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Incorporating Energy Efficiency and Sustainable Energy Practices in the Renovation and Retrofitting of a 50-Year-Old Independent House

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Highlights

- Incorporating Energy Efficiency in retrofitting of a 50-year-old Building
- Rooftop solar in renovated building
- Renovated buildings can be sustainable.

Abstract

The authors, a homeowner and an architect without in-depth technical knowledge of energy efficiency, embarked on the renovation of a 50-year-old house in Bangalore, India. The result was a design that combined family needs with energy efficiency and sustainability. The 3000 m^2 property underwent a comprehensive retrofit, encompassing energy-efficient practices and renovation with renewable energy solutions, showcasing a blending of architectural design and sustainable systems.

Load reduction strategies included double-glazed windows, solar chimneys for stack-effect cooling, cool roofs, plants for shading, and energy-efficient appliances. Efficient systems, such as a VRF system, BLDC fans, LED lights, and home automation with sensors, have been installed for improved cooling, ventilation, and lighting. The house generates and uses renewable energy through a 4.89 kW rooftop solar array, a 200-liter solar water heater with a heat pump, and a 300-liter storage tank. Additional sustainability efforts also included rainwater harvesting and material reuse to reduce embodied energy.

Keywords: Renovation, Retrofit, Independent House, Energy Efficiency, Rooftop Solar

Introduction

In the face of growing energy demands and concerns about climate change, there is an increasing need to focus on energy efficiency and sustainability in residential buildings [1,2]. The building sector accounts for a significant portion of global energy consumption and greenhouse gas emissions. As such, improving the energy performance of both new and existing buildings is crucial for reducing the environmental impact of the built environment [3].

In countries like India, where most residential plots fall outside the purview of building codes, such as the Eco Niwas Samhita, there is a vast untapped potential for energy efficiency improvements in independent single-family homes. With rapid urbanization and a growing population, the renovation of older residential buildings presents a unique opportunity to incorporate energy efficiency measures and renewable energy systems, ultimately contributing to India's Nationally Determined Contribution [4].

This paper presents the case study of a 50-year-old independent house in India, renovated and retrofitted, with a focus on energy efficiency and sustainability. The homeowner, an advocate of energy efficiency with limited technical expertise, collaborated with a talented architect to transform the house into a beautiful, energy-efficient, and sustainable home that met the family's requirements. The retrofit process incorporated load reduction measures efficient systems, and the renovation process included renewable energy systems to achieve the desired energy performance.

The primary objectives of this paper are to:

- Share the experiences and challenges faced during the renovation process to demonstrate the feasibility of incorporating energy efficiency measures and renewable energy systems in an older, independent house.

- Provide costing of the energy efficiency measures and renewable energy systems implemented during the renovation. Also, it will highlight the challenges of calculating ROI due to the lack of BAU of the retrofitted energy-efficient equipment.
- Offer valuable insights to industry professionals, policymakers, and homeowners interested in energy-efficient renovation of independent single-family homes.

Background

The paper presents the case study of a 50-year-old independent house in Bangalore, India, renovated and retrofitted with a focus on energy efficiency and sustainability. The homeowner, an advocate of energy efficiency with limited technical expertise, collaborated with a talented architect to transform the house into a beautiful, energy-efficient, and sustainable home that met the family's requirements. The renovation process incorporated load reduction measures, efficient systems, and renewable energy systems to achieve the desired energy performance.

Background and Design Considerations

The architect's brief was to modernize a 50-year-old building with two residential units into a single-unit home for a multigenerational family of three and their three pets. The 30x60 site was in an urban residential area, featuring a G+2 story load-bearing structure. The renovation maintained the external walls and roof slabs while reconfiguring internal spaces to accommodate the family's needs. Older internal walls were carefully removed and replaced with new ones, supported by structural steel members.

Energy Efficiency Measures and Renewable Energy Systems

This transformation featured:

Renovation introduced a solar chimney for passive cooling, reduced window sizing to decrease cooling load, and installed a rooftop solar power system and heat pump. To maintain energy efficiency, local materials were used, and existing teak doors were repurposed, and cool roof tiles were used on the terrace and inner courtyard. The final design incorporated individual preferences while ensuring the home remained comfortable for the family's pets.

The measures undertaken can be classified into three main categories:

- Load Reduction
- Efficient Systems and
- Renewable Energy Systems Each of these measures are detailed below:

Measures: Each of the Measures are detailed below:

Load Reduction:

- The 3000 m2 house building envelope was largely kept intact.
- Windows were sized to maintain a 15-20% window to floor area ratio
- The windows were replaced with double-glazed units with uPVC window frames
- A solar chimney was installed in the atrium to create stack-effect cooling.
- A cool roof was installed, along with plants for shading
- Energy-efficient appliances such as a microwave, oven, dishwasher, washing machine, refrigerator, and dryer were installed in the kitchen and utility

The implementation of load reduction measures, including proper window sizing and the use of double-glazed windows, contributed to improved thermal performance and reduced cooling loads. The solar chimney and cool roof further enhanced the building's thermal performance by providing natural ventilation and minimizing heat gain. The energy-efficient appliances contributed to an overall reduction in energy consumption.

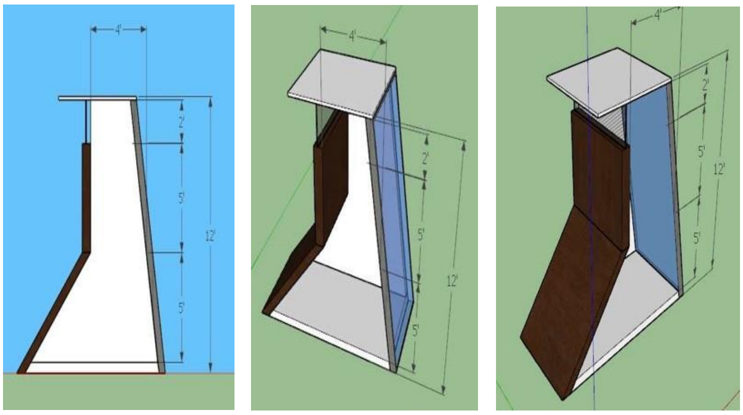

Figure 1: Drawings of Solar Chimney

Figure 2: Photo showing the constructed Solar Chimney

Efficient systems for providing cooling, ventilation, and light. They are:

- VRF system – ODU 10 HP with R410A refrigerant
- BLDC fans – 9 nos
- LED lights and home automation with sensors and dimmers

The VRF system, BLDC fans, and LED lights with home automation sensors and dimmers have significantly improved the efficiency of cooling, ventilation, and lighting systems. The VRF system offered better zoning capabilities and improved temperature control while minimizing energy consumption. The BLDC fans provided energy savings of up to 50% compared to conventional fans, and the LED lights, coupled with home automation, led to a reduction in energy usage for lighting.

Renewable energy systems:

- The terrace has been fitted with 4.89 kW of rooftop solar panels
- There is also a 200-liter solar water heater with a heat pump and a 300-liter storage tank

The installation of a 4.89 kW rooftop solar panel system and a solar water heater with a heat pump contributes to the production of clean, renewable energy for the house. The aim is to reduce the overall grid electricity consumption, resulting in lower energy bills and a smaller carbon footprint.

Others:

- Green cover with plants on all 3 floors of the house; small water bodies in the form of two aquariums and a small tank
- Rainwater harvesting
- Repurposing old teak doors into new doors
- Energy-efficient pumps and motors for pumping water

The green cover, rainwater harvesting, and repurposing of materials further enhanced the sustainability of the house. The green cover provides natural shading and helps maintain a comfortable microclimate within the house. Rainwater harvesting has enabled water conservation, while the reuse of old teak doors and energy-efficient pumps and motors have contributed to reduced embodied energy and operational energy consumption, respectively.

Figure 3: Image of the house before renovation and retrofit, 1971

Figure 4: Image of the house before renovation and retrofit, 2021

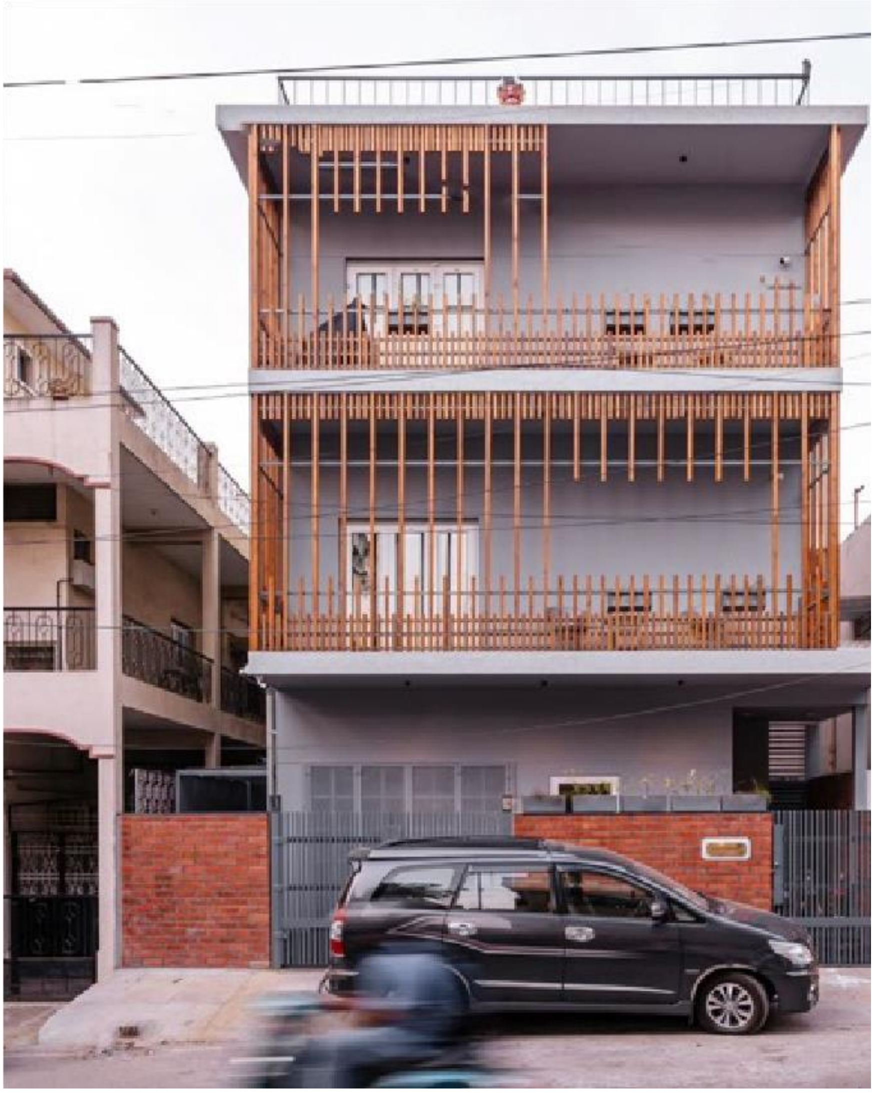

Figure 5: Image of the house after renovation and retrofit, 2023

Figure 6: Interiors Now

Costing

The determination to make the house energy efficient, combined with discounts negotiated for the equipment and appliances, aided in implementing energy efficiency measures. The costs are detailed below.

Table 1: Costing of Energy-Efficient Equipment

Appliance	Discount	Cost for EE Appliance in INR After Discount +GST	Cost of Business-As-Usual (BAU) Appliance	Incremental Cost of Appliance	Energy Savings Compared to BAU
VRF (including 8 units)	30%	4,25,000	1,72,000	2,53,000	20%
Home Automation	37%	2,00,000	0	2,00,000	10%
uPVC with double glazed windows	27%	13,00,000	6,50,000	6,50,000	NA
Kitchen Appliances	25%	5,95,000	1,85,000	4,10,000	NA
BLDC (9 Fans)	-	33,000	12,600	20,400	NA
Efficient pumps, motor, solar water heater,	-	4,39,000	2,50,000	1,89,000	Pumps 15%, water heater 50%.
heat pump and storage tank					
Total		**29,92,000**	**12,69,600**	**17,22, 400**	

The total cost for implementing energy efficiency measures and renewable energy systems during the renovation was INR 29,92,000. The incremental cost was INR 19,53,400.

Unclear Return on Investment (ROI):

To calculate the return on investment (ROI) for each energy efficiency measure (not including the renewable energy system), the annual energy cost savings need to be estimated; only then can the payback period be determined.

As seen in Table 1, various vendors gave only percent savings estimates compared to a Business As Usual (BAU) appliance or equipment. Also, for windows, kitchen appliances, and BLDC fans, the vendors did not provide even the percentage of energy savings.

If the BAU energy consumption numbers for each equipment or appliance were provided by the vendors, the ROI or payback calculation could have been done.

The 4.89 kW rooftop PV system cost INR 4,31,000, and no discounts were provided for that system.

Challenges

The homeowner and the architect faced several challenges during the renovation period:

- The payback for the entire suite of efficiency improvements is unknown despite the percentage savings numbers provided by some vendors and the significant discounts received from manufacturers. The incremental cost of appliances, energy efficiency, and renewable energy measures are nearly 1.5 times the cost of generic appliances. But for the passion of the homeowner, the incremental cost would have been a strong deterrent to implementing energy efficiency.
- Coordination among various vendors: A lack of clear communication and coordination among the different vendors involved in the renovation process led to work being redone. Ensuring smooth communication and collaboration among vendors is crucial for successful project execution.
- GRIHA rating: Applying for a GRIHA rating (Green Rating for Integrated Habitat Assessment) was considered to certify the energy efficiency and sustainability of the house. However, the cost of obtaining the rating – Rupees 1 lakh was deemed better spent on implementing energy-efficient measures. The decision to prioritize actual improvements over certification reflects a focus on tangible benefits. The homeowner was also unclear about the benefits of obtaining a GRIHA rating for a renovated house.
- Limited material recycling facilities: The architect discovered information about material recycling facilities relatively late in the renovation process. Additionally, there are not many such facilities in the city, making it challenging to incorporate recycling and reuse strategies in the project. Increased awareness and access to material recycling facilities can significantly improve the sustainability of renovation projects.
- Lack of Electricity Bills: Since the solar panels were installed and commissioned, BESCOM has yet to issue an electricity bill.

These challenges highlight the importance of effective communication, prioritizing investments, and increasing awareness of sustainable construction practices.

Addressing these challenges can help homeowners and architects to navigate the renovation process and achieve the desired outcomes in terms of energy efficiency and sustainability.

Conclusion

This paper has demonstrated that renovating and retrofitting an older, independent house with energy efficiency and sustainability in mind is not only achievable but also possible, even with limited technical expertise and a strong determination. The renovation of the 50-year-old house resulted in a beautiful, energy-efficient, and sustainable home that met the family's requirements.

The cost analysis and unclear return on investment calculations provide an understanding of the financial issues associated with implementing energy efficiency measures and renewable energy systems during the renovation process. With an unknown payback period, the energy efficiency measures and renewable energy systems cannot be scaled up in a retrofit and renovation process where limited technical expertise is available to the owner. Integration of costs and savings of various appliances and equipment needs to be presented clearly to the owner. Perhaps a simple calculation tool that empowers the owner to ask for the relevant information would help building owners make informed choices.

We recognize that the energy efficiency and environmental benefits contribute to the overall value of the investment. Furthermore, such measures can improve the comfort and indoor air quality of the building, enhancing the occupants' well-being and overall satisfaction with their living environment. However, these may not be considerations entertained by less motivated homeowners.

As India strives to meet its Nationally Determined Contribution, the findings and observations of this paper are highly relevant to the large market of independent single-family homes that currently fall outside the scope of residential building codes. The experiences and costs associated with implementing energy efficiency measures in the renovation process offer valuable insights for industry professionals, policymakers, and homeowners interested in making their homes more sustainable and energy-efficient in the renovation process can provide valuable information for industry professionals, policymakers, and homeowners.

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