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# SIMULATION-BASED EVALUATION OF ENERGY PERFORMANCE IN ADAPTIVE REUSE OF HISTORIC BUILDINGS ACROSS DIFFERENT CLIMATIC ZONES OF SRI LANKA

**A. Tharmitha[1], G.Y Jayasinghe[2], M.K.M. Prabodani[3], K. Anojan[4] and R.U. Halwatura[5]**

## *ABSTRACT*

*Adaptive reuse involves reusing historical structures without demolishing or reconstructing while preserving cultural and heritage values. In Sri Lanka, colonial-era buildings have been converted to modern purposes; their post-reuse energy performance remains measured. This study evaluates the impact of adaptive reuse on energy performance across three climatic zones in Sri Lanka, Jaffna (dry), Galle (intermediate) and Nuwara Eliya (wet) using Autodesk Revit 2025 Insight simulation. It aims to (a) Analyse architectural, material and functional changes (b) Quantify Energy use intensity (EUI), and (c) Propose strategies to maximize energy efficiency without compromising heritage integrity. Field data were modelled for pre- and post-modification phases to analyse EUI and end-use components (cooling, lighting and equipment). Comparative simulations generated retrofit recommendations. Results indicate EUI increased in adaptive-reuse buildings. In Jaffna EUI increased from 29.96 to 78.24 kWh/m²·year, and reduced to 42.54 kWh/m²·year after retrofit. In Galle, EUI increased from 28.87 to 67.72 kWh/m²·year, and decreased to 38.5 kWh/m²·year after retrofitting. In Nuwara Eliya, the EUI increased from 22.90 to 39.83 kWh/m²·year, and reduced to 30.5 kWh/m²·year after retrofit. The difference between the pre- and post-modification EUI was highest in the dry-zone case, followed by the intermediate zone, while the wet-zone case exhibited the lowest increase, due to climatic conditions, material replacement and purpose of the building. The findings show that poorly designed adaptive reuse, particularly enclosed spaces and light partitions, can increase cooling-related energy demand by 30-50% in dry and intermediate regions. Energy-efficient retrofit strategies can reduce energy consumption in such buildings.*

**Keywords :** *Adaptive Reuse; Energy Performance; Energy Use Intensity (EUI); Historical Buildings; Sri Lanka.*

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# 1. INTRODUCTION

Buildings are important parts of daily life and society, providing shelter, cultural identity, and economic value. Yet, the building sector is a major source of environmental problems. It accounts for nearly 39 % of global energy-related Green House gas (GHG) emissions, with approximately 28 % arising from operational energy use for heating, cooling, and lighting, and 11 % from embodied emissions during construction (Slavkovic & Stephan, 2025). Reducing both operational and embodied energy is therefore central to achieving climate-resilient and sustainable built environments. Adaptive-reuse is the process of repurposing existing buildings for new functions while preserving their cultural and architectural value provides a more sustainable option to demolition and new construction. By extending a building's lifespan, adaptive reuse conserves embodied energy and minimizes material waste, saving up to 95 % of embodied energy otherwise lost during reconstruction (De Silva et al., 2019). It also supports the circular-economy approach by reducing landfill waste and resource demand (Rodrigues & Freire, 2017).

The global application of adaptive reuse has revealed considerable benefits for both the environment and the economy. Strategies like upgrading insulation, optimizing Heating, Ventilation, and Air Conditioning (HVAC) systems, and incorporating renewable technologies can successfully lower operational expenses and cut carbon emissions (Rodrigues & Freire, 2017). For example, post-retrofit studies from Europe and the Middle East document reductions in carbon emissions of up to 60%, alongside major gains in energy efficiency (Jaber et al., 2025; Ruparathna et al., 2016). These findings underscore the power of adaptive reuse to advance sustainable urban development without sacrificing cultural continuity.

In Sri Lanka, the reuse of Dutch-era and British-era heritage buildings has become increasingly common in urban centres such as Galle, Jaffna, and Nuwara Eliya. Many of these colonial structures have been converted into residences, offices, restaurants, and museums, yet few have been systematically assessed for their energy performance. A comparative evaluation by Thirukumaran et al. (2024) found that reused Dutch-era buildings exhibited reduced cooling demand due to high thermal mass, but very limited detailed studies have been done. Despite growing interest in adaptive reuse, most Sri Lankan research focuses on architectural conservation or economic feasibility rather than simulation-based performance evaluation. In this regard, this research uses Autodesk Revit 2025 Insight (Energy Plus engine) in the analysis of EUI prior to and after adaptive reuse of selected historic buildings in three climatic conditions, which include Jaffna (dry), Galle (intermediate) and Nuwara Eliya (wet). The investigation measures the effects of the operations energy, breaks down significant end-use elements, such as cooling, lighting, equipment, and generates climate responsive retrofit suggestions that ought to enhance energy performance without interfering with heritage integrity. This research assesses the effects of adaptive reuse on operational energy performance of historic buildings in Sri Lanka's climatic zones, and identifies the key factors driving EUI variability with climate-responsive retrofits. This study contributes existing research by offering a BIM-based comparative study of adaptive reuse across diverse climatic zones, expressing pre- and post-energy performance, and showing that adaptive reuse can increase operational energy demand in the absence of climate-responsive design.

## 2. LITERATURE REVIEW

The ability to enable continued use of the existing structures and at the same time reducing demolition waste and protecting cultural heritage has made adaptive reuse an even greater factor in sustainable built environment development. Adaptive reuse prolongs the life of the buildings and mitigates environmental effects that are normally experienced in new constructions (Bullen & Love, 2011; Tam & Hao, 2019). Reutilizing the existing buildings will save a significant amount of embodied energy that is stored in the building materials and thus will contribute to the preservation of sustainable resource management and act in line with the principles of the circular economy (Foster, 2020).

Some of the researches emphasized that adaptive reuse would not only ensure the preservation of heritage value, but also represents an imperative means of achieving the sustainable development aims. Being more economical in terms of the use of new materials, as well as construction waste, and environmental impact as compared to demolition and building construction, conservation and reutilization of existing buildings reduce the demand (Rodrigues & Freire, 2017). Furthermore, adaptive reuse projects can also strengthen the urban regeneration and cultural preservation by keeping the historically significant buildings in modern urban environments (Penića et al., 2015; Vidyullatha et al., 2023). Older buildings are often characterized by special architectural and climatic design qualities that enable passive thermal control. Classical architectural design features, including mass masonry, high ceilings, courtyards, and covered openings, improve thermal stability and reduce the changes in the indoor temperature (Martínez-Molina et al., 2016). Such passive design measures have historically developed to meet the local climatic conditions prior to the use of mechanical cooling systems which became common. Natural ventilation and orientation of buildings are conclusive in thermal comfort and energy saving in warm and humid climates (Haase & Amato, 2009). Many of the colonial and historic buildings in the tropical areas such as Sri Lanka were built with materials and architectural characteristics that are natural in promoting passive cooling. Lime mortar structures, clay or limestone structures of construction and elevated roofing structures facilitate increased heat loss and air circulation in interiors. These conventional design methods can play a significant role in maintaining the interior thermal comfort without necessarily relying on mechanical systems (Ariyarathna et al., 2023). As a result, old buildings converted into modern purposes can demonstrate quite an efficient energy saving when the properties of passive design are preserved.

However, the adaptive reuse of heritage buildings comes with a number of technical and regulatory issues. Historical authenticity is often restrained by conservation laws on significant structural changes or technological modernizations. Due to this, the introduction of the new technologies, related to energy efficiency, like photovoltaic arrays, facade insulations, or glazing changes, can be limited in the case of a heritage building (Conejos et al., 2016). These restrictions will hinder achieving the desired level of energy-efficiency and still maintaining the architectural integrity of historic structures. The balance between the conservation needs and the modern lived-in needs is another important issue in the adaptive reuse projects. Modifications to old structures that have been converted to other purposes, i.e. offices, hotels or commercial buildings may be in need of some extra services like air conditioning, lighting and mechanical systems. These changes may increase the operation energy consumption in case the passive design elements are not combined with the contemporary building services (Ruparathna et al., 2016). It follows that all retrofit interventions should be carefully planned so that they can upgrade the energy performance without jeopardizing heritage values.

Energy performance analysis has now been an essential tool in measuring the sustainability of adaptive reuse projects. With the tools of energy simulation, researchers are able to assess energy consumption in different design conditions and retrofit approaches of buildings. The popularity of Building Information Modelling (BIM), software applications like Autodesk Revit, have been used to address this purpose because of the ability to produce elaborated three-dimensional models including building geometry, material characteristics, occupancy, and climatic information (Abdullah & Hatem, 2023). The combination of simulation tools, including Autodesk Insight, and BIM models allows estimating such energy indicators as the yearly energy consumption and EUI. These instruments provide useful information on the effects of the differences in design of changes on the energy performance of buildings (Veerendra et al., 2024). The simulation-based analysis makes it possible to consider alternative retrofit strategies and find solutions that would improve energy efficiency and maintain conservation restrictions. The use of simulation techniques in the past has been used to compare the energy performance of adaptive reuse buildings to their modern equivalent. The results show that historic buildings can do as well (or even better) than modern structures when the passive design features are prudently maintained (Thirukumaran et al., 2024). Specifically, the thermal mass of thick masonry walls can be used to balance the temperature inside buildings and can decrease the cooling energy consumption during warm seasons.

Despite such observations, the performance of adaptive reuse buildings in terms of operational energy may vary depending on many factors, such as climatic conditions, retrofit design plans, and building orientation as well as the urban environment. In urban areas, the geometry of streets, the surrounding buildings, and shading may have a significant influence on the exposure of the sun and ventilation of the air (Perera et al., 2025). Thus, the adaptive reuse building should be assessed in various climatic regions and architectural settings to be able to properly estimate the actual energy efficiency of these buildings. Despite the fact that many articles shedding light on the environmental and cultural advantages of adaptive reuse are available, there is still a gap in the literature that assesses the energy performance of adaptive reuse in diverse climatic conditions. Most studies carried out previously are rather a qualitative discussion of heritage conservation than a quantitative analysis of the building energy performance (Martínez-Molina et al., 2016). This gap shows the need to have a study which would combine conservation values with stringent energy performance assessment.

All in all, the literature that is available demonstrates that adaptive reuse has a great potential of improving sustainability in the built environment. Adaptive reuse is able to participate in the sustainable building development by conserving embodied energy, passive design of climatic strategies and the use of modern energy analysis tools. Nevertheless, additional studies are inevitable to determine the impact of various retrofit measures on energy performance in heritage buildings especially in the tropical climatic conditions like Sri Lanka.

# 3. METHODOLOGY

## 3.1 RESEARCH DESIGN AND ANALYTICAL FRAMEWORK

The research paper uses a simulation-based comparative analysis methodology (quantitative) to determine the operational energy consequences of adaptive reuse in three climatic zones in Sri Lanka (Dry, Intermediate, Wet). To separate the effects of functional transformation and envelope modification an experimental pre- post modelling approach was used. The EUI was defined as the primary performance metric, expressed in kWh/m²·year. The methods were consistent as all the models were simulated under identical conditions of the boundary. The general methodological workflow can be seen in Figure 1.

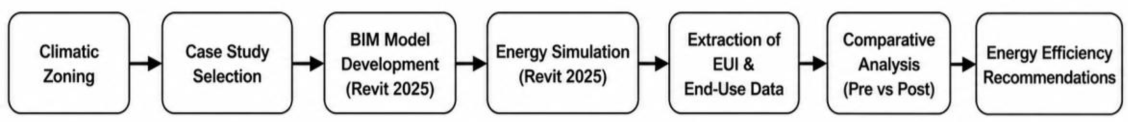


*Figure 1: Overall methodological workflow*

## 3.2 CLIMATIC ZONING AND CASE STUDY SELECTION

Three historically significant buildings were carefully selected to represent Sri Lanka's major different climatic zones to demonstrate both pre and post modification phases of adaptive reuse. One heritage building in adaptive reuse was chosen in each of the three zones: Jaffna (Dry Zone), Galle (Intermediate Zone), and Nuwara Elisha (Wet Zone) (Dissanayake et al., 2024). The three case studies were chosen based on methodological scope, climate zone representation, and data access. Each has been modelled as pre- and post-reuse (six models in total). The small sample size allows for in-depth analysis and consistency, while capturing the diversity of Sri Lanka's Dry, Intermediate, and Wet climate zones with accessible and well-documented changes. While the case studies feature various forms of adaptive reuse, the approach guarantees comparative validity by controlling simulation information (climate, occupant, material and operational settings). The study focuses on relative energy performance changes (before and after the reuse) rather than absolute comparison across buildings. This normalised approach enables a valid comparison using Energy Use Intensity (EUI) despite differences in the nature and scale of retrofit interventions. Because:

- They are located under different climatic zones.
- Their site-specific characteristics are suitable for proposing strategies to meet heating and cooling demands.
- The buildings' any of the elements have undergone the adaptive reuse concept by having modifications.

A summary of the case study buildings is presented in Table 1 : Summary of case study of Buildings.Table 1.

*Table 1 : Summary of case study of Buildings.*

| Climatic Zone | Code | Location And Building Name | Original Function | Adapted Function |
|---|---|---|---|---|
| Dry zone | A (A1/A2) | Jaffna - Rusichatti Restaurant | Residential(A1) | Restaurant(A2) |

| Climatic Zone | Code | Location And Building Name | Original Function | Adapted Function |
|---|---|---|---|---|
| Intermediate Zone | B (B1/B2) | Galle -National Fort Museum | Warehouse(B1) | Museum(B2) |
| Wet Zone | C (C1/C2) | Nuwara Eliya- Post office | Post Office(C1) | Post-Office (C2) |

## 3.3 FIELD DATA COLLECTION

Primary data were gathered using on-site measurements, architectural documents, photographic survey, and structured interviews among the stakeholders. The data that were captured were building size, wall thickness, roof structure, window area to wall, orientation, space zoning, occupancy time, and adaptive changes. Archival drawing and standardized material databases were used as a secondary source to get thermal property assignment data.

## 3.4 MODEL DEVELOPMENT

BIM of the three case-study buildings used were developed using Autodesk Revit 2025 to reflect the pre and post modification stages of the building. The models were made out of on-site observations, architectural measurements, surveys with photos, and interview with the stakeholders organized on site visits. The geometry of the building, assemblies of the envelope, orientation and functional zoning of each model were reproduced to be representative of the physical characteristics of the buildings. The thermal properties, such as conductivity (k), density (rho), and specific heat capacity (c) have been allotted based on the values that have been reported in the literature sources and on the standardized databases of materials. The post-modification models included new envelope materials and spatial designs that indicate the adaptive reuse interventions. The relevant architectural and spatial modifications under the pre- and post-modification conditions are shown in Table 2, and typical BIM models of the structures are shown in Figure 4, Figure 3 and Figure 2.

*Table 2 :Pre-modification conditions and adaptive reuse interventions in the selected case-study buildings.*

| Building Code – Location- Climatic Zone | Pre Modification Condition | Adaptive Reuse Modifications (Post-Modification Condition) |
|---|---|---|
| Building A<br>Jaffna – Dry Zone | A one storey residential building with an open plan design. | Vertical subdivision was used to create an upper floor made of timber; an enclosed space was created on the upper floor using gypsum-board partitioning; an aluminium-framed door was installed with whiteboard paneling, and a staircase was created using wood. |
| Building B<br>Galle – Intermediate Zone | Five limestone columns hold the interior of a big, undivided warehouse. | The interior space was divided with the help of timber and gypsum-board partitioning; a compartment with the basement was made out of cement; a space with a two-storey area was divided with a help of a wooden floor and staircase; and eight extra columns were made out of concrete in order to strengthen the structure of the modified roofline. |

| Building Code – Location-Climatic Zone | Pre Modification Condition | Adaptive Reuse Modifications (Post-Modification Condition) |
|---|---|---|
| Building C<br>Nuwara Eliya – Wet Zone | The interior of the post office is large and has little internal partitions. | Divans were put in place internally in the corridors with partition walls of aluminium and fitted with whiteboard panels to create enclosed office spaces. |

*Figure 2 : Building A*

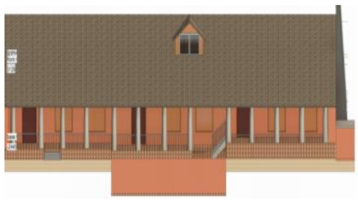

*Figure 4: Building B*

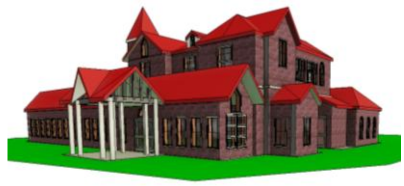

*Figure 3 : Building C*

## 3.5 SIMULATION PLATFORM AND CONFIGURATION

Autodesk Revit 2025 in combination with Insight (with the computational engine of Energy Plus (v23.1.0)) was used to carry out energy simulations. The workflow that was built on the BIM reduced the error amount in geometry translations and guaranteed the congruence in the result of architectural modelling and the thermal simulation process. The selection of weather files of the ISD-TMYx library was carried out based on the climatic similarity: Karaikal (Jaffna), Colombo Bandaranaike (Galle), and Sapporo (proxy Nuwara Eliya).

*Table 3 : Key simulation parameters*

| Parameter | Specification |
|---|---|
| Simulation Engine | Energy Plus v23.1 |
| Software Platform | Revit 2025 + Insight |
| Lighting & Equipment Loads | Insight default |
| HVAC Setpoints | Standardized comfort range |
| Infiltration Rates | Default values |

## 3.6 ENERGY SIMULATION

To guarantee that pre- and post-modification situations could be compared, simulations were carried out using standardised internal load conditions. The operational schedules were determined based on observations on the field and are summarised in Table 4.

*Table 4 : Orientation, function and occupancy schedule*

| Building Code | Orientation | Floor Area ($m^2$) | Function | Operating Schedule |
|---|---|---|---|---|
| A1 | 15° E of N | 91.65 | Residential | 24 h/day |
| A2 | 15° E of N | 91.65 | Restaurant | 12 h/day, 7 days/week |
| B1 | East | 246.86 | Warehouse | 24 h/day |
| B2 | East | 246.86 | Museum | 9 h/day, 5 days/week |
| C1 | 9° S of E | 966.50 | Post Office | 9 h/day, 5 days/week |

| Building Code | Orientation | Floor Area (m²) | Function | Operating Schedule |
|---|---|---|---|---|
| C2 | 9° S of E | 966.50 | Post Office | 9 h/day, 5 days/week |

### 3.7 ENERGY PERFORMANCE AND COMPARATIVE ANALYSIS

The sum of energy used in the building was obtained. Those results are based on available historical details and simulation data. The values before modification were confirmed through research and conversations with users. However, the post-modification results could vary depending on how the building is used in practice and the local weather conditions. "Energy use intensity (EUI)" can be calculated by using the following,

$$EUI = \frac{Total\ Energy\ Consumption\ (kWh/year)}{Gross\ Floor\ Area\ (m^2)} \quad (01)$$

where, EUI = Energy Use Intensity (kWh/m²·year)

This software has the facility to give a building's energy in "Kilo Watts per square meter (kWh/m$^2$)" as a summary at the end of each simulation. This will help in the comparative analysis of each building regarding the different usage purposes, different materials used for the modifications and climatic conditions. Comparative metrics were defined as follows,

$$\Delta EUI = EUI_{post} - EUI_{pre} \left(\frac{kWh}{m^2} \cdot year\right) \quad (02)$$

where, $\Delta EUI$= change in energy use intensity (kWh/m²·year)
$EUI_{post}$= EUI after adaptive reuse
$EUI_{pre}$= EUI before adaptive reuse

$$\Delta\% = \frac{(EUI_{pre} - EUI_{post})}{EUI_{pre}} \times 100\% \quad (03)$$

*where,*
*$\Delta\%$ = percentage change in energy performance (%)*
*$EUI_{post}$ = EUI after adaptive reuse*
*$EUI_{pre}$ = EUI before adaptive reuse*

These parameters measure absolute and relative change of energy performance after it is changed and hence ease in evaluation of effectiveness of the adaptive reuse strategies applied. In visual interpretation, the comparison of graphs was used to explain the difference in the EUI of various climatic regions and building typologies. The comparative analysis of the three climatic zones showed the sensitivity of variation in EUI to temperature variations, material properties, and functions of a building, hence demonstrating the effect of adaptive reuse interventions on energy.

### 3.8 INSIGHT BASED PARAMETRIC ANALYSIS

The third insight is an analysis based on parameters which is informed by insight. The parametric evaluation of envelope performance, glazing ratios, and the scenario of system efficiency was performed in Revit Insight to determine the possible ways to improve the energy-efficiency level.

### 3.9 RETROFIT SCENARIO DEVELOPMENT

Retrofit strategies were identified, based on the key energy drivers from the post-modification simulations, for each climatic zone. In Jaffna (dry zone), measures involved passive cooling (insulation, shading, glazing, and reduced air conditioning). In Galle (intermediate zone), strategies included reducing heat gain, improving ventilation, humidity control, and daylighting. In Nuwara Eliya (wet zone), measures targeted daylight and lighting efficiency. These were modelled and evaluated with the primary performance indicator being Energy Use Intensity (EUI).

### 3.10 MODEL ASSUMPTIONS AND VALIDATION

The simulations were all performed using the standardized HVAC setpoints, lighting loads and infiltration assumptions. Field observations were used to obtain occupancy schedules. Since the reliable historical utility data were not available, the formal calibration was not realized; consequently, the results are uncalibrated but internally consistent comparative simulations. This research assesses operational energy performance using simulation-derived Energy Use Intensity (EUI), which is the predominant energy demand during building operation, especially in tropical regions. Embodied energy (materials and construction) is not considered due to lack of detailed life-cycle information. Thus, the results represent operational energy performance only. In spite of these shortcomings, the managed simulation platform offers a strong foundation on the analysis of adaptive reuse measures under climatic condition.

## 4. RESULTS AND DISCUSSION

### 4.1 RELIABILITY OF SIMULATION OUTPUTS

Autodesk Revit 2025 using Insight workflow based on Energy Plus simulation engine was used to simulate energy performance (Deepa et al., 2008). Just like in any model-driven method, the sensitivity of predicted values is related to assumptions on occupancy schedules, equipment/lighting power densities, HVAC operation, material thermal properties and choice of weather file. Thus, the values of EUI in the reports are to be understood as more comparative performance trends between stages and climatic regions instead of precise metered consumption. The results represent operational energy performance, not including embodied energy.

### 4.2 PRE AND POST MODIFICATION ENERGY PERFORMANCE

The simulated energy performance was conducted using Autodesk Revit 2025 with Insight to evaluate the impact of adaptive reuse in three climatic regions in Sri Lanka (Dry Zone (Jaffna), Intermediate Zone (Galle) and Wet Zone (Nuwara Eliya). Energy Use Intensity (EUI) and annual energy consumption were taken as the key measures to compare pre-modification, post-modification, and optimised retrofit situations. Table 5 gives the simulated energy variables of the three case studies. It was noted that all buildings had a significant rise in the operational energy intensity following the reuse, primarily through the addition of mechanical cooling and additional lighting load related to compartmentalization of the building interiors.

*Table 5 : Simulated energy performance indicators for pre- and post-modification phases.*

| Parameter | A1-Pre | A2-Post | B1-Pre | B2-Post | C1-Pre | C2-Post |
|---|---|---|---|---|---|---|
| EUI (kWh/m²·yr) | 29.96 | 78.24 | 28.87 | 67.72 | 22.90 | 39.83 |
| Total energy (kWh/yr) | 2,746.8 | 7,170.3 | 7,123.5 | 16,716.2 | 22,131.0 | 38,492.1 |

| Parameter | A1-Pre | A2-Post | B1-Pre | B2-Post | C1-Pre | C2-Post |
|---|---|---|---|---|---|---|
| Cooling (kWh/yr) | 0 | 4,536 | 0 | 5,389 | 0 | 5,389 |
| Lighting (kWh/yr) | 0 | 2,628 | 0 | 3,285 | 0 | 10,368 |

## 4.3 Comparative EUI Trends Across Climatic Zones

The changes in EUI are underscored in the Figure 5. The dry zone restaurant (A) showed the greatest growth (+161%), then intermediate zone (B, +135%) and the wet zone (C, +74%). This ranking (Dry > Intermediate > Wet) reflects high sensitivity in climatic conditions of the adaptive reuse outcome under the assumptions of design and operation used.

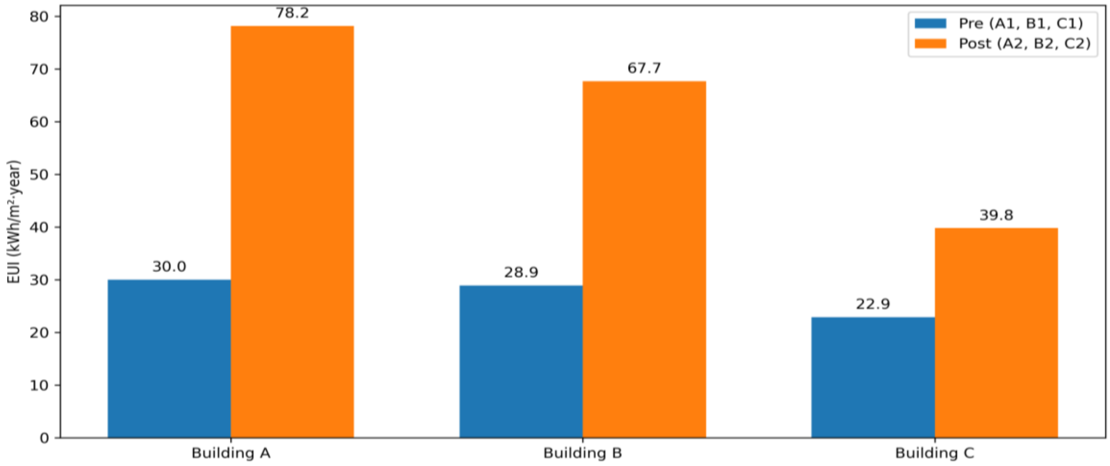


*Figure 5 : Energy use intensity of pre and post phases of selected building*

## 4.4 Cause and Effect Interpretation

In the three buildings, the most prevalent sources of greater post-reuse EUI included: (1) internal gains in functional transformation (e.g. residence to restaurant/ museum) reduced cross-ventilation and access to daylight; (2) material replacement by lightweight partitions and high thermal-mass envelope, which decreased thermal mass effect and increased peak cooling demand. Other heritage-building studies have also recorded similar function-based increases in energy demand following reuse as mechanical systems are added and greater service expectations are imposed that increase the operational loads(Alasmar et al., 2024). De Silva (2019), who have found that in arid tropical areas, heritage buildings are converted into more energy-intensive structures when the old passive systems are substituted with lightweight materials. Sealed exhibit spaces could also enhance the cooling and dehumidification dependency in warm-humid environments(Thirukumaran et al., 2024). In cooler and highland conditions, daylight is limited so lighting may be the primary end-use, and daylight strategy and controls are particularly significant. It contributes to Ruparathna et al. (2016) who found out that lighting is a dominant end-use in high-altitude heritage buildings where thermal loads are low. Its better roof insulation and concrete column support. however, enhanced the heat loss and the envelope life of wet climatic conditions.

## 4.5 EFFECT OF PROPOSED RETROFITS (SIMULATION GUIDED IMPROVEMENTS)

Climate-responsive retrofit packages were modelled to test energy reduction pathways that were compatible with heritage character. Table 5 and Table 6 is a summary of the proposed EUI results and the fall as compared to the post-modification scenario. The greatest absolute change is the dry zone with passive cooling restoration, shading, and glazing improvements, which decrease EUI of 78.24 to approximately 42.5 kWh/m$^2$yr (or 45% change). The middle zone is the most successful in receiving the benefits of the ventilation-related humidity control and daylight enhancements (67.72 to the approximate of 38.5 kWh/m$^2$yr, or 43 %). The wet zone records moderately but significantly with the help of the measures of daylight and lighting efficiency (39.83 to approximately 30.5 kWh/m$^2$yr, 25 %).

*Table 6 : Recommended altered EUI values of selected buildings*

| Parameter | Building A (Jaffna) | | | Building B (Galle) | | | Building C (Nuwara Eliya) | | |
|---|---|---|---|---|---|---|---|---|---|
| | *A1* | *A2* | *A3* | *B1* | *B2* | *B3* | *C1* | *C2* | *C3* |
| Cooling Energy (kWh/year) | 0 | 4536 | 1800 | 0 | 5389 | 2000 – 2500 | 0 | 5389 | 4000 |
| Lighting Energy (kWh/year) | 0 | 2628 | 1000 | 0 | 3285 | 1200 – 1500 | 0 | 10368 | 4000–5000 |
| Total Energy (kWh/year) | 2746.8 | 7170.3 | 3200 – 3800 | 7123.5 | 16716.2 | 8500 – 9500 | 22131 | 38492.1 | 19000 – 22000 |
| EUI (kWh/m²·year) | 29.96 | 78.24 | 42.5 | 28.87 | 67.72 | 38.5 | 22.90 | 39.83 | 30.5 |
| Peak Cooling Load (kW) | 5.04 | 7.79 | 5.0–5.8 | 13.58 | 13.58 | 11–12 | 23.41 | 23.41 | 18–19.5 |

In order to read the difference in energy performance more well, the below Table 7 summarizes the difference between (ΔEUI) and percentage change between the pre- and post and the proposed modification phases. It also determines the main force that affects change of every climatic setting.

*Table 7 : Comparison of Energy Use Intensity (EUI) before and after proposed modifications*

| Building/Zone | EUI Pre | EUI Post | EUI Proposed | Key retrofit focus | Δ vs Post |
|---|---|---|---|---|---|
| A – Jaffna (Dry) | 29.96 | 78.24 | 42.5 | Shading + roof insulation; reduce A/C reliance; fans; low-E glazing | ↓45% |
| B – Galle (Intermediate | 28.87 | 67.72 | 38.5 | Restore cross-ventilation; humidity-aware operation; daylight + sensors | ↓43% |

| Building/Zone | EUI Pre | EUI Post | EUI Proposed | Key retrofit focus | Δ vs Post |
|---|---|---|---|---|---|
| C – Nuwara Eliya (Wet) | 22.90 | 39.83 | 30.5 | Daylight recovery (translucent partitions); LED + daylight dimming; glazing | ↓24% |

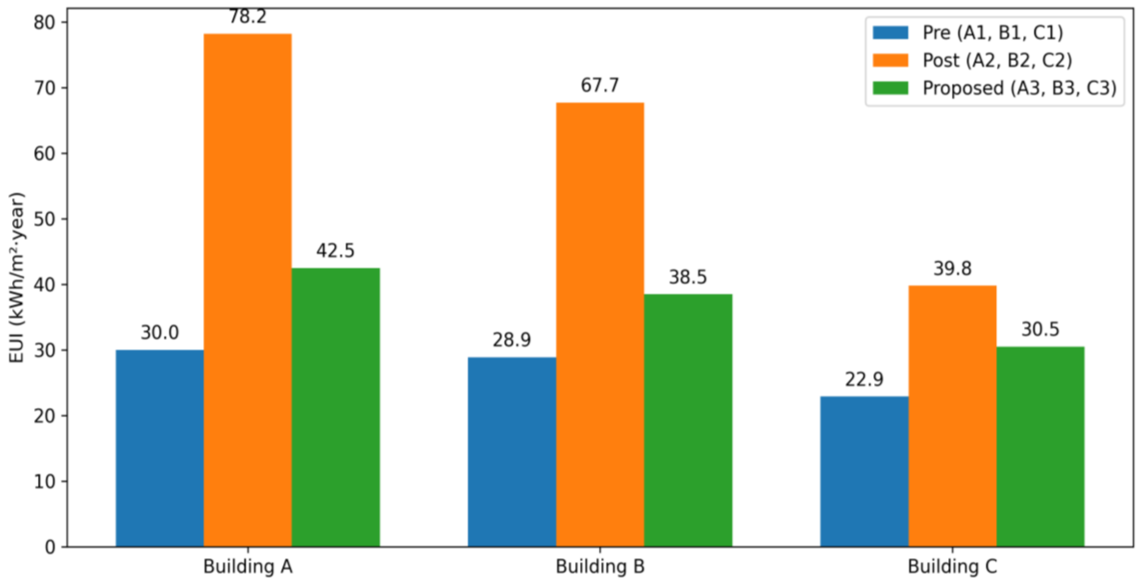


*Figure 6 : EUI of pre, post and alternative phases of selected buildings after implementing proposed modifications*

## 5. CONCLUSIONS

The current study assessed the energy performance of the adaptive reuse in three historic buildings located in three different climates of Sri Lanka (in the dry zone (Rusichatti Restaurant, Jaffna), in the intermediate zone (National Galle Fort Museum, Galle), and in the wet zone (Nuwara Eliya Post Office, Nuwara Eliya)) through the deployment of the Autodesk Revit Insight 2025 simulations. The results confirm the idea that the adaptive reuse changes significantly the energy performance due to the building envelope, spatial organization, and functional purpose alteration.

In all cases, Energy Use Intensity (EUI) rose after adaptation, and this showed that reuse does not in itself necessarily result in efficient operation. The example of the dry-zone was the most excessive with the reduction of 29.96 to 78.24 kWh/m²·year (+161%), due to the loss of thermal mass and cross-ventilation and the introduction of mechanical air-conditioning. Intermediate-zone museum showed an increase of 28.87 to 67.72 kWh/m²·year (67.72%) with the biggest increase recorded on the enclosure of exhibition spaces and the increased demand due to lighting. The wet-zone office grew by 22.90 to 39.83 kWh/m²·year (74%), which was primarily due to a decrease in daylight penetration and the reliance on artificial lighting. There was also a clear hierarchy of climatic conditions: Dry > Intermediate > Wet, which supported climatic conditions as the key factor of post-reuse performance.

Retrofit simulations showed that there was a lot of recuperative potential. EUI fell in Jaffna, down to 42.5 kWh/m²·year ( -50%), 78.24. In Galle, it dropped to 67.72 to 38.5 kWh/m²·year (-43%). Daylight-responsive interventions in Nuwara Eliya reduced EUI by 39.83 to 30.5 kWh/m²·year (-24%). These findings indicate that climate-sensitive retrofits can also significantly reduce the penalties of operations, as well as retain heritage integrity. It highlights the significance of protecting passive architecture components, such as thermal mass, shaded verandahs, courtyards, and natural ventilation as of the fact that their interference directly increases cooling and lighting loads. Functioning together with specific efficiency improvements, adaptive reuse can create a quantifiable environmental value. The Insight workflow enabled a comparative analysis of the pre and post intervention situations and retrofit options in a systematic way allowing to provide a structured decision-support framework to buildings undergoing adaptive-reuse.

Taken together, the adaptive reuse projects in Sri Lanka are to be approached as the challenges of the climate-responsive performance. Green benefits would only occur when the legacy of passive systems is honored and supported by simulation-based design and thus the historic buildings would provide a significant contribution to the low-carbon development.

### 5.1 PRACTICAL AND THEORETICAL IMPLICATIONS

This study demonstrates that adaptive reuse can raise operational energy demand without climate-sensitive strategies. Practically, it identifies the need to retain passive elements and consider climate-specific retrofit strategies to enhance energy efficiency. Theoretically, it challenges the assumption that adaptive reuse inherently improves energy efficiency, clarifies the difference between embodied energy benefits and operational performance, and offers a BIM-driven comparative framework for assessment across climatic zones.

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