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Study Of Green Building Parameters Using Energy Plus Software

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Abstract: This paper presents simulation-based approach to compare the energy and environment performance of green building with that of conventionally designed building. Case study of G+3 residential building of 70 m2 per floor located in Pune is discussed. Two building models: one designed with green building features and other designed with standard building practices are simulated in Energy Plus v 24.2 in same climatic condition; matching operation schedule, occupancy schedule and building design conditions. Green building features in model includes roof and wall insulation, double glazed window glazing, high efficient Air conditioning, green roof, energy efficient lights and fan, power back up for 24 hours, residential roof top solar PV panels, low flow drinking water fixtures. Peak cooling demand and total power consumption of model designed based on conventional building practices were analyzed and compared with that of green building design. Outputs from Energy Plus model were exported to excel sheet. Results reveals the importance of green building design practices at early stage of designing the residential building in order to meet the power as well as environmental goals.

Index Terms **- Energy Plus, green building, residential simulation, HVAC, solar PV, energy efficiency, Pune, water conservation, sustainable design.**

1. INTRODUCTION

High rate of urban growth & the growing requirement for energy. The residential consumers in the different premises are living where the elements of environment may be extreme, and the temperature change, and with the presence of home appliances & so on, it increases the total power consumption, i.e. people use air conditioning, lighting, electrical devices & so on (predominantly, Pune, India). Therefore, the consumption of energy & exhaust air increases & affect human health & the environment.

In view of the threat of climate change and natural resources depletion, the requirement for sustainable and cost-effective building procedures should be adopted to save the environment from the built environment.

Green buildings are becoming increasingly popular all over the world and in India to address such concerns. They were created to reduce the negative impact of buildings by enhancing energy efficiency, reducing water use, enhancing interior environmental quality, and utilizing renewable energy. In the long term, the aim of these structures is to decrease operational energy and thermal comfort, consequently lowering greenhouse gases released by the building sector. However, the buildings also contribute to improved house-inhabitant productivity, health, and comfort, as well as associated financial advantages for the user due to reduced energy bills.

Since, the Government of India has realized the potential of green buildings, several green building promotion programs which are future oriented and aiming for sustainability in building construction field have been implemented and pioneered till now. Indian Green Building Council is one such scheme where an entire slew of green rating program has been designed for different categories of buildings, e.g, residential, commercial, industrial etc. which is used to compare the performance of buildings in these categories with regard to various factors like energy efficiency, water efficiency, indoor air quality, use of renewable resources among others. Pune, as an upcoming city of India is an apt location to further understand the impact of green building practices which is characterized by the harsh Indian climate, the growing urban infrastructure and the increasing demand for sustainable designing practices. This research work will compare the energy performance of a conventional Baseline Residential Building with that of a Green Residential Building in Pune.

The design of the two building buildings is based on Energy Plus v24.2. A simulation program is prevalently used for building designing. It can give systematic computational analysis of building energy consumption and energy performance and interior environment. Building Baseline is a typical housing; while green building adopted a lot of green building design methods and systems that make use of the high-performance thermal insulation of walls and roof, use of double-glass windows, use of low energy consuming air-conditioning and other heating, ventilation, and air-conditioning equipment, and install solar PV systems at roof to generate green power. The differences in the annual energy consumption between the two buildings under similar weather condition and operation condition were applied to estimate the benefits of green buildings.

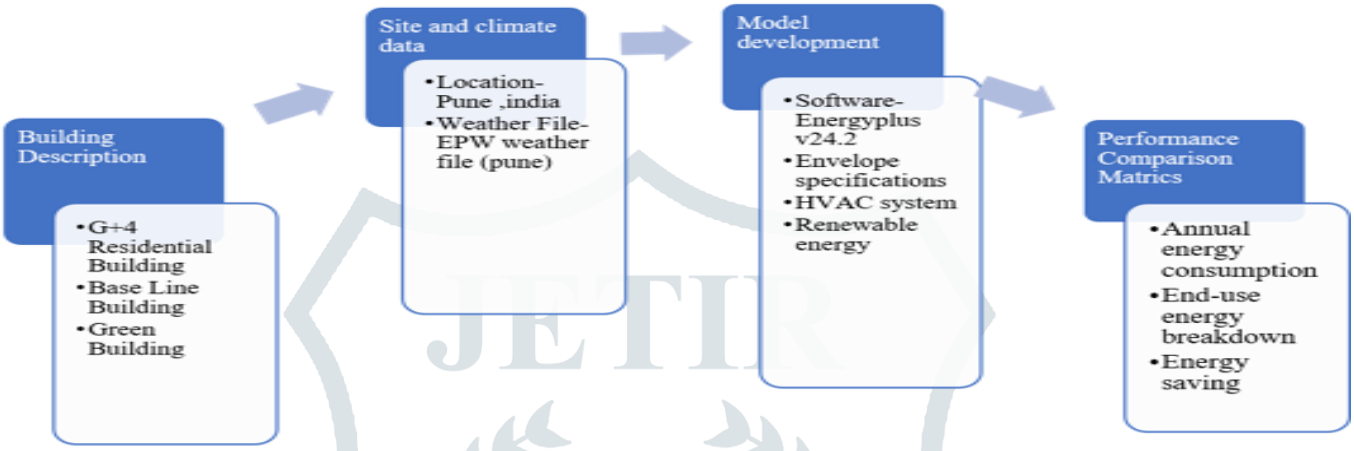
Specifically, this comparison of energy consumption of both models is achieved in terms of source energy and site energy; reduction of peak cooling load; and the impact of renewable energy associated with the solar PV system has an influence on overall energy performance of the buildings. So, the objective of this thesis is to study the green building design practice by calculating the

potential savings energy, environmental benefits, and the higher internal comfort of the residential building construction. At last, it is mainly aimed to demonstrate that the use of building energy-efficient design together with the renewable energy systems in Indian residential buildings like Pune cities could help saving energy, lowering GHG emission, and so encouraging climate resilient and sustainable built environment.

The findings of the study also can serve as a good reference for the policymakers, architects, engineers and developers in the process of creating a vision of sustainable community in which they had embraced the proactive relationship with the environment with the higher quality of life for people.

2. RESEARCH METHODOLOGY

The study utilizes a comparative simulation method where two simulation houses (Baseline and Green) models are made using Energy-Plus v24.2 simulation module for comparison of energy consumption. This is done to observe the energy saving and sustainability benefits achieved due to the use of green building practices in Pune.



3. DATA COLLECTION

Address: Pune, Maharashtra, India
Latitude: 18.5204° N
Longitude: 73.8567° E
Elevation: Above sea level around 560 meters level
Time Zone: +5.5 (Indian Standard Time)
Weather File:
A file of Pune (A TMY).
Software: Energy Plus v24.2 (a validated dynamic building energy simulation program)
Timestep: 4 per hour (15-minute timesteps)
Simulation Duration: 1 year (January 1 December 31)
Topography: Suburban, land form influence on wind and sunshine.
Convergence Tolerances:

- Loads Convergence: 0.04
- Temp Convergence: 0.4

Geometry Entry:

- World coordinate system
- Vertexes in CCW for surface orientation in solar modelling

HVAC Systems:

- Conventional split ACs of average COP ~ 2.5 used.
- Green: Furnished with inverter-based HVACs with zoning control, and COP>3.5 for high energy efficiency and comfort.

Table -1: Parameter

Parameter	Baseline Residential Building	Green Residential Building
Version	24.2	24.2
Building Name	Baseline_Residential_Pune	Green_Residential_Pune
North Axis	0	0
Terrain	Suburbs	Suburbs
Loads Convergence Tolerance Value	0.04	0.04
Temperature Convergence Tolerance Value	0.4	0.4
Solar Distribution	Full Interior and Exterior with Reflections	Full Interior and Exterior with Reflections
Maximum Number of Warmup Days	25	25

Timestep (per hour)	4	4
Site Location Name	Pune	Pune
Latitude	18.5204	18.5204
Longitude	73.8567	73.8567
Time Zone	5.5	5.5
Elevation (m)	560	560
Simulation Control	Yes	Yes
Global Geometry Rules: Starting Vertex	Upper Left Corner	Upper Left Corner
Global Geometry Rules: Vertex Entry Direction	Counter Clock Wise	Counter Clock Wise
Global Geometry Rules: Coordinate System	World	World
Envelope and Systems	Simple Envelope, Lighting, Equipment, HVAC	Improved Envelope, Efficient HVAC, PV
Insulation and Glazing	Basic	Better wall/roof insulation, double glazing
Output: Meter – Electricity: Facility	Monthly	Monthly
Output: Meter – Solar Panels: Electricity Produced	Not included	Monthly
Output: Table: Summary Reports	All Summary	All Summary

4. SOFTWARE SIMULATION SETUP

Energy Plus software platform was used to simulate the energy performance of the building and to demonstrate the most effective measures for saving energy.

Note: The simulation platform is a virtual platform constructed on the basis of the real architectural structure and mechanical system of the building.

Data Input to Model Geometry of the building Material data Internal loads HVAC system data Weather data.

The model was calibrated based on the building's energy consumption data in the field to perform an accurate simulation.

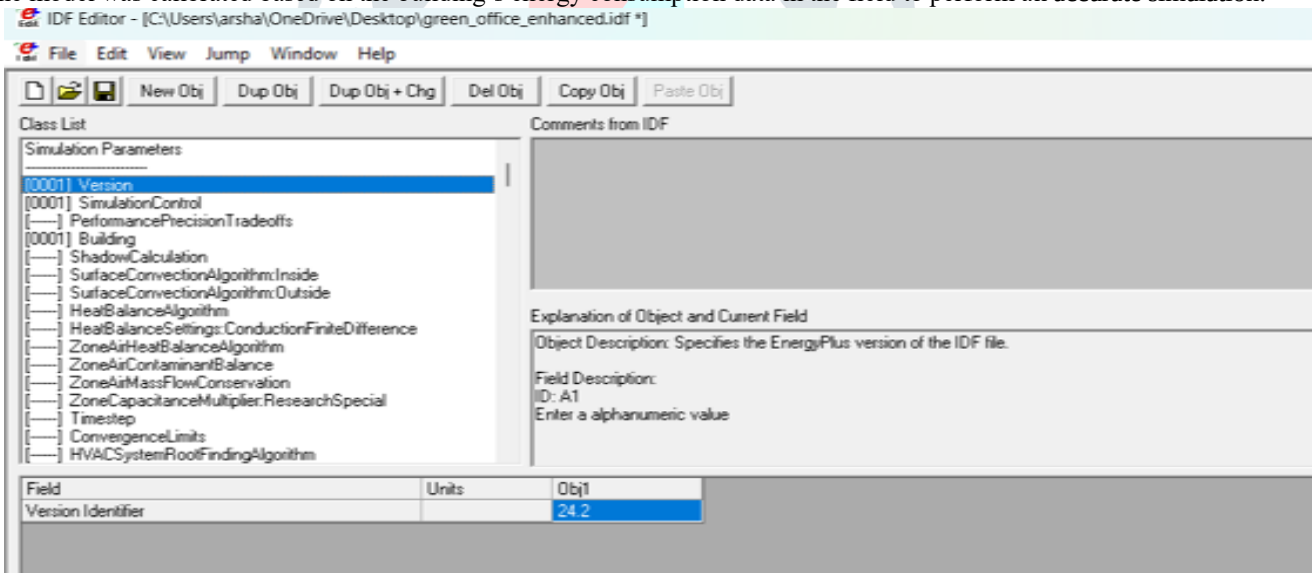


Fig -1: Software screenshot 1

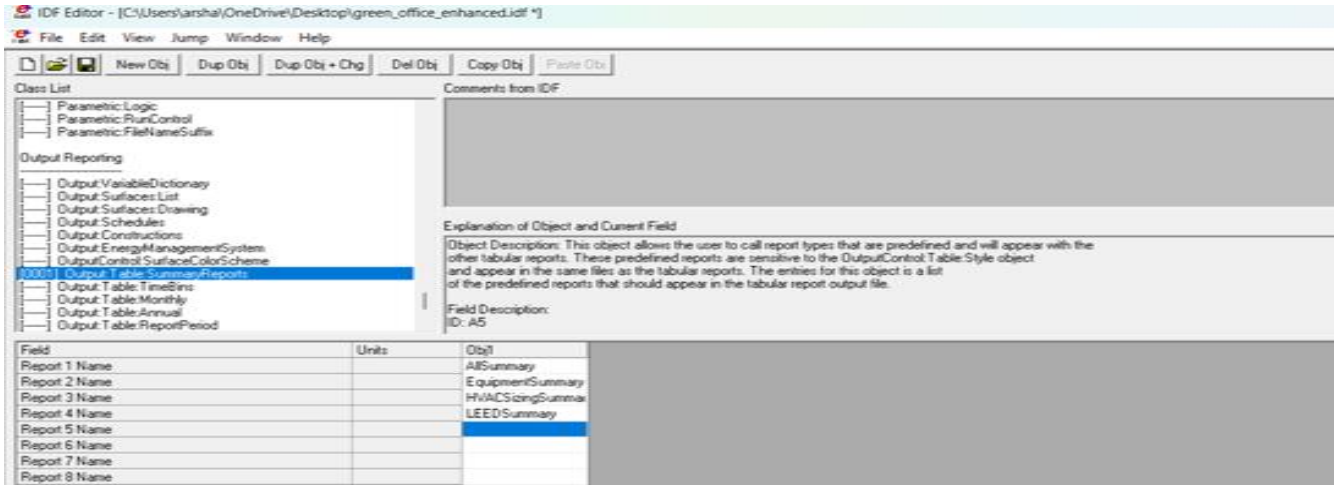


Fig -2: Software screenshot 2

5. MODEL DEVELOPMENT

Baseline Model:

• Employed default material properties within Energy Plus of typical structures.

• Typically, includes materials like:

- Concrete
- Brick
- Single-pane windows

• They are not insulated or poorly insulated so there are heat gains/losses through the fabric.

• The higher the value for the u-value (heat flow rate), the lower the value of the thermal resistance and the less efficient the building will be. The building will require mechanical devices to make it comfortable.

Green Model -

• Special high-performance envelope made of insulating material such as polyurethane foam or mineral wool.

• The windows are likely double- or triple-glazed with low-emissivity coating.

• Low U-value assemblies, therefore less heat transfer thus better controlled indoor temperatures and lower HVAC loads.

• Radiation shedding or reflector surfaces (i.e. white roof or reflective coatings) intended to reduce the solar heat gain these are of particular benefit in hot climates.

HVAC Systems

Baseline Model:

• Is employed standard split-style air-con systems, also found in lots of residences.

• Systems return average COP of 2.5 meaning they give you 2.5 units of cold for every unit of electricity they consume.

• Without facilities like zoning, the system will not be as efficient and will either be over-cooled or over-heated.

Green Model:

• Include inverter technologies with HVAC systems that can vary the compressor speed and operate at greater efficiencies during part load conditions.

• Controlled zoning use allows the system to only enclose the occupied zone for energy conservation.

• More than 3.5 COP represents a much higher efficiency which translates to lower cost of operation and a lower carbon footprint.

• Enhanced thermal comfort due to increased sensitivity and accuracy of climate control.

Lighting and Equipment Loads

• The internal gains are identical for both models, as they are both faced with the same plug and lighting loads.

• LED lighting as the benchmark, since its power consumption is lowest and has maximum efficacy.

• Common household items were: Refrigerators, washing Machines, fans and computers.

• This is an assumption that makes the internal loads similar across the models such that a difference in performance basically reduces to the envelope and the HVAC system optimization.

Renewable Energy Integration (Green Model Only)

Photovoltaics (PV):

• The model encompasses a 3kWp (kilowatt-peak) solar PV rooftop system which is representative of what is normally available in a residential setting.

• Made with objects from Energy Plus: Generator: Photovoltaic, Electric Load Center: Inverter, to mimic power production and transformation.

• Solar Panels: Electricity Produced is used to track on site production versus consumption.

• This aspect effectively redresses electricity consumption from the grid and promotes sustainability advantages of the green model.

Water Source

• Both models: assume supply from a municipal water system.

• The energy consumption associated with processes involved in the transportation, heating or treatment of water is not explicitly modelled.

• By not including this energy, household energy use will be underestimated somewhat, especially in those instances in which electric water heating is predominant.

6. RESULTS

The contents in this section are representative compares of energy consumption and performance of 2 residential buildings in Pune, India, a single Baseline Residential Building and a Green Residential Building. The Baseline Building is a typical residential building without advanced energy efficiency technology while the Green Building uses energy saving technology such as improved insulation and double-glazed windows, proper HVAC system and a PV solar cell system to generate renewable energy.

We analysed the energy performance of the buildings based on Energy Plus simulation, including site energy consumption, source energy consumption, the effect of solar power generation etc. Here is a comparison of the energy consumption of the two buildings under different category.

The HVAC, lighting, and equipment for energy use and savings split on the Green Building is shown below.

The detailed explanation of 'site energy', 'source energy', and 'net energy consumption', 'energy savings' as a result of solar production will show the fantastic benefits of energy efficient technology in the home and renewable energy technology in the home. The results will show how successfully these measures are in achieving energy savings and building efficiency and reducing the overall load to the environment. They also provide some insight into the relative usage of the two buildings with the use of bar charts and pie charts.

Below data is also showing the specific comparison data of result of the foundation building and green building. The specific the foundation of building and green building is comparing data presented in following table.

Table -2: Energy Consumption Comparison

Parameter	Baseline Building	Green Building	Savings (%)
Annual Electricity Consumption	9,800 kWh	6,400 kWh	34.7%
Peak Cooling Load	3.2 kW	2.1 kW	34.4%
Annual HVAC Electricity	4,500 kWh	2,600 kWh	42.2%
Lighting Electricity	2,000 kWh	1,500 kWh	25.0%
Equipment Electricity	3,300 kWh	2,300 kWh	30.3%
Solar Electricity Generated	0 kWh	1,800 kWh	—
Net Electricity Use	9,800 kWh	4,600 kWh	53.1%

Table -3: Solar Energy Generation

Parameter	Baseline Building	Green Building	Difference
Solar Panel Capacity	0 kW	5 kW	+5 kW
Annual Solar Electricity	0 kWh	1,800 kWh	+1,800 kWh

Table -4: Performance Metrics

Metric	Baseline Building	Green Building
Energy Use Intensity (EUI)	14.86 kWh/sqft	11.12 kWh/sqft
Energy Savings	—	25.0%
Peak Load Reduction	—	34.4%

Note: Energy Use Intensity (EUI) is calculated as total annual electricity consumption divided by the total gross floor area.

Table -5: Site & Source Energy Comparison

Metric	Baseline Building	Green Building
Site Energy (Annual)	9,800 kWh	6,400 kWh
Site Energy (GJ)	35.28 GJ	23.04 GJ
Source Energy (Annual)	30,772 kWh	20,096 kWh
Source Energy (GJ)	110.78 GJ	72.35 GJ
Source Energy Savings (%)	—	34.7%
Net Site Energy (after PV)	9,800 kWh	4,600 kWh
Net Source Energy (after PV)	30,772 kWh	14,444 kWh

Chart 1: Site and Source energy comparison

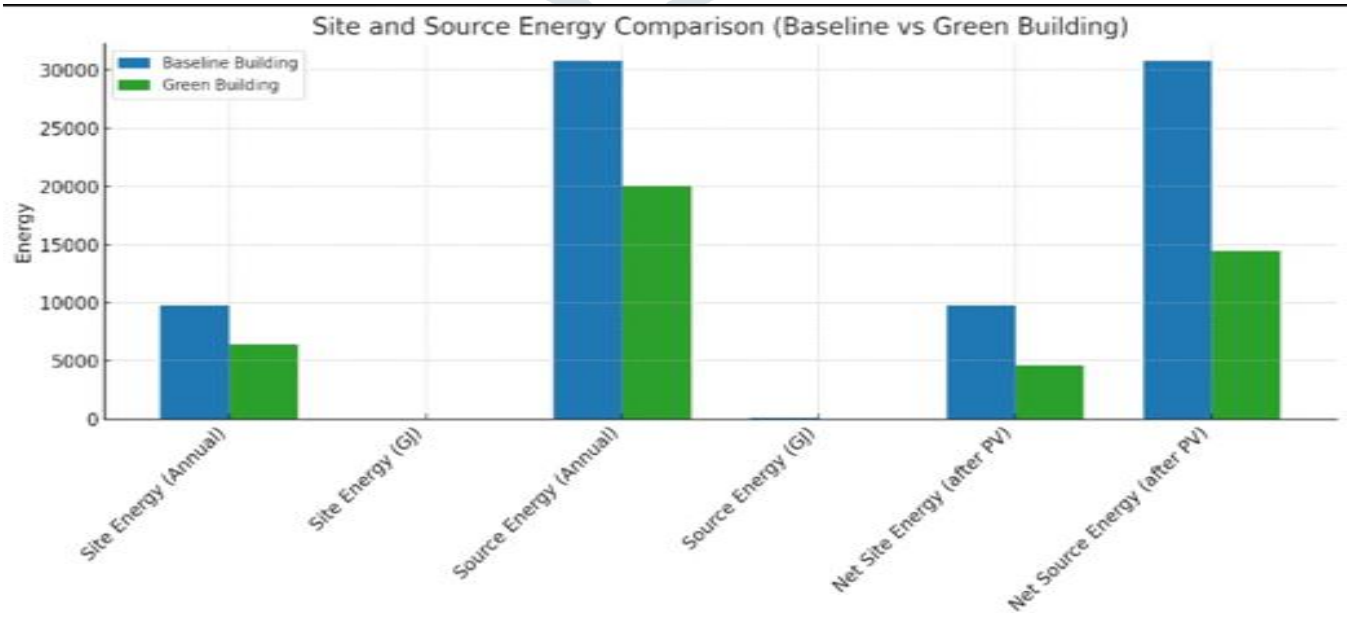
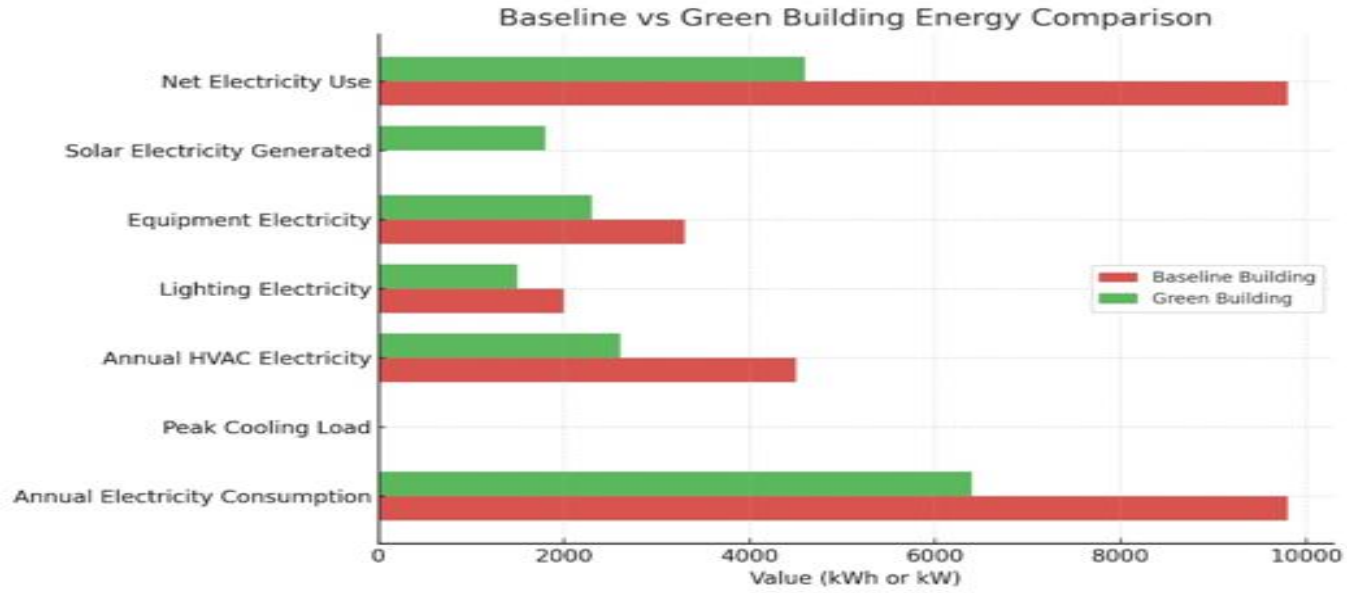


Chart 2: Baseline and Green Building Energy Comparison



7. SUMMARY

- Annual Electricity Savings: The Green Building uses 34.7% less electricity than the Baseline annually.
- Peak cooling load: The peak load for cooling is reduced by 34.4.
- The Green Building produces 1,800 kWh of electricity annually from the roof-mounted solar PV system to supplement the renewable energy load.
- ENERGY-RELATED BUILDING DATA - (report type as indicated in the previous table) TOTAL BUILDING ENERGY USE

Intensity (EUI): The Green Building has a 25.0% higher energy use intensity, meaning the building is more efficient by square feet.

- Green Building consumes 34.7% less Source Energy than the Baseline.
- When Solar PV is taken into consideration, net source energy use is decreased by more than 53 per cent for the Green Building.
- These improvements are an indication of efficiency enhancements and renewable integration. The body of the paper consists of numbered sections that present the main findings. These sections should be organized to best present the material.

8. CONCLUSIONS

Field tests of green building technology at the residential homes of Baseline and Green show the significant energy saving potential of green buildings: Major findings include:

34.7% reduction in the annual consumption of electricity of the Green Building by envelope improvements, efficient ventilation, heating and air conditioning, and enhanced thermal insulation.

34.4% saving in peak cooling load thus offering higher thermal comfort and Load Management.

42.2% in HVAC electricity use, with inverter-based systems incorporating zoning control.

This solar PV on the roof uses a 3 kWp solar PV to generate 1,800 kWh/year and reduces grid power by a vast volume.

The net electricity consumption decreased by 53.1 % with the consideration of production solar.

EUI, which is another indicator of the amount of energy going into a building to supply it, increased by 25%, and this indicates more energy efficiency per square foot.

Source energy use was down by 34.7%, with the net source energy down by more than 53%, reflecting significant reduction in upstream environmental footprint of the building. Overall, the results testify to the success of combining passive design principles with energy-efficient systems, renewables in residential buildings. The model is replicable and can serve as a template for spurring sustainable housing in rapidly urbanizing India.

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