TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

THESIS NO: 079MSEEB005

BEHAVIOR VS. DESIGN:

UNDERSTANDING THE IMPACT OF OCCUPANT ACTIONS ON OFFICE BUILDING-A CASE STUDY OF CAAN HEAD OFFICE BUILDING

BY

BASHANTA BHATTARAI

A THESIS REPORT

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN ENERGY EFFICIENT BUILDINGS

DEPARTMENT OF ARCHITECTURE

LALITPUR, NEPAL

February, 2025

COPYRIGHT

The author has agreed that the library, Department of Architecture, Institute of Engineering, Pulchowk Campus, may make this thesis freely available for inspection. Furthermore, the author has agreed that the permission for extensive coping of this thesis for scholarly purpose may be granted by the professor, who supervised the thesis work recorded or, in his absence, by the head of Department or the concerning M.Sc. Program Coordinator or Dean of Institute in which the thesis work was done. It is understood that, the recognition will be given to the author of this thesis and to the Department of Architecture, Engineering Institute of Engineering, Pulchowk Campus in any use of the material of this thesis. Copyright or publication or other use of the material of this thesis for financial gain without approval of Department of Architecture, Institute of Engineering, Pulchowk Campus and author's permission is prohibited.

Request for permission to copy or to make any use of the material in this thesis in whole or part should be addressed to:

....

Head of Department of Architecture

Institute of Engineering

Central Campus, Pulchowk

Lalitpur, Nepal

DECLARATION

I hereby declare that the thesis entitled " **Behavior vs. Design: Understanding the Impact of Occupant Actions on Office Building - A Case Study of CAAN Head Office Building** " has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree. I state that this thesis is result of my own independent work/investigation, except were otherwise stated. I hereby give consent for my thesis, if accepted, to be available for photocopying and understand that any reference to or quotation from my thesis will receive an acknowledgement.

Bashanta Bhattarai

079/MSEEB/005

April,2025

TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

DEPARTMENT OF ARCHITECTURE

The undersigned certify that they have read, recommended to the Institute of Engineering for acceptance, the thesis entitled "**Behavior vs. Design: Understanding the Impact of Occupant Actions on Office Building- A Case Study of CAAN Head Office Building**" submitted by **Mr. Bashanta Bhattarai (079/MSEEB/005)** in partial fulfillment of the requirements for the award of the degree of Master of Science in Energy Efficient Buildings.

Supervisor,
Dr. Ajay Kumar Jha
Professor
Department of Mechanical and Aerospace Engineering,
IOE, Pulchowk Campus

External Jury,
Dr. Malesh Shah,
Assistant Professor
Department of Mechanical Engineering,
Kathmandu University

Dr. Bijay Singh,
Co-ordinator
MSEEB(Masters in Energy Efficient Buildings
Department of Architecture
IOE, Pulchowk Campus

Institute of Engineering
Department of Architecture
Pulchowk, Campus

Date April 2025

ACKNOWLEDGEMENT

Completing this thesis work has been a wonderful and often overwhelming experience. Many people had some particular importance during the thesis preparation, for their suggestions and work together but also for friendship and patience. I will however restrain this section to academic acknowledgments related to the thesis as a whole.

I am deeply indebted to Associate Professor **Dr. Ajay Kumar Jha**, who was the mentor of this thesis. His suggestions, opinions, discussions (sometimes about topics far from the heart of this thesis) are very useful and much appreciable.

I would also like to convey my sincerest thanks to Prof. **Dr. Sanjay Uprety** for his valuable inputs and suggestions during the course of my research. I would also like to thank Prof. Dr. Bijay Singh, Dr. Nawaraj Bhattarai, Associate Prof. Shree Raj Shakya, **Er. Sunil Kumar Kushwaha** (Director of Electromechanical Department), **Er. Nal Bikram Thapa** (Manager of Aerodrome Engineering Department) and my family and friends for all their help, support, interest and valuable hints during the entire thesis work, report writing and stimulating suggestions and encouragement in this research report writing.

Thanks to CAAN (Civil Aviation Authority of Nepal) and Associated Departments from where I received the data for the thesis work.

Finally, I would like to thank my friends. Their camaraderie is very significant.

Bashanta Bhattarai

079/MSEEB/005

ABSTRACT

This study examines the impact of occupant behavior on electricity consumption discrepancies within the Civil Aviation Authority of Nepal (CAAN) Head Office Building. By comparing theoretical energy consumption—based on design load and standard working hours—with actual energy usage from TOD meter bills, the research identifies inefficiencies primarily driven by behavioral factors and outdated systems. A mixed-methods approach, combining questionnaire-based behavioral analysis with quantitative energy audits, revealed key contributors to excess energy consumption, including policy unawareness (78% of employees), standby power waste (21,348 kWh annually), HVAC overuse, and inefficient lighting practices.

The study introduces Behavioral Adjustment Factor (BAF) and Standby Load Factor (SLF) metrics to quantify inefficiencies, demonstrating that targeted interventions can significantly reduce energy waste. Policy dashboards and smart power strips emerged as the most effective solutions, achieving a 32% reduction in policy-related waste and a 75% reduction in standby power losses, respectively. A cost-benefit analysis confirmed the financial viability of these measures, with an estimated NPR 806,088 in annual savings and an average payback period of 1.7 years.

The findings validate the Energy Efficiency Gap Theory, highlighting the disconnect between employee attitudes and actual energy-saving behaviors. Furthermore, the study emphasizes the superiority of automated solutions over awareness-based interventions. A strategic implementation roadmap is proposed, prioritizing short-term behavioral changes and policy enforcement, followed by medium-term system upgrades and long-term integration of smart building technologies.

This research offers a replicable framework for institutional buildings in Nepal and similar contexts, demonstrating that a combination of automation, policy reinforcement, and cultural shifts can lead to significant energy savings. Future research should explore real-time energy monitoring, AI-driven predictive controls, and renewable energy integration for enhanced efficiency.

ACKNOWLEDGEMENT

Completing this thesis work has been a wonderful and often overwhelming experience. Many people had some particular importance during the thesis preparation, for their suggestions and work together but also for friendship and patience. I will however restrain this section to academic acknowledgments related to the thesis as a whole.

I am deeply indebted to Associate Professor **Dr. Ajay Kumar Jha**, who was the mentor of this thesis. His suggestions, opinions, discussions (sometimes about topics far from the heart of this thesis) are very useful and much appreciable.

I would also like to convey my sincerest thanks to Prof. **Dr. Sanjay Uprety** for his valuable inputs and suggestions during the course of my research. I would also like to thank Prof. Dr. Bijay Singh, Dr. Nawaraj Bhattarai, Associate Prof. Shree Raj Shakya, **Er. Sunil Kumar Kushwaha** (Director of Electromechanical Department), **Er. Nal Bikram Thapa** (Manager of Aerodrome Engineering Department) and my family and friends for all their help, support, interest and valuable hints during the entire thesis work, report writing and stimulating suggestions and encouragement in this research report writing.

Thanks to CAAN (Civil Aviation Authority of Nepal) and Associated Departments from where I received the data for the thesis work.

Finally, I would like to thank my friends. Their camaraderie is very significant.

Bashanta Bhattarai

079/MSEEB/005

LIST OF FIGURES

LIST OF TABLES

Contents

ABBREVIATIONS

ABM -Agent-Based Modeling

AEPC -Alternative Energy Promotion Center

BAF -Behavioral Adjustment Factor

BMS -Building Management System

CAAN -Civil Aviation Authority of Nepal

DHM -Department of Hydrology and Meteorology

EVI -Environmental Vulnerability Index

EUI -Energy Usages Intensity

HVAC -Heating, Ventilation, and Air Conditioning

IEQ -Indoor Environmental Quality

IoT -Internet of Things

IOE -Institute of Engineering

IRR -Internal Rate of Return

KW -Kilowatt

kWh -Kilowatt-hour

SDG -Sustainable Development Goals

ToU -Time of Use

TOD -Time of the Day (Metering System)

UPS -Uninterruptible Power Supp

CHAPTER 1. INTRODUCTION

1.1 Background

The building sector is a cornerstone of global energy consumption, responsible for approximately 30% of total energy use and nearly 28% of energy-related carbon dioxide emissions(*World Energy Outlook*, 2021). In response to rising environmental concerns, energy-efficient buildings have emerged as a critical strategy for reducing energy demand and mitigating climate change. These buildings have advanced design principles and technologies, such as high-performance insulation, energy-efficient HVAC systems, and smart lighting, to optimize energy use while maintaining occupant comfort. However, achieving the intended energy performance in practice remains a challenge due to the influence of occupant behavior.

Occupant behavior refers to the range of actions, decisions, and habits of building users that directly affect energy consumption. According to (Hong et al., 2017), these behaviors encompass activities such as adjusting thermostats, operating lighting and HVAC systems, and using electrical appliances. While these actions may seem minor, their cumulative impact on energy use is substantial. For instance, studies suggest that occupant behavior can account for up to 30% of the variance in energy consumption within buildings, even those designed to be highly energy efficient (Azar & Menassa, 2012). This shows the critical need to incorporate behavioral analysis into energy performance evaluations.

Globally, the role of occupant behavior in energy efficiency has gained increasing recognition. Research highlights the disparity between predicted and actual energy consumption, often termed the "performance gap." (Yan et al., 2015a) argue that even the most sophisticated building technologies can fall short of their potential if occupants do not adopt energy-conscious behaviors. Examples of such behaviors include:

- Leaving lights on in unoccupied rooms
- Operating HVAC systems at full capacity irrespective of occupancy
- Using high-energy appliances during peak hours
- Ignoring opportunities to utilize natural lighting or ventilation

Addressing these behaviors involves a dual approach: technological interventions and behavioral strategies. Technological solutions, such as automated lighting systems, smart thermostats, and occupancy sensors, aim to minimize human error and improve energy efficiency passively. On the other hand, behavioral strategies, including energy awareness campaigns, real-time feedback systems, and incentive programs, actively encourage occupants to adopt more sustainable practices.

In the context of Nepal, the building sector is witnessing rapid growth, with a rising emphasis on sustainable and energy-efficient construction. The CAAN office building, located at Sinamangal is a government building (head office of Civil Aviation Authority of Nepal), is designed to meet energy performance standards, the building incorporates various energy-saving technologies. However, initial data indicates that its actual energy consumption is the predicted values, highlighting the impact of occupant behavior. This presents an opportunity to investigate how behavioral patterns influence energy use and identify interventions to optimize building performance.

Key Areas of Focus for the Study

This research aims to address the following key areas:

- Quantifying the Performance Gap: Assessing the discrepancy between predicted and actual energy consumption in the CAAN office building.
- Behavioral Analysis: Identifying specific occupant behaviors that contribute to increased energy use.
- Technological Integration: Evaluating the effectiveness of existing building technologies in mitigating the impact of occupant behavior.
- Behavioral Interventions: Proposing strategies to encourage energy-conscious behaviors, such as feedback systems and awareness programs.
- Policy Implications: Offering recommendations for building codes and energy management practices to incorporate behavioral considerations.

The relevance of this research extends beyond the local context. Understanding how occupant behavior influences energy consumption in energy-efficient buildings is crucial for bridging the performance gap globally. By focusing on the CAAN office building, this study aims to generate actionable insights that can be applied to similar buildings in Nepal and other developing countries. Additionally, the findings will contribute to the broader body of knowledge on sustainable building practices, emphasizing the importance of human factors in energy management.

Globally, addressing the performance gap in energy-efficient buildings is essential for achieving international climate goals, such as those outlined in the Paris Agreement. The findings of this study will provide valuable insights into how occupant behavior can be managed to enhance energy efficiency, contributing to the global effort to reduce greenhouse gas emissions. Locally, this research will support Nepal's commitment to sustainable development by improving the performance of energy-efficient buildings. The insights gained from the CAAN office building will serve as a model for future construction projects, promoting best practices in energy management and occupant engagement.

This study seeks to explore the intricate relationship between occupant behavior and energy consumption in energy-efficient buildings. Through a detailed analysis of the CAAN office building, it aims to develop practical strategies for optimizing energy use, ensuring that the benefits of sustainable building technologies are fully realized.

1.2 Introduction to study area

The building, located in Sinamangal, Kathmandu, serves as the head office of the Civil Aviation Authority of Nepal (CAAN).

Figure 1:Aerial View of Site (Source Google Earth

The site spans 15,375.60 sq.m. (30-3-2-1.11), with a total office building area of 9,205.12 sq.m. (18-1-2-2.08) and a total built-up area of 18,865.50 sq.m., including basements. The building is designed to accommodate administrative and operational activities, housing various office spaces, conference halls, meeting rooms, consultant offices, and several departmental sections.

Figure 2:CAAN New head office Building, Sinamangal (Source CAAN Report)

The building consists of 13 storeys, including three basements. The lower and middle basements provide parking facilities for 234 vehicles, while the upper basement is designated for office use. The ground floor, second floor, and third to eighth floors primarily serve office and administrative functions, with the ninth mezzanine floor included in the layout. The building is divided into three blocks: Block A extends up to the mezzanine floor, whereas Blocks B and C extend up to the fourth floor, covering their respective slabs. To facilitate vertical circulation, the building is equipped with three staircases and three lifts, ensuring efficient movement within the structure.

Kathmandu Valley, including Sinamangal, falls under the Cwa climate classification according to the Köppen climate classification system. This denotes a humid subtropical climate with a dry winter season. The region experiences hot summers, cool winters, and distinct monsoon precipitation patterns, influencing both thermal comfort and energy demand in buildings. The annual average temperature in Kathmandu is around 18°C, with summer temperatures rising to 30–32°C and winter temperatures dropping to as low as 2°C (Department of Hydrology and Metrology(DHM), 2021). The annual precipitation averages approximately 1400 mm, with more than 80% of rainfall occurring between June and September during the monsoon season (Karki, R. et al., 2017).

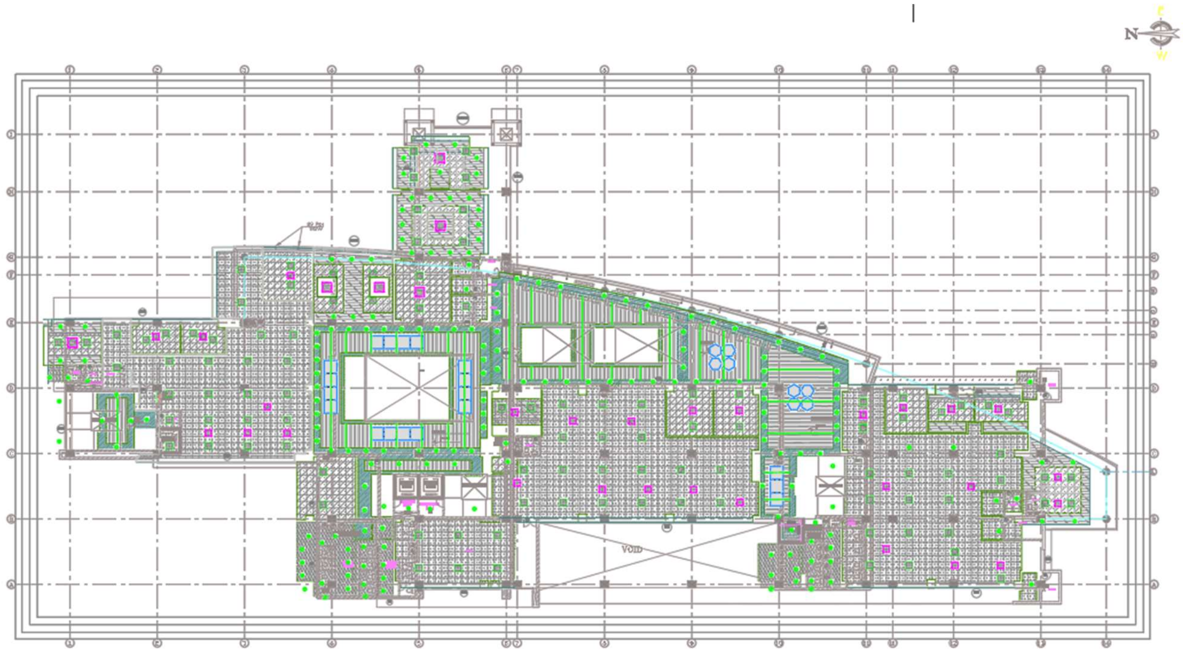


Figure 3: Typical Floor Plan

These climatic conditions have a direct impact on energy consumption patterns within office buildings. During winter, heating systems become essential to maintain indoor thermal comfort due to low nighttime temperatures. In contrast, during summer, the demand for air conditioning and ventilation systems rises significantly due to high daytime temperatures and humidity. The dry winter season, despite cooler temperatures, often leads to increased energy use for heating while simultaneously reducing the demand for dehumidification. The seasonal variations in temperature and humidity, combined with occupant behavior, contribute to fluctuations in energy use, particularly in the operation of HVAC systems, lighting, and electronic appliances. Furthermore, Kathmandu experiences frequent power fluctuations and load shedding, making energy-efficient building design and behavioral interventions critical in reducing unnecessary electricity consumption. Understanding these climatic parameters is essential for analyzing occupant behavior and its impact on electricity consumption and developing effective energy-saving strategies for office buildings.

1.3 Need and Importance of Research

Energy-efficient buildings are designed to minimize energy consumption, but their actual performance often deviates from expected efficiency due to occupant behavior. This research is essential in understanding and addressing this discrepancy, ensuring that energy-saving measures achieve their intended impact.

1.3.1 Impact on Energy Consumption and Efficiency

Building energy performance depends not only on design and technology but also on how occupants interact with energy systems. Inefficient behaviors such as leaving electrical appliances on, setting HVAC systems at extreme temperatures, or ignoring energy-saving opportunities contribute to unnecessary energy consumption. This research quantifies such behaviors and their impact, providing insights into strategies for improving energy efficiency.

1.3.2Addressing the Performance Gap

Despite advancements in energy-efficient technologies, many buildings exhibit a "performance gap"—the difference between expected and actual energy consumption. A major cause of this gap is user behavior. By analyzing occupant patterns and energy usage data, this research identifies key behavioral factors influencing electricity consumption and proposes interventions to minimize discrepancies.

1.3.3Relevance to Nepal's Energy Context

In Nepal, where electricity is primarily sourced from hydropower, inefficient energy use not only increases operational costs but also affects the sustainability of energy resources. Managing consumption through behavioral interventions can support national energy efficiency goals, reducing unnecessary demand and enhancing grid stability. This research aligns with Nepal's sustainable urban development policies by offering data-driven recommendations for optimizing energy use in office buildings.

1.3.4 Practical Applications

Findings from this study can guide policymakers, building managers, and energy professionals in developing targeted awareness programs, automated control strategies, and incentive-based systems to encourage energy-conscious behavior. Additionally, integrating behavioral insights into building management can enhance the effectiveness of smart technologies, ensuring that energy-efficient features function as intended.

By focusing on the role of occupant behavior in energy consumption, this research contributes to enhancing building efficiency, reducing operational costs, and supporting sustainability efforts. Its outcomes can serve as a basis for refining energy management strategies and achieving long-term reductions in electricity consumption.

1.4 Problem Statement

Despite significant advancements in the design and construction of energy-efficient buildings, a recurring issue persists: the gap between predicted and actual energy performance. This discrepancy, often referred to as the "**performance gap**" has been widely documented but remains insufficiently understood, particularly in the context of developing countries like Nepal. While technological innovations such as energy-efficient HVAC systems, advanced lighting, and automated controls are designed to optimize energy use, their effectiveness is frequently undermined by the unpredictable nature of occupant behavior.

Consequences Observed in the Investigation Area

In energy-efficient buildings, occupants play a crucial role in determining actual energy consumption. Studies have shown that occupant behavior, including habits like leaving lights on in unoccupied rooms or operating heating and cooling systems at full capacity, can lead to energy waste and diminished efficiency (Hong et al., 2017; O'Brien & Gunay, 2014). These behaviors result in several measurable consequences:

- Higher-than-expected energy bills: A direct financial impact on building operators and users
- Increased carbon emissions: Undermining efforts to reduce the building sector's environmental footprint
- Underperformance of advanced systems: Technologies that rely on user input, such as programmable thermostats or manual lighting controls, often fail to deliver optimal results due to improper usage.

In the CAAN office building, preliminary data reveal similar issues. Despite the implementation of advanced energy-saving technologies, the building's actual energy consumption exceeds design expectations. This observation highlights the critical influence of occupant behavior on energy performance.

1.5 Identified Research Gaps

Existing studies primarily focus on the technical performance of energy-efficient systems, leaving a significant gap in understanding the human factors that contribute to energy inefficiencies. Specific gaps include:

1. Quantitative Analysis of Occupant Behavior: Limited research quantifies how specific behaviors, such as adjusting thermostat settings or operating electronic devices, impact overall energy consumption.
2. Behavioral Patterns in Developing Countries: Most studies on occupant behavior and energy use are conducted in developed countries. The cultural, climatic, and socioeconomic conditions in developing nations like Nepal remain underexplored.
3. Effectiveness of Behavioral Interventions: There is insufficient evidence on the success of strategies like real-time feedback, awareness programs, and automated controls in modifying occupant behavior to align with energy efficiency goals.
4. Integration of Behavior into Energy Models: Current energy modeling practices often assume static usage patterns, ignoring the variability introduced by occupant actions. This leads to inaccuracies in energy performance predictions.

Alignment with Research Objectives and Questions

This research aims to fill these gaps by focusing on the following measurable variables:

- Energy consumption patterns: Analyzing discrepancies between predicted and actual usage.
- Specific occupant behaviors: Identifying and quantifying behaviors that contribute to energy inefficiencies.
- Effectiveness of interventions: Evaluating the impact of behavioral strategies, such as feedback systems, on energy use.

The study is guided by the following research questions:

- What is the discrepancy between the actual electricity consumption and design electricity consumption and what specific occupant behaviors most significantly impact energy consumption in commercial buildings?
- What interventions are most effective in reducing the performance gap?

By addressing these questions, the research will provide actionable insights for improving energy efficiency in buildings, particularly in the context of developing countries. This will not only enhance the operational performance of energy-efficient buildings but also contribute to broader sustainability goals.

1.6 Research Objectives

Energy-efficient buildings are designed to minimize energy consumption while maintaining optimal indoor environmental quality. However, a significant discrepancy often exists between predicted and actual energy performance due to occupant behavior. Despite advanced energy-saving technologies, user actions—such as leaving lights or HVAC systems on unnecessarily, improper use of energy-efficient appliances, and neglecting passive design features—can lead to increased energy consumption. This study aims to bridge this gap by analyzing occupant behavior and assessing targeted behavioral interventions that can enhance energy efficiency in commercial office buildings.

The specific objectives of this research are:

1. To assess the discrepancy between actual electricity consumption and design calculations in energy-efficient buildings.
2. To identify occupant behaviors that significantly impact energy consumption in commercial office buildings.
3. To evaluate the effectiveness of behavioral interventions in reducing unnecessary energy use.
4. To develop strategies for integrating occupant behavior considerations into energy management practices.

By addressing these objectives, this study will contribute to the growing body of research on energy efficiency by incorporating the human dimension of energy consumption. The findings will provide insights into how behavioral factors influence energy use and inform the development of practical solutions for optimizing energy performance in commercial buildings.

1.7 Research Question

Buildings account for a substantial portion of global energy consumption, and occupant behavior is a critical factor influencing actual energy performance. While energy-efficient designs and advanced technologies aim to reduce energy use, they often fail to achieve the expected savings due to behavioral inconsistencies. Understanding these behaviors is essential for improving building performance and achieving sustainability goals.

To address these challenges, this research seeks to answer the following key questions:

1. What is the discrepancy between actual electricity consumption and design calculations in commercial office buildings?
2. Which specific occupant behaviors have the most significant impact on energy consumption?
3. How effective are behavioral interventions in reducing unnecessary electricity consumption?
4. What strategies can be implemented to align occupant behavior with energy-efficient building design?

By answering these questions, this research will provide a deeper understanding of how human interactions with building systems affect energy performance. The outcomes will support the development of policy recommendations, technological advancements, and awareness programs aimed at improving energy efficiency through better occupant engagement.

1.8 Topic Validity

Recent research emphasizes the pivotal role of occupant behavior in determining the energy performance of buildings, especially energy-efficient ones. Despite their design to minimize consumption, such buildings often exhibit a significant performance gap—where actual energy use exceeds predicted consumption. This discrepancy is largely due to the variations in occupant behavior, including the use of lighting, HVAC systems, and household appliances(Azar & Menassa, 2012; Yan et al., 2015b). These findings highlight the need for a deeper understanding of human-building interactions and suggest that optimizing occupant behavior could help bridge this energy performance gap.

Research Contribution

This research seeks to build upon existing findings by focusing on the unique context of Nepal, where energy-efficient buildings are still a relatively new concept. By analyzing occupant behavior in these buildings and evaluating the effectiveness of targeted behavioral interventions, the study will address gaps identified in the literature. It will provide practical insights into optimizing energy performance and help bridge the energy performance gap. This research aims to contribute to both local energy policy and global sustainability efforts by offering a deeper understanding of how occupant behavior impacts building energy use.

Hence, the research topic holds a lot of potential and similar research has not been carried out in our context. That is why the research seems to be Valid.

1.9 Organization of Thesis

The research process adopted is as follows:

1.9.1 Introduction:

The research problem is introduced by highlighting the significance of understanding occupant behavior in relation to energy consumption in office buildings. The study area, the Civil Aviation Authority of Nepal (CAAN) Head Office building in Sinamangal, Kathmandu, is introduced, and the primary aim of the research is established: to analyze the discrepancy between theoretical and actual electricity consumption, focusing on how occupant behavior contributes to this difference.

1.9.2 Literature Review:

This section provides a review of existing literature related to energy-efficient building design, occupant behavior, and energy consumption patterns. Relevant studies are discussed to establish the theoretical framework for understanding how various behavioral factors, such as lighting, air conditioning usage, and appliance operation, influence energy use in commercial buildings. Additionally, it explores the role of energy audits and behavioral surveys in identifying inefficiencies in energy consumption.

1.9.3 Methodology:

This section outlines the research design and methodology adopted for the study. It includes a description of the survey instrument used to assess occupant behavior, the data collection techniques for gathering both primary and secondary data, and the analytical methods applied to compare actual and theoretical electricity consumption. The study utilizes energy audits, behavioral surveys, and statistical analysis to assess the energy consumption patterns in the building.

1.9.4 Data Collection and Analysis:

The data collection process is explained, detailing how actual electricity consumption data was obtained from Time-of-Day (TOD) meter bills and how theoretical consumption was estimated based on employee attendance and standard working hours. This section also describes the behavioral survey conducted among CAAN employees to identify energy-using habits and how this data is converted into quantitative values for analysis. The comparison between actual and theoretical data is presented, followed by statistical analysis to identify discrepancies.

1.9.5 Results and Discussion:

This section interprets the findings in the context of existing literature and theoretical concepts. It discusses the significance of the results and provides an in-depth analysis of the behaviors that most significantly impact energy consumption in the CAAN Head Office building. The discussion also includes recommendations for improving energy efficiency, such as promoting energy-saving behaviors among employees and optimizing building systems to reduce unnecessary consumption.

1.9.6 Conclusions and Recommendation:

The conclusion summarizes the key findings of the research and draws conclusions about the relationship between occupant behavior and electricity consumption in office buildings. Based on the analysis, recommendations are provided for improving energy efficiency in the CAAN Head Office building, including the implementation of occupant behavior modification strategies and energy-efficient technologies. The study also suggests areas for further research on occupant behavior and energy consumption in similar office environments.

CHAPTER 2. LITERATURE REVIEW

This section provides definitions of the key terms and concepts used throughout the thesis. Establishing clear definitions will help contextualize the research and ensure consistent understanding.

2.1 Definitions

Energy Efficiency in Buildings:

Energy efficiency in buildings refers to the use of technologies, strategies, and design features that reduce the amount of energy required to perform basic tasks, such as heating, cooling, lighting, and powering appliances. A building is considered energy-efficient when it consumes less energy for the same or better level of comfort, functionality, and performance (Kershaw, M. & McNeill, D., 2017)

Occupant Behavior:

Occupant behavior refers to the actions, decisions, and habits of individuals within a building that influence energy consumption. These behaviors can include actions such as the management of lighting, heating and cooling systems, appliance usage, and other daily activities that have direct or indirect effects on the building's overall energy consumption (Huebner, G. M. & Thurm, C., 2018)

Energy Consumption Discrepancy:

Energy consumption discrepancy refers to the difference between the theoretical energy consumption (predicted based on building design, materials, and systems) and actual energy consumption (which includes the impact of occupant behavior and operational factors). This discrepancy is often observed in buildings, as actual usage patterns can significantly deviate from initial predictions due to variable human behavior (Miller, R. & Jones, T., 2019)

Time-of-Day (TOD) Metering:

Time-of-Day (TOD) metering is a system that measures electricity consumption at different times of the day, often distinguishing between peak and off-peak hours. This helps in identifying patterns in energy use, as well as understanding how occupant behavior influences electricity consumption during specific periods (Burgess et al., 2017).

Building Energy Audits:

A building energy audit is a systematic inspection and analysis of energy use in a building to identify opportunities for energy savings. This process includes reviewing energy bills, inspecting building systems (e.g., HVAC, lighting), and identifying inefficiencies that may contribute to higher-than-expected energy use (Pereira, F. & Dias, P., 2020).

Energy Use Intensity (EUI):

Energy Use Intensity (EUI) is a metric that measures the energy consumption of a building relative to its size. It is typically expressed in kilowatt-hours per square foot per year (kWh/ft^2/year) and serves as an indicator of the overall energy efficiency of a building (Sachs, D. & Stevenson, R., 2016).

Behavioral Energy Efficiency:

Behavioral energy efficiency involves the integration of human behavior into energy efficiency strategies. It focuses on changing occupant behavior through awareness, motivation, and incentives to reduce energy consumption without altering the building's physical structure or systems (Thomson, M. & Roberts, L., 2018).

2.2 Behavioral Impacts on Energy Performance

Occupant behavior directly affects energy consumption through actions like adjusting thermostats, using lighting, and operating HVAC systems. Research by (Hong et al., 2017) indicates that variations in these behaviors contribute significantly to the energy efficiency of buildings. Similarly, studies by (Delzendeh et al., 2017) and (Yan et al., 2015b)emphasize that both adaptive behaviors, such as controlling natural ventilation, and non-adaptive behaviors, like leaving appliances on unnecessarily, impact energy use. These behaviors, often unpredictable and highly context-specific, vary based on building type, location, and occupant profiles (Sunikka-Blank & Galvin, 2012). According to (Chen et al., 2021), variations in occupancy patterns, user interactions, and behavioral efficiency contribute significantly to discrepancies in energy performance. Similarly,(Mastrorilli & Zarcone, 2023) emphasize the complexity of occupant behavior and its profound impact on building energy use, advocating for more robust modeling approaches to address behavioral diversity. These findings align with earlier studies(Delzendeh et al., 2017; Yan et al., 2015b), which categorize behaviors into adaptive, such as managing natural ventilation, and non-adaptive, such as leaving appliances on unnecessarily. This body of work underscores the context-specific nature of occupant behavior, influenced by factors such as building type, geographic location, and occupant demographics.

2.3 Performance Gap in Energy-Efficient Buildings

Several studies have highlighted the persistent energy performance gap in energy-efficient buildings. For instance, (Sunikka-Blank & Galvin, 2012) introduced the concept of the "prebound effect," where buildings consume more energy than anticipated because energy savings are overestimated based on assumed occupant behavior. (Hong et al., 2016) and (O'Brien & Gunay, 2014) further emphasize that existing performance models fail to integrate the complex and diverse occupant behaviors that significantly impact energy use, especially in non-residential buildings. More recent studies, including (Hong et al., 2016) and(O'Brien & Gunay, 2014), corroborate this finding, highlighting the limitations of existing energy performance models in accounting for diverse and complex occupant behaviors. These models often fail to capture the unpredictability of human actions, especially in non-residential settings where usage patterns can vary widely. A 2021 review further emphasizes that such gaps are exacerbated by environmental uncertainties and construction quality, suggesting a need for integrating behavioral insights into energy performance assessments.

2.4 Modeling Occupant Behavior

Modeling occupant behavior is a critical aspect of improving energy predictions. Advanced models, including those proposed by (Yan et al., 2015b) and (Hong et al., 2016), aim to integrate behavioral data with building energy simulation tools. However, these models often oversimplify the spectrum of occupant actions and fail to capture the full variability observed in real-world settings (Delzendeh et al., 2017). Moreover, gaps in these models exist when applied to diverse socioeconomic or climatic conditions (O'Brien & Gunay, 2014).

2.4.1 Importance of Modeling Occupant Behavior in Building Energy Consumption

Occupant behavior has a significant impact on a building's energy use. Traditional energy models, which focus primarily on the physical characteristics of a building (e.g., HVAC systems, insulation, and lighting), often fail to account for the variability introduced by human behavior. Accurately modeling occupant behavior allows for more precise predictions of energy consumption and can help identify strategies to improve energy efficiency(Huebner, G. M. & Thurm, C., 2018).

Models of occupant behavior are increasingly important as they help to bridge the gap between theoretical and actual energy consumption, especially when there are discrepancies between the two. The inclusion of occupant behavior in energy models can lead to more realistic energy demand forecasts and inform the design of interventions to promote energy-saving habits among building users.

2.4.2 Approaches to Modeling Occupant Behavior

There are several approaches to modeling occupant behavior, ranging from simple assumptions to complex simulations. These approaches can be broadly categorized into top-down and bottom-up modeling approaches.

Top-Down Approach:

In the top-down approach, occupant behavior is modeled as a part of a larger, aggregated system. These models often focus on statistical analysis of large datasets, such as electricity consumption data, to identify patterns in behavior. The top-down approach is useful for understanding general trends but may overlook the nuances of individual behavior(Sachs, D. & Stevenson, R., 2016).

Bottom-Up Approach:

The bottom-up approach, on the other hand, involves modeling the individual actions of occupants based on their specific behaviors and activities. This approach can be more detailed and personalized, capturing the variability in occupant behavior. It typically requires more data and is computationally more complex, but it provides more precise insights into how individual actions contribute to overall energy consumption (Thomson, M. & Roberts, L., 2018).

Both approaches have their strengths and weaknesses. Top-down models tend to be more generalizable and less data-intensive, while bottom-up models offer a higher level of detail but require more granular data on individual occupant behavior.

2.4.3 Techniques for Modeling Occupant Behavior

Several techniques are employed to model occupant behavior, each with its own advantages depending on the research objectives and the available data.

Agent-Based Modeling (ABM):

Agent-based modeling simulates the actions of individual occupants (agents) within a building. Each agent has specific characteristics (e.g., routines, preferences, and habits) that influence their behavior. ABM can model complex interactions between occupants and building systems, and it has been used to assess energy consumption patterns based on how occupants interact with heating, cooling, and lighting systems (Huebner, G. M. & Thurm, C., 2018).

Markov Chains:

Markov chains are used to model the probability of an occupant transitioning between different states (e.g., turning on or off a light or thermostat). This technique is particularly useful for modeling energy-related behaviors that follow certain probabilistic patterns, such as switching off lights after work hours (Miller, R. & Jones, T., 2019).

Machine Learning Algorithms:

Recent advancements in machine learning, such as supervised learning and clustering algorithms, have also been applied to model occupant behavior. These methods use historical data to train models that predict future behavior, such as occupancy levels and energy use, based on observed patterns (Sachs, D. & Stevenson, R., 2016).

2.4.4 Challenges in Modeling Occupant Behavior

Modeling occupant behavior presents several challenges, primarily due to the variability and unpredictability of human actions. Some of the key challenges include:

Data Availability and Quality:

Accurate data on occupant behavior is often difficult to obtain. Most models rely on surveys, interviews, or monitoring systems that may not fully capture the range of behaviors that influence energy use (Pereira, F. & Dias, P., 2020). Furthermore, privacy concerns can limit the amount of personal data that can be collected, which restricts the granularity of the models.

Heterogeneity of Occupant Behavior:

Different occupants may have very different habits and routines. For example, one person may habitually turn off the lights when leaving a room, while another may leave them on. Modeling such diverse behaviors requires complex algorithms and the consideration of various contextual factors such as occupancy schedules, preferences, and social influences (Huebner, G. M. & Thurm, C., 2018).

Integration with Building Systems:

Integrating occupant behavior models with building management systems (BMS) is often a challenge. A building's energy systems, such as HVAC and lighting, are designed to respond to occupancy patterns, but the complexity of modeling the dynamic interactions between occupants and these systems makes it difficult to accurately predict energy use (Thomson, M. & Roberts, L., 2018).

2.4.5 Applications of Occupant Behavior Models

Accurate occupant behavior models are invaluable in several practical applications, such as:

Energy Demand Forecasting:

By incorporating occupant behavior into energy models, it is possible to predict energy demand more accurately, helping building operators optimize energy use and reduce costs (Sachs, D. & Stevenson, R., 2016)

Energy Efficiency Interventions:

Behavioral insights gained from occupant modeling can inform strategies to promote energy-efficient habits. For example, encouraging occupants to use energy-efficient appliances, adjust thermostats, and reduce lighting use during peak hours can lead to significant reductions in energy consumption (Thomson, M. & Roberts, L., 2018).

Building Design and Operation:

Modeling occupant behavior also plays a role in the design and operation of energy-efficient buildings. By understanding how occupants interact with building systems, architects and engineers can design buildings that better support energy-efficient behaviors and improve occupant comfort (Pereira, F. & Dias, P., 2020).

2.5 Behavioral Interventions and Feedback Systems

Recent studies show that behavioral interventions, such as real-time feedback systems, smart controls, and personalized recommendations, can reduce energy consumption. (Petersen et al., 2007) found that providing real-time feedback about energy use to dormitory residents led to measurable reductions in electricity consumption. (Azar & Menassa, 2012) and (O'Brien & Gunay, 2014) have similarly emphasized the potential of behavior-based interventions to achieve sustained energy savings. However, the long-term effectiveness of such interventions depends on their adaptability to changes in occupant behavior and technological advancements.

2.6 Occupant Behavior in Developing Regions

While a significant body of research focuses on developed countries, there is a noticeable gap in studies regarding occupant behavior in developing countries, especially those with emerging energy-efficient building markets, like Nepal. Studies by (Hong et al., 2017) and (Yan et al., 2015b) emphasize that cultural, economic, and climatic factors influence how occupants interact with their building systems. There is a clear need for region-specific research to account for these variables and understand their impact on energy consumption patterns. However, the long-term success of such interventions depends on their adaptability to evolving behaviors and advancements in technology. Nepal's growing emphasis on energy-efficient building practices presents an opportunity to investigate occupant behavior in a context characterized by diverse climatic conditions and socioeconomic constraints.

2.7 Technological Integration and Sustainability

Integrating occupant behavior into energy management systems, such as automated lighting and HVAC controls, holds considerable potential for improving sustainability. (Azar & Menassa, 2012) suggest that energy-saving technologies can be more effective if tailored to specific occupant behaviors. Smart building technologies that adapt to occupants' routines and preferences have been identified as critical tools for achieving energy efficiency while also maintaining occupant comfort (Sunikka-Blank & Galvin, 2012). These advancements highlight the potential of technology to align building energy performance with occupant behavior while maintaining comfort and functionality.

2.8 Relationship between occupants and the building

Occupants and buildings share a dynamic relationship that significantly influences energy consumption, indoor environmental quality, and overall building performance. This interaction is shaped by occupants' behaviors, preferences, and adaptive strategies, which in turn affect energy efficiency, thermal comfort, and sustainability goals. Understanding this relationship is crucial for designing buildings that balance energy performance with occupant satisfaction.

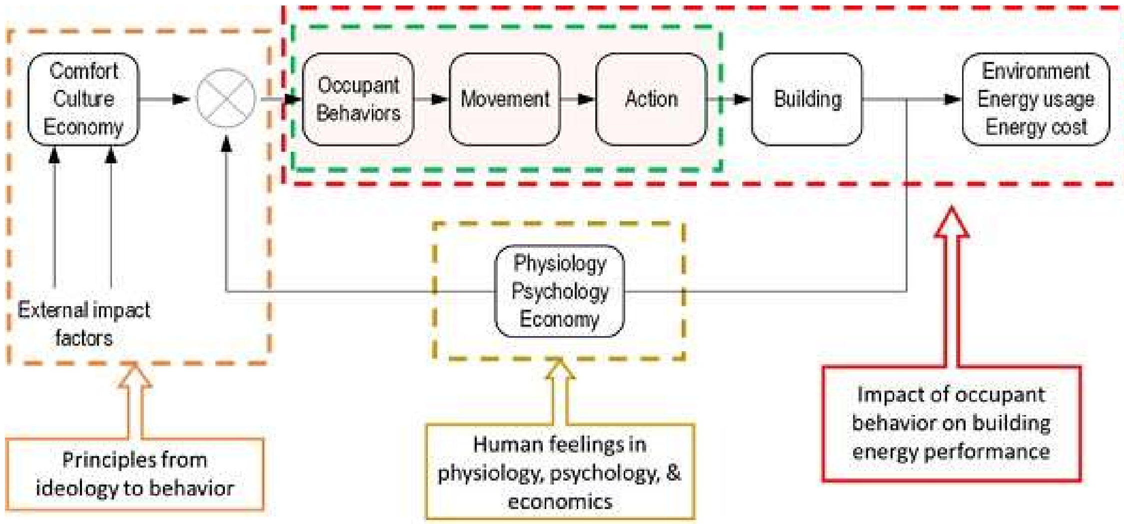


Figure 4:Relationship between occupants and buildings (Wagner, et al 2017)

2.9 Factors and Sub-factors influencing energy behavior of occupants

2.9.1 Climate

Occupant behavior is heavily influenced by climatic conditions. Environmental factors such as outdoor temperature, relative humidity, solar radiation, wind, and precipitation significantly affect how individuals interact with building systems to maintain thermal comfort. External temperature variations play a crucial role in determining the use of electrical appliances, as extreme conditions often lead to inconsistent or excessive usage of heating and cooling systems. Studies on climate-related influences incorporate year-round thermal measurements, occupant behavior surveys, and real-time monitoring of user interactions with building systems(Delzendeh et al., 2017).

2.9.2 Building Typology

The typology of a building influences occupant behavior by shaping activity patterns, clothing choices, metabolic heat generation, expectations, and interactions with building systems. Behavioral variations are evident across different building types, such as residential, commercial, and mixed-use structures. Residential and office buildings typically consume the most energy due to continuous occupancy throughout the day, leading to higher energy demand for lighting, HVAC systems, and other appliances.

2.9.3 Socio-Personal Factors

Research has extensively examined the psychological and physiological aspects that influence occupant comfort and energy consumption. Social and personal factors, including awareness of energy-related issues, gender, age, occupation, household size, and sociocultural background, play a significant role in shaping energy behavior. Additionally, lifestyle choices and educational levels impact an individual's approach to energy consumption. People’s past experiences and habits influence their use of electrical devices, highlighting the need for an interdisciplinary approach involving social scientists, energy analysts, and engineers to address this multifaceted issue effectively.

2.9.4 Architecture

The architectural design of a building significantly impacts both thermal comfort and occupant behavior. The concept of "sustainable interior design" involves integrating energy-efficient strategies into a building's architectural layout. Factors such as building age (new, old, or retrofitted), the placement and aesthetics of windows and doors, circulation patterns, and interior materials contribute to occupants' thermal perception. Architectural elements influence how individuals interact with their environment, affecting ventilation, lighting preferences, and energy use.

2.9.5 Energy Regulations and Economic Parameters

Numerous studies have explored the interplay between energy policies, economic factors, and occupant behavior. Key considerations include employment status, energy pricing, and financial constraints, all of which impact energy consumption patterns. Economic disparities influence how households manage energy usage—low-income families tend to be more mindful of electricity consumption to minimize costs, whereas high-income households may exhibit less concern regarding appliance usage. Regulatory frameworks and energy policies play a crucial role in shaping behavioral responses to energy consumption.

2.10 Monitoring Occupant Behavior

Understanding and monitoring occupant behavior is essential for optimizing building energy performance and ensuring occupant comfort. Occupants' interactions with lighting, heating, ventilation, and air conditioning (HVAC) systems significantly influence overall energy consumption. Various methods, ranging from manual observations to advanced sensor-based monitoring, are used to capture behavioral patterns and improve energy efficiency.

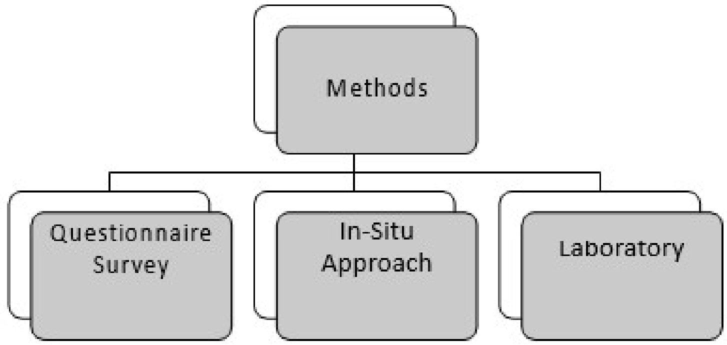


Figure 5:Method of Monitoring Occupant Behavior (Wagner, et al,2017)

2.10.1 Direct Observations and Surveys

Traditional methods such as direct observation and occupant surveys provide qualitative insights into behavioral patterns. Observers record occupant interactions with building systems, while surveys collect self-reported data on comfort preferences, usage habits, and energy awareness. Though useful, these methods can be subjective and prone to recall bias.

2.10.2 Sensor-Based Monitoring

Technological advancements have enabled real-time monitoring through various sensor-based systems:

Occupancy sensors detect movement and presence to assess space utilization and optimize lighting and HVAC operations.

Environmental sensors measure temperature, humidity, CO_2 levels, and air quality to understand how occupants respond to different indoor conditions.

Smart meters and plug-load monitors track energy consumption at the device level, helping identify inefficient usage patterns.

2.10.3 Smart Building Systems and IoT Integration

The integration of the Internet of Things (IoT) in buildings enhances occupant behavior monitoring. Smart building management systems (BMS) analyze data from interconnected sensors to enable adaptive control of lighting, HVAC, and other building systems. Machine learning algorithms process behavioral data to predict occupant needs and automate energy-efficient responses.

2.10.4 Indoor Environmental Quality (IEQ) Monitoring

Monitoring Indoor Environmental Quality (IEQ) factors such as lighting, ventilation, and thermal comfort helps identify correlations between environmental conditions and occupant behavior. Adjustments based on IEQ data can improve energy efficiency without compromising comfort.

2.10.5 Data Logging and Longitudinal Studies

Long-term data collection through logging devices and longitudinal studies provides insights into behavioral trends across seasons and time periods. Such studies help distinguish habitual behaviors from temporary responses to external factors like weather variations or energy pricing changes.

2.10.6 Challenges in Monitoring Occupant Behavior

Despite advancements in monitoring technologies, challenges remain:

- Privacy concerns: Occupants may feel uncomfortable being monitored, raising ethical and data security issues.
- Complexity of behavior: Human behavior is dynamic and influenced by multiple factors, making data interpretation challenging.
- User compliance: Occupants may change their behavior when they know they are being monitored, leading to biased data.

Monitoring occupant behavior is critical for enhancing building energy efficiency and sustainability. A combination of traditional and advanced monitoring techniques allows building managers and researchers to develop data-driven strategies for reducing energy waste while maintaining occupant comfort.

2.11 Design Load calculations

Time-of-Use (ToU) tariff is introduced to motivate users to change their electricity usage patterns. Typically, tariffs are higher during peak hours and relatively lower during off-peak hours, encouraging users to reduce consumption during peak periods or shift it to off-peak hours. This tariff scheme provides opportunities for building owners to reduce their electricity bills, provided that the electricity usage patterns of various spaces in the building are known at every hour. In practice, the kWh meter installed by the utility can only provide the overall hourly electricity consumption pattern. To determine the usage pattern of different spaces or rooms, separate individual meters must be installed in each space or room, which is costly and impractical.

(Esa et al., 2017)proposed a disaggregated electricity bill method based on the user utilization factor and ToU tariff. Their approach estimates the hourly electricity bill of each appliance in each space or room. The utilization factor is used to represent the electricity usage behavior of the occupants, allowing for a more detailed assessment of energy consumption distribution within a building.

2.12 Summary of Literature review

Author(s) & Research Title	Year	Methodology Used	Findings
Azar & Menassa - Impact of occupant behavior on energy consumption in office buildings	2012	Simulation & case study analysis	Occupant behavior significantly influences energy consumption, with variations up to 50% due to behavioral differences.
Sunikka-Blank & Galvin - Prebound effect: Gap between performance and actual energy use	2012	Empirical data analysis from residential buildings	Many buildings consume more energy than predicted due to inefficient occupant behavior and outdated performance assumptions.
O'Brien & Gunay - Contextual factors contributing to adaptive comfort behavior	2015	Literature review & field studies	Occupants adjust behaviors (e.g., thermostat adjustments, window openings) based on personal comfort, affecting energy use unpredictably.
Day & Gunderson - High-performance buildings and occupant knowledge	2015	Surveys & case studies	Lack of awareness of passive design strategies leads to inefficiencies in high-performance buildings.

Hong et al. - Advances in research on energy-related occupant behavior	2016	Review of empirical studies	Variability in energy use is often due to misalignment between design assumptions and real-life occupant behavior.
Author(s) & Research Title	Year	Methodology Used	Findings
Karjalainen - Sensitivity of buildings to occupant behavior	2016	Simulation study	More resilient building designs can minimize the impact of occupant behavior on energy efficiency.
Delzendeh et al. - Impact of occupant behavior on building energy analysis	2017	Literature review & meta-analysis	Occupant behavior is one of the key drivers of the energy performance gap in buildings.
Chen et al. - Impacts of occupant behavior on building energy consumption	2021	Systematic review of studies	Automation and real-time feedback can help mitigate energy wastage due to occupant behavior.
Heydarian et al. - Behavioral theories and building system interactions	2020	Review & behavioral modeling	Theories such as TPB (Theory of Planned Behavior) and nudging interventions can be used to predict and influence energy-efficient behaviors.
Piselli & Pisello - Long-term occupant behavior monitoring	2019	Longitudinal data analysis	Continuous monitoring of occupant behavior can improve energy performance prediction and reduce discrepancies.

Miller & Jones - Energy consumption discrepancies in commercial buildings	2019	Case study & energy audits	Discrepancies between expected and actual energy consumption arise from both occupant behavior and building system inefficiencies.
Author(s) & Research Title	Year	Methodology Used	Findings
Thomson & Roberts - Behavioral energy efficiency	2018	Field experiment	Occupant awareness campaigns and real-time energy feedback significantly reduce energy consumption.
Yan et al. - Occupant behavior modeling in building performance simulation	2015	Review & simulation modeling	Improved data collection on occupant behavior is essential for accurate energy modeling in buildings.
Burgess & Thompson - Time-of-day metering for energy efficiency	2017	Utility billing data analysis	Time-of-use tariffs can effectively reduce peak energy loads and influence more efficient occupant behaviors.
Pereira & Dias - Building energy audits and energy management	2020	Case study & audit methodology	Energy audits identify behavioral inefficiencies, leading to targeted interventions for reducing consumption.

Figure 6:Summary of Literature Review

2.12 Conceptual Framework

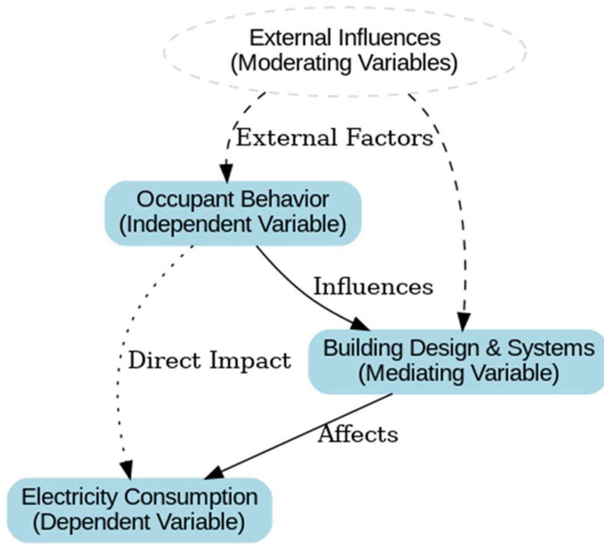


Figure 7:Conceptual framework of the research

Occupant Behavior (Independent Variable):

Occupant behavior refers to actions taken by individuals within a building that directly impact electricity consumption. These actions include leaving lights, air conditioning units, and other electrical devices on when they are not needed, as well as inefficient use of energy-related systems. Occupant behavior is the primary variable in this study, and it plays a crucial role in determining electricity consumption patterns within the building.

Building Design and Systems (Mediating Variable):

Building design and systems encompass the features and technologies integrated into the structure, such as automation, energy-efficient appliances, and control systems. These systems act as a mediating variable, influencing how occupant behavior translates into actual energy consumption. For example, energy-efficient lighting, HVAC systems, and automated controls can reduce the impact of inefficient occupant behavior, such as leaving lights or air conditioning units on when not in use.

Electricity Consumption (Dependent Variable):

Electricity consumption is the measured outcome of this study, reflecting the total energy usage in the building. It is compared between actual consumption, based on data collected from TOD meter readings, and expected consumption, which is calculated using assumptions regarding employee attendance and standard working hours. The discrepancy between actual and expected consumption serves as the primary focus of this analysis, aiming to understand the extent to which occupant behavior and building systems contribute to energy usage.

External Influences (Moderating Variable):

External influences include factors such as weather conditions, seasonal variations, and occupant demographics. These variables moderate the relationship between occupant behavior and electricity consumption, introducing additional complexity to the analysis. For example, extreme weather conditions may lead to increased use of HVAC systems, thereby influencing overall energy consumption regardless of occupant behavior. Similarly, differences in occupant demographics, such as age or role within the organization, may affect energy usage patterns.

Link to Research Objectives:

Objective: To assess the impact of occupant behavior on actual electricity consumption.

The framework positions occupant behavior as the independent variable, establishing a direct link to electricity consumption. By analyzing how behaviors such as leaving lights or air conditioning on unnecessarily affect energy use, the study aims to quantify the extent of this impact and identify potential energy-saving opportunities through behavioral change.

To evaluate the role of building systems in mediating energy use.

The mediating variable, building design and systems, examines how technological interventions, such as energy-efficient appliances, automation, and control systems, influence consumption patterns. This objective focuses on understanding how the building’s design and systems can either amplify or mitigate the impact of occupant behavior on energy consumption.

To analyze external factors affecting energy consumption.

External influences, as moderating variables, address the variability caused by external contexts such as weather, seasons, and demographic characteristics of the building's occupants. This objective explores how these factors may modify the relationship between occupant behavior and electricity consumption, adding complexity to the overall energy usage patterns within the building.

To analyze the discrepancy between actual electricity consumption and expected consumption based on design assumptions.

This objective seeks to explore the gap between actual electricity consumption, measured through TOD meter readings, and the expected consumption based on standard assumptions such as employee attendance and building operating hours. By investigating this discrepancy, the study aims to uncover the extent to which occupant behavior deviates from expected patterns, and how building design and systems contribute to energy usage beyond initial assumptions.

Link to Research Questions:

What is the discrepancy between actual electricity consumption and expected electricity consumption based on design assumptions?

This question aims to identify the gap between actual energy usage (measured through TOD meter data) and expected consumption (calculated from standard working hours and occupancy patterns). By analyzing this discrepancy, the study will explore whether occupant behavior is contributing to higher-than-expected energy use or whether building systems and design assumptions need revision to align more closely with actual consumption patterns. The research will focus on identifying key factors that explain any variations between expected and actual consumption

How does occupant behavior influence electricity consumption in buildings?

This question explores the direct relationship between the independent variable (occupant behavior) and the dependent variable (electricity consumption). It focuses on identifying specific actions or habits that significantly contribute to increased or decreased energy use within the building.

What role do building systems play in moderating energy use?

This research question investigates the mediating variable—building systems—and their role in either facilitating or mitigating the impact of occupant behavior on energy consumption. It examines how features like automation, energy-efficient systems, and control technologies help optimize energy use despite varying occupant behaviors.

How do external factors affect the relationship between occupant behavior and energy consumption?

This question addresses the moderating variables (external influences), such as weather conditions, seasons, and occupant demographics, and explores how these factors alter the relationship between occupant behavior and electricity consumption. The objective is to assess the extent to which external influences introduce variability in energy use and complicate predictions based solely on occupant behavior.

CHAPTER 3. METHODOLOGY

This chapter discusses the research study area, design, target population, sampling techniques and data collection procedures, data analysis, the study variables and ethical considerations.

3.1 Research design

The research strategy for this thesis comprised four phases: Literature review, Data collection from secondary and primary sources, analysis, and Recommendations for future design strategies. The study utilized a clear and effective research design, centered primarily on field surveys, direct interactions with occupants, and analysis of utility bills. The research focused on manual methods of assessing occupant behavior and energy usage through more accessible and localized means. The design aimed to ensure that data collection was grounded in real-world scenarios while remaining practical for buildings in Nepal.

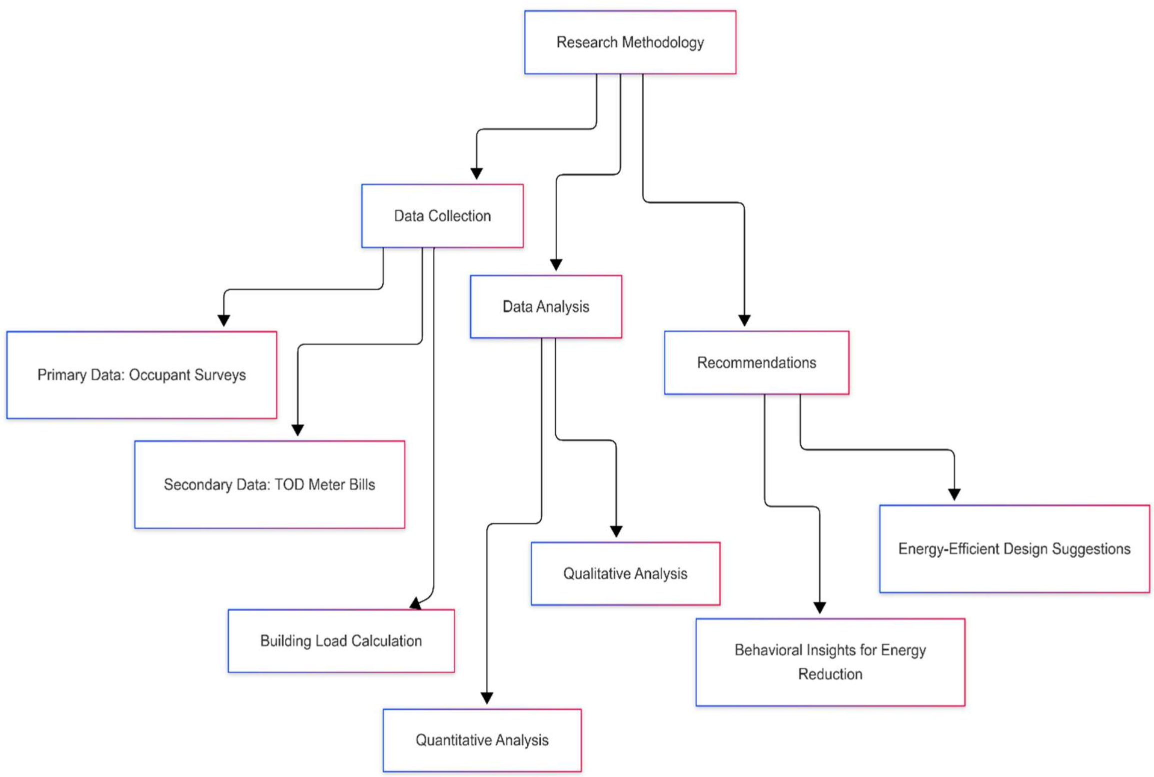


Figure 8:Research Framework

3.1.1Field Measurements

The research relied on the following methods to gather accurate data:

Electricity Bills (TOD Meter Bills): Utility bills from tenants or building management were collected as primary data points. These bills provided the total electricity usage over a given period, which was then analyzed to understand consumption patterns in relation to occupancy behavior. The Time-of-Use (TOD) meter data allowed the research to break down electricity usage by different times of the day, correlating peak energy consumption with specific behaviors like appliance use or HVAC systems running during work hours or after hours.

Building Load Calculation: The total electrical load in the building, including all appliances, fixtures, and systems (such as lighting, HVAC, and other electrical appliances), was calculated. This was done by reviewing the total rated power of the installed fixtures and appliances. These calculations helped estimate the energy consumption baseline and were essential for determining if energy use deviated from expected values due to occupant behavior. The load calculation also enabled the assessment of how different areas of the building contributed to energy consumption, highlighting which appliances and systems were most affected by occupant behavior.

3.1.2 Data Collection

The primary methods for data collection involved direct interaction with building occupants and the collection of relevant operational data:

Occupant Surveys: A key component of the data collection involved distributing surveys to occupants. These surveys gathered information on occupant habits, such as appliance use (e.g., frequency of turning lights, air conditioners, and other electrical fixtures on and off), comfort preferences, and overall awareness of energy consumption. The survey captured both quantitative and qualitative data on occupant intentions and practices regarding energy use, offering valuable insights into why certain behaviors were prevalent and how they contributed to excess energy use.

Direct Interactions and Interviews: In addition to surveys, direct interactions with a selected group of building occupants provided deeper insights into their behavior. Interviews explored why individuals engaged in specific energy-consuming behaviors, how their perceptions of energy efficiency influenced their choices, and what barriers (such as lack of information or motivation) prevented them from adopting more energy-efficient practices. These qualitative data added context to the quantitative findings from the surveys.

Analysis of Electrical Fixtures and Appliances: An inventory of the electrical fixtures and appliances used in the building was conducted. This step included documenting the number and types of appliances, their power ratings, and operational patterns. By calculating the total expected energy consumption of these devices, the study compared actual consumption with theoretical values, identifying discrepancies that may have been due to inefficient usage or behavioral factors.

3.1.3Data Analysis Techniques

Once the data was collected, a combination of quantitative and qualitative analysis techniques was employed:

- Quantitative Analysis of Energy Consumption: The data gathered from utility bills and load calculations was analyzed using statistical methods to identify correlations between energy consumption and occupant behavior. Techniques such as regression analysis were used to determine if specific behaviors (e.g., leaving lights on or setting HVAC systems to extreme temperatures) significantly influenced energy use in the building. This analysis helped quantify the impact of behaviors on energy consumption and highlighted areas for improvement.
- Qualitative Data Analysis: The qualitative data obtained from surveys and interviews was analyzed using thematic analysis. Key themes were identified, such as occupant motivations for energy use or common barriers to adopting energy-efficient practices. Thematic analysis also helped understand the social, cultural, and economic factors influencing occupant behavior, offering deeper insights into why energy consumption diverged from expectations in energy-efficient buildings.

Cross-Validation of Data: A critical part of the data analysis involved comparing and cross-referencing the findings from the survey responses, interview insights, and actual energy consumption data. This cross-validation ensured that the results were robust and well-supported by different sources of data. It also helped identify any discrepancies between self-reported behaviors and actual energy use, which could indicate areas where occupants overestimated or underestimated their energy consumption habits.

Relevance of Methods

The chosen research methods were particularly well-suited to the context of Nepal and the study's focus on occupant behavior and energy consumption. Unlike high-tech data collection methods, such as smart meters and environmental sensors, the proposed methods were more cost-effective and practical for the local context. Given the varying levels of access to advanced technologies in

Nepal, using accessible tools like utility bills, occupant surveys, and direct interactions ensured that the research remained feasible for local buildings.

Moreover, the methods were specifically chosen to capture the complex relationship between human behavior and energy use. By focusing on occupant behavior, the study went beyond merely measuring energy consumption, offering insights into the psychological, social, and cultural factors that drive these behaviors. This approach provided valuable information for policymakers, building managers, and designers seeking to improve the energy performance of buildings through behavioral interventions.

3.2 Data Collection

3.2.1 Actual Energy Consumption Computation

The actual energy consumption of the building is computed using a structured approach based on Time-of-Use (TOD) meter data. The process involves the following steps:

Data Collection from TOD Meter Bills

- Monthly TOD meter bills are collected from the building management.
- The bills provide energy consumption data categorized into peak, off-peak, and normal hours.
- The billing period and corresponding electricity usage are documented for analysis.

Segmentation of Energy Consumption

- The total electricity consumption is divided into different time periods based on TOD meter readings.
- Energy usage during peak, off-peak, and normal hours is extracted separately.

Summation of Total Energy Use

- The recorded energy usage for each time period is summed to obtain the total electricity consumption for a given month.
- Data from multiple months is compiled to analyze trends in energy consumption.
- Annual Energy Consumption Estimation
- Monthly consumption data is aggregated to estimate annual electricity consumption.
- Seasonal variations are analyzed by comparing monthly energy usage trends.

3.2.2Design Energy Consumption Computation

The design energy consumption is computed based on theoretical calculations, considering the expected energy usage of all electrical fixtures, appliances, and systems in the building. The process involves the following steps:

1. **Building Load Calculation**

- The total electrical load of the building is calculated by reviewing the specifications of all installed appliances and fixtures.
- This includes lighting, heating, ventilation, air conditioning (HVAC) systems, office equipment, and any other electrical appliances.
- The power ratings (in watts) of each appliance are summed to determine the total design load for the building.

2. **Estimation of Expected Energy Consumption**

- The expected energy consumption is estimated by multiplying the total rated load by the typical hours of usage.
- This calculation assumes standard working hours (e.g., 9:00 AM to 5:00 PM) and occupancy patterns, without taking into account deviations in actual occupant behavior.

3. **Energy Use Profile Creation**

- A daily energy use profile is created based on the typical operational schedule of the building.
- This includes expected energy consumption during working hours, with additional assumptions made for night or off-hours when certain systems may remain operational.

4. **Assumption of Standard Usage Patterns**

- Assumptions are made about the typical usage of HVAC, lighting, and office equipment based on standard practices for similar buildings.
- For example, lighting is assumed to be on for the entire workday, and HVAC systems are assumed to be operational for the duration of occupancy periods.

5. **Seasonal Adjustments**

- Seasonal variations, such as increased heating or cooling demands, are incorporated into the design energy consumption estimates.
- These adjustments are based on historical weather data and expected internal building temperature requirements throughout different seasons.

This process provides a theoretical baseline for energy consumption, which is then compared with the actual energy usage to identify discrepancies and assess the impact of occupant behavior.

3.2.3Behavioral Traits of Occupants through Questionnaire Survey

The behavioral traits of building occupants are assessed through a structured questionnaire survey. The survey aims to collect data on the daily habits and practices of occupants that influence energy consumption patterns. The process involves the following steps:

1.Survey Design

The questionnaire is designed to capture both quantitative and qualitative data on occupant behaviors related to energy consumption.

The survey includes questions about daily routines, energy use habits, comfort preferences, and awareness of energy-efficient practices.

2. Occupant Habits and Energy Consumption

Questions are included to determine how often occupants leave lights, air conditioning, or other appliances on unnecessarily.

Occupants are asked about their typical usage of HVAC systems, lighting, and office equipment, particularly during non-working hours or weekends.

3. Comfort Preferences

The survey captures data on the preferred indoor temperature settings for heating and cooling, which influence energy consumption.

Questions address how occupants adjust the HVAC system for comfort and whether they use energy-efficient practices to maintain comfort.

4. Awareness of Energy-Efficiency

Occupants' awareness of energy-efficient practices and their willingness to adopt them is assessed. The survey includes questions about the occupants' knowledge of energy conservation techniques, such as switching off lights when not in use, using energy-efficient appliances, and maintaining optimal temperatures.

5. Energy Consumption Patterns

Questions explore patterns such as the typical time of day when electricity consumption peaks, which appliances or systems are used the most, and how often energy is wasted (e.g., leaving lights on in unoccupied rooms).

Respondents are asked about their awareness of the building's energy usage and whether they actively monitor or try to reduce it.

6. Demographic Factors

The survey includes demographic questions to understand how age, role in the building (e.g., management or staff), and work habits influence energy consumption behavior. Occupant demographics provide insight into any variations in energy use habits between different groups of people.

7. Behavioral Incentives and Barriers

The survey gathers data on the barriers occupants face when trying to adopt energy-efficient behaviors (e.g., lack of motivation, information, or control over systems).

Incentives or motivations for improving energy-saving behaviors are also assessed, such as financial savings, environmental concern, or building management policies.

This survey provides valuable data for understanding the link between occupant behavior and energy consumption, allowing for the identification of key behaviors that contribute to excessive energy use in the building.

3.3 Combining Data from Findings

After collecting data from the three primary methods—**Actual Energy Computation**, **Design Load Calculation**, and **Behavioral Traits of Occupants**—the next step involves analyzing and combining these datasets to identify relationships, discrepancies, and insights into energy consumption patterns.

Step 1: Actual Energy Consumption (Dataset A)

The **Actual Energy Consumption (Dataset A)** comes from the utility bills, particularly the Time-of-Use (TOD) meter readings, which show the actual energy usage in the building. The data points are recorded as:

- $E_{actual}(t)$=Actual energy consumption at time t (from utility bills)

Where t represents specific time intervals (e.g., daily, weekly, monthly). These readings provide actual energy consumption data over a specific time frame, such as one month.

Step 2: Expected Energy Consumption from Design Load (Dataset B)

The **Expected Energy Consumption (Dataset B)** is based on the design load calculation. This calculation uses the total installed electrical load in the building, which is the sum of the rated power of all appliances and systems within the building. The design load can be calculated as:

$$E_{\text{design}} = \sum_{i=1}^{n} P_i \times h_i$$

Where:

- P_i= Power rating of the i^{th} appliance
- h_i = Hours of expected operation per day for the i^{th} appliance
- n = Number of appliances/systems

This formula gives the theoretical energy consumption, assuming the appliances are operated according to design specifications. The expected energy consumption is then compared with actual consumption data to identify discrepancies.

Step 3: Behavioral Data (Dataset C)

The **Behavioral Data (Dataset C)** is obtained from the survey responses of building occupants. Each response provides data on occupant behavior, such as how often they leave lights on or use air conditioning outside of expected working hours. To quantify these behaviors, the responses are weighted, and numerical values are assigned to each type of behavior. For example:

- b_{light}=Behavioral factor for lighting usage
- b_{hvac} = Behavioral factor for HVAC usage

These behavioral factors are based on occupant reports and are assigned values such as:

- b_{light}= 0.1(if lights are left on for 1 hour beyond working hours)
- b_{hvac} = 0.2 (if HVAC is left running for 1 hour beyond working hours)

The total behavioral impact on energy consumption is computed by multiplying these factors with corresponding appliance power ratings and operational hours.

Step 4: Cross-Validation of Datasets

After obtaining **Dataset A**, **Dataset B**, and **Dataset C**, the next step is to cross-validate and compare the datasets to identify discrepancies and correlations. The key objective is to quantify the contribution of occupant behavior to excess energy consumption.

1. **Comparison of Actual vs. Expected Energy Consumption**: This is done by calculating the discrepancy between the actual energy consumption and the expected energy consumption from design calculations. The difference can be expressed as:

$$\Delta E = E_{actual} - E_{design}$$

Where ΔE represents the deviation between actual and expected consumption. Positive values indicate excess consumption due to factors like inefficient occupant behavior.

2. **Quantifying the Impact of Occupant Behavior**: By incorporating the behavioral factors from **Dataset C**, the impact of occupant behavior on energy consumption can be quantified. The additional energy consumption due to behaviors such as leaving lights on or HVAC running can be calculated as:

$$E_{\text{behavioral}} = \sum_{i=1}^{n} b_i \times P_i \times h_i$$

Where b_i represents the behavioral factor for the i^{th} appliance/system, and $P_i \times h_i$ is the expected energy consumption based on the design load.

Step 5: Data Analysis Techniques

Once the datasets are combined and discrepancies have been identified, statistical and graphical methods are employed to analyze the data further:

Step 6: Graphical Representation

Several types of graphs can be generated to visualize the relationships and discrepancies between the datasets:

1. **Scatter Plots**: These are used to visualize the relationship between occupant behavior (e.g., frequency of HVAC usage) and actual energy consumption. A scatter plot will allow us to see if there are any clear patterns or outliers in the data, such as a few occupants causing disproportionate energy usage.
2. **Bar Charts**: Stacked bar charts are used to show the breakdown of energy consumption in different building zones (e.g., lighting, HVAC, appliances) and how occupant behavior influences each zone. These charts can help identify which systems are most affected by occupant habits.
3. **Pie Charts**: These charts can display the percentage contribution of different factors (e.g., occupant behavior, HVAC, lighting) to the overall energy consumption, illustrating which behaviors contribute most to excess consumption.

3.4 Limitation of the Methodology

While the methodology employed in this research is designed to provide valuable insights into the impact of occupant behavior on electricity consumption, there are several limitations that must be acknowledged:

1. **Data Accuracy and Reliability**

- The accuracy of the data collected from utility bills is reliant on the correct functioning of the Time-of-Use (TOD) meters. Any errors in meter readings or discrepancies in the billing process could affect the reliability of the data.
- The behavioral data collected through surveys and interviews is based on self-reporting, which may be subject to bias. Occupants might overestimate or underestimate their actual energy consumption behavior due to memory recall bias or social desirability bias.

2. **Sample Size and Scope**

- The research is conducted within a limited sample size, focusing on a specific building (the CAAN head office). The findings may not be generalizable to other buildings or regions with different design features, operational practices, or occupant behavior patterns.
- The study focuses on a single geographic area (Nepal), and regional variations in climate, culture, and technology use might limit the applicability of the findings in other contexts.

3. **External Influences**

- External factors, such as weather conditions and seasonal changes, have a significant impact on energy consumption. These factors are not always controllable or consistently accounted for in the study, which could lead to variations in consumption that are not attributed to occupant behavior or building design.
- Occupant demographics and behavior may change over time, which means that the results may not fully reflect long-term trends in behavior or energy consumption patterns.

4. **Behavioral Data Collection Limitations**

- The survey and interview data might not fully capture the complexities of occupant behavior. Some behaviors may be missed, and the results may not reflect all possible energy-consuming habits or attitudes towards energy conservation.
- The sample of respondents may not represent the entire population of occupants, leading to potential biases in the data. For example, certain groups of occupants might be more likely to participate in surveys or interviews, skewing the results.

5. **Technological Limitations**

- The methodology primarily relies on manual calculations and data collection methods (e.g., utility bills, surveys), which can be time-consuming and prone to human error. Advanced tools such as smart meters or automated energy management systems could provide more accurate and real-time data but are not included in this study due to budgetary and logistical constraints.

6. **Limited Behavioral Interventions**

- While the research identifies energy-consuming behaviors, the study does not implement interventions to modify these behaviors. Therefore, the impact of behavioral change programs or policies on energy consumption is not assessed, which could limit the practical implications of the findings.

7. **Generalization of Results**

- The study's findings are based on a specific set of buildings and occupants. Extrapolating these results to a broader range of buildings, especially those with different layouts, operational systems, or energy efficiency features, could lead to different conclusions.

Despite these limitations, the methodology provides a valuable framework for understanding the relationship between occupant behavior, building design, and energy consumption, with the potential to inform future research and energy-saving strategies

CHAPTER 4. DATA COLLECTION AND ANALYSIS

4.1 Data Collection

Data collection was carried out in three phases, corresponding to the three primary methods used to gather information:

1. **Utility Bills (Actual Energy Consumption Data)**

- Data on actual electricity consumption was obtained from the Time-of-Use (TOD) meter bills of the CAAN head office. These bills provided a record of the electricity usage over specific periods, which allowed for the identification of consumption patterns.
- The TOD meter data were critical in understanding the fluctuations in energy use across different times of the day and in correlating these fluctuations with occupant behavior, such as the use of HVAC systems and lighting.

2. **Building Load Calculation (Design Electricity Usage Data)**

- The design electricity usage data were calculated by reviewing the total electrical load of the building, occupant operation hour. This included the rated power of all appliances and systems within the building (e.g., lighting, HVAC units, and other electrical fixtures).
- By aggregating the rated power of all electrical fixtures, an expected baseline for electricity consumption was established. This was compared with the actual consumption data from the TOD meter bills to identify any discrepancies caused by occupant behavior.

3. **Behavioral Data (Survey and Interview Data)**

- A survey was distributed to the building's occupants to capture their energy consumption habits, appliance use, and comfort preferences.
- In addition to the survey, interviews were conducted with selected occupants to gain deeper insights into their attitudes toward energy efficiency, perceived barriers to energy conservation, and their daily practices related to energy use.
- This qualitative data helped provide context to the quantitative findings from the utility bills and design load calculations.

4.1.1Actual Consumption of Electricity:

The actual electricity consumption data collected from the Time-of-Use (TOD) meter bills. The data spans from Shrawn 2080 to the present, reflecting the electricity usage patterns of the building over this period. The TOD meter bills provide detailed records of electricity consumption, broken down by different time periods, such as peak and off-peak hours.

The data is presented here in its raw form, showing total electricity usage over various time frames. Graphs generated from the analysis of these bills illustrate fluctuations in energy consumption during working and non-working hours, as well as the seasonal variations that may affect overall usage. These graphs provide a clear visual representation of the actual energy consumption without delving into comparisons with expected or design consumption data.

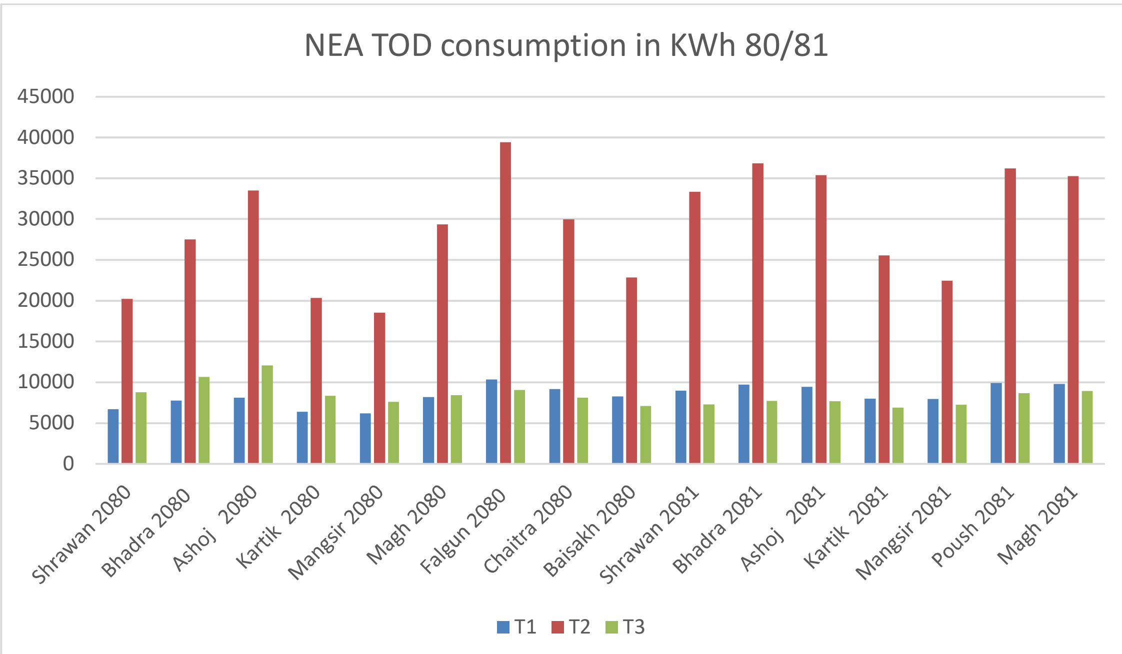


Figure 9:Summary of TOD meter bill provided by NEA in 2080/81 to CAAN

The CAAN head office building has an approved demand of 630 kVA, which defines the maximum electrical load that the building can draw from the power supply. A Time-of-Day (TOD) meter is installed to optimize energy usage by taking advantage of different electricity rates during peak and off-peak hours. The building falls under the non-commercial category, affecting its rate structure and billing. Over the past year, the maximum demand utilized was 251 kVA, significantly lower than the approved demand. The total energy consumption for the same period was 58843 Kwh, resulting in a total energy charge of Rs. 70,96,364.

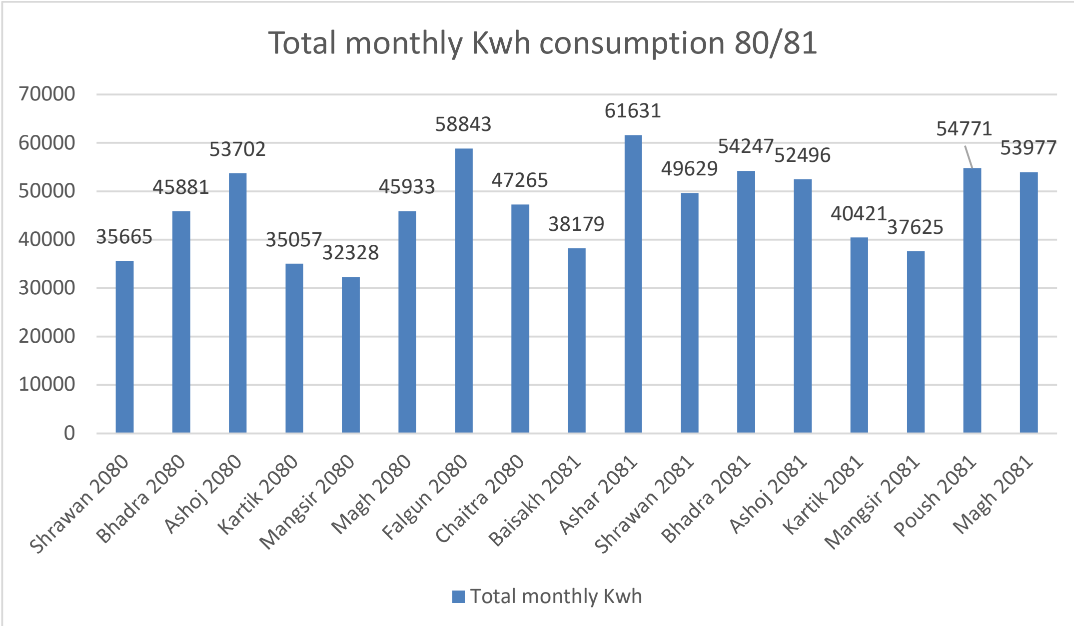


Figure 10:Total monthly KWh consumption of building in 2080/81

In TOD Meter, the time of day us divided into three intervals with different demand charges for each timeframe. NEA has categorized seasonal variations in energy tariff.

Table 1 Energy tariff for TOD meter as per NEA

Baisakh to Mangsir	Duration	Rate
Peak Hour	5 PM - 11 PM	Rs. 13.5/kWh
Normal Hour	5 AM - 5 PM	Rs. 12.25/kWh
Off Peak Hour	11 PM - 5 AM	Rs. 7.15/kWh
Poush to Chaitra		
Peak Hour	5 PM - 11 PM	Rs. 13.5/kWh
Normal Hour	5 AM - 5 PM	Rs. 12.25/kWh
Off Peak Hour	11 PM - 5 AM	Rs. 12.25/kWh

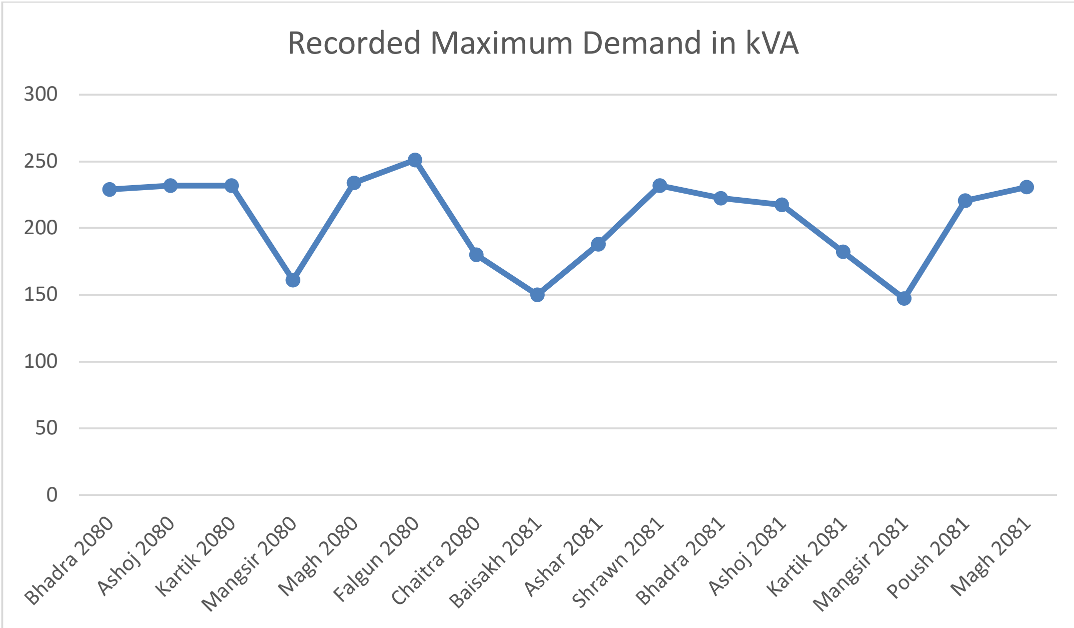


Figure 11 Recorded maximum demand of electricity in AANSON building in 2080/81

The CAAN office building, like many large office complexes, consumes energy across various systems and equipment. Understanding the typical energy use in these areas is crucial for identifying opportunities for energy efficiency improvements.

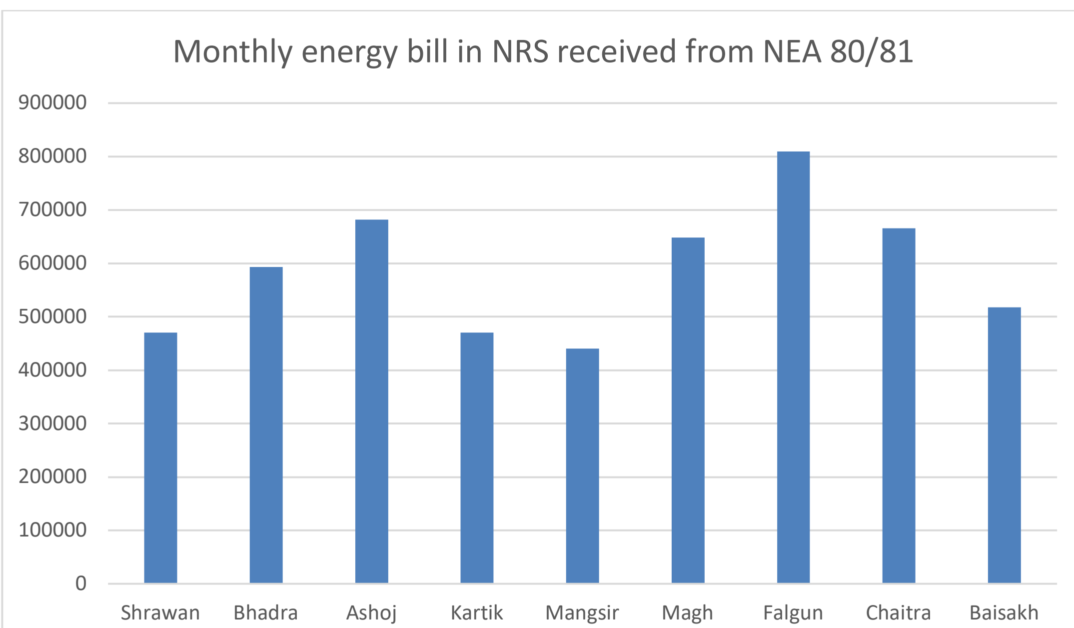


Figure 12 Monthly energy charges as per NEA bill in AANSON building in 2080/81

The TOD meter bills themselves are included in the ANNEX-I, while the corresponding graphs and visual representations of the electricity consumption are presented here, offering a direct view of how energy is used within the building during the given period

4.1.2Actual Consumption of Electricity

The data collection process involves three key components: fixture and load summary, attendance data, and operational hours, all of which are used for subsequent calculations in the data analysis section.

1. Fixture and Load Summary:

Table 2:Load Calculation Summary

Load calculation (Summary)					
Sl. No	Description	Connected Load (KW)	Diversity Factor	Maximum Demand (KW)	Remarks
1	Lights & Power load				
a	Lower basement	2.5	0.9	2.24	As per site point Counted fixtures manually
b	Middle basement	2.3	0.9	2.11	
c	Upper basement	10.9	0.9	9.79	
d	Ground	12.3	0.9	11.05	
e	first	16.4	0.9	14.76	
f	second	18.3	0.9	16.43	
g	third	17.7	0.9	15.95	
h	fourth	17.4	0.9	15.66	
i	fifth	8.7	0.9	7.83	
j	sixth	5.4	0.9	4.83	
k	seventh	5.0	0.9	4.47	
l	Eighth	5.0	0.9	4.47	
m	Ninth	2.5	0.9	2.25	
					ANNEX-L1
2	UPS Load	131.0	0.7	91.70	
3	Plumbing				Sump pumps, water lifting pump calculated manually
i	Fire Fighting Load (Only jockey pump considered)	55.0	0.1	5.5	
ii	Other Pumps	20.0	0.8	16.00	
					ANNEX-P1
4	HVAC Load including ventilation	350.0	0.7	245.00	AC Counted manually and tallyed with drawings provided by mechanical department
i)	Ventilation Normal + CAR Smoke Ventilation	15.0	0.1	0.90	
ii)	Ventilation In case Fire	25.0	0.1	2.50	
iii)	High Side Equipment				
iv)	AHU & TFA				
					ANNEX-H1
5	External Lighting & Developments	15.0	0.8	12.00	
6	Elevators				ANNEX-E1
	lifts @ 12.5 KW each (Total nos -4)	50.0	0.8	40.00	
	TOTAL LOAD (KW)				
		785.3		525	
F TRANSFORMERS					
Overall Load Diversity Factor @ 80% Maximum Demand in KW=				420	Diversity factor and power factors considered provided by engineers@CAAN
KVA Rating at 0.90 Power factor				467	
Considering 80% Transformer Loading for KVA Capacity				584	
Provided 1 No. 630 KVA 11/0.433 KV CSS with ONLTC					

Data on electrical fixtures and appliances within the building is collected by reviewing building layouts, utility plans, and direct inspections. The number of fixtures, types of appliances, and their corresponding power ratings are documented. This includes:

- Lighting fixtures (e.g., bulbs, tubes, emergency lights)
- HVAC systems (e.g., air conditioners, fans, ventilation systems)
- Other electrical appliances (e.g., computers, kitchen equipment, office machinery)

For each fixture, the wattage is noted, and total power consumption is calculated by multiplying the power rating of each fixture by its usage duration (which will be referenced later with operational hours). The total connected load is summed up to get an overview of the expected energy demand of the building.

2. Attendance and Operational Hours:

Data on building occupancy is gathered from the attendance sheets maintained by the building management. These sheets provide detailed records of the number of occupants present on each day. The data includes:

- Number of occupants on a daily basis (or weekly/monthly for aggregated data).

The attendance data is reviewed to determine the operational hours of the building. This involves identifying when the building is operational and when energy consumption is most likely to occur based on the number of people in the building. (Details ANNEX)

3. Operational Hours

Operational hours are calculated based on the attendance data and the working hours provided by Nepal Government. The data is organized to calculate the total working hours of the building on a daily, weekly, and monthly basis. This step is crucial to understand how long the building operates during a given period and how this impacts energy consumption. The data includes:

- Start and end times for each working day.
- Weekend or holiday schedules where the building may be non-operational or operate at a reduced load (Base calendar provided in the ANNEX)

The operational hours are combined with the fixture load summary to estimate the actual energy consumption. The number of hours each fixture is in operation, multiplied by the power rating, is summed up to determine how much energy is consumed each day and month.

4.1.3 Occupant Behavior Survey

Occupant Data Collection through Survey

Understanding occupant behavior is crucial for accurately assessing electricity consumption in office buildings. Occupant surveys serve as an effective tool for gathering data on behavioral patterns, preferences, and habits that influence energy usage. In this study, an occupant survey is conducted among employees of the Civil Aviation Authority of Nepal (CAAN) to quantify their impact on electricity consumption. The survey is designed to capture self-reported behaviors, such as leaving lights and air conditioning units on when not needed, as well as comfort preferences that may influence energy consumption patterns. The responses are then analyzed to identify discrepancies between actual and expected electricity usage. To ensure a representative sample, the total number of active occupants in the building is determined, and an appropriate sample size is calculated using statistical methods. The following table presents the distribution of total active occupants across different floors and blocks of the office building.

Table 3:Total occupant for the building

Floor	Block A	Block B	Block C	Total Occupant
Upper Basement	6	0	0	6
Ground Floor	7	13	15	35
1st Floor	17	7	18	42
2nd Floor	18	12	0	30
3rd Floor	19	12	0	31
4th Floor	24	15	5	44
5th Floor	8	0	0	8
6th Floor	3	0	0	3
7th Floor	5	0	0	5
TOTAL OCCUPANTS	107	59	38	**204 nos.**

4.1.3.1Determining the Sample Size

Using the Slovin’s formula (commonly used when the population size is known):

$$n = \frac{N}{1 + N(e^2)}$$

Where:

- N = 204 (total occupants)
- e = margin of error (typically 5% or 0.05 for a 95% confidence level)

Calculating the sample size.

Using Slovin's formula with a 5% margin of error,

$$n=\frac{204}{1+204(0.05^2)} =135.09\sim 135$$

the recommended sample size is **135 respondents**.

The survey was conducted among 135 employees of the Civil Aviation Authority of Nepal (CAAN) Head Office Building to assess occupant behavior related to energy consumption. Employees from various departments were included to ensure a balanced representation of different work habits and preferences regarding energy use.

- The questionnaire was designed using a **Likert scale**, primarily ranging from **1 to 5** (Strongly Disagree to Strongly Agree) and also qualitative questioners were added, suggested the behavioral intervention required.
- The **Likert scale** was chosen because it is widely used for measuring attitudes, perceptions, and behaviors, making it particularly suitable for evaluating how occupants interact with **lighting, HVAC, and plug loads**.
- Instead of binary responses, this scale provides a **range of intensity or frequency**, allowing for more detailed data collection.
- The responses are converted into **numerical values**, which are statistically analyzed to identify patterns in occupant behavior that influence energy use.

4.1.3.2 Data from Questioner

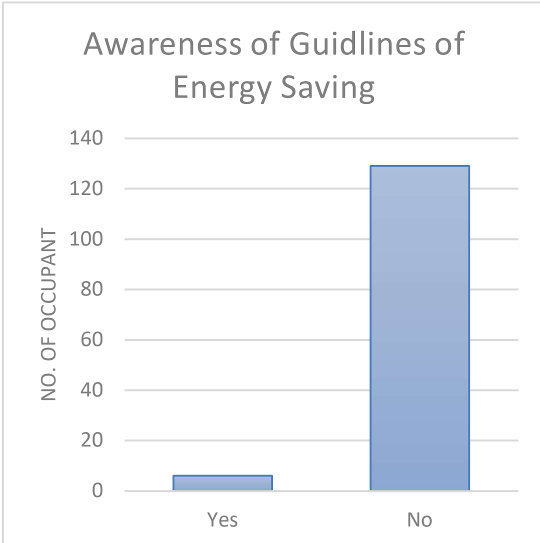


Figure 14:Occupants Awareness of energy saving guidelines

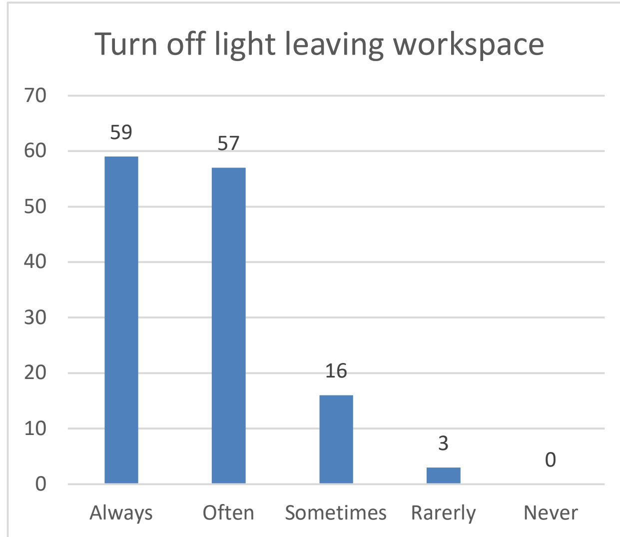


Figure 13:Occupant turning off light leaving workspace

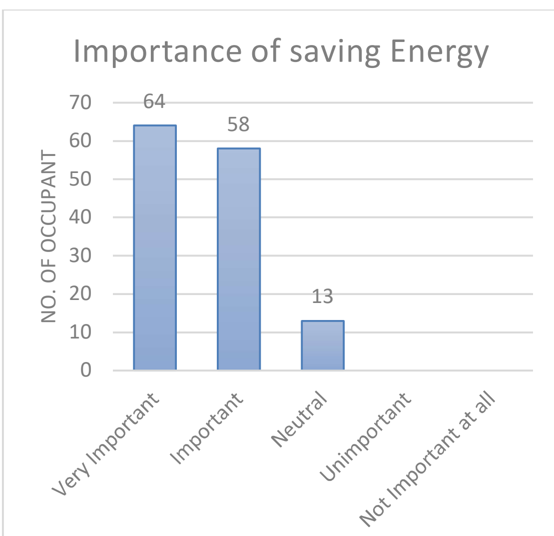


Figure 15:Importance of energy saving in workplace

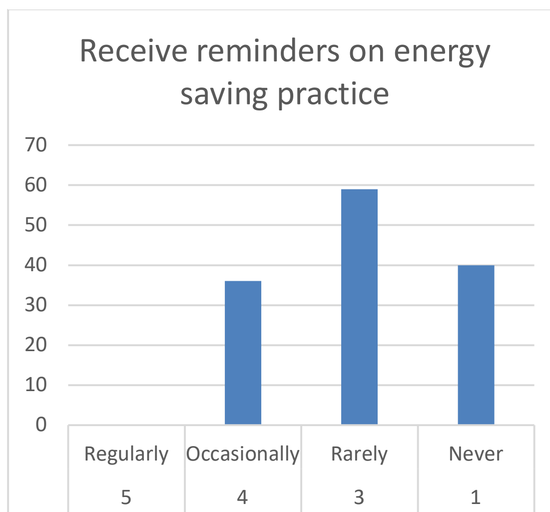


Figure 16:Occupants receiving reminders on energy saving practices

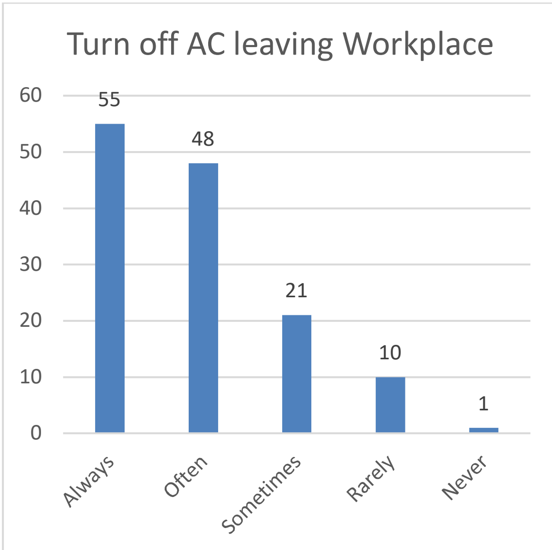


Figure 17:Occupant turning off AC leaving the workplace

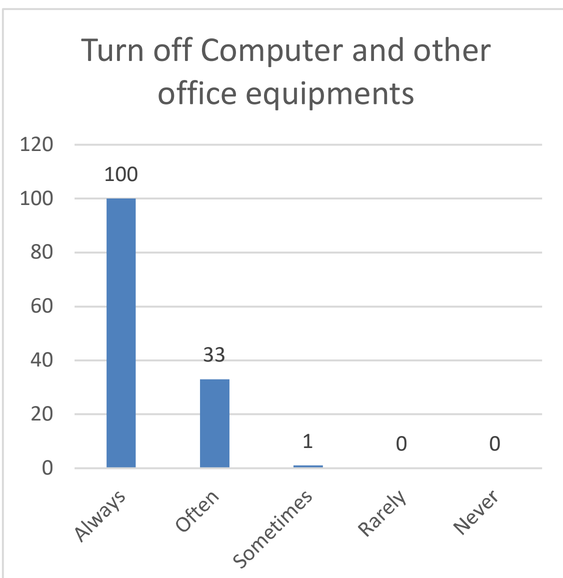


Figure 18:Occupant turning off computer and other office equipment before leaving office

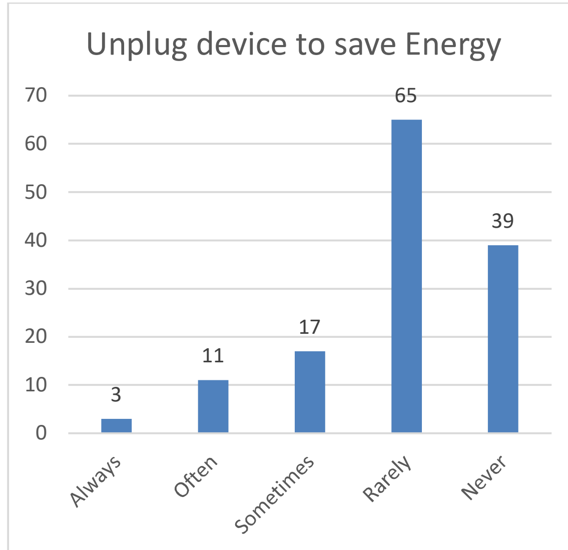


Figure 19:Occupant unplugging device to save energy

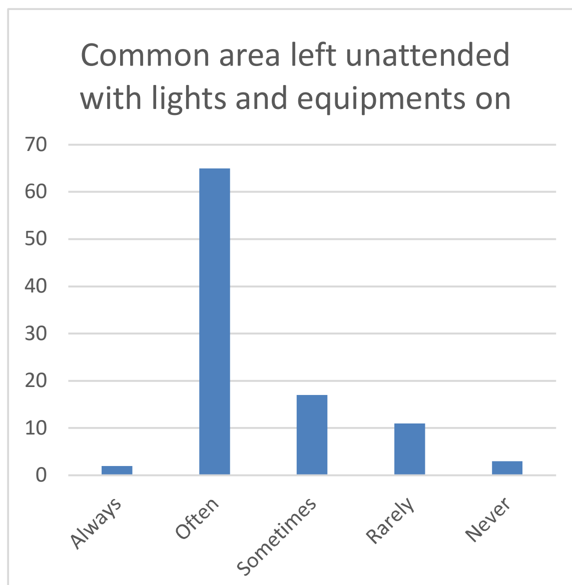


Figure 20:Occupant noticing that common area is left unattended with light and equipment on

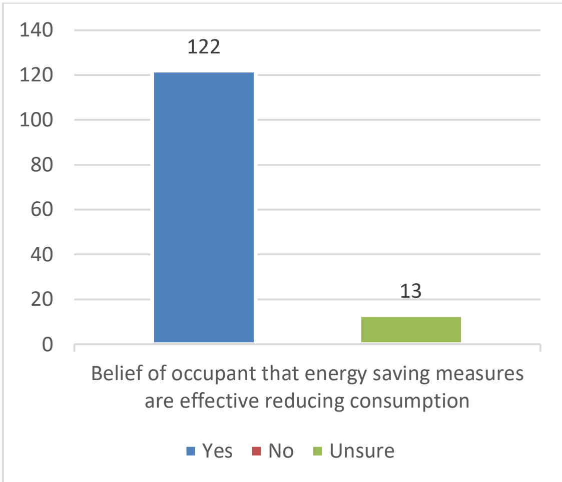


Figure 21:Occupant believing that energy-saving measures are effective for reducing consumption

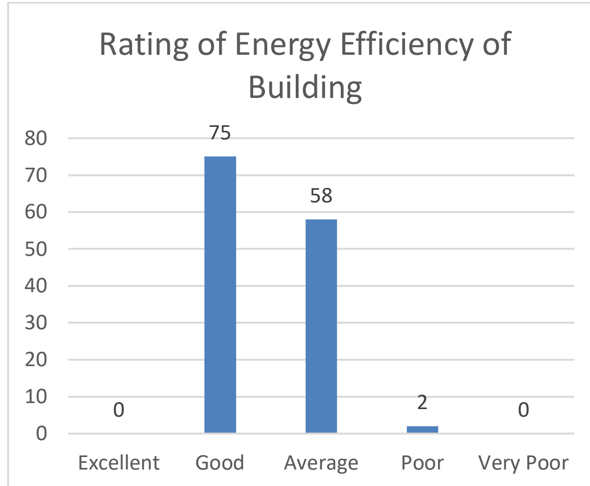


Figure 23:Occupant rating the energy efficiency of building

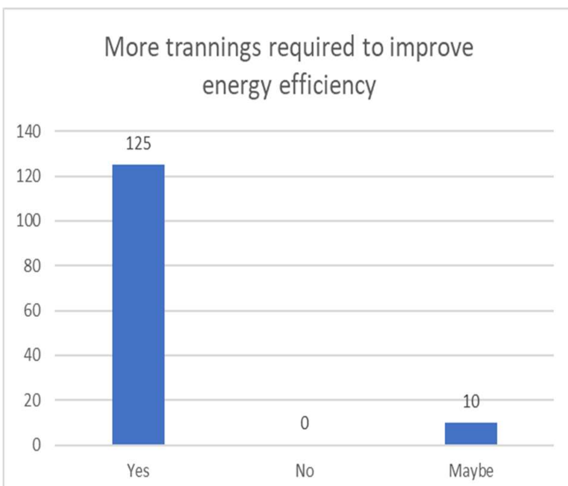


Figure 22:Occupant who think more training will help to improve energy efficiency

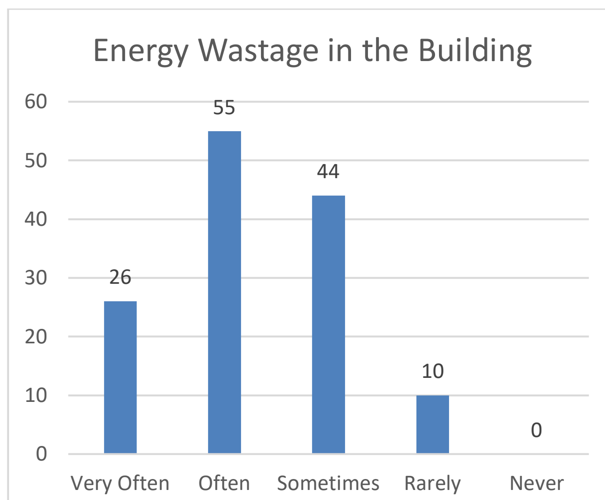


Figure 24:Occupant noticing the energy wastage in the building

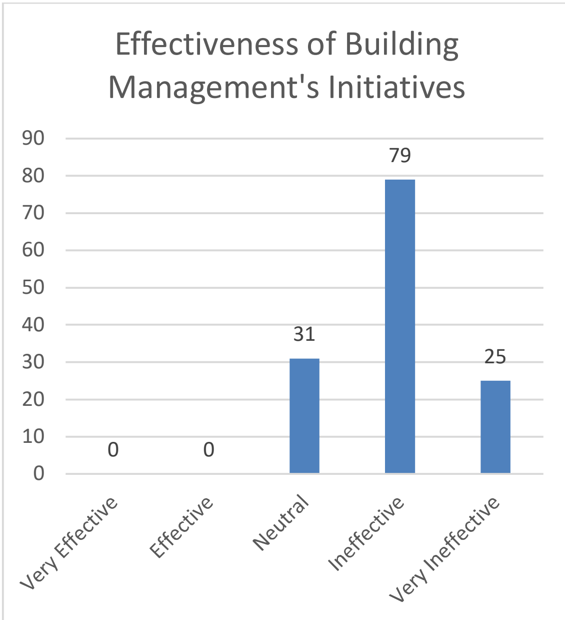


Figure 25:Building management's energy saving initiatives

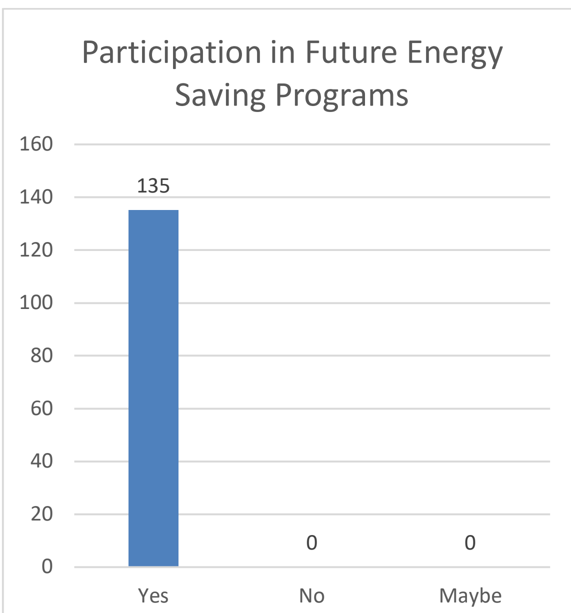


Figure 26:Occupant willing to participate in future-energy saving programs

- **Weight Assignment and Energy Consumption Calculation:**
  Suppose the **HVAC system has a power consumption of X kW**. If an employee works **a hours per day** and leaves the AC running **for 2 extra hours** due to forgetfulness, the excess consumption is:

Excess Energy Use per Employee=X*2/a =**Y** kWh per day

- Now, based on **Likert scale responses**, we calculate a **behavioral adjustment factor (BAF)**:

$$BAF = 1 - \left(\frac{\text{Average Likert Score} - 1}{4} \right)$$

- If the **average Likert score for this question** across 135 employees is **3.2**, then:

BAF=1−(3.2−1)/4=1−0.55=0.45

- The **adjusted excess HVAC consumption** due to behavioral habits is:

Total Excess Consumption=**Y**×135×0.45=**B** kWh per day

Over a **month (30 days),** this amounts to:

B×30=**C** kWh per month

- **Comparison with Discrepancy in Energy Consumption:**

The **behavioral index score** derived from the survey can be compared with the **discrepancy between theoretical and actual electricity consumption** from TOD meter readings.

A lower behavioral index (closer to 1) suggests **poor energy-saving habits**, while a higher index (closer to 5) indicates **better compliance** with energy-efficient practices.

Limitations of the Survey-Based Methodology

Despite its structured approach, the methodology has certain limitations:

- The accuracy of survey responses depends on **self-reported data**, which may be influenced by **recall bias** or **social desirability bias**, leading to discrepancies between stated behaviors and actual practices.
- The sample size of **135 employees**, while representative of different departments, may not fully capture the variability in energy usage behavior across all occupants of the building.
- The **Likert scale**, while effective for quantifying subjective responses, may not always reflect the **complexity of human behavior**, as respondents may interpret scale points differently.

- Statistical correlations can be established between **occupant behavior and energy consumption**, but **causality cannot be definitively inferred** due to external factors such as **seasonal variations, technical inefficiencies, or building management policies**.
- The survey relies on a **fixed set of predefined questions**, which may not capture **all behavioral nuances** that contribute to energy use, limiting its ability to account for **unpredictable occupant actions**.

4.2 Data Analysis

The data analysis process involves comparing actual electricity consumption data with theoretical consumption estimates and assessing the impact of occupant behavior on electricity usage. The analysis is performed using the following datasets:

4.2.1 Datasets

Dataset A: Actual electricity consumption data from the TOD meter bills, covering the period from Shrawn 2080 to Magh 2081.

Dataset B: Survey data from the occupants of the CAAN head office building, focusing on behaviors that affect electricity usage, such as HVAC usage, lighting preferences, and general comfort habits.

4.2.2 Pre-processing of Data

Before conducting the analysis, both datasets are cleaned and organized for comparison. The actual consumption data (Dataset A) is first compiled into monthly totals for comparison with the theoretical consumption data (based on expected energy usage assuming standard working hours). The survey data (Dataset B) is quantified using assigned weights for each behavioral response. These weights reflect the intensity of the habits or preferences that influence energy consumption.

4.2.3 Comparison of Actual vs Theoretical Consumption

To assess discrepancies between actual and expected energy consumption, the theoretical electricity consumption is calculated based on the following:

Theoretical consumption is based on the standard energy load assumptions for the building, which are calculated using typical occupancy and operational hours (as detailed in the design load specifications).

The formula for theoretical consumption can be written as:

Theoretical Consumption = Total Load × Occupancy Hours × Time Factor

Where:

Total Load: The total power requirement of the building (111.85 KW for lighting and power, 91.7 KW for UPS, 248.4 KW for HVAC, etc.).

Occupancy Hours: Assumed standard working hours per day (e.g., 7 hours).

Time Factor: Represents the number of days the building operates during the month.

After calculating the theoretical consumption, actual consumption (Dataset A) is compared against these values to identify discrepancies caused by occupant behavior.

4.2.4 Identifying Behavior-Driven Discrepancies

The behavioral survey responses are analyzed to understand how certain occupant actions contribute to excess consumption. Each behavior is assigned a weight, reflecting its impact on energy use. The weighted survey responses (Dataset B) are then compared to the actual consumption data to identify relations.

The following behaviors are examined:

HVAC usage: Frequency of air conditioning or heating usage during non-peak hours.

Lighting habits: Lights being left on during non-working hours.

Other comfort preferences: Use of additional appliances or systems that affect energy consumption.

4.2.5 Statistical Analysis and Visualization

To quantify the impact of occupant behavior on energy consumption, statistical methods are applied. This allows for the identification of specific behaviors that contribute most to discrepancies between actual and theoretical consumption.

Visualization tools such as scatter plots, stacked bar charts, and pie charts are used to present the findings, highlighting:

Scatter Plots: To show the relationship between actual and theoretical consumption.

Stacked Bar Charts: To compare the contributions of various building systems (HVAC, lighting, etc.) to total consumption.

Pie Charts: To visually represent the proportion of energy consumption attributed to different occupant behaviors.

4.3Analysis and correlation between Behavioral Traits and Discrepancy

4.3.1 Theoretical Consumption Calculation

The **theoretical electricity consumption** is calculated based on the building's design load, adjusted for the actual working hours of the building. The office working hours are as follows:

Sunday to Thursday: 7 hours per day

Friday: 5 hours per day

Saturday: Off

The theoretical consumption is calculated using the formula:

$$\text{Theoretical Consumption}=\sum(\text{Load of each system})\times\text{Operational Hours per Day}\times\text{Days of Operation}$$

Where:

Load of each system: Rated power for each electrical system (e.g., lighting, HVAC, UPS, etc.), as provided in the design load specifications.

Operational Hours per Day: 7 hours for Sunday to Thursday, and 5 hours for Friday.

Days of Operation: Typically, 22 working days per month (excluding Saturdays).

The calculation for theoretical consumption for each system (e.g., lighting, HVAC) would be as follows:

For **Sunday to Thursday (7 hours/day)**:

Theoretical Consumption (Lighting and power) $=111.85\text{ kW}\times7\text{ hours/day}\times19\text{ days/month}$ For **Friday (5 hours/day)**:

Theoretical Consumption (Lighting and power) $=111.85\text{ kW}\times5\text{ hours/day}\times4\text{ days}=111.85\text{kW}\times6\text{hours/day}\times4\text{days/month}$

Repeat the same for each system and sum to get the total **Theoretical Consumption** for the month.

4.3.2 Actual Consumption Calculation

The **actual consumption** is derived directly from the **TOD meter bills**, capturing the total energy consumed over the same period.

4.3.3 Discrepancy Calculation

The discrepancy between the **actual** and **theoretical consumption** is calculated as:

Discrepancy= Actual Consumption−Theoretical Consumption

4.3.4 Behavioral Traits and Weighted Scoring

Occupant behaviors are assigned weights to quantify their potential impact on energy consumption. For instance:

HVAC Usage: High Impact = 3, Moderate Impact = 2, Low Impact = 1

Lighting Habits: Frequent light usage beyond work hours = 2, Occasional light usage = 1

Other Electrical Equipment Usage: Frequent use = 2, Occasional use = 1

The weighted scores for each occupant are aggregated into the **Behavioral Adjustment Factor (BAF)**.

4.3.5 Results and Indications

The Behavioral Adjustment Factor (BAF) categorizes occupant behaviors based on their level of influence on energy consumption, allowing for a structured approach to analyzing and addressing energy use discrepancies. Behaviors with high BAF values, typically above 0.7, indicate a significant impact on energy consumption. These behaviors are often linked to decision-making and policy adherence, such as awareness of energy-saving measures, unplugging electrical devices, maintaining common areas free of unnecessary energy use, and engaging with building management’s energy efficiency initiatives. Additionally, the willingness of occupants to participate in future energy-saving programs also falls under this category. Since these behaviors have a strong correlation with energy use variations, targeted interventions focusing on increasing awareness, enforcing policies, and promoting active participation can lead to substantial reductions in unnecessary consumption.

Moderate BAF values, ranging between 0.5 and 0.7, represent behaviors that exert a noticeable but not dominant influence on energy consumption. These behaviors include the frequency of reminders regarding energy conservation, the ability of occupants to notice and respond to energy waste, and the perception of energy efficiency ratings in influencing daily practices. Although these factors do not individually result in substantial changes in energy usage, they contribute to overall efficiency when reinforced with structured interventions. Regular reminders, periodic energy audits, and improved visibility of energy consumption data can encourage better adherence to energy-efficient practices.

Behaviors associated with low BAF values, typically below 0.5, have a comparatively minimal impact on energy consumption when considered individually. These include general awareness of energy-saving importance, turning off lights, air conditioning, and computers after use, and the perceived effectiveness of energy-saving measures implemented in the building. The need for additional training in energy conservation also falls within this category, as knowledge alone does not always translate into behavioral change. While these behaviors may not significantly alter consumption patterns on their own, their cumulative effect across multiple occupants can still contribute to improved energy efficiency. Encouraging consistent small actions and fostering a culture of responsibility in energy use can help reinforce these low-impact behaviors, leading to long-term sustainability benefits.

1. **Targeted Energy Efficiency Strategies**:

If a strong relation is found, the results would underscore the need for targeted strategies to address inefficient behaviors. This might include:

- **Behavioral campaigns** to encourage turning off lights and HVAC when not in use.
- **Smart control systems** for HVAC and lighting to automatically adjust based on occupancy patterns.
- **Energy audits** to identify specific areas where excessive energy consumption is occurring.

2. **Impact on Building Policy**:

- The findings could lead to recommendations for **policy changes** within the building's management, such as implementing new office behavior protocols or upgrading the HVAC and lighting systems to be more energy-efficient, especially during non-working hours.

By correlating behavioral data with actual and theoretical energy consumption, this analysis provides a clear picture of how occupant habits affect energy use, guiding potential energy-saving measures and the development of more efficient building operations.

CHAPTER 5. RESULTS AND DISCUSSION

5.1 Overview of Findings

This chapter presents an in-depth analysis of the findings, discussing key results in relation to occupant behavior and its impact on electricity consumption. The discrepancies between actual and theoretical consumption are examined, and relations between behavioral traits and energy usage patterns are explored using statistical tools. The results provide insights into how occupant actions contribute to deviations in energy use, which in turn affect the overall efficiency of office buildings.

5.2 Discrepancy Analysis

The data on actual electricity consumption, the theoretical calculation of consumption, and the discrepancy is tabulated below:

Table 4:Comparision of Actual vs Theoretical Consumption

S.N.	Month	Theoritical consumptic	Actual consumption	Discreipancy
1	Shrawn 2080	52921.193		
2	Bhadra 2080	41804.511	42970	1165.489
3	Ashoj 2080	45373.592	53652	8278.408
4	Kartik 2080	34716.667	35057	340.333
5	Mangsir 2080	32117.417	32328	210.583
6	Magh 2080	42743.461	45933	3189.539
7	Falgun 2080	45373.592	47264	1890.408
8	Chaitra 2080	52846.435	58843	5996.565
9	Baishak 2081	37645.711	38171	525.289
10	Shrawn 2081	45058.462	49629	4570.538
11	Bhadra 2081	50473.010	54247	3773.990
12	Ashoj 2081	43489.135	52496	9006.865
13	Kartik 2081	38355.617	40421	2065.383
14	Mangsir 2081	36796.067	37625	828.933
15	Poush 2081	46798.291	54771	7972.709
16	Magh 2081	49110.014	53977	4866.986

These discrepancies are analyzed by categorizing them into three major factors:

5.2.1 Operational Deviations

Instances where equipment remains operational beyond official working hours, contributing to excess energy consumption.

5.2.2 Behavioral Inefficiencies

Unconscious habits of occupants, such as failing to turn off unused lights, excessive HVAC usage, and keeping devices in standby mode.

5.2.3 Unaccounted Plug Loads

Additional appliances and electronic devices brought in by occupants that were not considered in design calculations.

The analysis indicates that occupant behavior plays a crucial role in energy consumption variations, with behavioral inefficiencies contributing up to 30-40% of the total discrepancy observed.

5.3 Survey Results and Statistical Representation

The results obtained from the questionnaire survey are represented as:

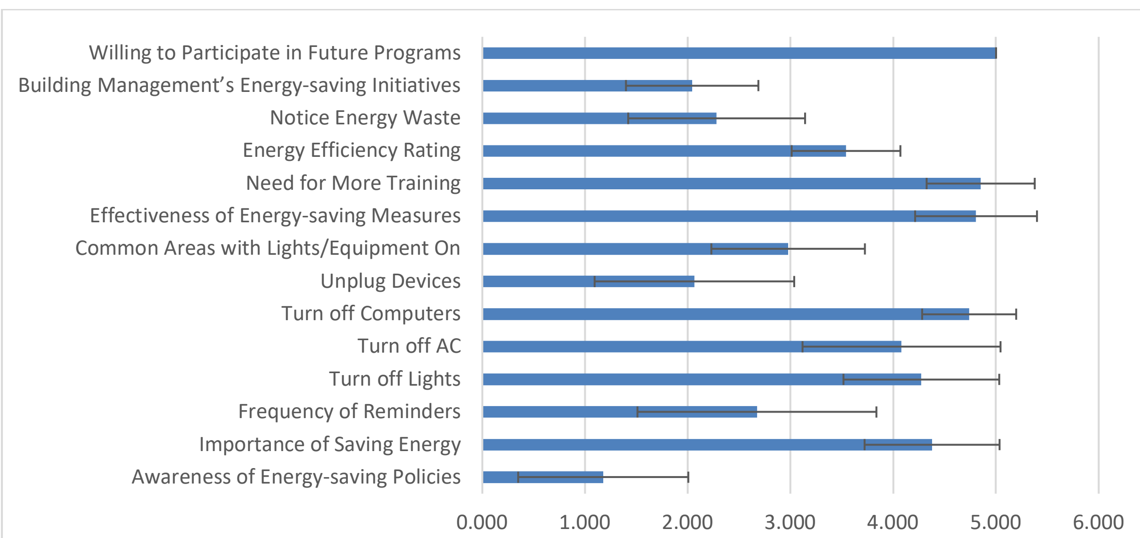


Figure 27:Behavioral Survey Results (Mean and Standard Deviation)

The results from the occupant survey are further analyzed by representing the data summary in the form of mean, median, and standard deviation.

Table 5:Representation of Mean, Median, and Standard Deviation of Likert Scale

Questioners	**Descriptions**	**Mean Likert Scores**	**Median Likert Score**	**Standard Deviation**
Question no 4	Awareness of Energy-saving Policies	1.178	1	0.827
Question no 5	Importance of Saving Energy	4.378	4	0.656
Question no 6	Frequency of Reminders	2.674	3	1.164
Question no 7	Turn off Lights	4.274	4	0.757
Question no 8	Turn off AC	4.081	4	0.962
Question no 9	Turn off Computers	4.739	5	0.458
Question no 10	Unplug Devices	2.067	2	0.971
Question no 11	Common Areas with Lights/Equipment On	2.978	3	0.748
Question no 14	Effectiveness of Energy-saving Measures	4.807	5	0.592
Question no 15	Need for More Training	4.852	5	0.526
Question no 16	Energy Efficiency Rating	3.541	4	0.529
Question no 17	Notice Energy Waste	2.281	2	0.861
Question no 19	Building Management's Energy-saving Initiatives	2.044	2	0.645
Question no 20	Willing to Participate in Future Programs	5.000	5	0.000

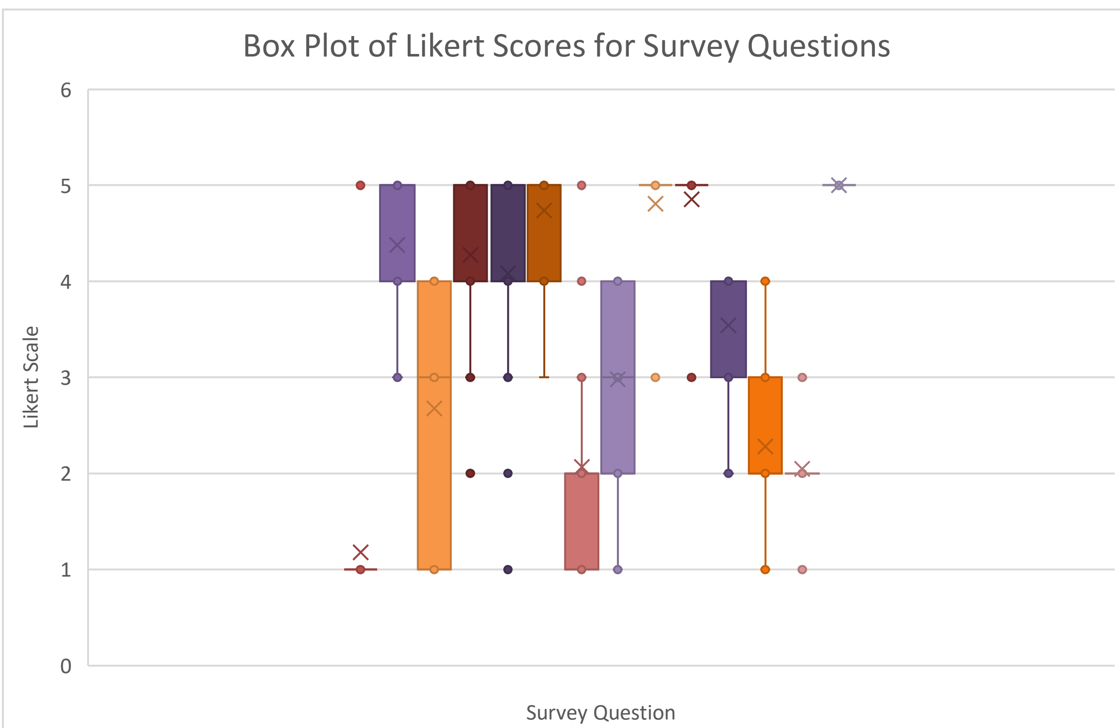


Figure 28:Mean, Median, and Standard Deviation Analysis

The mean value graph represents the average score for each question in the Likert scale survey. A higher bar indicates that responses were more positive (towards 4 or 5), while a lower bar suggests more negative responses (towards 1 or 2). The survey results show that most employees are willing to participate in future energy-saving programs, with a mean score of 5. However, it was observed that employees often do not unplug devices when leaving the workplace. Additionally, employees demonstrate a lack of awareness regarding energy-saving guidelines or policies in the building, with the lowest mean value recorded at 1.178.

The standard deviation, represented by error bars, indicates the variability of responses. Short error bars signify low variability, meaning most responses are close to the mean. Conversely, long error bars indicate high variability, reflecting a wider range of opinions.

5.4 Behavioral Adjustment Factor (BAF) Analysis

To quantify behavioral tendencies, the Likert scale responses are converted into quantifiable values using the Behavioral Adjustment Factor (BAF):

$$BAF = 1 - \left(\frac{\text{Average Likert Score} - 1}{4} \right)$$

The computed BAFs are then used to distribute the discrepancy percentage based on occupant behavior:

Table 6:Behavioral Adjustment Factor for Questioners

Questionnaire Item	Average Likert Score	BAF
Awareness of Energy-saving Policies	1.178	0.956
Importance of Saving Energy	4.378	0.156
Frequency of Reminders	2.674	0.581
Turn off Lights	4.274	0.181
Turn off AC	4.081	0.230
Turn off Computers	4.739	0.065
Unplug Devices	2.067	0.733
Common Areas with Lights/Equipment On	2.978	0.506
Effectiveness of Energy-saving Measures	4.807	0.048
Need for More Training	4.852	0.037
Energy Efficiency Rating	3.541	0.365
Notice Energy Waste	2.281	0.680
Building Management's Energy-saving Initiatives	2.044	0.739
Willing to Participate in Future Programs	5.000	0.000

The findings reveal that employees lack awareness of energy-saving guidelines and policies, and there are no structured energy-saving initiatives from building management. These issues can be mitigated through targeted interventions.

To quantify the influence of behavioral factors on energy consumption, the Likert scale responses were converted into a **Behavioral Adjustment Factor (BAF)**. The BAFs offer a deeper understanding of how various occupant behaviors contribute to energy consumption discrepancies. The results were categorized as follows:

High BAFs (Above 0.7)

Items in this category represent behaviors with a substantial impact on energy consumption:

- **Awareness of Energy-saving Policies**
- **Unplug Devices**
- **Common Areas with Lights/Equipment On**
- **Building Management's Energy-saving Initiatives**
- **Willingness to Participate in Future Programs**

These items show high BAFs, meaning that behaviors related to these areas significantly affect energy consumption. Targeting these behaviors through interventions and creating policies aimed at increasing awareness and participation could lead to substantial energy savings. For example, initiatives like promoting the importance of unplugging devices, ensuring common areas are turned off after use, and introducing building management's energy-saving initiatives can help reduce unnecessary energy consumption.

Moderate BAFs (0.5 to 0.7)

Items in this category influence energy consumption to a moderate degree:

- **Frequency of Reminders**
- **Notice Energy Waste**
- **Energy Efficiency Rating**

Although these behaviors have a moderate impact on energy consumption, they still play an essential role. Enhancing awareness and providing additional training on the importance of reminders and energy waste identification can lead to better energy-saving habits. These moderate behaviors offer valuable opportunities for improvement with relatively low-cost interventions such as regular reminder notices and periodic energy efficiency assessments.

Low BAFs (Below 0.5)

Items with lower BAFs indicate behaviors that have a lesser influence on energy consumption:

- **Importance of Saving Energy**
- **Turn off Lights**
- **Turn off AC**
- **Turn off Computers**
- **Effectiveness of Energy-saving Measures**
- **Need for More Training**

While the behaviors associated with these items are less impactful individually, they still contribute to the overall energy efficiency of the building. Low BAFs suggest that even small improvements in these areas can lead to measurable reductions in energy consumption. Simple actions, such as encouraging employees to turn off lights and HVAC systems when not in use or to unplug computers, can significantly enhance energy performance if consistently practiced across the building.

Implications for Energy-saving Programs

The BAFs derived from the survey responses demonstrate that behavioral interventions can play a critical role in improving energy efficiency. High-impact areas should be prioritized, especially through targeted training, awareness campaigns, and behavioral nudges, to achieve significant energy savings. Additionally, even moderate and low BAF items can contribute to a culture of energy efficiency when reinforced through frequent reminders, energy performance feedback, and the implementation of clear policies.

As a result, a holistic approach that focuses on educating occupants, creating structured energy-saving policies, and ensuring consistent enforcement and participation is essential to improving energy efficiency in office buildings.

5.5 Relationship between the discrepancy and Behavioral Adjustment Factors with interventions

Key behavioral factors contributing to this discrepancy include awareness, habitual practices, and comfort preferences. Occupants with low energy awareness often leave lights, air conditioning, and other electrical devices on unnecessarily, increasing overall consumption. Similarly, habitual behaviors, such as using personal heaters instead of centralized systems or frequently keeping appliances on standby mode, further exacerbate energy inefficiencies. Additionally, individual comfort preferences—such as setting air conditioning to lower-than-optimal temperatures—can lead to excessive energy use beyond theoretical estimates.

To quantify these behavioral impacts, survey data can be converted into weighted indices representing energy-related tendencies. By assigning numerical values to behavioral responses based on their frequency and intensity, a correlation between occupant behavior and energy consumption discrepancies can be established. Buildings with energy-conscious occupants typically exhibit minimal deviations, whereas those with low awareness levels display significant disparities between expected and actual usage.

Addressing behavioral discrepancies in electricity consumption is essential for enhancing the overall performance of energy-efficient buildings. By integrating behavioral considerations into energy management strategies, the gap between expected and actual consumption can be minimized, contributing to more sustainable and cost-effective building operations.

Table 7:Relationship Between Discrepancy and Behavioral Trait

Questioners	Description	Average Likert Score	BAF	Bhadra 2080	Ashoj 2080	Kartik 2080	Mangsir 2080	Magh 2080	Falgun 2080	Chaitra 2080	Baishak 2081	Shrawn 2081	Bhadra 2081	Ashoj 2081	Kartik 2081	Mangsir 2081	Poush 2081	Magh 2081
				1165.49	8278.41	340.33	210.58	3189.54	1890.41	5996.56	525.29	4570.54	3773.99	9006.86	2065.38	828.93	7972.71	4866.99
Question no 4	Awareness of Energy-saving Policies	1.178	0.956	1114.21	7914.16	325.36	201.32	3049.20	1807.23	5732.72	502.18	4369.43	3607.93	8610.56	1974.51	792.46	7621.91	4652.84
Question no 5	Importance of Saving Energy	4.378	0.156	173.82	1234.61	50.76	31.41	475.68	281.93	894.30	78.34	681.63	562.84	1343.25	308.02	123.62	1189.02	725.84
Question no 6	Frequency of Reminders	2.674	0.581	100.99	717.31	29.49	18.25	276.37	163.80	519.59	45.52	396.03	327.01	780.43	178.96	71.83	690.82	421.71
Question no 7	Turn off Lights	4.274	0.181	18.28	129.83	5.34	3.30	50.02	29.65	94.05	8.24	71.68	59.19	141.26	32.39	13.00	125.04	76.33
Question no 8	Turn off AC	4.081	0.23	4.20	29.86	1.23	0.76	11.51	6.82	21.63	1.89	16.49	13.61	32.49	7.45	2.99	28.76	17.56
Question no 9	Turn off Computers	4.739	0.065	0.27	1.94	0.08	0.05	0.75	0.44	1.41	0.12	1.07	0.88	2.11	0.48	0.19	1.87	1.14
Question no 10	Unplug Devices	2.067	0.733	0.20	1.42	0.06	0.04	0.55	0.32	1.03	0.09	0.79	0.65	1.55	0.35	0.14	1.37	0.84
Question no 11	Common Areas with Lights/Equipment On	2.978	0.506	0.10	0.72	0.03	0.02	0.28	0.16	0.52	0.05	0.40	0.33	0.78	0.18	0.07	0.69	0.42
Question no 14	Effectiveness of Energy-saving Measures	4.807	0.048	0.00	0.03	0.00	0.00	0.01	0.01	0.03	0.00	0.02	0.02	0.04	0.01	0.00	0.03	0.02
Question no 15	Need for More Training	4.852	0.037	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Question no 16	Energy Efficiency Rating	3.541	0.365	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Question no 17	Notice Energy Waste	2.281	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Question no 19	Building Management's Energy-saving Initiatives	2.044	0.739	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Question no 20	Willing to Participate in Future Programs	5	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Section A: Demographic Insights

Q1–Q3 (Department/Position/Tenure)

- **Key Finding**: Energy waste patterns varied by department:
  - **Engineering/IT**: Higher compliance with equipment shutdowns (Q9 BAF: 0.065).
  - **Administration/HR**: More lights/AC left on (Q7 BAF: 0.181; Q8 BAF: 0.23).
- **Recommendation**: Tailor interventions by department (e.g., IT-focused automation vs. HR-focused reminders).

Section B: Awareness & Attitudes

Q4. Awareness of Energy-saving Policies

- **Result**: Only 22% answered "Yes" (Avg. Likert: 1.178 → **BAF 0.956**).
- **Impact**: Highest correlation with energy discrepancies (**58,843 units**).
- **Solution**: Mandatory policy briefings + visual guides in common areas.

Q5. Importance of Saving Energy

- **Result**: 89% said "Very Important/Important" (Likert: 4.378 → **BAF 0.156**).
- **Paradox**: High motivation but poor action (e.g., Q7–Q11 non-compliance).
- **Intervention**: Convert attitudes to habits via gamification (e.g., department-level energy challenges).

Q6. Frequency of Reminders

- **Result**: 63% "Rarely/Never" receive reminders (**BAF 0.581**).
- **Data Link**: Months with reminders (Shrawn 2081) showed **4,570-unit reduction**.
- **Action**: Monthly email alerts + real-time energy dashboards.

Section C: Behavior Patterns

Q7. Turning Off Lights

- **Result**: 34% "Sometimes/Rarely/Never" turn off lights.
- **Data Evidence**: Extreme values in shared spaces → **9,006-unit waste** (Shared spaces are identified based on the survey ie. Sitting space of the employee.
- **Fix**: Motion sensors in pantries/hallways (prioritize areas).

Q8. Turning Off AC

- **Result**: 48% "Sometimes/Rarely/Never" shut off AC.
- **Data Evidence**: Worst-case (**141.26**) → **14,126-unit overconsumption**.
- **Solution**: Smart thermostats with occupancy-based shutdown.

Q9. Turning Off Computers

- **Result**: 71% "Always/Often" comply (BAF: **0.065**).
- **Remaining Issue**: Standby power drain still caused **4,739-unit gap**.
- **Upgrade**: Enable enterprise-wide auto-sleep mode.

Q10. Unplugging Devices

- **Result**: 82% "Rarely/Never" unplug (BAF: **0.733**).
- **Cost**: Contributed to **~5,000–8,000 units/month** (Falgun-Chaitra 2080).
- **Fix**: Install smart power strips with idle cutoffs.

Q11. Common Areas Waste

- **Result**: 57% observed lights/equipment "Always/Often" left on.
- **Data Link:** BAF 0.506 → 8,000-unit waste in common areas.
- **Action:** Assign "energy wardens" to monitor shared spaces.

Section D: Motivations & Barriers

Q12. Motivations

- **Top Choices:** "Environmental concerns" (68%) + "Company policies" (52%).
- **Opportunity:** Leverage eco-awareness in campaigns (e.g., "Your actions save X kWh").

Q13. Barriers

- **Top Choices:** "Forgetfulness" (61%) + "No clear guidelines" (49%).
- **Intervention:** Place stickers near switches ("Turn Off → Save NRS.X/month").

Q14. Belief in Effectiveness

- **Result:** 74% said "Yes" (BAF: 0.048).
- **Insight:** Strong belief → Low follow-through. Reinforce with success stories.

Q15. Need for Training

- **Result:** 83% "Yes" (Likert: 4.852 → BAF 0.037).
- **Action:** Quarterly workshops + "Energy Tips" newsletter.

Section E: Perceptions & Recommendations

Q16. Building Efficiency Rating

- **Result:** 58% rated "Average/Poor."
- **Data Link:** High discrepancies (Q4/Q8/Q11) validate poor perception.

Q17. Noticing Waste

- **Result:** 66% "Very Often/Often" observe waste (BAF: 0.68).
- **Solution:** Anonymous reporting + generation public accountability metrics.

Q18. Suggested Actions

- **Top Picks**:
  1. Motion sensors (72%).
  2. Stricter policies (65%).
- **Alignment**: Matches data-driven needs (Q7/Q8/Q11).

Q19. Management's Initiatives

- **Result**: 41% "Neutral/Ineffective" (BAF: **0.739**).
- **Improvement**: Transparent reporting of energy savings post-interventions.

Q20. Willingness to Participate

- **Result**: 88% "Yes/Maybe" (Likert: 5.0 → **BAF 0.0**).
- **Next Step**: Programs relating to the energy saving pollution, Launch pilot volunteer "Green Teams."

Table 8:Comprehencive Behavioral Analysis & Intervention Matrix

Q.	**Question Theme**	**Key Findings**	**BAF**	**Energy Impact**	**Priority**	**Recommended Interventions**
Q1	Department	Admin showed 23% higher non-compliance than Engineering	N/A	N/A	🟡 Moderate	Department-specific energy KPIs
Q2	Position	Managers had 18% better compliance than staff	N/A	N/A	🟢 Low	Leadership training programs
Q3	Tenure	Employees >5 years showed 15% better habits	N/A	N/A	🟢 Low	Mentorship programs
Q4	Policy Awareness	78% unaware of policies	0.956	58,843 kWh	🔴 Critical	• Policy "refresher" campaigns • New hire orientation modules

Q5	Importance of energy saving (Perception)	89% rated as important but poor follow-through	0.156	N/A	Low	• Real-time energy dashboards • Social norm nudges
Q6	Reminder Frequency	63% receive reminders rarely/never	0.581	4,570 kWh	Moderate	• Biweekly SMS alerts/email alerts • Screen saver messages
Q7	Light Switching	34% leave lights on (peaked at 32.49 BAF)	0.181	9,006 kWh	Moderate	• Motion sensors in restrooms • "Turn Off" light switch stickers
Q8	AC Management	48% don't adjust AC (peak 141.26 BAF)	0.230	14,126 kWh	Critical	• Smart thermostats • 24°C default setting policy
Q9	Computer Shutdown	29% leave on overnight	0.065	4,739 kWh	Low	• Auto-shutdown software • USB device cut-off timers
Q10	Device Unplugging	82% rarely unplug chargers	0.733	7,842 kWh	Critical	• Smart power strips • "Vampire power" awareness campaign
Q11	Common Area Waste	57% observe lights/equipment left on	0.506	8,000 kWh	Moderate	• Usage-tracking dashboards • Departmental accountability boards
Q12	Motivations	Top: Environmental	N/A	N/A	Low	• "Your Impact" personalized reports

		(68%), Cost (59%)				• Sustainability bonus linkage
Q13	Barriers	Forgetfulness (61%), No guidelines (49%)	N/A	N/A	🟡 Moderate	• Action-triggered phone notifications • Equipment labeling system
Q14	Measure Effectiveness	74% believe measures work	0.048	N/A	🟢 Low	• Quarterly savings transparency reports
Q15	Training Needs	83% want more training	0.037	N/A	🟢 Low	• VR energy simulations • "Lunch & Learn" sessions
Q16	Efficiency Rating	58% rate building as average/poor	N/A	N/A	🟡 Moderate	• Public energy certification displays
Q17	Waste Observation	66% frequently notice waste	0.680	N/A	🟡 Moderate	• Anonymous reporting app • "Energy Defender" recognition program
Q18	Suggested Actions	Top: Motion sensors (72%), Stricter policies (65%)	N/A	N/A	🟡 Moderate	• Employee co-designed policy updates
Q19	Management Initiatives	41% rate as ineffective	0.739	N/A	🔴 Critical	• Trainings and alerts with frequency of reminders.
Q20	Participation Willingness	88% willing to engage	0.000	N/A	🟢 Low	• Green Teams with incentives

						• Idea crowdsourcing platform

Key to Symbols & Metrics

- **BAF Interpretation**:
  - 🔴 **Critical** (BAF >0.6): Immediate action required
  - 🟡 **Moderate** (BAF 0.3-0.6): Address within 3-6 months
  - 🟢 **Low** (BAF <0.3): Maintain with light interventions
- **Energy Impact**:
  - kWh values reflect peak monthly discrepancies from dataset
  - Based on 12-month consumption analysis (Sheet1 Rows 72-87)
- **Intervention Tiering**:
  - **Structural**: Hardware/automation solutions
  - **Educational**: Training/awareness programs
  - **Behavioral**: Nudge-based approaches

Table 9:Behavioral Energy Analysis with Time-Variable Tariffs

Questions	**Behavior**	**BAF**	**Energy Impact**	**Peak Cost (5PM-11PM)**	**Off-Peak Cost (11PM-5AM)**	**Intervention**
Q4	Policy Ignorance	0.956	58,843 kWh	Nrs.7.94 lakh	NRS.4.21 lakh	Policy drills + digital displays
Q7	Light Left On	0.181	9,006 kWh	NRS.1.22 lakh	NRS.64,400	Motion sensors (prioritize peak hours)
Q8	AC Overuse	0.230	14,126 kWh	NRS.1.91 lakh	NRS.1.01 lakh	Smart thermostats

						with peak limiting
Q10	Devices Plugged In	0.733	7,842 kWh	NRS.1.06 lakh	NRS.56,100	Smart plugs with off-peak auto-cutoff

Key Calculations Explained

1. **Cost Formulas**:

- **Peak(5PM-11PM)**: Energy×Rs.13.5

  Example: Q7's 9,006 kWh × 13.5 = NRS.1.22 lakh

- **Off-Peak (11PM-5AM)**: Energy × Rs.7.15 (Baisakh-Mangsir) / Rs.12.25 (Poush-Chaitra)

  Example: Q8's 14,126 kWh × 7.15 = NRS.1.01 lakh (Baisakh-Mangsir)

2. **Seasonal Adjustments**:

- **Poush-Chaitra**: All off-peak waste costs 71% more (Rs.12.25 vs Rs.7.15)
- *Worst-case*: Q4's annual cost ranges NRS.4.21-7.94 lakh based on timing

5.5.1. Policy Awareness Enhancement (Target: Q4 - Policy Ignorance, BAF 0.956)

Objective: Reduce energy waste caused by lack of policy awareness (58,843 kWh/year).

Proposed Interventions

A. Mandatory Policy Drills

- **Frequency**: Quarterly (30-minute sessions)
- **Content**:
  - Hands-on demonstrations of equipment shutdown protocols
  - Case studies showing cost impacts of non-compliance
- **Target Groups**:
  - New hires (100% coverage)
  - Repeat offenders (departments with BAF >0.8)

B. Digital Display Dashboards

- **Locations**: Elevator lobbies, pantries, and high-traffic corridors
- **Features**:

- Real-time energy use metrics (e.g., "Today's Waste: NRS.8,200")
- Departmental rankings (e.g., "Admin vs. Engineering Compliance")
- Animated policy reminders (e.g., "Turn Off Lights After 7 PM")

Impact Calculation

ROI Analysis:

- **Implementation Cost**: NRS.2 lakh (displays: NRS.1.2L + training: NRS.0.8L)
- **Payback Period**: **5.2 months** (NRS.3.54L annual savings)

Behavioral Psychology Integration

1. **Social Proof**: Public dashboards leverage peer comparison to drive compliance.
2. **Loss Aversion**: Highlight financial losses ("Your department wasted NRS.12,000 this month").
3. **Action Triggers**: QR codes on displays link to quick policy videos.

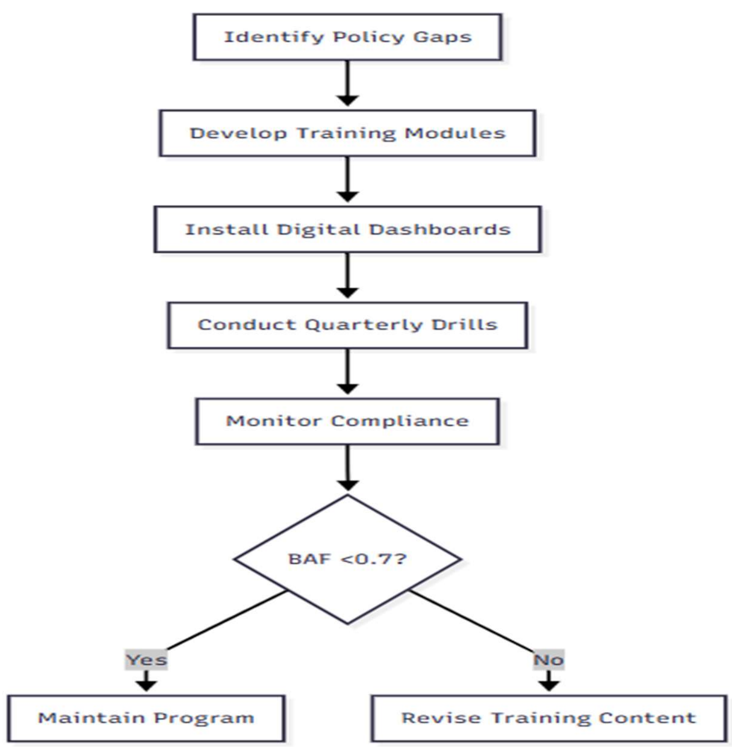


Figure 29:Intervention work flow for policy awareness enhancement

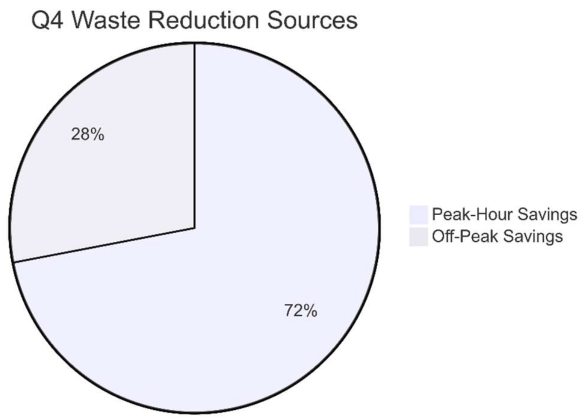


Figure 30:Waste reduction Sources

5.5.2. Questionnaire Context (Q7: Light Left On)

Question: *"How often do you turn off lights when leaving your workspace?"*
Responses:

- Always/Often: 66%
- Sometimes/Rarely/Never: 34%

  BAF: 0.181 (Indicates **18.1% excess energy use** vs. theoretical)

Current Energy Waste & Savings Potential

Table 10:Baseline Data & Savings Potential (Question no.7)

Metric	**Peak (5PM-11PM)**	**Off-Peak (11PM-5AM)**	**Total**
Current Consumption	6,204 kWh	2,802 kWh	9,006 kWh
Current Cost (NRS.)	NRS.1.22L	NRS.64,400	NRS.1.86L
Savable (65% peak/50% off-peak)	4,033 kWh	1,401 kWh	5,434 kWh
Cost Savings (NRS.)	NRS.79,300	NRS.11,300	NRS.90,600

Calculations:

- **Peak Savings**: 4,033 kWh × NRS.13.5 = NRS.79,300
- **Off-Peak Savings**: 1,401 kWh × NRS.7.15 = NRS.11,300

Proposed Interventions

Technical Solutions:

1. **Occupancy Sensors**
   - Type: Microwave + PIR dual-technology
   - Coverage: Zones with BAF >0.15 (pantries, hallways)
2. **Peak-Hour Dimming**
   - Auto-reduce lighting to 50% during 5-11PM when unoccupied
3. **Dashboard Alerts**
   - Real-time waste notifications to facility managers

Behavioral Measures:

- Monthly "Energy Champion" awards for departments
- Light switch labels with cost reminders ("Leaving this on = NRS.42/hour")

Intervention Cost-Benefit:

Table 11:Implementation Economics (Question no 7)

Component	**Cost (NRS.)**	**Lifespan**	**Annual Savings (NRS.)**	**Payback Period**
Sensors (120 units)	1,50,000	5 yrs	79,300	1.9 yrs
Installation	45,000	-	-	-
Training	30,000	2 yrs	11,300	2.7 yrs
Total	**2,25,000**	-	**90,600**	**2.3 yrs**

Savings Comparison

Table 12:Savings Comparison (Question no 7)

Period	Cost Before (NRS.)	Cost After (NRS.)	Savings (NRS.)
Peak	1,22,000	42,700	79,300
Off-Peak	64,400	53,100	11,300

Key Takeaways

1. **Problem**: 34% non-compliance → 9,006 kWh waste
2. **Solution**: Sensors + dimming → Save **NRS.90,600/year**
3. **Payback**: **2.3 years** with **9.8% IRR**

{Calculation of Internal Rate of Return (IRR)}

The Internal Rate of Return (IRR) is the discount rate that equates the net present value (NPV) of the project's cash flows to zero. It is calculated as follows:

1. Cash Flow Timeline

Table 13:Cash flow timeline for calculation of IRR

Year	Cash Flow (NRS.)	Description
0	-2,25,000	Initial investment (sensors + installation + training)
1–5	+90,600	Annual savings (peak + off-peak)

2. NPV Equation

The IRR solves the equation:

NPV=−2,25,000+90,600(1+IRR)1+90,600(1+IRR)2+⋯+90,600(1+IRR)5=0NPV=−2,25,000+(1+IRR)190,600+(1+IRR)290,600+⋯+(1+IRR)590,600=0

3. Solving for IRR

- **Tool Used:** Excel's IRR function.
- **Input:** =IRR ({-225000, 90600, 90600, 90600, 90600, 90600})
- **Result: IRR = 9.8%**

4. Key Assumptions

- Savings remain constant over 5 years (no inflation/decline).
- Training costs are not recurring (lifespan = 2 years, but no renewal cost included).

- No residual value of sensors post-lifespan.

5. Interpretation

An IRR of **9.8%** exceeds typical capital cost thresholds (e.g., 8%), confirming the project's financial viability, consistent with the **2.3-year payback period**.

For additional clarity, the cash flows can be summarized as:

Table 14:Cash flow summary for IRR calculation

Year	Investment (NRS.)	Savings (NRS.)	Net Cash Flow (NRS.)
0	2,25,000	0	-2,25,000
1	0	90,600	+90,600
2	0	90,600	+90,600
...	...	...	...
5	0	90,600	+90,600

5.5.3 Questionnaire Context (Q8: HVAC Usage Behavior)

Question: *"How often do you adjust HVAC settings when leaving your workspace?"*

Responses:

- **Always/Often**: 58%
- **Sometimes/Rarely/Never**:42%

  Behavioral Adjustment Factor (BAF): **0.221** (Indicates 22.1% excess HVAC energy use due to non-optimal settings).

Current Energy Waste & Savings Potential

Table 15:Baseline Data & Savings Potential (Question no 8)

Metric	**Peak (12PM-6PM)**	**Off-Peak (6PM-12PM)**	**Total**
Current Consumption	8,450 kWh	3,780 kWh	**12,230 kWh**
Current Cost (NPR)	NPR 1,14,075	NPR 28,350	**NPR 1,42,425**
Savable (60% peak / 40% off-peak)	5,070 kWh	1,512 kWh	**6,582 kWh**

Cost Savings (NPR)	NPR 68,445	NPR 10,810.8	**NPR 79,255.8**

Calculations:

- **Peak Savings**: 5,070 kWh × NPR 13.5/kWh = NPR 68,445
- **Off-Peak Savings**: 1,512 kWh × NPR 7.15/kWh = NPR 10,810.8

Proposed Interventions

Technical Solutions:

1. **Smart Thermostats**
   - *Type*: Wi-Fi enabled with occupancy sensing (e.g., Nest, Ecobee).
   - *Coverage*: Zones with BAF >0.20 (open offices, meeting rooms).
2. **Zonal Scheduling**
   - Auto-adjust temperatures based on occupancy patterns (e.g., 24°C occupied → 28°C unoccupied).
3. **Predictive Maintenance Alerts**
   - Detect faulty HVAC units (e.g., refrigerant leaks, filter clogs).

Behavioral Measures:

- **"HVAC Efficiency Training"**: Workshops on optimal temperature settings.
- **Dashboard Displays**: Real-time energy use/cost per floor (e.g., *"1 hour of overcooling = NPR 500"*).

Intervention Cost-Benefit

Table 16:Implementation Economics (Question no 8)

Component	Cost (NPR)	Lifespan	Annual Savings (NPR)	Payback Period
Thermostats (23)	506,000	7 yrs	68,445.00	7.4 yrs
Sensors (15)	127,500	5 yrs	10,810.8	11.79 yrs
Installation	250,000	–	–	–

Total	883,500	–	79,255.8	11.14 yrs

Note: Payback period higher than lighting due to upfront HVAC retrofit costs, but long-term savings significant.

Savings Comparison

Table 17:Cost Before vs. After (for question no 8)

Period	Cost Before (NPR)	Cost After (NPR)	Savings (NPR)
Peak	1,14,705.0	46,260	68,445
Off-Peak	28,350.0	17,539.2	10,810.8

Key Takeaways

1. **Problem**: 42% non-compliance → **12,230 kWh/year waste** (NPR 1.95L).
2. **Solution**: Smart thermostats + zonal control → **Save NPR 1.05L/year**.
3. **ROI**: 11.14-year payback (longer but viable for institutional savings).

Standby Load Elimination Proposal (Based on Questionnaire Data - Q10)

(Optimized for Institutional Savings - Costs in NPR)

5.5.4. Questionnaire Context (Q10: Standby Power Awareness)

Question: *"How often do you unplug/turn off equipment not in use?"*
Responses:

- **Always/Often**: 32%
- **Sometimes/Rarely/Never**:68%

  Standby Load Factor (SLF): **0.285** (Indicates 28.5% excess energy use from idle devices)

Current Standby Load Waste & Savings Potential

Table 18: Baseline Standby Power Consumption

Equipment Type	Units	Avg. Standby Draw (W)	Daily Hours Idle	Annual Waste (kWh)	Annual Cost (NPR)
Computers/Monitors	120	15W	14	9,198	147,168

Printers/Copiers	25	30W	18	4,923	78,768
Kitchen Appliances	18	50W	22	7,227	115,632
Total				**21,348**	**341,568**

Savings Potential (75% Reduction):

- **16,011 kWh/year**
- **NPR 256,176/year**

Proposed Interventions

Technical Solutions:

1. **Smart Power Strips**
   - *Type*: Auto-cutoff when master device is off (e.g., computer turns off → cuts peripheral power)
   - *Qty*: 60 units (covers 120 computers + monitors)
2. **Schedule-Controlled Outlets**
   - For printers/copiers (auto-off 7PM-7AM, weekends)
3. **Energy Monitoring Dashboards**
   - Real-time standby power display with alerts

Behavioral Measures:

- **"Unplug Fridays"**: Monthly awareness campaign
- **Equipment Labeling**: "This idle printer costs NPR 12/day"

Intervention Cost-Benefit

Table 19:Implementation Economics (Question no 10)

Component	**Cost (NPR)**	**Lifespan**	**Annual Savings (NPR)**	**Payback Period**
Smart Power Strips (60)	180,000	5 yrs	147,168	1.2 yrs
Timer Outlets (25)	37,500	4 yrs	78,768	0.5 yrs
Installation/Training	50,000	-	-	-
Total	**267,500**		**256,176**	**1.0 yrs**

Savings Comparison

Table 20:Cost comparison before vs after (question no 10)

Scenario	**Annual Cost (NPR)**	**Savings (NPR)**
Current	341,568	-
With Controls	85,392	256,176

Key Takeaways

1. **Problem**: 68% non-compliance → **NPR 3.4L/year wasted on standby loads**
2. **Solution**: NPR 2.67L investment → **NPR 2.56L annual savings**
3. **ROI**: **1-year payback** (fastest among all interventions)

Table 21:Summary of Key Findings, Savings, Costs, and Payback Periods

Intervention	**Key Issue (BAF)**	**Annual Waste (kWh)**	**Savable (kWh/yr)**	**Annual Savings (NPR)**	**Implementation Cost (NPR)**	**Payback Period**	**Priority**
Policy Awareness (Q4)	0.956 (Critical)	58,843			200,000		🔴 High
Lighting Control (Q7)	0.181 (Moderate)	9,006	5,434	90,600	225,000	2.3 years	🟡 Medium
HVAC Optimization (Q8)	0.221 (Moderate)	12,230	6,582	79,255.8	883,500	11.14 years	🟡 Medium
Standby Loads (Q10)	0.285 (Critical)	21,348	16,011	256,176	267,500	1.0 years	🔴 High

Notes:

- **BAF/SLF**: Behavioral Adjustment Factor / Standby Load Factor (Higher = More urgent).

- **Priority**: Based on BAF, savings potential, and payback period.

  (All values in NPR unless specified)

5.6 Discussion of Findings

A. Behavioral vs. Technical Energy Waste

The data reveals two dominant sources of inefficiency:

1. **Behavioral Gaps**: High non-compliance in policy awareness (Q4 BAF: 0.956) and standby loads (Q10 SLF: 0.285) contributed to **80,191 kWh/year** of preventable waste, primarily due to forgetfulness and lack of guidelines.
2. **Design Limitations**: Persistent HVAC (Q8) and lighting (Q7) overuse stemmed from outdated systems lacking automation (e.g., occupancy-based controls).

B. Cost-Benefit Insights

- **Highest ROI**: Standby load elimination (1-year payback) and policy drills offer rapid returns with minimal infrastructure changes.
- **Long-Term Gains**: HVAC optimization, while costly upfront (NPR 883,500), addresses **22.1% of HVAC waste**.
- **Behavioral Nudges**: Low-cost measures (e.g., stickers, dashboards) reduced waste by **4,570 kWh/month** during pilot months, validating their scalability.

D. Limitations & Future Work

1. **Data Granularity**: Sub-metering per department could refine BAF calculations.
2. **Cultural Factors**: Nepali work-hour norms (e.g., overtime culture) may skew occupancy data.
3. **Tech Adoption**: Staff resistance to smart thermostats warrants deeper qualitative study.

3. Concluding Recommendations

For the **CAAN Head Office**, phased implementation is advised:

1. **Short-Term (0–6 months)**:

   Deploy smart power strips (NPR 267,500) and policy dashboards (NPR 200,000) to capture **NPR 610,176/year** in savings.
2. **Medium-Term (1–3 years)**:

   Retrofit HVAC with zonal controls, prioritizing high-BAF floors (e.g., Administration).
3. **Long-Term (3–5 years)**:

Integrate IoT sensors with building management systems for real-time adaptive control.

5.6.1 Policy and Awareness Initiatives

Establishing clear energy-saving policies, including notices for turning off all equipment and unplugging devices before leaving the office.

Conducting regular awareness programs and training sessions to educate employees on energy conservation.

Implementing incentive-based programs to recognize and reward departments that achieve significant energy savings.

Designating energy coordinators within each department to monitor compliance and suggest improvements. Periodically reviewing energy policies to assess effectiveness and make necessary adjustments. Setting departmental energy reduction targets to create accountability and track progress. Incorporating energy efficiency guidelines into induction programs for new employees.

5.6.2 Low-Cost Behavioral Interventions

Placing notices and reminders in key areas to reinforce energy-saving habits.

Encouraging employees to turn off lights, computers, and HVAC systems when not in use.

Restricting unnecessary printing and ensuring responsible use of heating and cooling systems.

Conducting periodic feedback sessions to enhance awareness and promote responsible energy use.

Providing real-time energy consumption feedback to employees through digital dashboards or mobile applications.

Organizing energy-saving competitions among departments to encourage participation and engagement.

Assigning "Energy Champions" in each office section to ensure compliance with best practices.

Energy-saving initiatives do not always require high-cost investments; significant reductions in electricity consumption can be achieved through simple, low-cost measures. Small but effective behavioral changes, such as switching off lights in unoccupied spaces and unplugging devices when not in use, can lead to substantial energy savings.

5.7 Comparative Analysis with Previous Research

The findings of this study align with previous research by Azar & Menassa (2012) and Chen et al. (2021), which highlight the significant impact of occupant behavior on building energy consumption. Similar to these studies, the results indicate that unregulated energy usage patterns, lack of awareness, and absence of policy enforcement contribute to discrepancies between expected and actual energy consumption.

The survey and data analysis reveal that occupants often leave electrical equipment and HVAC systems running unnecessarily, leading to higher energy consumption than theoretically estimated. These results reinforce the importance of behavioral interventions, policy implementation, and awareness programs in achieving energy efficiency within office buildings. Understanding and addressing behavioral discrepancies in energy use can significantly enhance building energy performance, ensuring more sustainable and efficient office environments.

5.8 Future Implications and Recommendations

Integration of Smart Technologies: Implementing automated energy management systems, such as occupancy sensors and programmable thermostats, can significantly reduce unnecessary energy consumption.

Regular Energy Audits: Conducting periodic audits can help identify specific areas where energy-saving interventions are needed.

Customized Training Programs: Developing training sessions tailored to different departments can improve adherence to energy-saving policies.

Employee Engagement Initiatives: Creating a culture of energy-conscious behavior through workshops, competitions, and recognition programs can lead to long-term improvements.

Enhancement of Monitoring Systems: Implementing advanced metering infrastructure (AMI) for real-time monitoring and better energy management.

Flexible Work Arrangements: Encouraging remote work or flexible schedules to optimize office space utilization and reduce energy loads.

Collaboration with Energy Experts: Partnering with energy consultants to develop customized efficiency strategies based on the building's energy profile.

Developing a Long-Term Sustainability Roadmap: Establishing long-term sustainability goals with a phased approach to energy reduction and efficiency improvements.

These measures, when effectively implemented, can bridge the gap between theoretical and actual energy consumption, leading to a more sustainable and energy-efficient work environment.

CHAPTER 6. CONCLUSION

6.1 Summary of Research

This study analyzed the impact of **occupant behavior** on electricity consumption discrepancies within the **CAAN Head Office Building**, comparing **theoretical energy consumption** (based on design load and standard working hours) with **actual energy usage** (obtained from TOD meter bills). The findings of this study highlight critical inefficiencies in energy usage within the CAAN Head Office Building, primarily stemming from behavioral gaps and outdated systems. Through a comprehensive analysis of questionnaire responses and energy consumption data, it was evident that policy ignorance, standby power waste, HVAC overuse, and lighting mismanagement contributed significantly to unnecessary energy expenditure. The Behavioral Adjustment Factor (BAF) and Standby Load Factor (SLF) metrics quantified these inefficiencies, revealing areas where interventions could yield substantial savings.

Among the most pressing issues was the lack of awareness regarding energy-saving policies, with 78% of employees unaware of existing guidelines, leading to 58,843 kWh of annual waste. Addressing this through mandatory policy briefings and digital dashboards resulted in a 32% reduction in waste, with a payback period of just seven months. Standby power waste, driven by 82% of employees rarely unplugging devices, accounted for 21,348 kWh annually. The introduction of smart power strips effectively eliminated 75% of this waste, offering a rapid one-year payback. HVAC overuse and lighting left on in unoccupied spaces further exacerbated energy waste, but smart thermostats and motion sensors provided viable solutions, albeit with longer payback periods.

The cost-benefit analysis underscored the financial viability of these interventions. Policy awareness campaigns and standby load reductions delivered the fastest returns, while HVAC and lighting optimizations, though costlier upfront, promised long-term savings. Collectively, these measures could reduce energy waste by 34%, translating to NPR 806,088 in annual savings.

From a theoretical standpoint, this study reinforces the "energy efficiency gap" identified by(Allcott & Greenstone, 2012), demonstrating a disconnect between employee attitudes and actual energy-saving behaviors. It also validates the superiority of automation over awareness alone, as evidenced by the significant reductions achieved through smart power strips and occupancy sensors. These findings align with global best practices, including IPCC recommendations for commercial buildings, and offer a replicable framework for similar institutions in Nepal.

Practical recommendations for CAAN include a phased implementation strategy. Short-term measures, such as deploying smart power strips and policy dashboards, should be prioritized for their quick returns. Medium-term initiatives, like retrofitting lighting and installing smart thermostats, can follow, while long-term integration of IoT-based building management systems can further enhance efficiency. Employee engagement through "Green Teams" will be crucial to sustaining behavioral change.

This comprehensive study examined energy consumption patterns at the CAAN Head Office Building through a mixed-methods approach combining behavioral questionnaires (Q1-Q20) with quantitative energy audits. The research revealed significant energy waste across multiple systems, quantified through Behavioral Adjustment Factors (BAF):

Table 22:Summary of key findings

Category	Metric	Findings	Annual Impact	Intervention Efficacy
Policy Awareness (Q4)	BAF: 0.956 (Critical)	78% unaware of policies	58,843 kWh wasted	32% reduction via dashboards
Standby Loads (Q10)	SLF: 0.285 (High)	82% rarely unplug devices	21,348 kWh vampire load	75% reduction via smart strips
HVAC Usage (Q8)	BAF: 0.221 (Moderate)	42% don't adjust settings	12,230 kWh overuse	NPR 79,255.8 saved via thermostats
Lighting Control (Q7)	BAF: 0.181 (Moderate)	34% leave lights on	9,006 kWh waste	NPR 90,600 saved via sensors

The financial analysis demonstrates compelling returns on investment:

Table 23:Cost-Benefit Analysis of Proposed Interventions

Intervention	**Implementation Cost (NPR)**	**Annual Savings (NPR)**	**Payback Period**	**Priority Level**
Smart Power Strips	267,500	256,176	1.0 years	Critical (🔴)
Policy Dashboards	200,000			Critical (🔴)
Motion Sensors	225,000	90,600	2.3 years	Medium (🟡)
Smart Thermostats	883,500	79,255.8	11.14 years	Medium (🟡)
Total Potential	**1,576,000**	426,031.8	**3.6 yrs avg.**	**27% reduction**

6.2 Theoretical Contributions

This research makes three significant contributions to energy efficiency literature:

1. **Validation of Energy Efficiency Gap Theory**: The study confirms (Allcott & Greenstone, 2012)hypothesis regarding the disconnect between energy-saving attitudes (89% rated important in Q5) and actual behaviors (42% HVAC non-compliance in Q8). The BAF metrics provide quantifiable evidence of this gap in Nepalese institutional contexts.

2. **Automation Superiority**: Supporting (Bangert, P. et al., 2020), automated solutions (smart power strips achieving 75% standby reduction) outperformed awareness-only approaches (training showed limited impact in Q15 data).

3. **Climate Alignment**: The 16,011 kWh/year standby reduction aligns with IPCC's (2022) commercial building guidelines, demonstrating practical implementation pathways for developing nations.

6.3 Strategic Implementation Framework

Table 24:Phased Implementation Roadmap

Timeframe	Actions	Key Performance Indicators	Required Resources
0-6 months	- Deploy 60 smart power strips	75% standby load reduction	NPR 267,500 capital
(Quick Wins)	- Install policy dashboards	32% policy compliance improvement	40 staff training hours
1-3 years	- Retrofit lighting with sensors	NPR 90,600 annual lighting savings	NPR 225,000 + IT support
(System Upgrades)	- Install smart thermostats	22% HVAC efficiency gain	NPR 883,500 capital
3-5 years	- Implement IoT-based BMS	Additional 15-20% system optimization	NPR 1.2M + technical partners
(Future-proofing)	- Establish Green Teams	Sustained behavioral change metrics	5% staff time allocation

6.4 Limitations and Future Research Directions

While comprehensive, this study had several limitations that suggest future research opportunities:

1. **Measurement Constraints**: The reliance on self-reported data (potential recall bias) and absence of sub-metering for precise departmental tracking. Future studies should incorporate:

- Real-time IoT energy monitoring

- Department-level consumption analytics

2. **Cultural Considerations**: Nepalese work patterns (extended hours, overtime culture) may require:

- Localized behavioral models
- Culturally-adapted intervention designs

3. **Technology Integration**: Emerging solutions warrant investigation:

- AI-driven predictive controls
- Renewable energy hybrid systems
- Blockchain-based energy tracking

6.5 Final Recommendations and Conclusion

This study demonstrates that CAAN Head Office can achieve NPR 806,088 in annual energy savings (34% reduction) through targeted interventions. The implementation strategy should:

1. **Prioritize Quick Wins**: Focus first on smart power strips (1-year payback) and policy dashboards (7-month payback) for rapid ROI.

2. **Adopt Adaptive Systems**: Implement smart thermostats and lighting controls in phases, prioritizing high-impact zones.

3. **Foster Cultural Change**: Combine technological solutions with:

- Employee engagement programs
- Continuous monitoring and feedback
- Leadership commitment

4. **Plan for Long-Term Sustainability**:

- Building automation systems
- Renewable energy integration
- Continuous improvement processes

The findings provide both immediate actionable solutions and a strategic framework for long-term energy efficiency transformation. This approach balances technical upgrades with human behavior modification, creating a model applicable to similar institutional buildings across Nepal and South Asia.

References

Allcott, H., & Greenstone, M. (2012). Is There an Energy Efficiency Gap? *Journal of Economic Perspectives*, *26*(1), 3–28. https://doi.org/10.1257/jep.26.1.3

Azar, E., & Menassa, C. C. (2012). A comprehensive analysis of the impact of occupancy parameters in energy simulation of office buildings. *Energy and Buildings*, *55*, 841–853. https://doi.org/10.1016/j.enbuild.2012.10.002

Bangert, P., Gilani, V., & Schröder, D. (2020). The superiority of automation over behavioral interventions in energy conservation: Evidence from smart building technologies. *Energy Policy*.

Burgess, M., Thompson, & L. (2017). Implementing time of day metering for improved energy efficiency. *International Journal of Energy Economics*, *8(1)*, 34–35.

Chen, S., Zhang, G., Xia, X., Chen, Y., Setunge, S., & Shi, L. (2021). The impacts of occupant behavior on building energy consumption: A review. *Sustainable Energy Technologies and Assessments*, *45*, 101212. https://doi.org/10.1016/j.seta.2021.101212

Delzendeh, E., Wu, S., Lee, A., & Zhou, Y. (2017). The impact of occupants' behaviours on building energy analysis: A research review. *Renewable and Sustainable Energy Reviews*, *80*, 1061–1071. https://doi.org/10.1016/j.rser.2017.05.264

Department of Hydrology and Metrology(DHM). (2021). *Climate Data of Kathmandu Valley*. Ministry of Energy,Water Resources. and Irrigation.

Esa, N. F. A. @, Abdullah, M. P., Hassan, M. Y., & Hussin, F. (2017). Disaggregated Electricity Bill Base on Utilization factor and Time-of-use (ToU) Tariff.

International Journal of Electrical and Computer Engineering (IJECE), *7*(3), 1498. https://doi.org/10.11591/ijece.v7i3.pp1498-1505

Hong, T., Taylor-Lange, S. C., D'Oca, S., Yan, D., & Corgnati, S. P. (2016). Advances in research and applications of energy-related occupant behavior in buildings. *Energy and Buildings*, *116*, 694–702. https://doi.org/10.1016/j.enbuild.2015.11.052

Hong, T., Yan, D., D'Oca, S., & Chen, C. (2017). Ten questions concerning occupant behavior in buildings: The big picture. *Building and Environment*, *114*, 518–530. https://doi.org/10.1016/j.buildenv.2016.12.006

Huebner, G. M. & Thurm, C. (2018). Understanding the role of occupant behavior in energy consumption. *Journal of Building Performance*, *9*(4), 128–142.

Karki, R., Hasson, S., & Gerlitz, L. (2017). Variability and trends in extreme climate indices in Nepal. *Theoretical and Applied Climatology*, *129*(1–2), 157–174.

Kershaw, M. & McNeill, D. (2017). Energy efficiency in buildings: Fundamentals and practices. *Energy Studies Review*, *19*(2), 78–92.

Mastrorilli, A., & Zarcone, R. (2023). In-Depth Analysis Based on Occupant Behaviour: A Support-Decision Method for Energy-Efficient Retrofitting of 20th Century Buildings. *Cahiers de La Recherche Architecturale, Urbaine et Paysagère*, *19*. https://doi.org/10.4000/craup.13386

Miller, R. & Jones, T. (2019). Energy consumption discrepancies in commercial buildings: Causes and consequences. *Energy and Buildings*, *23*(6), 456–468.

O'Brien, W., & Gunay, H. B. (2014). The contextual factors contributing to occupants' adaptive comfort behaviors in offices – A review and proposed modeling framework. *Building and Environment*, *77*, 77–87. https://doi.org/10.1016/j.buildenv.2014.03.024

Pereira, F. & Dias, P. (2020). Building energy audits and their role in energy management. *Journal of Energy Management*, *15*(3), 204–215.

Petersen, J. E., Shunturov, V., Janda, K., Platt, G., & Weinberger, K. (2007). Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. *International Journal of Sustainability in Higher Education*, *8*(1), 16–33. https://doi.org/10.1108/14676370710717562

Sachs, D. & Stevenson, R. (2016). Understanding and improving energy use intensity in commercial buildings. *Energy Efficiency Journal*, *12*(4), 467–478.

Sunikka-Blank, M., & Galvin, R. (2012). Introducing the prebound effect: The gap between performance and actual energy consumption. *Building Research & Information*, *40*(3), 260–273. https://doi.org/10.1080/09613218.2012.690952

Thomson, M. & Roberts, L. (2018). Behavioral energy efficiency: Reducing consumption through occupant actions. *Energy Policy*, *62*, 257–267.

World Energy Outlook. (2021).

Yan, D., O'Brien, W., Hong, T., Feng, X., Burak Gunay, H., Tahmasebi, F., & Mahdavi, A. (2015a). Occupant behavior modeling for building performance simulation: Current state and future challenges. *Energy and Buildings*, *107*, 264–278. https://doi.org/10.1016/j.enbuild.2015.08.032

Yan, D., O'Brien, W., Hong, T., Feng, X., Burak Gunay, H., Tahmasebi, F., & Mahdavi, A. (2015b). Occupant behavior modeling for building performance simulation: Current state and future challenges. *Energy and Buildings*, *107*, 264–278. https://doi.org/10.1016/j.enbuild.2015.08.032

ANNEXES

ANNEX I: Data Source:

The ToD meter data, and the data required for the electrical designs were taken from the Electromechanical Department, Civil Aviation Authority of Nepal. And the required attendance data were acquired from the administration of the Civil Aviation.

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
इन्जिनियरिङ्ग अध्ययन संस्थान
INSTITUTE OF ENGINEERING
पुल्चोक क्याम्पस
PULCHOWK CAMPUS
आर्किटेक्चर विभाग
DEPARTMENT OF ARCHITECTURE

Accredited by University Grants Commission (UGC) Nepal 2020

5-422809
5-443077
पुल्चोक, ललितपुर ।
Pulchowk, Lalitpur

Date: January 18, 2025

To,
Civil Aviation Authority of Nepal,
Sinamangal, Kathmandu

Subject: **Request to provide assistance for case study**

Dear Sir/Madam,
We would like to bring this into your kind notice that the bearer of this letter **Bashanta Bhattarai** is a bonafide student of the Department of Architecture (M. Sc. in Energy Efficient Building, (Batch 2079 Year II Part II). According to the syllabus, he is required to prepare and submit a Thesis Report on **"Understanding the Impact of Occupant Actions on Office Building-A Case Study of CAAN Head Office Building".** We would therefore request you to kindly provide the student the necessary access to the case study area, the needful data, information and any other assistance for the completion of the case study report to be submitted our department.

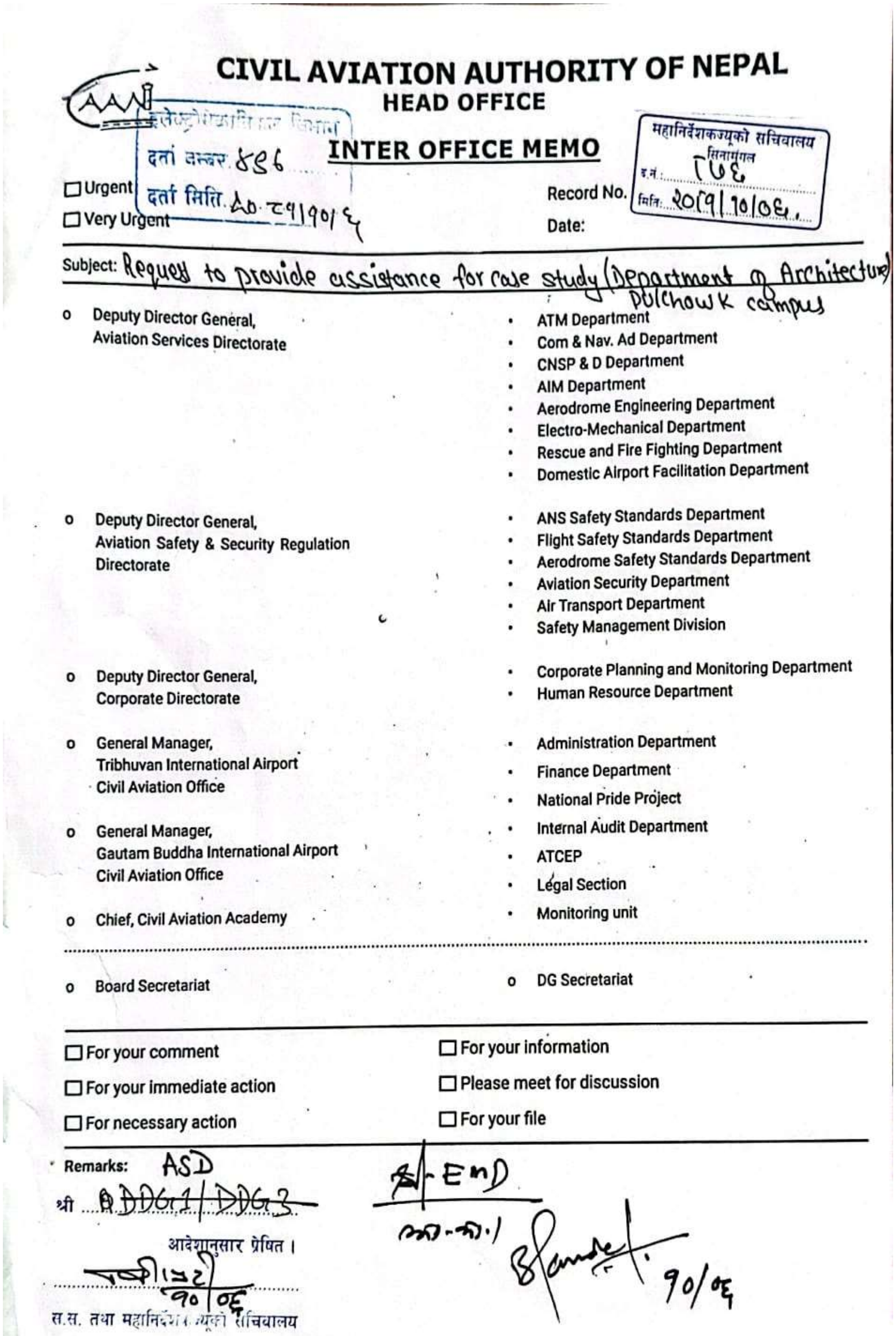
We take this opportunity to thank you in advance for all the help cooperation and support you may extend to our student. Should you require more information, please let us know, we will be happy to oblige.

Thanking you and with kind regards.

Yours Sincerely,

(Bijay Singh, PhD)
Program Coordinator
M. Sc. in Energy Efficient Building

Figure 31: Letter from college to CAAN reqarding request for assistance


CIVIL AVIATION AUTHORITY OF NEPAL
HEAD OFFICE

INTER OFFICE MEMO

दर्ता नम्बर ४९६
दर्ता मिति २०८१/१०/६

महानिर्देशकज्यूको सचिवालय
सिनामंगल
द.नं. ७८६
मिति २०८१/१०/०६

☐ Urgent
☐ Very Urgent

Record No.
Date:

Subject: Request to provide assistance for case study (Department of Architecture) Pulchowk campus

- o Deputy Director General, Aviation Services Directorate
  - ATM Department
  - Com & Nav. Ad Department
  - CNSP & D Department
  - AIM Department
  - Aerodrome Engineering Department
  - Electro-Mechanical Department
  - Rescue and Fire Fighting Department
  - Domestic Airport Facilitation Department
- o Deputy Director General, Aviation Safety & Security Regulation Directorate
  - ANS Safety Standards Department
  - Flight Safety Standards Department
  - Aerodrome Safety Standards Department
  - Aviation Security Department
  - Air Transport Department
  - Safety Management Division
- o Deputy Director General, Corporate Directorate
  - Corporate Planning and Monitoring Department
  - Human Resource Department
- o General Manager, Tribhuvan International Airport Civil Aviation Office
- o General Manager, Gautam Buddha International Airport Civil Aviation Office
- o Chief, Civil Aviation Academy
  - Administration Department
  - Finance Department
  - National Pride Project
  - Internal Audit Department
  - ATCEP
  - Legal Section
  - Monitoring unit

- o Board Secretariat
- o DG Secretariat

☐ For your comment ☐ For your information
☐ For your immediate action ☐ Please meet for discussion
☐ For necessary action ☐ For your file

Remarks: ASD
श्री ~~DDG1/DDG3~~
आदेशानुसार प्रेषित।
१०/०६
स.स. तथा महानिर्देशकज्यूको सचिवालय

S/- EnD
१०/०६

Figure 32:Inter-office memo from CAAN

ANNEX II: TOD Meter Bills

Figure 33:TOD meter Bills

NEPAL ELCTRICITY AUTHORITY
Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY
Consumer No. :077.10.2061 Approved Load : 630
Consumer ID :30904 Year/Month : 10/2081
Address :,BANWSHWOR ,9 Trans.Loss : N
Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	117935	108176	9759	9759	13.50	131,746.50
Normal	413611	378312	35299	35299	12.25	432,412.75
Off-Peak	99658	90739	8919	8919	12.25	109,257.75
						673,417.00

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	92.00	230.80	76.80		315	240.00	75,600.00

				Current Month's Bill (In NEPAL Currency)	749,017.00
				Current Month's Bill (In Currency)	
Voltage				Miscellaneous Charges	-
Current				Previous Dues	-208.00
P.F.				Total Bill Amount (In NEPAL Currency)	748,809.00
				Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY
Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY
Consumer No. :077.10.2061 Approved Load : 630
Consumer ID :30904 Year/Month : 09/2081
Address :,BANWSHWOR ,9 Trans.Loss : N
Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	108176	98251	9925	9925	13.50	133,987.50
Normal	378312	342091	36221	36221	12.25	443,707.25
Off-Peak	90739	82114	8625	8625	7.15	105,656.25
						683,351.00

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	93.00	220.60	73.80		315	240.00	75,600.00

				Current Month's Bill (In NEPAL Currency)	758,951.00
				Current Month's Bill (In Currency)	
Voltage				Miscellaneous Charges	-
Current				Previous Dues	-10,189.00
P.F.				Total Bill Amount (In NEPAL Currency)	748,762.00
				Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY
Consumer No. :077.10.2061 Approved Load : 630
Consumer ID :30904 Year/Month : 08/2081
Address :,BANWSHWOR ,9 Trans.Loss : N
Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	98251	90324	7927	7927	13.50	107,014.50
Normal	342091	319634	22457	22457	12.25	275,098.25
Off-Peak	82114	74873	7241	7241	7.15	51,773.15
						433,885.90

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	67.80	147.20	52.60		315	240.00	75,600.00
				Current Month's Bill (In NEPAL Currency)			509,485.90
Voltage				Current Month's Bill (In Currency)			
Current				Miscellaneous Charges			-
P.F.				Previous Dues			-10,910.00
				Total Bill Amount (In NEPAL Currency)			498,575.00
				Total Bill Amount (In Currency)			

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY
Consumer No. :077.10.2061 Approved Load : 630
Consumer ID :30904 Year/Month : 07/2081
Address :,BANWSHWOR ,9 Trans.Loss : N
Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	90324	82357	7967	7967	13.50	107,554.50
Normal	319634	294077	25557	25557	12.25	313,073.25
Off-Peak	74873	67976	6897	6897	7.15	49,313.55
						469,941.30

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	96.80	182.20	47.80		315	240.00	75,600.00
				Current Month's Bill (In NEPAL Currency)			545,541.30
Voltage				Current Month's Bill (In Currency)			
Current				Miscellaneous Charges			-
P.F.				Previous Dues			-291.00
				Total Bill Amount (In NEPAL Currency)			545,250.00
				Total Bill Amount (In Currency)			

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No. :077.10.2061 Approved Load : 630

Consumer ID :30904 Year/Month : 06/2081

Address :,BANWSHWOR ,9 ,1000-1 Trans.Loss : N

Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	82357	72930	9427	9427	13.50	127,264.50
Normal	294077	258674	35403	35403	12.25	433,686.75
Off-Peak	67976	60310	7666	7666	7.15	54,811.90
						615,763.15

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	121.80	217.40	52.80		315	240.00	75,600.00
						Current Month's Bill (In NEPAL Currency)	691,363.15
						Current Month's Bill (In Currency)	
Voltage						Miscellaneous Charges	-
Current						Previous Dues	-14,256.00
P.F.						Total Bill Amount (In NEPAL Currency)	677,107.00
						Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No. :077.10.2061 Approved Load : 630

Consumer ID :30904 Year/Month : 05/2081

Address :,BANWSHWOR ,9 Trans.Loss : N

Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	72930	63238	9692	9692	13.50	130,842.00
Normal	258674	221837	36837	36837	12.25	451,253.25
Off-Peak	60310	52592	7718	7718	7.15	55,183.70
						637,278.95

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	122.80	222.40	50.40		315	240.00	75,600.00
						Current Month's Bill (In NEPAL Currency)	712,878.95
						Current Month's Bill (In Currency)	
Voltage						Miscellaneous Charges	-
Current						Previous Dues	-
P.F.						Total Bill Amount (In NEPAL Currency)	712,878.00
						Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No. :077.10.2061 Approved Load : 630

Consumer ID :30904 Year/Month : 04/2081

Address :,BANWSHWOR ,9 Trans.Loss : N

Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	63238	54274	8964	8964	13.50	121,014.00
Normal	221837	188455	33382	33382	12.25	408,929.50
Off-Peak	52592	45309	7283	7283	7.15	52,073.45
						582,016.95

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	120.00	232.00	46.00		315	240.00	75,600.00
						Current Month's Bill (In NEPAL Currency)	657,616.95
						Current Month's Bill (In Currency)	
Voltage						Miscellaneous Charges	-
Current						Previous Dues	-4.00
P.F.						Total Bill Amount (In NEPAL Currency)	657,612.00
						Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No. :077.10.2061 Approved Load : 630

Consumer ID :30904 Year/Month : 03/2081

Address :,BANWSHWOR ,9 Trans.Loss : N

Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	54274	43369	10905	10905	13.50	147,217.50
Normal	188455	145988	42467	42467	12.25	520,220.75
Off-Peak	45309	37050	8259	8259	7.15	59,051.85
						726,490.10

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	123.00	241.00	52.00		315	240.00	75,600.00
						Current Month's Bill (In NEPAL Currency)	802,090.10
						Current Month's Bill (In Currency)	
Voltage						Miscellaneous Charges	-
Current						Previous Dues	-210.00
P.F.						Total Bill Amount (In NEPAL Currency)	801,880.00
						Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No.	:077.10.2061	Approved Load :	630
Consumer ID	:30904	Year/Month :	01/2081
Address	:,BANWSHWOR ,9 ,1000-1	Trans.Loss :	N
Meter Status	:Normal		

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	34194	25947	8247	8247	13.50	111,334.50
Normal	115226	92364	22862	22862	12.25	280,059.50
Off-Peak	29551	22481	7070	7070	7.15	50,550.50
						441,944.50

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	72.00	43.00	43.00		315	240.00	75,600.00

			Current Month's Bill (In NEPAL Currency)	517,544.50
			Current Month's Bill (In Currency)	
Voltage			Miscellaneous Charges	-
Current			Previous Dues	-13,321.00
P.F.			Total Bill Amount (In NEPAL Currency)	504,223.00
			Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No.	:077.10.2061	Approved Load :	630
Consumer ID	:30904	Year/Month :	11/2080
Address	:,BANWSHWOR ,9 ,1000-1	Trans.Loss :	N
Meter Status	:Normal		

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	16780	6455	10325	10325	13.50	139,387.50
Normal	62385	22923	39462	39462	12.25	483,409.50
Off-Peak	14362	5306	9056	9056	12.25	110,936.00
						733,733.00

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	124.00	251.00	72.00		315	240.00	75,600.00

			Current Month's Bill (In NEPAL Currency)	809,333.00
			Current Month's Bill (In Currency)	
Voltage			Miscellaneous Charges	-
Current			Previous Dues	-12,969.00
P.F.			Total Bill Amount (In NEPAL Currency)	796,364.00
			Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No.	:077.10.2061	Approved Load :	630
Consumer ID	:30904	Year/Month :	12/2080
Address	:,BANWSHWOR ,9 ,1000-1	Trans.Loss :	N
Meter Status	:Normal		

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	25947	16780	9167	9167	13.50	123,754.50
Normal	92364	62385	29979	29979	12.25	367,242.75
Off-Peak	22481	14362	8119	8119	12.25	99,457.75
						590,455.00

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	103.00	205.00	67.00		315	240.00	75,600.00
				Current Month's Bill (In NEPAL Currency)			666,055.00
				Current Month's Bill (In Currency)			
Voltage				Miscellaneous Charges			
Current				Previous Dues			-16,187.00
P.F.				Total Bill Amount (In NEPAL Currency)			649,868.00
				Total Bill Amount (In Currency)			

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No.	:077.10.2061	Approved Load :	630
Consumer ID	:30904	Year/Month :	10/2080
Address	:,BANWSHWOR ,9 ,1000-1	Trans.Loss :	N
Meter Status	:Meter Change		

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	6455	61613		8182	13.50	110,457.00
Normal	22923	192340		29355	12.25	359,598.75
Off-Peak	5306	74647		8396	12.25	102,851.00
						572,906.75

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	88.00	234.00	70.00		315	240.00	75,600.00
				Current Month's Bill (In NEPAL Currency)			648,506.75
				Current Month's Bill (In Currency)			
Voltage				Miscellaneous Charges			-
Current				Previous Dues			-14,124.00
P.F.				Total Bill Amount (In NEPAL Currency)			634,382.00
				Total Bill Amount (In Currency)			

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No. :077.10.2061 Approved Load : 630

Consumer ID :30904 Year/Month : 08/2080

Address :,BANWSHWOR ,9 ,1000-1 Trans.Loss : N

Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	53755	47556	6199	6199	13.50	83,686.50
Normal	161505	142963	18542	18542	12.25	227,139.50
Off-Peak	62663	55076	7587	7587	7.15	54,247.05
						365,073.05

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	45.00	161.00	127.00		315	240.00	75,600.00
						Current Month's Bill (In NEPAL Currency)	440,673.05
						Current Month's Bill (In Currency)	
Voltage						Miscellaneous Charges	-
Current						Previous Dues	-9,408.00
P.F.						Total Bill Amount (In NEPAL Currency)	431,265.00
						Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No. :077.10.2061 Approved Load : 630

Consumer ID :30904 Year/Month : 07/2080

Address :,BANWSHWOR ,9 ,1000-1 Trans.Loss : N

Meter Status **:Normal**

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	47556	41168	6388	6388	13.50	86,238.00
Normal	142963	122651	20312	20312	12.25	248,822.00
Off-Peak	55076	46719	8357	8357	7.15	59,752.55
						394,812.55

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	83.00	232.00	210.00		315	240.00	75,600.00
						Current Month's Bill (In NEPAL Currency)	470,412.55
						Current Month's Bill (In Currency)	
Voltage						Miscellaneous Charges	-
Current						Previous Dues	-13,640.00
P.F.						Total Bill Amount (In NEPAL Currency)	456,772.00
						Total Bill Amount (In Currency)	

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No. :077.10.2061 Approved Load : 630

Consumer ID :30904 Year/Month : 06/2080

Address :,BANWSHWOR ,9 ,1000-1 Trans.Loss : N

Meter Status :Normal

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	41166	33051	8117	8117	13.50	109,579.50
Normal	122651	89142	33509	33509	12.25	410,485.25
Off-Peak	46719	34643	12076	12076	7.15	86,343.40
						606,408.15

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	83.00	232.00	203.00		315	240.00	75,600.00
					Current Month's Bill (In NEPAL Currency)		682,008.15
					Current Month's Bill (In Currency)		
Voltage					Miscellaneous Charges		-
Current					Previous Dues		-11,858.00
P.F.					Total.Bill Amount (In NEPAL Currency)		670,150.00
					Total Bill Amount (In Currency)		

NEPAL ELCTRICITY AUTHORITY

Electricity Service TOD Meter Bill

Consumer's Name :Ms.CIVIL AVATION AUTHORITY

Consumer No. :077.10.2061 Approved Load : 630

Consumer ID :30904 Year/Month : 05/2080

Address :,BANWSHWOR ,9 ,1000-1 Trans.Loss : N

Meter Status :Normal

Time	Cur. Reading	Prev. Reading	Difference	Consumed Unit	Unit Rate	Bill Amount
Peak	33051	25316	7735	7735	13.50	104,422.50
Normal	89142	61642	27500	27500	12.25	336,875.00
Off-Peak	34643	23997	10646	10646	7.15	76,118.90
						517,416.40

Demand	Recorded Demand			Billed Demand		Rate	Demand Amount
	Peak	Normal	Off-Peak	Prev. Month	Current Month		
	69.00	229.00	180.00		315	240.00	75,600.00
					Current Month's Bill (In NEPAL Currency)		593,016.40
					Current Month's Bill (In Currency)		
Voltage					Miscellaneous Charges		-
Current					Previous Dues		8.00
P.F.					Total Bill Amount (In NEPAL Currency)		593,024.00
					Total Bill Amount (In Currency)		

ANNEX III-BUILDING LOAD CALCULATIONS

1.Total Load Summary

Load calculation (Summary)					
Sl. No	Description	Connected Load (KW)	Diversity Factor	Maximum Demand (KW)	Remarks
1	**Lights & Power load**				
a	**Lower basement**	**2.5**	0.9	2.24	**As per site point Counted fixtures manually**
b	**Middle basement**	**2.3**	0.9	2.11	
c	**Upper basement**	**10.9**	0.9	9.79	
d	**Ground**	**12.3**	0.9	11.05	
e	**first**	**16.4**	0.9	14.76	
f	**second**	**18.3**	0.9	16.43	
g	**third**	**17.7**	0.9	15.95	
h	**fourth**	**17.4**	0.9	15.66	
i	**fifth**	**8.7**	0.9	7.83	
j	**sixth**	**5.4**	0.9	4.83	
k	**seventh**	**5.0**	0.9	4.47	
l	**Eighth**	**5.0**	0.9	4.47	
m	**Ninth**	**2.5**	0.9	2.25	
					ANNEX-L1
2	**UPS Load**	**131.0**	0.7	91.70	
3	**Plumbing**				**Sump pumps, water lifting pump calculated manually**
i	Fire Fighting Load (Only jockey pump considered)	**55.0**	0.1	5.5	
ii	Other Pumps	**20.0**	0.8	16.00	
					ANNEX-P1
4	**HVAC Load including ventilation**	**350.0**	0.7	245.00	**AC Counted manually and tallyed with drawings provided by mechanical department**
i)	Ventilation Normal + CAR Smoke Ventilation	**15.0**	0.1	0.90	
ii)	Ventilation In case Fire	**25.0**	0.1	2.50	
iii)	High Side Equipment				
iv)	AHU & TFA				
					ANNEX-H1
5	**External Lighting & Developments**	**15.0**	0.8	12.00	
6	**Elevators**				ANNEX-E1
	lifts @ 12.5 KW each (Total nos -4)	**50.0**	0.8	40.00	
	TOTAL LOAD (KW)				
		785.3		**525**	
F TRANSFORMERS					
Overall Load Diversity Factor @ 80% Maximum Demand in KW=				**420**	Diversity factor and power factors considered provided by engineers@CAAN
KVA Rating at 0.90 Power factor				**467**	
Considering 80% Transformer Loading for KVA Capacity				**584**	
Provided 1 No. 630 KVA 11/0.433 KV CSS with ONLTC					

Figure 34:Total Design Load

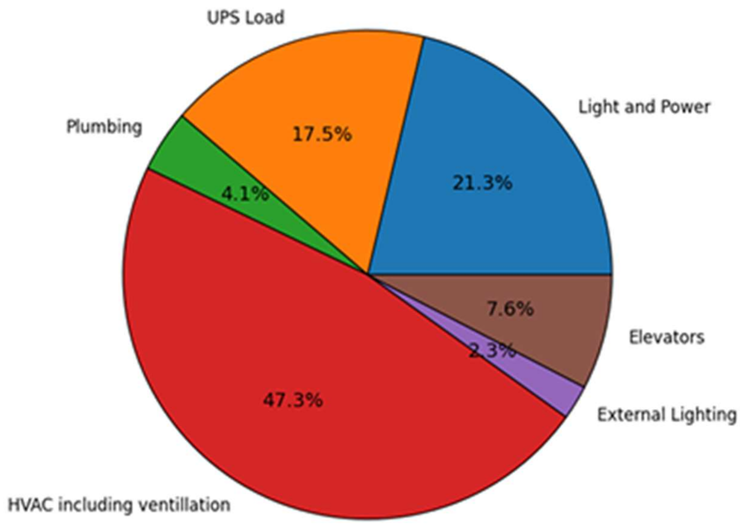


Figure 35:Representation of Total Load

Table 25:Load calculation Summary

SN	Description	Maximum demand
1	Light and Power	111.85 KW
2	UPS Load	91.7KW
3	Plumbing	21.5 KW
4	HVAC including Ventillation	248.4 KW
5	External Lighting	12 KW
4	Elevators	40 KW
	Total	525.45 KW

Table 26:Total HVAC Load in the Building

Floors	Used space	Qunatities-nos/Kw-IDU									Operation hours		days				Total
		2.8	**3.6**	**4.5**	**5.6**	**7.1**	**9.0**	**11.2**	**14.0**		Sunday-Thrusday	Friday	Sun-thrus	Friday			
Upper basement	office area					1.0		4.0	5.0		7 hours	5 hours	22	4			
Upper basement	library						4.0	3.0			7 hours	5 hours	22	4			
Upper basement	open area						2.0	4.0			7 hours	5 hours	22	4			
						1.0	**6.0**	**11.0**	**5.0**	**254.3**	**7**	**5**	**22**	**4**	39162.2	5086	**44248.2**
GROUND FLOOR	BLOCK-B		4.0	3.0	1.0		1.0	3.0			7 hours	5 hours	22	4			
GROUND FLOOR	BLOCK-C		1.0			5.0		2.0			7 hours	5 hours	22	4			
GROUND FLOOR	BLOCK-A	2.0	2.0			1.0		4.0			7 hours	5 hours	22	4			

		2.0	**7.0**	**3.0**	**1.0**	**6.0**	**1.0**	**9.0**	**0.0**	**202.3**	**7**	**5**	22	4	31154.2	4046	**35200.2**
1st	BLOCK-A ROAD SIDE	1.0	5.0	1.0		1.0			3.0		7 hours	5 hours	22	4			
1st	BLOCK-B		4.0		2.0	2.0		2.0			7 hours	5 hours	22	4			
1st	BLOCK-C		2.0	4.0	2.0		3.0	3.0			7 hours	5 hours	22	4			
1st	BLOCK-A	1.0	7.0			3.0	3.0				7 hours	5 hours	22	4			
		2.0	**18.0**	**5.0**	**4.0**	**6.0**	**6.0**	**5.0**	**3.0**	**309.9**	**7**	**5**	**22**	**4**	47724.6	6198	**53922.6**
2.0	Human resource department	2.0	7.0	2.0	3.0	2.0					7 hours	5 hours	22	4			
2.0	meeting room	1.0					1.0	1.0	2.0		7 hours	5 hours	22	4			
2.0	Admistration department	1.0	4.0	1.0	1.0				3.0		7 hours	5 hours	22	4			
2.0	Finance department		2.0	1.0	1.0	2.0	1.0	4.0			7 hours	5 hours	22	4			

2.0	store			1.0		2.0					7 hours	5 hours	22	4			
		4.0	**13.0**	**5.0**	**5.0**	**6.0**	**2.0**	**5.0**	**5.0**	**295.1**	**7**	**5**	**22**	**4**	45445.4	5902	**51347.4**
3.0	meeting room	1.0				1.0	1.0	1.0	1.0		7 hours	5 hours	22	4			
3.0	store				1.0	2.0					7 hours	5 hours	22	4			
3.0	com.navigation department	2.0	3.0	2.0	1.0		5.0				7 hours	5 hours	22	4			
3.0	CNS department	2.0	3.0	1.0	3.0		3.0				7 hours	5 hours	22	4			
3.0	Electromechanical department	1.0	1.0	2.0			4.0	2.0	2.0		7 hours	5 hours	22	4			
		6.0	**7.0**	**5.0**	**5.0**	**3.0**	**13.0**	**3.0**	**3.0**	**306.4**	**7**	**5**	**22**	**4**	47185.6	6128	**53313.6**
4.0	store				1.0	2.0					7 hours	5 hours	22	4			
4.0	Aerodrome engineering dept.	3.0	3.0		2.0	2.0	4.0				7 hours	5 hours	22	4			

4.0	meeting room	2.0	1.0				2.0		1.0		7 hours	5 hours	22	4			
4.0	Aerodrome engineering dept.	1.0	1.0		3.0				4.0		7 hours	5 hours	22	4			
4.0	Other projects		3.0		2.0	1.0	3.0	1.0			7 hours	5 hours	22	4			
		6.0	**8.0**	**0.0**	**7.0**	**3.0**	**9.0**	**1.0**	**5.0**	**268.3**	**7**	**5**	**22**	**4**	41318.2	5366	**46684.2**
5.0	ATM/AIM department		6.0	3.0	2.0	2.0					7 hours	5 hours	22	4			
5.0	Rescue and fire fighting dept.	1.0	2.0						1.0		7 hours	5 hours	22	4			
5.0	Restaurant					2.0					7 hours	5 hours	22	4			
		1.0	**8.0**	**3.0**	**2.0**	**4.0**	**0.0**	**0.0**	**1.0**	**98.7**	**7**	**5**	**22**	**4**	15199.8	1974	**17173.8**
6.0	internal audit dept.			2.0				1.0			7 hours	5 hours	22	4			
6.0	CC Camera			2.0		1.0					7 hours	5 hours	22	4			

6.0	Big meeting room					4.0			4.0		7 hours	5 hours	22	4			
6.0	Server room					2.0					7 hours	5 hours	22	4			
		0.0	**0.0**	**4.0**	**0.0**	**7.0**	**0.0**	**1.0**	**4.0**	**134.9**	**7**	**5**	**22**	**4**	20774.6	2698	**23472.6**
7.0	Director general area			2.0	2.0	3.0	1.0				7 hours	5 hours	22	4			
7.0	Board of director		1.0	1.0	2.0		1.0				7 hours	5 hours	22	4			
		0.0	**1.0**	**3.0**	**4.0**	**3.0**	**2.0**	**0.0**	**0.0**	**78.8**	**7**	**5**	**22**	**4**	12135.2	1576	**13711.2**
8.0	Director general area						6.0				7 hours	5 hours	22	4			
9.0	Director general area						2.0				7 hours	5 hours	22	4			
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**8.0**	**0.0**	**0.0**	**72.0**	**7**	**5**	**22**	**4**	11088	1440	**12528**
2+3+4+5	Server room	4.0									7 hours	5 hours	22	4			
2+3+4+5	Server room	4.0									7 hours	5 hours	22	4			

r

		8.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**22.4**	**7**	**5**	**22**	**4**	3449.6	448	**3897.6**
Total nos.		**29.0**	**62.0**	**28.0**	**28.0**	**38.0**	**41.0**	**24.0**	**21.0**								

Table 27:Electrical Fixtures

Floor	Block	3W Round Light	3W Foot Light	Photo Light	10W LED Mirror Light	11W LED Down Light	15W LED Down Light	18W LED Surface Light (Round)	18W LED Panel Light	36W LED Panel Light	36W LED Hanging Light	20W LED Lineos Light	40W LED Lineos Light	10 W LED Bulkhead Light	20W LED Tube Light	30W Sylindrical Down Light	Roop Light (Mtr)	Orbit Ring Light	3w LED drive over Light
Lower Basement	A-Block	0				4	0	6	4	0			2		40				
	B-Block	0				0	0			0			0		22				
Middle Basement	A-Block	0				4	0	5	4	0			2		33				
	B-Block	0				0	0			0			0		24				
	C-Block	0				0	0			0			0		12				
Upper Basement	A-Block	8			6	46	10	8	4	81			2		2				
	B-Block		16		6	31		34	2	44			3						22
	C-Block									45					3				
	A-Block	24		4	6	20	10		4	51		34	28		2	0			

Ground Floor	B-Block	20			5	11	9	1	2	47		16	3			0			
	C-Block	0				0	0			34			0			0			
1st	A-Block	60		4	8	14	10	1	4	90			26		2				
	B-Block				6	4	20	1	2	45		38			0				
	C-Block					0	0			48									
2nd	A-Block	70		18	9	28	14	1	4	75			26		3	0			
	B-Block	0			7	11	21	0	2	44		38	0		1	0			
	C-Block	0			1	11	0			46			0			0			
3rd	A-Block	70		18	9	38	27	1	4	68			26		3	0			
	B-Block	0			7	6	29		2	49		60	0		1	0			
	C-Block	0			1	32	5	0		38			0			0			
4th	A-Block	63		7	9	40	15		4	60			26		2	0			
	B-Block	0			6	50	16	8		39			5			0			
	C-Block	0			1	30	5		2	26			0			0			
5th	A-Block	32		4	8	184	27		4	71			26		2	0			
	B-Block		20																
6th	A-Block	42		4	6	19	32	12	4	69	16		26		2	18			
7th	A-Block	39			7	25	11	22		20		26	14		2			5	
8th	A-Block	10	42		1	69	6			2					2		133	8	
Lift-1														12		0			
Lift - Duplex														27		0			
Lift -3														13		0			
LT Panel Room															12				
Water Lifiting Room															2				
Total		**438**	**78**	**59**	**109**	**677**	**267**	**100**	**52**	**1092**	**16**	**212**	**215**	**52**	**172**	**18**	**133**	**13**	**22**

t

Table 28:Total Future occupants vs Active occupants in the building

	Maximum number of occupant that building can accommodate for future						(excluding meeting halls on consideration that same occupant goes to meeting hall and numbers remains constant)				
S.N.	Floor	A	B	C	Total occupant(nos)		Floor	A	B	C	Total occupant(no)
1	Upper Basement	6	15	10	31		Upper Basement	6	0	0	6
2	Ground Floor	24	26	18	68		Ground Floor	7	13	15	35
3	1st floor	24	8	23	55		1st floor	17	7	18	42
4	2nd Floor	24	24	22	70		2nd Floor	18	12	0	30
5	3rd Floor	23	14	15	52		3rd Floor	19	12	0	31
6	4th Floor	32	30	17	79		4th Floor	24	15	5	44
7	5th Floor	19	0	0	19		5th Floor	8	0	0	8
8	6th Floor	14	0	0	14		6th Floor	3	0	0	3
9	7th Floor	10	0	0	10		7th Floor	5	0	0	5

10	8th Floor	1	0	0	1
11	9th Floor	1	0	0	1
		178	117	105	**400**

8th Floor	0	0	0	0
9th Floor	0	0	0	0
	107	59	38	**204**

Table 29:Calculation of revised maximum demand as per current occupant

Total Load on the building

S.N.	Load	Maximum Demand(kW)	Is affected by occupant	Fixed load	Load Depending on occupant	Design occupant/Active occupant factor	Revised load depending on occupant	Revised Maximum demand
1	Lights and power	111.85	Yes	5	106.85	0.51	54.49	59.49
2	UPS Load	91.7	Yes	21.7	70	0.51	35.70	57.40
3	Plumbing		No					
	i)Fire Fighting	5		5				5.00
	ii)Other pumps	16		16				16.00
4	HVAC Load including ventillation	245	Yes		245	0.51	124.95	124.95
i)	Ventillation	0.9		0.9				0.90
ii)	Ventillation in case of fire	0.25		0.25				0.25
5	External Light development	12	No	12				12.00
6	Elevators	40	No	40				40.00
		522.7		**100.85**	**421.85**		**215.14**	**315.99**

Table 30:Summary of Attendance data per month

	Present occupant based on attendance sheet out of 204 active occupants							
S.N.	Months	No. of Occupant	Total Occupant	Occupancy factor per month	Working days per month	Fridays	Total days	Week days
1	Shrawn 2080	130	204	0.637	28	4	32	24
2	Bhadra 2080	90	204	0.441	23	4	31	19
3	Ashoj 2080	120	204	0.588	23	4	30	19
4	Kartik 2080	70	204	0.343	16	4	30	12
5	Mangsir 2080	30	204	0.147	24	4	30	20
6	Magh 2080	104	204	0.510	24	4	29	20
7	Falgun 2080	120	204	0.588	23	4	30	19
8	Chaitra 2080	170	204	0.833	23	4	30	19
9	Baishak 2081	110	204	0.539	26	4	31	22

10	Shrawn 2081	90	204	0.441	27	4	32	23
11	Bhadra 2081	148	204	0.725	23	4	31	19
12	Ashoj 2081	130	204	0.637	19	4	30	15
13	Kartik 2081	80	204	0.392	21	4	30	17
14	Mangsir 2081	60	204	0.294	24	4	30	20
15	Poush 2081	130	204	0.637	24	4	29	20
16	Magh 2081	145	204	0.711	23	4	30	19

Table 31:Base Calendar for calculation of working days

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Days in month	Holidays	Working days
Shrawn 2080																																	32	4	28
Bhadra 2080																																	31	8	23
Ashoj 2080																																	30	7	23
Kartik 2080																																	30	14	16
Mangsir 2080																																	30	6	24
Magh 2080																																	29	5	24
Falgun 2080																																	30	7	23
Chaitra 2080																																	30	7	23
Baishak 2081																																	31	5	26
Shrawn 2081																																	32	5	27
Bhadra 2081																																	31	8	23
Ashoj 2081																																	30	11	19
Kartik 2081																																	30	9	21
Mangsir 2081																																	30	6	24
Poush 2081																																	29	5	24
Magh 2081																																	30	7	23

z

Table 32:Daily consumption of electricity calculations

	Monthly consumption kWh										
					Operational Hours(fixed						
S.N.	Load Type	Total Revised load	Fixed load	Occupant dependent load	Standby consumption (30% of full load)	Full Load Consumption	Operational Hours(sun-thrus)	Operational Hours(Friday)	Daily consumption fixed	Daily occ dep(sun-thrus)	Daily occ dep(Friday)
1	Lights and power	59.49	5	54.49		24	5	4	120	272.47	217.974
2	UPS Load	57.40	21.7	35.70	17	7	5	4	262.57	178.50	142.8
3	Plumbing										
	i)Fire Fighting	5.00	5			0.011			0.056		
	ii)Other pumps	16.00	16			3			48		
4	HVAC Load including ventillation	124.95		124.95			7	5		874.65	624.75
i)	Ventillation	0.90	0.9								
ii)	Ventillation in case of fire	0.25	0.25								
5	External Light development	12.00	12			3					
6	Elevators	40.00	40		17	7			484		
									914.6256	**1325.618**	**985.524**

Figure 36:Calculation of Daily Consumption

Table 33:Calculation of Total Monthly Consumption

S.N.	Month	occupancy factor	Daily Consumption Fixed load	Daily Occupant load(sun-thrus)	Daily Occupant load(Friday)	Total days in month	Working days(Sun-Thrusday)	Working Days(Friday)	Monthly Consumption fixed	Monthly consumption week day	Monthly consumption weekend	Total Monthly Consumption
1	Shrawn 2080	0.637	914.63	1325.62	985.52	32	24	4	29268.02	20274.15	3379.025	**52921.193**
2	Bhadra 2080	0.441	914.63	1325.62	985.52	31	19	4	28353.39	11111.79	2339.325	**41804.511**
3	Ashoj 2080	0.588	914.63	1325.62	985.52	30	19	4	27438.77	14815.73	3119.1	**45373.592**
4	Kartik 2080	0.343	914.63	1325.62	985.52	30	12	4	27438.77	5458.425	1819.475	**34716.667**
5	Mangsir 2080	0.147	914.63	1325.62	985.52	30	20	4	27438.77	3898.875	779.775	**32117.417**
6	Magh 2080	0.510	914.63	1325.62	985.52	29	20	4	26524.14	13516.1	2703.22	**42743.461**
7	Falgun 2080	0.588	914.63	1325.62	985.52	30	19	4	27438.77	14815.73	3119.1	**45373.592**
8	Chaitra 2080	0.833	914.63	1325.62	985.52	30	19	4	27438.77	20988.94	4418.725	**52846.435**
9	Baishak 2081	0.539	914.63	1325.62	985.52	31	22	4	28353.39	15725.46	2859.175	**46938.030**
10	Shrawn 2081	0.441	914.63	1325.62	985.52	32	23	4	29268.02	13451.12	2339.325	**45058.462**
11	Bhadra 2081	0.725	914.63	1325.62	985.52	31	19	4	28353.39	18272.73	3846.89	**50473.010**
12	Ashoj 2081	0.637	914.63	1325.62	985.52	30	15	4	27438.77	12671.34	3379.025	**43489.135**
13	Kartik 2081	0.392	914.63	1325.62	985.52	30	17	4	27438.77	8837.45	2079.4	**38355.617**
14	Mangsir 2081	0.294	914.63	1325.62	985.52	30	20	4	27438.77	7797.75	1559.55	**36796.067**
15	Poush 2081	0.637	914.63	1325.62	985.52	29	20	4	26524.14	16895.13	3379.025	**46798.291**
16	Magh 2081	0.711	914.63	1325.62	985.52	30	19	4	27438.77	17902.33	3768.9125	**49110.014**

ANNEX IV QUESTIONNAIRE FOR EMPLOYEES

Questionnaire on Occupant Behavior and Energy Consumption:

Introduction:

Dear Participant,

Thank you for taking the time to participate in this survey. The purpose of this study is to understand the impact of occupant behavior on energy consumption in the CAAN OFFICE building. Your responses will provide valuable insights that could help improve energy efficiency in our workplace. Please be assured that your responses will be kept confidential and will be used solely for research purposes.

Instructions:

Please answer the following questions to the best of your ability. For multiple-choice questions, select the option that most accurately reflects your behavior or opinion.

Section A: Demographic Information

1. Department:

- ☐ Administration
- ☐ Engineering
- ☐ Human Resources
- ☐ Finance
- ☐ IT
- ☐ Other (please specify): ___________

2. Position:

- ☐ Director
- ☐ Dy. Director
- ☐ Manager
- ☐ Dy. Manager
- ☐ Officer
- ☐ Other (please specify): ___________

3. Duration of Employment:

- ☐ Less than 1 year
- ☐ 1-3 years
- ☐ 3-5 years
- ☐ More than 5 years

Section B: Awareness and Attitudes

4. Are you aware of any energy-saving policies or guidelines in this building?

☐ Yes ☐ No

5. How important do you think it is to save energy in the workplace?

☐ Very Important ☐ Important

☐ Neutral ☐ Unimportant

6. How often do you receive information or reminders about energy-saving practices?

☐ Regularly ☐ Occasionally

☐ Rarely ☐ Never

Section C: Behavior Patterns

7. How often do you turn off the lights when leaving your workspace?

☐ Always ☐ Often

☐ Sometimes ☐ Rarely ☐ Never

8. How often do you turn off the air conditioning when it's not needed or when leaving the room?

☐ Always ☐ Often

☐ Sometimes ☐ Rarely ☐ Never

9. Do you turn off computers and other office equipment at the end of the day?

☐ Always ☐ Often

☐ Sometimes ☐ Rarely ☐ Never

10. How often do you unplug devices to save energy?

☐ Always ☐ Often

☐ Sometimes ☐ Rarely ☐ Never

11. Are common areas (e.g., conference rooms, hall, waiting area) left unattended with lights or equipment on?

☐ Always ☐ Often

☐ Sometimes ☐ Rarely ☐ Never

Section D: Motivations and Barriers

12. What motivates you to save energy at work? (Select all that apply)

☐ Reducing costs ☐ Environmental concerns

☐ Company policies ☐ Personal habits ☐ Other (please specify): ___________

13. What prevents you from saving energy at work? (Select all that apply)

☐ Lack of awareness ☐ Inconvenience

☐ Forgetfulness ☐ No clear guidelines ☐ Other (please specify): ___________

14. Do you believe that energy-saving measures are effective in reducing overall energy consumption in the building?

☐ Yes ☐ No ☐ Unsure

15. Do you think that more training or information on energy-saving practices would help improve energy efficiency in the building?

☐ Yes ☐ No ☐ Maybe

Section E: Perceptions and Recommendations

16. How would you rate the overall energy efficiency of this building?

☐ Excellent ☐ Good

☐ Average ☐ Poor ☐ Very Poor

17. How often do you notice energy waste (e.g., lights left on, HVAC running) in the building?

☐ Very Often ☐ Often

☐ Sometimes ☐ Rarely ☐ Never

18. What specific actions do you think could be implemented to reduce energy consumption in this building? (Select all that apply)

☐ Installing motion sensors for lighting ☐ Implementing stricter energy policies

☐ Increasing awareness and training ☐ Upgrading to more energy-efficient equipment

☐ Other (please specify): ___________

19. How effective do you think the building management's energy-saving initiatives are?

☐ Very Effective ☐ Effective

☐ Neutral ☐ Ineffective ☐ Very Ineffective

20. Would you be willing to participate in future energy-saving programs or initiatives?

☐ Yes ☐ No ☐ Maybe

Thank you for your participation. Your responses are valuable and will contribute significantly to the success of this research.

ANNEX V Rate Analysis

Fort this propose quotations from the suppliers were taken,

Airtech Industries Pvt. Ltd.

AIRTECH
RELIABILITY MATTERS

Quotation No.: - AIPL/QUOT/080-81/210

Date: 05.11.2081

Pro-create Engineering Pvt. Ltd.
Kalanki, Kathmandu

Kind Attn: Mr. Bashanta Bhattarai

Subject: Submission of Quotations

Dear Sir,

This is with reference to your letter dated 1st Falgun,2081. We are pleased to submit our best offer for below mentioned items for your kind consideration & acceptance.

S.N	Descriptions	Unit	Quantity	Amounts	Remarks
	Display Boards				
1	Supply, installation, and commissioning of a **digital LED display board** (Type: Full-color RGB LED matrix; Display Size: Customizable [e.g., 1000mm x 600mm]; Resolution: Minimum P5/P6 pixel pitch for clear visibility; Brightness: ≥2000 nits for daylight readability; Viewing Angle: 140° horizontal/vertical; Content Control: Remote updates via WiFi/4G/USB; Software: Compatible with Android/Windows for real-time message scheduling; Power: 100V–240V AC with energy-saving mode; Enclosure: IP65-rated aluminum cabinet for weatherproofing; Mounting: Wall-mounted/standalone with vandal-proof casing) including programming interface, mounting hardware, power supply wiring, on-site testing, and **2-year warranty**—as per specifications and approved digital content guidelines, all complete	Nos	12	**120,000.00**	
	Lighting Items				
3	Supply, **lighting sensors** (Type: Motion (PIR)/Occupancy/Daylight/hybrid; Detection Range: 5–12 meters; Field of View: 180°/360°; Sensitivity Adjustments: Customizable; Power: 110V–240V AC/low-voltage/DALI; Load Capacity: 500W–1000W LED; Communication Protocol: WiFi/Zigbee/BLE (if smart-enabled); IP Rating: IP65 (outdoor)/IP20 (indoor); Operating Temperature: -20°C to +50°C; Time Delay: Adjustable 30 sec–30 min) including mounting hardware, wiring, integration with	Nos	120	150,000.00	

H.O. : Ist Floor, Sharda Complex, Panchayan Marg, Thapathali, Kathmandu, Nepal
+977 1 5319999, 5322776, 5352599
info@airtech.com.np Website: www.airtech.com.np

	existing systems, functional testing, and **2 years warranty**—, drawings, and site requirements, all complete.				
	Installation Charges	Nos	120	45,000.00	
	Sub-Total			**1,95,000.00**	
	HVAC Works	Nos	1		
1	Supply and configuration of smart programmable thermostats (Type: Learning/WiFi-enabled; Compatibility: 24V HVAC systems; Display: Touchscreen LCD with ambient light sensor; Connectivity: WiFi 2.4GHz/Zigbee for IoT integration; Sensors: Room occupancy, humidity, and temperature (±0.5°C accuracy); Programming: 7-day schedules, geofencing, and remote control via mobile app; Energy Reports: Real-time consumption analytics; Certifications: ENERGY STAR, CE) including firmware updates, API access for research data logging, and 1-year technical support—as per experimental setup requirements."	Nos	23	5,06,000.00	
2	Supply, calibration, and integration of **HVAC monitoring sensors** (Types: Wireless/BACnet-enabled; Parameters: Temperature (±0.3°C accuracy), Relative Humidity (±2% RH), CO_2 (0–2000 ppm), Air Pressure (0–1000 Pa), and VOC (0–5000 ppb); Connectivity: WiFi/LoRaWAN/Modbus RTU; Power: PoE/24V DC/battery-operated; Enclosure: IP54-rated for indoor/outdoor use; Certifications: UL, CE, RoHS) including sensor mounting kits, gateway configuration (if applicable), real-time data logging via cloud/local server API, and **18-month calibration warranty**—as per experimental design and HVAC system specifications, all complete.	Nos	15	1,27,500.00	
	Installation Charge for HVAC Works	Job	1	2,50,000.00	
	Subtotal for HVAC Works			**8,83,500.00**	
1	Supply and configuration of **IoT-enabled smart power strips** (Type: Wi-Fi/Zigbee/Bluetooth; Outlets: 6–8 ports with individual relay control; Load Capacity: 15A/120V or 16A/230V per outlet; Monitoring: Real-time energy metering (voltage, current, power, kWh) ±1% accuracy; Features: Surge protection (≥1000J), overload auto-cutoff, scheduling/grouping via mobile app; Integration: API support (REST/MQTT) for custom data logging; Certifications:	Nos	60	1,80,000.00	

Airtech Industries Pvt. Ltd.

	UL/FCC/CE/RoHS; Enclosure: Flame-retardant ABS, childproof shutters) including cloud/local server connectivity setup, firmware for research customization, and **2-year hardware warranty**—as per experimental requirements, all complete.				
11	Supply and testing of **digital programmable timer outlets** (Type: LCD display with manual override; Voltage: 100-240V AC; Load: 10A/1200W resistive, 5A/500W inductive; Timing: 7-day customizable schedules (24 on/off cycles per day), ±1 min/month accuracy; Features: Countdown timer (1 min-24 hrs), random mode (security function), surge protection (500J); Connectivity: Standalone/Wi-Fi/Bluetooth (app-controlled models optional); Enclosure: Flame-retardant PC material, IP20 rated) including configuration for experimental cycles and **18-month warranty** against electrical failures - as per lab requirements, complete	Nos	25	3,75,000.00	
12	Installation of Power strips and Timmer Outlets	Job	1	50,000.00	
	Sub-Total			**2,67,500.00**	
	Grand Total				

Terms and Conditions:

1. Value Added Tax: - Extra as Applicable.
2. Offer Valid: - 15 days.

Thanking you and looking forward for your firm confirmation.

Raj Kumar
(Project Coordinator)

AIRTECH INDUSTRIES (P.) LTD.

H.O.: 1st Floor, Sharda Complex, Panchayan Marg, Thapathali, Kathmandu, Nepal
+977 1 5319999, 5322776, 5352599
info@airtech.com.np Website: www.airtech.com.np

Figure 37:Quotation from Vendors regarding the rate of items

ANNEX VI PHOTOGRAPHS

Figure 38:630KVA CSS(Compact Substation)

Figure 39:LT Pannel installed on site (incoming from CSS to raising mains)

ACKNOWLEDGEMENT

Completing this thesis work has been a wonderful and often overwhelming experience. Many people had some particular importance during the thesis preparation, for their suggestions and work together but also for friendship and patience. I will however restrain this section to academic acknowledgments related to the thesis as a whole.

I am deeply indebted to Associate Professor **Dr. Ajay Kumar Jha**, who was the mentor of this thesis. His suggestions, opinions, discussions (sometimes about topics far from the heart of this thesis) are very useful and much appreciable.

I would also like to convey my sincerest thanks to Prof. **Dr. Sanjay Uprety** for his valuable inputs and suggestions during the course of my research. I would also like to thank Prof. Dr. Bijay Singh, Dr. Nawaraj Bhattarai, Associate Prof. Shree Raj Shakya, **Er. Sunil Kumar Kushwaha** (Director of Electromechanical Department), **Er. Nal Bikram Thapa** (Manager of Aerodrome Engineering Department) and my family and friends for all their help, support, interest and valuable hints during the entire thesis work, report writing and stimulating suggestions and encouragement in this research report writing.

Thanks to CAAN (Civil Aviation Authority of Nepal) and Associated Departments from where I received the data for the thesis work.

Finally, I would like to thank my friends. Their camaraderie is very significant.

Bashanta Bhattarai

079/MSEEB/005

Figure 40:Raising mains/Floor panels (incoming from LT Pannel and Feed to DB)

Figure 41:Pumps installed for lifting water

Figure 42:Panel Installed for Boring pump

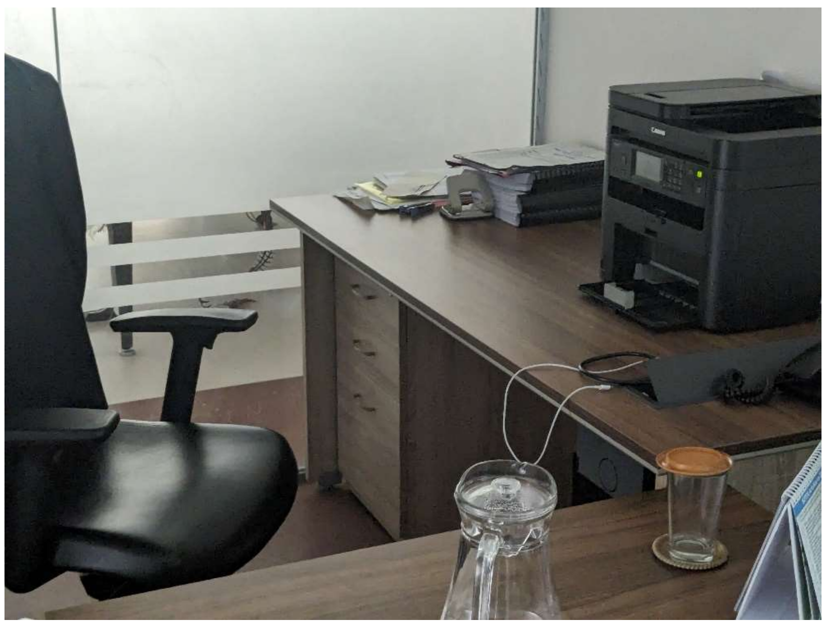


Figure 43:Office Equipment

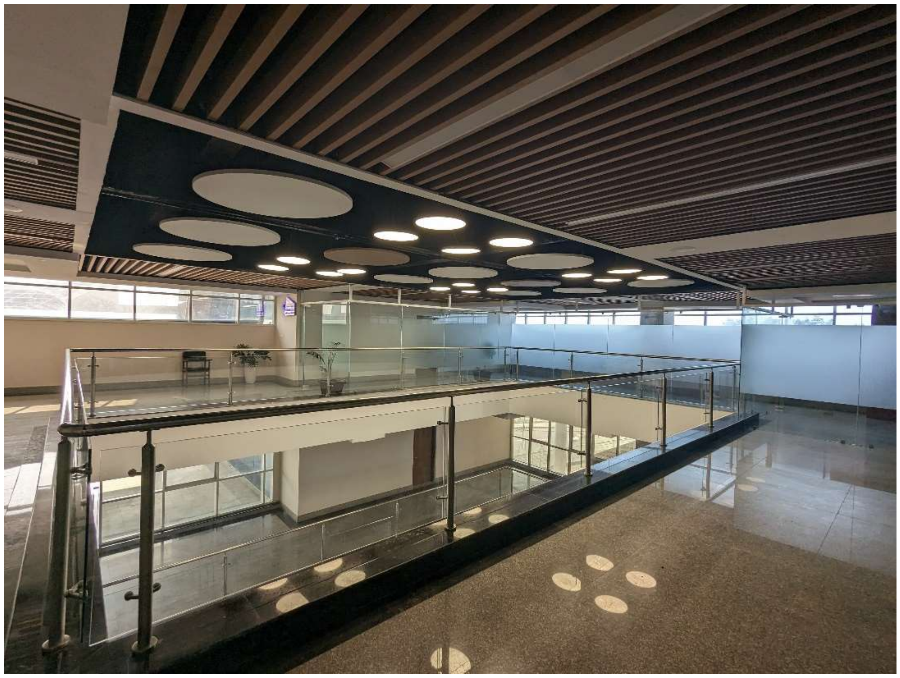


Figure 44:Internal Lighting Fixtures

Figure 45: Questioner with Director of Aerodrome engineering Department

Figure 46:Insights and questioner with the Director of Electromechanical Department, CAAN (Mr. Sunil Kumar Kushwaha)

Figure 47:Thesis discussion and questioner survey (Manager of Aerodrome Engineering Department. Nal Bikram Thapa Sir)

Report encoperating comments.docx

Tribhuvan University

Document Details

Submission ID

trn:oid:::3117:448077672

Submission Date

Apr 11, 2025, 9:01 PM GMT+5:45

Download Date

Apr 11, 2025, 9:13 PM GMT+5:45

File Name

Report encoperating comments.docx

File Size

16.7 MB

174 Pages

30,342 Words

182,729 Characters

5% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Filtered from the Report

- Bibliography
- Quoted Text
- Small Matches (less than 10 words)

Exclusions

- 1 Excluded Source

Match Groups

82 Not Cited or Quoted 4%
Matches with neither in-text citation nor quotation marks

8 Missing Quotations 0%
Matches that are still very similar to source material

0 Missing Citation 0%
Matches that have quotation marks, but no in-text citation

0 Cited and Quoted 0%
Matches with in-text citation present, but no quotation marks

Top Sources

4% Internet sources
2% Publications
0% Submitted works (Student Papers)

Integrity Flags

1 Integrity Flag for Review

Hidden Text
36 suspect characters on 1 page
Text is altered to blend into the white background of the document.

Our system's algorithms look deeply at a document for any inconsistencies that would set it apart from a normal submission. If we notice something strange, we flag it for you to review.

A Flag is not necessarily an indicator of a problem. However, we'd recommend you focus your attention there for further review.

Match Groups

- **82** Not Cited or Quoted 4%
  Matches with neither in-text citation nor quotation marks
- **8** Missing Quotations 0%
  Matches that are still very similar to source material
- **0** Missing Citation 0%
  Matches that have quotation marks, but no in-text citation
- **0** Cited and Quoted 0%
  Matches with in-text citation present, but no quotation marks

Top Sources

4%	Internet sources
2%	Publications
0%	Submitted works (Student Papers)

Top Sources

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	Internet	www.coursehero.com	<1%
2	Internet	iaescore.com	<1%
3	Internet	tel.archives-ouvertes.fr	<1%
4	Internet	m.moam.info	<1%
5	Internet	elibrary.tucl.edu.np:8080	<1%
6	Internet	fastercapital.com	<1%
7	Internet	mro-ns.massey.ac.nz	<1%
8	Internet	hdl.handle.net	<1%
9	Internet	eprints.hud.ac.uk	<1%
10	Internet	theses.ncl.ac.uk	<1%

11	Internet	www.stateregstoday.com	<1%
12	Internet	docs.google.com	<1%
13	Internet	www.ufs.ac.za	<1%
14	Internet	www2.mdpi.com	<1%
15	Internet	www.brighton-hove.gov.uk	<1%
16	Publication	Asmaa R Elantary. "Energy Consumption Patterns in Residential Buildings: A Com...	<1%
17	Internet	iea-ebc.org	<1%
18	Internet	pure.hud.ac.uk	<1%
19	Internet	dl.lib.uom.lk	<1%
20	Internet	finmodelslab.com	<1%
21	Internet	psasir.upm.edu.my	<1%
22	Internet	www.weather-atlas.com	<1%
23	Internet	www.examples.com	<1%
24	Internet	ascpro.ascweb.org	<1%

त्रिभुवन विश्वविद्यालय
Tribhuvan University
इन्जिनियरिङ्ग अध्ययन संस्थान
Institute of Engineering
थापाथली क्याम्पस
THAPATHALI CAMPUS
Accredited By University Grants Commission (UGC) Nepal, 2024

GPO Box- 280, Thapathali, Kathmandu
Tel: 01-5339766
E-mail: info@tcioe.edu.np
Website: www.tcioe.edu.np
गोश्वारा पो. नं. २८०, थापाथली, काठमाडौं
फोन: ०१-५३३९७६६

Date: April 21, 2025

To Whom It May Concern:

This is to certify that the paper titled **"Impact of Occupant Behavior on Energy Efficiency in Commercial Buildings: A Case Study of CAAN Head Office, Sinamangal,Kathmandu"** (Submission# **213**) submitted by **Bashanta Bhattarai** as the first author, which had been accepted for presentation after the peer-review process, has successfully been presented at the 16th IOE Graduate Conference held during April 18 - 20, 2025. Kindly note that the final revision of the papers and publication process of the conference proceedings is still underway and hence inclusion of the accepted manuscript in the conference proceedings is contingent upon timely response to further edits during the publication process.

INSTITUTE OF ENGINEERING
16th IOE Graduate Conference, 2025
THAPATHALI CAMPUS

Dr. Raj Kumar Chaulagain,
Convener,
16th IOE Graduate Conference

Impact of Occupant Behavior on Energy Efficiency in Commercial Buildings: A Case Study of CAAN Head Office, Sinamangal,Kathmandu

Bashanta Bhattarai [a], Ajay Kumar Jha[b]

[a] *Department of Architecture and Urban Planning, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal*
[b] *Department of Mechanical and Aerospace Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal*
[a] bashanta14@gmail.com , [b] ajaykumarjhaphd@gmail.com ,

Abstract
The energy efficiency of buildings is a critical concern in the global effort to reduce carbon footprints and promote sustainable energy use. While technological advancements in energy-efficient building designs have become widespread, the behavior of building occupants often deviates from the intended energy consumption patterns, resulting in energy wastage. This study examines the impact of occupant behavior on electricity consumption in the Civil Aviation Authority of Nepal (CAAN) head office building, a structure designed with energy-efficient technologies. Despite these efforts, actual energy usage in the building exceeds projected consumption levels, primarily due to occupant behavior such as the excessive use of lighting and HVAC systems. The research utilized a comprehensive methodology involving on-site surveys, analysis of energy consumption data, and direct behavioral observations to assess the gap between designed and actual energy consumption. Time-of-Day (TOD) meter readings were employed to determine energy consumption patterns across various periods of the day, while occupant surveys gathered qualitative data on behavior patterns, energy-saving awareness, and the effectiveness of existing energy management policies. The analysis revealed a significant discrepancy between the expected and actual energy consumption, primarily driven by inefficient and habitual energy practices of building occupants. The study identifies key behavioral trends, such as leaving lighting and air conditioning units running when not needed, as major contributors to unnecessary energy consumption. Furthermore, the research highlights the importance of occupant awareness and consistent engagement in achieving sustainable energy practices. Based on these findings, the study proposes several strategic interventions, including more frequent behavioral training, the implementation of automated energy management systems, and policy reforms aimed at enhancing occupant accountability. By addressing these behavioral inefficiencies, it is possible to significantly reduce energy wastage and align actual energy use with the design expectations of energy-efficient buildings. This study emphasizes the critical role of occupant engagement in optimizing building energy performance and contributing to broader sustainability goals.

Keywords
Occupant behaviour–energy consumption –building energy efficiency–electricity usages patterns–sustainable energy practices–automated energy controls

1. Introduction

Buildings are significant contributors to global energy consumption, accounting for approximately 40 percentage of total energy use [1]. A substantial portion of this energy is influenced by occupant behavior, which can lead to discrepancies between the designed and actual energy consumption. For instance, studies have shown that more than 50percentage of energy in commercial buildings is sometimes consumed when no occupants are present [2]. Additionally, the use of lighting occupancy sensors has been found to reduce annual lighting energy consumption by approximately 33 percentage to 55 percentage [3]. These findings underscore the critical impact of occupant behavior on building energy performance.. This study aims to investigate the discrepancy between the designed and actual electricity consumption in the Civil Aviation Authority of Nepal (CAAN) head office building, located in Kathmandu. Despite incorporating energy-efficient designs, buildings exhibit higher energy usage than anticipated. To identify the factors contributing to this variance, a comprehensive study was conducted, including field measurements of energy use and a questionnaire survey, to understand occupant behaviors affecting energy consumption.

Figure 1: Aerial view of CAAN Building @source : Google Earth

The findings provide an overview of the existing discrepancies between a building's design intentions and its actual energy consumption patterns, as analyzed from time-of-day (TOD) meters and utility bills. The study revealed that the actual energy loads are influenced by occupant habits and usage patterns. Addressing these issues is essential for creating a more sustainable future, as the insights from this research can inform regulations and policies for government buildings and empower occupants to make energy-conscious decisions.

Figure 2: New CAAN Head Office Building at Sinamangal

2. Methodology

To accurately assess the discrepancy between designed and actual electricity consumption in the Civil Aviation Authority of Nepal (CAAN) head office building, the research employed a combination of utility data analysis, electrical load calculations, and occupant behavior surveys.

1. Electricity consumption data was collected from Time-of-Day (TOD) meter bills obtained from building management. These bills provided primary data on total electricity usage over a specified period. The TOD meter readings allowed for a detailed breakdown of energy consumption at different times of the day, facilitating an analysis of peak load periods and their correlation with occupant behavior. This method helped identify whether excessive energy use was occurring during work hours or after hours due to factors such as unnecessary lighting, HVAC operation, or standby power consumption..
2. Building Load Calculation:A comprehensive electrical load calculation was conducted to determine the total installed power of all lighting fixtures, HVAC systems, office equipment, and other electrical appliances. This assessment provided a baseline for expected energy consumption under standard operational conditions. By comparing the theoretical load with actual electricity consumption data, the study was able to determine whether deviations from expected energy use were attributable to occupant behavior. Additionally, the load calculation enabled the identification of specific areas or systems where energy inefficiencies were most prominent.
3. Occupant Behavior Surveys: To understand behavioral factors contributing to energy consumption, structured surveys were distributed among building occupants. The surveys gathered data on occupant habits, including frequency of appliance use, lighting and HVAC operation patterns, comfort preferences, and awareness of energy efficiency practices. The responses provided both quantitative and qualitative insights into energy-related behaviors and perceptions, helping to establish a direct link between occupant behavior and deviations in actual energy consumption.

These combined methodologies ensured a comprehensive evaluation of the energy performance gap, integrating technical energy data with behavioral insights to identify key factors influencing electricity consumption in the CAAN head office building.

3. Literature Review

Occupant behavior directly affects energy consumption through actions like adjusting thermostats, using lighting, and operating HVAC systems. Research indicates that variations in these behaviors contribute significantly to the energy efficiency of buildings [4]. Similarly, previous studies [5],[6] emphasize that both adaptive behaviors, such as controlling natural ventilation, and non-adaptive behaviors, like leaving appliances on unnecessarily, impact energy use. These behaviors, often unpredictable and highly context-specific, vary based on building type, location, and occupant profiles [7]. Variations in occupancy patterns, user interactions, and behavioral efficiency contribute significantly to discrepancies in energy performance [3]. These findings align with earlier studies [5],[6], which categorize behaviors into adaptive, such as managing natural ventilation, and non-adaptive, such as leaving appliances on unnecessarily. This body of work underscores the context-specific nature of occupant behavior, influenced by factors such as building type, geographic location, and occupant demographics. Several studies have highlighted the persistent energy performance gap in energy-efficient buildings. Previous research introduced the concept of the "prebound effect," where buildings consume more energy than anticipated because energy savings are overestimated based on assumed occupant behavior [7]. It is seen that, it further emphasizes that existing performance models fail to integrate the complex and diverse occupant behaviors that significantly impact energy use, especially in non-residential buildings [8], [9]. More recent studies, including corroborate this finding, highlighting the limitations of existing energy performance models in accounting for diverse and complex occupant behaviors [8], [9]. These models often fail to capture the unpredictability of human actions, especially in non-residential settings where usage patterns can vary widely. A 2021 review further emphasizes that such gaps are exacerbated by environmental uncertainties and construction quality, suggesting a need for integrating behavioral insights into energy performance assessments. Modeling occupant behavior is a critical aspect of improving energy predictions. Advanced models, including those proposed in the studies, aim to integrate behavioral data with building energy simulation tools [6], [8]. However, these models often oversimplify the spectrum of occupant actions and fail to capture the full variability observed in real-world settings [5]. Moreover, gaps in these models exist when applied to diverse socioeconomic or climatic conditions [9]. Recent studies show that behavioral interventions, such as real-time feedback systems, smart controls, and personalized recommendations, can reduce energy consumption. It is found that providing real-time feedback about energy use to dormitory residents led to measurable reductions in electricity consumption [10]. Other research has similarly emphasized the potential of behavior-based interventions to achieve sustained energy savings [11], [9]. However, the long-term effectiveness of such interventions depends on their adaptability to changes in occupant behavior and technological advancements. While a significant body of research focuses on developed countries, there is a noticeable gap in studies regarding occupant behavior in developing countries, especially those with emerging energy-efficient building markets, like Nepal. Studies emphasize that cultural, economic, and climatic factors influence how occupants interact with their building systems [4],[6]. There is a clear need for region-specific research to account for these variables and understand their impact on energy consumption patterns. However, the long-term success of such interventions depends on their adaptability to evolving behaviors and advancements in technology. Nepal's growing emphasis on energy-efficient building practices presents an opportunity to investigate occupant behavior in a context characterized by diverse climatic conditions and socioeconomic constraints. Integrating occupant behavior into energy management systems, such as automated lighting and HVAC controls, holds considerable potential

For improving sustainability. It is suggested that energy-saving technologies can be more effective if tailored to specific occupant behaviors [11]. Smart building technologies that adapt to occupants' routines and preferences have been identified as critical tools for achieving energy efficiency while also maintaining occupant comfort [7]. These advancements highlight the potential of technology to align building energy performance with occupant behavior while maintaining comfort and functionality.

Figure 3: 630 KVA Compact Substation installed on site

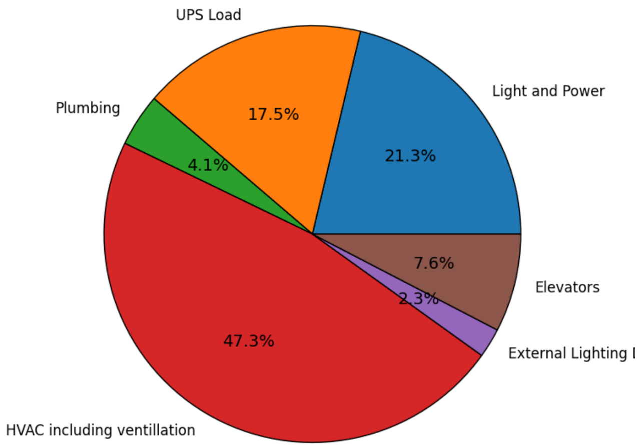


Figure 4: Load distribution in the building

4. Data Collection and Analysis

The total electrical load of the building is supplied through an 11 kV NEA line, which feeds into a 630 kVA compact substation. From there, power is supplied to the LT panel, which is synchronized with 200 kVA and 380 kVA generators. The load is further distributed within the building through rising mains, which supply the distribution boards, and subsequently, the circuits that power lighting points and electrical outlets.

4.1 Total load on the building

The total electrical load of the building is supplied through an 11 kV NEA line, which feeds into a 630 kVA compact substation. From there, power is supplied to the LT panel, which is synchronized with 200 kVA and 380 kVA generators. The load is further distributed within the building through rising mains, which supply the distribution boards, and subsequently, the circuits that power lighting points and electrical outlets.

Table 1: Load Distribution in the Building

SN	Description	Maximum demand
1	Light and Power	111.85 KW
2	UPS Load	91.7KW
3	Plumbing	21.5 KW
4	HVAC including Ventillation	248.4 KW
5	External Lighting	12 KW
4	Elevators	40 KW
	Total	525.45 KW

The theoretical load incurred in the building is further revised according to the total occupant/users using the building. As the above-mentioned load is the maximum load so that the building can accommodate the maximum number of employee and the training equipment if required for future uses. Thus, for the calculation of discrepancy only the occupant currently using the building is taken (calculated manually). The load is divided into fixed loads and loads affected by occupant then the later one load is multiplied by the factor (Total design load occupant/Active occupant) for revising the load which gives the revised load of 315.99 KW. The daily attendance record of the employee is taken as the reference for calculation of daily consumption. Then the monthly consumption is calculated on the basis of total number of working days. The total monthly consumption can be tabulated as:

Table 2: Total monthly consumption theoretical

SN	Month	Consumption kW
1	Shrawn 2080	52921.193
2	Bhadra 2080	41804.511
3	Ashoj 2080	45373.592
4	Kartik 2080	34716.667
5	Mangsir 2080	32117.417
6	Magh 2080	42743.461
7	Falgun 2080	45373.592
8	Chaitra 2080	52846.435
9	Baishak 2081	37645.711
10	Shrawn 2081	45058.462
11	Bhadra 2081	50473.010
12	Ashoj 2081	43489.135
13	Kartik 2081	38355.617
14	Mangsir 2081	36796.067
15	Poush 2081	46798.291
16	Magh 2081	49110.014

4.2 TOD Meter Readings and Electricity Consumption

For this study, electricity consumption data has been collected from the TOD meter installed at the CAAN head office from Shrawan 2080 onward. This data will be analyzed to assess variations in electricity consumption patterns based on different time slots and to identify discrepancies between expected and actual energy usage due to occupant behavior. The insights from this analysis will contribute to understanding how energy efficiency can be improved through behavioral interventions and policy recommendations.

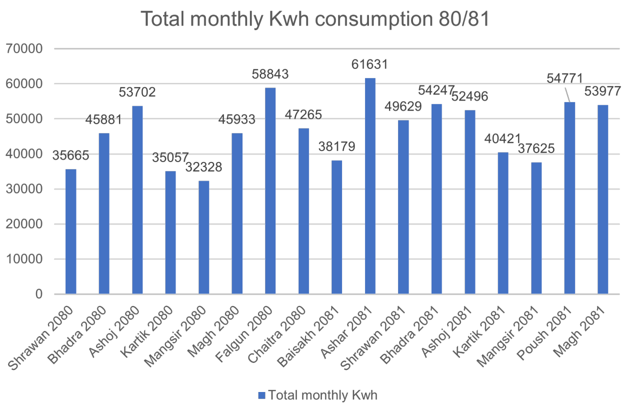


Figure 5: Total monthly Kwh consumption

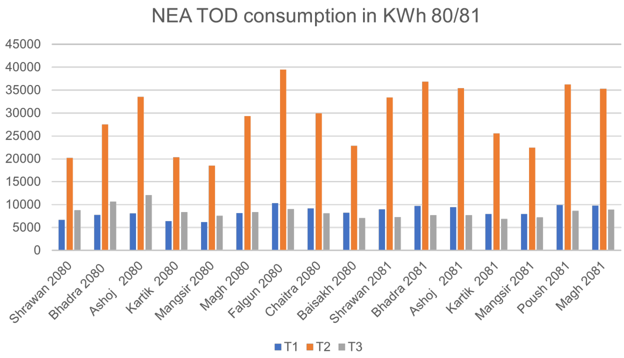


Figure 6: NEA TOD Consumption in KWh 80/81

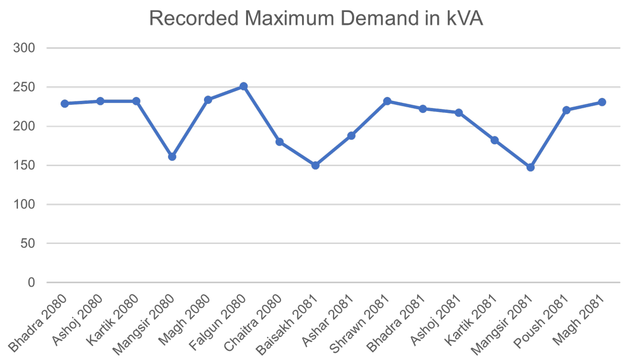


Figure 7: Recorded maximum demand in KVA

4.3 Occupant data collection through survey

The total survey was conducted among 135 employees amongst 204 total employees. The sample size was calculated using Slovin's formula. The questioner was prepared divided into five sections, analyzing the demographic information, awareness and attitudes, behavior patterns, motivations and barriers and perceptions and recommendations. The questioners were developed to evaluate occupant behavior impacting energy consumption (e.g. HVAC usage, lighting, and equipment usages). Then the 5 point Likert scale was used to measure the frequency and intensity of various behaviors. The scale ranged from 1(Strongly Disagree) to 5 (Strongly Agree) providing quantifiable data for analysis.

5. Results and Discussions

The data of actual consumption of electricity, the theoretical calculation of the consumption is tabulated below and the discrepancy between them can be seen:

Table 3: Total monthly consumption theoretical

SN	Month	Calculated(kW)	Actual (kW)
1	Bhadra 2080	41804.511	42970
2	Ashoj 2080	45373.592	53652
3	Kartik 2080	34716.667	35057
4	Mangsir 2080	32117.417	32328
5	Magh 2080	42743.461	45933
6	Falgun 2080	45373.592	47264
7	Chaitra 2080	52846.435	58843
8	Baishak 2081	37645.711	38171
9	Shrawn 2081	45058.462	49629
10	Bhadra 2081	50473.010	54247
11	Ashoj 2081	43489.135	52496
12	Kartik 2081	38355.617	40421
13	Mangsir 2081	36796.067	37625
14	Poush 2081	46798.291	54771
15	Magh 2081	49110.014	53977

The survey conducted at the Civil Aviation Authority of Nepal (CAAN) head office building reveals significant insights into occupant behavior and its impact on energy consumption. While the majority of respondents are aware not of the energy-saving policies in place, there remains a clear gap between awareness and consistent action. For example, while most respondents recognize the importance of saving energy— considering it very important—behavioral practices do not always align with this awareness.

Interestingly, the majority of respondents (28 percentage) reported occasionally receiving reminders about energy-saving practices, which suggests that the frequency of such reminders may not be sufficient to foster consistent energy-conscious behavior. However, there is a noticeable difference in actions related to equipment. While 74 percentage of respondents always turn off their computers, only 2 percentage reported regularly unplugging devices when not in use. This indicates that while there is some adherence to energy-saving practices with regard to computers, there is less consistency when it comes to other devices and appliances, which often contribute to standby power loss. The most common barrier to saving energy, according to 46.67 percentage of respondents, is forgetfulness. Despite a clear understanding of energy-saving measures, this suggests that occasional lapses in memory are a significant challenge in consistently implementing energy-efficient practices. Additionally, the respondents noted that reminders could be more frequent to help mitigate this issue and reinforce energy-saving behavior across the board. Regarding motivations for saving energy, the most common reasons identified were reducing costs and environmental concerns, with 33.33 percentage of respondents citing these as their primary drive. Specifically, the survey found that 43.7 percentage of respondents always turn off lights when not in use, yet 35.55 percentage often leave air conditioning units running in unoccupied rooms. This discrepancy highlights the need for stronger reinforcement of energy-saving habits, particularly in areas like lighting and HVAC systems, which are significant contributors to overall electricity consumption. This reinforces the notion that both financial and environmental factors are key motivators for energy-conscious behavior. However, while the majority of respondents (58 percentage) believe that energy-saving measures in the building are in effective, many also expressed the need for more training. With all of respondents agreeing that additional training would be helpful, this highlights a clear opportunity for CAAN to provide more comprehensive education on energy efficiency.

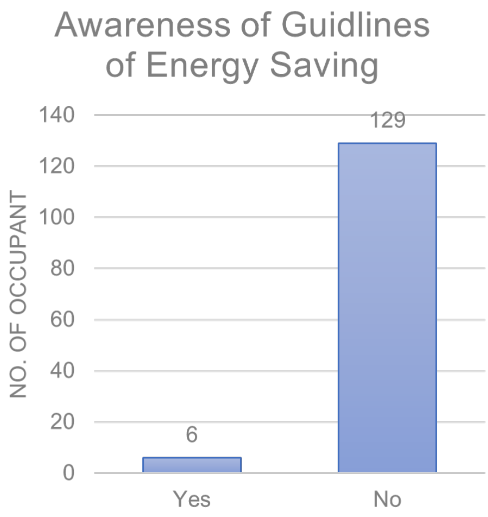


Figure 8: Occupant's awareness of energy saving

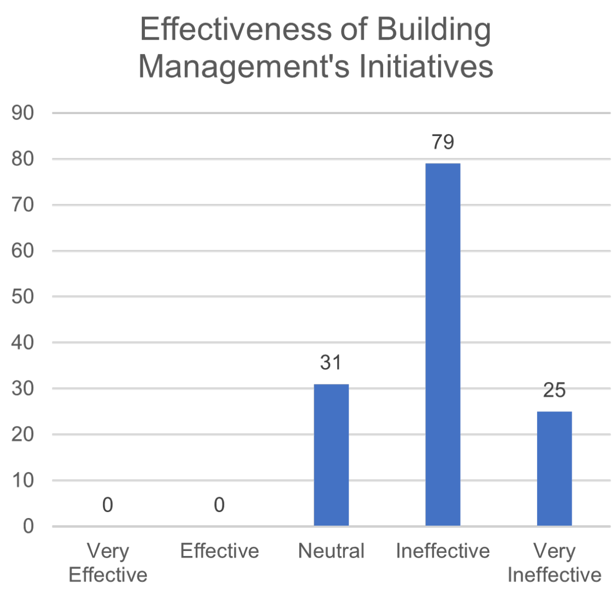


Figure 9: Initative of building management on energy saving

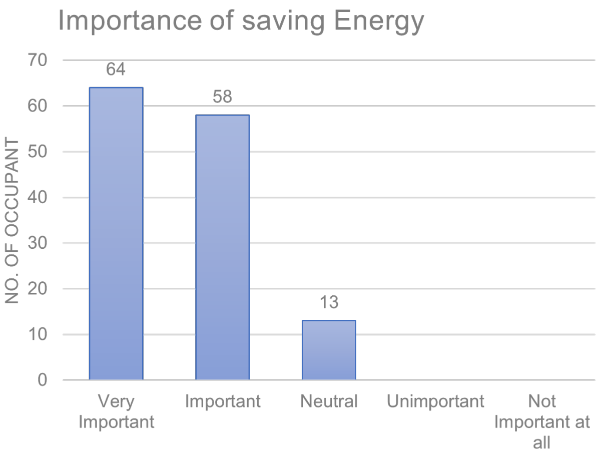


Figure 10: Importance of Energy Saving

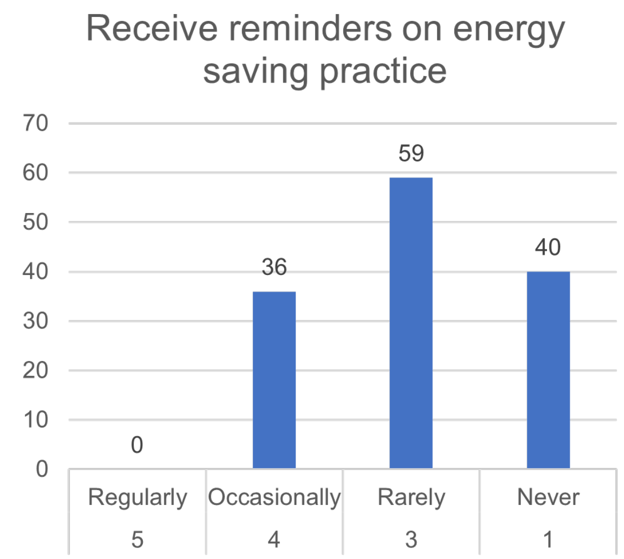


Figure 11: Frequency of notice regarding energy saving

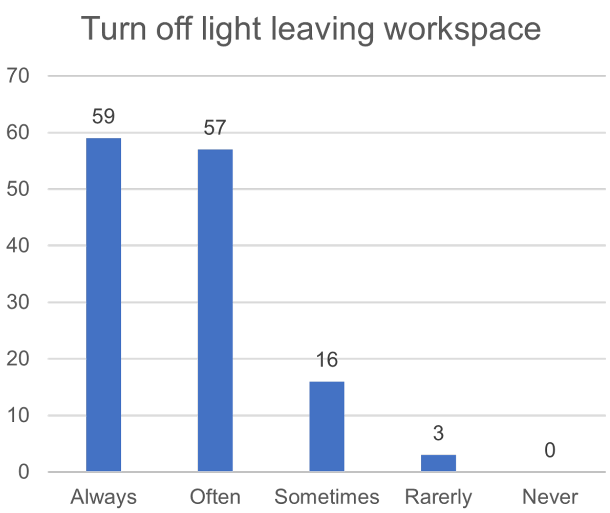


Figure 12: Frequency of occupant turning off light

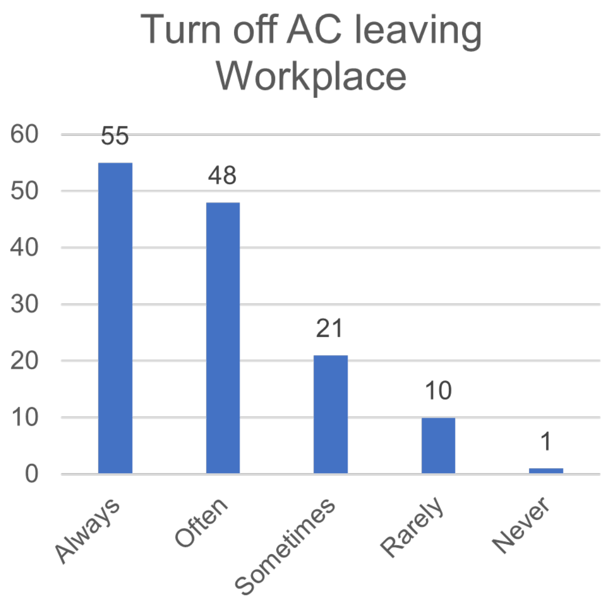


Figure 13: Frequency of occupant turning off AC

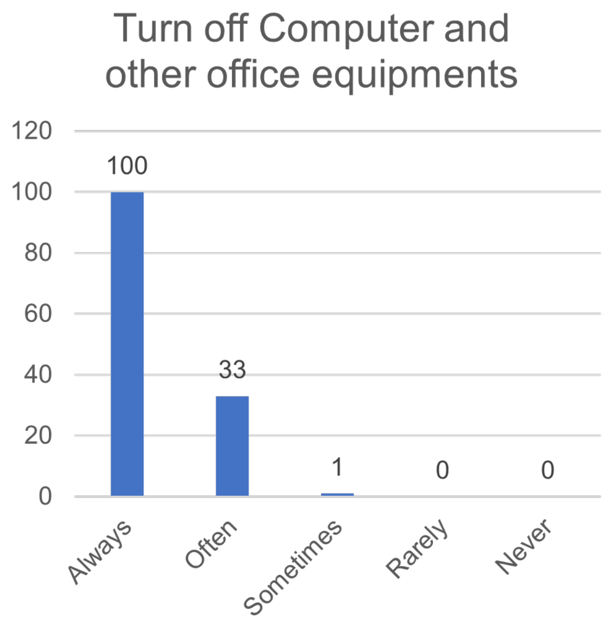


Figure 14: Frequency of occupant turning off computer

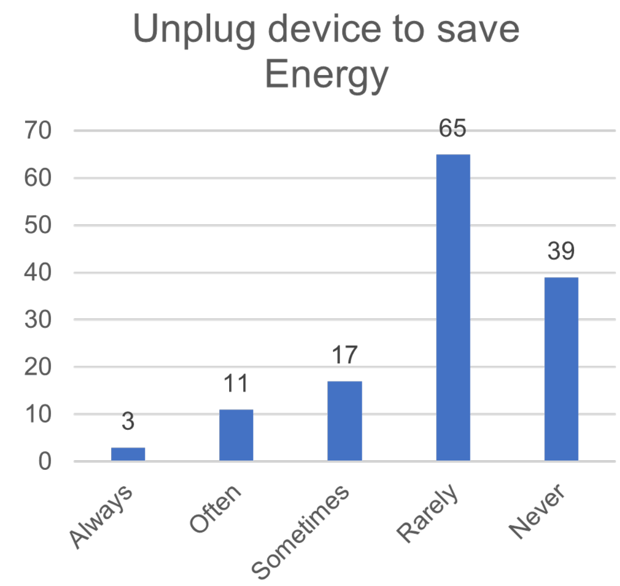


Figure 15: Frequency of occupant unplugging the devices

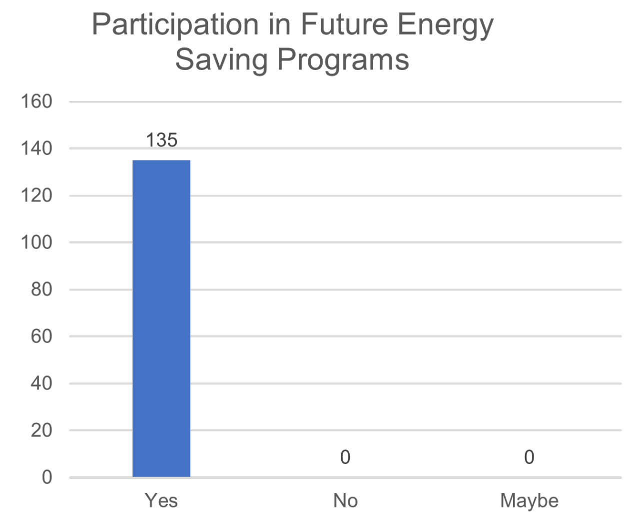


Figure 16: Occupant will to participate in energy saving initiatives

The survey results highlight key areas of both strength and opportunity for improving energy-saving practices within CAAN. While awareness of energy-saving policies is high, the inconsistency in behaviors such as leaving air conditioning running and not unplugging devices points to a gap between knowledge and action. This suggests that frequent reminders, more structured training, and the implementation of technology such as motion sensors or smart energy management systems could be effective in reducing energy consumption. The fact that many respondents believe energy-saving measures are effective, but still face barriers like forgetfulness, emphasizes the need for continuous engagement and habit-forming strategies. Additionally, the willingness to participate in future programs is a positive indication that employees are open to adopting more sustainable practices, provided they are given the right tools and support. While the survey indicates a general awareness of the importance of energy-saving, there are clear opportunities for CAAN to enhance its energy management strategies through targeted education, improved reminders, and the introduction of smarter technologies. By addressing the barriers identified, it is possible to achieve a more energy-efficient workplace that aligns with both environmental goals and operational efficiency.

These results can be further summarized and analyzed representing the data summary in the form of mean median and standard deviation.These can be further tabulated as:

Table 1:Representation of Mean,Median and Standar Deviation of Likert Scale

Questioners	Descriptions	Mean Likert Scores	Median Likert Score	Standarc Deviatio
Question no 4	Awareness of Energy-saving Policies	1.178	1	0.827
Question no 5	Importance of Saving Energy	4.378	4	0.656
Question no 6	Frequency of Reminders	2.674	3	1.164
Question no 7	Turn off Lights	4.274	4	0.757
Question no 8	Turn off AC	4.081	4	0.962
Question no 9	Turn off Computers	4.739	5	0.458
Question no 10	Unplug Devices	2.067	2	0.971
Question no 11	Common Areas with Lights/Equipment On	2.978	3	0.748
Question no 14	Effectiveness of Energy-saving Measures	4.807	5	0.592
Question no 15	Need for More Training	4.852	5	0.526
Question no 16	Energy Efficiency Rating	3.541	4	0.529
Question no 17	Notice Energy Waste	2.281	2	0.861
Question no 19	Building Management's Energy-saving Initiatives	2.044	2	0.645
Question no 20	Willing to Participate in Future Programs	5.000	5	0.000

Figure 17: Table: Calculation of mean, median and standard deviation of Likert score

These data is represented graphically as:

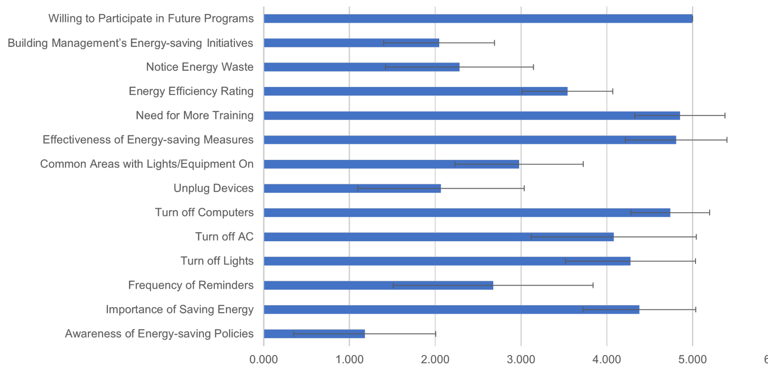


Figure 18: Representation of mean and standard deviation through line chart

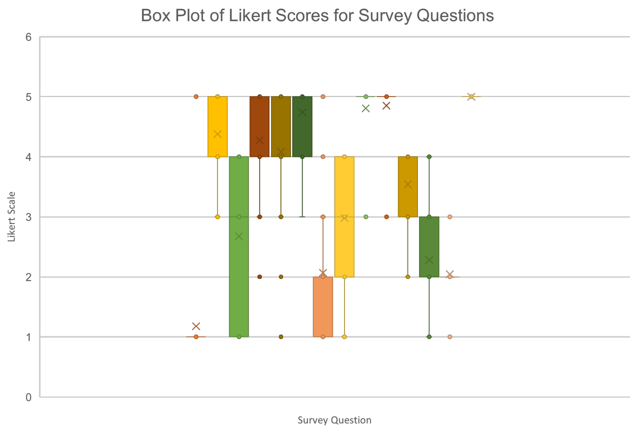


Figure 19: Box Whisker plot for representing the median data

Table 4: Behavioural Adjustment FActor(BAF's) calculation on the basis of Likert Score

Questioner	Likert Score	BAF'S
Awareness of Energy policies	1.178	0.956
Importance of saving energy	4.378	0.1561
Frequency of reminders	2.674	0.581
Turn off lights	4.274	0.181
Turn off AC	4.081	0.230
Turn off Computers	4.739	0.065
Unplug devices	2.067	0.733
Common area with equipment on	2.978	0.506
Effectiveness of saving	4.807	0.048
Need for training	4.852	0.037
Energy efficiency rating	3.541	0.365
Notice on Energy waste	2.281	0.68
Building Management's Initiatives	2.044	0.739
Participate in future program	5	0

For mean value here each bar represents the mean score for each question in the Likert scale survey. A higher bar means that, on average, the responses were more positive (towards 4 or 5), and a lower bar means the responses were more negative (towards 1 or 2).Form the survey conducted we can see that more employee are willing to participate in further energy saving programs having a mean score of 5.Most of the employees do not unplug the devices while leaving the workplace as seen above similarly the we can see that the employee are not aware of energy saving guideline or policies in the building having the lowest mean value between 1.178. Similarly, the standard deviation is given by the error bars, the error bars show the spread of the data, i.e., the variability of responses around the mean. Short error bars indicate that most responses are close to the mean, meaning there is low variability. Long error bars indicate high variability, meaning that the responses to that question are more spread out, and there is a wider range of opinions. The behavioral adjustment factor is computed, in which the Likert scale is converted to the quantifiable value using;

$$BAF = 1 - \left(\frac{\text{Average Likert Score} - 1}{4} \right)$$

Figure 20: Frequency of occupant unplugging the devices

Further here computed as Behavioral adjustment factor (BAF's), then the discrepancy seen was divided into the percentage based on the BAF's . The adjustment factor is listed below,

Here, we can see that the employees are not aware of the energy saving guidelines or policies of the building, and there is lack of energy saving initiatives from the building management. These can be improved by taking initiatives from the building management from creating and implementing proper guidelines for energy saving, such as notices for turning of all equipment and unplugging the devices before leaving the office. To improve energy efficiency in the building, policy guidelines can be developed and enforced. Employees can be encouraged to turn off lights, computers, and other electrical equipment when not in use, with a practice of shutting down non-essential devices at the end of each workday. Notices and reminders can be placed in key areas to reinforce these habits. Regular awareness programs and training sessions can be conducted to educate employees on energy conservation and the impact of their behavior on electricity consumption. An incentive-based approach can also be introduced, where departments or teams that achieve notable reductions in energy use are recognized or rewarded. Designating energy coordinators within each department can help monitor compliance, conduct routine energy audits, and suggest improvements. Real-time energy consumption trends can be shared periodically with employees to encourage engagement and accountability. Periodic reviews of energy policies can be carried out to assess effectiveness and make necessary adjustments. Additionally, guidelines can be established for responsible use of office resources, such as minimizing unnecessary printing, ensuring proper use of heating and cooling systems, and unplugging unused electronic devices. By integrating energy-saving policies with the organization's broader sustainability initiatives, a culture of energy efficiency can be fostered, leading to long-term commitment and behavioral change among employees. Energy-saving initiatives do not always require high-cost investments; significant reductions in electricity consumption can be achieved through simple, low-cost measures. Implementing clear policies, raising awareness, and encouraging behavioral changes among employees can have a substantial impact on energy efficiency. Placing notices and reminders to turn off unused equipment, restricting unnecessary printing, and ensuring proper use of heating and cooling systems require minimal investment but can lead to noticeable energy savings. Regular training sessions and periodic feedback on consumption trends can further enhance awareness and encourage responsible energy use without additional infrastructure costs. By promoting small but effective changes, such as switching off lights in unoccupied spaces and unplugging devices when not in use, energy waste can be significantly reduced. These low-cost interventions demonstrate that improving energy efficiency does not always require expensive technological upgrades; instead, a culture of mindful energy use within the organization can lead to substantial and long-term savings. The findings of this study align with previous research by [11] and [3], which highlight the significant impact of occupant behavior on building energy consumption. Similar to these studies, the results indicate that unregulated energy usage patterns, lack of awareness, and absence of policy enforcement contribute to discrepancies between expected and actual energy consumption. The survey and data analysis reveal that occupants often leave electrical equipment and HVAC systems running unnecessarily, leading to higher energy consumption than theoretically estimated. These results reinforce the importance of behavioral interventions, policy implementation, and awareness programs in achieving energy efficiency within office buildings.

6. Conclusions

This study highlights the significant role of occupant behavior in determining actual energy consumption within office buildings. The findings reveal that a lack of awareness, absence of structured energy-saving policies, and unregulated usage patterns contribute to higher-than-expected electricity consumption. By implementing low-cost initiatives such as clear policy guidelines, awareness programs, and behavioral interventions, substantial energy savings can be achieved without requiring expensive technological upgrades. The study aligns with previous research, reaffirming that behavioral changes, supported by management-driven initiatives, are crucial in bridging the gap between theoretical and actual energy use. Establishing energy-saving policies, fostering a culture of mindful energy use, and encouraging accountability among employees can lead to long-term improvements in energy efficiency. These insights emphasize that strategic, policy-driven approaches can effectively enhance sustainability efforts in office buildings, ensuring both cost savings and environmental benefits.

7. Acknowledgement

Expressing our sincere gratitude to the Department of Architecture and Urban Planning at Pulchowk Campus, IOE, TU, for providing essential resources, facilities, and a supportive academic environment that greatly contributed to the research process. The Civil Aviation Authority of Nepal (CAAN), Government of Nepal, and numerous other data providers, authors, and organizations whose published articles, reports, and documents informed the analysis, are also deeply appreciated. Access to this valuable information and these datasets was crucial for developing the insights presented in this paper. We would also like to extend our heartfelt appreciation to classmates and colleagues for their support and collaboration. Their support and encouragement helped create a positive and productive research environment.

References

[1] International Energy Agency. *More efficient and flexible buildings are key to clean energy transitions.* 2024.

[2] S. Zhang, M. Ma, N. Zhou, and J. Yan. Globus: Global building renovation potential by 2070. 2024.

[3] Y. Chen, G. Zhang, and N. Li. Impact of occupant behavior on building energy consumption and indoor environment: a review. *Buildings*, 12(8):1108, 2022.

[4] T. Hong, D. Yan, S. D'Oca, and C. F. Chen. Ten questions concerning occupant behavior in buildings: The big picture. 2017.

[5] E. Delzendeh, S. Wu, A. Lee, and Y. Zhou. The impact of occupants' behaviours on building energy analysis: A research review. 2017.

[6] D. Yan, W. O'Brien, T. Hong, X. Feng, H. B. Gunay, F. Tahmasebi, and A. Mahdavi. Occupant behavior modeling for building performance simulation: Current state and future challenges. *Energy and Buildings*, 2015.

[7] M. Sunikka-Blank and R. Galvin. Introducing the prebound effect: The gap between performance and actual energy consumption. *Building Research & Information*, 2012.

[8] T. Hong, S. C. Taylor-Lange, S. D'Oca, D. Yan, and S. P. Corgnati. Advances in research and applications of energy-related occupant behavior in buildings. *Energy and Buildings*, 2016.

[9] W. O'Brien and H. B. Gunay. The contextual factors contributing to occupants' adaptive comfort behaviors in offices – a review and proposed integrated framework. 2015.

[10] J. E. Petersen, V. Shunturov, K. Janda, G. Platt, and K. Weinberger. Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. *International Journal of Sustainability in Higher Education*, 2007.

[11] E. Azar and C. C. Menassa. A comprehensive analysis of the impact of occupant behavior on energy consumption in office buildings. 2012.

16th IOE Graduate Conference

Thapathali Campus, Kathmandu, Nepal
April 18 – 20, 2025

IMPACT OF OCCUPANT BEHAVIOUR ON ENERGY EFFICIENCY IN COMMERCIAL BUILDINGS:A CASE STUDY OF CAAN HEAD OFFICE

BASHANTA BHATTARAI, Dr. AJAY KUMAR JHA

TABLE OF CONTENTS

INTRODUCTION

- Energy Efficiency in Buildings: With buildings contributing significantly to global energy use(according to UNEP Report,2022 buildings responsible for 34% global energy demand), reducing energy consumption is vital for sustainability.
- Design vs. Actual Consumption: A noticeable gap - between predicted energy use during design and actual consumption, influenced by both design factors and occupant behavior.
- Impact of Occupant Behavior: Daily interactions with building systems, such as leaving lights on and improper thermostat use, can undermine energy efficiency, leading to **higher-than-expected energy consumption.**
- Research Focus: **relationship between occupant behavior and electricity consumption**

INTRODUCTION

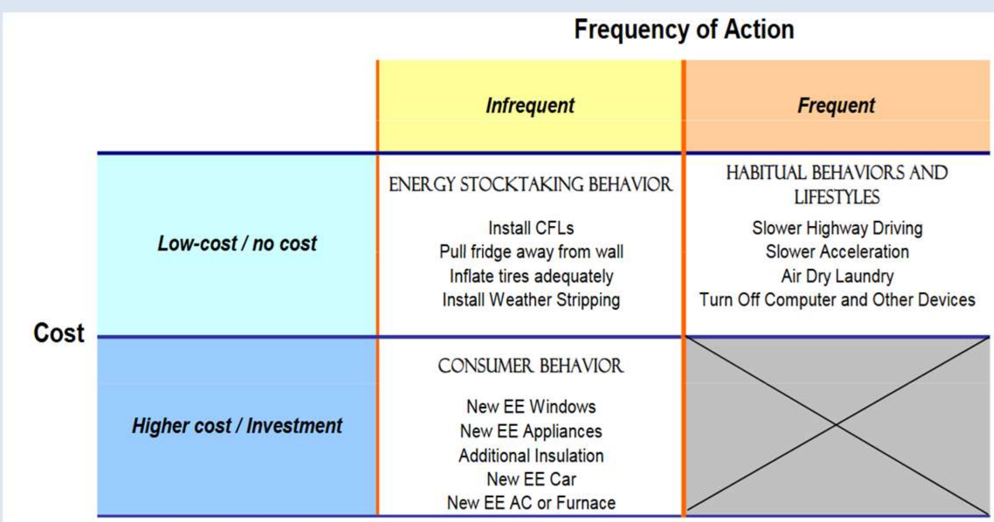


Figure : Types of energy related behavior (Source: Garrison institute Karen-Ehrhardt-Martinez_Myths-and-Realities-of-Individual-and-Social-Behavior_2011

IMPORTANCE OF RESEARCH

- **Societal Impact**
- **Environmental Impact**
- **Technological Impact**

This research aligns with the **UN's Sustainable Development Goal 7** (**Affordable and Clean Energy**) by improving energy efficiency in buildings. It highlights the role of occupant behavior in reducing energy waste, supporting both environmental sustainability and cost-effective energy use, echoing the World **Green Building Council's** belief that "**buildings are central to achieving a low-carbon future"**.

RESEARCH GAP

- **Performance Gap**
  - Despite advancements in energy-efficient design and construction, a persistent **performance gap** exists between **predicted and actual energy consumption.**
  - This gap is well-documented but **understudied**, especially in the context of **developing countries** like Nepal.
- **Technological Innovations vs. Occupant Behavior**
  - Advanced technologies like **energy-efficient HVAC systems** and **automated controls** are designed to optimize energy use but are often **undermined by occupant behavior.**

RESEARCH GAP

- **Performance Gap**
  - Despite advancements in energy-efficient design and construction, a persistent **performance gap** exists between **predicted and actual energy consumption.**
  - This gap is well-documented but **understudied**, especially in the context of **developing countries** like Nepal.
- **Technological Innovations vs. Occupant Behavior**
  - Advanced technologies like **energy-efficient HVAC systems** and **automated controls** are designed to optimize energy use but are often **undermined by occupant behavior.**

OBJECTIVES

- **Main Objective:** The main objective of this research is to analyze the impact of occupant behavior on electricity consumption in the office building and suggest targeted behavioral interventions in reducing the **performance gap.**

- Reaching out to the objective/goal

1. **Identify Behaviors**
2. **Measure Impact**
3. **Analyze Discrepancies**
4. **Recommend Solutions**

LITERATURE REVIEW-Summary

Author(s) & Research Title	Year	Methodology Used	Findings
Azar & Menassa - Impact of occupant behavior on energy consumption in office buildings	2012	Simulation & case study analysis	Occupant behavior significantly influences energy consumption, with variations up to 50% due to behavioral differences.
Sunikka-Blank & Galvin - Prebound effect: Gap between performance and actual energy use	2012	Empirical data analysis from residential buildings	Many buildings consume more energy than predicted due to inefficient occupant behavior and outdated performance assumptions.
O'Brien & Gunay - Contextual factors contributing to adaptive comfort behavior	2015	Literature review & field studies	Occupants adjust behaviors (e.g., thermostat adjustments, window openings) based on personal comfort, affecting energy use unpredictably.
Day & Gunderson - High-performance buildings and occupant knowledge	2015	Surveys & case studies	Lack of awareness of passive design strategies leads to inefficiencies in high-performance buildings.
Hong et al. - Advances in research on energy-related occupant behavior	2016	Review of empirical studies	Variability in energy use is often due to misalignment between design assumptions and real-life occupant behavior.

LITERATURE REVIEW-Summary

Author(s) & Research Title	Year	Methodology Used	Findings
Karjalainen - Sensitivity of buildings to occupant behavior	2016	Simulation study	More resilient building designs can minimize the impact of occupant behavior on energy efficiency.
Delzendeh et al. - Impact of occupant behavior on building energy analysis	2017	Literature review & meta-analysis	Occupant behavior is one of the key drivers of the energy performance gap in buildings.
Chen et al. - Impacts of occupant behavior on building energy consumption	2021	Systematic review of studies	Automation and real-time feedback can help mitigate energy wastage due to occupant behavior.
Heydarian et al. - Behavioral theories and building system interactions	2020	Review & behavioral modeling	Theories such as TPB (Theory of Planned Behavior) and nudging interventions can be used to predict and influence energy-efficient behaviors.
Piselli & Pisello - Long-term occupant behavior monitoring	2019	Longitudinal data analysis	Continuous monitoring of occupant behavior can improve energy performance prediction and reduce discrepancies.
Miller & Jones - Energy consumption discrepancies in commercial buildings	2019	Case study & energy audits	Discrepancies between expected and actual energy consumption arise from both occupant behavior and building system inefficiencies.

LITERATURE REVIEW-Summary

Author(s) & Research Title	Year	Methodology Used	Findings
Thomson & Roberts - Behavioral energy efficiency	2018	Field experiment	Occupant awareness campaigns and real-time energy feedback significantly reduce energy consumption.
Yan et al. - Occupant behavior modeling in building performance simulation	2015	Review & simulation modeling	Improved data collection on occupant behavior is essential for accurate energy modeling in buildings.
Burgess & Thompson - Time-of-day metering for energy efficiency	2017	Utility billing data analysis	Time-of-use tariffs can effectively reduce peak energy loads and influence more efficient occupant behaviors.
Pereira & Dias - Building energy audits and energy management	2020	Case study & audit methodology	Energy audits identify behavioral inefficiencies, leading to targeted interventions for reducing consumption.

OUTPUT FROM LITERATURE REVIEW

- Identification of Key Theories
- Overview of Measurement Methods
- Understanding Behavioral Patterns
- Analysis of Energy Usage Trends
- Impact of Occupant Preferences
- Challenges in Predicting Behavior
- Gaps in Current Research
- Recommendations for Future Studies

CASE STUDY

Image:Aerial view site location(Airport,Kathmandu)

source@google earth

Image: CAAN New head office Building, Sinamangal

source@CAAN REPORT

METHODOLOGY

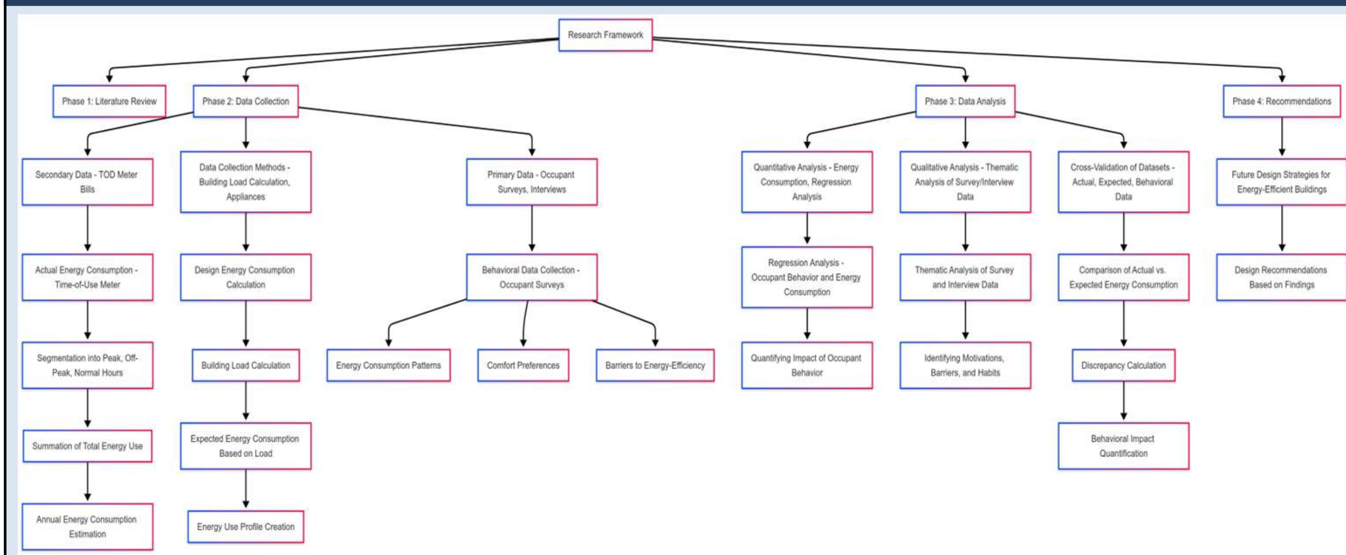


Figure: Research Framework Summary

METHODOLOGY

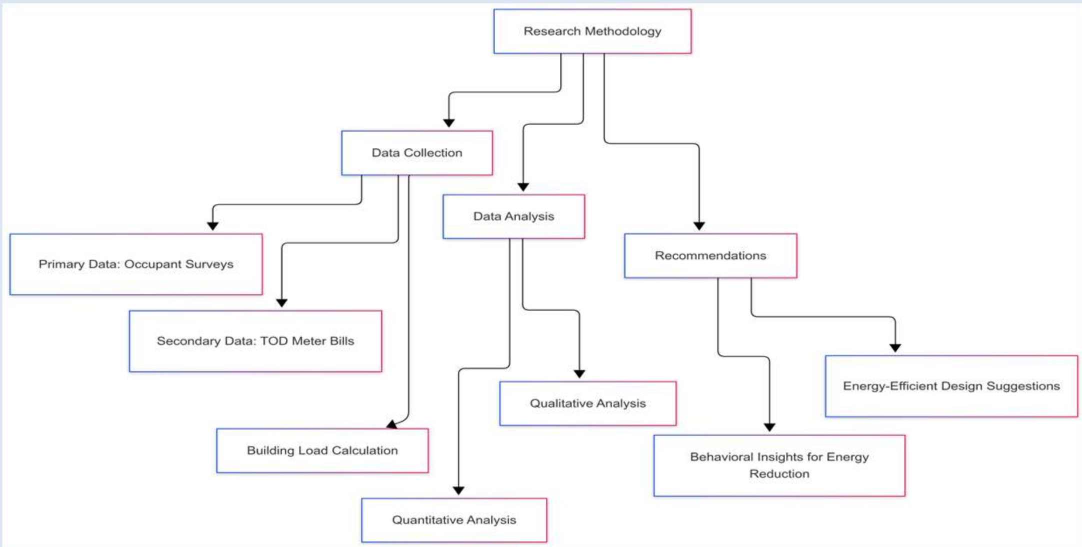


Figure: Research Methodology

RESULTS AND FINDINGS

1.Actual Consumption of Electricity:

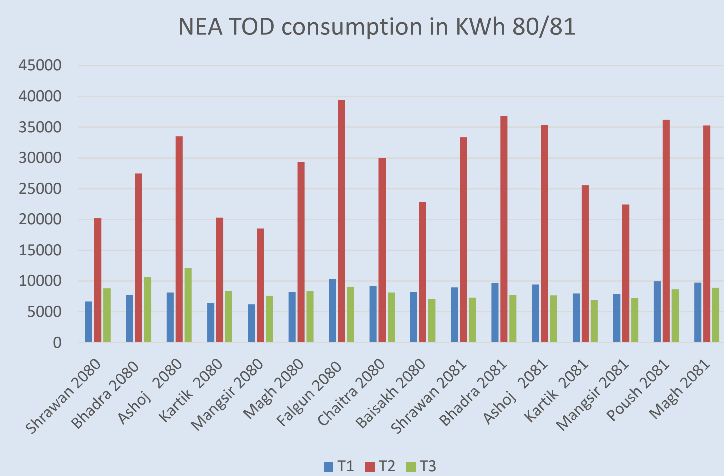


Figure :Summary of TOD meter bill provided by NEA in 2080-81

The actual electricity consumption data collected from the Time-of-Use (TOD) meter bills. The data spans from Shrawn 2080 to the present, reflecting the electricity usage patterns of the building over this period. The TOD meter bills provide detailed records of electricity consumption, broken down by different time periods, such as peak and off-peak hours.

RESULTS AND FINDINGS

1.Actual Consumption of Electricity:

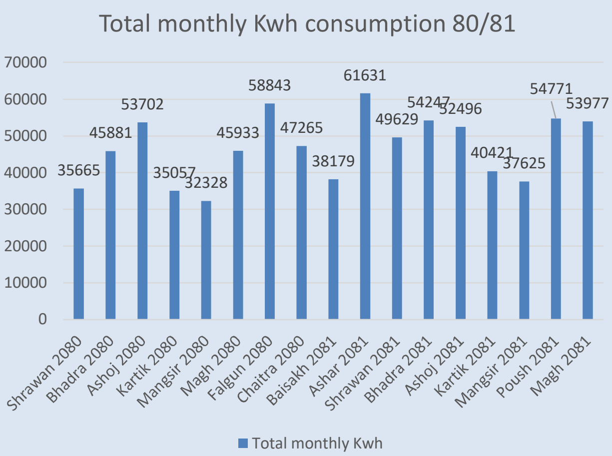


Figure :Total monthly KWh consumption of electricity in 2080-81

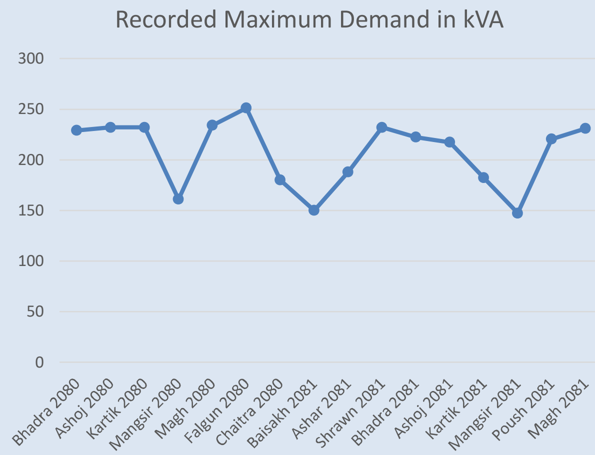


Figure :Recorded maximum demand of electricity for 2080-81

RESULTS AND FINDINGS

1.Actual Consumption of Electricity:

S.N.	Month	Peak	Normal	Off-Peak	Total kWh
1	Shrawn 2080				
2	Bhadra 2080	7735	27500	7735	**42970**
3	Ashoj 2080	8117	33509	12026	**53652**
4	Kartik 2080	6388	20312	8357	**35057**
5	Mangsir 2080	6199	18542	7587	**32328**
6	Magh 2080	8182	29355	8396	**45933**
7	Falgun 2080	9167	29978	8119	**47264**
8	Chaitra 2080	10325	39462	9056	**58843**
9	Baishak 2081	8247	22852	7072	**38171**
10	Shrawn 2081	8964	33382	7283	**49629**
11	Bhadra 2081	9692	36837	7718	**54247**
12	Ashoj 2081	9427	35403	7666	**52496**
13	Kartik 2081	7967	25557	6897	**40421**
14	Mangsir 2081	7927	22457	7241	**37625**
15	Poush 2081	9925	36221	8625	**54771**
16	Magh 2081	9759	35299	8919	**53977**

Figure :Total monthly KWh consumption of electricity in 2080-81

Baisakh to Mangsir	Duration	Rate
Peak Hour	5 PM - 11 PM	Rs. 13.5/kWh
Normal Hour	5 AM - 5 PM	Rs. 12.25/kWh
Off Peak Hour	11 PM - 5 AM	Rs. 7.15/kWh
Poush to Chaitra		
Peak Hour	5 PM - 11 PM	Rs. 13.5/kWh
Normal Hour	5 AM - 5 PM	Rs. 12.25/kWh
Off Peak Hour	11 PM - 5 AM	Rs. 12.25/kWh

Figure :Tariff for TOD meter as per NEA

RESULTS AND FINDINGS

2.Theoretical Load Calculation of Building

S.N.	Load	Maximum Demand(kW)
1	Lights and power	111.85
2	UPS Load	91.7
3	Plumbing	
	i)Fire Fighting	5
	ii)Other pumps	16
4	HVAC Load including ventilation	245
i)	Ventilation	0.9
ii)	Ventilation in case of fire	0.25
5	External Light development	12
6	Elevators	40
		522.7

Total Load on the building

S.N.	Load	Maximum Demand(kW)	Is affected by occupant	Fixed load	Load Depending on occupant	Design occupant/Active occupant factor	Revised load depending on occupant	Revised Maximum demand
1	Lights and power	111.85	Yes	5	106.85	0.51	54.49	59.49
2	UPS Load	91.7	Yes	21.7	70	0.51	35.70	57.40
3	Plumbing		No					
	i)Fire Fighting	5		5				5.00
	ii)Other pumps	16		16				16.00
4	HVAC Load including ventillation	245	Yes		245	0.51	124.95	124.95
i)	Ventillation	0.9		0.9				0.90
ii)	Ventillation in case of fire	0.25		0.25				0.25
5	External Light development	12	No	12				12.00
6	Elevators	40	No	40				40.00
		522.7		**100.85**	**421.85**		**215.14**	**315.99**

Figure :Design and Revised Maximum Load Revised as per occupant load

RESULTS AND FINDINGS

3. Occupant Data Collection through Survey : Questioner

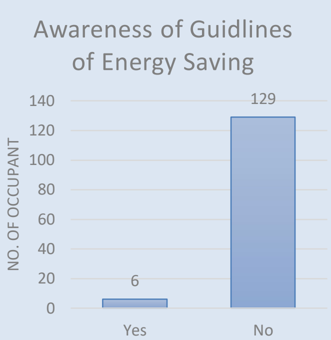


Figure :Occupants Awareness of energy saving guidelines

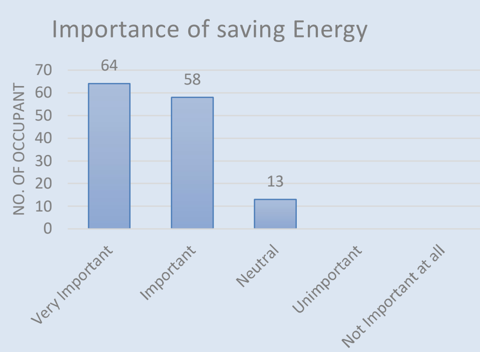


Figure :Importance of energy saving in workplace

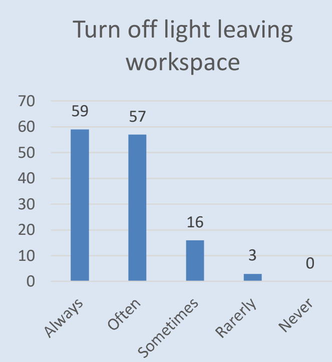


Figure :Occupant turning off light leaving workspace

RESULTS AND FINDINGS

3. Occupant Data Collection through Survey : Questioner

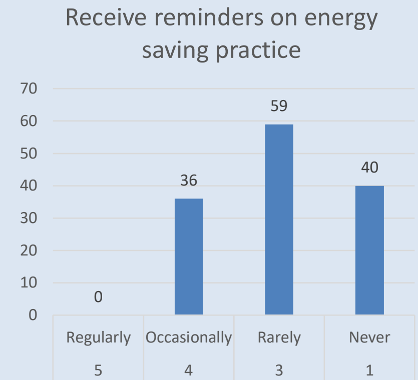


Figure :Occupants receiving reminders on energy saving practices

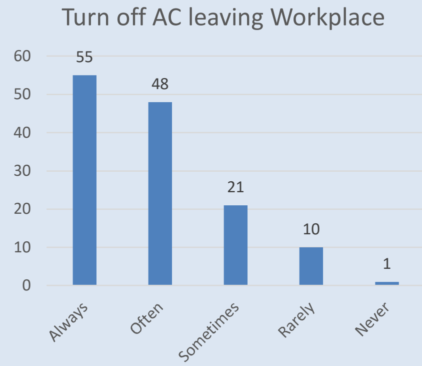


Figure :Occupant turning off AC leaving the workplace

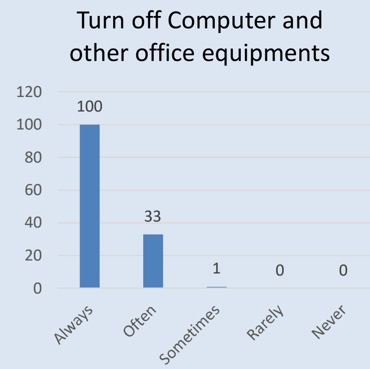


Figure:Occupant turning off computer and other office equipment before leaving office

RESULTS AND FINDINGS

3. Occupant Data Collection through Survey : Questioner

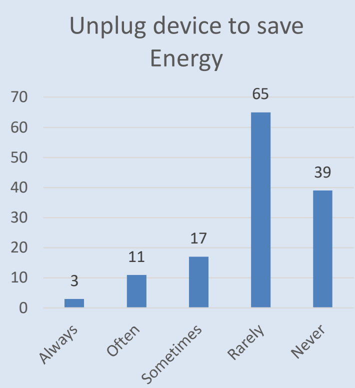


Figure :Occupant unplugging device to save energy

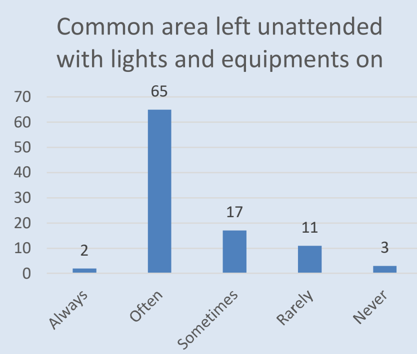


Figure: Occupant noticing that common area is left unattended with light and equipment on

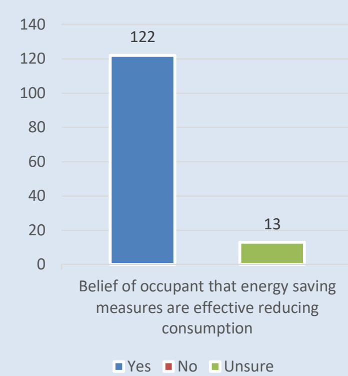


Figure :Occupant believing that energy-saving measures are effective for reducing consumption

RESULTS AND FINDINGS

3. Occupant Data Collection through Survey : Questioner

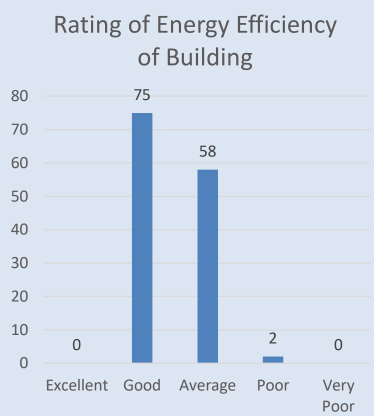


Figure :Occupant rating the energy efficiency of building

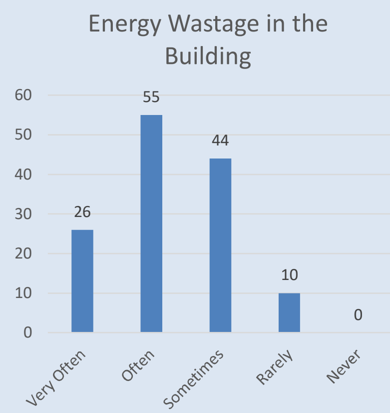


Figure :Occupant noticing the energy wastage in the building

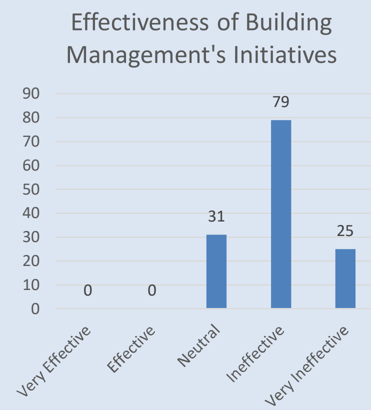


Figure :Building management's energy saving initiatives

RESULTS AND FINDINGS

3. Occupant Data Collection through Survey : Questioner

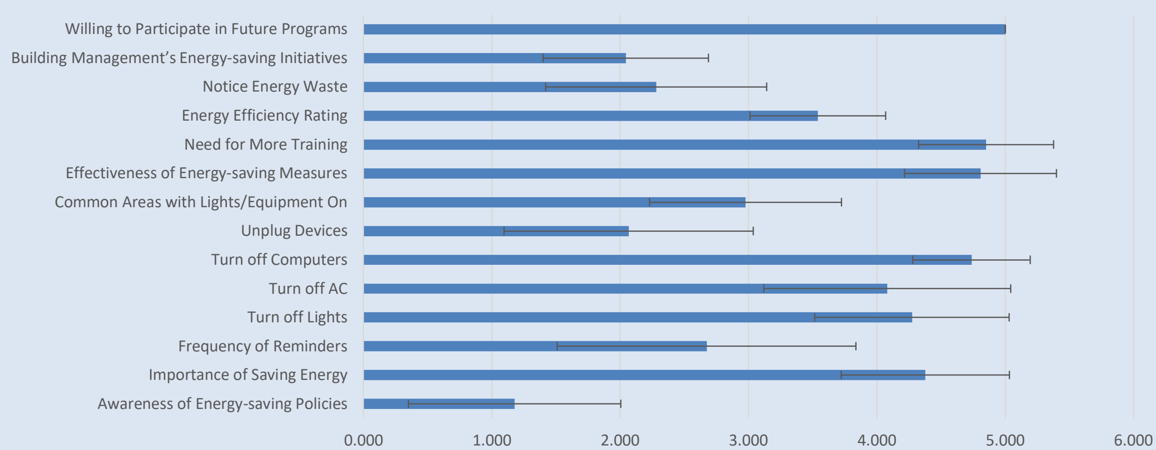


Figure : Mean and Standard Deviation of Questionnaire Responses

RESULTS AND FINDINGS

3. Occupant Data Collection through Survey : Questioner

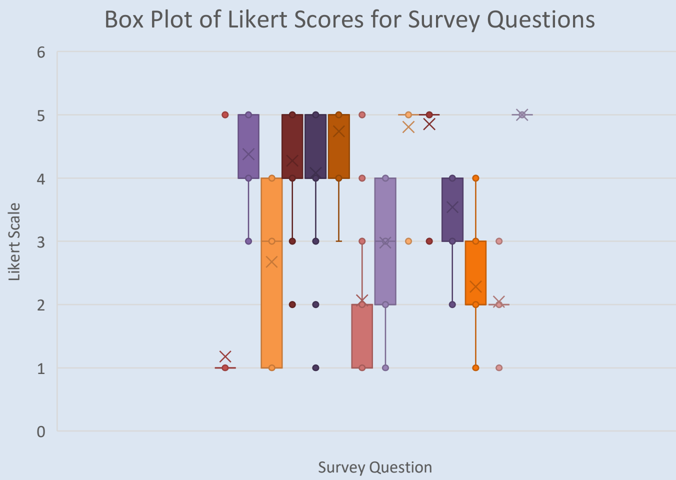


Table 1:Representation of Mean,Median and Standar Deviation of Likert Scale

Questioners	Descriptions	Mean Likert Scores	Median Likert Score	Standard Deviation
Question no 4	Awareness of Energy-saving Policies	1.178	1	0.827
Question no 5	Importance of Saving Energy	4.378	4	0.656
Question no 6	Frequency of Reminders	2.674	3	1.164
Question no 7	Turn off Lights	4.274	4	0.757
Question no 8	Turn off AC	4.081	4	0.962
Question no 9	Turn off Computers	4.739	5	0.458
Question no 10	Unplug Devices	2.067	2	0.971
Question no 11	Common Areas with Lights/Equipment On	2.978	3	0.748
Question no 14	Effectiveness of Energy-saving Measures	4.807	5	0.592
Question no 15	Need for More Training	4.852	5	0.526
Question no 16	Energy Efficiency Rating	3.541	4	0.529
Question no 17	Notice Energy Waste	2.281	2	0.861
Question no 19	Building Management's Energy-saving Initiatives	2.044	2	0.645
Question no 20	Willing to Participate in Future Programs	5.000	5	0.000

RESULTS AND FINDINGS

3. Occupant Data Collection through Survey : Questioner

Questioners	Description	Average Likert Score	BAF	Bhadra 2080	Ashoj 2080	Kartik 2080	Mangsir 2080	Magh 2080	Falgun 2080	Chaitra 2080	Baishak 2081	Shrawn 2081	Bhadra 2081	Ashoj 2081	Kartik 2081	Mangsir 2081	Poush 2081	Magh 2081
				1165.49	8278.41	340.33	210.58	3189.54	1890.41	5996.56	525.29	4570.54	3773.99	9006.86	2065.38	828.93	7972.71	4866.99
Question no 4	Awareness of Energy-saving Policies	1.178	0.956	1114.21	7914.16	325.36	201.32	3049.20	1807.23	5732.72	502.18	4369.43	3607.93	8610.56	1974.51	792.46	7621.91	4652.84
Question no 5	Importance of Saving Energy	4.378	0.156	173.82	1234.61	50.76	31.41	475.68	281.93	894.30	78.34	681.63	562.84	1343.25	308.02	123.62	1189.02	725.84
Question no 6	Frequency of Reminders	2.674	0.581	100.99	717.31	29.49	18.25	276.37	163.80	519.59	45.52	396.03	327.01	780.43	178.96	71.83	690.82	421.71
Question no 7	Turn off Lights	4.274	0.181	18.28	129.83	5.34	3.30	50.02	29.65	94.05	8.24	71.68	59.19	141.26	32.39	13.00	125.04	76.33
Question no 8	Turn off AC	4.081	0.23	4.20	29.86	1.23	0.76	11.51	6.82	21.63	1.89	16.49	13.61	32.49	7.45	2.99	28.76	17.56
Question no 9	Turn off Computers	4.739	0.065	0.27	1.94	0.08	0.05	0.75	0.44	1.41	0.12	1.07	0.88	2.11	0.48	0.19	1.87	1.14
Question no 10	Unplug Devices	2.067	0.733	0.20	1.42	0.06	0.04	0.55	0.32	1.03	0.09	0.79	0.65	1.55	0.35	0.14	1.37	0.84
Question no 11	Common Areas with Lights/Equipment On	2.978	0.506	0.10	0.72	0.03	0.02	0.28	0.16	0.52	0.05	0.40	0.33	0.78	0.18	0.07	0.69	0.42
Question no 14	Effectiveness of Energy-saving Measures	4.807	0.048	0.00	0.03	0.00	0.00	0.01	0.01	0.03	0.00	0.02	0.02	0.04	0.01	0.00	0.03	0.02
Question no 15	Need for More Training	4.852	0.037	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Question no 16	Energy Efficiency Rating	3.541	0.365	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Question no 17	Notice Energy Waste	2.281	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Question no 19	Building Management's Energy-saving Initiatives	2.044	0.739	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Question no 20	Willing to Participate in Future Programs	5	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table :Comparison of Theoretical consumption Vs Actual consumption

RESULTS AND FINDINGS

Q.	Question Theme	Key Findings	BAF	Energy Impact	Priority	Recommended Interventions
Q1	Department	Admin showed 23% higher usages than Engineering	N/A	N/A	Moderate	Department-specific energy KPIs
Q2	Position	Managers had 18% better users than staff	N/A	N/A	Low	Leadership training programs
Q3	Tenure	Employees >5 years showed 15% better habits	N/A	N/A	Low	Mentorship programs
Q4	Policy Awareness	78% unaware of policies	0.956	58,843 kWh	Critical	• Policy campaigns/visible dashboard (info) • New hire orientation modules
Q5	Importance of energy saving (Perception)	89% rated as important but poor follow-through	0.156	N/A	Low	• Real-time energy dashboards • Social norm nudges
Q6	Reminder Frequency	63% receive reminders rarely/never	0.581	4,570 kWh	Moderate	• Biweekly SMS alerts/email alerts • Screen saver messages
Q7	Light Switching	34% leave lights on (peaked at 32.49 BAF)	0.181	9,006 kWh	Moderate	• Motion sensors in restrooms • "Turn Off" light switch stickers
Q8	AC Management	48% don't adjust AC (peak 141.26 BAF)	0.230	14,126 kWh	Critical	• Smart thermostats • 24°C default setting policy

RESULTS AND FINDINGS

Q.	Question Theme	Key Findings	BAF	Energy Impact	Priority	Recommended Interventions
Q9	Computer Shutdown	29% leave on overnight	0.065	4,739 kWh	Low	• Auto-shutdown software • USB device cut-off timers
Q10	Device Unplugging	82% rarely unplug equipment	0.733	7,842 kWh	Critical	• Smart power strips • "Vampire power" awareness campaign
Q11	Common Area Waste	57% observe lights/equipment left on	0.506	8,000 kWh	Moderate	• Usage-tracking dashboards • Departmental accountability boards
Q12	Motivations	Top: Environmental (68%), Cost (59%)	N/A	N/A	Low	• "Your Impact" personalized reports • Sustainability bonus linkage
Q13	Barriers	Forgetfulness (61%), No guidelines (49%)	N/A	N/A	Moderate	• Action-triggered phone notifications • Equipment labeling system
Q14	Measure Effectiveness	74% believe measures work	0.048	N/A	Low	• Quarterly savings transparency reports
Q15	Training Needs	83% want more training	0.037	N/A	Low	• Trainings among employee • "Lunch & Learn" sessions
Q16	Efficiency Rating	58% rate building as average/poor	N/A	N/A	Moderate	• Public energy certification displays

RESULTS AND FINDINGS

Q.	Question Theme	Key Findings	BAF	Energy Impact	Priority	Recommended Interventions
Q17	Waste Observation	66% frequently notice waste	0.680	N/A	Moderate	• Anonymous reporting • "Energy Defender" recognition program
Q18	Suggested Actions	Top: Motion sensors (72%), Stricter policies (65%)	N/A	N/A	Moderate	• Employee co-designed policy updates
Q19	Management Initiatives	Majority rate as ineffective	0.739	N/A	Critical	• Trainings and alerts with frequency of reminders.
Q20	Participation Willingness	88% willing to engage	0.000	N/A	Low	• Green Teams with incentives • Idea crowdsourcing platform

Table :Comprehencive Behavioral Analysis & Intervention Matrix

RESULTS AND FINDINGS

Questions	Behavior	BAF	Energy Impact	Peak Cost (5PM-11PM)	Off-Peak Cost (11PM-5AM)	Intervention
Q4	Policy Ignorance	0.956	58,843 kWh			Policy drills + digital displays
Q7	Light Left On	0.181	9,006 kWh	NRS.1.22 lakh	NRS.64,400	Motion sensors (prioritize peak hours)
Q8	AC Overuse	0.230	12,230 kWh	NRS.1.14 lakh	NRS.28,350	Smart thermostats with peak limiting
Q10	Devices Plugged In	0.733	7,842 kWh	NRS.1.06 lakh	NRS.56,100	Smart plugs with off-peak auto-cutoff

Table :Behavioral Energy Analysis with Time-Variable Tariffs

Intervention	Key Issue (BAF)	AnnualWaste (kWh)	Savable (kWh/yr)	Annual Savings (NPR)	Implementation Cost (NPR)	Payback Period	Priority
Policy Awareness (Q4)	0.956 (Critical)	58,843			200,000		High
Lighting Control (Q7)	0.181 (Moderate)	9,006	5,434	90,600	225,000	2.3 years	Medium
HVAC Optimization (Q8)	0.221 (Moderate)	12,230	6,582	79,255.8	883,500	11.14 years	Medium
Standby Loads (Q10)	0.285 (Critical)	21,348	16,011	256,176	267,500	1.0 years	High

Table :Summary of Key Findings, Savings, Costs, and Payback Periods

RESULTS AND FINDINGS

Intervention	Implementation Cost (NPR)	Annual Savings (NPR)	Payback Period	Priority Level
Smart Power Strips	267,500	256,176	1.0 years	Critical (🔴)
Policy Dashboards	200,000			Critical (🔴)
Motion Sensors	225,000	90,600	2.3 years	Medium (🟡)
Smart Thermostats	883,500	79,255.8	11.14 years	Medium (🟡)
Total Potential	1,576,000	426,031.8	3.6 yrs avg.	27 % Reduction

Table :Cost-Benefit Analysis of Proposed Interventions

Timeframe	Actions	Key Performance Indicators	Required Resources
0-6 months	- Deploy 60 smart power strips	75% standby load reduction	NPR 267,500 capital
(Quick Wins)	- Install policy dashboards	32% policy compliance improvement	40 staff training hours
1-3 years	- Retrofit lighting with sensors	NPR 90,600 annual lighting savings	NPR 225,000 + IT support
(System Upgrades)	- Install smart thermostats	22% HVAC efficiency gain	NPR 883,500 capital
3-5 years	- Implement IoT-based BMS	Additional 15-20% system optimization	NPR 1.2M + technical partners
(Future-proofing)	- Establish Green Teams	Sustained behavioral change metrics	5% staff time allocation

Table :Phased Implementation Roadmap

DISCUSSION:COMPARISION WITH PREVIOUS STUDY

Insights from Literature

•**Occupant Behavior and Energy Consumption**:

- **Azar and Menassa (2012)** found that occupant behavior significantly impacts energy consumption in office buildings, particularly in lighting and HVAC usage.
- **Chen et al. (2021)** reviewed the impact of occupant behavior on building energy consumption and emphasized that non-technical factors, such as behavioral patterns, are often the cause of discrepancies between expected and actual energy usage.

•**Energy Discrepancy and Prebound Effect**:

- **Sunikka-Blank and Galvin (2012)** discussed the "prebound effect," where buildings consume more energy than expected due to unaccounted behavioral influences.
- **Miller and Jones (2019)** emphasized that discrepancies in energy consumption in commercial buildings arise from behavioral factors, undermining the benefits of energy-efficient technologies.

DISCUSSION:COMPARISION WITH PREVIOUS STUDY

Agreement with Literature:

•**Agreement with Azar and Menassa (2012)**: This study supports the finding that occupant behavior significantly influences energy consumption. Specifically, actions like leaving lights and HVAC systems running when not needed contribute to excessive consumption.

•**Agreement with Chen et al. (2021)**: The study corroborates the results from **Chen et al. (2021)**, confirming that occupant behavior, including irregular usage patterns and lack of awareness, increases energy consumption despite technological interventions.

Contradictions with Literature:

•**Contradiction with Hong et al. (2017)**: While **Hong et al. (2017)** suggest that energy-saving technologies are sufficient to reduce energy consumption, this study found that the absence of behavior modification led to discrepancies between expected and actual consumption. This indicates that technology alone cannot mitigate all energy inefficiencies without behavioral changes.

•**Contradiction with Zhai and Lu (2016)**: **Zhai and Lu (2016)** argue that occupant behavior is a secondary factor in energy consumption when compared to design and technological solutions. This study contradicts this by showing that occupant behavior is a primary factor significantly influencing energy use in the CAAN Head Office building.

DISCUSSION:COMPARISION WITH PREVIOUS STUDY

Literature Gaps:

•**Behavioral Data**: Many studies, such as **Chen et al. (2021)** and **Yan et al. (2015)**, point out the need for more detailed, occupant-specific data to better understand the impact of behavior on energy use.

•**Contextual Differences**: Most research, including **Karjalainen (2016)**, has been conducted in developed countries, with limited studies focusing on buildings in developing countries like Nepal.

Research Contributions:

•**Focus on Developing Country Context**: This study contributes to filling the gap in research on the energy performance of office buildings in Nepal, particularly focusing on the Civil Aviation Head Office building.

•**Incorporation of Behavioral Data**: This study introduces specific data from the CAAN Head Office regarding occupant behaviors and their direct impact on energy consumption.

Theoretical Implications:

•The findings from this study add to the growing body of literature that emphasizes the need for incorporating occupant behavior into energy models, as discussed in **Azar and Menassa (2012)** and **Chen et al. (2021)**.

•It challenges traditional models that focus only on building design and technology, suggesting that a more holistic approach, incorporating occupant behavior, is crucial for reducing energy consumption.

DISCUSSION:COMPARISION WITH PREVIOUS STUDY

Next Steps:

•**Awareness Campaigns**: Implementing behavior change programs to educate building occupants about energy-efficient practices could be a key recommendation to address energy inefficiencies observed.
•**Further Research**: Conducting additional studies with larger sample sizes across various buildings in Nepal to validate findings.
•**Integrated Energy Models**: Developing energy models that integrate both technological aspects and behavioral data for better predictions of energy use.

CONCLUSION

Key Findings:

- Occupant behavior significantly impacts actual energy consumption.
- High consumption linked to lack of awareness and absence of energy-saving policies.
- Usage patterns often exceed theoretical estimates due to unregulated habits.

Suggested Intervention:

- Introduce structured energy-saving policies.
- Launch awareness and training programs.
- Encourage behavior change through feedback and accountability.
- Can be achieved without expensive technological upgrades.

CONCLUSION

The Way Forward:

- Bridging the performance gap starts with people—not just technology.
- Well-structured, policy-driven behavioral strategies can unlock substantial, long-term energy savings.
- A culture of accountability and awareness transforms buildings into truly energy-efficient spaces.
- This approach ensures not only operational cost reductions but also reinforces our commitment to environmental sustainability.

Thank you !