Parametric Approach for Makinga Building Energy Efficient

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***Abstract*- Energy efficiency in buildings has emerged as a critical aspect of sustainable development and environmental conservation. This research paper presents a comprehensive review of energy-efficient building design strategies, technologies, and practices. The paper covers Energy modelling and simulation with eQUEST Software that can be used in the designing, development, and operation of buildings to increase its energy efficiency. This includes passive design features, such as building orientation and envelope, as well as active systems, such as HVAC, equipment, and lighting. Moreover, it highlights the role of building regulations, certification systems, and occupant behavior in achieving energy efficiency goals. The paper concludes with a discussion of future goals in energy-efficient building design.**

Keywords– Energy Efficiency, eQUEST, Energy Simulation, HVAC.

1 INTRODUCTION

An energy-efficient building is a structure that has been designed, constructed, and operates in a way that reduces the amount of energy needed for its operation while still providing a comfortable and functional environment for its occupants.

Energy-efficient buildings are characterized by the integration of various elements, including effective insulation, meticulous air sealing, high-performance heating, ventilation, and air conditioning (HVAC) systems, as well as energy-efficient lighting and appliances. These collective design and technology choices serve to significantly diminish the energy requirements for tasks such as heating, cooling, lighting, and powering the building. Consequently, this leads to decreased energy expenditures and a more environmentally friendly footprint [1].Furthermore, energy-efficient buildings often integrate renewable energy systems, such as solar panels or wind turbines, to further diminish their dependence on fossil fuels and curtail carbon emissions. In essence, the overarching objective of an energy-efficient building is to maximize resource utilization and minimize waste, all while ensuring a comfortable and fully functional living or working environment. Within the scope of this project, our aim is to attain energy efficiency for the sample building through the utilization of energy simulation methods as shown in figure 1 [2].

Figure 1: Energy Efficiency measures for buildings

Energy simulation and modeling is the process of creating a computer-based representation of a building or system to evaluate its energy performance. This involves using specialized software (in this case, eQUEST) to analyze a variety of factors, including building geometry, materials, HVAC systemsand lighting. The software also takes into account externalfactors that can affect energy consumption, such as climate, weather patterns, and occupancy.

Energy simulation and modeling serve as valuable tools for forecasting a building or system's energy consumption across a range of operational scenarios. They enable the identification of inefficiencies and offer insights into the advantages associated with energy-saving approaches, including the incorporation of renewable energy sources, enhanced insulation, and the optimization of building controls. To facilitate the process, we have chosen a representative building located in the United States as our sample, on which we will conduct simulations to enhance its energy efficiency.

By using energy simulation and modeling, architects, engineers, and building owners can design and construct buildings that are more energy-efficient, reducing operating costs and environmental impacts while maintaining comfort and productivity for occupants shown in figure 2.

Energy simulation can be used for a variety of purposes, including:

- Building design optimization: Energy simulation can be used to optimize the design of a building for maximum energy efficiency, such as by optimizing the orientation and shape of the building, the selection of materials, and the HVAC system design.
- Energy Performance Evaluation: Energy simulation proves invaluable for evaluating the energy performance of existing buildings or systems, pinpointing areas ripe for enhancement and optimization.
- Adherence to Energy Regulations and Guidelines: Energy simulation serves as a powerful tool to demonstrate conformity with energy-related regulations and standards, such as LEED (Leadership in Energy and Environmental Design) and ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) benchmarks.
- Analysis of Energy Conservation Benefits: Energy simulation offers a means to thoroughly scrutinize the potential benefits stemming from energy conservation measures, such as the retrofitting of existing structures with more efficient lighting or HVAC systems.

Overall, energy simulation is a powerful tool for analyzing the energy performance of buildings and systems, reducing energy costs and greenhouse gas emissions, and improving indoor comfort and occupant satisfaction.

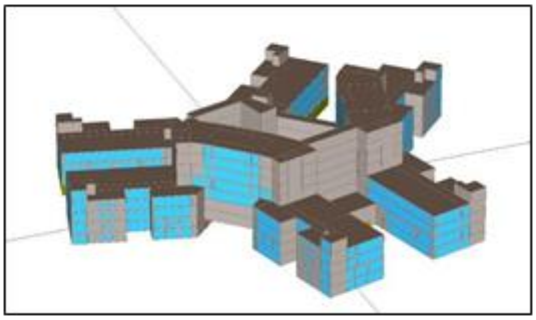

Figure 2: Example Energy Model of IIM, Ranchi AdminBlock

The first question is what is needed to reduce energy consumption and make the building energy efficient. Howit is going to be profitable to the owner. Is there any financial aid available in context to the Energy simulation?The simple answer to these questions is yes. Obviously, itwill decrease the annual utility bill of the building but there is something more interesting that follows.

Section 179D, commonly referred to as the Energy Policy Act of 2005, represents a federal tax incentive initiative within the United States. It is designed to encourage building owners and designers to incorporate energy-efficient systems and materials into their construction projects. This program offers deductions aimed at offsetting the costs associated with implementing energy-efficient solutions in commercial buildings.

Under Section 179D, building owners have the opportunity to claim deductions of up to $1.80 per square foot for eligible buildings. These qualifying structures may encompass newly constructed buildings, those undergoing renovations, or even retrofits with energy-efficient lighting systems, HVAC systems, and improvements to the building envelope.

To qualify for this deduction, buildings must adhere to specific energy efficiency standards established by the Department of Energy (DOE). These standards align with the guidelines set forth by the ASHRAE. Compliance is evaluated across three critical systems: lighting, HVAC, and the building envelope.

For lighting systems, the deduction requires a reduction in lighting power density of at least 25 percent below the ASHRAE standard. Meanwhile, the HVAC system must exhibit a reduction in the building's overall energy and power costs by at least 15 percent below the standard benchmarks. Additionally, criteria must be met concerning the building envelope, including aspects like the solar reflective index of the roof, which should be a minimum of 78.

It's important to note that the 179D tax deduction can be claimed by either the building owner or, under specific circumstances, by the designer responsible for the incorporation of energy-efficient systems. This tax incentive applies to buildings that were placed in service between January 1, 2006, and December 31, 2023. Table 1 shows the summary report of energy savings.

Table 1 Summary of Savings requirements and tax deductions

	Fully Qualifying Property	**Partial QualifyingProperty**		
		Envelope	***HVAC and SHW***	***Ligh ting***
Savings Requirements	50% energy and power cost savings	10% energy and power cost savings	15% energy and power cost saving s	25% energy and pow er cost savings
Tax Deduction	Cost of qualifying property up to $1.80/ft^2	Cost of qualifying property up to $0.60/ft^2	Cost of qualifying proper ty up to $0.60/ ft^2	Cost of qualifyi ng property up to $0.6 0/ft^2

The benefits of the 179D tax deduction can be significant for building owners and designers. By reducing the energy consumption of a building, owners can save money on energy bills and reduce their carbon footprint. Designers can use the deduction to market their expertise in energy-efficient design, which can lead to new business opportunities.

In conclusion, Section 179D is a federal tax incentive program that encourages building owners and designers toincorporate energy-efficient systems and materials into their buildings. The program provides deductions for the costs of implementing energy-efficient systems in commercial buildings and can be a significant benefit for those who qualify.

2 SOFTWARE AND SETUP

Energy modeling software, in a general context, is most effectively employed for the purpose of comparing and assessing relative energy performance rather than making precise predictions about actual building energy consumption. Industry experts indicate that the accuracy of energy models in forecasting real building performance typically falls within a range of +/-10% to +/-40% [3].

It's important to acknowledge that several factors can contribute to discrepancies in energy model forecasts. These factors include overly optimistic assumptions regarding system performance, the influence of unpredictable and uncertain variables such as actual weather conditions, the construction process, and instances where modeling assumptions are overly simplified. Nevertheless, it's worth noting that the foundational principles of building science and calculation algorithms that underlie most energy modeling software are robust and dependable [4].

These tools serve as valuable assets for comparing and contrasting the relative impacts of various design alternatives. Building simulation through energy modeling can play a pivotal role in processes such as value engineering, performance optimization, and the formal and informal development of designs by providing guidance for the selection of building components [5]-[7].

2.1 Energy Simulation Procedure

A. CAD Zoning

We begin with the fundamental modelling stage, known as CAD (Computer aided design). As for energy modelling, we must build the structure first so for that reason we are using CAD as shown in fig. 3. In this project, we are zoning the building in accordance with the acquired drawings or blueprints usingthe ZWCAD software.

Figure 3: CAD Interface and Zoning

This CAD Zoning is done in three phases:

- External Zoning: This determines the outer boundary of the structure and hence describes the area of the building. Because we utilize areaas a measure for various characteristics like LPD (Lighting Power Density) and EPD (Equipment Power Density), matching the area is crucial. This will help to build the exterior walls of the structure.
- Internal Zoning: This is done based on the type of HVAC system serving in the specific space. We divide the building internally and assign the system that is serving in that zone. For that it is important to do the Zoning very cautiously. Although a lot of zones make the building complicated, but we have to do what is necessary.
- Assembly: After creating the zones internally, we must assemble the building in CAD according to the instructions provided. To do this, we must ensure that the outermost edges of each level coincide with one another, unless a structural adjustment has been performed. The CAD Drawings are put together using the WBLOCK command before being imported into the eQUEST software.

B. Wizard Model Simulation

The "Wizard Model" in eQUEST is a user-friendly interface that guides users through the process of creating a building energy model as shown in figure 4. It's a step-by-step process that allows users to input information about the building's geometry, construction, HVAC systems, and other features.

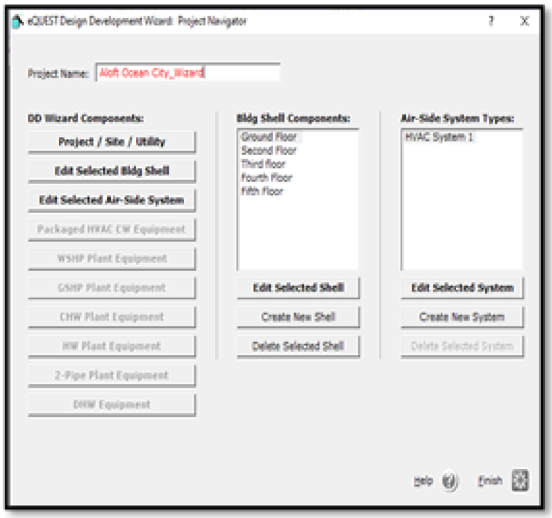

Figure 4: Wizard Model Interface in eQUEST Software

In Wizard model, first we import the CAD assembly and start constructing the building according to the plans that we acquire (fig. 5).

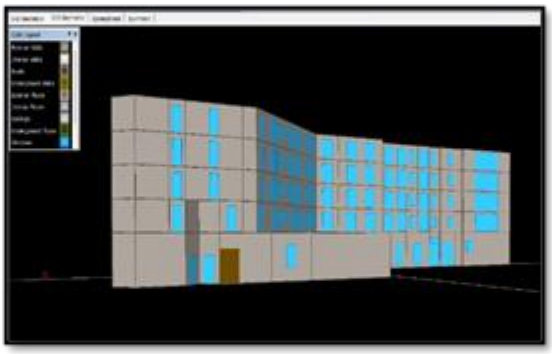

Figure 5: Wizard Model of the Building

C. Baseline Model

A baseline model is a standard against which various design options or energy-saving techniques can be evaluated. It represents the building's energy performance without any specific energy-saving features or systems. The baseline model acts as a benchmark against which one can contrast various design approaches or energy conservation measures (ECMs). It aids in evaluating the energy savings brought on by the adoption of various energy-efficient technologies, systems, or design changes. Typically, the baseline model is developed according to a predefined standard or code, such as ASHRAE Standard 90.1 or local energy codes. It represents the minimum requirements that a building should meet in terms of energy performance. The baseline model accounts for factors like building geometry, orientation, construction materials, HVAC systems, and lighting systems, among others [8].

By comparing the proposed design or energy efficiency measures to the baseline model, the software can quantify the energy savings achieved and evaluate the overall performance of the building. This analysis helps designers, architects, and engineers make informed decisions regarding energy-efficient design strategies and the economic viability of different options. For this project, we're using ASHRAE 90.1 Standard (ip) 2007 as well as a few other references that we'll specify inthe sections where they'll be used.

2.1.4 Proposed Model

Proposed models in energy simulation are developed withthe aim of advancing the field by introducing new and innovative approaches to enhance the accuracy, efficiency,or scope of energy simulations. These models are typically designed to address specific challenges or to incorporate advanced technologies and methodologies into the simulation process, enabling more comprehensive and detailed analysis of energy systems [9].

The diversity of proposed models arises from the varied applications and contexts in which energy simulations are employed. Each specific scenario may require a unique modeling approach tailored to its requirements and objectives. Researchers and practitioners continually strive to develop novel models that push the boundaries of energy simulation, seeking to overcome limitations, improve accuracy, and capture intricate interactions withincomplex energy systems.

These proposed models often focus on improving keyaspects of the simulation process. For example, one modelmight seek to refine the representation of the building envelope, accounting for factors such as thermal bridging, air leakage, and solar radiation distribution. By incorporating these details, the model can provide more precise assessments of energy performance, thereby enabling targeted optimization strategies. [10]-[12]

3 SIMULATION RESULT

Now, we will compare the simulation results after running simulations for the baseline and proposed models in orderto find energy consumption savings. In order to do that wehave to analyze the results first.

In the process of analyzing the results of simulation, a veryimportant term came into play, i.e. Throttling hours. In HVAC (Heating, Ventilation, and Air Conditioning) systems, the term "throttling hours" refers to the amountof time the system is in operation at a reduced capacity orwith restricted functioning. To maximize energy consumption and maintain a comfortable indoor atmosphere, throttling is frequently used as a control approach.

In accordance with ASHRAE 90.1 (ip) 2007 guidelines, the allowable limit for unmet load hours in either the proposed design or the baseline building design should not surpass 300 hours out of the 8760 hours simulated. Furthermore, for the proposed the number of unmet load hours must not exceed the count of unmet load hours for the baseline building design by more than 50 hours.

To meet these stipulated criteria, our initial step involves addressing any potential excess in unmet load hours by minimizing throttling hours if they are present.

Since the Sum of throttling hours in both the baseline and proposed design is not more than 300. Additionally, the proposed design does not exceed the baseline design hoursby 50. So, we are all ready to start calculating our savings.

First, we are going to analyze the monthly consumption (fig. 6) and then we are going to bring up our savings with the helpof annual end-use.

The data obtained by the simulation of Baseline (Shown in Table. 2) and proposed model (Shown in Table. 3) aregiven below.

Table 2 Monthly Energy Consumption by End-Use (kWh) [Baseline]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.10	0.44	2.92	13.03	18.58	26.03	31.03	30.67	21.00	10.47	4.60	0.67	159.55
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	3.84	2.74	1.81	0.31	0.09	0.00	-	-	0.01	0.42	1.33	4.53	15.09
HP Supp.	21.81	9.78	3.77	0.20	-	-	-	-	-	0.42	4.83	8.05	48.85
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	7.58	6.85	7.58	7.34	7.58	7.34	7.58	7.58	7.34	7.58	7.34	7.58	89.26
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.25	9.26	10.25	9.92	10.25	9.92	10.25	10.25	9.92	10.25	9.92	10.25	120.65
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	20.49	18.51	20.49	19.83	20.49	19.83	20.49	20.49	19.83	20.49	19.83	20.49	241.30
Total	64.07	47.57	46.82	50.62	56.99	63.12	69.36	68.99	58.10	49.63	47.85	51.57	674.78

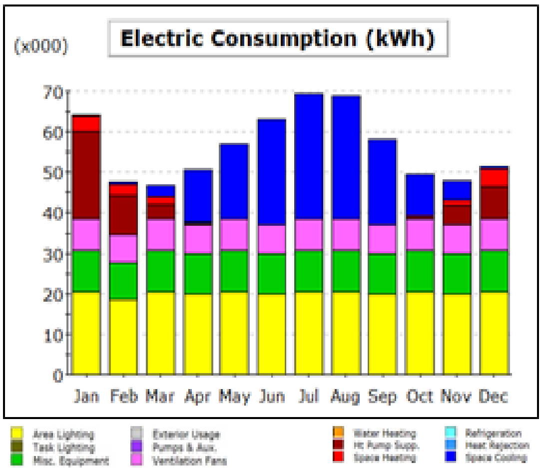

Figure 6 Monthly Energy Consumption by End-Use (kWh) [Baseline]

Table 3 Monthly Energy Consumption by End-Use (kWh) [Proposed]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.02	0.09	0.81	4.82	8.07	12.92	15.62	15.71	8.80	3.68	1.26	0.07	71.87
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	10.70	4.93	2.27	0.20	0.01	-	-	-	-	0.19	1.89	6.59	26.78
HP Supp.	1.61	0.72	0.30	0.00	-	-	-	-	-	0.01	0.31	0.58	3.52
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.22	0.10	0.11	0.30	0.44	0.60	0.65	0.66	0.41	0.20	0.12	0.13	3.93
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.25	9.26	10.25	9.92	10.25	9.92	10.25	10.25	9.92	10.25	9.92	10.25	120.65
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	4.30	3.89	4.30	4.16	4.30	4.16	4.30	4.30	4.16	4.30	4.16	4.30	50.67
Total	27.10	18.98	18.04	19.41	23.08	27.60	30.82	30.92	23.30	18.63	17.65	21.91	277.44

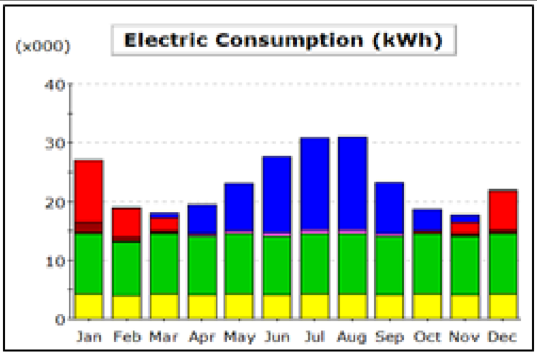

Figure 7 Monthly Energy Consumption by End-Use (kWh) [Proposed]

3.1 Savings calculation

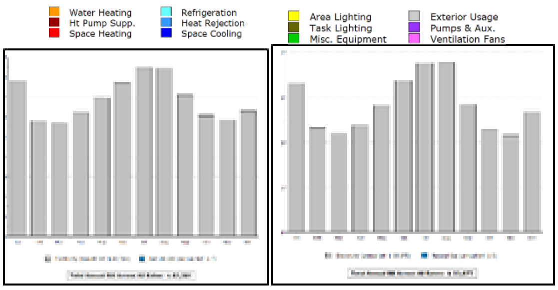

Figure 8 (a) Monthly Utility Bills (b) Monthly Utility(Baseline) (Proposed)

Table 4 Savings calculation in Monetary terms

Project Name:	***Aloft Ocean City***
Building Address:	4501 Coastal Hwy, OceanCity, MD 21842, USA
Area (Sq. ft.):	73,464
State Name:	Maryland
Process Loads (kWh):	120,650
Baseline Utility Bill:	80,982
Proposed Utility Bill:	33,875
Electricity Rate($/Unit):	0.1221
Natural Gas Rate($/Unit):	0.8940
Modelling Software:	eQUEST v3.65

Energy ConsumptionBaseline:	66,251
Energy Consumption Proposed:	19,144
Savings in Monetaryterms:	**71.10%**

The financial help factor utilized in the computation aboveis based on the amount of money saved (Table-4, 5). Although improving the building's energy efficiency and lowering energy consumption are our key goals, this also shows that the building's consumption has decreased somewhat, which lowers the utility bill by 71% (fig. 7, 8).

Table 5 Savings calculation in Energy Consumption

Project Name:	**Aloft Ocean City**
Building Address:	4501 CoastalHwy, Ocean City, MD 21842
Area (Sq. ft.):	73,464
State Name:	Maryland
Baseline Annual Energyconsumption By End-use	663.245
Proposed Annual Energy consumption By End-use	277.44
Savings in Energy Consumption:	**58.17%**

4. CONCLUSION AND FUTURE SCOPE

In conclusion, energy simulation is a powerful tool for making buildings more energy efficient. Through the use of advanced modeling techniques and accurate data inputs, energy simulation can accurately predict and evaluate the energy performance of a building. This allows architects, engineers, and designers to make informed decisions and implement strategies to optimize energy consumption andreduce environmental impact. The benefits of using energy simulation in making buildings energy efficient are numerous. Firstly, it provides valuable insights into the energy consumption patterns of a building, identifying areas of improvement and potential energy-saving measures. By simulating different scenarios, such as changing insulation levels, adjusting HVAC systems, or incorporating renewable energy sources, stakeholders canassess the impact of these changes on energy consumption,comfort levels, and overall building performance.

The future of energy simulation for building energy efficiency is poised for significant advancements driven bybreakthroughs in simulation software and the integration of cutting-edge technologies. Real-time and cloud-based capabilities are set to revolutionize energy simulation,enabling designers and operators to access and analyze building performance data in real-time, resulting in more accurate and dynamic energy assessments. Moreover, the integration of Internet of Things (IoT) technologies will play a pivotal role in energy simulation. By connecting various sensors and devices throughout a building, IoT allows for real-time data collection on energy consumption, occupancy patterns, and environmental conditions. This wealth of data empowers energy simulation models to provide more precise predictions and insights, facilitating informed decision-making regarding energy efficiency measures.[12]-[14].

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