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Sustainable Building Renovation: A Case of Hospital Buildings in Kathmandu

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Abstract

In Nepal, most of the existing hospitals were built with poor attention to climate, local materials and technology and energy concerns in planning stage, which result in intense use of mechanical devices for maintaining indoor thermal comfort.

In this research, the energy consumption status of two different types of hospital buildings in Kathmandu were studied thoroughly and possible Sustainable Building Renovation strategies were taken into consideration for improving the energy performance of building i.e., reducing the operational energy demand. Since the building envelope and lighting plays a vital role in energy consumption, they were mainly focused in this research for energy efficiency. During the study, a bioclimatic chart for Kathmandu was developed which shows thermal comfort range of 18°C - 28°C. The energy tool, Ecotect analysis 2011 was used for building energy simulation and heating and cooling loads were calculated in existing and intervention scenarios with the consideration of internal thermal comfort range. Two intervention scenarios were analyzed in the existing building i.e., adding extra 110 mm brick wall in the existing case to make cavity wall and adding EPS cement sandwich panel as insulation in the existing exterior walls. The EPS cement sandwich panel intervention was better option for renovation in existing buildings. With the use of EPS panel, the reduction of total annual heating and cooling load was found to be 26.74% and 47.02% and its simple payback period was found to be 26.5 years and 45.2 years in Kirtipur hospital and Tilganga Institute of Ophthalmology respectively.

For interior artificial lighting in the buildings, it was found that most of the lamps were used inefficient i.e., fluorescent tube light (FTL)of 40W. So FTL was replaced by T-8 LED tube lights of 20W with double of its efficiency and cost was calculated. Almost 50% cost could be saved in lighting only. The simple payback period of replacing lights was found to be 0.71 years and 1.03 years in Kirtipur hospital and Tilganga Institute of Ophthalmology respectively.

Keywords

Sustainable, Renovation, Energy, Thermal comfort, Building envelope, Lighting

1. Introduction

Buildings and constructions are the major driver of energy demand which consumes 36% of the final energy in the global context. The final energy demand of the global building sector energy consumption has increased by 5 EJ (from 120 EJ in 2010 to 125 EJ in 2016) due to less energy efficient technologies, where 82% of the final building energy was supplied by fossil fuels [1].

It is estimated that by 2056, global economic activity will have increased fivefold, global population will have increased by over 50%, global energy consumption will have increased nearly threefold and global manufacturing activity will have increased at least threefold. With respect to such significant influence of the building industry, the sustainable building approach has a high potential to make a valuable contribution to sustainable development [2]. There has been significant progress in recent years in improving the energy efficiency of new buildings, driven by technological improvements and various regulatory requirements and policy initiatives, and there is beginning to be a critical mass of very low energy buildings or even zero energy buildings in various regions of the world. However, a large percentage of existing buildings are significantly less efficient than most newly constructed buildings and have major opportunities for improvement. Also the energy efficiency improvements represented less than 10% of total global investment in buildings and construction[1]. Determining the most effective set of policies to significantly improve the existing building stock is a key challenge for energy policy makers around the world. Energy savings through the renovation of the existing building stock is one of the most attractive and low cost options to reduce the emissions of CO2 and improve the energy security.

2. Need and importance of research

In Nepal, various new smart cities are under planning stage with proper considerations of passive design strategies and renewable energy integration. So a big question is *'What should be done to the existing buildings?'* Even if all new buildings from today on were built to be net zero energy, it would take several decades for the change to have an appreciable effect on overall building energy consumption. So there should also be significant considerations in the existing buildings for improving energy efficiency and sustainability.

Existing hospital buildings are designed without consideration of local climate and proper passive design strategies. So they rely on energy intensive mechanical means for heating and cooling spaces in order to maintain thermal indoor comfort. Therefore, sustainable building renovation of existing buildings is required to improve energy performance which helps to reduce operational energy demand of the buildings and consequently reduces national energy demand. The building materials used in buildings are of poor thermal properties which cannot resist the temperature of the local climate resulting in almost no temperature difference between outside and inside. As hospitals deal with the health of people, the indoor comfort is must i.e., indoor air quality, thermal comfort, acoustic comfort and visual comfort in order to heal the patients quickly and increase the efficiency of staffs as well. The operational and maintenance cost of the building is decreased after sustainable renovation which can give cost benefit to the organization team, staffs and patients.

This research has not been done yet in Nepal, so the results from this research would be fruitful not only to the hospital buildings in Kathmandu, but also to other purpose buildings, designers and policy makers.

3. Research Objective

The main objective of the research is:

- To determine the possibilities of Sustainable Building Renovation strategies for improving the energy performance in the existing hospital buildings in Kathmandu.

The specific objectives of the research are:

- To find and analyze the electricity consumption data of the existing hospital building.
- To analyze interventions under passive design strategies for improving energy performance focusing on the envelope of the building.
- To do the financial analysis of the interventions.

4. Literature Review

The improvement of energy performance in buildings in a global concerns and governments around the world have taken strong measures towards the retrofit of existing buildings in terms of improving energy performance. The most significant benefits of energy consumption assessment were the improvement of envelope thermal insulation, lighting and glazing. As for thermal envelopes, they include outer walls, roof, foundation, windows and doors [3]. The purpose of the thermal envelope is to prevent heat transfer from interior of a building to its exterior environment in winter and vice versa in summer. Building envelope are responsible for over 60% of heat losses in conventional building and there is a great heat flux reduction potential by incorporating additional insulation to building envelopes[4].

The ultimate goal of passive design is to eliminate the need for any active mechanical systems to maintain occupant comfort, though this is not a realistic goal for most commercial building projects. They give best result in new building design but they can play important role during retrofits of existing buildings but may be more challenging. Each renovation that follows a passive design approach offers an opportunity to optimize the interaction of buildings and their local microclimates, taking advantage of energy efficiency opportunities for relatively low cost. Through the use of passive solutions it is possible to reduce the use of mechanical systems and the energy demand by 70% in moderate climate [5].

In moderate climate, large window areas facing south with a WWR between 40% and 60% are most suitable to balance solar control and solar gain. However, an overhang or flexible shading system should be provided to reduce the risk of overheating. Any fenestration areas facing north, east and west should be kept small (WWR 10–20%)[5].

5. Research Methodology

The methodological approach that was used in my research was on the basis of 'Post Positivism' paradigm as both quantitative and qualitative research was done. The case study approach was used in the research. Various methods such as semi-structured interviews, questionnaire, observations and measurements of buildings' physical dimensions were recorded of the selected cases. Notes and photographs of the permissible areas were only taken. The data were collected through walkthrough energy audit and load measurement using multi-meter from all electrical distribution boards installed in the buildings. The building related energy calculations were done from the collected data and architectural building drawings provided by the respective personnel. The climatic data from nearer stations were collected and developed a bioclimatic chart for the case area in order to get the basic ideas of passive solar design strategies in the context. The building models of cases were developed in the energy software called Ecotect Analysis 2011. The collected climatic data was input in the energy tool for getting the idea of operational energy status for maintaining thermal comfort level inside the building. Different possible interventions were done and simulations were done accordingly for reduction of operational energy costs for maintaining thermal comfort i.e., heating and cooling loads throughout a year. Finally, solutions and recommendations were made for reducing energy consumption in building operational phase in the existing building and possible use of passive design strategies.

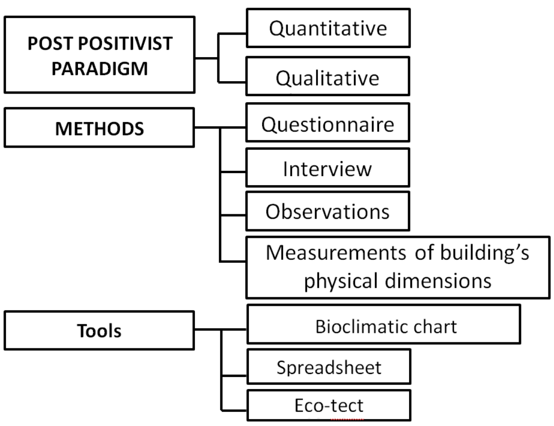

Figure 1: Research methodology chart

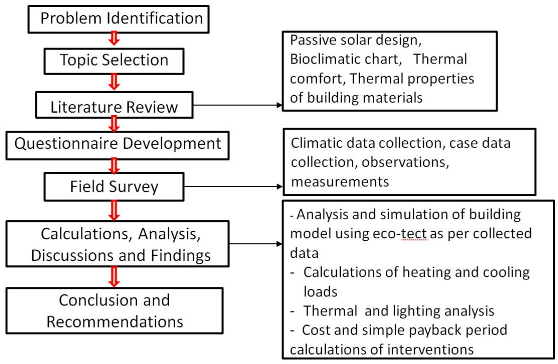

Figure 2: Research methodology chart

6. Study Limitation

The limitations of the research are as following:

- Only two different types of hospitals of Kathmandu were studied thoroughly.
- The energy data of case areas were collected for 4 days of duration only in the month of Poush. The operating hours of electrical equipment were recorded by asking the concerned personnel of the building.
- Energy related to building envelope and artificial lighting were only taken into consideration.
- The thermal calculations were done only on eco-tect.
- Indoor air quality and indoor and outdoor temperature of case areas were not considered in this study.

7. Research Case Area

There has been a global concern about the energy use (mainly fossil fuels) and its negative impact in the environment like GHG emissions from the health sector. So the global organization was formed named Global Green and Healthy Hospitals (GGHH). GGHH is a worldwide network of hospitals; health systems and health organizations committed to reducing the health sector's environmental footprint and advocating for policies that promote environmental and public health. The main agenda of GGHH is *to promote greater sustainability and environmental health in the health sector and thereby to strengthen health systems globally*[6]. GGHH has set 10 interconnected goals which include energy and buildings, so the research is mandatory. These goals are properly linked with sustainable development goals.

There are few hospitals in Kathmandu which are enlisted as a member of GGHH organization. For case study, the hospitals with GGHH membership were proposed to be selected as per the classification on basis of objectives. Two hospitals were chosen with different objectives which are as:

- Kirtipur Hospital as general hospital
- Tilganga Institute of Ophthalmology (TIO) as special hospital

These two hospitals have different objectives and time of operation. As Kirtipur hospital is a general hospital and operates for 24X7 days and TIO is a eye special hospital which operates for 12 hours a day only. These cases were studied thoroughly and in-depth analysis was done to reduce the operational energy cost for maintaining indoor thermal comfort. Passive design analysis was also done in the existing building. The energy analysis for existing building will vary according to its location, shape and size and functions. But overall concept of the research will be similar and these buildings with be the representative for similar objective other hospitals.

8. Data Presentation

8.1 Kirtipur Hospital, Kathmandu

The main building consists of 2 rectangular blocks joining with a vertical circulation space in between. As the building is designed in the North-East slope terrain, it has 3 basements levels. The longest face of the main building is oriented to East and West direction. The building is oriented to South West direction with a tilt angle of about 71° from South. It has poor orientation regarding the climatic data of Kathmandu. As the surrounding site consists of evergreen trees, it has a cool effect in summer months as well as shades summer sun but it also obstructs winter sun completely in Southern facade. The Southern solar radiation is only received in the roof area. Hence the building receives mainly Eastern and Western solar radiation.

Table 1: Window to wall ratio of Kirtipur hospital

	South	North	East	West
Window area(m2)	440	563	2768	1711.75
Wall area(m2)	3510	2890	11280	7415
Window wall ratio	12.54	19.48	24.54	23.08

Table 1 shows the window to wall ratio (WWR) of Kirtipur hospital. Only the North façade meets the standard range according to literature review. The window area in South façade is very less and in East and West facades its bit more than range.

The main source of energy in the building is national grid line (electricity) and alternative source is diesel for generator and electricity from solar pv of 66.62 kWp. The electricity generated from solar pv is used in operation theatre and ICU. It saves up to 30% of energy saving 1 million Nepali rupees till the end of 2018 AD.

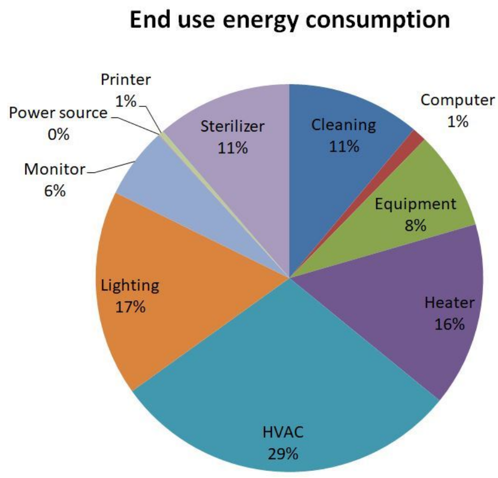

Figure 3: Energy consumption in the main building *(Source: Sunfarmer Nepal Pvt. Ltd., 2018)*

Figure 3 shows that HVAC has the highest share of 39% (10408 kWh per month) following by lighting with 22% share (6018 kWh per month). In coldest months (Mangsir, Poush and Magh), the heating loads are used and in hottest months (Ashad, Shrawan, Bhadra), the cooling loads are used. The remaining months may or may not use the heating or cooling loads or it may use both heating and cooling loads.

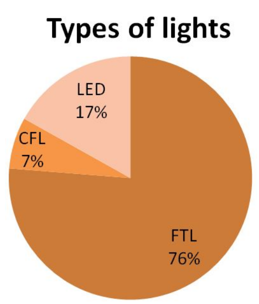

Figure 4: Types and no. of lights used in the main building

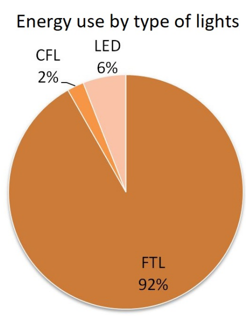

Figure 5: Energy used by types of light in the main building

Figure 4 shows 76% of the artificial lamps used in the building are inefficient i.e, Fluorescent tube light whereas the remaining are efficient lamps (CFL and LED). Figure 5 shows 92% of lighting energy is consumed by FTL.

8.2 Tilganga Institute of Ophthalmology(TIO), Kathmandu

TIO is a specialist hospital which is the implementing body of Nepal Eye Program, a non-profit community based organization. The main or new building is 7 storied including basement and attic space and has total built up area of approx. 6209 m^2. The main building has elongated rectangular plan form with longest side facing south and North. The building has good orientation, 20° from South, regarding passive design standards of temperate climate. The building is located at the compact settlement hence the shadows from nearby structures fall on some areas of East facade. But the Southern winter sun is not obstructed in this building.

Table 2: Window to wall ratio of Tilganga Institute of Ophthalmology

	South	North	East	West
Window area(m2)	478.36	450.28	162.11	128.85
Wall area(m2)	1170.93	1172.86	515.15	665.10
Window wall ratio	40.85	38.39	31.47	19.37

Table 2 shows the window to wall ratio (WWR) of Tilganga Institute of Ophthalmology. According to the literature review, window area in South and West facades are sufficient but it is more in North and East facades. The window areas can be reduced for maintaining internal comfort level but need to consider required daylight intensity in the spaces.

The main source of energy in the building is national grid line (electricity) and alternative source is diesel for generator. According to electricity bill of 2075 BS, the total average load consumption per month is 27043 kWh and 26148 kWh in winter and summer respectively.

In the figure 6, it can be seen that HVAC has the highest share of 39% (10408 kWh per month) following by lighting with 22% share (6018 kWh per month). In coldest months (Mangsir, Poush and Magh), the heating loads are used and in hottest months (Ashad, Shrawan, Bhadra), the cooling loads are used. The remaining months may or may not use the heating or cooling loads or it may use both heating and cooling loads.

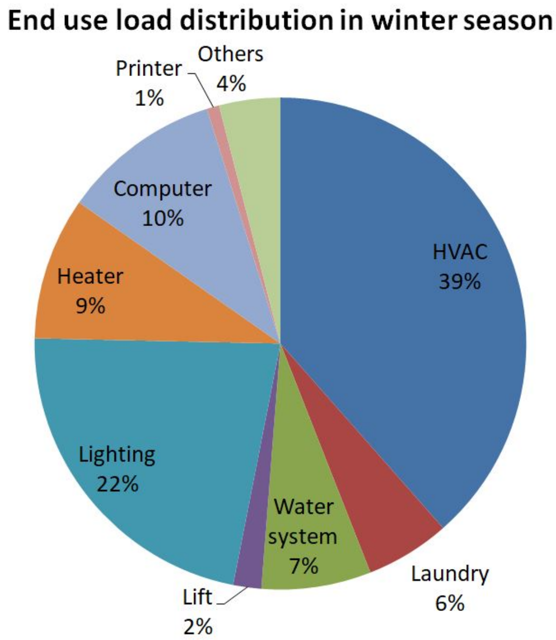

Figure 6: Energy consumption in the main building

Figure 7 shows that 67% of the artificial lamps used in the building are inefficient i.e, Fluorescent tube light whereas the remaining are efficient lamps (CFL and LED). And figure 8 shows that 80% of lighting energy is consumed by FTL.

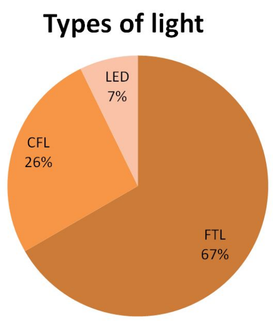

Figure 7: Types and no. of lights used in the main building

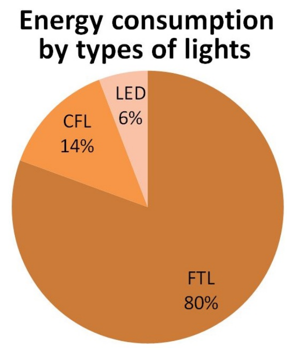

Figure 8: Energy used by types of light in the main building

8.3 Development of bioclimatic chart of Kathmandu

From the figure 9, the separate comfort zone has been created for winter and summer season with the temperature range of 18.84°C to 23.84°C and 23.03°C to 28.03°C respectively. It has a moderate climate having comfortable conditions but may cause some

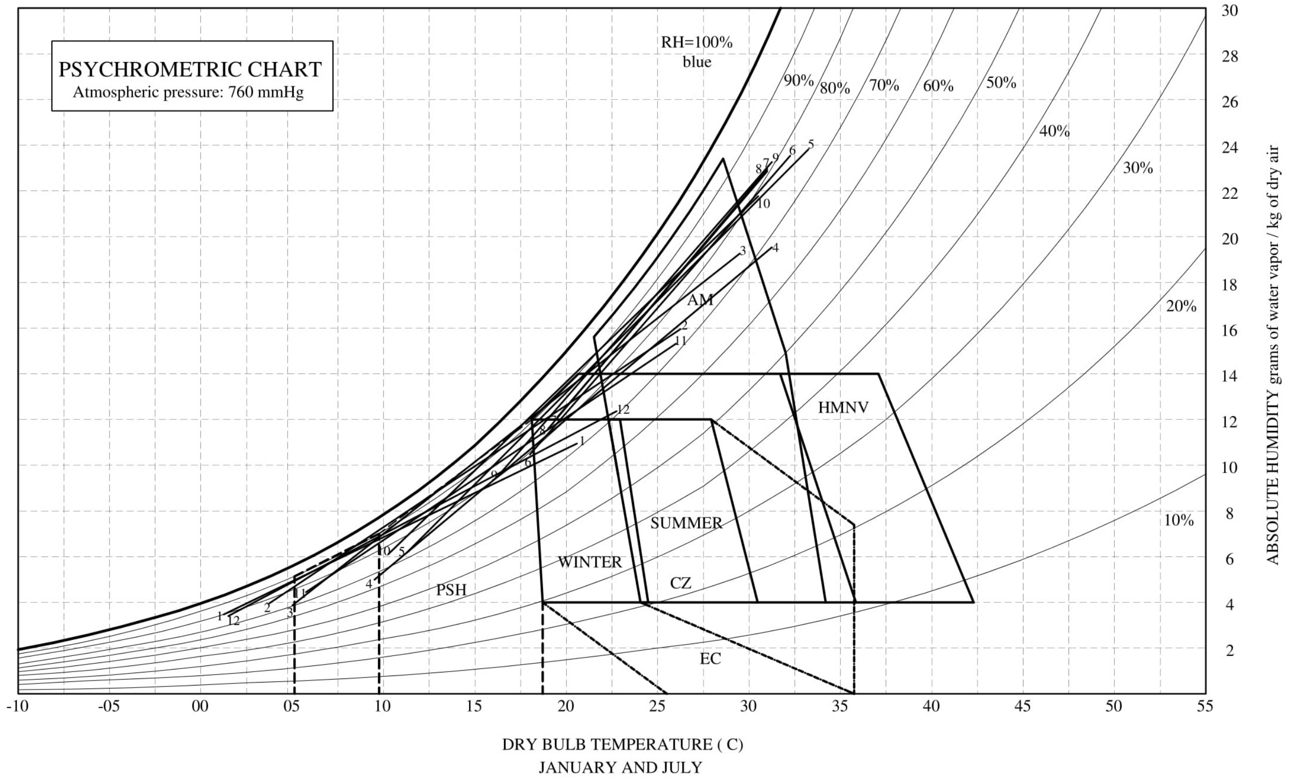

Figure 9: Bioclimatic chart of Kathmandu

discomfort by cold stress in winter and heat stress in summer. In the bioclimatic chart, it is seen that most of the days in a year lies out of the comfort zone area but there is a high possibilities to convert most of the days to thermal comfort with the proper application of passive solar design strategies in the buildings of Kathmandu. Only few days of the months December, January, and February needs active heating and some days the months between April and October needs active cooling.

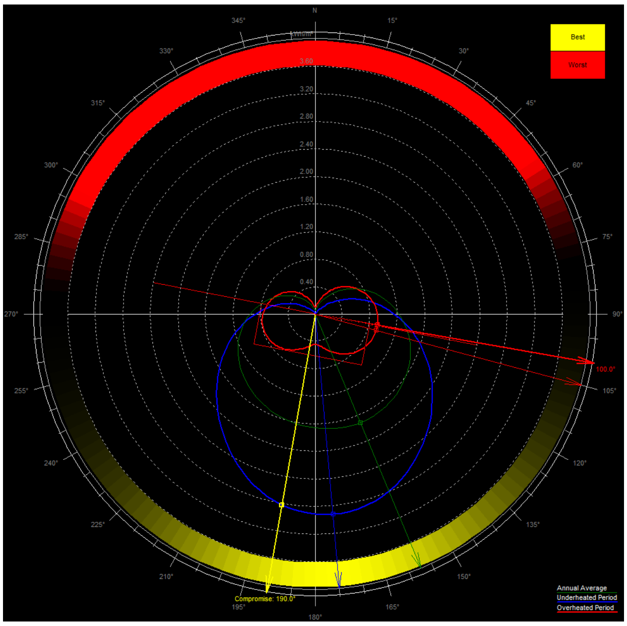

Figure 10: Best orientation for buildings in Kathmandu

9. Result and discussion

According to the Ecotect analysis, the best orientation for both of sites is 190° from North. Figure shows that the building should be elongated to East and West, facing South direction for proper day lighting and energy saving. Whereas the North oriented buildings are worst in terms of day lighting and energy saving.

9.0.1 Kirtipur Hospital

The building material and construction details in the building envelope in existing and intervention are shown below in table 3:

Table 3: Building materials in existing and intervened scenarios

S.N.	Existing scenario	U-value	Scenario I (Cavity wall)	U-value	Scenario II (Eco panel)	U-value
1	350mm brick wall with 10mm both side cement plaster	1.4	-	-	-	-
2	350mm brick wall with 10mm cement plaster inside only	1.44	-	-	-	-
3	220mm brick wall with 10mm both side cement plaster	1.87	Existing + 50mm air gap + 110mm brick wall + 10mm cement plaster	1.12	Existing + 50mm EPS cement sandwich panel	1
4	220mm brick wall with 10mm cement plaster inside only	1.96	Existing + 50mm air gap + 110mm brick wall + 10mm cement plaster	1.15	Existing + 50mm EPS cement sandwich panel	1.09
5	150mm RCC slab with 40mm concrete screed and 10mm tile	2.16	Existing + 450mm air gap + 12mm gypsum false ceiling	1.49	-	-
6	Aluminium framed single glazed window	6	Aluminium framed double glazed window	2.41	-	-
7	CGI sheet with air gap and gypsum false ceiling	2.7	Existing + 50mm thick expanded polystyrene (EPS)	0.56	-	-

9.0.2 Comparison of heating and cooling loads

Figure 11 shows the comparison of monthly heating and cooling loads in all 3 scenarios. The total annual heating and cooling load in existing scenario was 201642 kWh and the total annual load in scenario I was found 159773 kWh which was reduced by 27.16% and in scenario II it was found 160400 kWh which was reduced by 26.74%. The heating load was found maximum in January month and the cooling load was found maximum in May in all 3 scenarios.

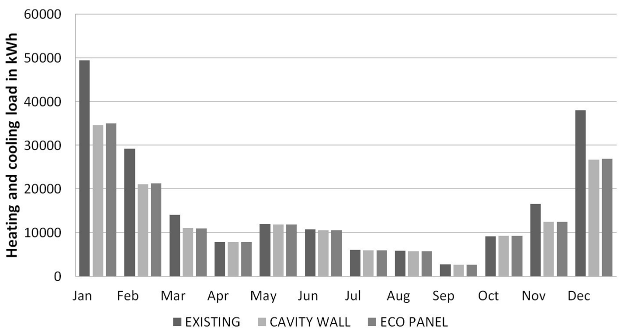

Figure 11: Monthly heating and cooling loads in existing and intervened case

9.0.3 Comparison of fabric gains

While comparing with the existing case, the monthly average fabric gains was reduced in almost every month except in April and October.

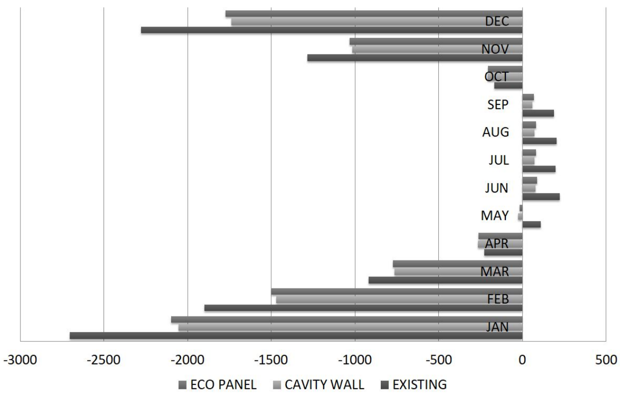

Figure 12: Monthly average fabric gains in existing and intervened case

9.0.4 Comparison of fabric loss

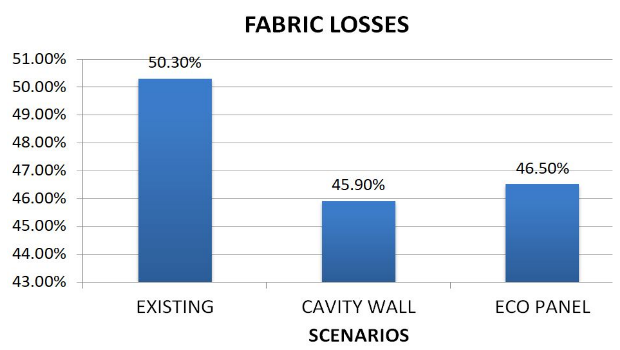

Figure 13: Monthly average fabric loss in existing and intervened cases

In the existing scenario, the fabric or envelope loss from the building was found to be 50.3% and after interventions, the loss from the building fabric is reduced by 4.4% and 3.8% in scenario I and II respectively.

9.1 Tilganga Institute of Ophthalmology

The existing building materials and technology used in the case building of TIO is similar as of Kirtipur hospital. The interventions were also done similarly except that the roof was not intervened because the building consists of attic space used to store materials only.

9.1.1 Comparison of heating and cooling loads

Figure 14 shows the comparison of monthly heating and cooling loads in all 3 scenarios. The total annual heating and cooling load in existing scenario was 40063 kWh and the total annual load in scenario I was found 23583 kWh which was reduced by 46.7% and in scenario II it was found 24117 kWh which was reduced by 47%. The heating load was found maximum in January month and the cooling load was found maximum in June in all 3 scenarios.

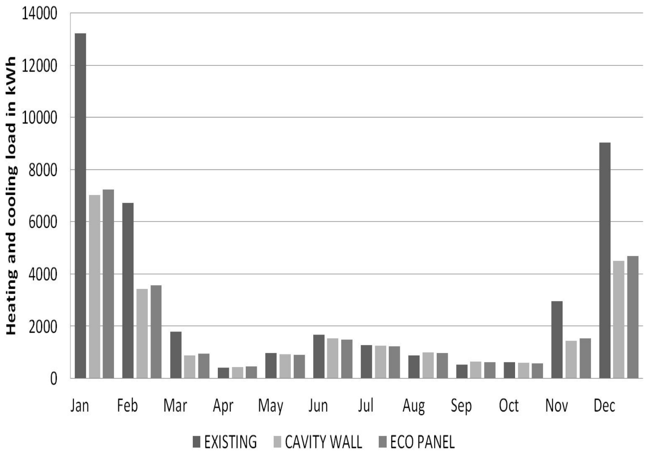

Figure 14: Monthly heating and cooling loads in existing and intervened case

9.1.2 Comparison of fabric gains

While comparing with the existing case, the monthly average fabric gains was reduced in almost every month except in March.

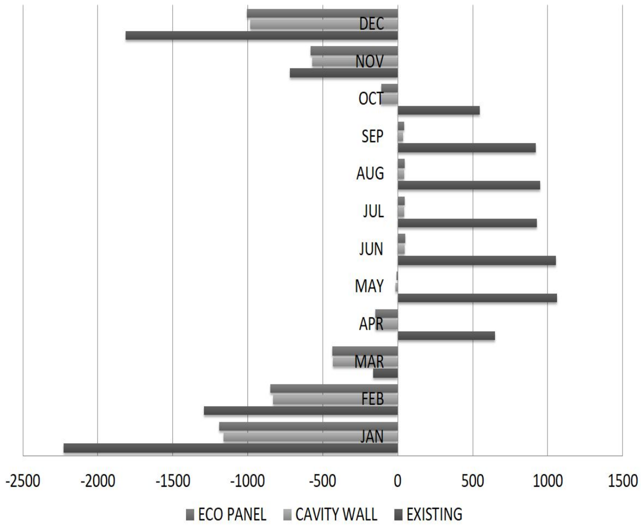

Figure 15: Monthly average fabric gains in existing and intervened case

9.1.3 Comparison of fabric loss

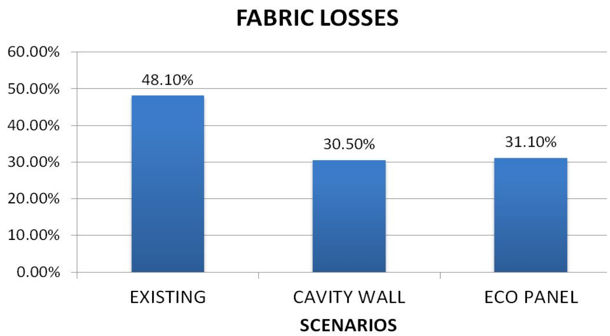

Figure 16: Monthly average gains breakdown in existing and intervened case

In the existing scenario, the fabric or envelope loss from the building was found to be 48.1% and after interventions, the loss from the building fabric is reduced by 17.6% and 17% in scenario I and II respectively.

10. Conclusion and recommendation

10.1 Conclusion

In Nepal there are numerous hospital buildings but almost all of them have not considered the local climate, passive design strategies and energy integration during the design and construction phase. This resulted in heavy dependence on mechanical means for thermal comfort which lead to maximum energy wastage, maximum operational bills and high energy demand in the national context.

From the study, it was found that the average minimum electricity consumption per month were 30,000 kWh and 25,000 kWh in Kirtipur hospital and TIO respectively. The results show that possible interventions for both cases may be double glazing, adding extra wall or insulation in exterior wall only, adding insulation in false ceiling. The results showed that scenario I i.e., cavity wall has higher reduction in loads than of scenario II i.e., EPS cement sandwich panel in both case areas. Also the simple payback period of scenario I is lesser than scenario II. But since Kathmandu is earthquake prone area and scenario II have comparatively very less loads in building structure i.e., 1/6th of brick wall and also it occupies very less internal space than scenario I, it will be better to go for scenario II. The simple payback period for scenario II was found to be 26.5 years and 45.2 years in Kirtipur hospital and TIO respectively. Also the inefficient lights (FTL) were changed to efficient lights (LED) to reduce the energy consumption of the building resulted in higher saving of 3180 kWh/month and 2765 kWh/month with lesser payback period of 0.71 years and 1.03 years in Kirtipur hospital and TIO respectively.

10.2 Recommendation

The recommendations from the research are as follows:

10.2.1 For existing building

- Since the operational cost for heating and cooling loads in the building is heavily dependent upon materials and technology in envelope, the envelope should be changed with low U-value materials considering factor of structural safety and economy. It is better to use light weight insulation materials.
- Openings are the weakest points of heat flow so it is better to double glaze the openings since only this change can save huge energy. Also the leakage points in the envelope should be properly sealed.
- False ceiling with proper insulation should be given to the top floor of the building because the roof is also the main point of heat transfer.
- Energy audit should be done regularly and energy management should be done accordingly to at least minimize the energy waste.

10.2.2 For new building

- Proper site selection should be done without obstruction of solar access and wind flow in the building.
- Climatic considerations should be done before designing a building.
- Local materials and technology could be considered to the possible extent.
- Orientation and planning of a building should be done in such a way that most of the rooms get sufficient daylight.
- There must be proper consideration of passive design strategies in order to minimize the use of mechanical means to maintain thermal comfort inside the building. Otherwise extra retrofit with heavy extra cost needs to be invested for thermal comfort as in the existing building.
- Opening sizes and positions should be calculated according to the face of building and its internal function. WWR should be more than 40% in South face and 10-20% in remaining facades in temperate climate.
- Proper type and size of sun shading devices should be done in order to avoid the summer sun and receive the winter sun.
- Use of energy efficient lights such as LED lamps should be suggested by the designers to the clients.

References

[1] Thibaut Abergel, Brian Dean, and John Dulac. Towards a zero-emission, efficient, and resilient buildings and construction sector: Global status report 2017. *UN Environment and International Energy Agency: Paris, France*, 2017.

[2] Peter O Akadiri, Ezekiel A Chinyio, and Paul O Olomolaiye. Design of a sustainable building: A conceptual framework for implementing sustainability in the building sector. *Buildings*, 2(2):126–152, 2012.

[3] Ingy El-Darwish and Mohamed Gomaa. Retrofitting strategy for building envelopes to achieve energy efficiency. *Alexandria Engineering Journal*, 56(4):579–589, 2017.

[4] Roberto Garay Martinez. Highly insulated systems for energy retrofitting of façades on its interior. *Procedia environmental sciences*, 38:3–10, 2017.

[5] Susanne Bodach. *Climate responsive building design for low-carbon development in Nepal*. PhD thesis, Technische Universität München, 2016.

[6] J Karliner and R Guenther. Global green and healthy hospitals: A comprehensive environmental health agenda for hospitals and health systems around the world, 2013.