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Optimizing Energy Efficiency in Commercial Buildings through Advanced Building Strategies

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Abstract
The pressing issue of climate change and its correlation with greenhouse gas emissions has propelled a heightened emphasis on energy-efficient building practices, particularly within the commercial sector. This study delves into advanced design strategies aimed at maximizing energy efficiency while upholding quality and comfort standards. By scrutinizing a functioning commercial building in Gurugram, Haryana, data was gathered to construct an energy model using eQUEST. Analysis encompassed various building facets such as envelope components (e.g., walls, roofs, and windows), HVAC systems, lighting, and occupancy patterns. The outcomes furnish valuable insights into pivotal factors influencing energy efficiency and propose tailored strategies for integration into commercial building design. This methodical approach, informed by case evaluation, seeks to optimize energy performance and cost-effectiveness across diverse building types and climates.
Keywords: *Energy Modelling, eQUEST, Design, Analysis, Optimizing.*

1. Introduction
In recent years, countries around the globe have been enacting energy policies aimed at attaining low-carbon and energy-saving goals. Central to these efforts is the emphasis on enhancing energy consumption efficiency while simultaneously reducing overall energy usage. Furthermore, by drawing insights from the practices of energy-saving industries abroad to bolster the growth of Energy Service Companies (ESCOs), the energy performance contracting model enables energy consumers to compensate ESCOs for the expenses associated with energy-saving projects through the realized energy efficiency gains, fostering a mutually beneficial scenario. The collaboration between the US Department of Energy (DOE) and the industrial sector has resulted in the establishment of a framework for measuring and verifying energy efficiency known as the International Performance Measurement and Verification Protocol (IPMVP). Through the use of standardized methods for measurement and verification (M&V), this protocol aims to validate the achieved energy efficiency resulting from energy-saving initiatives, thus alleviating concerns among energy consumers regarding the effectiveness of energy efficiency measures [1]. The Efficiency Valuation Organization (EVO), a private, non-profit entity, sponsors the International Performance Measurement and Verification Protocol (IPMVP). The IPMVP offers a comprehensive summary of the leading techniques currently available for verifying the outcomes of energy efficiency, water efficiency, and renewable energy initiatives. Within the IPMVP, there are four options for M&V methods: A through D. Option D involves utilizing numerical simulation to enhance the measurement and verification (M&V) process for building energy savings. It enables the assessment of the potential impact of implementing various energy-saving measures on a building's overall energy consumption beforehand [2]. The conditions

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surrounding building energy consumption have been the subject of extensive research. Zhu [3] evaluated the energy-saving measures in accordance with the Energy Star standard and examined the impact of different energy-saving measures on building energy consumption conditions using eQUEST simulation software models. Kim et al. used eQUEST to simulate the energy consumption conditions of community emergency service centers [4] data mining techniques were utilized to contrast the initial building's baseline energy consumption status with 12 HVAC options, 127 roof structures, 88 wall materials, and 12 building orientations. This analysis facilitated the calculation of energy efficiency gains. The findings revealed that HVAC systems exerted the most significant influence on building energy consumption, resulting in an annual savings of US$150 in efficient energy usage and building orientation had the least impact on energy use, saving an estimated 11–17 US dollars per year on energy efficiency. Yu and others. [5] EQUEST was employed to investigate the influence of different factors, including building envelope shielding, external wall thermal insulation, external wall thermal emission, window-to-wall ratio, and glass type, on air conditioner energy usage in residential constructions. Their findings indicated that enhancements in envelope shielding and external wall insulation were effective in reducing air conditioner energy consumption, achieving energy savings rates of 11.31% and 11.55%, respectively [6] claimed that older hotels used enormous amounts of energy because strict rules and limits had not been set. Sozer investigated passive designs that could successfully lower building energy consumption using eQUEST software simulation. In the end, he showed that insulation, shielding, and window type can reduce heating and cooling energy consumption by 40%. [7] Studies on the impact of insulation in building walls on building energy reduction have demonstrated that insulation can cut building electricity use and CO_2 emissions by about 40%. [8] Installed a green roof system in a nursery school and used empirical research and theoretical simulation to demonstrate that the system could successfully lower cooling loads by roughly 6–49%. Using TRYSNS software, [9] investigated the energy consumption of contemporary homes and discovered that installing roof insulation reduced cooling and heating loads considerably. [10] Provided low-energy building design parameters for building designers to consider, such as building orientation, wall construction, building shields, glass classification, and passive heating and cooling systems. Window blind size and color optimization has been shown to reduce building air conditioner electricity use by 14.1% during the summer, according to [11]. Research on window blind size and color optimization has demonstrated significant energy-saving potentials in buildings. During the summer, it was found that optimizing window blinds could reduce air conditioner electricity usage by 14.1% [Li et al., 12]. Additionally, solar film coating and light control methods were shown to reduce lighting power density energy consumption by 21.2% and air conditioner energy consumption by 6.9% in offices [Li et al., 12]. Green roof installation techniques were examined by Castleton et al. [13] for their energy-saving potential. Phillip et al. [14] utilized TRACE600 to simulate commercial building energy consumption and identified 20 energy-saving measures for future engineers designing air conditioning systems. Kawamoto et al. [15] evaluated the energy-saving potential of office equipment management, accounting for approximately 2% of Japan's annual commercial energy consumption. Sensitivity analysis on wall structure, materials, window frames, and HVAC systems in government buildings was conducted by Tavares et al. [16] using Visual DOETM simulation tools. Yin et al. [17] showed that double low-E windows with solar film coatings could effectively reduce annual electrical use and peak demand in commercial buildings, with internal and external solar film coatings reducing cooling loads by 2.2% and 27.5%, respectively. Kim et al. [18] used IES VE energy analysis programming to investigate the impact of different exterior shading devices on air conditioning loads in residential buildings, highlighting the effectiveness of exterior shading devices in reducing air conditioning energy consumption. The studies previously discussed primarily concentrated on evaluating the

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effectiveness of different energy-saving strategies and designs in reducing overall energy usage in buildings. However, they did not delve into assessing the precision of simulation outcomes produced by adjusting software parameters. Consequently, this research aims to investigate the level of discrepancy in simulation results and the calibration of energy consumption parameters within eQUEST software. By ensuring the accuracy of the simulation models, this study then explores how alterations in energy consumption parameters impact the overall energy usage within a building.

2. eQUEST

EQUEST (Fast Vitality Reenactment Apparatus) is a vitality modeling program that utilizes the U.S. DOE's recreation instrument DOE-2. Numerous versions of eQUEST have been created since its beginning. EQUEST 3.65 is the most recent adaptation created by DOE in October 2018. Its cost-free accessibility and appropriateness in every building advancement organized (from the starting planning stage to the ultimate stages) have made eQUEST one of the foremost prevalent vitality modelling programs in use nowadays. EQUEST has three distinctive input wizards where clients can input different parameters of the building. The three wizards in eQUEST are schematic plan wizard, design development wizard, and energy efficiency wizard. Schematic plan wizard is utilized within the most punctual stages of the plan, where small data of almost all the building parameters is known. It as it were inquiring for basic inputs from the client. In the point-by-point improvement wizard, more specific data approximately the building parameters is required. The vitality productivity measure wizard permits clients to analyze numerous scenarios for the plan demonstrated with essential input data to analyze the building's vitality performance. The precision of results from building vitality modelling computer programs like eQUEST depends on the precision of the data entered the program. Indeed, the foremost experienced energy modelers might not precisely obtain results coordinating 100% with the real comes about. This is often because all vitality modelling programs have a few confinements. Successful Modeling Capability of eQUEST. EQUEST is an excellent energy modelling and recreation apparatus to assess the energy execution of different sorts of buildings. However, not all building highlights can be successfully modelled in eQUEST. The accuracy of eQUEST recreation depends upon whether eQUEST can successfully show these highlights or not. [19]

3. Methodology

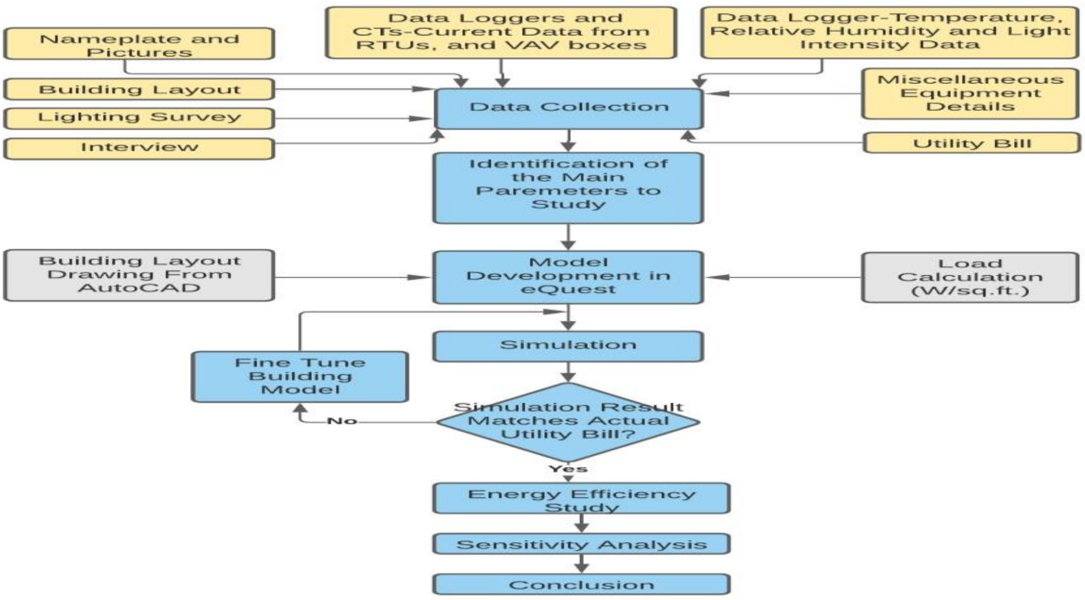

Figure 1 Methodology

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The research aims to discern the most influential building parameters impacting energy performance, utilizing data obtained from energy modeling of an operational commercial building in Gurugram, Haryana, and GR Infra. A baseline simulation model is developed in eQUEST, calibrated and validated against actual utility bills spanning a year. To assess the influence of selected building parameters on energy performance, variations in baseline values are tested at two levels: Low and High values. This investigation, conducted in the context of GR Infra building in Gurugram, aims to identify the top three parameters with the highest impact on the overall energy performance of the structures. The research methodology overview is depicted in Figure 1 in below.

4. Model Development

EQUEST version 3.64 was used to develop the building model. When the EQUEST software is opened, it offers two wizards to choose from. Schematic Design Wizard (SDW) and Design Development Wizard (DDW). The SDW is generally used for pre-design phase studies of smaller/simple structures with simple schedules and limited data. The DDW is used for later stages of design or studies of existing buildings of complex shapes and sizes with complicated schedules. Thus, more input of data is required in the DDW. Since the study is being performed on an existing building with detailed data availability, the DDW was selected. The wizard opens a set of seven windows that require general information about the building address, project information, and several seasons. Then the wizard takes users to the navigator, where users can input more information about the building. Figure 2 shows the EQUEST Model.

4.1. Project Description

- Building Type: Office
- Gross Floor Area: 4, 17,848 ft2
- W.W.R (Window wall ratio): North 59%, South 61.5%, East 63%, West 20%
- Location: Gurgaon
- Occupancy: 9AM to 6 PM Weekdays
- Workings days per annum: 305
- No. of Floors: 2 Basement + Stilt + 7

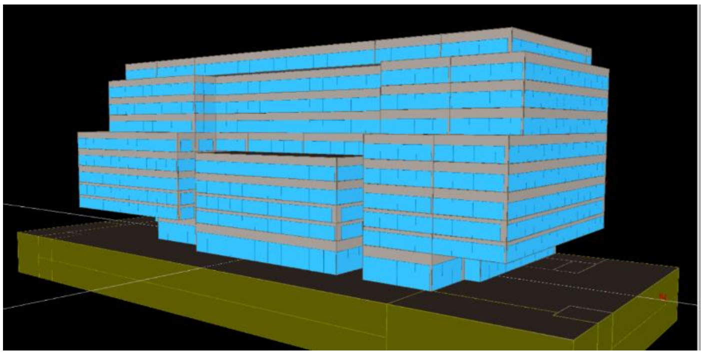
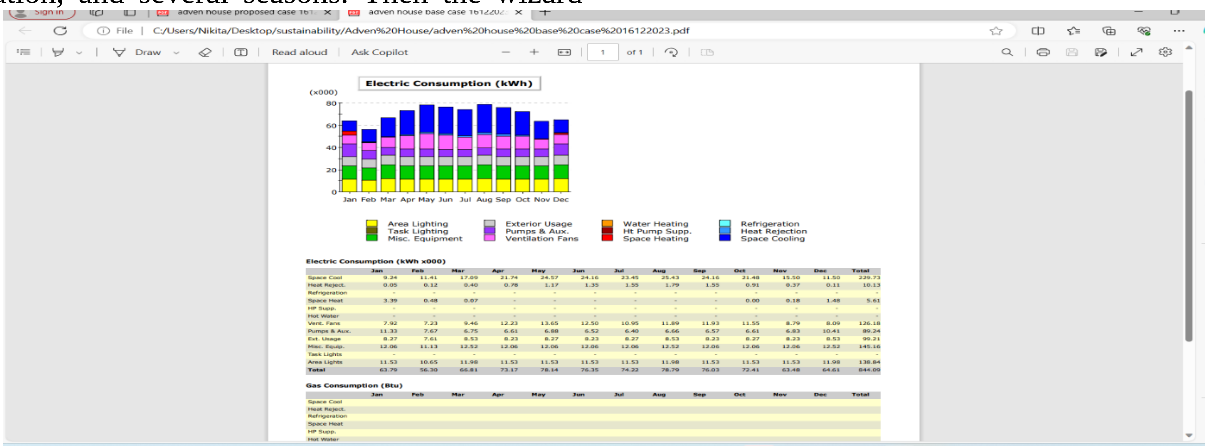


Figure 2 EQUEST Model

5. Result and Discussion

The results and discussions of the study on optimizing the energy performance of the HVAC system in an office building with eQUEST software are as follows. The buildings, initial baseline results did not satisfy the calibration criteria. The building baseline simulation result had the same pattern of monthly energy consumption as the actual utility bill. The results are depicted in Figure 3 and Table no 1



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	9.24	11.41	17.09	21.74	24.57	24.16	23.45	25.43	24.16	21.48	15.50	11.50	229.73
Heat Reject.	0.05	0.12	0.40	0.78	1.17	1.35	1.55	1.79	1.55	0.91	0.37	0.11	10.13
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	3.39	0.48	0.07	-	-	-	-	-	-	0.00	0.18	1.48	5.61
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	7.92	7.23	9.46	12.23	13.65	12.50	10.95	11.89	11.93	11.55	8.79	8.09	126.18
Pumps & Aux.	11.33	7.67	6.75	6.61	6.88	6.52	6.40	6.66	6.57	6.61	6.83	10.41	89.24
Ext. Usage	8.27	7.61	8.53	8.23	8.27	8.23	8.27	8.53	8.23	8.27	8.23	8.53	99.21
Misc. Equip.	12.06	11.13	12.52	12.06	12.06	12.06	12.06	12.52	12.06	12.06	12.06	12.52	145.16
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	11.53	10.65	11.98	11.53	11.53	11.53	11.53	11.98	11.53	11.53	11.53	11.98	138.84
Total	63.79	56.30	66.81	73.17	78.14	76.35	74.22	78.79	76.03	72.41	63.48	64.61	844.09

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													

Figure 3 Electric Consumption (kWh)

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The electric consumption of base line model are shown in Figure 4.

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	9.24	11.41	17.09	21.74	24.57	24.16	23.45	25.43	24.16	21.48	15.50	11.50	229.73
Heat Reject.	0.05	0.12	0.40	0.78	1.17	1.35	1.55	1.79	1.55	0.91	0.37	0.11	10.13
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	3.39	0.48	0.07	-	-	-	-	-	-	0.00	0.18	1.48	5.61
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	7.92	7.23	9.46	12.23	13.65	12.50	10.95	11.89	11.93	11.55	8.79	8.09	126.18
Pumps & Aux.	11.33	7.67	6.75	6.61	6.88	6.52	6.40	6.66	6.57	6.61	6.83	10.41	89.24
Ext. Usage	8.27	7.61	8.53	8.23	8.27	8.23	8.27	8.53	8.23	8.27	8.23	8.53	99.21
Misc. Equip.	12.06	11.13	12.52	12.06	12.06	12.06	12.06	12.52	12.06	12.06	12.06	12.52	145.16
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	11.53	10.65	11.98	11.53	11.53	11.53	11.53	11.98	11.53	11.53	11.53	11.98	138.84
Total	63.79	56.30	66.81	73.17	78.14	76.35	74.22	78.79	76.03	72.41	63.48	64.61	844.09

Figure 4 **Electric Consumption of Baseline Model**

The electric consumption of proposed strategy are depicted in Figure 5 and Figure 6 respectively

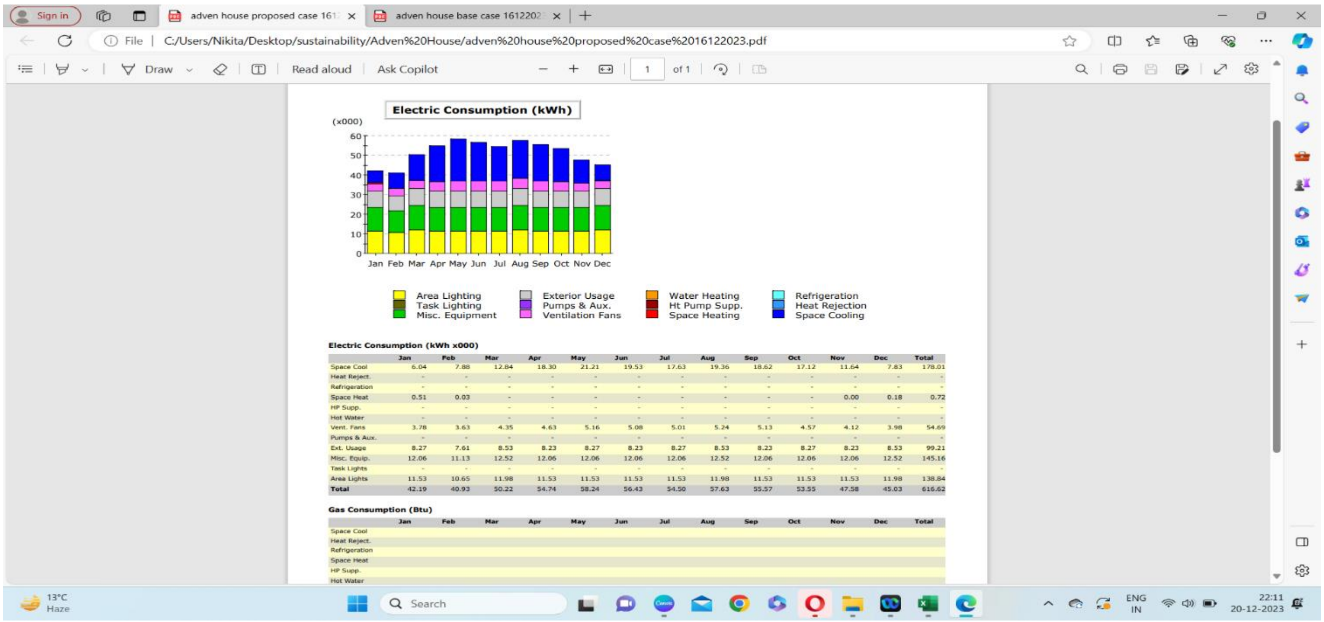

Figure 5 **Electric Consumption of Proposed Model**

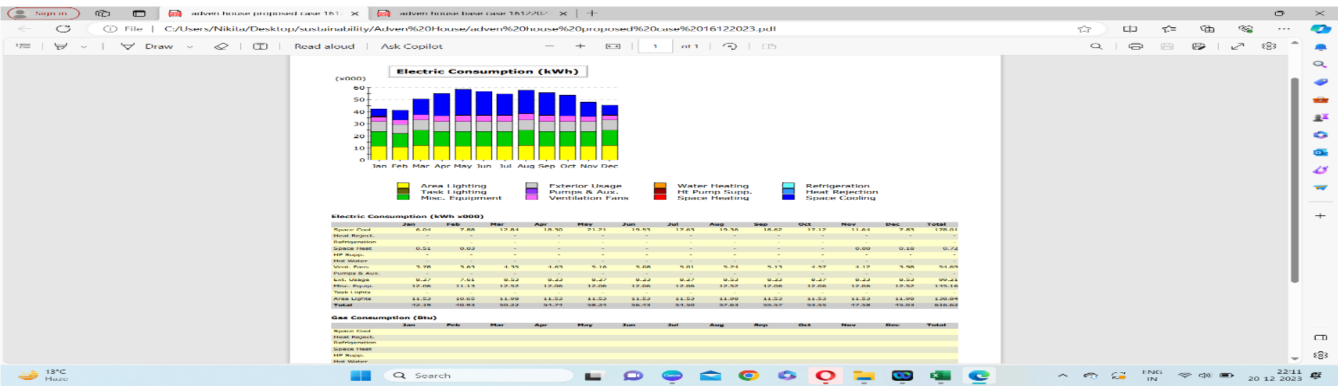

Figure 6 **Electric Consumption of Proposed Model**

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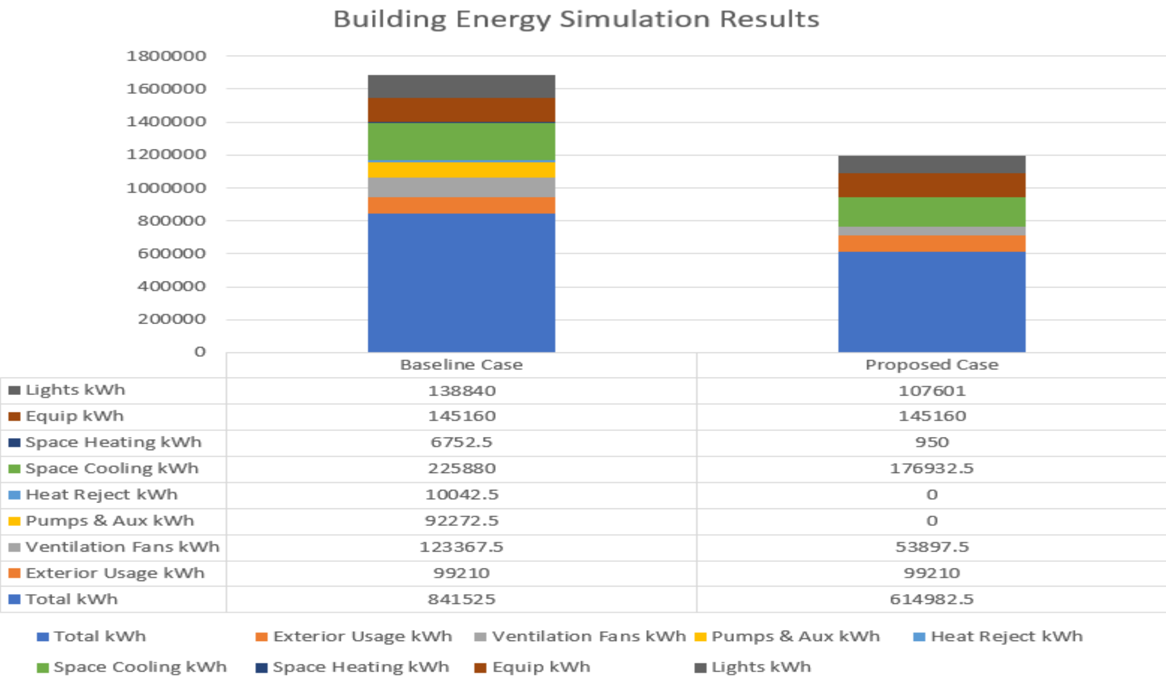
5.1. Comparison Graph



	Baseline Case	Proposed Case
Lights kWh	138840	107601
Equip kWh	145160	145160
Space Heating kWh	6752.5	950
Space Cooling kWh	225880	176932.5
Heat Reject kWh	10042.5	0
Pumps & Aux kWh	92272.5	0
Ventilation Fans kWh	123367.5	53897.5
Exterior Usage kWh	99210	99210
Total kWh	841525	614982.5

Figure 7 Comparison Graph of Baseline Model and Proposed Model

6. Savings

The saving achieved by implementing our propose model are shown in Table no 1. The cost savings are calculated by the above formula in chich the cost of Base case is subtracted by proposed case and the is hole divided by the 100

Savings = Base Case – Proposed Case / Base Case * 100

Points Achieved
12 Points

Table 1 Total Energy Consumption

Cases	Total Energy Consumption (KWh/Year)	Savings
Base Case Average	844090	---
Proposed Case	616620	26.94%

The study identified three major factors involved in achieving an energy-efficient building, namely efficient design, efficient material, and alternative resources. It helped in identifying measures to be taken in each step while constructing a building, including the design, construction, and occupancy stages of a building. Even though the specification required for the material as per ASHRAE was lower than the one used on-site, the project was able to achieve energy savings of 26.94%. This demonstrated that, in certain cases such as this project, the innovative method made a major contribution to energy consumption reduction in the building. It was also observed that the cost of the cooling system, inclusive of initial, operation, and maintenance, is saved by 80–90% when compared to the cost of VRF and VAV systems. The results also highlighted the importance of incorporating alternative resources and efficient materials in achieving energy savings. The findings of the study emphasize the significance of implementing innovative methods and technologies to optimize energy performance in commercial buildings. Moreover, the significant energy savings achieved in this project can serve as a model for future sustainable building designs, providing valuable insights for the construction industry. This study showcases the potential for integrating advanced building strategies to achieve substantial energy savings and environmentally friendly outcomes in commercial buildings. The energy analysis conducted on the GR INFRA office building has yielded substantial and multifaceted benefits, underscoring the project's commitment to sustainability. The achievement of a remarkable 27% reduction in energy consumption not only signifies operational efficiency but also highlights the success of targeted energy efficiency measures. Moreover, the implementation of strategic energy-efficient measures not only improves occupant comfort but also showcases a dedication to creating environmentally responsible spaces. The demonstrated cost efficiency, with tangible long-term savings resulting from upfront investments, further solidifies the business case for embracing sustainable practices. Beyond the financial gains, this initiative contributes meaningfully to environmental responsibility by reducing the building's carbon footprint and its overall impact on the environment. This success story sets a strong example for future sustainable building designs and reinforces the importance of integrating advanced building strategies to achieve substantial energy savings and environmentally friendly outcomes in commercial buildings. Figure 7 shows the Comparison Graph of Baseline Model and Proposed Model.

Conclusion and Future Work

In conclusion, the energy analysis done on the GR INFRA office building appeared to have a huge diminish in how much energy it employs, which highlights the project's commitment to maintainability. Accomplishing a 27% decrease in energy utilization demonstrates that the building is working proficiently, which energy-saving measures are viable. This not as it were spares cash for the company but too makes a difference the environment and sets a great case for other commercial buildings to take after. This inquiry emphasizes how critical it is for commercial buildings to be energy proficient to diminish their effect on climate alteration. By centering on way better building plan strategies, counting both detached and dynamic frameworks, this consider has given important bits of knowledge into how to spare energy while keeping the building comfortable and high-quality. By examining different variables that influence energy utilize in commercial buildings, this inquiry has appeared to determine which ones are most vital. Utilizing information from a genuine commercial building, the consider made a show to see how things just like the building's structure, its warming and cooling frameworks, lighting, and how numerous individuals are in it influence it's in general vitality utilize. The comes about of this consider allow valuable data for making commercial buildings more vitality productive. This may help architects and building proprietors to make savvy choices to make strides energy execution. Moreover, this ponder proposes a straightforward way to incorporate detached plan choices when arranging new commercial buildings that utilize discuss conditioning. This strategy considers both how well the building employments vitality and how much it costs. It might work for different sorts of buildings and completely different climates, making it simpler to utilize sustainable building hones more broadly. In outline, this inquiries about makes a difference endeavor to form commercial buildings more vitality proficient, supporting the move toward more feasible hones. The victory of the GR INFRA office building shows how critical it is for commercial properties to prioritize vitality effectiveness and natural duty.

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