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Original Article

Developing and Designing the Energy Efficient Model for NRSC, IMGEOS Data Center using e-Quest Software

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Abstract - *More than 1/3 rd. of the energy is consumed by the buildings in the world. The construction industry has grown very rapidly over the past 3 decades and is consuming a lot of natural resources and energy. It is the need of the hour to design and develop innovative technologies that are environmentally friendly and sustainable. Developing sustainable building infrastructure mainly focuses on energy efficiency, limited use of natural resources, water conservation, and reducing emissions. Energy efficiency is the main part of sustainability. In this research, we propose a strategy for incorporating solar passive techniques to obtain energy efficiency in an ISRO Data centre by using sustainable green building technology [1]. The maximum building operation maintenance costs are due to the use of electrical energy usage. This research study explains the design strategies to be considered for making the building energy efficient. The study explains the details of the various construction materials along with their technical properties used in the buildings for achieving energy efficiency. ASHRAE has set up the baseline model for energy efficiency in the buildings. We used e-Quest simulation software for finding out the most energy efficient model for the project. Different scenarios with different parameters are evaluated by using the e-Quest software and are compared with the ASHRAE baseline model to find out the most energy efficient scenario. Thus, this research explains the design strategies and the methodology to be adopted for building sustainable and energy-efficient data centers.*

Keywords - *Energy Efficiency, E-Quest, Green Building, LEED Rating, Sustainable.*

1. Introduction

Buildings consume a lot of resources and energy during their construction, operation, and maintenance. During the past 3-4 decades, the construction of buildings for industrial, commercial, residential and other purposes has increased rapidly and speedily throughout the globe. Massively utilizing natural resources will cause depletion of these resources and also deteriorate the surrounding environment. Hence, the buildings should be designed and constructed with less use of natural resources and energy. The new technology for developing sustainable buildings is green building technology.

Green buildings are structures that are resource-efficient and environment-friendly throughout their life period. Buildings will consume much energy for their operation and maintenance during their life period. This energy is produced due to fossil fuels, which deteriorate the environment. So, using more energy is not sustainable design and construction practice. Hence, while designing and constructing the buildings, the main focus is on the point of the building's yearly energy. Consumption should be as low as possible. This paper explains the design methodology of the IMGEOS building of the National Remote Sensing Centre (NRSC) ISRO, Hyderabad, as a green building. A detailed methodology and materials used for achieving energy efficiency are explained.

These green buildings shall be designed by considering the orientation of the sun and weather conditions so as to minimize the use of external heating and cooling systems for achieving energy efficiency. The total annual energy consumption of the building is calculated, and the methods required to reduce the energy consumption to the possible extent are explained in detail so as to make the building LEED Platinum-rated energy efficient building. The subject building is in a hot region, and hence, the aim should be to reduce the solar heat gain into the building for less cooling load. The orientation and envelope of the building are designed in such a way that the solar heat gain will be less by using solar passive techniques. The materials used are innovative, and the paper explains their properties and the advantages achieved due to them for realizing the energy efficient building.

The e-Quest software is used for calculating and analyzing the energy efficiency of this facility. The e-Quest is a very good and easy tool used to calculate the building energy. The e-QUEST energy analysis software operates on the DOE 2.1 simulation engine.

All features of the DOE-2.2 simulation engine are enabled by this energy simulation tool, and it can do conformity evaluations in accordance with California's Title 24 energy code and LEED standards [2]. The e-Quest calculates hourly building energy consumption. In this software, heating/cooling loads are calculated using transfer function methodology.

Both a baseline analysis and energy efficiency simulations are available with e-QUEST. For the baseline analysis, e QUEST generates a second model of the structure that iscompliant with the regulations in effect at the time of the baseline (as per ASHRAE standard).

The comparability of these two models allows us to verify if the model used to construct the actual design case complies with the baseline case. Alternate designs (scenarios) can be compared in terms of their energy efficiency using the simulation. It facilitates clear and concise demonstration of the impact of parameter adjustments on energy usage and occupant comfort.

Thus, this study clearly explains the strategies, innovative green materials and the methodology that needs to be applied for constructing the green building as a LEED rated energy efficient green building.

2. Methodology and Materials

Solar passive techniques are used for designing green buildings. In hot regions, the aim is to reduce the solar heat gain into the building and in cold regions, the aim is to maximize the solar heat gain into the buildings for achieving less load of cooling and heating requirements.

Fig. 1 Location plan of the facility buildings

As shown in the above Figure 1, the facility buildings consist of four blocks: A, B, C, and D, which are the four sections of the IMGEOS facility. They consist of a satellite data reception area, control room, data processing division, disaster management area, etc.

The net air-conditioned area of the buildings is 58,000 square feet. The service bay complex for utilities of the campus is built separately. Eight antenna ground stations are built around the 4 blocks, which receive the satellite data and transmit it to each block.

The main parameters that affect the thermal conditions in a building are orientation and building envelope.

2.1. Orientation

The orientation of a building plays a vital role in designing sustainable green buildings. In hot and dry regions, the aim is to minimize the solar gain effect. Orientation means positioning the building to the sun's path in different seasons to take advantage of the sun and wind directions (or) to be protected from their effects.

The buildings are built in semicircular shapes so as to take advantage of sun and wind directions, i.e. less sun heat and more wind flow into the buildings. The building site latitude is 17. 38 degrees north, longitude is 78.48 degrees east. So, the building is built in an east-to-west direction, as shown in Figure 1, so as to minimize the solar heat gain and better flow of wind into the buildings.

2.2. Building Envelope

The building envelope decides the amount of heat gain, heat loss and wind that enters inside.

There are 4 blocks called A, B, C, and D, built-in semicircular shapes with maximum daylight view on both sides. There is a central courtyard connecting all the 4 blocks.

The factors that affect the building envelope are materials and construction techniques, roof, walls, and finishes, which are explained below.

Sustainable buildings will use less amount of energy and other resources. Green buildings will use construction materials with low embodied energy.

Atmosphere heat enters into the buildings through walls, roofs and windows. Suitable innovative construction materials are to be used for walls and roofs to reduce the heat ingress into the building. By reducing the outside heat entry into the buildings, the requirement of AC cooling load for the building comes down. Thus, energy efficiency can be achieved.

Fig. 2 External wall

2.3. Materials & Construction Techniques

Building materials with low energy content will be used to achieve energy efficiency in green buildings. The green building materials will add good air quality and comfort inside the buildings.

In the IMGEOS Buildings, the following green technology engineering innovative materials and components are used [3].

2.4. External Walls

Cavity external walls with air gaps between them are constructed. This will reduce the heat ingress into the buildings. Hollow Aerocon blocks are used in the double wall with a U value of 0.061 Btu/hr.ft2.0F, as shown in Figure 2 above.

External walls are cavity walls with air gaps in between to minimize the heat ingress into the building.8-inch Aerocon wall + Airgap + 8inch Aerocon in double wall areas with U value of 0.061 Btu / hr.ft 2.0F as shown in Figure 3.

2.5. Aerocon Blocks

Aerocon blocks are an innovative product with excellent thermal insulation and durability. They are non-combustible and have excellent thermal and acoustic properties. By using Aerocon blocks with air gaps between them around 28% of heat is reduced inside the buildings, which leads to savings on the air conditioning costs [4].

Fig. 3 View of building with insulated glass

2.6. Insulated Glass

About 20 % of the energy is lost through windows and doors. Hence, we need energy-efficient windows in sustainable buildings.

Double-layer glass windows will have 2 layers of glass with an insulation gap in between them, which will reduce the heat flow in either direction.

Hence, the project used double glassed windows with a low heat transmission value of 35% and a high light transmission value of 65% [5]. They will act as thermal insulation and will reduce the heat ingress into the building by 45%.

2.7. Under-Deck Thermal Insulation

Under-deck thermal insulation prevents 90% of the radiant heat from entering inside the building which helps in reducing the space cooling load of the building and makes the inner atmosphere more pleasant.

Under deck thermal insulation of 75mm thick with a U-value of 0.072 Btu / hr.ft2 / °F has been used in the project, as shown in Figure 4.

Fig. 4 Under deck thermal insulation in the building

2.8. Roofs

Building roofs receive incident solar heat and transfer it into the buildings. High albedo paints are used to reflect the solar light and heat; thus, the roof is prevented from getting heated up. High Albedo paint with 45% reflectivity of solar radiation is used in the project to have cool roofs [6].

Thus, by using under-deck thermal insulation and high albedo paint with high reflectivity, the heat ingress into the buildings through the roof will be reduced to a great extent, which results in saving the energy requirement for cooling the buildings.

Fig. 5 View of roof with albedo paint

Fig. 6 Daylight pipe

2.9. Energy-Efficient Lighting

Energy-efficient buildings need energy-efficient lighting and controls for energy saving. Nowadays, LED is the most energy-efficient lighting technology used for buildings. The lighting controls [7], such as occupancy sensors, LUX cum occupancy sensors, timers, DALI dimming systems etc., are used in the project for energy saving. The Bureau of Energy Efficiency specifies to use of LPD 11.50 W/Sq .mtr in green buildings. The project used 8.6 W /Sq. Mtr LPD in office areas and 1.6 W /Sq. Mtr LPD in parking areas, which saves 20 % of energy. The project used LED lights, T8 tubes, task lights, daylight controllers, a dimming system, solar daylight pipes, etc., to achieve energy savings.

2.10. Day Light Pipe

The day Light pipe is an innovative material which is used to bring natural sun light into the interior portions of the buildings. It will have a light collector, light transmitter, and light diffuser pipe. It is an excellent artificial light substitute to light the interior corners of the building facilities [8].

2.11. Energy-Efficient AC Loads

By using sustainable architectural design principles, the load on the HVAC systems is reduced. For achieving energy efficiency in AC systems, Variable Frequency Drives (VFDs) are used. Pumps, water chillers, and motors of AC systems are energy efficient. Natural ventilation, radiant cooling, thermal-mass storage, and passive solar control are some of the applications of basic thermodynamic principles [9].

3. Modelling Process

In 2007, Southern California Edison (SCE) commissioned James Hirsch and Associatesto create e-Quest (3.65), a free and open-source programme that is based on DOE-2.2 (GBS, 2018). All features of the DOE-2.2 simulation engine are enabled by this energy simulation tool, and it can do conformity evaluations in accordance with California's Title 24 energy code and LEED standards [10].

e- Quest calculates hourly building energy consumption. In this software, heating/cooling loads are calculated using transfer function methodology.

Both a baseline analysis and energy efficiency simulations are available with e QUEST. For the baseline analysis, e QUEST generates a second model of the structure that iscompliant with the regulations in effect at the time of the baseline (as per ASHRAE standard). The comparability of these two models allows us to verify if the model used to construct the actual design case complies with the baseline case. Alternate designs (scenarios)can be compared in terms of their energy efficiency using the Energy Efficiency Simulation. It facilitates clear and concise demonstration of the impact of parameter adjustments on energy usage and occupant comfort.

This is the model of IMGEOS - NRSC prepared on e-Quest software. There are a total of five simple wizards/screens in the app that collect the essential data,such as 1. Project and Site: This section provides an overview of the project and its location. 2. The 2D and 3D geometry for the building is created once the AutoCAD drawings are imported into the system at 2nd Stage 3. Third, internal burdens include everything listed in the data-gathering phase. This includes all of the unchanging information, like the schedule, operations, and occupancy loads. 4. Climate Control (HVAC) on the Water Side The software is pre-configured with all the necessary settings for all the HVAC parameters [11, 12]. The default data may be altered to reflect the user's preferences in terms of the real information. All the Air-conditioning, ventilation, and Air-Handling Unit (AHU) equipment, as well as the exhaust and fresh air intake systems, are discussed in Section 5. This final section, "Utility and Economics," discusses utility rates and financial considerations when estimating power needs. Each and every piece of data necessary for making an accurate prediction is included inthe lengthy and thorough input phase.

As an overview of the study case's entire growth across four distinct blocks 45,786 sq. After importing the layout in Auto Cad format, e-Quest users can begin to categorize the building's interior into climate-controlled and non-climate-controlled areas. At this point, the exterior facade is also established.

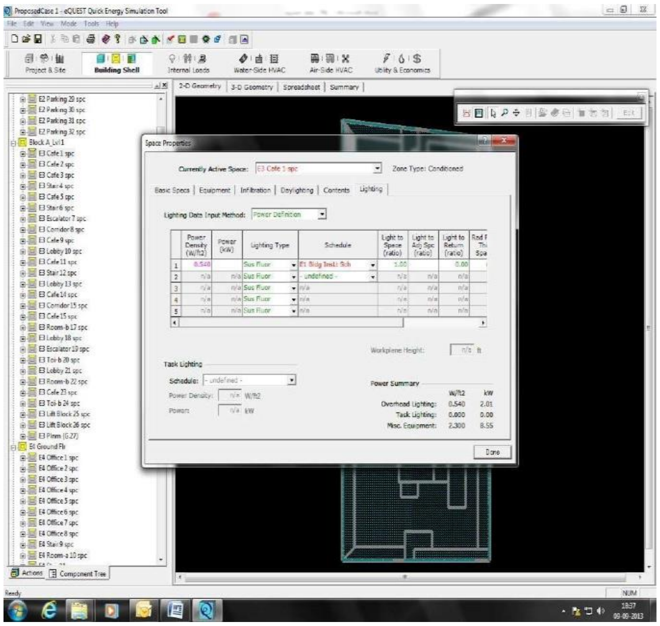

Fig. 7 Design case inputs – SW side

By specifying the height, roof, etc., the two-dimensional plan takes on a wholly new three-dimensional appearance. Figure 7 depicts this. Following the inputs provided, the full campus is developed in three dimensions. The model can more easily generate the baseline and other potential outcomes thanks to this 3D perspective. The 3D view is also necessary to ensure the software accurately represents the final desired design or form for energy modelling.

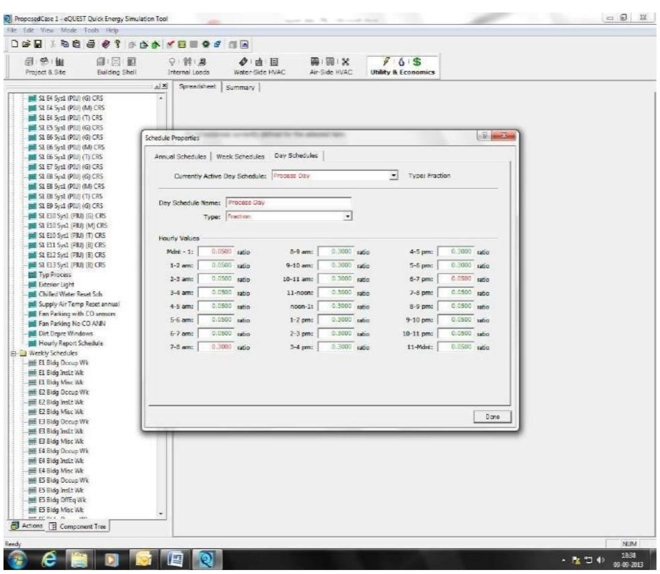

Fig. 8 Occupancy schedules

The building's operational schedule is depicted in Figure 9. In contrast, an input displaying the occupancy schedule shown in Figures 8 and 10 depicts the default schematic process arrangement generated by the software for the air-side system parameters. Similar input panels for specific data are available for the HVAC on the water side, as well.

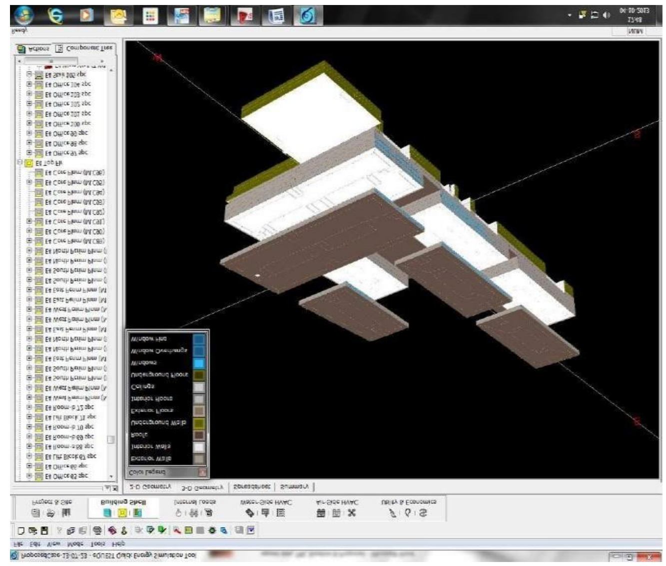

Fig. 9 Building operational schedules

In order to estimate how much money a building will save utilities each year, energy modelling is used. Energy modelling is an iterative procedure that takes as inputs a number of possible scenarios representing changes to the design parameters. 1. If the scenario with the given parameters can reach the baseline scenario in terms of energy usage. 2. Varying inputs in the simulation allow for the analysis of multiple possible features. 3. It is a great tool for visually representing how adjusting various parameters impacts things like energy use and how happy people are in a building 4. The developer can pick the most efficient energy layout.

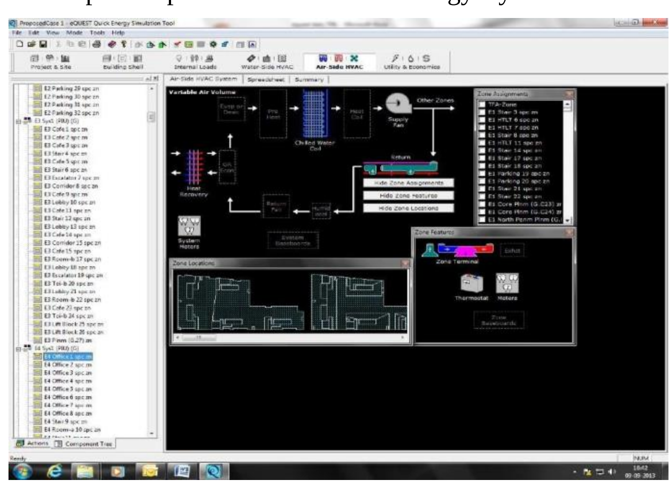

Fig. 10 Air side HVAC system parameters

Table 1. Model input parameters

S. No.	Model Inputs	Parameters
1	Exterior Wall Construction	9 inch Brick Wall 10-inch Cavity Brick Wall (10mm thick. Concrete board + 25mm XPS insulation + 460mm air gap + 4mm ACP Cladding)
2	Roof Construction	RCC Roof without Insulation 6" R.C.C slab + 3" XPS Insulation + 4" screed + 1" PCC
3	Window-to-Wall Ratio	40%, 35 % , 30 %
4	Glazing	Single Clear, Double Glazed Unit (DGU)
5	Shading Devices	None 6 Inches Recessed Windows Deep Recessed Windows
6	Lighting Power Density	Same as ASHRAE Base case 20% Reduction from Base Case
7	HVAC System Type	Constant Air Volume Variable Air Volume
8	Fan Control in A.H.U.'s	Constant Speed Variable Speed
9	Chillers Parameter	2 x 500 TR Water - Cooled Rotary Screw Chillers 2 x 500 TR Water - Cooled Centrifugal Chillers 20
10	Demand Control Ventilation	Yes
11	Ventilation	CO_2 Sensors

The green building establishments need energy efficiency, water efficiency, and incorporation of renewable energy sources for the campus (both on and offsite). It is important to highlight that designing for energy efficiency plays a significant role in getting LEED certification for green buildings [13].

The Leadership in Energy and Environmental Design (LEED) assessment system is a consensus-based, voluntary benchmark for creating high-performance, environmentally friendly buildings. Intended to "assess environmental performance from the whole building viewpoint over the complete building's life cycle, giving a comprehensive definition for what defines a 'Green Building, [14]'". This document sets forth criteria for identifying environmentally friendly structures. Site selection, water efficiency, energy usage, and other factors (Credits) are taken into account. Environment, energy efficiency, and sustainability to be awarded one of four certification levels (Certified, Silver, Gold, or Platinum) based on their overall performance in these areas [15].

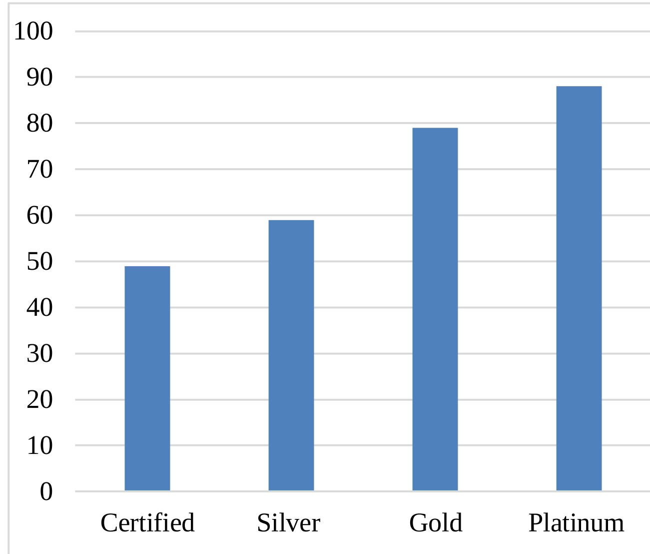

Fig. 11 Points for energy efficiency under LEED Vs. Certification points

There are 4 levels of LEED (Leadership in Energy and Environmental Design) certification:

Certified (40-49 points),

Silver (50-59 points),

Gold (60- 79 points),

Platinum (80+ points)

4. Results & Discussion

The simulation study breaks down the overall energy usage in detail over all six scenarios with respect to different design characteristics and their permutations and combinations. It was determined how much electricity would be needed in each of the other five scenarios by using Scenario 6 as a reference case. Table 2 shows that Scenario 6 is 28.98% more expensive than Scenario 1. Again, Scenario 2 is slightly less expensive than the baseline (by 3.76 percentage points). Scenario 3 had a greater value after being compared (21.37%), while Scenario 4 had a lower value (11.17%).

These energy partitions also aid in fine-tuning input parameters to get the best possible choice during the energy simulation's iterative phase. As can be seen in Table 2, it is also possible to compare the overall energy use over all six scenarios. The largest energy consumption is seen in Scenario 1, which includes the conference centre. Scenario 6 is the baseline, and all other possibilities, including Scenario 5, are lower.

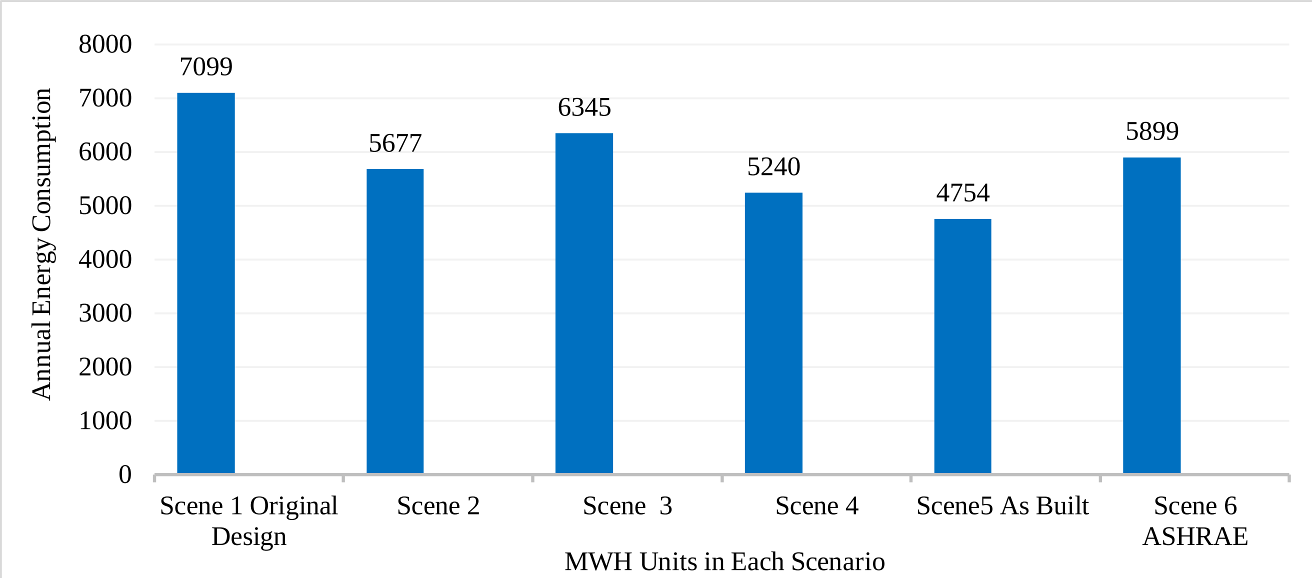

Fig. 12 Energy in each scenario

All other possible outcomes, measured in total building MWh consumption, are likewise provided by the modelling software. Table 2 outlines the investigation in full. Energy consumption is calculated for each scenario, and the results are compared to the ASHRAE baseline case (Scenario- 6). Below each metric is a percentage increase vs scenario6 that can be used as a comparison scale.

This is done to assess how well each parameter performs, with an eye towards selecting the optimal option for the final design scenario.

In order to achieve LEED certification, a building must reduce its energy consumption by at least 10% compared to baseline levels established by the LEED rating system.

Table 2. Scenario analysis in MWH calculated

Input Parameters	Scenario 1: Conv. Design	Scenario 2 (Parameters Modified)	Scenario 3 (Parameters Modified)	Scenario 4 (Parameters Modified)	Scenario 5: As Built Design	Scenario 6: Ashrae Baseline
Lighting	820	711	794	711	700	845
% increase	-	15.11	15.11	15.11	17.15	-
Power points	1032	1032	1013	1035	1002	1047
Air Cooling	3146	2866	3000	2606	2159	2931
% increase	-20.25%	0	-53.32%	9.09%	24.68%	-
Heat Rejection	50	28	39	26	23	27
% increase	-106.5%	0	-39.35%	8.3%	14.81%	-
Motors & pumps	305	250	290	199	203	253
% increase	-23.51%	0	23.55%	19.79%	19.76%	-
Fans	1516	510	989	497	502	515
% increase	-217.13%	0	0	2.53%	2.52%	-
Escalators	215	264	205	150	150	265
% increase	0	0	0	43.4%	43.4%	-
Out Door Lighting	15	16	15	16	15	16
Total	**7099**	**5677**	**6345**	**5240**	**4754**	**5899**
Savings	**-16.90%**	**3.76%**	**-07.02%**	**11.17%**	**19.41%**	**-**

Table 2 shows that compared to the ASHRAE baseline (Scenario 6), the as-built design (Scenario 5) results in a 19.41% decrease in energy usage. Scenario 5 was found to be the most energy-efficient when compared to the other four and the baseline reference (Scenario 6).

Hence, it is found with the help of e-QUEST design software that the energy requirement of the campus has been decreased to 4754 MWH units against 5899 MWH units of electricity, as shown in the above Table 2, which results in a saving of 19.41% of the electrical energy requirement. These savings are possible due to the implementation of strategic passive solar techniques and the use of the above-explained green construction materials such as Aerocon blocks, double-glazed window panes, under-deck thermal insulation, High roof albedo paint for reducing the cooling load inside the building. Also, the use of energy-efficient lighting, pumps, motors, chillers and other air conditioning equipment as explained above.

5. Conclusion

The above study shows that compared to the ASHRAE baseline (Scenario 6), the as-built design (Scenario 5) results in a 19.41% decrease in energy usage. Scenario 5 was found to be the most energy-efficient when compared to the other four and the baseline reference (Scenario 6), after incorporating the Solar passive techniques, Energy efficient lighting, and HVAC systems as explained above for Integrated Multi-mission Ground Segment Earth Observation Satellite (IMGEOS), ISRO campus at Hyderabad with 45,786 sqm area. The LEED India Core and Shell rating version 1.0 Platinum level qualification was achieved due to the service design's compliance with IGBC and ASHRAE standards for this project.

Fig. 13 LEED platinum certificate

Hence, the building meets the LEED standards and is considered a sustainable green building. Economic and environmental considerations have combined to elevate the priority of maximizing building energy efficiency. This study reaffirms the importance of including sustainability concepts in the design of all future data centre facilities of ISRO (or) other similar IT establishments around the globe. The energy usage of the IT industry is the greatest of any industry. A helpful standard for all future buildings is the creation of energy modelling to achieve energy efficiency in Data centers and the strategies employed to achieve it. The findings of this study will aid policymakers in designing more resource- and Energy-efficient buildings [16].

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