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Potential of Energy Retrofit Implementation in Non-Residential Existing Buildings

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Abstract

The building industry's most important service right now is sustainability. From the other perspective, the contract administrator does not openly embrace or comprehend the sustainability initiatives in the facilities management sector. As a result, the building industry is the biggest global source of greenhouse gas emissions. Energy retrofitting is a sensible alternative to demolishing every existing structure because doing so would be unfeasible. However, very few individuals use energy-saving strategies.

In this research, two different primary case studies have been taken. Hospital building are chosen for case study research among non-residential existing structures since they consume more energy than other non-residential existing building categories. One of the case studies is the hospital of Trondheim, Norway. The purpose of this case study was to comprehend the energy retrofit measures and its economic benefits. In addition, this case study served as a basis for the proposal for the second case study, which was carried out in Kathmandu, Nepal. The objective of the second primary case study, which is also a hospital, is to determine whether or not the building's energy retrofit would be financially viable.

The focus of this paper is the notion of energy retrofitting as a potential remedy. Through the use of a questionnaire, an interview with a key individual, an energy audit, and a case study, the study explores whether or not existing non-residential buildings can be retrofitted in an economically effective way that will result in a reduction in the amount of electricity they consume. The results show that this is possible, despite the fact that the term "economically efficient" is subjective. Green technologies used in the energy retrofit process that could be suggested for a future project could be the subject of further investigation in this study.

Keywords

Energy retrofit, Energy efficient building, Sustainable reimbursement

1. Introduction

Numerous developed nations place a strong emphasis on locating efficient strategies for lowering the building sector's carbon footprint and increasing energy savings. As a result, numerous nations began to consider more environmentally friendly strategies for new projects and developments. [1]

The scenario for Nepal's energy consumption in 2017 is depicted in chart 1. The construction, operation and maintenance, and demolition phases of the building sector use the majority of the energy here. Any nation's economy is primarily based on its buildings. Nonetheless, they also significantly influence global energy consumption. The difficulty and significance of the current building structure cannot be overstated. In a nation like Nepal, which has endured a severe power crisis in recent years, it is particularly challenging to achieve sustainability in the current building scenario. It has been discovered that no research has yet been conducted to identify the success factors for energy retrofitting implementation.

2. Problem Statement

The energy demand is significantly greater than the supply, resulting in an imminent and potentially catastrophic energy crisis. The historical availability of reasonably priced power in Nepal is said to be one of the main causes for why buildings have been planned and built in such a way that they are inefficient about energy use. The built environment is under a lot of social and economic pressure to find a practical solution to the present power supply problem.

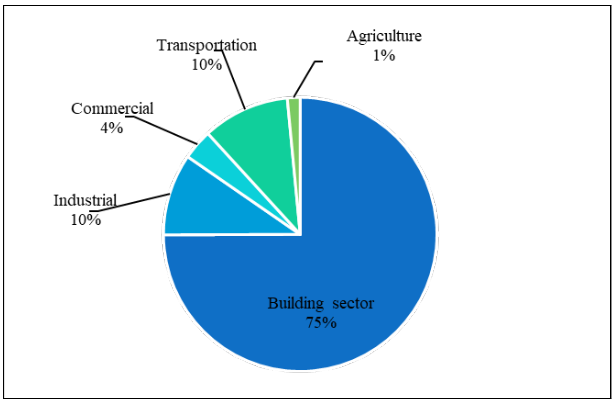

Figure 1: Energy consumption by sector, 2017 *(source: MOF, 2017; WECS, 2010)*

A significant portion of greenhouse gas emissions can be attributed to existing buildings, particularly non-residential ones [2]. Energy retrofitting is urgently needed to lessen the negative effects of existing buildings on the environment. It is well known that the bulk of existing structures has a lifespan of 50 to 100 years and that reusing existing structures rather than constructing new green ones is more resource-efficient and sustainable. Demolition and rebuilding could be avoided through modifications; As a result, less waste is produced during construction and fewer materials are required. [3]

Even though energy retrofit is not a novel idea in developing nations like Nepal, this idea has not yet been applied to Nepal on a theoretical and practical level. However, energy retrofit is one of the possible solutions to make the existing building energy efficient.

3. Research Purpose

The main objective of the research is:

- To identify the green technology to enhance the energy efficiency used in energy retrofitting.

The specific objective of the research is:

- Determining the profitability of energy retrofit solutions in existing non-residential buildings.

4. Research Question

The following are the main queries this research report raises:

1. What are the green technologies used in green retrofit?
2. Which green technology is the most energy efficient?
3. What is the success rate of energy retrofit using these green technologies?
4. What could be the main challenge in the adoption of energy retrofit in a non-residential existing building?
5. Is it financially and economically feasible to improve the energy efficiency of an existing non-residential building in Kathmandu?

5. Literature Review

According to consumption statistics, commercial buildings consume significantly more energy than other types of buildings [4]. How a building was constructed directly affects its performance. Energy can be wasted unnecessarily due to straightforward design and construction flaws in the beginning. However, if this issue already exists, investing in retrofitting can partially address it. [5]

"Retrofitting existing buildings presents by far the largest potential for the incorporation of renewable energy technologies and energy efficiency measures into buildings". [4]

The primary goal of Energy Retrofit is to change or modify the systems, equipment, or parts of the building to save energy or reduce energy use [6]. Energy-efficiency proponents contend that the use of energy-efficient technologies may lead to several advantages that are not directly connected to energy. It is frequently suggested that the societal advantages include things like greater employment and production, as well as better comfort and public health. [7]

The framework for choosing green technology consists of a six-phase screening method and a conceptual model with several aspects. The conceptual model is constructed in three dimensions: the x-axis represents the building systems and components, the y-axis represents the project life cycle, and the z-axis represents performance measurements [8]. On the structure level, the energy retrofit technology or arrangements should fulfill the main specific necessities in the Structure Guidelines and should not make other textures, administrations, and fittings less pleasant than they were before. Building Guidelines provide standards for the design and construction of structures to ensure the safety and well-being of those who live in them. [8]

6. Research Methodology

The research framework has been developed about the individual objective, research question, parameters/ variables, and methodology to be used. The research approach applied in this research is both qualitative and quantitative in nature.

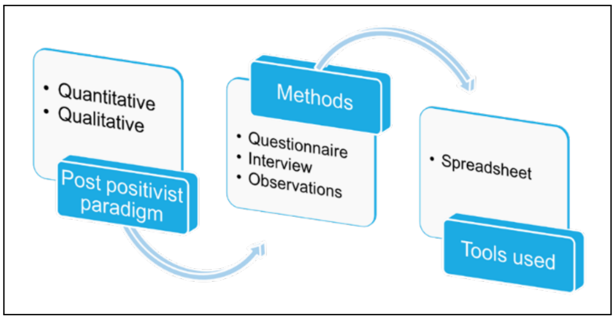

Figure 2: Research Methodology

The given figure represents the methodology used for the primary case study area to collect the data. Both qualitative and quantitative data are collected with the method of open-end and close-end questionnaire surveys. The observation method has also been used to understand the existing scenarios. The collected data has been used for the intervention scenario to check the feasibility of implementing the energy retrofit concept.

7. Limitation of the study

The research work is mainly focused on the "Potential of Energy Retrofit in Non-Residential Existing Buildings in Kathmandu, Nepal". The research area in Trondheim, Norway is more focused on one of the hospitals building (i.e., Women-child center, St. Olavs Hospital) to understand the technologies used in energy retrofit and its economic benefits for the same. One of the hospital buildings in Kathmandu, Nepal—the Paropakar Maternity and Women's Hospital—will be the focus of the investigation, which will only investigate the viability of an energy retrofit. The energy retrofit will receive more attention in the feasibility study. The hospital's energy consumption scenario serves as the basis for the data collection. A few case studies on various types of energy-retrofitted non-residential existing buildings have been carried out with the assistance of literature to gain an understanding of the concept, procedure, green technologies utilized, and methods utilized during the energy retrofit process. In addition, the energy savings and potential of the energy retrofit concept are examined in these case studies. The effectiveness of green technologies has also been evaluated with the help of literature reviews.

The subject of the primary case study is limited to the electricity component of energy efficiency, even though the energy aspects of a building encompass numerous aspects related to and associated with the reduction in energy consumption. The research only looked at the financial benefits of retrofitting an existing hospital building; it did not look at the other benefits.

8. Study Area

The study area for the research work has been chosen as a hospital building in two different countries, i.e., Norway and Nepal. The hospital building is also one of the non-residential buildings which use more energy for operation. Hospital or health care center is also important infrastructure that consumes more energy per day.

The research in the hospital of Norway has been selected to understand the energy-saving techniques used and the potential of energy and cost saving due to the applied energy retrofit. However, research in hospitals in Nepal has been conducted to find out the feasibility of the energy retrofit concept and its economic viability

9. Findings and Analysis

The findings and analysis are based on three different research areas:

1. Green technologies:
    - This study sought to comprehend the various green technologies utilized in the

energy retrofit process of existing buildings.

2. Women and Child Center at St. Olavs Hospital, Trondheim, Norway:
   - The purpose of this case study was to investigate the possibility of energy retrofitting an existing hospital building.
3. Paropakar Maternity and Women's Hospital, Kathmandu, Nepal:
   - This research has been carried out to check the feasibility of energy retrofit in the existing hospital building.

9.1 Green technologies

Green technologies and/or measures can be used to improve existing buildings' energy performance, which is a practical way to implement the idea of sustainable development in the construction industry.

The selection of green technology depends on various energy retrofit actions that might have various influences on linked constructing sub-systems. The selection of green technologies is done by focusing on these five factors:

1. Construction time,
2. Construction prices,
3. Material and labor expenses
4. Quality of work,
5. Timelines

Green technologies should be selected based on the building regulation criteria which may vary in the type of technology.

9.2 St. Olavs Hospital, Trondheim, Norway

The St. Olav hospital is the university hospital integrated with NTNU, the Faculty of Medicine and Health Sciences. It is the local hospital for the population of southern Trøndelag. It was built in 2009 with a gross area of 31,000 m². It is part of St. Olavs Hospital Trust that operates all the hospitals in Sør-Trøndelag and is thus indirectly state-owned. [9]

6 buildings consume energy at St. Olavs Hospital. Electricity, heating, and cooling statistics are included in the Hospital building's energy consumption. The Women-Child Center is among the structures which is the focus of the research area.

In 2006, the Woman-Child Center, which has a gross size of 31,200 m2, was inaugurated. Births, gynecology, and pediatrics all utilize it. In addition, research and instruction are conducted in the facility. A hospital school is also located here. There are 187 patient beds, 9 surgery rooms, and 14 labor and delivery facilities.

Figure 3: Womens and child center, Trondheim, Norway

9.2.1 Energy Retrofit Measures used in The Hospital

Electricity is the building's primary energy source. Radiators are utilized for the building's cooling and heating system. Otto Koch, an energy management technician, claims that the building uses 11,001,500 kWh of energy annually.

The main strategy of energy saving was carried out at the same time as the maintenance project. Energy saved within the building is 20% on heating, 10% on cooling, and about 5% on electricity by controlling the operation of the end use.

The hospital's energy consumption data for various months from 2019 to 2022 July are presented in the table below.

Table 1: Energy Consumption of the Hospital

Month	2022 [kWh]	2021 [kWh]	2020 [kWh]	2019 [kWh]
January	1,263,146	1,358,012	1,031,758	1,196,889
February	2,382,538	2,509,661	2,076,782	2,221,837
March	3,468,130	3,635,063	2,898,642	3,259,323
April	4,460,972	4,670,638	3,731,290	4,081,887
May	5,263,607	5,470,222	4,596,077	4,883,540
June	5,903,474	6,101,896	5,260,232	5,512,924
July	6,535,796	6,742,807	5,868,617	6,194,656
August		7,397,475	6,483,054	6,794,093
September		8,099,972	7,170,554	7,510,873
October		8,972,407	8,017,454	8,477,164
November		10,093,011	9,005,918	9,497,418
December		11,365,235	10,151,794	10,437,431

Source: St. Olavs Hospital

Table 2: Energy Retrofit Measures used in the hospital

Energy retrofit measures		Savings				
		kWh/year Electric	kWh/year Thermal	kWh/year Sum	NOK/year including VAT.	Payback year
Building wise	Sun protection by the installation of ext. blinds with motor control	-	43,000	43,000	21,500	43.1
Water-borne heat	Optimizing room temperature Nighttime lowering of room temperature Quantity regulation heat rates Interlock heating/cooling/ventilation	-	90,000	90,000	45,000	0.7
Cooling	Demand management cooling Recycling process cooling Optimized use MTU Free cooling	-	30,000	30,000	15,000	2.2
Air treatment	Log real operation Time management Temperature effect degree rot. Recyclers Exhaust air recovery Reduced supply of air temperature at night	-	4,78,000	4,78,000	2,39,000	4.1
Lighting	Lighting culverts Demand management light larger rooms Daylight sensors	33,000	-	33,000	28,875	0.6
Electric heating	Heating cables in roof drains and another snow melting (roofs/canopies)	1,000	-	1,000	875	9.3
Operational technical	Analyze/optimize SD systems for energy efficiency Energy meters, such as e.g., snow melting facilities, underfloor heating courses, ice water courses, etc.	15,000	20,000	35,000	23,125	1.4
Total saved per year		**49,000**	**6,61,000**	**7,10,000**	**3,73,375**	

This case study lays out that the energy retrofit concept can reduce energy consumption and saves the cost of energy at the same time. Furthermore, it contributes to reducing carbon emissions by adopting green technologies.

The building saves up to 368,800 kWh per year in electrical energy after taking the aforementioned measures. In a similar vein, it saves 3,736,000 kWh annually in thermal energy and, on average, saves NOK 2,190,700 annually in energy costs.

The energy retrofit measures used in the women and child center are shown in Table 2.

9.3 Paropakar maternity and women's hospital, Kathmandu, Nepal

The Paropakar Maternity and Women's Hospital is located in Thapathali, Kathmandu, Nepal. Its alternate name is Prasuti Griha. It was founded in August 1959 in memory of Indra Rajya Laxmi Devi Shah by the late king Mahendra and Paropakar, a non-governmental organization with roots in the local community. It is situated on a sizable plot of land that it owns on the Bagmati River's north bank, not far from the Thapathali Bridge.

With 415 beds, it is a major central hospital. Of those, 336 are for indoor admission, 241 are for obstetrics, 61 are for gynecology, and 34 are for infants. It has 79 service beds. [10]

The energy systems used in the hospital are to meet the facilities such as heating, cooling, light, and other medical equipment. The annual energy consumption of the hospital per square meter of hospital area is 178.92 kWh/m² for Reference Year 2076/2077. The annual energy consumption of the hospital per number of beds in the hospital is 3070.71 kWh/bed for Reference Year 2076/2077.

Figure 4: Main building of Paropakar Maternity and Women's Hospital, Kathmandu, Nepal

The energy consumption in the lighting system can be reduced by replacing the high-watt old tube lights with LED lights. The energy will be saved by 39.95% by the simple changes. Likewise, replacing the old electric fans with five-star super fans will reduce the energy by 50%.

Table 3: Energy consumption and cost per day within the main building of the hospital

Electrical Appliance	Total No.	Power (W)	Total Power (W)	Operating Hrs.	Energy Consumption (kWh/Day)	Electricity Cost Per Day (NRs.)
Tube Light	327	20	6,540	24	156.96	18,83.52
	4	20	80	8	0.64	7.68
LED	306	12	3,672	24	88.128	1,057.54
Fan	96	70	6,720	12	80.64	967.68
Lift	2	5830	11660	24	279.84	3,358.08
Air conditioner	10	1,500	15,000	24	360	4,320
	3	1,500	4500	8	36	432
Autoclave	1	18,000	18,000	18	324	3,888
OT light	3	40	120	12	1.44	17.28
Total energy consumption per day					**1,327.648**	**14,048.26**
Total energy consumption per year					**484,923.432**	**5,127,614.9**

Table 4: Energy and cost saving through an intervened scenario

Existing scenario	Intervened scenario	Energy saved/ year (kWh)	Energy cost-saving annual (NRs)	Payback period
20 W tube lights	12 W LED lights	23,009.6	276,115.2	0.48 years
70 W approx. fan	35 W superfan	14716.8	176601.6	3.31years
18 kW autoclave	Operate off-peak hour	-	5,91,300	-

10. Result and Discussion

The main critical factor in implementing energy retrofit technology is the time taken in the process of retrofit. Institutional buildings like hospitals appear to be difficult in managing the flow of patients. Some of the market barriers found were misplaced incentives, market structure, customs, and information. Similarly, financial barriers such as initial investment and payback period are the main reason for being behind these types of concepts. Customers are not motivated to upgrade technology since they are clueless about the expense of their monthly power bill. The owners of the building find that the energy audit process is costly and also there are difficulties in the selection of green technology due to the lack of knowledge.

However, the case study conducted evidence that the application of the energy retrofit concept helps in reducing energy consumption and energy cost. Energy retrofit can also be accomplished on a small scale.

11. Conclusion

The building's energy use pattern is the primary focus of the research area. Through a primary survey, the energy data have been gathered to determine the type of energy used in the building. Additionally, the building envelope has been observed to determine which energy retrofits are best suited to particular applications.

The study demonstrates that green technology and energy retrofitting are valued in addition to the cost. Additionally, it contributes to the creation of a healthy atmosphere within the building and its surroundings.

The pattern of energy consumption changes significantly with even the smallest improvement to the appliances and management system. Energy demand is reduced, and the selection of electrical and mechanical equipment is maximized thanks to improvements that reduce the amount of energy consumed by commonly used building appliances.

By incorporating environmentally friendly technologies or cost-effective technical measures, existing buildings can enhance their overall sustainability performance. As a result, energy retrofitting is a novel concept; However, retrofitting costs money, so it has both financial and economic repercussions.

Green technology and energy retrofit are valued under financial consideration. The slightest upgrade in the appliances and management system makes a huge difference. Energy consumption can be reduced by improving the commonly used appliances in the building. Also, it can be reduced by optimizing the choice of electrical and mechanical equipment used in the building. The existing non-residential buildings can improve their overall building performance by incorporating green technologies or cost-effective technical measures.

12. Recommendation

1. For the thermal comfort retrofit, it would be recommended to investigate the climatic data of the specific area under investigation as well as the performance of the building envelope. To conduct an energy audit on various aspects of the building envelope, it is necessary to collect all floor plans and construction details.
2. To determine the air quality produced by air conditioners, it is recommended to conduct an indoor air quality assessment.
3. It is recommended that roofing loads be identified before installing solar PV or solar water heating systems.
4. It is suggested that a study be conducted to determine which component of a building energy audit companies most frequently focus on.
5. An energy management system and technicians to monitor the building's energy system are recommended.
6. It is recommended to set up an energy management system and hire technicians to keep an eye on the building's energy system.

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