Journal of Engineering Issues and Solutions

# Energy Efficient Homes: Design Strategies and Economic Analysis

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*Received: May 5, 2025; Revised: July 5, 2025; Accepted: July 12, 2025*

*https://doi.org/10.3126/joeis.v4i1.81569*

## Abstract

The residential sector in Nepal is the largest consumer of energy. Despite the growing interest in energy-efficient (EE) building practices, there is a misconception among the stakeholders that EE homes are more expensive than Business-as-Usual (BAU) homes due to a lack of awareness about life cycle cost benefits. Using case study methodology, the study is structured to analyze the economic aspect of two EE homes and one BAU home in Kathmandu's temperature climate, based on initial incremental cost, Net Present Value (NPV), and pay-back period over a 40-year lifespan. The results show that EE homes have a higher initial incremental cost of up to 22.19% compared to BAU home. However, there is an annual energy cost savings, which demonstrates a lower NPV of EE homes up to 20.30%, indicating long-term economic benefits. The life-cycle analysis shows that the initial incremental cost can be returned within a pay-back period of 4.3 years for the EE home with brick cavity wall and 10 years for the EE home with rammed earth wall. The findings show that the EE design strategies, though requiring initial incremental cost, have substantial operational savings and low NPV of cost, making them cost-effective on a long-term basis. This study suggests the integration of EE strategies in the residential practices of Nepal at the policy level, guided by cost-benefit analysis.

***Keywords:*** *Energy Efficient Homes, Initial Incremental Cost, Kathmandu, NPV, Payback period*

## 1. Introduction

In Nepal, the residential sector has highest energy consumption with 60.75%, followed by other economic sectors like the industrial sector with 20.91%, transportation sector with 10.43%, the commercial sector with 5.04%, construction and mining sectors with 1.92% and the agriculture sector with 0.95% (WECS, 2023). Despite the growing interest in energy efficient practices in Nepal, EE homes are perceived as financially unviable due to higher initial costs. While international studies have shown the long-term benefits of EE buildings through life-cycle analysis, the study in Nepal's residential sector remains scarce. A lack of awareness about life-cycle costs, payback periods, and cost-benefit ratios contributes towards the unwillingness among stakeholders to build EE homes. This study addresses this gap by providing a detailed comparative economic analysis of two energy-efficient (EE) homes and a conventional Business-as-Usual (BAU) home in temperate climate of Kathmandu, exploring design strategies and actual energy use patterns, which reveal incremental cost, Net Present Value (NPV) and payback periods over a 40-year life span, as an empirical evidence of the viability of EE homes in Nepal.

## 1.2. Objective of Study

**General Objective**

To study the economic aspect of constructing an Energy Efficient (EE) home compared to a Business As Usual (BAU) home, in the climatic context of Kathmandu.

**Specific Objectives**

a. To study the design strategies of EE homes built in Kathmandu.

b. To compare the cost-benefit ratio of EE homes with BAU home based on initial incremental cost, NPV of cost, and payback period.

## 1.3 Literature Review

### *1.3.1 Energy Efficient Homes*

An energy-efficient home is designed to minimize energy consumption while maintaining or enhancing occupant comfort and indoor environmental quality (Torres, Ordonez, & Montes, 2012). Energy efficiency strategies may be passive or active. Passive strategies are design approaches that optimize a building's energy performance by using natural sources of energy such as sunlight, wind, and thermal mass, without relying on mechanical or electrical systems (Suhaimi, Ramli, Hamid, Kassim, & Munaff, 2020). Appropriate building orientation, use of shading devices, and careful positioning of openings can optimize natural light and airflow, decreasing dependence on artificial lighting and mechanical ventilation systems (Olatunde, Okwandu, Akande, & Sikhakhane, 2024). Active strategies incorporate advanced technologies and systems, including energy-efficient lighting, daylight harvesting, renewable energy sources like solar panels and wind turbines, as well as smart digital tools and automated controls that monitor, manage, and optimize energy use in real time (Olatunde, Okwandu, Akande, & Sikhakhane, 2024). A combination of both passive and active strategies provides a holistic approach to energy efficiency.

### *1.3.2 Economic Parameters for Cost-Benefit Analysis*

The extra cost for EE buildings is commonly referred to as "incremental costs" and consists of differences in costs that occur when constructing an energy-efficient building instead of a non-energy-efficient building (Alexeew, Anders, & Zia, March 2015). While initial costs for EE buildings may be higher, studies suggest that these investments can yield substantial returns over time. The "Net Present Value (NPV)" is the present value of all expected future costs associated with a project or investment, discounted at a specified rate to account for the time value of money. The NPV is calculated using the following formula (Wieloch, 2019)

$$NPV = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

Where:

Ct = Cash inflow at time t

r = Discount rate

n = Number of time periods

The "payback period" is the time in which the recovery of the initial outlay of investment is expected through the cash inflows generated by the investment (Boardman, Reinhart, & Celec, 2006).

*1.3.3 Comparison in National and International Context*

In Nepal, few existing energy-efficient practices in the residential sector of Kathmandu primarily focus on passive design strategies and the use of locally available low-energy materials. Some studies show that incorporating rammed earth construction can lead to significant energy savings and enhanced thermal comfort in buildings (Uprety, Uprety, & Shrestha, 2024). But cost-effectiveness and performance-based design are often ignored. In contrast, international best practices integrate both passive and active energy efficiency strategies within a performance-based design framework. Countries with green building policies incorporate advanced envelope insulation, airtightness, high-efficiency HVAC systems, solar photovoltaic systems with storage, and real-time energy monitoring through building automation systems (Olatunde, Okwandu, Akande, & Sikhakhane, 2024). India, for instance, has implemented the Energy Conservation Building Code (ECBC) (Rawal & Kumar, 2010) and established the Green Rating for Integrated Habitat Assessment (GRIHA) and LEED India, which are widely adopted in both public and private sectors (TERI, 2020). Similarly, China has enforced mandatory green building standards such as the Three Star Rating System, and studies show that China's policies have led to significant reductions in operational energy consumption and stimulated the green construction industry (Cao, Cong, Kamaruzzaman, & Aziz , 2022)

Furthermore, while EE buildings in Nepal focus more on initial construction cost, international standards emphasize quantifiable energy savings and return on investment. A study by the Indian Energy and Resources Institute found that energy-efficient buildings in India achieved energy savings of up to 36% compared to conventional structures, with life-cycle costs significantly lower than those of conventional buildings (Alexeew, Anders, & Zia, March 2015). Another study shows that passive houses have proven to be able to reduce heating demand of buildings in central European climates by approximately 90% as compared to the existing building stock, at a reasonable cost (Feist & Schnieders, 2009). A study conducted in the temperate climate of Europe shows that a source energy reduction of 90% and beyond is suitable for new building in compare to baseline case and shows that energy savings eventually balance in the initial incremental cost (Parker D. & D' Agostino D., 2023). An international study in Iran that assessed 22 load-bearing wall systems, encompassing 18 earthen techniques (both stabilized and unstabilized) and 4 conventional systems show that unstabilized compressed earth blocks (UCEB) are the most cost-effective, with a life cycle cost of $4.43 per square meter while stabilized rammed earth walls are the most expensive, with costs reaching up to $29.41 per square meter and fired brick walls had a moderate cost of $18.56 per square meter (Dormohamadi, Rahimnia , & Bunster , 2024). Regarding incremental cost, the first on-site net zero energy building of India, Indira Paryavaran Bhawan has shown an incremental cost of 18% to 20% (Firstgreen Consulting, 2023). Similarly, a study by the National Institute of Standards and Technology, USA shows 15% incremental cost for using passive and active EE measures (Kneifel & O'Rear, 2016).

### 1.4 Limitation of Study

Due to lack of energy-certified residential buildings in Nepal, this study includes houses without any energy certification. The study is limited to the operational energy of buildings in terms of heating, cooling, cooking, and lighting. It doesn't consider any form of embodied energy in the life cycle of a building.

## 2. Materials and Methods

### 2.1. Research Methodology

The study is based on exploratory and descriptive research methodology, using an inductive research method. Case study methodology has been used, selecting three residential buildings, one Business-as-Usual (BAU) and two Energy-Efficient (EE) homes, in the temperate climate of Kathmandu. The rationale for selecting only three case studies is to generate in-depth contextual economic insights rather than generalized statistics. A study regarding sample size shows that the more information the selected cases hold relevant to the scope, the fewer cases are needed (Malterud, Siersma, & Guassora, 2015). A study of the energy efficiency performance and cost-benefit analysis in Thailand has considered only three case studies and shows the energy savings of 79.2 to 81.6% for the on-site energy use and pay-back period of 7.2 to 8.5 years (Lohwanitchai & Jareemit, 2021). Moreover, a limited availability of EE homes in Nepal, with accessible energy data and interviews, suggested selecting few data rich comparative study. Selecting cases of rammed earth and cavity brickwork provided a diverse basis for comparative analysis

### 2.2. Data Collection

*2.2.1 Collection of Primary Data*

Energy-efficient strategies adopted in the houses were studied through direct observation and interviews with the owner and architect. Primary data included the calculation of energy consumption for appliances commonly used for cooking, lighting, heating, and cooling. This was derived from household information, such as daily usage patterns and monthly electricity, water, and waste bills. Details regarding initial construction and equipment costs, as well as annual maintenance and repair expenses, were collected through user interviews and document reviews. To calculate energy consumption, data on the number of electrical appliances, their power ratings (kW), and duration of daily usage were analyzed.

*2.2.2 Collection of Secondary Data*

Secondary data is utilized to estimate the life cycle cost by projecting current expenses over a 40-year building lifespan. This data is derived from various market rates. Regarding per unit rate of electricity, for single-phase low-voltage consumers (230 volts, 15 amperes), the current energy charge is Rs 9.50 per unit for usage ranging from 15 to 100 units, with a minimum monthly charge of Rs 100. According to NEA's proposed tariff adjustments, a 10% hike would raise the energy charge to Rs 10.45 per unit, while a 15% increase would bring it to Rs 10.925 per unit. (Nepal Electricity Authority, 2024). Regarding yearly change in electricity rate, the Government of Nepal reduced electricity tariffs by an average of 1.04%, from November 17, 2021 but conversely, in February 2024, NEA proposed a tariff hike ranging from 10% to 15% to address a per-unit deficit of NPR 0.12 (www.fiscalnepal.com, 2024). NEA fiscal year reports from 2010 to 2024, clearly state that the electricity cost is slightly changing towards an increment or decrement based on financial and operational conditions (Nepal Electricity Authority, 2024). Therefore, the increment in cost of electricity is taken only 1% in the study.

Discount Rate of 6% has been taken, referring to Nepal Rastra Bank reports from 2014 to 2024 (Nepal Rastra

Bank, 2014-2024). Cost of replacing equipment is calculated by taking the annual 3.33% increase in dollar value, referring to the data from 2014 as 1 USD=NPR 100/- to 2024 as 1 USD=NPR 133.9/- (International Monetary Fund, 2024).

Regarding inflation rate of Solar PV cells, the global average price had decreased by approximately 90% from 2010 to 2020, but after 2021, due to the commodity price increment of polysilicon over 200% and steel about 100%, the price of solar PV also increased, further influenced by tariff rates (International Energy Agency, 2023). On average, a yearly decrement rate of 20% can be considered, as suggested by Swanson's Law, which observes that for every doubling of cumulative installed capacity, solar module prices tend to drop by about 20% (Wu, Lan, Lin, & Huang, 2017). Regarding the production capacity of Solar PV, the pre-monsoon (March to May) and post-monsoon (October to November) periods allow solar panels to receive longer sunshine durations, averaging around 8 hours per day. In contrast, the summer monsoon season (June to September) gets reduced sunlight of about 5 hours per day, while the winter months (December to February) receive approximately 7 hours of sunlight daily (Regmi & Adhikary, 2012). The inflation rate of construction materials is assumed to be 8% annually, based on the year-on-year percentage change observed between 2014 and 2024, as reported by Nepal Rastra Bank (Nepal Rastra Bank, 2014-2024).

### 2.3. Quantitative Analysis Method

Performing a cost-benefit analysis considering the 40-year lifespan of a house takes into account several economic parameters. Initial Capital Cost (NRs) includes construction cost, design cost, and the initial investment in equipment used for EE measures. Annual energy consumption (kWh) and annual fuel cost (NRs) include the energy consumption for operational energy for heating, cooling, cooking, and lighting. Future Cost (NRs) is estimated by forecasting yearly costs over the building's 40-year lifespan, taking inflation rates into account. Net Present Value (NPV) is determined by adding the initial cost to the projected future costs. Annual savings are computed by taking the difference between the NPVs of two scenarios and dividing it by the 40-year lifespan. The payback period is determined by dividing the additional incremental cost by the annual savings. Cost-Benefit Ratio is calculated by dividing the initial incremental cost by the total saving obtained from NPV.

## 2.4 The Research Area

Table 1 Selection of case studies

| Category | Typology | Special Features |
|---|---|---|
| Residence A | Business-As-Usual | **Construction system and materials:**<br>• RCC Structure with solid brick masonry wall<br>• Single glazed windows<br>**Water and waste management:**<br>• Fully dependent on local water supply and waste collection |
| Residence B | Energy Efficient Home | **Construction system and materials:**<br>• 1'-6" thick load-bearing rammed earth wall with mud plaster and reinforcement<br>• Reinforced concrete footing and bond beam<br>• 2" thick compressed earth floor, floor heating, PVC sheet, Styrofoam insulation above 2" thick PCC floor<br>• 24 gauge CGI and PVC sheet for roofing with 12mm flatten bamboo and rafters, with 3" thick glass wool insulation<br>• Double glazed windows with UPVC frames<br>**Water and waste management:**<br>• Rainwater harvest, deep boring and grey water recycling<br>Other energy efficiency strategies are explained in section 3.1.2. |
| Residence C | Energy Efficient Home | **Construction system and materials:**<br>• RCC structure with Brick Cavity Wall (4.5" inner and outer leaf with 2" air cavity)<br>• 5mm polyurethane foam, 19mm marine plyboard and 25mm thick soft wood flooring are used above RCC floor<br>• Thermocol for insulation in RCC roof and Extruded Polystyrene Foam only in roof of solar room<br>• Double glazed windows with UPVC frames<br>**Water and waste management:**<br>• Deep boring and geotextile used in landscape for water surface drainage<br>Other energy efficiency strategies are explained in section 3.1.3. |

The study focuses on evaluating the current state of energy-efficient design strategies and energy consumption. Additionally, a cost-benefit analysis has been conducted for hypothetically improved scenarios of both EE homes. These improvements involve reducing the capacity of Solar PV, which currently exceeds the actual requirement. Enhanced water and waste management systems have also been proposed. No significant changes to construction methods are considered necessary in the existing conditions. Each house is privately owned by a single family and is not rented out.

## 2.5 Tools and Software

Microsoft Excel has been used as software, and self-generated calculation sheets have been used for economic analysis.

# 3. Results and Discussion

## 3.1 Study of Design Strategies

### *3.1.1. Residence A*

This BAU case, situated at Kalanki, Kathmandu, has a built-up area of 3,637 sq. ft. It lacks significant passive design elements and energy-efficient technologies, except for a solar water heater and CFL lighting. The building depends entirely on the local electricity supply, as well as local water supply and waste management services.

**Figure 1**: Exterior view of Residence A

### *3.1.2 Residence B*

**Figure 2:** Exterior view of Residence B

This EE home, situated at Budhanilkantha, Kathmandu, has a built-up area of 2263 sq. ft. This house is focused more on passive strategies than energy-efficient technologies. It is owned by an environmental engineer Mr Hemendra Bohora.

**Passive Energy Efficiency Strategies**: The building is oriented along the east-west axis to maximize sunlight exposure from the south. Within the landscaped area, a natural pool located on the southern side helps to create a comfortable microclimate. This EE home has a rectangular shape, featuring windows, larger on the south side and smaller on the north.

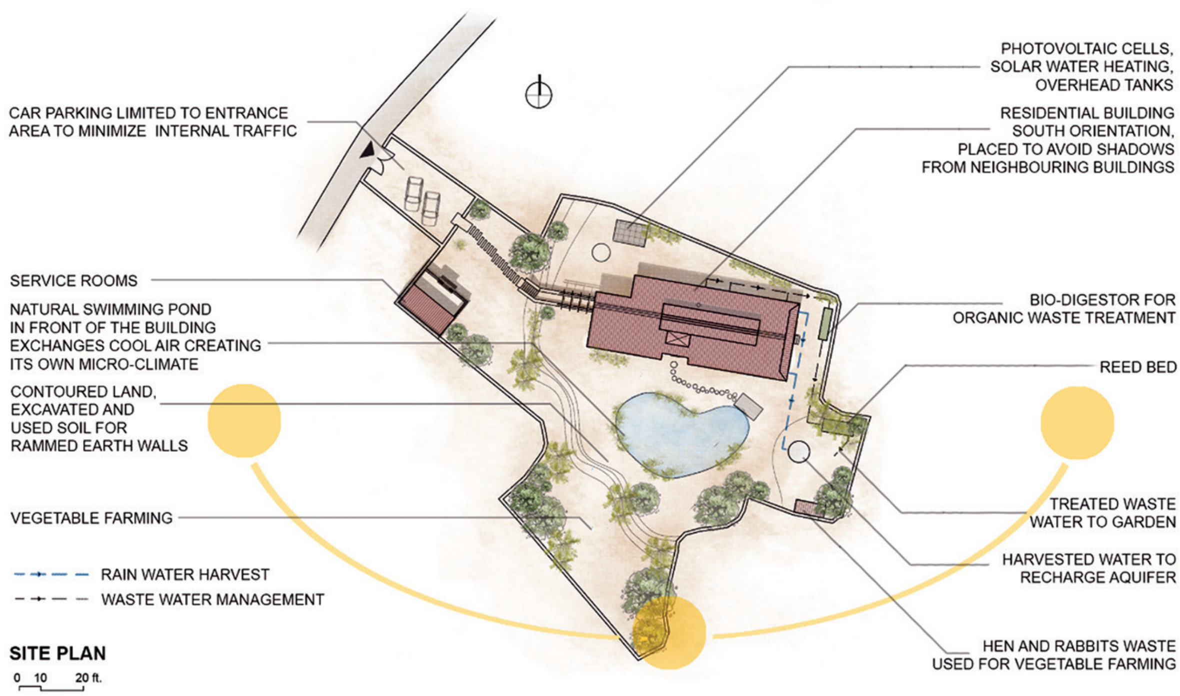


**Figure 3**: Site Plan of Residence B

Source: (Thapa, 2019)

Regarding water management, rainwater harvesting is implemented to reduce dependence on the local water supply. Additionally, underground water is filtered and utilized for drinking and household needs. For wastewater management, greywater is directed through drainpipes to filtering beds before reaching REED plants. The treated water is then collected in a soak pit and used for gardening. Solid waste is composted to produce manure for fertilizer.

Wind stack effect is generated through clerestory windows situated above the lobby in the center, which remain closed during winter and open during summer. Habitable spaces are oriented to the south, while utility and service areas are oriented to the north side.

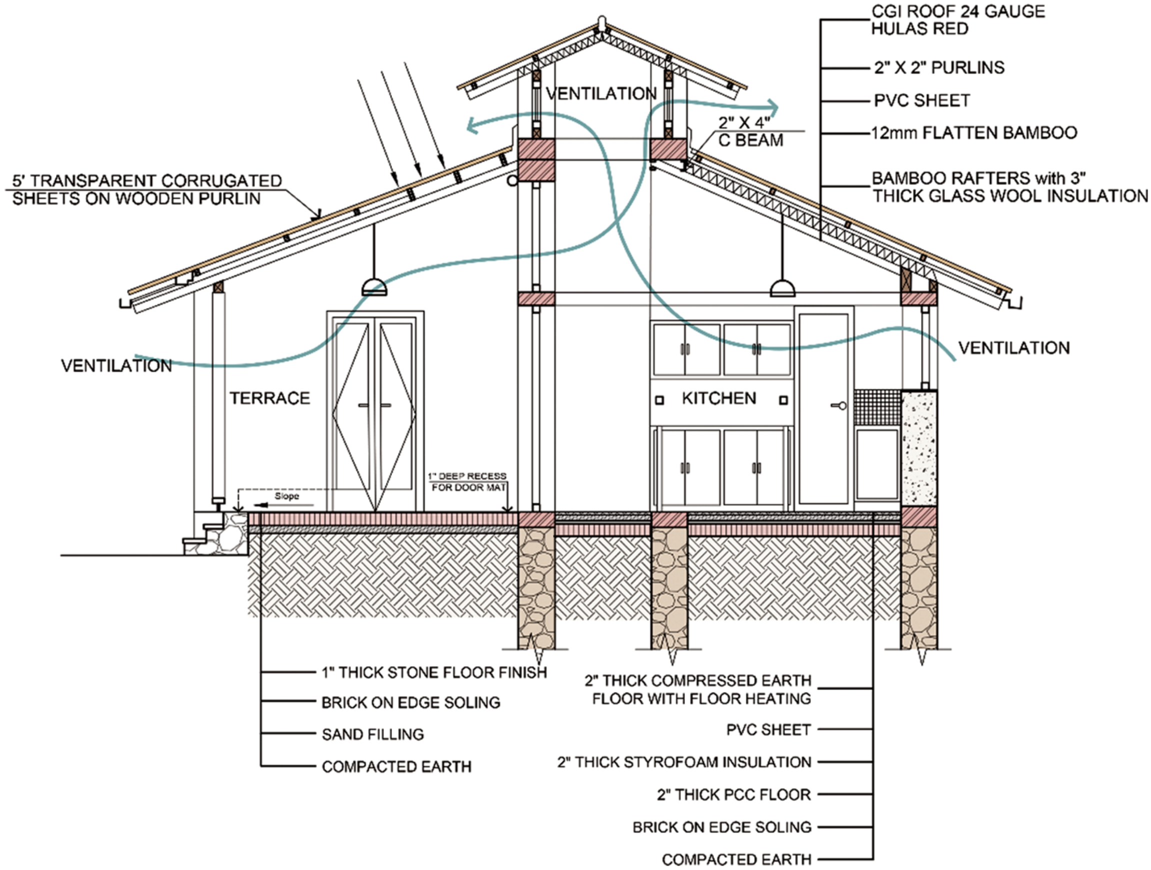


**Figure 4**: Sectional Profile of building with details of floor and roof

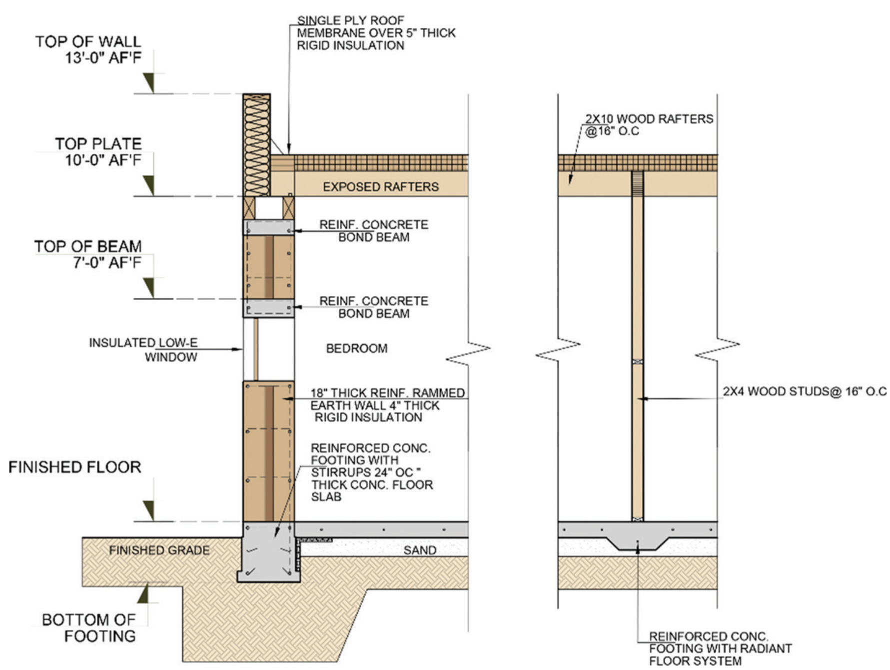


**Figure 5**: Details of Rammed Earth Wall

**Active Energy Efficiency Strategies:** Solar photovoltaic (PV) cells and solar water heaters are utilized. A programmable thermostat monitors the electricity consumption pattern from the solar PV system. The solar PV system is designed to generate 2.8 kW of electricity. However, the improved scenario incorporates a 2 kW solar PV system because the energy usage calculations for the current setup indicate that 2 kW of electricity generation is sufficient for the house.

*3.1.3 Residence C*

This EE house, situated at Maharajgunj, has a built-up area of 3906 sq. ft. This house has both passive design strategies and energy-efficient technologies. It is owned by Architect Ujjwal Man Shakya, a prominent practitioner in green building design.

**Figure 6**: Exterior view of Residence C

**Passive Energy Efficiency Strategies:**

The building is oriented towards south-west, and the site includes abundant trees and vegetation, especially on the western side. Large windows on the south and smaller windows on the north enhance natural daylight, solar heating, and cross ventilation.

The building has a sloped roof designed to accommodate solar PV panels, along with a rooftop garden. A designated solar space on the second floor provides a passive solar heating system for two south-facing bedrooms, while a larger 200 sq. ft. solarium supplies warm air to the lower floors and a laundry drying room, using solar-energy-driven blowers. All windows, except those in the solar room on the third floor, are double-glazed with UPVC frames.


**Figure 7**: Site Plan of Residence C

**Active Energy Efficiency Strategies**: The solar photovoltaic system produces only 2 kW of electricity, which is inadequate at present for the larger built-up area. So, a 3-kW solar panel is proposed for the improved case. A solar water heater is used to heat up to 1000 liters of water. For winter heating, Solar Air Panels (SAPs) and diffusers are used, while summer cooling is achieved by directing cool air through a duct next to a 40-foot concrete wall by the lap pool. Space heating is also provided by a black-painted metal fireplace, supplemented by a fan that distributes warm air.

**Figure 8**: Duct to supply hot and cold air

**Figure 9**: Exterior view of solar room

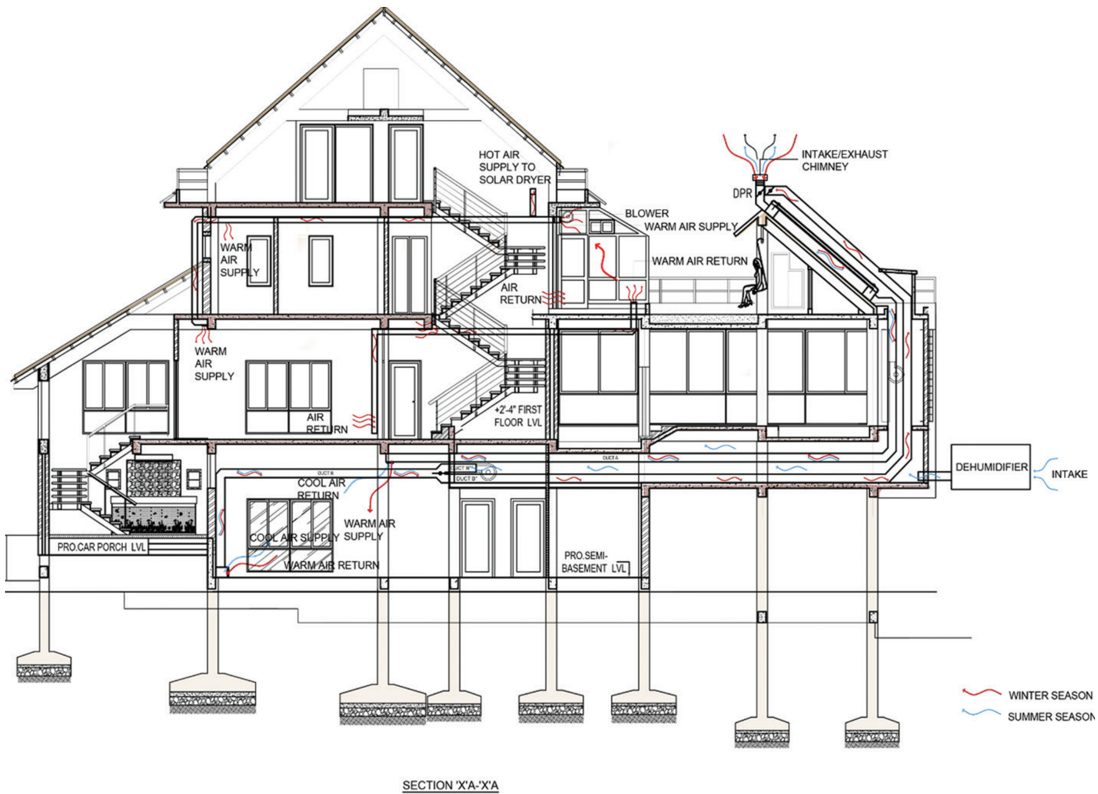


**Figure 10**: Building section showing air supply using ducts, dehumidifier and chimney

Regarding water and waste management, rainwater and surface water are recharged, while the house also relies on the local water supply. The household depends on the local waste management system, as the waste is neither composted nor recycled.

## 3.2 Economic Analysis of EE Homes

### *3.2.1. Incremental Cost for Construction of EE Houses*

**Table 1:** Comparison of Initial Incremental Cost (NRs Per Sq. Ft.)

| | Residence A | Residence B | | Residence C | |
|---|---|---|---|---|---|
| | | Existing Scenario | Improved Scenario | Existing Scenario | Improved Scenario |
| | Incremental Cost per Sq. Ft. (NRs) | | | | |
| **Initial Design and Construction Cost** | 3825.00 | 4590.00 | 4590.00 | 4080.00 | 4080.00 |
| **Installation Cost of Solar PV System** | 0.00 | 303.14 | 185.59 | 107.53 | 176.65 |
| **Installation Cost of energy efficient measures** | 28.05 | 55.50 | 55.50 | 46.52 | 46.52 |
| **Initial Capital Cost** | 3853.05 | 4948.64 | 4831.10 | 4234.05 | 4303.17 |
| **Extra Investment in Initial Cost** | | 1095.59 | 978.05 | 381.00 | 450.12 |

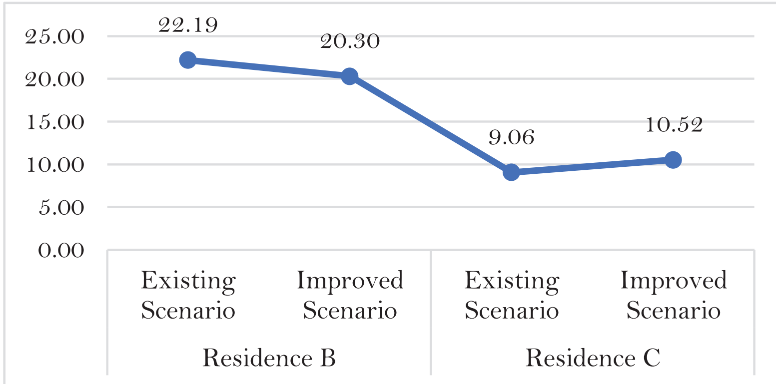


**Figure 11**: Comparison of initial incremental cost in compared in Residence A (%)

The incremental of up to 20.30% in improved case, closely aligns with the built examples in India and USA, and in European countries with temperate climate, as mentioned in section 1.3.3. Residence B with rammed earth technology has the highest initial cost esp. the construction cost, which corresponds to the finding by Dormohamadi, Rahimnia , & Bunster that rammed earth walls are expensive than fired brick walls, as mentioned in section 1.3.3.

*3.2.2. Annual Energy Consumption and Annual Fuel Cost*

The annual energy consumption is highest in Residence A because of its full dependency on the local electricity supply. Residence C has higher energy consumption than Residence B due to partial dependency on the local electricity supply for heating and cooling during peak summer and winter. Reduction in energy consumption ranges from to 61.5% to 92%, which corresponds to the findings of Feist & Schnieders and Parker D. & D' Agostino D., both in temperate climate of Europe as mentioned in section 1.3.3.

**Table 2**: Comparison of Annual Energy Consumption and Annual Fuel Cost (Per Sq. Ft.)

| | Residence A | Residence B | | Residence C | |
|---|---|---|---|---|---|
| | | Existing Scenario | Improved Scenario | Existing Scenario | Improved Scenario |
| **Annual Energy Consumption using solar PV (kWh)** | 4.32 | 0.46 | 0.46 | 2.24 | 1.79 |
| **Annual Fuel Cost for 40 years life span (NRs)** | 8182.22 | 665.43 | 665.43 | 3125.84 | 2499.12 |

*3.2.3. Net Present Value (NPV) of Cost*

**Table 3**: Comparison of Net Present Value of Cost (NRs per Sq. Ft.)

| | Residence A | Residence B | | Residence C | |
|---|---|---|---|---|---|
| | | Existing Scenario | Improved Scenario | Existing Scenario | Improved Scenario |
| **Initial Capital Cost** | 3853.05 | 4948.64 | 4831.10 | 4234.05 | 4234.05 |
| **PV of future Cost** | 3660.51 | 912.03 | 978.13 | 1953.31 | 1751.01 |
| **Net Present Value (NPV)** | 7513.55 | 5860.66 | 5809.23 | 6187.35 | 5985.06 |

NPV of Residence A is highest, due to the highest annual energy consumption and fuel cost, despite having the lowest initial investment. Residence B has the lowest NPV, due to the substantial reduction in heating and cooling load. Residence C is dependent on mechanical heating and cooling during peak seasons, leading to higher annual energy consumption.

*3.2.4. Comparison of Initial Capital Cost and NPV of Cost*

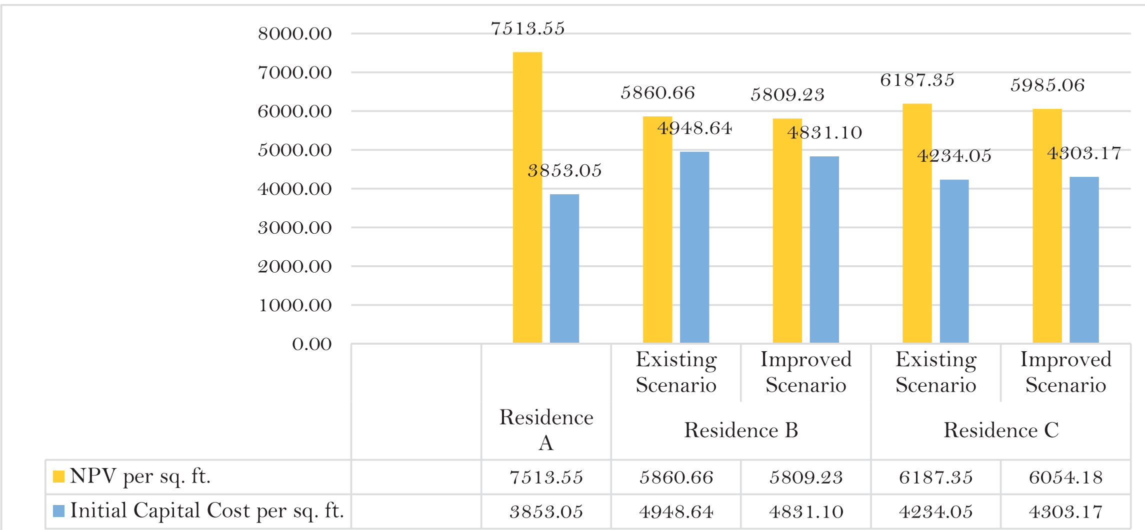


**Figure 12**: Comparison of Initial Capital Cost and NPV (NRs per sq.ft)

Residence B has the highest initial capital cost but the lowest NPV in the 40-year life span, due to the substantial reduction in heating and cooling load, using EE measures in all seasons of the year. Though Residence C has an initial capital cost lower than Residence B, NPV is higher because of the dependency on local electricity during peak summer and winter. Both EE homes compensate for the higher initial incremental cost due to annual energy savings.

*3.2.5. Comparison of Annual Savings and Pay-back Period*

**Table 4:** Comparison of Annual Savings (NRs per Sq. Ft.) and Pay-back period (Years)

| | Residence A | Residence B | | Residence C | |
|---|---|---|---|---|---|
| | | Existing Scenario | Improved Scenario | Existing Scenario | Improved Scenario |
| | **Annual Savings over life-cycle per Sq. Ft.** | | | | |
| **Life Span (Years)** | 40.00 | 40.00 | 40.00 | 40.00 | 40.00 |
| **Discount Rate** | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **Saving from NPV (NRs)** | | 1652.89 | 1704.33 | 1326.20 | 1528.50 |
| **Annual Saving (NRs)** | | 109.85 | 113.27 | 88.14 | 101.59 |
| **Pay-back Period (Years)** | | 9.97 | 8.63 | 4.32 | 4.43 |

Unlike BAU, Residence B and C, being energy efficient, provide annual savings. Initial incremental cost can be returned in pay-back period of 8 years 7.5 months to 10 years in Residence B and approximately 4 years

5 months in Residence C. Residence C has an early pay-back period due lower initial incremental cost, but annual savings closer to Residence B. This range of energy savings and payback period supports the findings of Lohwanitchai & Jareemit, 2021 with three case studies in Thailand, as mentioned in section 2.1.

*3.2.6. Comparison of cost-benefit ratio*

**Table 5**: Comparison of Cost-Benefit Ratio

| | Residence A | Residence B | | Residence C | |
|---|---|---|---|---|---|
| | | Existing Scenario | Improved Scenario | Existing Scenario | Improved Scenario |
| **Incremental Cost per Sq.ft. (NRs)** | | 1095.59 | 978.05 | 381.00 | 381.00 |
| **Benefit per Sq. ft. (NRs)** | | 1652.89 | 1704.33 | 1326.20 | 1528.50 |
| **Cost-Benefit Ratio** | | 0.66 | 0.57 | 0.29 | 0.25 |

Residence C has the best cost-benefit ratio, because of its good annual savings and earlier pay-back period, despite of initial incremental cost lower than of Residence B.

*.2.7 Sensitivity Analysis*

Sensitivity analysis has been conducted for two of the economic parameters. NPV is calculated at a lower discount rate of 4%, existing at 6% and higher discount rate at 8%, 10% and 12%.. Since Residence A has the highest future cost, there is a greater NPV decline when the discount rate increases. Since Residence B has the lowest future cost, it is the least affected by the increasing discount rate.

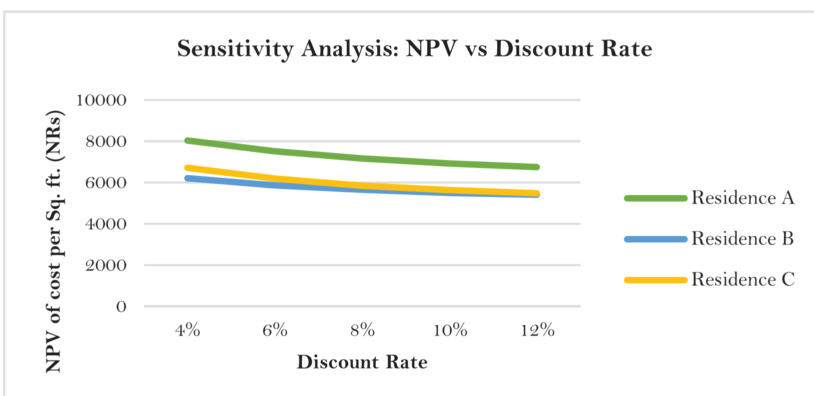


**Figure 13**: Sensitivity Analysis for NPV vs Discount Rate

Also, NPV is calculated for changing rate of electricity at -3%, -1%, 1%, 3% and 5%. The sharpest increase in NPV of Residence A shows that the electricity rate volatility directly impacts the long-term cost-effectiveness of non-energy-efficient buildings.

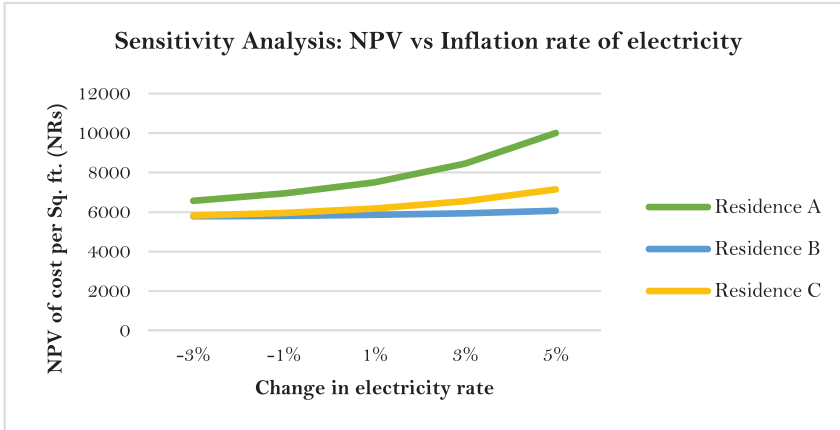


**Figure 14**: Sensitivity Analysis for NPV vs Inflation rate of Electricity

## 4. Conclusion and Recommendations

The study shows that energy-efficient homes are based on fundamental strategies such as the use of sustainable building materials, incorporating passive solar techniques, water conservation, and efficient waste management. Despite higher initial incremental costs up to 22.19%, EE homes demonstrate significant annual energy savings, leading to a lower NPV of cost up to 20.30% less than the BAU home. The cost-benefit ratio is most favorable in Residence C with brick cavity wall , followed by Residence B with rammed earth technology, indicating higher return per unit investment in EE measures. Residence C has the earliest payback period due to moderate initial investment and considerable operational savings. The BAU home's cost-effectiveness is more sensitive to changes in discount rate and electricity prices, showing its vulnerability to market fluctuations while EE homes, particularly with lower operational cost, retain better financial stability under varying economic conditions.

This study recommends incentives such as tax subsidies for projects that are built energy efficient. Design guidelines should prioritize contextual EE strategies supported by data from local case studies, such as mandatory use of double glazing in homes of Kathmandu Valley.

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