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# Impact of Occupant Behaviour on Energy Efficiency in Residential Buildings: A Case Study of Biratnagar, Nepal

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**Abstract**

Buildings are a major contributor to energy use and environmental impact since they require energy for lighting, heating, cooling, and other appliances. Building energy use contributes significantly to global consumption of energy and emission of greenhouse gases. Building energy footprint reduction initiatives are crucial for attaining sustainability and combating climate change. This paper uses a case study that is specifically focused on Biratnagar to examine the considerable but frequently underappreciated impact of occupant behaviour on energy efficiency within residential buildings. The Terai Region of Nepal is the warmest part of the country, with typical summer temperatures easily exceeding 35℃, which makes the atmosphere there exceedingly difficult for those who live there. The study takes a comprehensive approach, combining qualitative and quantitative techniques to examine how occupant behaviour affects variations in energy use in residential environments. The results highlight how occupant behaviour has a significant impact on energy efficiency and estimate the amount of energy saved when behavioural changes are adopted among occupants of the building. Consumption of heating, cooling, lighting, and appliances varies greatly depending on daily routines and personal preferences. Additionally, reducing energy waste depends heavily on awareness and expertise of energy-saving techniques. A questionnaire survey of 25 houses was carried out in residential area of Biratnagar among which detail energy survey of five houses was performed. The results from the survey was fed as input in the energy modelling software, Autodesk Ecotect, for evaluating the amount of energy saved when improved energy behaviours are shown by the occupants. A significant decrease in electrical energy consumption of the five case study buildings was observed when the base case scenario and optimized case scenarios were compared. A reduction of 15.83%, 9.69%, 12.19%, 10.98% and 12.41% was observed among the five case study buildings respectively.

**Keywords**

Occupant Behaviour, Residential Buildings, Energy Consumption, Energy Modelling, Ecotect, Cooling Load

## 1. Introduction

One of the main causes of global warming is urbanization. It uses more than 40% of global energy and emits as much as one-third of global greenhouse gas, both in developed and developing countries [1]. A recent report from Intergovernmental Panel on climate change (IPPC) predicts that the surface temperature of Earth during the 21st century is likely to rise a further 0.3 to 1.7 °C (0.5 to 3.1 °F) for their lowest emissions scenario and 2.6 to 4.8 °C (4.7 to 8.6 °F) for the highest emissions [2] . Buildings are a major contributor to energy use and environmental impact since they require energy for lighting, heating, cooling, and other appliances. Building energy use contributes significantly to global consumption of energy and emission of greenhouse gases. Energy consumed in various sectors has led to the overuse of non-renewable resources and eventually affected the environment. The CO2 emissions have increased due to excessive consumption of energy. Among all other sectors, buildings consume the maximum amount of the world's energy. Various factors affect the energy consumption in a building. The energy consumption in a building can be reduced by numerous measures like improvement in materials of the building envelope, adopting new construction technology, and more. The Terai Region of Nepal is the warmest part of the country, with typical summer temperatures easily exceeding 35°C, which makes the atmosphere there exceedingly difficult for those who live there. The summer season lasts six months in the Terai region of Nepal, from Baisakh to Ashoj, making it difficult for the locals to endure the heat inside the structures there.

The goal is to discuss a problem that is specifically related to human behavior toward the usage of electrical appliances and their operation schedules. It presents a general overview of the behavioral habits of occupants in residential buildings. A change in usage patterns can result in saving energy in a considerable amount. To capture occupants' actual behavior in buildings and identify energy-wasteful behavior based on field data, a questionnaire survey was carried out in residential buildings located in Biratnagar, Nepal.

This paper provides an overview of different ways to optimize and lower the energy use in a residential building, which will in turn motivate Energy Efficient Building Designs in Nepal. Overall, reducing energy consumption, limiting environmental impact, and enhancing occupant quality of life all depend on an understanding of how occupant behavior affects energy efficiency in residential buildings. To create a more sustainable future, this field of study can influence regulations, improve building design techniques, and enable building occupants to make energy-conscious decisions.

## 2. Methodology

The methodology used in this paper is based on literature reviews and questionnaire surveys. It uses mixed-methods methodology, combining qualitative and quantitative approaches. In order to learn more about occupant behavior, lifestyle choices, awareness of energy-saving techniques, and preferences for indoor comfort, surveys and interviews are done.

A questionnaire survey of 25 houses was carried out in residential area of Biratnagar among which detail energy survey of five houses was performed. The five houses were selected in a manner so that it includes the houses of all types i.e. single-storeyed and multi-storeyed. Also, low-income families and high-income families both aspects were taken into consideration to determine the sample. The results from the survey was fed as input in the energy modelling software, Autodesk Ecotect, for evaluating the amount of energy saved when improved energy behaviours are shown by the occupants.

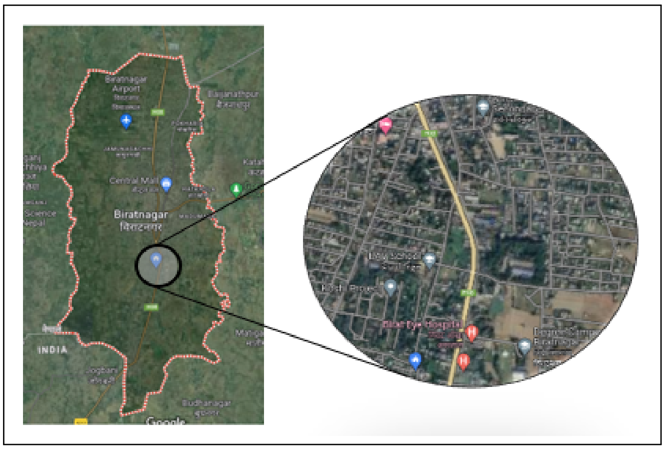


**Figure 1:** Case study area
(Source: https://www.google.com/maps/place/Biratnagar)

### 2.1 Climatic Analysis

Biratnagar is a city in southern Nepal. It is the administrative hub of Province No. 1 and the second-largest city in Nepal. Biratnagar, which is located in the Morang District, is a significant regional industrial, commercial, and educational hub. It is located at latitude 87°16', longitude 26°26', and elevation of 80m[3].

A bioclimatic chart, also known as a comfort chart or climate chart, is a graphical illustration which helps in illustrating the connection between different climatic parameters and environmental comfort or conditions for humans. Biratnagar is categorized as having a mild, moderate climate, with most of the rainfall occurring in the summer and very little in the winter. The mean annual temperature is 25°C, and there is 1737 millimeters of rain on average each year.

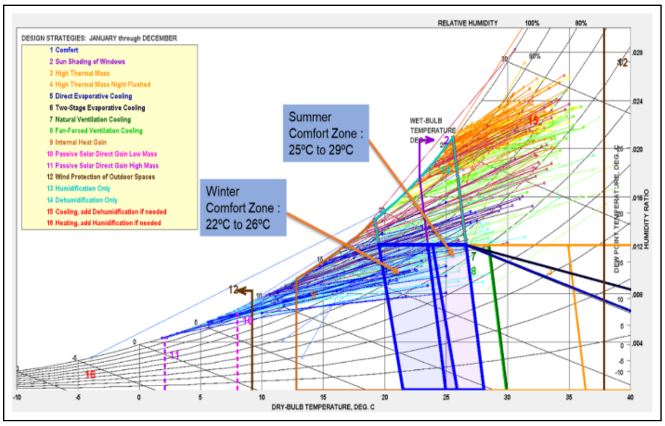


**Figure 2:** Bioclimatic Chart of Biratnagar, Nepal ( As extracted from Climate Consultant Software)

## 3. Literature Review

The aim of this research is centered on the notion that alterations in occupant consumption habits can significantly reduce the quantity of energy used by a building. When it comes to building energy efficiency, the shift in occupant behavior has not generally been the subject of extensive research. This is a low-cost investment strategy in which energy consumption in a building can be reduced simply by changing the behavior of the structure's residents. A building is energy efficient "if it delivers more services for the same energy input, or the same services for less energy input" [4].

Occupant behavior, which can be represented by occupancy and the operation of various devices and systems, including window, blind, lighting, heating, ventilation, and air conditioning systems, is characterized by human-building interactions that are related to energy use. In buildings, improved occupant behavior can have a variety of beneficial consequences on various building performance, energy efficiency, and sustainability factors.

The benefits of enhanced occupant behaviour in buildings are wide-ranging and include everything from cost and energy savings to increased indoor comfort, health, and environmental sustainability. A combination of education, communication, technological advancements, and supportive building design can be used to promote responsible behaviour.

On the one hand, occupant behavior is influenced by external factors such as culture, economy, and climate, as well as internal factors such as individual comfort preferences, physiology, and psychology; on the other hand, occupant behavior drives occupants' interactions with building systems, which strongly influence the building operations and, as a result, energy use/cost and indoor comfort, which in turn influences occupant behavior, creating a closed loop[5] .

In this study, Ecotect is used for energy analysis of buildings and evaluating energy consumption. It is a comprehensive concept-to-detail sustainable building design tool software. It provides a broad variety of simulation and building energy analysis capabilities that can enhance both the efficiency of already-existing structures and the performance of future building designs. With the use of this application, architects and builders may imagine and model how a structure will function in its surroundings.

## 4. Energy Modelling and Simulation

The process of developing a model by the use of computer software to perform the energy analysis of the building is termed as building energy modelling. It helps in evaluating the overall energy consumption of the building including heating loads, cooling loads and other loads. It aids in optimizing the energy performance of the building by providing best energy-saving, cost-saving and carbon reduction options. The questionnaire survey was carried out in residential area of Biratnagar. It was carried out in 25 houses among which detail survey of 5 houses was carried out. The measurements of plan along with energy consumption data was noted down during the detail survey.

The energy behaviour of occupants can highly affect the total energy consumption in a building. The energy survey of electrical appliances along with their operation schedules was noted down. The operation hours of these appliances can be reduced by having a concerned behaviour of occupants. The old electrical appliances could be replaced by energy-star rating appliances which in turn can reduce the energy consumption in a building. The cases along with improved behaviour were developed and modelled in the energy analysis software.

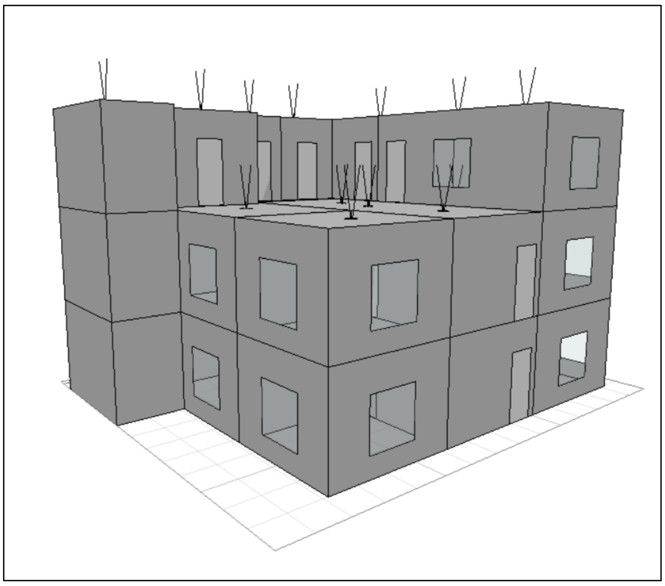

**Figure 3:** Case study building

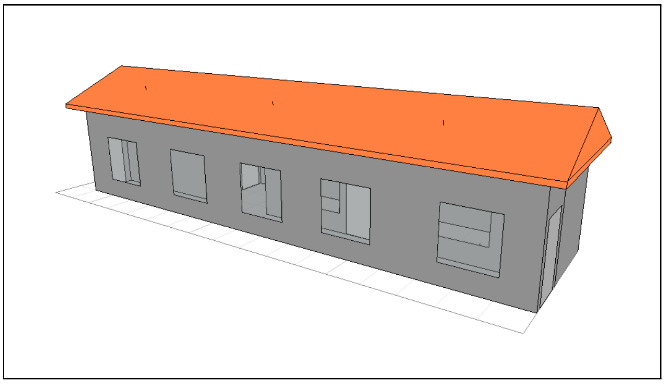

**Figure 4:** Case study building

An example of a case study building that has been modeled into the energy analysis program is the building model shown above. According on the information provided by the respondents during the questionnaire survey, the base case software inputs were entered. Since the building's air leaks were more noticeable in the base scenario, the infiltration rate had a higher value. This was enhanced for the best-case scenario to increase the building's airtightness. An airtight structure improves the effectiveness of the installed air-conditioning equipment. Below is a presentation of the program inputs for optimum cases.

**Table 1:** Software parameters

| Inputs | Value | Remarks |
|---|---|---|
| No. of occupancy | 1-3 | Varies |
| Humidity | 60% | Indoor |
| Infiltration rate | 0.5 ACH (well-sealed) | Mixed-mode ventilation |
| | 1 ACH (Average) | Natural ventilation |
| Air speed | 0.3 m/s (Barely noticeable) | |
| | 0.5 m/s (Pleasant breeze) | |
| Comfort range | 22°C - 29°C | Natural Ventilation |
| HVAC setting | 22°C - 26°C | |

The inputs in the highlighted cells have been intervened in the improved case scenario.

## 5. Results and Discussion

The questionnaire study of the 25 households contributed to our understanding of the fundamental energy behaviour of occupants inside a residential building. It provides qualitative results based on the feedbacks provided by the occupants. There is a possibility of promoting energy efficiency among the occupants by providing them with proper guidance and arranging energy awareness programs for the local people. According to a research, it was concluded that energy awareness campaigns can definitely be a worthwhile investment [6] .

The percentage reduction in household energy use was computed using a case study of five residential structures. The findings indicate that in the optimum circumstances, a reduction of between 10% and 15% can be seen. By implementing some of the behavioural adjustments in the routine operation of the air conditioners, a considerable drop in the cooling load was also noticed in the optimal circumstances. By changing the thermostat's default setting and examining the room's air leaks, a reduction in cooling loads of about 30–35% was observed.

Numerous researches have been carried out regarding to evaluation of amount of energy saved when some improved behavioural changes are adopted among the occupants of the buildings. A research result shows that the annual electricity usage would decrease by 39% if occupancy patterns and light schedules were matched, and the A/C thermostat was set to 24°C rather than 22°C [7]. In addition, for residential buildings, the energy-saving potential of occupant behavior in building energy performance is between 10% and 25%, and 5% to 30% for commercial buildings [8] . According to a survey, high-income and highly educated households have a tendency to buy energy-efficient appliances, but they also use more energy than other homes do [9] . Also, vernacular homes encouraged households to maintain their traditional daily routines associated with sustainable, energy-saving activities.

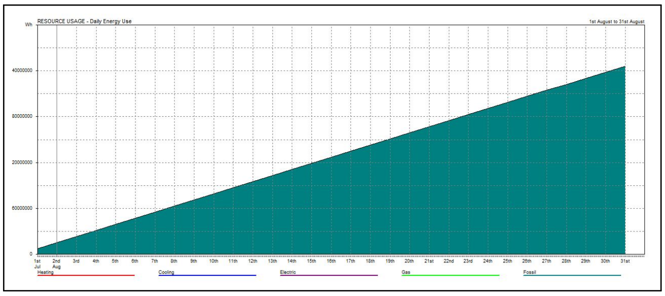

**Figure 5:** Total electricity consumption chart from Ecotect

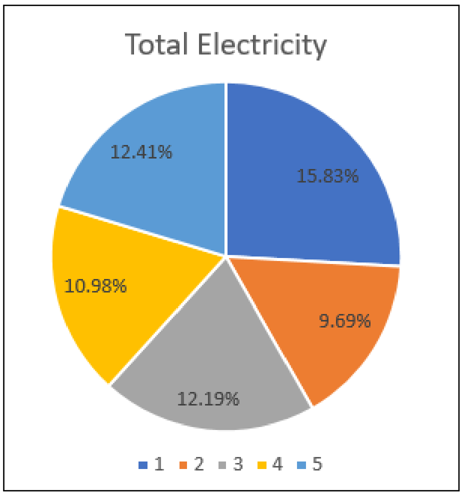


**Figure 6:** Reduction in total electricity consumption in case buildings for peak summer month - August

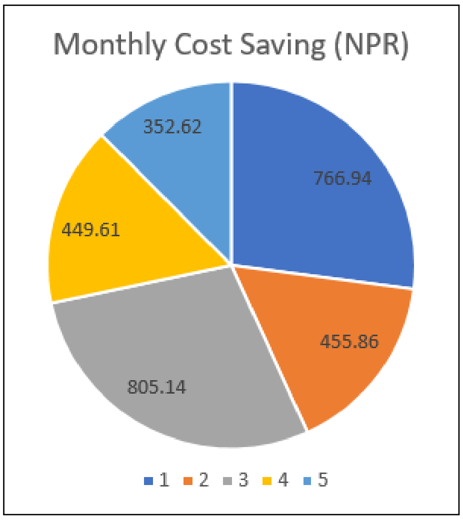


**Figure 7:** Total cost savings in case buildings for peak summer month - August

A significant decrease in electrical energy consumption of the five case study buildings was observed when the base case scenario and optimized case scenarios were compared. A reduction of 15.83%, 9.69%, 12.19%, 10.98% and 12.41% was observed among the five case study buildings respectively. This result also validates with the researches of other researchers that have been performed. The total operational hours of electrical appliances and lights were reduced for developing the optimized case scenario which provided us with the following results as shown in the chart.

In accordance with the units saved monthly in the optimized cases, a certain amount of cost saving can also be evaluated based on the above results. Monthly cost savings of NPR 766.94, NPR 455.86, NPR 805.14, NPR 449.61 and NPR 352.62 can be calculated from the units saved for the five case study buildings respectively.

The cooling loads were also reduced in the optimized case scenario through interventions in the operating temperature of air-conditioning units and the infiltration rates in the building envelope. A reduction of 35.26%, 37.80%, 35.64% and 30.56% was observed when the base case scenario and optimized case scenarios were compared based on the results provided by the energy modelling software, Ecotect.

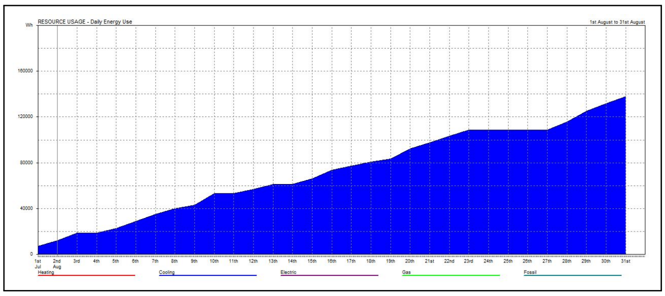

**Figure 8:** Cooling load chart from Ecotect

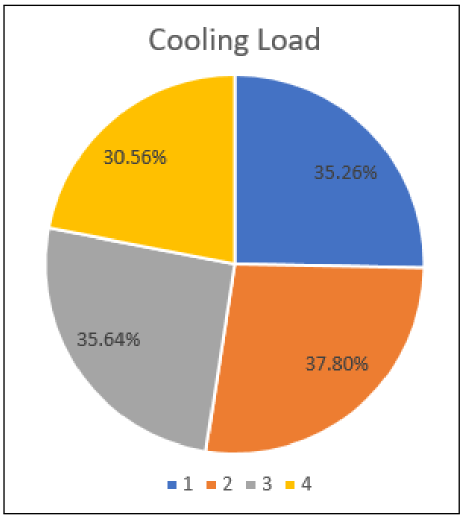


**Figure 9:** Reduction in total cooling loads in case buildings for peak summer month - August

## 6. Conclusion

Energy consumed in a household can be controlled when occupants show concerned behaviour when it comes switching off lights and other electrical appliances when not in use or when no one is present. In a research it has been stated that vernacular homes encouraged households to maintain their traditional daily routines associated with sustainable, energy-saving activities [9] . Occupants often operate the AC unit at the preset setting. The default temperature can be changed to 22°C, which will eventually result in a significant energy savings. Therefore, while comparing the base case and optimized case scenarios, a considerable amount of reduction in cooling loads can be observed when the thermostat temperature was changed from 16°C - 20°C to 22°C - 26°C.

Lights and other electrical equipment were also found to be using more energy than usual. Reduced electrical appliance idle time results in significant energy savings. It is recommended to unplug electrical equipment after usage to reduce the amount of energy used while they are not in use. A building's thermostat temperature is extremely important for energy conservation.

In summary, the Biratnagar case study emphasizes the importance of the occupant behaviour in determining energy efficiency outcomes in residential structures. It urges stakeholders to consider inhabitants as active participants in the energy conservation equation rather than just passive users, calling for a paradigm shift in the way we think about sustainability. We can pave the path for more sustainable, energy-efficient home environments not only in Biratnagar but in urban places all over the world by raising awareness, offering resources for energy-conscious decision-making, and creating conditions that encourage responsible behaviour. This study is a testament to the ability to address the urgent global concerns of energy efficiency and environmental stewardship by fusing architectural innovation with informed, sustainable living habits.

## References


[1] Pekka Huovila, Mia Ala-Juusela, Luciana Melchert, Stéphane Pouffary, Chia-Chin Cheng, Diana Ürge-Vorsatz, Sonja Koeppel, Niclas Svenningsen, and Peter Graham. Buildings and climate change: Summary for decision-makers. 2009.

[2] RK Pachauri and L Mayer. Climate change 2014: Synthesis report; intergovernmental panel on climate change: Geneva, switzerland, 2015. *Google Scholar*.

[3] Wikipedia. https://en.wikipedia.org/wiki/biratnagar. 2004.

[4] Antonio Martínez-Molina, Isabel Tort-Ausina, Soolyeon Cho, and José-Luis Vivancos. Energy efficiency and thermal comfort in historic buildings: A review. *Renewable and Sustainable Energy Reviews*, 61:70–85, 2016.

[5] Da Yan, Tianzhen Hong, Bing Dong, Ardeshir Mahdavi, Simona D'Oca, Isabella Gaetani, and Xiaohang Feng. Iea ebc annex 66: Definition and simulation of occupant behavior in buildings. *Energy and Buildings*, 156:258–270, 2017.

[6] Okatoseng Tsametse Masoso and Louis Johannes Grobler. The dark side of occupants' behaviour on building energy use. *Energy and buildings*, 42(2):173–177, 2010.

[7] Adil Al-Mumin, Omar Khattab, and Gopisetti Sridhar. Occupants' behavior and activity patterns influencing the energy consumption in the kuwaiti residences. *Energy and buildings*, 35(6):549–559, 2003.

[8] Yan Zhang, Xuemei Bai, Franklin P Mills, and John CV Pezzey. Rethinking the role of occupant behavior in building energy performance: A review. *Energy and Buildings*, 172:279–294, 2018.

[9] Ebru Ergöz Karahan, Özgür Göçer, Kenan Göçer, and Didem Boyacıoğlu. An investigation of occupant energy-saving behavior in vernacular houses of behramkale (assos). *Sustainability*, 13(23):13476, 2021.