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Adaptive Reuse and Energy Performance: Case Study of *Newa Chhen*

Sajina Shrestha [a], Sanjaya Uprety [b]

[a, b] *Department of Architecture, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
✉ [a] sajina.762541@puc.tu.edu.np, [b] suprety@ioe.edu.np

Abstract

Adaptive reuse in traditional buildings is gradually growing all over the world. To conserve the heritage, architectural values, socio-cultural, and economic aspects, repurposing old buildings is widely adopted in Nepal. Research and studies are found in the repurposing of traditional buildings, but merely in the context of energy performance. This research investigated the energy performance of a typical historical building subjected to adaptive reuse. A pilot case study was carried out on Newa Chhen, a traditional building, to understand the energy performance of the building. This building was used as a residence and was converted into a bed and breakfast after renovation. Energy modeling using Autodesk Ecotect, 2011 was performed to study the change in energy demand. Necessary data and information were collected from interviews, field visits, available diagrams, and literature. The analysis showed that the heating and cooling loads increased by 36% and 11% after adaptive reuse, respectively. Alternatives for optimization of the demands were also studied by intervening in the fenestration only due to limitations of preserving the exterior façade in its original form. The single-glazed window was first replaced by a double-glazed and then by a double-glazed LowE with the wooden window frame. The results showed that the heating load and cooling load is reduced by 25% and 10%, respectively, in the former option, whereas the heating load and cooling load is reduced by 31% and 15% for the latter. The research concludes that altering the window material can have a considerable effect on energy performance of traditional building.

Keywords

Traditional Buildings, Adaptive Reuse, Building Materials, Energy Performance

1. Introduction

Most historic structures are often considered essential assets for regional tourism growth because of their socio-cultural and heritage values. A growing awareness that it is less expensive and time-saving to convert and re-purpose old buildings to newer functions compared to dismantling and reconstructing has promoted widespread interest in adaptive reuse. Adaptive reuse, also known as building reuse, in architecture is a process of re-purposing an existing structure to serve new functions by retaining the original features and extending its useful life [1].

In the context of Nepal, mainly in Kathmandu valley, adaptive reuse is found in both the traditional old and modern contemporary buildings. Boutique hotels, bed-and-breakfasts, living museums, boutiques, and even individual residences have been converted from conventional houses. Among the practices discovered are *Swotha, Heranya-laya, and Babar Mahal Revisited*. Large historic buildings and palaces are repurposed into government offices, security bases, prisons, hotels, and museums [2].

Adapting historic buildings has a subsequent impact on their energy performance. Adaptive reuse should be adopted through minimal intervention in exterior façades to preserve historical significance. When adapting historic buildings for reuse, energy efficiency is often not considered due to lack of foresight and because energy efficiency opportunities may conflict with their maintenance. It is challenging to investigate historic buildings for energy efficiency with the limited availability of resources and constraints. Optimizing the heating and cooling demands after the adaptive reuse in buildings with specific rigid principles and the limitation of alterations is a major challenge in the research [3].

The main objective of this research is to study the energy performance of an old traditional building after adaptive reuse in terms of heating and cooling load through simulation. Case scenarios are also developed as optimization options by intervening in the fenestration to study their effect on energy performance. Exterior envelope is not altered due to limitations of the façade of the traditional buildings should be preserved in its original form. This research is performed for temperate climate in Lalitpur district using Ecotect software.

2. Study Method

This research was based on the pragmatic paradigm to investigate the energy performance in a traditional building subjected to adaptive reuse. A research problem solution explained by pragmatism involves concepts, methods, approaches, principles, or a combination of these [4].

This research followed the mixed method along with the single case study as it best fitted to obtain the research objective. Available works of literature were explored and reviewed analytically to investigate the building's adaptive reuse and energy performance through a case study. This included studying the available diagrams and photographs. The climatic data were collected from available sources, and the field data was collected using instrument.

In the case study, the as-is condition of the building, considering its current use of materials and space arrangement, was referred to as the base case scenario. As the exterior facade intervention was not appropriate, alteration of fenestration options was analyzed to observe the change in energy demand. The required information on material, quantity, and type of electrical appliances were obtained by interviewing the owner and an expert involved in the renovation work. A field survey was also performed to visually verify the information collected.

Energy modeling with a simulation tool was performed on the case study building based on quantitative and observable analyses. First, a simulation was performed for the originally built building. Further, case scenarios were created for the building after adaptive reuse as follows:

- Case 1- The case building was simulated for its present use in this case.
- Case 2- Simulation was performed by altering the fenestration of Case 1 with double glazing.
- Case 3- Simulation was performed for double glazing with lowE-coating.

3. Literature Review

3.1 Evolution of Adaptive Reuse

1977: Two international symposia; 'Old into New' held in Glasgow and 'Old and New Architecture: Design Relationship,' held in Washington DC which led to publications that set the foundation for the emergence of a new discipline. [5].

1976: Radolfo Machado published a moment defined a text, 'Architecture as Palimpsest' where Machado transcended the 'internal conflict' between restoration and anti-restoration movement. [5].

In the 1960s – 1970s: Carlo Scarpa in Italy, Raphael Moneo in Spain, and Sverre Fhen in Norway began to work with historic buildings, which was reflected in conservation and restoration theory along with its publication. [5].

1964: "Adaptive reuse' was introduced as a form of 'conservation' practice and was defined as "the conservation of monuments is facilitated by making use of them for some socially useful purpose." [5]
The 1960s: Several architects and design theorists began to show increasing interest in working with historic buildings. [5].

1933: The fourth Congrès Internationaux d'Architecture Moderne (CIAM) congress analyzed and decided the historic buildings should only be preserved under certain quite specific conditions and were to be termed as 'isolated monuments', which further developed the issue towards 'scientific restoration' and 'value-assessment.' [5]

1931: The influence of Boito on Italian and International conservation served as a key factor in the adaptation of the Athens Charter [5].

Until the 19th century, the heritage notion was considered antique and medieval buildings. But due to the destruction by the world war, awareness of the value of historic buildings and interest in their preservation increased. Conservationists started considering vernacular architecture, industrial buildings, and historic cities, and the idea of "conserving" rapidly expanded. [5]

3.2 Traditional Newari Building

Ground Floor *(Chhidi)*: The traditional building usually is faced toward the street space used for shops and workshops. Another face of a building toward the courtyard is space used for drying crops, storage, and other cultural purposes. The ground floor is used for storage, so small windows are provided. Wooden narrow stair connects floor to floor in the house [6].

First Floor *(Matan)*: The first floor is used for bedrooms, and room sizes are divided according to building size. The central wall is further divided to create the bedroom with a solid partition [6].

Second Floor *(Chota)*: The second floor is used as a living space for visitors and families. The thick central wall is replaced by a wooden post. A large window (sa jhya) is provided in the walls for natural light [6].

Attic Space *(Baiga)*: The attic space is used for kitchen space and the puja room, which prefers the top floor. The house has no chimney stack but a Bhaupa, a hole in a roof covered by the curved terracotta terminal that lets the smoke out and obstructs rain [6].

Material used: Wood and clay are used as building materials. Locally produced tiles, and in some cases straw thatches, are used as roofing. Brick with mud mortar is used for walls, and wood is used for opening and flooring [6].

3.3 Principles and Policies

Article 10 of the Venice Charter states that modern conservation and construction techniques that have been shown to be effective based on scientific findings and experience may be used to enhance a structure if conventional methods are deemed to be insufficient. Reconstruction, as defined by the Burra Charter, is the process of returning to a known earlier state without adding any new components by combining or removing existing elements. According to Article 22 of the 2004-published Burra Charter, new work should be immediately recognizable as such but must respect and have little impact on the cultural significance of the location. The Declaration on Dresden states that reconstruction should only be done in rare circumstances to protect historically significant structures. [7]

Conservation of Historic Buildings: Conservation should be performed with minimal intervention in the historical evidence to preserve the original identity to the best possible. The current generation must look after and preserve the heritage rather than only modernize the world. [8]

Conservation Guidelines: The classified heritages under the jurisdiction of the department are defined by the Ancient Monument Preservation Act, 1963. This act recommends to adopt the traditional construction materials, technologies, and techniques and consider the participation of local people while reconstructing or renovating the heritage sites. [9]

Cultural Heritage and Energy: The International Council on Monuments and Sites (ICOMOS) established the International Specialist Committee on Energy and Sustainability (ISCES) to address environmental and climate concerns by balancing energy needs and cultural needs. ICOMOS aims to inject vitality and sustainability into the conversation around cultural heritage.

3.4 Building Physics

Thermal Properties: Thermal capacity and resistance exist in varying degrees in all building materials. These attributes are affected by three factors; density, conductivity, and specific heat. [10].

U-Value: To optimize energy use, it is important to study heat loss. The heat loss from the building components per unit area can be determined using the heat transfer coefficient (U). Indoor comfort is characterized by this U-value by establishing its maximum value for different materials [11].The heat transfer can be calculated using the equation:

$$Q = U \cdot A \cdot (T_i - T_o) \tag{1}$$

Where, Q= Heat transfer (W), U= U-Value (W/m^2K), $A = Area(m^2)$, T_i= Inside Temperature (K), T_o=Outside Temperature (K).

3.5 Building Envelope

The building envelope, which is in direct contact with the external environment, is used for lighting, cooling, heating, and ventilation. Therefore, it is an important factor for energy measurements and defined as the “interface of energy losses” [12].

Fenestration: One of the most vulnerable thermal control points inside of buildings is window glazing.

The windows account for 10–20% of the total heat loss in a typical home [11].

3.6 Energy Performance

According to the World Energy Council energy efficiency refers to “a reduction in the energy used for a given energy service (heating, lighting, etc.) or level of activity”. Energy efficiency has been identified as an approach to address challenges including energy security, the social and economic effects of high energy prices, and worries about climate change. Additionally, research has shown that energy efficiency is economical and promotes corporate competitiveness. The majority of the total electricity used by all types of buildings is used for lighting [13]. [14] concluded that the old traditional buildings are 1°C to 2°C warmer in winter and 1°C to 2°C cooler in summer as compared to the modern residences. Also, energy savings of minimum of 10-20% are obtained in traditional buildings in Kathmandu.

4. Case Study

4.1 Location

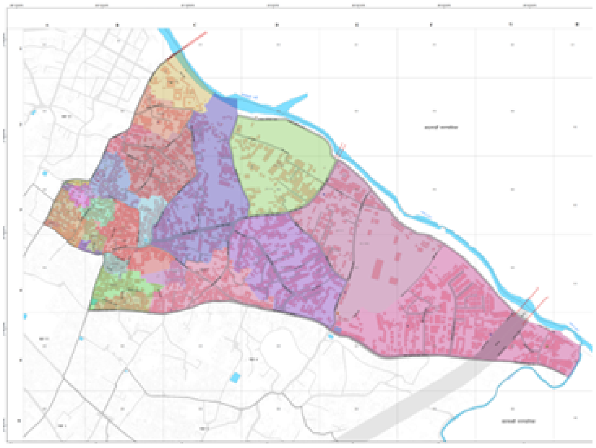

Figure 1: Map of Lalitpur Metropolitan Ward no. 9

One of the world’s oldest Buddhist cities dating to the 16th century, Patan is located in the Lalitpur district. On the road to *Bangalamukhi*, at a historic site known as *Swotha*, the proposed building, *Newa Chhen*, is situated in the centre of the medieval city of Patan Durbar Square, a UNESCO World Heritage Site in Lalitpur Metropolitan Ward No. 9.

4.2 Bioclimatic Chart

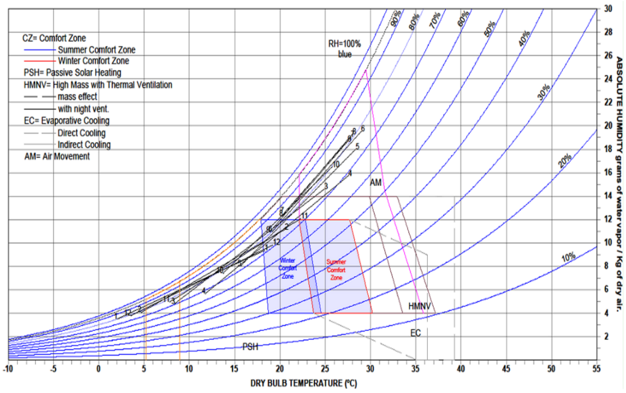

Figure 2: Bioclimatic chart for Lalitpur

The monthly data for the highest mean temperature with humidity in the evening and the lowest mean temperature with humidity in the morning is plotted on the Szokolay bioclimatic chart. The hottest month are from May to September whereas the coldest three months are December through February, with nighttime lows of 5 degrees Celsius. When passive techniques are unable to meet the need for heating during this time, conventional heating is required to maintain the desired temperature in the room.

4.3 Historical Background of Building

As part of a partnership with the Patan tourism board, the UNESCO world heritage centre funded *Newa Chhen’s* rehabilitation work in the late 1990s with the goal of bringing it back to its former glory from the 17th century while also adding contemporary conveniences for accommodation. The “Shrestha house pilot project” was the formal name of the renovations [15].

4.4 Building Description

Figure 3: View of the *Newa Chhen* Building

Before the adaptive reuse, the *Newa Chhen* building was used for residential cum commercial purposes. The front facade is facing the street and the rear facade is facing the courtyard. The floor height of all building floors is 6 ft 11 inches, the same as before adaptive reuse. There are 44 windows of height 3 ft 6 inches and widths ranging from 1 ft 3 inches to 11 ft.

Ground Floor: Before adaptive reuse: Street-facing space was used as shops, storing and animal shelters. After adaptive reuse: Street-facing space is used as cafe, reception, kitchen, and store.

Figure 4: Ground floor before adaptive reuse

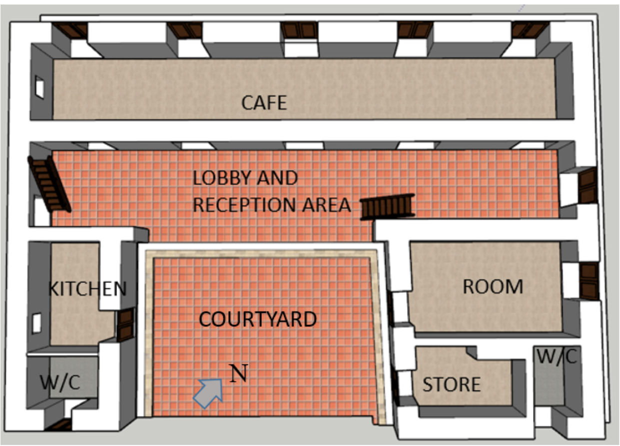

Figure 5: Ground floor after adaptive reuse

First Floor: Before adaptive reuse: Used as bedrooms, *dhukuti*, and open hall.
After adaptive reuse: Used as guest room with attached bath and sitting area.

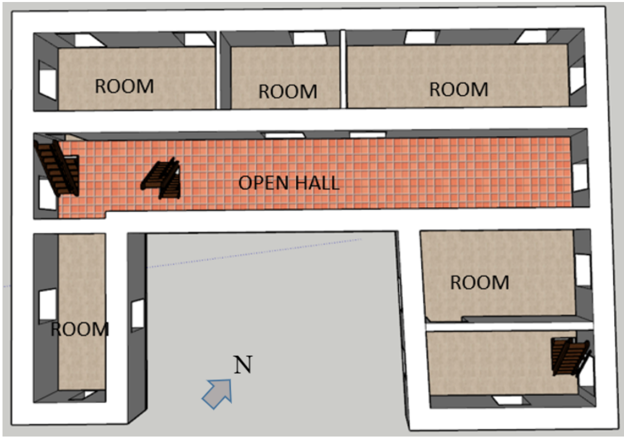

Figure 6: First floor before adaptive reuse

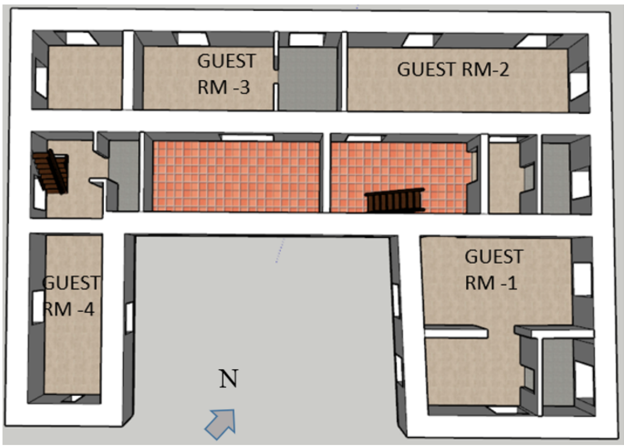

Figure 7: First floor after adaptive reuse

Second Floor: Before adaptive reuse: Used as bedrooms and living hall.
After adaptive reuse: Bedroom layout is modified, attached bath are provided for each bedroom, flooring with modern materials; slate and tiles.

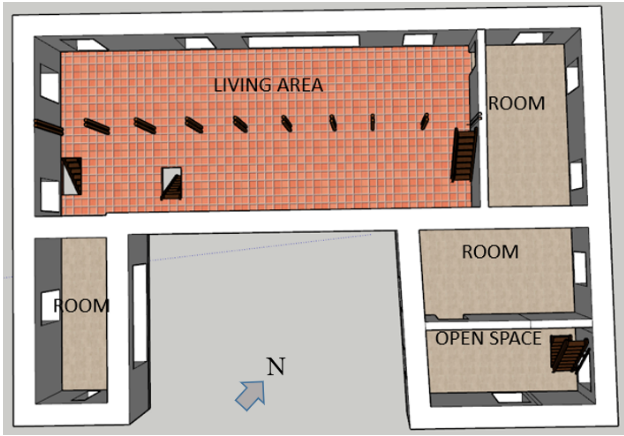

Figure 8: Second floor before adaptive reuse

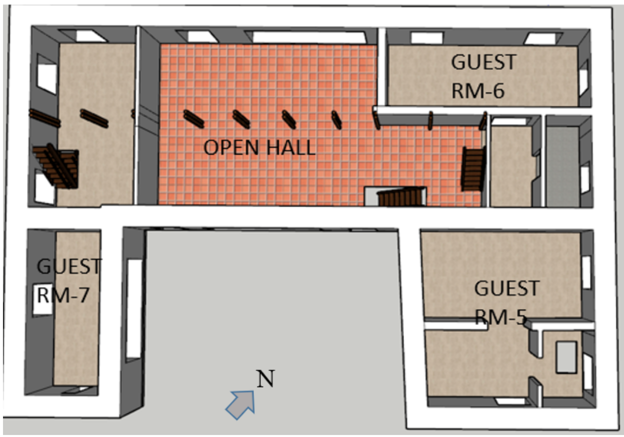

Figure 9: Second floor after adaptive reuse

Attic: Before adaptive reuse: Used as kitchen and *puja* space. After adaptive reuse: Converted to meditation area and guest room.

4.5 Data Collection

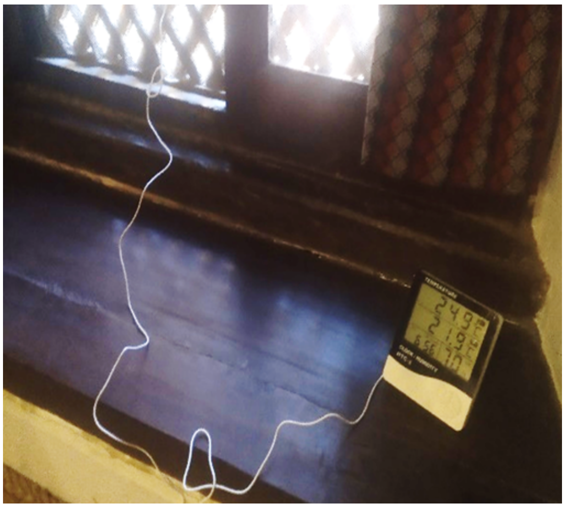

Figure 10: Hygro-thermometer setup

The hygro-thermometer was used to measure the indoor and outdoor temperature of the building. The temperature is measured on the first floor of the building for ten days, starting from the 20th of June 2022 to the 29th of June 2022.

4.6 Electricity used by Lights and Appliances

After considering the lighting and other electrical devices used in the building, the electricity consumption is calculated for the old building and the existing building. The annual electrical loads are obtained as; before adaptive reuse: 1879.2 kWh, and after adaptive reuse: 9640.08 kWh.

5. Simulation

5.1 Autodesk® Ecotect® Modeling

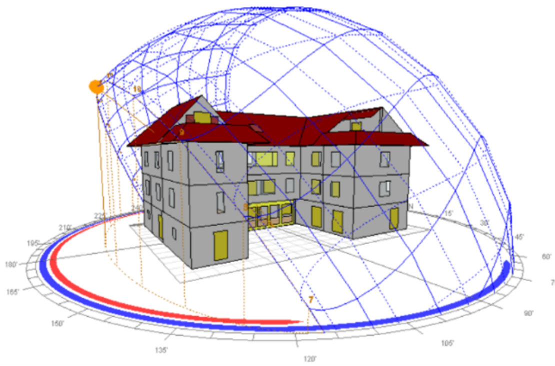

Figure 11: 3D-Model in Autodesk® Ecotect®

A thorough preliminary building energy performance analysis is carried out using the energy simulation Autodesk® Ecotect® Analysis 2011. The accuracy of Ecotect simulations has been shown in numerous investigations. To ensure the accuracy of the results, Ecotect was used to simulate the heating and cooling loads during the operational stage of the building under its defined geometry, material properties, and regional weather conditions. This is because the operational stage is typically significant in terms of energy consumption [16].

The building was modeled using Autodesk® Ecotect® v11.0. In the model, the comfort band given by neutrality temperature from the bioclimatic chart is set as 18°C to 26°C. The operation hour is set as it is being used as actual with different operation times for different zone in the building. The function of the room as per actual is referred to set the type of activity for each of the rooms in the model. The activity of occupants is assigned as sedentary in all zones as the activity affects the heat generated by the people. Other settings in the model are humidity: 60%; airspeed: 0.5 m/s (i.e. pleasant breeze); air change rate: 0.5 ACH (i.e. well-sealed); and clothing: 1 CLO. Furnitures inside the buildings are not considered in the model.

5.2 Building Materials

Table 1 shows the materials and thickness of the wall, floor and roof of the originally built building (before adaptive reuse). The building materials used during renovation are summarized in Table 2.

Table 1: Materials used before adaptive reuse

Building Component	t (mm)	U-Value (W/m^{2}K)	Materials	t (mm)
GF Walls				
External	500	1.16	BB	110
			MB	365
			MP	25
Internal	500	1.14	MP	25
			MB	450
			MP	25
FF Walls				
External	400	1.37	BB	110
			MB	265
			MP	25
Internal	500	1.14	MP	25
			MB	450
			MP	25
SF/Attic				
External	400	1.37	BB	110
			MB	265
			MP	25
Partition	225	1.97	MP	25
			MB	175
			MP	25
Floors	195	1.57	M	75
			WP	20
			WJ	100
Roof	180	1.86	BCT	10
			M	50
			WP	20
			WJ	100

GF=Ground Floor, FF=First Floor, SF=Second Floor, BB=Burnt Brick, MB=Mud Brick, MP=Mud Phuska, WP=Wooden Plank, WJ=Wooden Joist, M=Mud

6. Results and Discussion

6.1 Original vs Existing Building

Heating Loads: The energy demand for heating the old building is maximum in the month of January, which is 2629.15 kWh. After adaptive reuse, this demand increased for the month to 3483.64 kWh. The total heating load is increased after the adaptive reuse by 36%.

Table 2: Materials used after adaptive reuse

Building Component	t (mm)	U-Value (W/m^{2}K)	Materials	t (mm)
GF Walls				
External	500	1.15	BB	475
			CLP	25
Internal	500	1.15	BB	475
			CLP	25
FF Walls				
External	400	1.37	BB	110
			MB	265
			MP	25
Internal	500	1.14	MP	25
			MB	450
			MP	25
SF/Attic				
External	400	1.37	BB	110
			MB	265
			CLP	25
Partition	125	2.87	MP	75
			WP	20
			WJ	100
Floors GR	195	1.57	M	75
			WP	20
			WJ	100
Floors BL	180	1.96	BCT	75
			CS	50
			WP	20
			WJ	100
Roof	180	1.86	BCT	10
			M	50
			WP	20
			WJ	100

GF=Ground Floor, FF=First Floor, SF=Second Floor, GR=Guest Room, BL= Bathroom and Lobby, BB=Burnt Brick, CLP=Cement/Lime Plaster, MB=Mud Brick, MP=Mud Phuska, BCT=Burnt Clay Tile, CS=Cement Screed, WP=Wooden Plank, WJ=Wooden Joist, M=Mud

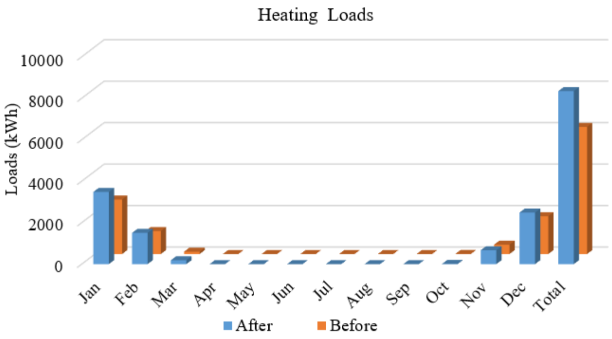

Figure 12: Comparison of heating loads

Cooling Loads: The results show that the cooling load before the adaptive reuse is maximum in May.

The analysis for the building in its existing current state has a cooling demand of a maximum of 2401.48 kWh in May. Overall, the cooling demand is increased by 10% after the building is reused.

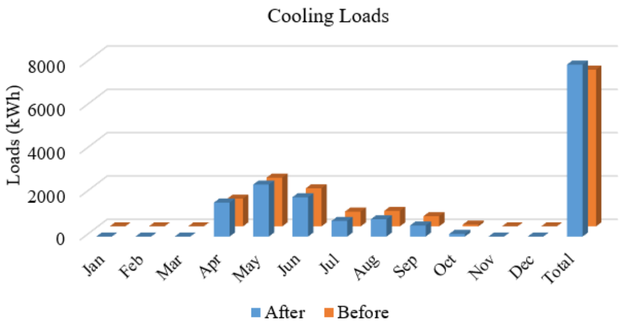

Figure 13: Comparison of cooling loads

6.2 Optimization Strategies

The single glazed, double glazed, and double low E with wooden framed window is used as Case1 (Base Case), Case 2, and Case 3, respectively. The result is compared and presented in the bar chart.

Heating Loads: The demand is maximum in January for all the cases. Overall, the total heating demand for the existing building (Case 1) is found to be maximum, while Case 3 has the lowest heating demand in total. Heating load is reduced in case 2 and case 3 by 25% and 31%, respectively.

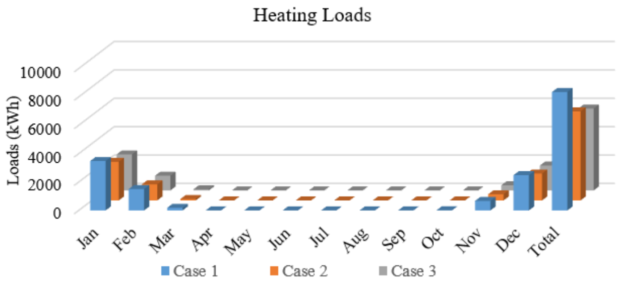

Figure 14: Comparison of heating loads

Cooling Loads: Similarly, the cooling demand is also found to be maximum for the Case 1 building in the month of May. In total, Case 1, Case 2, and Case 3 have a cooling demand of 7941.48 kWh, 7120.72 kWh, and 6756.68 kWh, respectively.

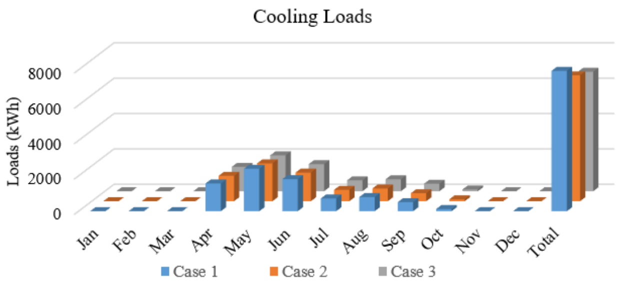

Figure 15: Comparison of cooling loads

7. Conclusion

The results showed that the heating load and cooling load was increased by 36% and 10%, respectively. When altering the window glazing in the existing building, the result showed that the heating load of a building was reduced by 25% when double glazed window was provided. The load was reduced by 31% when adopting double glazed lowE coat. Similarly, the cooling load was reduced by 9% and 13%, respectively. This comparison showed that in traditional buildings, altering the window material can have a considerable effect on energy performance.

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