.75	62.02	**60.07**	68.67	65.59	66.34	**63.70**	77.13	72.83	70.06	67.22	78.46	74.95
	0.8	61.71	61.14	68.11	67.23	66.31	65.52	76.82	75.63	70.25	68.56	77.59	79.24
	0.85	64.98	63.05	72.00	68.85	70.10	67.49	81.69	77.11	74.72	69.64	83.15	78.93
	0.9	64.37	63.76	71.05	70.08	69.29	68.44	80..38	78.99	73.57	71.16	82.49	80.84
	0.95	62.41	62.43	68.17	68.155	66.73	66.71	76.28	76.23	70.50	67.23	79.68	77.54
	1	67.53	67.50	73.42	73.42	71.88	71.84	81.64	81.63	75.66	73.86	83.46	83.56

4. CONCLUSIONS

Building energy requirements are the reason for a high percentage of energy use. In this article, Building Information Modeling (BIM) technology was used to accentuate the importance of this technology in such substantial subjects. it was found that the application of this technology Can lead to precognition of the designed building performance that provides a real opportunity to decision-makers to enhance the building performance in a way that minify the energy consumption, cost, and pollution.

The results showed that:

• Use suitable orientation of the building saves around 3%-4% of the energy and its cost.

• Reducing the windows to walls ration to 20% can reduce the energy and its cost 2%-4%, respectively.

• 1.5% of total energy can be saved by using the proper Morphology of building.

• Use a suitable HVAC system can save (15%-45%) of annual energy and (5%-30%) of its cost.

REFERENCES

1. Pacheco, R., Ordóñez, J., & Martinez, G. (2012). Energy efficient design of building: A review. Renewable and Sustainable Energy Reviews, 16(6), 3559-3573.

2. Pessenlehner. W., & Madhavi A. (2003). Building morphology, transparence, and energy performance.

3. Kim, S., Zadeh, P. A., Staub-French, S., Froese, T., & Cavka, B. T. (2016). Assessment of the Impact of Window Size, Position and Orientation on Building Energy Load Using BIM. Procedia Engineering, 145, 1424-1431.

4. Reeves and et al, "Guidelines for using Building Information Modeling for energy analysis of buildings," Buildings, vol. 5, no. 4, pp. 1361-1388, 2015.

5. Shaik, S., Gorantla, K., & Setty, A. B. T. P. (2016). Effect of Window Overhang Shade on Heat Gain of Various Single Glazing Window Glasses for Passive Cooling. Procedia Technology, 23, 439-446.

6. Muhaisen, A. S., & Abed, H. M. (2016). Effect of Building Proportions on the Thermal Performance in the Mediterranean Climate of the Gaza Strip. Journal of Engineering Research and Technology, 2(2).

7. Gao, Koch, and Wu, "Building Information Modelling based Building Energy Modelling: A review," Applied Energy, vol. 238, pp. 320-343, 01/22 2019.

8. Abanda and et al, "An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling)," Energy, vol. 97, pp. 517-527, 2016

9. Autodesk. (2014). Building Information Modeling for Sustainable Design. Available: https:// federal news network.com/wpcontent/uploads/pdfs/Building Information Modeling for Sustainable Design-white%20paper.pdf, Accessed on: November 15,2019

10. Central Electricity Authority's Year End Review 2020-21, New Delhi:CEA, MoP, from GOVERNMENT OF INDIA, Retrieved www.cea.nic.in/reports/yearly/annual report /2020-21/ar_20_21.pdf,2021.