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Optimization of Energy Consumption in Hotels – Case Study of Hotels of Nagarkot

Sushant Bahadur Malla [a], Sushil Bahadur Bajracharya [b]

[a, b] *Department of Architecture, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[a] sushantmalla@gmail.com, [b] sushil_bajracharya@ioe.edu.np

Abstract
Buildings and building construction sectors combined are responsible for over one-third of global final energy consumption and nearly 40% of total direct and indirect CO2 emissions. Hotel Buildings consume a significant amount of energy and contributes a considerable weightage to the building sector energy consumption. Hence, it is high time to shift to green energy source and focus on Energy Efficiency, Energy Saving and Energy Optimization. Energy optimization aims to make our homes, workplaces, hospitals, schools, and other buildings contributors to our individual and societal health and wealth by lowering overall energy consumption and coordinating the remaining energy use to take advantage of the availability of clean, zero-carbon energy sources. This research will help us to study the energy consumption/ energy cost and develop/ identify relevant energy conservation/ optimization opportunities with the help of Climatic Data Study, Questionnaire Survey and Energy Modeling for the Hotel Project in Nagarkot. The research focuses in 3 main hotels the Nagarkot Region Hotel Mystic Mountain, Club Himalaya and Hotel Country Villa. This research concludes that with proper implementation of several energy saving options, Savings in heating and cooling load of up to 54.67% and 58.85% could be achieved in hotel rooms by means of Energy Modeling/ Simulation.

Keywords
Energy Optimization, Energy Modeling, Hotels, Insulation, Passive Design Strategies, Heating/ Cooling Load

1. Introduction

Tourism is one of the world's leading economic sectors and is one of the major sources of Nepal's Economy and the main source of Foreign Exchange and revenue. The analytical study on tourism released by the Central Bureau of Statistics recently shows that Nepal's tourism industry provides 371,140 jobs. This represents 11.5 percent of persons engaged in all industries in the country. Tourism is Nepal's fourth largest industry by employment (National Economic Census - Analytical Report (Tourism), 2018). In 2013, the travel and tourism industry contributed 1.5 billion US-Dollars to Nepal's Gross Domestic Product (GDP) which corresponds to 8.2 percent of total GDP [1]. Nagarkot is a prominent highlight and tourism hub among all the activities and tourist attractions of Nepal. It is considered one of Kathmandu Valley's most scenic spots. The hotel industry is one of the most energy-intensive. Energy usage accounts for between 3% and 6% of hotel operating costs and accounts for 60 percent of CO2 emissions. It has increased from 25-30 percent over the last decade and is forecasted to continue growing due to more demanding standards and the development of electronic equipment [2]. In addition to a 50 percent rise between January 2020 and December 2021, the energy price index of the World Bank climbed by 26.3% between January and April 2022. The substantial rises in the price of coal, oil, and natural gas are reflected in this spike. The price of crude oil climbed by 350 percent in nominal terms between April 2020 and April 2022, which is the highest increase for any comparable two-year period since the 1970s. As energy prices has been drastically increasing, it is high time that we switch to renewable and clean source of energy and more over our main focus should be on energy conservation. Energy Optimization is the key to energy conservation. Energy optimization refers to how energy is used — and not used — in the built environment to optimize environmental and human advantages. This research will help us to study the energy consumption/ energy cost and develop/ identify relevant energy conservation/ optimization opportunities for the Hotel Project in Nagarkot.

2. Method of study

The Methodology for this specific research is as per figure no. 1. The research started by defining the project objective and moving on to Literature Review. The Literature review was carried out via research papers and internet sources. After the development of the literature review, necessary data collection was carried out with the help of Case Studies of Various similar types of Research, Information from the internet, climatic data, technical data of recommended materials and on-site investigation, and observation. A bioclimatic chart was developed from the climatic data obtained from the Department of Hydrology and Meteorology to better understand the climatic condition of the Nagarkot region. Further, the collected data were analyzed by means of ENERGY MODELLING via ECOTECT and Comparative analysis.

Figure 1: Research Framework

Energy modeling is a computerized, virtual simulation of a building or complex that focuses on energy consumption and life cycle costs of various energy-related goods such as HVAC, lighting, and hot water. ECOTECT is a highly visual and interactive building design and analysis tool that links a comprehensive 3D modeller with the broad range of analysis functions that are required to truly understand how a building design Finally, after DATA Analysis, we moved on to the interpretation and conclusion section.

3. Literature Review

3.1 Energy Performance of a Building

Energy performance is used as a benchmark to know the energy expenditure of the building over the year. The notion of energy performance refers to the amount of energy consumed each year by a building. It varies according to the building, which is more or less energy-intensive, but also according to its operation and its energy equipment (Oze Energies, 2020). Improving a building's energy performance involves reducing its energy use.

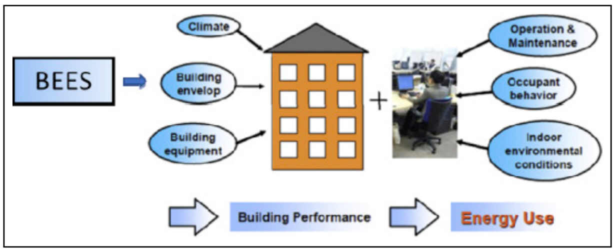

Figure 2: Building Energy Performance ([3])

3.2 Energy Consumption in Hotels

Hotels utilize the most energy and water per square foot due to their 24-hour, 365-day activities. In general, Energy consumption breakdown in hotels are as per fig 3. As the major energy consumption portion is covered by Heating, Ventilating and Air Conditioning, our main focus will be on Heating and Cooling loads in Hotel Rooms.

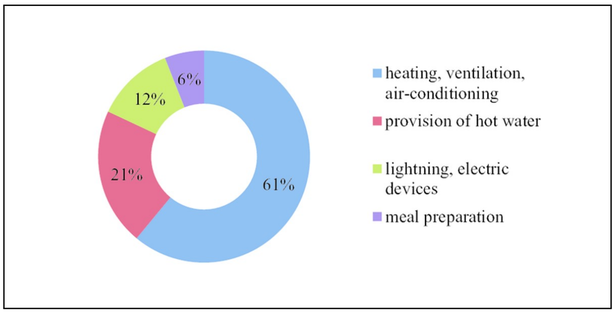

Figure 3: Breakdown of energy consumption in hotels ([4])

3.3 Factors affecting Energy Consumption in Hotels

3.3.1 Building Orientation

Building Orientation is the positioning of a building in relation to seasonal variations in the sun's path as well as prevailing wind patterns (McGee, Reardon, Clarke, n.d.). Because the sun is lower in the sky in the winter than it is in the summer, we can design and build structures that absorb the solar radiation in the winter and reject it in the summer. Overall comfort can be substantially increased and the need for heating and cooling can be decreased with the correct orientation.

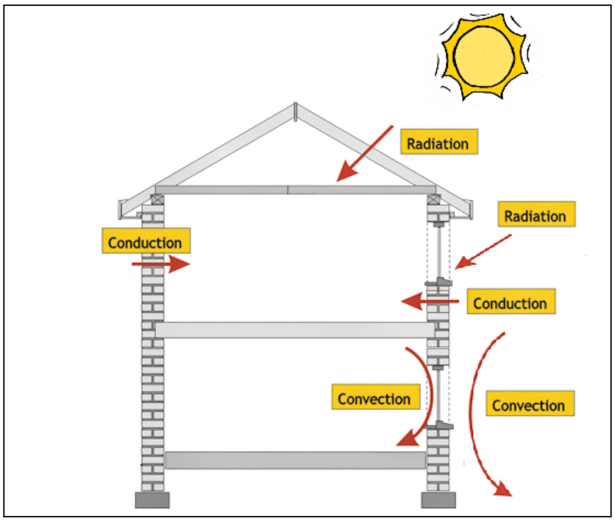

Figure 4: Interaction of Building Envelope with the Surrounding ([5]

3.3.2 Building Envelope

The building envelope is a protective component or layer that acts as a barrier between the outside environment and the inside of the structure. The building envelope, in general, is made up of a number of components and systems that protect the interior space from elements such as rain, wind, temperature, humidity, and UV radiation. The building envelope must balance ventilation and sunshine needs while also providing moisture and thermal protection appropriate for the site's climate.

3.3.3 Insulation

: Insulation is defined as material that is used to stop the passage of electricity, heat, or sound from one conductor to another. (Merriam-Webster, n.d.). Thermal insulation is the process of retarding the flow of heat from transferring between adjacent surfaces. (Corrosionpedia, 2019) In commercial buildings, insulators, also known as thermal insulation materials, are utilized to reduce the energy consumption of the cooling and heating systems. Different Types of Insulation systems are extruded polystyrene board, rock wool, glass wool, spray polyurethane foam etc.

4. Case Study Area

4.1 Introduction

Nagarkot is located 32 kilometers east of Kathmandu, Nepal, and at an elevation of around 2915 meters in the Bhaktapur District of Bagmati Province. Nagarkot is known for being the best place to enjoy the view of the Himalayas from the comfort of your hotel balcony. There are over 70 Hotels in Nagarkot. As per booking.com, there are over 30 registered hotels in Nagarkot. Amongst the registered Hotels/ Resorts, our focus will also be on Hotel Mystic Mountain, Club Himalaya by ACE Hotels and Hotel Country Villa.

4.2 Nagarkot Climatic Data

The climate details of Nagarkot collected from the Department of Hydrology and Meteorology are as per fig 5 and 6.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MEAN	T_{max}	13.1	15.9	19.2	21.6	22.4	22.7	21.9	22.3	21.6	20.4	17.2	14.4
	T_{min}	3.2	5.1	7.7	10.7	12.7	15.1	15.9	15.7	14.6	11.6	7.5	4.4
$T_{avg.}$		8.2	10.5	13.5	16.2	17.5	18.9	18.9	19	18.1	16	12.3	9.4

Figure 5: Avg. Temperature Data from 2012 to 2021 (From Department of Hydrology and Meteorology)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RH_{Avg}	65.9	65.8	59	59.9	73.8	86.5	92.6	91.7	91.1	82	73.7	70.6

Figure 6: Avg. Relative Humidity Data from 2012 to 2021

4.3 Bioclimatic Chart of Nagarkot

A bioclimatic chart is a psychometric tool used to show, evaluate, and simplify climatic information from the perspective of human comfort for any given region. The climatic details of Nagarkot as per data from Department of Hydrology and Meteorology is shown in Fig. 7. Results from the Bioclimatic Chart indicates the requirement of Active Heating During Winters (Mainly during January and December)

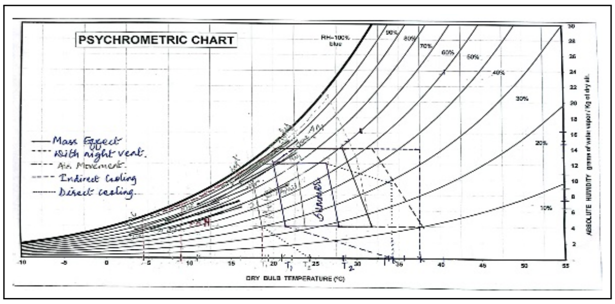

Figure 7: Bioclimatic Chart of Nagarkot

4.4 Data from Site Visit

A field visit was carried out in the 3 hotels on 2nd and 3rd July, 2022. A detailed interview was conducted with the respective technical personnel followed by a site inspection. As per the interview conducted at the site, there were issues/complaints regarding room heating during the winter seasons in all 3 hotels and as per the electricity bills collected, the bills spiked up during the winter season significantly which indicated the use of electricity mainly for heating.

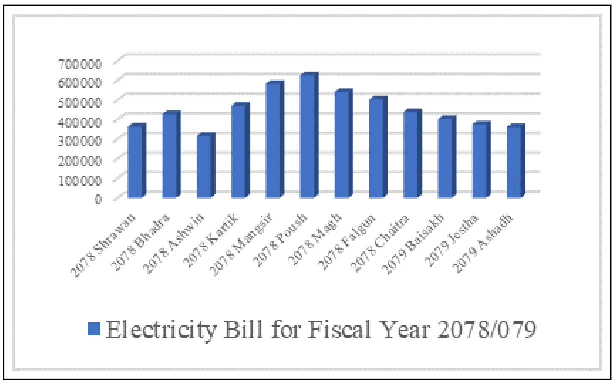

Figure 8: Electricity Bill Details for Fiscal Year 2078/079 (Club Himalaya)

5. Analysis And Findings

5.1 Base Case Model/Input

As all the hotel rooms are oriented in East/ North-East Direction, a Standard room sample from each hotel was considered, for the energy simulation part. All the standard rooms of three hotels are provided with a Flat Screen TV, Free Wifi, Coffee Maker, Hair Dryer, Private Balcony, and Mini Fridge (Except in Club Himalaya). The standard room size for Hotel Mystic Mountain is 8.25 m x 4.35 m x 2.55 m, for Club Himalaya is 5.40 m x 3.60 m x 2.55 m, and for Hotel Country Villa is 6 m x 3 m x 2.55 m. The input parameter considered in ECOTECT Energy Modeling for the base case as well as the various test scenarios are as follows:

- Clothing (Clo) = 1.00
- Humidity (%) = 50
- Air Speed (m/s) = 0.5
- Lighting Level (Luc) = 400
- No. of People = 2
- Activity = Resting (45 KW)
- Sensible Heat Gain (W/m2) = 5
- Latent Heat Gain (W/m2) = 2
- Air Change Rate (ACH) = 1
- Wind Sensitivity (ACH) = 0.5
- Type of Active System = Mixed Mode
- Efficiency (%) = 95
- Upper Band Comfort Level (°C) = 26
- Lower Band Comfort Level (°C) = 18

The thermal properties of the base case model (For Hotel Mystic Mountain, Club Himalaya and Hotel Country Villa) are as per table 1, 2 and 3.

Table 1: Thermal Properties of Base Case (Hotel Mystic Mountain)

Element	Materials/ width	Sp heat (J/Kg.K)	Thermal conductivity (W/m.k)
Wall	Plaster(10 mm) Brick(225 mm) Plaster (10 mm)	1088 836 1088	0.431 0.711 0.431
Door	Glass (10 mm)	836.80	1.046
Window	Glass(6 mm)	836.80	1.046
Floor	Concrete (150 mm) Parquet (25 mm)	656.90 2385.00	0.753 0.209
Ceiling	Concrete(150 mm) Screed(25 mm)	656.90 656.90	0.753 0.209
Main Door	Wood (40 mm)	2385.00	0.209

Table 2: Thermal Properties of Base Case (Club Himalaya)

Element	Materials/ width	Sp heat (J/Kg.K)	Thermal conductivity (W/m.k)
Wall	Plaster(10 mm) C. block (110 mm) Plaster (10 mm)	1088 836 1088	0.431 0.335 0.431
Door	Glass (10 mm)	836.80	1.046
Window	Glass(6 mm)	836.80	1.046
Floor	Concrete (150 mm) Parquet (25 mm)	656.90 2385.00	0.753 0.209
Ceiling	Concrete(150 mm) Screed(25 mm)	656.90 656.90	0.753 0.209
Main Door	Wood (40 mm)	2385.00	0.209

Table 3: Thermal Properties of Base Case (Hotel Country Villa)

Element	Materials/ width	Sp heat (J/Kg.K)	Thermal con. (W/m.k)
Wall	Plaster(10 mm) Brick(225 mm) Plaster (10 mm)	1088 836 1088	0.431 0.711 0.431
Door	Glass (10 mm)	836.80	1.046
Window	Glass(6 mm)	836.80	1.046
Floor	Concrete (150 mm) Parquet (25 mm)	656.90 2385.00	0.753 0.209
Ceiling	Concrete(150 mm) Screed(25 mm)	656.90 656.90	0.753 0.209
M Door	Wood (40 mm)	2385.00	0.209

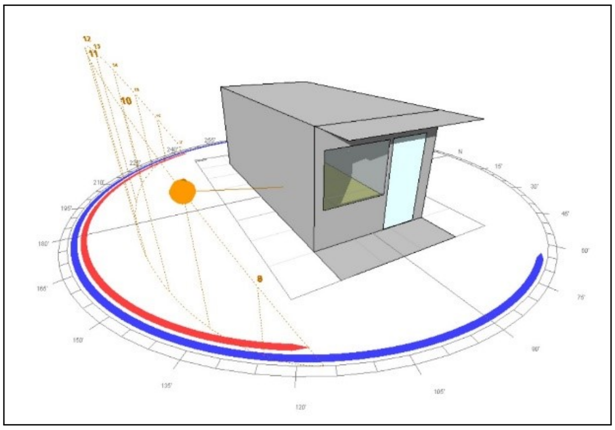

Figure 9: Base Model - Hotel Country Villa (Standard Room isolated for Modeling)

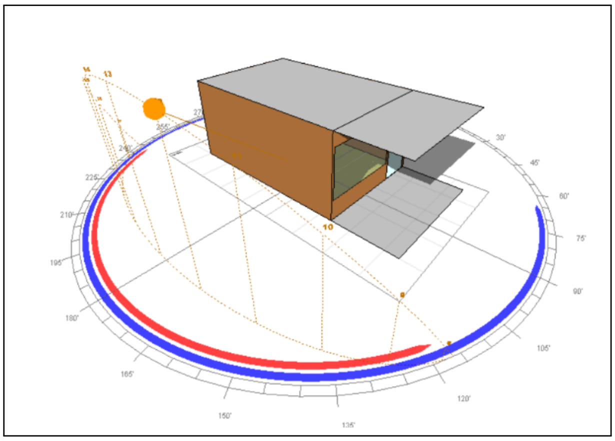

Figure 10: Base Model - Club Himalaya (Standard Room isolated for Modeling)

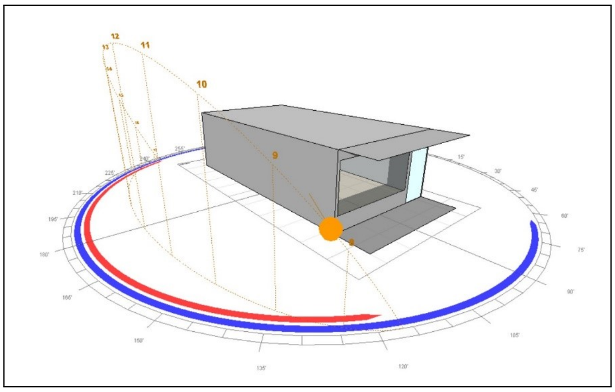

Figure 11: Base Model - Hotel Mystic Mountain (Standard Room isolated for Modeling)

5.2 Test Scenarios

With reference to the climatic condition of Nagarkot, various test scenarios were considered for all the three hotels with main focus on Passive Design Strategies (modification of the existing building envelope). The considered test scenarios are listed below:

i) Test Scenario 1 (S1) – Cavity Wall (50 mm Cavity)

ii) Test Scenario 2 (S2)– Cavity Walls with Extruded Polystyrene Board Insulation (50 mm Width)

iii) Test Scenario 3 (S3) – Cavity Wall (50 mm Cavity) with Low-E Double Glazed Aluminum Framed Openings

iv) Test Scenario 4 (S4) - Cavity Walls with Extruded Polystyrene Board Insulation (50 mm Width) with Low-E Double Glazed Aluminum Framed Openings

5.3 Proposed Scenarios Analysis/ Comparison

To assess the variation between energy consumption before and after the different suggested scenarios, the base model must first be examined to confirm that it accurately represents the overall building performance. As per the discussion with the Hotel Management/ Maintenance Team, the Collected electricity bill details, and the base model simulation, a substantial amount of energy is being used during the winter season for heating purposes. The overall outcome/ comparison of the Heating Load of the base case and various test scenarios for Hotel Mystic Mountain, Club Himalaya and Hotel Country Villa are as per table no. 4, 5, and 6. A decrease in heating load can be seen up to 52.57% in Hotel Mystic Mountain, a decrease in heating load can be seen up to 38.47% in Club Himalaya and Decrease in heating load can be seen up to 54.76% in Hotel Country Villa. As per the comparison of the various test scenarios, the introduction of Cavity Walls, XPS Insulation and Low-E Glazing reduces the heating and cooling load drastically, improving the overall thermal comfort of the rooms. The introduction of the discussed intervention will also reduce the load on the existing HVAC System further reducing the overall maintenance cost as well.

Table 4: Annual Heating Load Comparison in kWh (Hotel Mystic Mountain)

Base Case	S1	S2	S3	S4
4152	2529	2094	1969	1990
Reduction %	39.08	49.56	52	52.06

Table 5: Annual Heating Load Comparison in kWh (Club Himalaya)

Base Case	S1	S2	S3	S4
2430	1720	1715	1502	1495
Reduction %	29.2	29.4	39.19	38.47

Table 6: Annual Heating Load Comparison in kWh (Hotel Country Villa)

Base Case	S1	S2	S3	S4
2280	1070	1097	1033	1034
Reduction %	53.06	51.88	54.67	54.66

6. Conclusion

Hotel sector is a major energy consumer. Hotels are open all day, every day, and they must deliver a top-notch service whether there is just one visitor or a packed house. For our case, three reputed hotels in Nagarkot region in Nepal was considered for the study. The study was carried out via Questionnaire Survey/ Interview and Energy Modeling by means of ECOTECT SOFTWARE. Considering the availability of Materials in the market and practicality, four different test scenarios were tested to obtain the best energy optimization option. The various options being introduction are Cavity Walls, Insulation Systems, Double Glazed Low – E Windows and their combinations. Savings in heating and cooling load up to 54.67% and 58.85% could be achieved. Considering all the options, practicality, finances implementation of Cavity Walls would be the best viable option to obtain better energy optimization results in case of new as well as existing hotels in Nagarkot Region. As we are focusing on the Passive Design Strategies to reduce the heating/ cooling load, further research with focus on Active Heating/ Cooling System is required along with focus on energy consumption in the Food and Beverage Department which will definitely reduce energy cost greatly.

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References

[1] Susanne Bodach, Werner Lang, and Thomas Auer. Design guidelines for energy-efficient hotels in nepal. *International Journal of Sustainable Built Environment*, 5(2):411–434, 2016.

[2] Arvind Upadhyay and Celine Vadam. The role of energy consumption in hotel operations. In *Proceedings of the 22nd International Annual EurOMA Conference, Neuchatel, Switzerland*, pages 1–10, 2015.

[3] Xia Wang, Wei Feng, Weiguang Cai, Hong Ren, Chao Ding, and Nan Zhou. Do residential building energy efficiency standards reduce energy consumption in china?–a data-driven method to validate the actual performance of building energy efficiency standards. *Energy Policy*, 131:82–98, 2019.

[4] Patrycjusz Zarëbski, Jacek Borzyszkowski, and Mirosław Marczak. Sustainable development and tourism. example of investments connected with the installation of solar collectors in seaside lodging facilities. *Rocznik Ochrona Środowiska*, 17, 2015.

[5] Tawfeeq Wasmi M Salih and Lamyaa Abd Alrahman Jawad. Evaluating the thermal insulation performance of composite panels made of natural luffa fibres and urea-formaldehyde resin for buildings in the hot arid region. *Advances in Building Energy Research*, pages 1–15, 2022.