MINISTRY OF FEDERAL AFFAIRS & GENERAL ADMINISTRATION

switchasia Funded by the European Union

BUILDING ENERGY EFFICIENCY IN NEPAL

BUILDING Energy Efficiency in Nepal (BEEN)

Baseline Report on Operational Energy Consumption in Buildings

universität innsbruck Unit of Energy Efficient Buildings

MinErgy

Greentech Knowledge Solutions Pvt. Ltd.

UNE Normalización Española

BUILDING Energy Efficiency in Nepal (BEEN)

Baseline Report on Operational Energy Consumption in Buildings

universität innsbruck
Unit of Energy Efficient Buildings

MinErgy

Greentech Knowledge Solutions Pvt. Ltd.

UNE Normalización Española

Recommended citation
BUILDING Energy Efficiency in Nepal (BEEN) Project. (2024). Baseline Report on Operational Energy Consumption in Buildings. BUILDING Energy Efficiency in Nepal (BEEN) project funded by the European Union under the SWITCH-Asia Grants Programme. https://been.minergynepal.com/resources/#

Baseline Report on Operational Energy Consumption in Buildings

Published by
BUILDING ENERGY EFFICIENCY IN NEPAL

Edition
First

Disclaimer
This publication is funded by the European Union under the SWITCH-Asia Grants Programme. Its contents are the sole responsibility of the BEEN Project and do not necessarily reflect the views of the European Union.

This Baseline Report provides a comprehensive analysis of building characteristics and energy consumption patterns of three building typologies across four bio-climatic zones of Nepal. The findings and conclusions presented in this report may not be fully representative of the entire Nepal. Also, the contents should not be construed as an endorsement of any specific policy, practice, or approach to energy efficiency or renewable energy integration or building design. The BEEN project, its partners, and funders disclaim all responsibility for any errors or omissions or for the results obtained from the use of this information.

Edited by
Prof. Dr. Jagat Shrestha

Designed by
Nepal in Data, initiative of Bikas Udhyami

Photographs by
BUILDING Energy Efficiency in Nepal (BEEN), Urban Park

Available from
26th February, 2024

Email
info@beenproject.org

Address
Dakshinkali Chowk, Manbhawan, Lalitpur 44700

Phone
+ (977) 1-5421760
+ (977) 1-5421317

Preface

According to the estimates from the International Energy Agency (IEA) in 2023, buildings account for approximately 30% of global final energy consumption and 26% of global energy-related emissions. Developing countries are driving the demand for energy and consequently CO2 emissions, due to population growth, rapid urbanization and rising living standards. It is imperative to ensure that this development does not come at the cost of greater environmental concerns.

The road to energy efficiency in buildings worldwide requires knowledgeable and skilled building professionals, along with standards and regulations to enhance energy efficiency. Additionally, market mechanisms and ecosystems are needed to facilitate the adoption of principles, systems and products that enable the design, construction and operation of efficient buildings.

To effectively work on and develop the aforementioned aspects to improve energy efficiency in buildings, one must understand their starting point. In Nepal, there is an absence of baseline data on operational and embodied energy consumption. BEEN conducted a baseline study in its focus provinces of Bagmati, Lumbini and Gandaki to address this gap. This document presents the results of the baseline study, focusing on three building typologies: residential, day-use office and hotel buildings. The baseline study aims to understand energy usage patterns in the selected typologies across various bio-climatic zones in the selected provinces. This study holds the potential to be instrumental in defining energy consumption patterns specifically in residential, day-use office and hotel buildings, thereby paving the way for further such studies in other provinces and additional building typologies, and subsequently leading to the establishment of effective codes and standards in the future.

The primary objective of the study is to understand building energy consumption patterns, providing crucial insights into energy usage, building technology, construction techniques and materials. Furthermore, it seeks to assess the current status of energy efficiency measures, the adoption of alternative energy sources, and the level of awareness among the population regarding energy efficiency.

The authors welcome comments to help gather better results and understanding of building energy consumption data in Nepal from all readers.

Government of Nepal
Ministry of Federal Affairs & General Administration
Singhdurbar, Kathmandu

Tel 4200505, 4200299, 4200306
Fax No.: 4200322

Your Ref No.:

Our Ref. No.:

Message

Building Energy Efficiency in Nepal (BEEN) Project is a European Union funded project under its SWITCH-Asia Grants Programme. Led by Universität Innsbruck, Austria, a consortium of four national and international partners is implementing this four-year project. The project is engaged in various activities related to energy efficiency across 60 identified municipalities in three different provinces, covering all four bio-climatic regions of Nepal.

This program aids stakeholders, including municipal staff, micro, small and medium entrepreneurs and designers, in enhancing their capacity in design, policy formulation, accessing financial support, and developing marketing strategies. Furthermore, the project raises public awareness, conducts demonstration activities and undertakes various studies on energy efficiency in buildings.

This Baseline report serves as a significant document, providing insights into the actual patterns and practices of energy use at the household level in Nepal. Its broader utilization will undoubtedly raise awareness among stakeholders about energy efficiency, aiding in achieving the government's crucial objective of developing an enabling policy environment to promote Green Building. It will also incorporate energy efficiency (EE) and renewable energy (RE) measures in the design and construction of buildings and contribute to a low-carbon and resource-efficient building sector.

I appreciate and acknowledge the efforts of the BEEN project team in preparing this important document. I am positive this Baseline Report will serve as an important resource document for energy efficient building construction in Nepal.

Mr. Kamal Prasad Bhattarai

Acting Secretary

Ministry of Federal Affairs and General Administration

Date: 23rd February, 2024

EUROPEAN UNION
DELEGATION TO NEPAL

Head of Cooperation

Message

Energy efficiency helps reduce overall energy consumption and is therefore central to achieving the European Union’s climate ambition, while enhancing present and future energy security and affordability in Europe. To ensure that the European Union’s 2030 target of reducing greenhouse gas emissions by at least 55% (compared to 1990) can be met, the European Commission has revised the Energy Efficiency Directive, which came into place first in 2012, together with other energy and climate rules in 2023. It establishes ‘energy efficiency first’ as a fundamental principle of EU energy policy, giving it legal-standing for the first time. In practical terms, this means that energy efficiency must be considered by EU countries in all relevant policy and major investment decisions taken in the energy and non-energy sectors. The revised directive also puts a stronger focus on alleviating energy poverty.

Nepal is one of the fastest urbanising developing economies and a lot of energy is used for heating and cooling, leaving a large carbon footprint in the building sector in Nepal and increasing energy costs for consumers. The BUILDING Energy Efficiency in Nepal (BEEN) Project is funded by the European Union under the SWITCH-Asia Programme and developed the Baseline Study on Operational Energy Consumption in Nepal. This study comes at a timely moment as there is a need to systemically collect and methodically analyse large sets of data in order to document the prevailing building design and construction practices as well as the operational energy consumption scenarios of three building typologies across the four bio-climatic zones of Nepal.

The study will support viable policy instruments to reduce operational energy consumption as well as improving thermal comfort for the inhabitants. Comprehensive details on building design, building energy consumption, energy use patterns, and construction materials used in building envelopes provide insights and a knowledge base to analyse constraints and opportunities.

I would like to thank all the partners of the three tiers of Government, the private sector and home owners and of course the entire team of the BEEN project to support this valuable resource. It can be a key milestone to support Nepal’s transition to a circular economy and achieving the Sustainable Development Goals as well as the Nationally Determined Contributions by decoupling economic growth and environmental degradation, the main essence behind the philosophy of the EU’s SWITCH-Asia programme.

Dr. Marco GEMMER
Head of Cooperation
European Union in Nepal
21 February, 2024

Red. No.: 107/047/048

नेपाली वास्तुविद् समाज
Society of Nepalese Architects (SONA)

Ref No.

Message

The baseline study's findings serve as another achievement in our collective journey toward sustainable and efficient architectural practices. The revelation of a significant use of active devices for space cooling and heating underscores the urgency for architects to embrace energy-efficient measures in building designs.

The shift in construction practices towards modern methods, particularly in temperate and warm temperate zones, aligns with the dynamic nature of our architectural landscape. However, the escalating demand for space cooling in these regions calls for strategic interventions. SONA acknowledges the potential of innovative construction materials, passive cooling systems, and solar energy promotion as crucial in reducing overall energy consumption.

The presented report, intended to lay the foundation for the BEEN Project manual, reflects the commitment ofour architectural community to contribute meaningfully to sustainable development. Nevertheless, further actions are deemed essential. SONA advocates for a simulation-based approach to delve deeper into building typologies, a comprehensive study on the potential of Energy Conservation Measures (ECM), and a meticulous cost-effectiveness analysis for efficient envelope components.

Our organization also endorses the extension of the survey beyond current provinces and municipalities, including the eastern and far western regions, to capture diverse regional perspectives. Additionally, broadening the study to include other energy-intensive buildings like departmental stores and hospitals aligns with SONA's commitment to a holistic understanding of energy efficiency in architectural designs.

In closing, the Society of Nepalese Architects extends its best wishes and support to the researchers and institutions (Urban Park Pvt Ltd, BEEN, MinErgy Nepal) involved in this study. We commend their dedication to advancing knowledge in sustainable architecture and look forward to the continued success and impact of such vital research endeavours.

Member of
SAARCH arcasia uia

Top Floor, Churchil Complex, Baghdurbar, Sundhara, Kathmandu, Nepal
Tel: 977-1-5362252, Fax: 977-1-5362252, E-mail: sona2047@gmail.com
www.sona.org.np

Message

I am thrilled to announce the long-awaited release of the BUILDING Energy Efficiency in Nepal (BEEN) Project Baseline Survey Report. This comprehensive document represents a significant milestone in our ongoing mission to enhance energy efficiency in Nepal's building sector. In the following paragraphs, I'll provide you with a detailed overview of the report's contents and why it's essential for professionals across various domains.

The Baseline Survey Report is the culmination of months of dedicated effort by our team, spanning numerous cities, towns, and villages across Nepal. We meticulously collected data from approximately 1500 buildings, ensuring representation from 60 different local governments encompassing Nepal's diverse bio-climates. We aimed to provide a comprehensive snapshot of the current state of building construction techniques and energy usage patterns across buildings in different bio climates of Nepal.

For professionals working in design, architecture, and engineering, this report is an invaluable resource. It offers a wealth of information on prevailing building construction practices and energy consumption patterns, enabling informed decision-making when planning new projects or renovating existing structures. By examining factors such as materials selection, building envelope design, and energy systems integration, designers can optimize the energy performance of their buildings while minimizing environmental impact. Academics and researchers will find the Baseline Survey Report to be a rich source of data for further exploration and analysis. The report delves into various aspects of building energy efficiency, from the impact of different construction materials to the effectiveness of energy-saving technologies. This data provides a solid foundation for conducting in-depth studies and driving innovation in the field of sustainable building practices. Policymakers, too, stand to benefit significantly from the insights offered by the Baseline Survey Report. By understanding the current landscape of building construction and energy usage, policymakers can develop targeted interventions and policies aimed at promoting energy efficiency. From setting standards for building materials to implementing incentives for energy-saving upgrades, this report provides evidence-based guidance for shaping effective policies that align with Nepal's sustainability goals. Furthermore, the report's findings have broader implications for society as a whole. By promoting energy-efficient building practices, we can reduce greenhouse gas emissions, mitigate climate change impacts, and improve indoor air quality and comfort for building occupants. This not only benefits the environment but also enhances public health and well-being, contributing to overall societal resilience and prosperity. The findings presented in the Baseline Survey Report offer a roadmap for achieving this goal, providing actionable insights that can drive positive change at both the individual and societal levels.

In conclusion, I urge you to explore the insights presented in the Baseline Survey Report and consider how they can inform your work and decision-making processes. Together, let us harness the power of knowledge and innovation to create a more sustainable and resilient future for Nepal's buildings and communities.

Warm regards,

DI Dr. techn. Daniel Neyer
Project Leader (BEEN)

Acknowledgement

This comprehensive baseline study shades light on the current construction practices and operational energy consumption across different building typologies in the four bio-climatic zones of Nepal. We would like to acknowledge the support and contributions in various ways by numerous people and institutions to publish this report, which is the first of its kind in Nepal.

Publication of report, led by the BUILDING Energy Efficiency in Nepal (BEEN) Project, has been possible with the financial assistance of the European Union through SWITCH-Asia Grants Programme. The gratitude is due to Dr Ranjan Prakash Shrestha, Senior Programme Manager of Delegation of the European Union to Nepal for his strategic guidance in crafting this important knowledge product by gearing the study towards relevancy for Government of Nepal and practitioners.

We extend our heartfelt thanks to the Ministry of Federal Affairs and General Administration (MoFAGA), Department of Urban Development and Building Construction (DUDBC). Special recognitions are due for Er Prakirna Tuladhar (DDG, DUDBC), Er Machakaji Maharjan (DDG, DUDBC), Er Manoj Nakarmi (Sr Engineer, DUDBC), Ms Dikshya Thapa (Section Officer, MoFAGA), Prof. Dr Sushil B. Bajracharya (Assistant Dean, Institute of Engineering, Pulchowk) and Ar Pranita Sharma Pandey (Society of Nepalese Architects-SONA) for their strategic guidance to review and refine the study framework.

We extend our heartfelt thanks to the Urban Park Survey Team who have put their dedications to complete the meticulous task of managing the data collection and analysis. Their professional efforts have been instrumental for successful completion of the study.

We also extend our sincerest gratitude to the municipality representatives for their tremendous help. Lastly, we express our deepest appreciation to all the volunteers as well as respondents for their active engagement and cooperation. This study would not have been possible without their involuntary and sincere sharing of information.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

IEA	International Energy Agency
OECD	Organization for Economic Cooperation and Development
LEED	Leadership in Energy and Environmental Design
BREEAM	Building Research Establishment Environmental Assessment Method
NEA	Nepal Electricity Authority
MW	Mega Watts
BEEN	Building Energy Efficiency in Nepal
UIBK	Universität Innsbruck
MSME	Micro, Small and Medium Enterprises
HH	Households
MASL	Meters Above Sea Level
AEPC	Alternative Energy Promotion Centre
EE	Energy Efficient
RE	Renewable Energy
LPG	Liquid Petroleum Gas
MW	Mega Watt
NREP	National Rural Energy Programme
SWERA	Solar & Wind Energy Resource Assessment in Nepal
UNDP	United Nations Development Programme
EPI	Energy Performance Index
MJ	Mega Joule
OE	Operational Energy
LED	Light-emitting diode
RCC	Reinforced Cement Concrete
CGI	Corrugated Galvanized Iron
IOE	Institute of Engineering
DUDBC	Department of Urban Development and Building Construction
MOFAGA	Ministry of Federal Affairs and General Administration
SONA	Society of Nepalese Architects
GESI	Gender Equality and Social Inclusion
WWR	Window-Wall Ratio
kWh	Kilo Watt Hour
SMC	Sub Metropolitan City
NEEB	Nepal Energy Efficient Building Guidelines
RET	Renewable Energy Technology

EXECUTIVE SUMMARY

Over a span of a decade, 1.24 million houses are added to the building stock of Nepal summing up to 6.67 million houses in 2021. In 2022, the residential sector accounted for 60.59% of the national energy consumption. Driven by the rapid urbanization, market demands of space have resulted in buildings being designed without consideration of local bio-climate resulting in compromised thermal comfort and increased energy consumption to compensate for this discomfort throughout the lifespan of building operation. Further, use of building materials with high embodied energy adds up to higher carbon footprint in the building sector. Based on this backdrop, the BUILDING Energy Efficiency in Nepal (BEEN) Project, with the funding support of the European Union under the SWITCH-Asia Grants Programme, has been designed and being implemented in 60 municipalities of three provinces across the four bio-climatic zones of Nepal.

Despite the indicative reporting on the increased energy consumption in buildings, lack of comprehensive and concrete data on current status of operational energy, particularly for space conditioning, has hindered the process to take evidence-based decisions to design strategies responsive to the practitioners' needs as well as to devise feasible policy instruments suitable across the various bioclimatic zones of Nepal. In this context, the BEEN Project administered a baseline study aiming to obtain vivid and precise picture of building construction practices and energy consumption scenarios in residential, hotel/resort and day-use office buildings in four bioclimatic zones of Nepal. The baseline report intends to serve as a base document for development of passive design guidelines, design tools, technical standards and manuals. Representing all four bioclimatic zones, sample respondents from 1220 residential buildings, 121 hotels and 120 day-use office buildings were surveyed in the three target provinces of the BEEN project i.e. Bagmati, Lumbini and Gandaki. For each bioclimatic zone and building typologies, the report provides comprehensive information on i) building characteristics; ii) energy consumption, particularly on energy use, source, end-use device for space heating, cooling and lighting; iii) Energy Performance Index (EPI); iv) use of renewable energy; and v) perception and awareness on energy-efficiency measures. The report presents the key results on these parameters for each of the building typologies.

Key Results of Residential Buildings

Construction technology: Load-bearing construction is predominant (77%) in cold climate, followed by rubble masonry. Temperate and warm temperate climates predominantly have RCC frame constructions (90.8% and 86.6% respectively), followed by a small share of load-bearing construction. Cool temperate also have predominantly RCC frame constructions (58.7%), however with a significant share of load-bearing construction (38%).

Exterior wall: Houses in cold region have thicker walls while it gets reduced at lower altitudes. In cold, stone masonry is predominant whereas solid burnt bricks are key materials for wall construction in other bioclimatic zones.

Roof: Flat roof predominates in all bioclimatic zones, followed by inclined roofs. Over 80% houses have flat roof in cold, temperate and warm temperate zones whereas 67.8% flat roof and 30% inclined roof in cool temperate. In cold, two-layered roof made with mud and wooden planks are most common. RCC slab with cement plaster is predominant in temperate and warm temperate climates, while a mix of RCC with cement plaster and Corrugated Galvanised Iron (CGI) with wooden planks is typical in cool temperate.

Window: In cold climate, 46% houses have a window-to-wall ratio (WWR) between 0-10%. WWR is between 20-30% in most houses in cool temperate (41%), temperate (34%), and warm temperate (32%). Casement windows are predominant in all four bioclimatic zones, followed by sliding windows. Wooden frames with clear glass are the most common glazing and framing assembly across all zones. Continuous overhangs are the predominant type of window shading in all climates. In cold climate, 30.4% houses do not have window shading.

Perception: In all climates except for the cold, most respondents found daylight to be sufficient. In cold, 38% respondents reported insufficient daylight. Similarly, except in cold, most respondents found ventilation to be sufficient in summer. However, 37% respondents in cold climate reported insufficient ventilation. A significant portion (27-43%) reported cold air infiltration during winter with highest respondents (43%) from cold climate.

Fuel types: Almost all houses across all bioclimatic zones use electricity and LPG. Firewood is extensively used (88.7%) in cold climate, moderately (44.7%) in cool temperate, and minimally (7.2%) in warm temperate. Firewood use was not reported in temperate climate. Use of solar energy is highest in temperate climate (13.9%), followed by cool temperate (10.9%) and a small fraction (2.5%) in cold climate. Charcoal use (9.9%) is exclusive in cold climatic zone.

End use of energy: Energy for space cooling is used in warm temperate (99.7%) and temperate climate (92.1%). Water heating is reported in all zones, with 49.2% in cool temperate, the highest among the four climatic zones.

Similarly, space heating is also reported in all climates, with 38.3% houses in the temperate climate, the highest among the zones. In cold climate, only about 28.6% houses use energy for space heating.

Device for end uses: Fireplace and smokeless stoves are predominant for space heating (74%) in cold climate, while radiant heaters are common in cool temperate (72%), temperate (73%), and warm temperate (51%) zones. Fans are predominant cooling devices with 51% of houses using table fans in cool temperate zone, and 80% and 99% using ceiling fans in temperate and warm temperate zones respectively. Improved cookstoves are predominant for water boiling in cold climate, while electric kettles are common in remaining three climatic zones.

Energy consumption: Houses in warm temperate consume the highest electricity (2,228 kWh/y) followed by temperate (1,800 kWh/y), cool temperate (964 kWh/y) and cold (342 kWh/y). Regarding thermal energy consumption, houses in cold climate consume the highest energy (38,795 MJ/y) followed by cool temperate (18,034 MJ/y), warm temperate (8,709 MJ/y) and temperate (8,061 MJ/y).

Annual energy expenses: In cold climate, houses spend 68,359 rupees per year, the highest among the four zones, with 95% expenditure accounting for thermal energy. In warm temperate and temperate climates, houses spend on an average 42,616 and 40,084 rupees per year for energy, and expenses are evenly divided between electric and thermal energy. In cool climate, houses spend 29,058 rupees per year for energy, with about two-third of this expenditure for thermal energy.

Energy performance index (EPI): In warm temperate, the average electrical EPI of houses is 20.4 kWh/m^2.y, highest among four climatic zones. The average EPI decreases progressively from temperate (14 kWh/m^2.y), cool temperate (8 kWh/m^2.y), to cold climate (3.5 kWh/m^2.y). Similarly, the average thermal EPI in cold climate is the highest among four climatic zones at 483 MJ/m^2.y. For other zones, the average thermal EPI decreases from cool temperate (219 MJ/m^2.y), warm temperate (94 MJ/m^2.y), to temperate climate (63 MJ/m^2.y).

Integration of renewable energy technologies: Only 13% of surveyed houses have solar PV and solar water heater systems installed. In the cold region, 22% of buildings have solar PV system, the highest among the four climatic zones, while only 5% of buildings in warm temperate have solar PV installed, the lowest among the zones. The temperate zone has the highest penetration (28%) of solar water heating system, while none of the houses in warm temperate reported use of solar water heater.

Key Results of the Office Buildings

Construction technology: RCC frame construction with masonry infill is the most predominant construction practice for offices in cool (95.7%), temperate (82.9%) and warm temperate (81.6%) climates. While in cold climate, an equal mix of load-bearing and RCC frames (44.4% each) construction prevails.

Exterior wall: The office buildings in cold region have thicker walls while the wall thickness is smaller at lower altitudes. In cold region, stone masonry is predominantly used for wall construction whereas wall with solid burnt bricks is the predominant in other bioclimatic zones.

Roof: RCC slab with cement plaster predominates in all bioclimatic zones. 33 percent office buildings in cold climate, 30% in cool temperate, 27% in temperate and 32% in warm temperate have RCC roof with cement plaster.

Window: 56% buildings in cold climate have window-to-wall ratio (WWR) between 30-40%. In cool temperate, 35% buildings have WWR between 20–30% and another 35% have WWR above 40%. In temperate climate, 49% buildings have WWR above 40% while in warm temperate, 34% buildings have WWR between 30–40%. None of the office buildings in cold climate have WWR above 40 percent while none of the buildings in cool temperate and temperate climates have WWR less than 10 percent. Casement window (78%) is the most predominant window type in cold climate while in cool temperate, share of casement and sliding windows are evenly distributed (48% each). Similarly, in warm temperate 45% buildings have casement and 39% have sliding windows. However, in temperate zones, window types are distributed among various types, casement (39%), glass glazing with few openings (32%), sliding (15%), and structural glazing (12%).

Perception: In all climates except for the temperate, most respondents found daylight to be sufficient. In temperate climate, 51% respondents reported insufficient daylight. Similarly, except in the temperate climate, most respondents found ventilation to be sufficient in summer. In temperate climate, 51% respondents reported insufficient ventilation. A significant portion (21-32%) reported cold air infiltration during winter. The temperate climate has the highest proportion of respondents (32%) reporting air infiltration.

Fuel types: 100% office buildings across all bioclimatic zones use electricity while the use of LPG exceeds 63% across all climatic zones. Firewood usage is limited (17%) to cold climate while solar usage is limited (4%) to cool temperate. Diesel is used in cold (6%), temperate (12%) and warm temperate (11%) climates.

End use of energy: Lighting, cooking, water heating and space heating are used in offices across all bioclimatic zones. While space cooling is limited to cool temperate, temperate and warm temperate. 100% office buildings across all climatic zones use electricity for lighting, while cooking is carried out in above 68% office buildings in all climates. 100% offices use energy for space cooling in temperate and warm temperate zones while only 22% offices use energy for space cooling in cool temperate. Water heating is conducted in 50% of offices in cold climate, 37% in warm temperate, 27% in temperate and 26% in cool climates.

Device for end uses: Radiant heater is predominant device for space heating (87%) in cold climate, while electric conventional heater is common in cool temperate (75%). In temperate, radiant heater (56%) and AC (50%) are predominant devices for space heating and AC (65%) is the most predominant device in warm temperate. For space cooling, split AC (80%) is the most common device in cool temperate.

In temperate climates, split ACs (54%) and ceiling fans (51%) are predominant devices for space cooling. In warm temperate zone, ceiling fans are used in 74% while split ACs are also used in 50% of offices.

Power backup system: Most offices across all bioclimatic zones have power backup system. Inverter are predominant power backup system in cool temperate (67%), temperate (90%) and warm temperate (83%) zones while solar PV system is the main (80%) power backup system in cold region.

Energy consumption: Offices in warm temperate consume the highest electricity (25,691 kWh/y) followed by temperate (11,888 kWh/y), cool temperate (6,471 kWh/y) and cold (3,970 kWh/y). Regarding thermal energy consumption, offices in cold climate consume the highest energy (13,762 MJ/y) followed by temperate (10,900 MJ/y), warm temperate (8,413 MJ/y) and cool temperate (5,844 MJ/y).

Annual energy expenses: In warm climate, offices spend 315,657 rupees per year, the highest among the four climatic zones, with 91% expenditure accounting for electric energy. In temperate and cool temperate, offices spend on an average 171,969 and 93,100 rupees per year for energy, with 80% of that expenditure accounting for electric energy. In cold climate, annual energy expenses amount to 99,274 rupees per year, with approximately 54% of this expenditure for electric energy.

Energy performance index (EPI): In warm temperate, the average electrical EPI is 70 kWh/m^2.y, highest among four climatic zones. The average EPI decreases progressively from temperate (55 kWh/m^2.y), cool temperate (31 kWh/m^2.y), to cold climate (40 kWh/m^2.y). Similarly, the average thermal EPI in cold climate is highest among four climatic zones at 102 MJ/m^2.y. For other zones, the average thermal EPI decreases from temperate (48 MJ/m^2.y), warm temperate (46 MJ/m^2.y), to cool temperate (29 MJ/m^2.y).

Integration of renewable energy technologies: Only 19% offices have solar PV and 5% have solar water heater system installed. In the cold region, 67% office buildings have solar PV system, the highest among the four climatic zones, while only 5% offices in warm temperate have solar PV installed, the lowest among the zones. The cold climate has the highest penetration (22%) of solar water heating system, while none of the offices in warm temperate reported using solar water heater.

Key Results of the Hotels

Hotels are categorized based on their typologies. The survey analyses three main types: i) hotels with minimum tourist standards; ii) resorts; and iii) star hotels. In cold climate, the survey exclusively covered hotels meeting minimum tourist standards, while star hotels were assessed in temperate and warm temperate zones. Likewise, resorts were evaluated in cool temperate and warm temperate zones.

Construction technology: Load-bearing construction is more prevalent in cold climate, while RCC frame with masonry infill predominates other bioclimatic zones. A significant percentage of resorts (over 50%) also feature load-bearing structures, while star hotels exclusively utilize RCC frames. Trends before and after 2001 indicate a transition from load-bearing to RCC frame construction, even in hotels meeting minimum tourist standards and in resorts.

Exterior wall: Hotels in cold region have thicker walls while the wall thickness is smaller at lower altitudes. In cold region, stone masonry is predominantly used for wall construction whereas wall with solid burnt bricks is predominant in other bioclimatic zones.

Roof: Flat roof predominates in all bioclimatic zones, followed by inclined roofs. Over 83% hotels have flat roof in cool temperate, temperate and warm temperate zones whereas in cold climate, 71% hotels have flat roof and 24% have inclined roof. In cold climates, two-layered roofs made with mud and wooden planks are most common. RCC slab with cement plaster is predominant in cool temperate, temperate and warm temperate climates.

Window: Cold and cool temperate climate hotels have comparatively lower WWR as compared to other climates. The predominant WWR range remains 20-30% across cold and cool climates. For the temperate climate, the predominant range for WWR remained 20-40%. For the warm temperate, the WWR varied across different ranges, with 95% hotels having a WWR above 20%. Casement is the most predominant window type across all four bioclimatic zones followed by sliding window. Similarly, wooden framed window with single glass pane is the predominant window glazing and framing assembly across all four climates. Continuous overhang at roof level is the predominant type of shading used across all climates.

Fuel types: 100% of hotel buildings rely on electricity as their primary energy source. Almost all hotels use LPG especially for cooking across all climatic zones. Diesel (above 50%) fuel appears to be the third main source of energy in temperate and warm temperate climates while hotels in cold climate have a wide range of energy sources, including charcoal (24%), diesel (33%), firewood (33%), and petrol (29%).

Device for end uses: Firewood chimney is the predominant device for space heating (80%) in cold climate, while split AC is common in other climatic zones. 42% hotels in cool temperate, 89% in temperate and 94% hotel in warm temperate uses split AC for space heating. Similarly, split AC is the predominant cooling device across cool temperate (42%), temperate (63%) and warm temperate (60%). Ceiling fans are also commonly used in temperate and warm temperate zones. Device for water heating varied across bioclimatic zones. In cold climate, LPG geyser predominate (88%) whereas 100% hotels rely on solar heating in cool temperate zones. Similarly, in temperate climate, heat pump (46%) is the most common, while electric instant geyser (56%) dominates in warm temperate.

Power backup system: Power backup systems are present in over 80% of hotels in cold, temperate, and warm temperate climates, while only 42% of hotels in cool temperate zone have such systems. In warm climate, inverters are predominant (65%) for power backup, whereas in temperate climate, generators (66%) are more common. Similarly, in cool climate, inverters (50%) and solar PV systems (40%) dominate. In cold climate, generators are predominant (59%), followed by solar PV systems (53%).

Energy consumption: Hotels in warm temperate consume the highest electricity (30,446 kWh/y) followed by temperate (26,288 kWh/y), cool temperate (8,907 kWh/y) and cold (3,900 kWh/y). Regarding thermal energy consumption, hotels in warm temperate consume the highest energy (83,556 MJ/y) followed by temperate (80,753 MJ/y), cold (65,622 MJ/y) and cool temperate (36,841 MJ/y).

Annual energy expenses: Hotels in temperate climate spends 561,324 rupees per year, the highest among the four climatic zones, with 58% expenditure accounting for electric energy. Similarly, hotels in warm temperate spends 549,500 rupees per year, with 55% expenditure accounting for electric energy. Hotels in cola and cool temperate spend an average of 262,082 and 188,834 rupees per year for energy, with majority of that expenditure accounting for thermal energy.

Energy performance index (EPI): In warm temperate, the average electrical EPI is 79 kWh/m^2.y, highest among four climatic zones. The average EPI decreases progressively from temperate (39 kWh/m^2.y), cool temperate (27 kWh/m^2.y), to cold climate (8 kWh/m^2.y). Similarly, average thermal EPI in cold climate is the highest among four climatic zones at 264 MJ/m^2.y. For other zones, average thermal EPI decreases from warm temperate (221 MJ/m^2.y), temperate (135 MJ/m^2.y), to cool temperate (129 MJ/m^2.y).

Integration of renewable energy technologies: 15% have solar PV and 36% have solar water heater systems installed. In the cold region, 43% hotels have solar PV system, the highest among the four climatic zones, while only 5% hotels in warm temperate have solar PV installed, the lowest among the zones. The cool climate has the highest penetration (63%) of solar water heating system, while only 3% hotels in warm temperate reported using solar water heater.

INTRODUCTION

1.1 Background

The total energy, which encompasses both the embodied and the operational energy, constitutes a significant portion of global energy consumption. In addition to consuming substantial amount of energy, buildings contribute significantly to carbon dioxide emissions. According to the estimates from the International Energy Agency IEA) in 2023, buildings account for approximately 30% of global final energy consumption and 26% of global energy related emissions[1] (IEA 2023).

Nepal is currently undergoing rapid urbanization, establishing itself as the fastest urbanizing country, with Kathmandu Valley emerging as a thriving metropolitan hub in South Asia[2]. The 2021 census indicates a total of 6.67 million houses in Nepal, with 1.24 million houses added since 2011. This surge in housing demand has resulted in buildings designed without adequate consideration for the local climate, leading to uncomfortable indoor spaces and, subsequently, heightened energy consumption to address this discomfort. The escalating urbanization and evolving lifestyles have contributed to a notable increase in the overall operational energy demand within Nepalese buildings..Furthermore, the utilizationof building materials with high embodied energy content has led to a surge incarbon emissions from the building sector. According to the Energy Sector Synopsis Report 2021/2022, a staggering 70% of Nepal's total energy consumption, is attributed to the residential and commercial building sector. Acknowledging the vital role of building energy efficiency in sustainability, it is crucial to address the challenges posed by rapid urbanization and evolving lifestyles in Nepal. Implementing cost-effective mitigation investments in the buildings sector alone has the potential to achieve approximately 40% of emission reduction[3].

In Nepal, the absence of baseline data on operational and embodied energy consumption coupled with absence of building design codes and guidelines addressing thermal comfort and energy efficiency, has led to suboptimal performance in many new buildings. The buildings often fall short in terms of indoor thermal comfort and energy optimization. Furthermore, there is insufficientawarenessregarding the benefits of integrating energy efficiency (EE) and renewable energy (RE) into building design and construction. This lack of awareness extends to limited knowledge and capacity among micro, small, and medium-sized enterprises (MSMEs) engagedin building design and construction activities.

To address these challenges, the baseline study on operational and embodied energy consumption in Nepal aims to understand energy usage patterns in buildings across various bio-climatic zones and building typologies. This study holds a potential to be instrumental in defining energy consumption patterns specifically in residential, day-use office and hotel buildings, thereby paving the way for the establishment of effective codes and standards. The primary objective of the study is to delve into building energy consumption patterns providing crucial insights into energy usage, , building technology, construction techniques, and materials. Furthermore, it seeks to assess the current status of energy efficiency measures, the adoption of alternative energy sources, and the level of awareness among the population regarding energy efficiency.

1.2 Building Energy Efficiency in Nepal (BEEN)

The BEEN Project is a four-year research initiative (March 2022 – February 2026) funded by the European Union under the SWITCH-Asia Grants Programme. Universität Innsbruck (UIBK), Austria, is jointly implementing this research project with MinErgy Pvt. Ltd. (MinErgy), Nepal; Greentech Knowledge Solutions Pvt. Ltd. (GKSPL), India and Asociación Española de Normalización (UNE), Spain. The overarching objective of BEEN is to contribute to the development of low-carbon and resource-efficient practices in the Nepalese building sector. This will be achieved by integrating energy efficiency (EE) and renewable energy (RE) measures into the design and construction of new buildings, including in retrofitting of existing buildings. BEEN aims to achieve the overall objective through capacitating Building-MSMEs (Micro Small and Medium Enterprises) to adapt or transform their services and products for EE building design, construction and retrofitting. Additionally, the project seeks to increase market awareness of EE design and construction services, products and practices. Furthermore, it aims to enhance availability of financial products and services targeting EE and RE in building and construction

1 Buildings-Energy Systems-IEA (https://www.iea.org/energy-system/buildings)

2 Elisa Muzzini and Gabriela Aparicio. Urban Growth and Spatial Transition in Nepal: An Initial Assessment. Washington, D.C.:World Bank, 2013.http://public.eblib.com/choice/publicfullrecord.aspx?p=1165942_0

3 Ürge-Vorsatz, D., Metz, B. Energy efficiency: how far does it get us in controlling climate change? Energy Efficiency 2, 87–94 (2009). https://doi.org/10.1007/s12053-009-9049-7

sector. Lastly, BEEN intends to empower local, provincial and federal government units to devise and implement policies and /standards that promote EE in building sector.

1.3 Objective

The main objective of this assignment was to obtain clear and precise information on energy consumption scenarios in three distinct building typologies based on their use; Residential, Hotel/Resort, and Day-use office buildings, located in four different bio-climatic zones. The survey findings are presented in form of an analytical baseline report, intended to serve as the base document for the development of passive design guidelines, design tools, technical standards, manuals, and related policy provisions. The surveyed information encompasses comprehensive details on building design, building energy consumption, energy use patterns, and construction materials employed in building envelopes.

Specific Objectives

For each bio-climatic zone

- Identify typical building technologies and building materials in use for construction
- Identify typical energy end uses in buildings for thermal comfort and lighting
- Quantify the energy consumption in the buildings (residential, hotel and day use office buildings) focusing on space heating, cooling and lighting
- For each type of buildings, determine the Energy Performance Index (EPI) based on the bio-climatic regions
- Understand the construction technology and practices for construction of building envelope

1.4 Scope

The scope of work included the following tasks:

- To conduct baseline surveys using standardized methodology to identify energy consumption scenarios in three distinct typologies Residential, Hotels and Day-Use buildings situated in four bio-climate zones, three representative municipalities of each in Bagmati, Lumbini and Gandaki provinces of three different building typologies.
- To determine the appropriate sample size for each building typology
- To co-ordinate and consult with each representative municipality for no objection letter and acquire consensus from building owners for the survey
- To collect survey data in a manner that preserves the research validity, compiles and analyze the data, and prepare a final baseline report.

The data was collected from the following selected municipalities representing four different bio-climatic zones, shown in Table 5.

Table 1: Selected municipalities with respective bio-climatic zones and provinces for the survey

Climatic Zones	Representative Municipalities		
	Bagmati	Lumbini	Gandaki
Warm temperate <500masl	Bharatpur Metropolitan City (HH No.–77,838)	Butwal Sub-Metropolitan City (HH No.–41,012) Nepalgunj Sub-Metropolitan City (HH No. –26,491)	
Temperate 500–1500 masl	Lalitpur Metropolitan City (HH No.–49,044)	Tulsipur Sub-Metropolitan City (HH No.–41,012)	Pokhara Metropolitan City (HH No.–101,669)
Cool temperate 1501–2500 masl	Dhulikhel Municipality (HH No.–7,309) Gosainkunda Rural Municipality (HH No.–2,149)		Annapurna Rural Municipality (HH No.–5811)
Cold >2500masl			Gharapjhhong Rural Municipality (HH No.–921) VaragungMuktichhetra Rural Municipality (HH No.–666) Chame Rural Municipality (HH No.–333)

1.5 Limitation

Consultants have made a diligent effort to collect the comprehensive and accurate information for the baseline data; however the study has some limitations. The following limitations and adopted mitigation strategies are given in Table 6.

Table 2: Limitations and adopted mitigation measures

S.N.	Limitations	Mitigation Measures
1	The survey largely relied upon participants' self-reported data, which may be susceptible to biases. Respondents could under-report or over-report their energy consumption due to various reasons such as social desirability bias, memory recall errors, or a lack of awareness about energy usage.	The survey was conducted directly in the field, engaging with the respondents themselves. The process involved motivating and ensuring that the actual objectives of the survey were clearly communicated and understood by the respondents. Data assurance was carried out directly in the field, engaging with the respondents themselves. The process involved motivating and ensuring that the actual objectives of the survey were clearly communicated and understood by the respondents.
2	The respondents might have difficulties accurately recalling their energy consumption habits or may have different perceptions of what constitutes energy consumption. This can lead to errors or biases in the reported data.	The possibility of errors in the data was addressed by cross-checking with reliable sources. For instance, the bills from the respondents were verified again with NEA data wherever possible.
3	Surveys often rely on self-reported aggregate data, such as monthly or annual energy consumption. This lack of granularity can limit the ability to analyze specific factors, such as daily or hourly energy usage patterns, which can be crucial for understanding peak loads or demand variations	The collected data was cross-referenced wherever possible.

1.6 Using the results of this survey

The survey was done for a limited sample size and the reader must understand the all the results presented in this report are based on the surveyed buildings only. While the sample buildings were selected from all climatic zones and included multiple building typologies, the results need not be representative for the entire climatic zone or building typology.

LITERATURE REVIEW

2.1 Understanding the terminologies

2.1.1 Baseline study

A baseline study is an analysis of the current situation aimed at identifying the starting points for a program or project[4]. It examines the information that must be considered or analyzed to establish a baseline or starting point, serving as the benchmark against which future progress can be assessed or comparisons made.

2.1.2 Energy efficient (EE) buildings

Energy-efficient buildings refer to buildings that are designed or constructed to consume less energy while achieving the same utility as contemporary buildings of similar size, ensuring both thermal and visual comfort. These buildings aim to create a comfortable living space while minimizing energy consumption, there by optimizing resource efficiency. Energy-efficient buildings incorporate a combination of passive and active strategies to achieve their goals.

2.1.3 Renewable energy (RE)

Renewable energy for buildings refers to the energy generated from renewable sources such as solar, wind, hydro, geothermal, and biomass. Renewable energy systems can be integrated during the early design process as part of a new structure, or they could be added as retrofits. In this project, renewable energy measures specifically involve refer to solar for electricity generation, solar-based water heating systems and heating and cooling systems which include solar, biomass, and geothermal energy.

2.1.4 Passive design strategies

Passive design strategies refer to a set of design approaches that prioritize leveraging the natural environment to provide heating, cooling, ventilation, and lighting to a building[5]. These strategies rely on inherent laws of nature. The objective of passive design strategies is to establisha comfortable and energy-efficient indoor environment while minimizing the reliance on mechanical systems and reducing overall energy consumption. By capitalizing on climate, site conditions, and materials these strategies aim to create a building that operates in harmony with the surrounding environment.

2.1.5 Active design strategies

Active design strategies involve the use of purchased energy, which includes electricity and natural gas to maintain the comfort ofbuildings[6]. While passive measures contribute to thermal comfort, there may still be a need for air-conditioning to ensure comfort conditions are sustained throughout the year.

2.1.6 Operational Energy of Building

Operational energy (OE) encompasses the energy required to operate buildings, including space conditioning, cooking, hot water, lighting, and other appliances. It accounts for a significant and relatively longer portion of an infrastructure's service life, constituting 80%–90% of the total energy associated with the structure[7]. Various methods can be employed to reduce operational energy in buildings. These include improving the building envelope, incorporating renewable energy sources, implementing smart control systems, and enhancing occupant behaviour.

Passive design strategies play a crucial role in significantly reducing the operational energy costs of buildings. The incorporation of shading devices, for instance, can effectively lower cooling expenses. Additionally, the careful selection of appropriate materials contributes to reducing operational energy costs. The choice of suitable building materials and technology is a key approach to minimizing the operational energy expenses of a building. In colder regions of Nepal, for example, the use of thick stone wall is a prevalent practice. This building technique provides enhanced insulation, thereby reducing the costs associated with heating and cooling to a significant extent.

4 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Baseline_study
5 https://www.novatr.com/blog/passive-design-strategies-in-architecture
6 https://sustainabilityworkshop.venturewell.org/node/784.html
7 Life Cycle Energy analysis of Buildings: An overview, (Ramesh, Thillai, & K K, 2010)

2.1.7 Energy performance index of building

Energy Performance Index (EPI) is a performance indicator used to assess the energy performance of a building. It is a numerical value that indicates how efficiently a building consumes energy in comparison to its peers. The EPI is calculated by dividing the total energy consumed by the building throughout the year by its total built-up area. The outcome is a score that reflects the building's energy consumption intensity, measured in kilowatt-hours per square meter per year (kWh/sq. m./yr.) for electrical energy consumption. A lower EPI score signifies a more energy-efficient building.

EPI = annual energy consumption in kWh / total built-up area (excluding unconditioned basements)

The EPI can be used to benchmark a building's energy performance against similar buildings and to identify areas where energy efficiency can be improved. Building owners and managers can use the EPI to set energy efficiency targets, track progress towards those targets, and identify cost-effective measures to reduce energy consumption. The EPI is an important performance indicator for promoting sustainable buildings and reducing greenhouse gas emissions, as it encourages building owners and managers to prioritize energy efficiency and reduce their environmental impact.

EPI is further categorized into electrical EPI and Thermal EPI. Electrical EPI represents the annual usage of electrical energy per square meter of the occupant area. Meanwhile, Thermal EPI encompasses the total consumption of other energy sources, such as LPG, firewood, and diesel that require combustion and are used annually per square meter. Data on thermal energy consumption data were collected in terms of quantity and converted into Mega Joule. The Calorific Value (CV) is used to convert fuel consumption into energy. The value signifies the potential energy a fuel contains, which becomes available upon combustion. The CV value adopted for this study was as shown in Table 3:

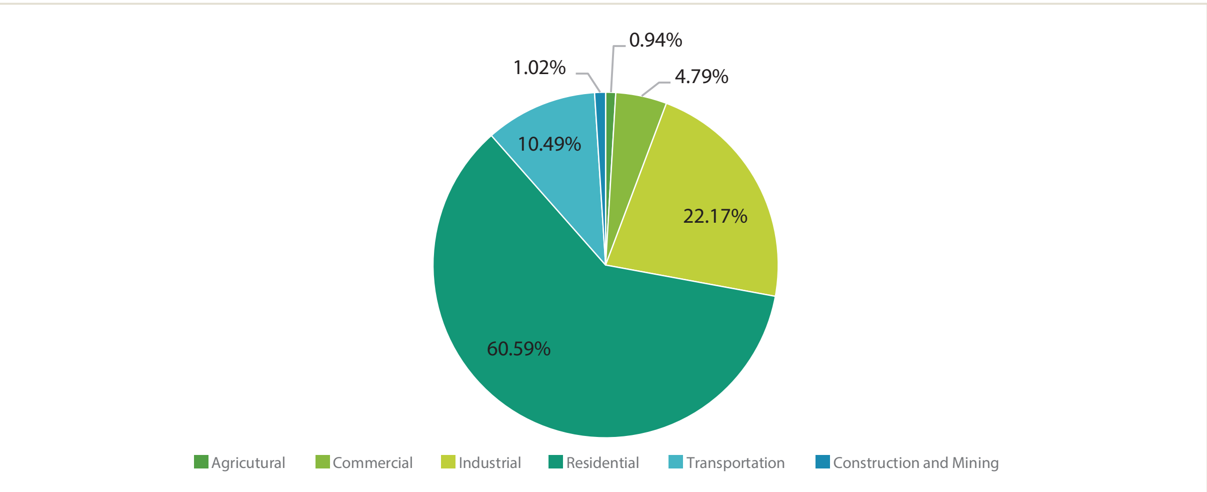
Table 3: CV values for different fuels adopted for this study

Liquefied petroleum gas (LPG)	49.3 MJ/kg
Diesel	38.6 MJ/L
Charcoal	29.6 MJ/KG
Petrol	34.2 MJ/L
Biomass	5 MJ/kg
Wood	16.2 MJ/Kg

2.2 Energy consumption in building sector in Nepal

Buildings in Nepal contribute significantly to the country's total energy consumption, accounting for 60.59%[8] as shown in Figure 2. Nepal's energy intensity is also comparatively high compared to global and Indian averages, indicating both increased energy consumption and lower energy efficiency levels.

Figure 1: Energy Consumption building sector in Nepal



The recent National Population and Housing Census of 2021 disclosed that Nepal's urban population has surged to21.01%, making a substantial increase of 3.9% since the 2011 census. This demographic shift indicates a consistent upward trajectory in energy consumption within buildings. Multiple factors contribute to the escalating demand for energy in this sector, including population growth, the ongoing process of urbanization, the expanding scope of economic activities, and improving living standards. Additionally, significant new additions to building

8 Energy Synopsis Report 2023 FY 2078/79 2023, http://wecs.gov.np/source/EnergySynopsisReport2023.pdf

stock are anticipated in the tourism and hospitality sector. Simultaneously, the rapid construction of public and commercial buildings, classified as high-energy-intensive structures, is underway. Moreover, the surge in energy consumption in buildings is worsened by inadequate thermal construction that fails to consider the climate and comfort needs of building occupants.

The building sector of Nepal primarily relies on biomass, electricity, liquefied petroleum gas (LPG), and kerosene as energy sources. While fuelwood still dominates residential energy consumption at 81.56%, its share has decreased from 87% in 2009, primarily due to the adoption of more efficient technologies[9]. However, the residential sector still faces risk in terms of energy security, with a growing dependence on imported LPG, which has more than doubled in consumption over the past decade. Notably, urban areas exhibit a distinct pattern of higher per capita energy consumption compared to rural areas mainly due to the increased use of electricity and LPG for lighting, cooking, heating, cooling, and other modern appliances.

Compared to the fiscal year 2018-2019, with a peak electricity demand of 1,320 MW, Nepal's total installed generation capacity is a mere 1,182 megawatts (MW). Among this, the Nepal Electricity Authority (NEA) holds 621 MW (contributing to 34% of the total electricity sold), while private investors possess 560 MW (representing 29% of the overall installed capacity). To bridge the gap, approximately 38% of total electricity sales were met through imports from India, reaching a maximum import of approximately 596 MW.[10] The import of fossil fuels such as LPG and kerosene also imposes a heavy burden on the national economy and contributes to greenhouse gas emissions.

The building sector in Nepal is confronted with numerous challenges in meeting the escalating energy demand. These challenges encompass an inadequate supply of electricity, a heavy dependence on imported fossil fuels, limited energy efficiency, and a shortage of renewable energy alternatives. The electricity supply situation in Nepal is characterized by frequent power outages, scheduled electricity rationing, and voltage fluctuations, all adversely affect the quality and reliability of service. Nepal harbours considerable potential for renewable energy sources, particularly in hydropower, solar, and wind energy. Nevertheless, this potential largely remains untapped due to factors such as insufficient investment, lack of infrastructure, and inadequate policy support.

To address these challenges, the government of Nepal has formulated various policies and plans aimed at promoting the development of the energy sector. Notable initiatives include the National Energy Strategy 2017, the Renewable Energy Subsidy Policy 2073, and the National Energy Efficiency Strategy 2075. These policies are designed to achieve several objectives: increase the share of renewable energy in the energy mix, enhance the energy efficiency of buildings and appliances, reduce dependence on imported fossil fuels, and improve the accessibility and affordability of energy services for all. The Renewable Energy Subsidy Policy supports Renewable Energy Technologies (RETs) by providing subsidies to reduce the initial upfront development costs, covering for 40% of initial cost such technologies[11].The National Energy Efficiency Strategy developed in 2018 envisions contributing to energy sustainability by increasing energy access through the efficient use of available resources.

In essence, the path forward required a strategic alignment of policy initiatives, investment efforts, and technological advancements to usher in a sustainable and resilient energy future for Nepal. While the challenges are substantial, the potential rewards in terms of energy security, environmental preservation, and economic growth are equally significant. By advancing with these policy measures and encouraging the widespread adoption of renewable energy and energy-efficient practices, Nepal can pave the way for a brighter and more sustainable energy landscape for both its present and future generations.

2.3 Status of building efficiency in Nepal

The status of building efficiency in Nepal presents a multifaceted scenario influenced by various policy and practical factors. Nepal has taken substantial steps to prioritize the protection and utilization of natural resources, including renewable energy, as mentioned in the Constitution of 2015. A range of policies and strategies has been formulated to align with this commitment. For example, the Rural Energy Policy of 2006 focuses on reducing dependence on traditional energy sources and promoting clean and affordable energy in rural areas. The National Energy Efficiency Strategy of 2018 aims to enhance energy access through efficient energy use and double the improvement rate of energy efficiency by 2030. Additional initiatives, such as the Biomass Energy Strategy (2017) and the National Climate Change Policy (2019), actively promote renewable energy and climate resilience.

Moreover, Nepal's commitment to addressing climate change challenges is underscored by its adoption of the Long-Term Strategy for Net Zero Emissions (2021) and the National Adaptation Plan (2021). These policies are

9 Energy Synopsis Report 2023 FY 2078/79 2023, http://wecs.gov.np/source/EnergySynopsisReport2023.pdf
10 An Analysis of Hydro-energy Deficit in Nepal
11 Renewable Energy Subsidy Policy, 2073

reinforced by the Fifteenth Periodic Plan and the Second Nationally Determined Contribution, both of which establish targets for renewable energy adoption and emission reduction. In 2022, the introduction of the RE Subsidy Policy and the National Renewable Energy Framework further emphasizes the country's commitment to expanding access to clean and affordable renewable energy while mobilizing financial resources and coordinating initiatives.

Nepal has pledged its commitment to the Paris Agreement, aiming to reduce its carbon footprint and mitigate the impacts of climate change. Although its Nationally Determined Contribution (NDC) outlines goals related to renewable energy use, air pollution reduction, forest coverage expansion, and climate change adaptation, it does not specifically address energy efficiency, particularly building energy efficiency. As a result, there are no specified targets within the NDC regarding the enhancement of building energy efficiency.

Energy codes and standards, which play a crucial role in enhancing building energy performance, are notably absent in Nepal. Unlike many other countries, Nepal does lacks specific guidelines, building codes, or regulations related to energy-efficient building design, whether for new construction or retrofitting existing structures. For instance, countries like India have established the Energy Conservation Building Code (ECBC) 2017, setting minimum energy performance standards for buildings. In Pakistan, the Energy Conservation Building Code was revised in 2023, encompassing various aspects of energy efficiency in buildings, including building envelope optimization, passive design, insulation, retrofitting, energy analysis monitoring, renewable energy, and energy management systems. Furthermore, internationally recognized green building certifications such as LEED and BREEAM are increasingly being embraced as standards for energy-efficient construction practices.

In Nepal scientific studies related to energy-efficient building designs are relatively recent within the context of modern architecture. Existing studies have primarily focused on household energy usage patterns and have not thoroughly explored the impact of building design on energy consumption in buildings. Nevertheless, it is important to note that the use of passive energy-efficient techniques has historical roots in various vernacular and traditional Nepalese architecture.

Despite these efforts, there remains a notable lack of awareness and publicity regarding the positive role energy efficiency plays in ensuring sustainable, adequate, and reliable energy supply in Nepal. Energy efficiency has yet to be fully integrated into the broader energy system, and awareness and capacity among Micro, Small, and Medium-sized Enterprises (MSMEs) in the building sector regarding energy-efficient practices and services are limited. While structural stability has understandably been a focal point in building design due to the seismic risks in Nepal, considerations of climate responsiveness and energy efficiency have not been widely incorporated into new building designs.

Efforts to address these gaps have recently been initiated, with the Society of Nepalese Architects (SONA) releasing a preliminary document, the Nepal Energy Efficient Building Guidelines (NEEB). This document aims to provide guidelines for energy-efficient practices in public buildings, demonstrating a positive step towards enhancing energy efficiency in the building sector.

In summary, Nepal has shown commitment to renewable energy and climate resilience, but building energy efficiency, including the implementation of energy codes and standards, remains an area that requires significant attention and development. The integration of energy-efficient building practices into modern architecture is still emerging, and there is a clear need for increased awareness, capacity building, and the establishment of specific guidelines and standards to promote energy efficiency in the building sector.

2.4 Potential of building energy efficiency in Nepal

The potential for building efficiency in Nepal is substantial and presents a promising avenue for addressing increasing energy demand and sustainability.

Nepal currently lacks specific codes and regulations related to building energy efficiency. This presents a significant opportunity for the country to develop its own guidelines and standards based on the experiences of neighbouring and global nations. By doing so, Nepal can effectively address the issue of carbon emissions and promote more sustainable and energy-efficient construction practices. This proactive approach can contribute to the reduction of greenhouse gas emissions and the overall improvement of environmental sustainability in Nepal's built environment.

Nepal's unique geographical features, particularly its high-altitude terrain with south-facing slopes, create a remarkable opportunity for harnessing solar energy and passive solar design. The country enjoys an average solar radiation level ranging from 3.6 to 6.2 kWh/m^2/day, and benefits from around 300 days of sunshine annually. These conditions make the development of solar energy technology promising in various regions of Nepal. According to reports from the Alternative Energy Promotion Centre (AEPC), the commercial potential for solar power grid connection is estimated at a substantial 2,100 MW. This showcases Nepal's significant potential for a range of solar energy technologies, including grid-connected photovoltaic (PV) systems, solar water heaters, solar lanterns, and solar home systems.

Additionally, the south-facing slopes offer a valuable advantage for orienting buildings, particularly in temperate and cold climates. Proper orientation can help reduce the energy demand for space heating, as it optimizes the utilization of sunlight for warmth. This aligns with Nepal's climatic conditions and further contributes to the efficient use of solar energy for both residential and commercial purposes.

Furthermore, research and studies have demonstrated that building efficiency can be significantly enhanced through simple alterations in construction materials and techniques. These changes can lead to a substantial reduction in energy consumption, up to 28.34%, while still maintaining a pleasing architectural aesthetic. Similar research on hotel buildings below 1000 meters in altitude has shown that modifying window placement can notably reduce energy usage in air conditioning. Interventions such as window-to-wall ratio (WWR) adjustments, roof thickness enhancements, and ground floor insulation can further contribute to building efficiency.

The traditional design of Nepalese buildings, developed over centuries, maximizes natural elements such as sunlight and wind. Locally available materials are utilized to create optimal indoor comfort. These passive techniques, well-suited to their specific climatic context, have proven highly effective without requiring energy-intensive active systems. Research on vernacular buildings in Nepal indicates significant energy efficiency, with optimization of design features resulting in average energy savings of 37%. Furthermore, increasing insulation in the building envelope can yield energy savings ranging from 26% to 50%, depending on the climate zone.

It is important to recognize that energy consumption closely correlated with comfort and socio-economic conditions. As lifestyles advance, the demand for comfort through active devices for space heating and cooling rises, consequently escalating energy consumption. To improve energy efficiency, one can explore alternative solutions that maintain the same comfort levels but with lower energy usage. Interventions in building construction techniques, promotion of alternative energy sources, enhancements to existing structures, and environmental interventions all contribute to achieve desired comfort levels in buildings while minimizing energy consumption.

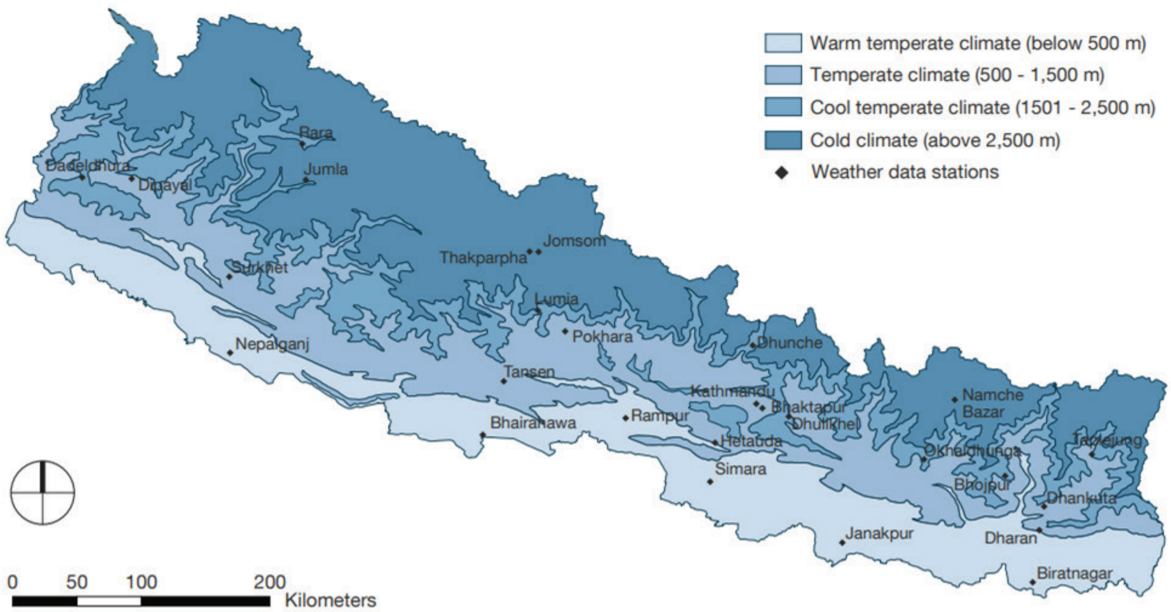
In conclusion, Nepal has abundant opportunities for enhancing building efficiency through the implementation of codes and regulations, the utilization of solar and wind energy, and improvements in building design and construction techniques. Embracing these possibilities can result in a notable reduction in energy consumption, fostering a more sustainable approach to meeting the country's energy needs. It is imperative to further explore and implement these strategies to achieve energy efficiency while ensuring the comfort and well-being of the people of Nepal.

INTRODUCTION TO BASELINE SURVEY

3.1 Nepal and its bio-climatic zone

The climatic zones in Nepal (Figure 2), as utilized this study, are divided into four zones based on elevation. These zones exhibit variations in climatic factors such as temperature, relative humidity and precipitation.

Figure 2: Map of Nepal showing different bio-climatic zones



3.1.1 Warm temperate zone (<500 masl):

The warm temperate zone in Nepal refers to the low-lying areas with an altitude below 500 meters above sea level (masl). This zone, also known as the Terai region, experiences relatively higher temperatures throughout the year with an average annual temperature ranging from 22-35°C in summer to 9-26°C in winter[12]. The warm temperate zone receives abundant rainfall, particularly during the monsoon season (June to September). Traditional settlements in this zone include Tharu Houses in Chitwan and Rana Tharu houses in the Far west, constructed predominantly with local materials like timber and thatch. In the eastern parts of Nepal, houses in the warm temperate zone commonly use timber and bricks as typical construction materials. In some areas houses are elevated from ground level to mitigate the threat of flooding.

3.1.2 Temperate Zone (500 – 1500 masl):

The temperate zone in Nepal includes the mid-hills region, with altitude from 500 to 1500 masl. This zone under goes a moderate climate featuring distinct seasons. Summers are generally mild, while winters can be cold. The average annual temperature in the temperate zone varies from 18-35°C in summer and 5-25°C[13] in winter, depending on the altitude. This zone exhibits a predominantly dense settlement pattern. Vernacular houses in this area commonly use stone and bricks as the primary construction materials.

3.1.3 Cool Temperate Zone (1501 – 2500 masl):

The Cool Temperate Zone in Nepal is situated at higher altitudes, ranging from 1501 to 2500 masl. This zone experiences cooler temperatures compared to the temperate zone, with mild summers are and relatively cold winters. The average annual temperature in the cool temperate zone varies from 14-26°C in summer and -2-20°C[14] in winter, depending on the altitude. Traditional houses in this climate zone feature a more elongated form compared to those in colder alpine climates. Row houses are predominant, mainly because they create a more elongated building volume. When possible, the longer facade is oriented toward the sun to enhance solar gains.

12 Design Guidelines for energy-efficient hotels in Nepal, Bodachm Lang and Auer, 2016
13 Design Guidelines for energy-efficient hotels in Nepal, Bodachm Lang and Auer, 2016
14 Design Guidelines for energy-efficient hotels in Nepal, Bodachm Lang and Auer, 2016

3.1.4 Cold Zone (>2500 masl):

The Cold Zone in Nepal encompasses the high-altitude regions, including alpine meadows and barren landscapes of the Himalayas. This zone faces extremely cold and harsh conditions due to its elevation exceeding 2500 masl. The average annual temperature in the Cold Zone ranges 7-22°C in summer and -10-2°C [15]in winter, depending on the altitude and season, with precipitation mainly occurring in the form of snowfall. Compact building volumes with rectangular building shapes dominate the architectural landscape in Nepal's Alpine climate region. Many houses in places like Manang and Mustang have an almost square ground floor plan. This compact building form effectively reduces the surface-to-volume ratio and, consequently, minimizes heat losses in this cold climate. Houses are strategically situated on the southern slope of hills or flat valleys to maximize solar heat gains. Stone and mud are predominantly used as building construction materials in these regions.

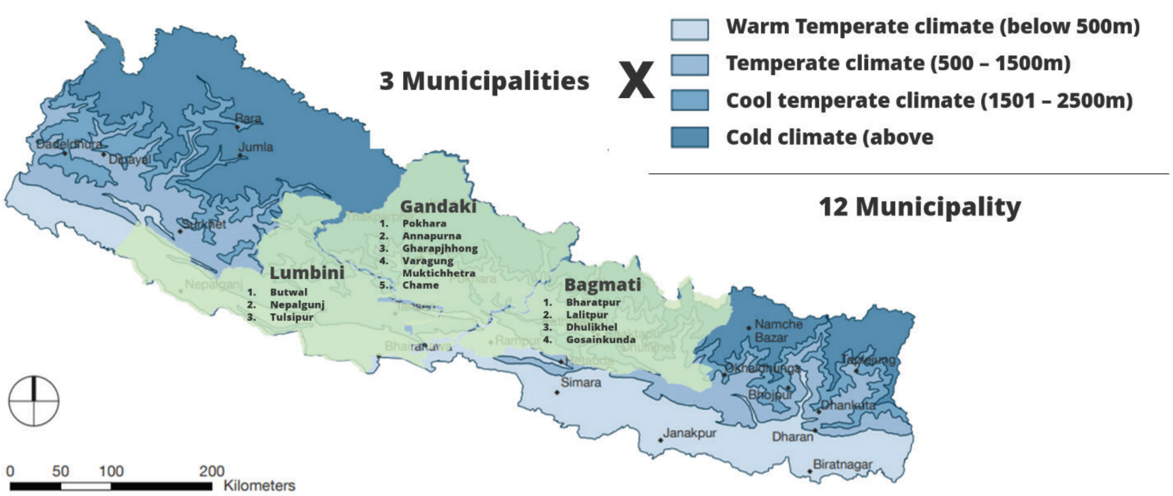
Table 4: Bio-climatic zones of Nepal: A summary

Bio-Climate Zone	Elevation Range (masl)	Average Annual Temperature (°C)	Typical Construction Material	Dominant House Form
Warm Temperate Zone	<500	Summer: 22-35 / Winter: 9-26	Timber, Hatch, Bricks	Varied
Temperate Zone	500 -1500	Summer: 18-35 / Winter: 5-25	Stone, Brick	Dense
Cool Temperate Zone	1501 -2500	Summer: 14-26 / Winter: -2-20	Stone	Row Houses
Cold Zone	>2500	Summer: 7-22 / Winter: -10-2	Stone, Mud	Compact

3.2 Selected provinces and municipalities

The study was carried out in 12 representative municipalities from the provinces, of Bagmati, Gandaki and Lumbini representing four distinct bio-climatic zones (refer Figure 4). Three municipalities were selected from each bio-climatic zone for survey. The socio-economic data for the respective municipalities were studied based on the census data from 2021.

Figure 3: List of local governments that were surveyed



3.2.1 Bagmati Province

3.2.1.1 Bharatpur Metropolitan City

Number of households in Bharatpur Metropolitan city was 96,591 in 2021 With a total population of the 369,268. According to the 2021 census, the average household size was found to be 3.82 people per household. In terms of housing construction, cement-bonded brick stone houses were the predominant ones, accounting for construction of 50.8% houses followed by RCC houses with pillars at 40.1%. For walls, cement-bonded brick or stone walls were the dominant assembly in over 92% of houses. CGI sheets were used in 49.7% of houses and RCC slabs48.3% as the predominant roof assembly in the municipality.

15 Design Guidelines for energy-efficient hotels in Nepal, Bodachm Lang and Auer, 2016

As for the water source, tap/piped water was the primary source for 52.1% of house holds followed by 30.7% with tube well connections. LPG was reported as the predominant cooking fuel for 88.0% households.

Figure 4: House at Bharatpur metropolitan city (Source: Urban Park)

3.2.1.2 Lalitpur Metropolitan City

The Census 2021 data for Lalitpur Metropolitan City reveals a total population of 294,098 individuals. The city exhibits a slight gender imbalance, with females comprising 50.1% and males accounting for 49.9% of the population. The city consists of 77,159 households. In terms of housing construction practices, RCC brick/stone is the most prevalent construction material at 50.9%, followed by cement-bonded brick/stone, which is the dominant wall type at 52.2%, while mud-bonded brick/stone accounts for 37.5%. The most common roof type is RCC slab at 83.6%. For drinking water sources, tap/piped water within the compound is the primary source at 45.1% followed by jarwater at 32.9% LPG is the primary fuel used for cooking by 93.6% of households. In terms of toilet facilities, flush toilets with public sewerage are the most common at 61.5%, followed by flush toilets with septic tank at 31%.A very small percentage, 0.1% of households have no toilet facilities.

Figure 5: Surveyed house at Lalitpur (Source: Urban Park)

3.2.1.3 Dhulikhel Municipality

Based on the census2021 data, Dhulikhel Municipality has a total population of 33,726 individuals, with a slight gender imbalance, comprising of48.8% males and 51.2% females. The municipality consists of 8,570 households. In terms of housing construction practices, 29.0% of houses are built with cement-bonded brick/stone, while 25.9% use mud-bonded brick/stone, and 41.3% employ RCC frames. Cement-bonded brick/stone is the dominant wall type at 69.6%, while mud-bonded brick/stone accounts for 25.9%. The most common roof types are RCC slab at 61.9% and CGI at 36.9%. Tap/piped water within the compound is the primary source of drinking water at 61.4%, and 22.0% rely on tap/piped water outside the compound. LPG is the most widely used fuel for cooking at

75.9%, followed by wood at 22.5%. Regarding toilet facilities, 73.1% of households have flush toilets with septic tanks, 30.1% have flush toilets with public sewerage, and 1.3% lack toilet facilities.

Figure 6: Traditional house surveyed at Dhulikhel municipality (Source: Urban Park)

3.2.1.4 Gosainkunda Rural Municipality

The Census 2021 data reveals that Gosaikunda Rural Municipality has a total population of 7,788 individuals, with a relatively balanced gender distribution of 49% males and 51% females. The municipality comprises 2,038 households. In terms of housing construction practices, 35.5% of houses use cement-bonded brick/stone, 26% utilize mud-bonded brick/stone, and 24.5% employ RCC frames. The predominant wall type is cement-bonded brick/stone at 56.4%, followed by mud-bonded brick/stone at 18.8% and wooden plank at 12.8%. Roofs are mainly made of CGI (corrugated galvanized iron) at 63.5%, with RCC slabs accounting for 33.3%. For drinking water sources, tap/piped water within the compound is the primary source at 53%, followed by tap/piped water outside the compound at 34.3%, and spout water at 9.6%. LPG is the most used fuel for cooking at 59.4%, while 39.9% of households still rely on wood. Regarding toilet facilities, 38.4% have flush toilets with septic tanks, 58% utilize pit toilets, and 1.3% of households have no toilet facilities. These insights from the census data can inform decision-making processes for infrastructure development, resource allocation, and service provision to improve the living standards and meet the needs of the residents in Gosaikunda Rural Municipality.

Figure 7: Surveyed house at Gosaikunda municipality (Source: Urban Park)

3.2.2 Lumbini Province

3.2.2.1 Butwal Sub-Metropolitan City

According to the 2021 census data, Butwal Sub-Metropolitan City has a total population of 194,335 individuals, with a slightly higher percentage of females at 51.2% compared to males at 48.8%. The sub-metropolitan city consists of 50,565 households. In terms of construction practices, 34.3% of houses use cement-bonded brick/stone, while RCC frames are employed in 60.4% of constructions. The predominant wall type in Butwal sub-metropolitan city is cement-bonded brick/stone, accounting for 95.6%. For roofing, RCC slabs are prevalent in 77.8% of houses, while CGI roofs are present in 21.2% of constructions. The primary source of drinking water within the sub-metropolitan city is tap/piped water within the compound: serving 86.9% of the population, while 8.6% rely on tap/piped water outside the compound. In terms of cooking fuel, LPG is widely used at 94.2%, whereas only 5.2% of households still rely on wood. Regarding toilet facilities, 82.6% of households have flush toilets with septic tanks, 14.7% utilize pit toilets, and 0.2% lack proper toilet facilities.

Figure 8: Surveyed house in Butwal (Source: Urban Park)

3.2.2.2 Nepalgunj Sub-Metropolitan City

The census 2021 data reveals that Nepalgunj Sub-metropolitan City has a total population of 164,444 individuals, with a slightly higher percentage of males at 50.3% compared to females at 49.7%. The sub-metropolitan city consists of 34,565 households, with an average household size of 4.76. In terms of construction practices, cement-bonded brick/stone is the most commonly used material, accounting for 48.9% of houses, followed by RCC frames at 28.2%, and mud-bonded brick/stone at 21%. The predominant wall type is cement-bonded brick/stone, observed in 78.5% of houses, while mud-bonded brick/stone is used in 18.9% of constructions. For roofing, RCC slabs are prevalent in 75.3% of houses, while CGI roofs are present in 19.3% of constructions.

In terms of the source of drinking water, 35.0% of the population relies on tap/piped water within the compound, while tube wells provide water for 32.1% of residents, and 19.0% rely on jar water. For cooking fuel, LPG is widely used, accounting for 77.8% of households, while 20.8% still rely on wood. In terms of toilet facilities, 67.5% of households have flush toilets with septic tanks, 19.7% utilize pit toilets, and a staggering 8.9% lack proper toilet facilities.

Figure 9: Surveyed house at Nepalgunj (Source: Urban Park)

3.2.2.3 Tulsipur Sub-Metropolitan City

According to the census 2021 data, Tulsipur Sub-Metropolitan City has a total population of 179,755 individuals, with a higher percentage of females at 52.8% compared to males at 47.2%. The sub-metropolitan city consists of 46,018 households, with an average household size of 3.91.

In terms of construction practices, mud-bonded brick/stone is the most commonly used material, accounting for 50.7% of houses, followed by cement-bonded brick/stone at 25.5%, and RCC frames at 23.6%. The predominant wall type in Tulsipursub-metropolitan city is cement-bonded brick/stone, observed in 49.6% of houses, while mud-bonded brick/stone is used in 47.2% of constructions. For roofing, RCC slabs are prevalent in 41.1% of houses, while CGI roofs are present in 55.8% of constructions.

Regarding the source of drinking water, the majority of the population, at 74.8%,relies on tap/piped water within the compound while covered wells supply water to 19.8% of residents. For cooking fuel, wood is still used by a significant portion of households at 44.8%, but LPG is also widely used, accounting for 51.8% of households. In terms of toilet facilities, 74.3% of households have flush toilets with septic tanks, 20.4% utilize pit toilets, and a small percentage of 1.1% lack proper toilet facilities.

Figure 10: House surveyed at Tulsipurrural municipality (Source: Urban Park)

3.2.3 Gandaki Province

3.2.3.1 Pokhara Metropolitan City

According to the census 2021 data, Pokhara Metropolitan City has a total population of 513,504 individuals, with a slightly higher percentage of females at 51.8% compared to males at 48.2%. The metropolitan city comprises of 140,459 households, with an average household size of 3.66.

In terms of construction practices, cement-bonded brick/stone is the most commonly used material, accounting for 45.7% of houses, followed by RCC frames at 44.2%, and mud-bonded brick/stone at 9.7%. The predominant wall type in Pokhara Metropolitan City is cement-bonded brick/stone, observed in 90.6% of houses, while mud-bonded brick/stone is used in 8.5% of constructions. For roofing, RCC slabs are prevalent in 62.8% of houses, while CGI roofs are present in 35.8% of constructions.

Regarding the source of drinking water, the majority of the population, at 65.2%, relies on tap/piped water within the compound, while tap/piped water outside the compound is available to 14.7% of residents. For cooking fuel, LPG is widely used, accounting for 90.8% of households, while wood is used by only 8.5% of households. In terms of toilet facilities, the majority of households, accounting for 90.6%, have flush toilets with septic tanks. A small percentage of 7.7% utilize pit toilets, while a minimal percentage of 0.2% lacks proper toilet facilities.

Figure 11: House surveyed at Pokhara SMC (Source: Urban Park)

3.2.3.2 Annapurna Rural Municipality

Census 2021 data reveals that Annapurna Rural Municipality has a total population of 22,099 individuals, with a slightly higher percentage of females at 51.6% compared to males at 48.4%. The rural municipality consists of 6,049 households, with an average household size of 3.65.

In terms of construction practices, mud-bonded brick/stone is the most used material, accounting for 66.7% of houses, followed by cement-bonded brick/stone at 17.4%, and RCC frames at 14.6%. The predominant wall type in Annapurna rural municipality is mud-bonded brick/stone, observed in 62.5% of houses, while cement-bonded brick/stone is used in 33.1% of constructions. For roofing, CGI roofs are prevalent in 56.8% of houses, stone roofing is observed in 23.7% of constructions, and RCC slabs are present in 18.9% of houses.

Regarding the source of drinking water, tap/piped water within the compound serves the majority of the population at 76.2%, while tap/piped water outside the compound is available to 18.0% of residents. For cooking fuel, wood is widely used, accounting for 68.9% of households, while LPG is utilized by 30.7% of households. In terms of toilet facilities, the majority of households, accounting for 86.9%, have flush toilets with septic tanks. A small percentage of 7.8% utilize pit toilets, while 1.2% of households lack proper toilet facilities.

Figure 12: Surveyed house at Annapurna rural municipality (Source: Urban Park)

3.2.3.3 Gharapjhhong Rural Municipality

According to the Census 2021 data, Gharapjhong Rural Municipality has a total population of 3,712 individuals, with a slightly higher percentage of males at 52.3% compared to females at 47.7%. The rural municipality consists of 1,127 households, with an average household size of 3.29.

In terms of construction practices, mud-bonded brick/stone is the predominant choice, accounting for 82.3% of houses, followed by cement-bonded brick/stone at 13.2%, and RCC frames at 4.4%. The wall type in Gharapjhong Rural Municipality is predominantly mud-bonded brick/stone, observed in 78.8% of houses, while cement-bonded brick/stone is used in 21.1% of constructions.

For roofing, the majority of houses, 70.5%, have mud roofs, while CGI roofs are present in 15.0% of houses, and RCC slabs are observed in 13.5% of constructions.

Regarding the source of drinking water, tap/piped water within the compound serves the majority of the population at 82.0%, while tap/piped water outside the compound is available to 16.6% of residents. For cooking fuel, the majority of households, accounting for 87.2%, use LPG, while 12.4% still rely on wood. In terms of toilet facilities, the majority of households, 94.3%, have flush toilets with septic tanks. A small percentage, (2.8%), utilizes pit toilets, while 0.4% of households lack proper toilet facilities.

Figure 13: Surveyed House at Gharapjhhong (Source: Urban Park)

3.2.3.4 Varagung Muktichhetra Rural Municipality

Based on the Census 2021 data, Varagung rural municipality has a total population of 2,036 individuals, with a nearly equal gender distribution of 49.9% males and 50.1% females. The rural municipality comprises of 723 households, with an average household size of 2.82.

In terms of construction practices, mud-bonded brick/stone is the most common choice, accounting for 86.3% of houses, followed by cement-bonded brick/stone at 11.1%, and RCC frames at 2.2%. The prevalent wall type in Varagung Rural municipality is predominantly mud-bonded brick/stone, observed in 85.9% of houses, while cement-bonded brick/stone is used in 13.1% of constructions. For roofing, the majority of houses, 82.2%, have mud roofs, while CGI (roofs are present in 4.1% of houses, and RCC slabs are observed in 11.1% of constructions.

Regarding the source of drinking water, tap/piped water within the compound serves 50.2% of the population, while tap/piped water outside the compound is available to 41.8% of residents. Additionally, 7.1% of the population relies on spouts for their drinking water. For cooking fuel, the majority of households (67.6%), use LPG (liquefied petroleum gas), while 32.2% still rely on wood. In terms of toilet facilities, the majority of households, (87.1%) have flush toilets with septic tanks. A small percentage, (6.1%) utilize pit toilets, while 5.4% of households lack proper toilet facilities.

Figure 14: Surveyed house at Varahung Muktichhetra (Source: Urban Park)

3.2.3.5 Chame Rural Municipality

The Census 2021 data reveals that Chame Rural Municipality has a total population of 1,276 individuals, with a higher percentage of males at 57.2% compared to females at 42.8%. The rural municipality consists of 389 households, with an average household size of 3.28.

In terms of construction practices, mud-bonded brick/stone is the most common choice, accounting for 64.0% of houses, followed by wooden pillars at 22.9%, and cement-bonded brick/stone at 12.1%. The prevalent wall types in Chame rural municipality are mud-bonded brick/stone at 49.1%, wooden plank at 37.8%, and cement-bonded brick/stone at 12.6%. For roofing, CGI roofs are the primary choice, observed in 87.9% of houses, while RCC slabs are present in 4.9% of constructions. Regarding the source of drinking water, tap/piped water within the compound serves the majority of the population at 65.3%, while tap/piped water outside the compound is available to 34.4% of residents.

For cooking fuel, the majority of households (71%) use wood, while 29.0% utilize LPG. In terms of toilet facilities, the majority of households, (88.9%) have flush toilets with septic tanks, while a small percentage of 1.3% lack proper toilet facilities.

Figure 15: Surveyed house at Chame (Source: Urban Park)

3.3 Selected Building Types

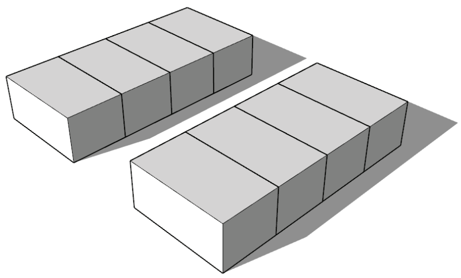
3.3.1 Residential Buildings

Residential buildings typically include various rooms and amenities essential for daily living, such as bedrooms, bathrooms, living rooms, kitchens, and dining areas. The layout and configuration of residential buildings can vary depending on cultural norms, regional preferences, and local building regulations.

3.3.1.1 Typologies and its definition

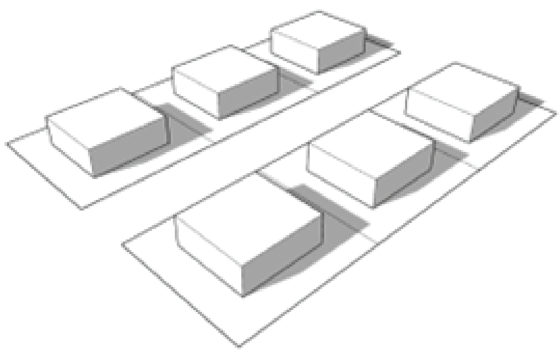
Row housing: Row housing (refer Figure 16) is a series of dwellings connected by two common sidewalls forming a continuous group. Generally, row houses have setbacks on two sides. Its sub-divisions include: single family homes, multi-family residences and multi-functional buildings.

Figure 16: Row housing typology



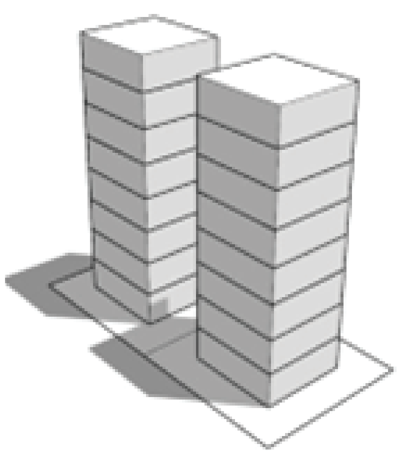
Independent housing: An independent dwelling (refer Figure 17) typically features set backs on all four or at least three sides. Its sub-divisions include single-family homes, multi-family residences and multi-functional buildings.

Figure 17: Independent housing typology



Apartment: Apartment buildings (refer Figure 18) are buildings with more than three independent families, and each unit holder must possess their ownership certificate.

Figure 18: Apartment model of group housing



Group housing: Group housing refers to a designated area with a compound or boundary that includes two or more buildings used for residential purposes. These buildings typically share similar design, form, and floor distribution, along with collective areas and facilities.

3.3.2 Day use office buildings

A day use building refers to a facility or structure designed and intended for temporary occupancy during the daytime, typically for specific activities or purposes. Unlike residential buildings or overnight accommodations, day use buildings are not intended for overnight stays. These buildings are typically utilized for various purposes such as offices, educational institutions, recreational facilities, shopping centers, community centers, or healthcare facilities.

3.3.2.1 Typologies and its definition

Individual office building: An individual office building is a standalone building designated to be used by a single tenant (refer Figure 19) or owner-occupied, or it may be multi-tenant occupied (refer Figure 20), typically on a floor-wise or partial floor basis.

Figure 19: Single-use office buildings

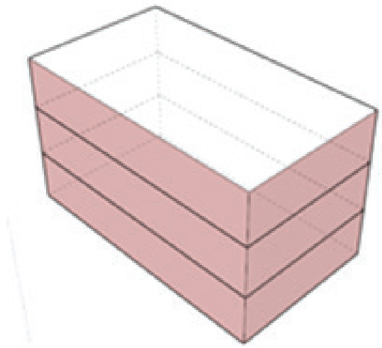
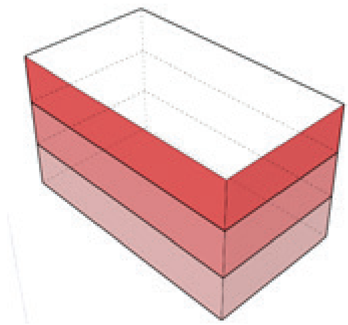


Figure 20: Multi-use office buildings



Mixed use building with office space: A single building with both office space (which may encompass entire floors or partial floor space (refer Figure 22 and Figure 23) and other building typologies, such as commercial space like departments stores, shops etc.is classified as mixed-use buildings. It is to be noted that these types of buildings should not have any residential spaces.

Figure 21: Single-tenant owner occupied office

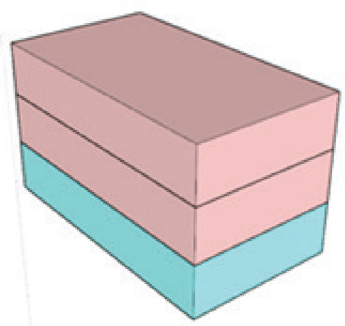
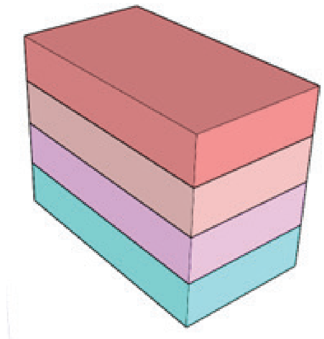


Figure 22: Multi-tenant office buildings



Further classification of office buildings according to time schedule includes:

Day-use office building: The building is occupied for one shift (e.g., 9:00 am to 5:00 pm) or 1.5 shifts (e.g., from 8:00 am to 8:00 pm).

24-hours-use office building: The building is occupied for three shifts (e.g., throughout the full day in three different shift)

For this survey, the office spaces which have built up area more than 1500 sq. ft are only considered for surveying.

3.3.3 Hotel buildings

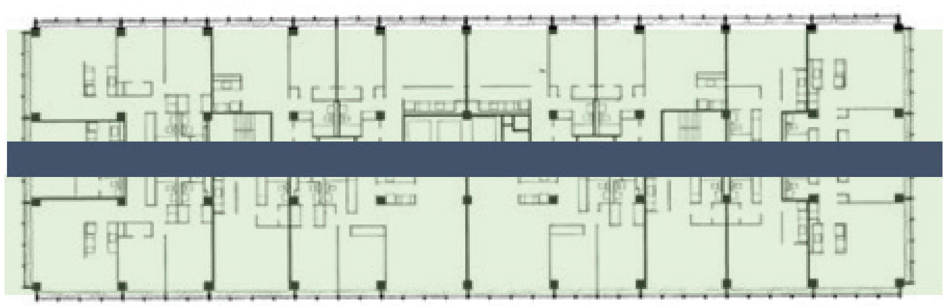
Hotel buildings are structures specifically designed and constructed to provide accommodation and hospitality services to guests. These buildings are dedicated to offering temporary lodging for travellers, tourists, or visitors. Hotel buildings typically feature multiple floors and consist of various rooms or suites that are furnished and equipped with amenities for guest comfort, including beds, bathrooms, seating areas, and often entertainment facilities such as televisions.

3.3.3.1 Typologies and its definition

Single loaded: In single-loaded typology of a hotel building, guest rooms are arranged linearly along one side of an elongated corridor (refer Figure 23).

Figure 23: Single-loaded hotel buildings

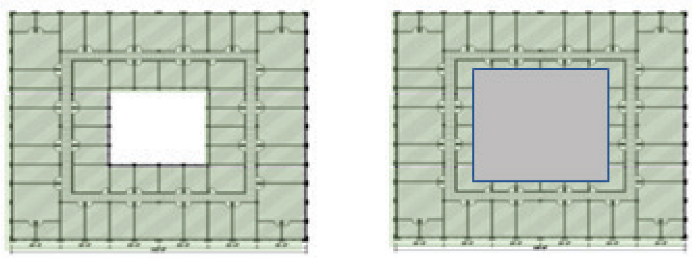
Figure 24: Double-loaded hotel building



Double-loaded: In the double-loaded typology of a hotel building, guest rooms are arranged linearly on both side of an elongated corridor (refer Figure 24).

Courtyard: The closed courtyard type (refer Figure 25), the building has a square layout with an interior open courtyard, while in the atrium typology the courtyard is covered by a roof.

Figure 25: Courtyard type hotel building



Hotel Buildings are further cauterized based on the level of services they provide into three different categories as:

- Star hotels
- Minimum tourist standard hotels
- Resorts

3.4 Need of the study

While previous study has focused on energy consumption, it has not provided comprehensive data on aspects such as construction techniques and bio-climate. Given the pioneering nature of this project, which addresses these gaps, its necessity becomes evident. In the previous reports, such as the Nepal Energy Sector Synopsis Report -2022, clarity is lacking in the identification of clusters and the count of data sampling and processing. Energy consumption in the commercial sector is subdivided into various categories, including hotels and offices, but specific details about each type of building are not available.

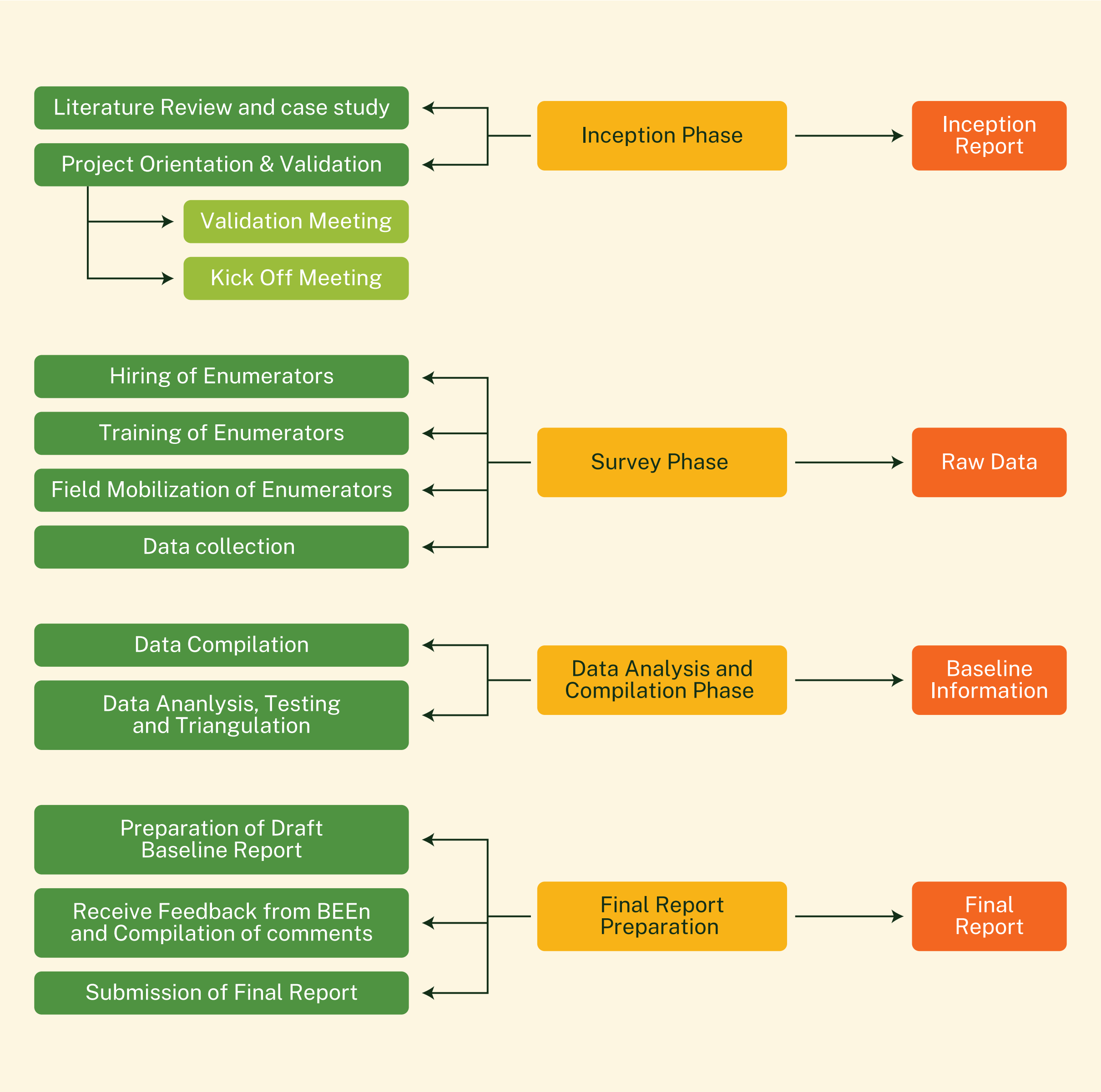
Surveys specifically focusing on energy consumption of residential, office and hotel buildings based on bio-climatic zones are not available. Calculations of consumption lack parameters such as the type of device and the duration of usage, which have not been covered in this report. In this project, buildings are sampled with retrofitting, and efficiency measures for EPI calculations.

By considering bio climatic zones and municipalities, the survey captures the influence of geographical and regional factors on energy consumption patterns and energy efficiency. Examining the use of different energy sources and devices provides insights into the diverse energy consumption practices and their environmental implications. Incorporating the number of occupants allows for a more accurate assessment of energy needs and demand, while assessing the annual cost for energy consumption highlights the economic impact of energy use. Finally, calculating the EPI provides a standardized measure to evaluate the energy performance of buildings, enabling meaningful comparisons and the identification of areas for improvement. Collectively, these additional variables broaden the scope of analysis, enhance the accuracy of results, and provide a more comprehensive understanding of energy consumption and efficiency, making the survey more competent and valuable in addressing energy-related challenges.

METHODOLOGY

4.1 Survey methodology

Figure 26: Methodology adopted in this study



4.1.1 Phase 1- Inception phase

The first phase commencedimmediately after the contract signing, initiating a comprehensive desk study that involved a through review of various literature onenergy consumption scenarios and, studies from different countries on energy efficiency in buildings. Similarly, socio economic data forrespective municipalities and the municipal profile of available municipalities were studied to establish baseline data. A preliminary study was carried out based on Census 2021 data.

Existing information on building typology and energy usage scenarios was gathered from various sources, including data on building structure, materials and foundations. Additionally, both energy usage and sources of energy were thoroughly examined. The client-provided questionnaire underwent a detailed study, followed by an introductory meeting with client. Subsequently, the questionnaires were validated through a workshop jointly organized with BEEN at DUDBC (refer Figure 27), attended by various experts and officials from government and IOE. The inception report derived from the kick off meeting with an adjusted project timeline and revised methodologies, was ultimately submitted. This report was prepared after finalizing the questionnaire, sample sizes and reject dates in collaboration with the client.

Figure 27: Validation workshop at DUDBC

4.1.2 Phase 2- Survey phase

During the inception phase, surveyors were recruited in accordance with the project's requirements and the specified sample size. In total, 40 surveyors, architectural students from various colleges were employed for the purpose of data collection from 12 representative municipalities as proposed in the project. To ensure a gender-balanced team for the data collection process, both male and female surveyors were hired.

The training program (refer Figure 28) organized by BEEN, was attended by enumerators, survey supervisors, the project coordinator, statistician and team leader from the consultant. During the training, experts from the client side provided briefings on survey ethics, issues related to GESI, questionnaire administration, and the use of Kobo Toolbox. Following the training, a pilot survey was conducted on three buildings; one multi-family residence in Chakupat, a high rise-building in Bakhundol and an office building in Pulchowk.

Figure 28: Training program for enumerators

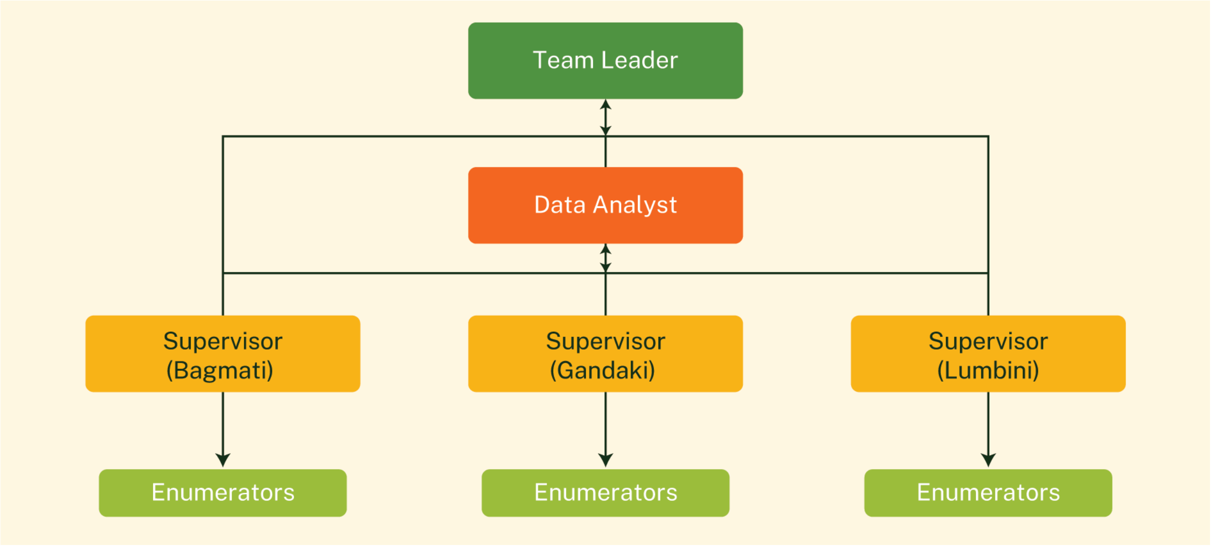
After training, a team of six to eight enumerators was deployed in selected local government units based on the sample sizes determined for each municipality. Survey supervisors also visited municipalities within their respective provinces. Before field mobilization, cluster identification for each municipality was conducted to ensure comprehensive data collection. Enumerators were instructed to gather data representing the trending construction technology in their respective localities (further explained in chapter 4.2). Municipal staff were informed about the project and briefed onits objectives. In coordination with the client,the consultant identified possible clusters in each municipality to gather survey information. In some municipalities, where in-person contact with municipal officers was not possible, communication was established through telecommunication.

In addition to the survey data, we gathered information such as socio-economic data, GPS coordinates, and photographs using Kobo Tool for data collection. Enumerators, equipped with tablets, collected data and had access to internet connectivity through 3G/4G networks, enabling immediate data uploads. The survey supervisor inspected the data collected by enumerators, providing guidance during the process.

To ensure data accuracy, supervisors and experts conducted thorough checks for irregularities. If issues were identified, enumerators were tasked with verifying or retaking the data. Following the supervisor's review, the data was then passed on to the team's data analyst, who further scrutinized it for any anomalies. After meticulous examinationby the analyst, the refined dataset was delivered to the client for their use and analysis.

Figure 29 shows data collection mechanism for the survey.

Figure 29: Data collection mechanism for the survey



The process of data sampling is further explained in chapter 4.2 and 4.3.

4.1.3 Phase -3 Data compilation and analysis phase

Various methods were employed for analyzing and testing the data. The identified clusters were provided to enumerators to collect un-biased data. Data triangulation was used, which involvingthe use ofmultiple methods or sources to cross-validate findings, was implemented to ensure the reliability and validity of the results. Collected data were regularly checked and validated by supervisors. In case of any discrepancies the data were cross validated with standard energy usage and rates. Data quality and processing arefurther explained in chapter 4.6.1 and 4.6.2.

The collected data werecleaned to obtain the necessary variables required for the analysis. In some cases, coded terms were changed, and data wereconsolidated. The cleaned data werethen analyzed in Microsoft Excel. An online meeting was held with the BEEN team to finalize the desired results from the analysis. As a large amount of data was collected in the survey, the meeting focused on determining the necessary analyses for the final report. After the meeting, table of contents for the report was also finalized. Data Analysis is further explained in chapter 4.6.3.

4.1.4 Phase -4 Final report preparation phase

After completing the process of data analysis and data cleaning, the draft report was prepared and submitted to BEEN. The report preparation involved organizing and presenting the findings in a clear and concise manner, using tables, graphs, and other visual aids to illustrate the key points. It also included a discussion of the implications of the findings, as well as any limitations or potential sources of bias that may have affected the results. The report was presented in a graphical format for easier use and understanding. The feedback and comments from the BEEN team were incorporated into the report and the final version along with the cleaned data, was submitted.

4.2 Sampling size

Sample sizes for different typologies were calculated using software while maintaining a 95% confidence interval and 5% margin of error per geographical region. The sample size for various municipalities was then predetermined based on the population ratio of each municipality to the total population in the geographic region, specifically for residential buildings. However, regarding the number of hotels and offices, the general availability of such services was taken into account. For instance, despite a higher sample size in Annapurna or Gharapjhong Municipality, the number of hotels and offices surveyed was higher in Pokhara or Lalitpur, reflecting the greater availability of such establishments in those areas. The distribution of the sample size is presented in Table 9. Total number of surveyed residential buildings was 1220, while that of hotels and day-use offices was 121 and 120 respectively. The formula to calculate sample size is provided below:[16]

16 https://www.surveymonkey.com/mp/sample-size-calculator/

Sample Size Calculation Formula

$$\text{Sample size} = \frac{\dfrac{z^2 \times p\,(1-p)}{e^2}}{1 + \left(\dfrac{z^2 \times p\,(1-p)}{e^2 N}\right)}$$

N = population size

e = Margin of error (percentage in decimal form)

z = z-score

For confidence level 95%, z= 1.96

Table 5: Sample size distribution for each local government

Name of Municipality	Sample Size	Residential Building	Hotel	Day use Offices
Bharatpur Metropolitan City	207	167	21	19
Butwal Sub-Metropolitan City	106	87	9	10
Nepalgunj Sub-Metropolitan City	70	51	10	9
Lalitpur Metropolitan City	98	77	10	11
Tulsipur Sub-Metropolitan City	85	68	7	10
Pokhara Metropolitan City	204	158	19	20
Dhulikhel Municipality	180	156	13	11
Gosainkunda Rural Municipality	53	43	5	5
Annapurna Rural Municipality	143	130	6	7
Gharapjhhong Rural Municipality	154	142	7	5
Varagunj Muktichhetra Rural Municipality	113	97	8	8
Chame Rural Municipality	55	44	6	5

4.3 Cluster identification

Clusters for different municipalities and rural municipalities were identified based on typologies, economic strata, and settlement density (refer Table 6). Each municipality had three distinct clusters: commercial area, urban residential area, and rural residential area, determined using satellite images. In rural residential clusters, settlement patterns exhibited sprawl characteristics, while urban areas displayed denser settlements. In cold eco-climatic regions, clusters were identified based on the sparse distribution of settlements across different wards according to land suitability. The consultant covered all the required typologies in the clusters as per survey requirements. The number of samples for different clusters was identified with the total sample size divided, not the typologies. Enumerators and the survey supervisors identified different typologies within the clusters. It was clarified that the commercial clusters in each municipality would cater to hotels and office typologies, while residential data were distributed in urban residential and rural residential zones.

Table 6: Identification of clusters in each municipality

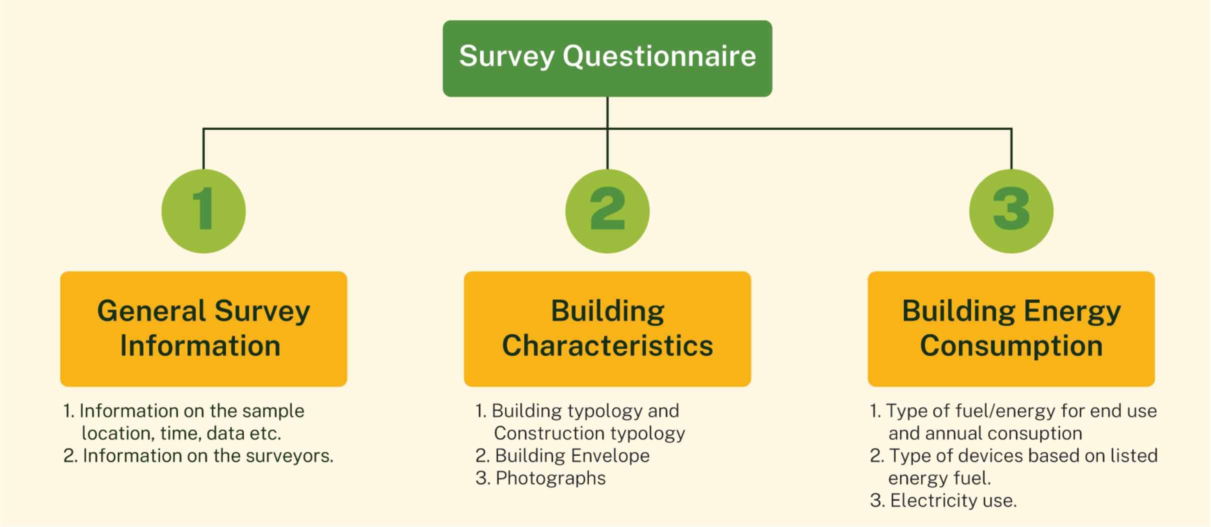
Municipality	Sample Size	Cluster 1	Cluster 2	Cluster 3
Bharatpur	207	Ward 1,2,3,10	Ward 5,6,7,8	Ward 16,17,19
Butwal	106	Ward 11,9	Ward 2,13	Ward 17,19,14
Nepalgunj	70	Ward 2,11,12(Bageshwari cluster)	Ward 1,18 (Airport cluster)	Ward 14,15,16
Lalitpur	98	Ward 12,16,19 (Patan cluster)	Ward 3,4 (Jhamsikhel, Jawlakhel)	Ward 14,15 (Satdobato)
Tulsipur	85	Ward 5	Ward 6	Ward 9
Pokhara	204	Ward 6,7,8	Ward 17,15	Ward 10,12
Dhulikhel	180	Ward4/5	Ward 6/7	Ward 9
Gosaikunda	53	Ward 6 Dhunche	Ward 5 Syaphrubesi	Ward 5 ThuloSyaphru
Annapurna	143	Ward 1	Ward 2/3	Ward 6
Gharapjhhong	154	Ward 2 Marpha	Ward 3 Syang	Ward 4/5 Jomsom
Varagunj Muktichhetra	113	Ward1	Ward3	Ward4
Chame	55	Ward1	Ward2 ,3	Ward4

4.4 Questionnaire

The BEEN team prepared three sets of questionnaires for three distinct building typologies. A team of experts from BEEN developed and validated these questionnaires with inputs from experts and consultants. The questionnaire was structures into three sections (refer Figure 30). The first section covered general survey information, encompassing details such as surveyor information, building location and type, and information about the interviewee.

The second section of the questionnaire primarily focused on the construction technology of the building. It began by identifying the basic typology of the building along with its year of construction. Subsequent questions delved into details such as the total built space and the area of the built space. Information regarding the building's construction method, envelope, outer wall assembly, roof construction, and window construction was also gathered in this section. Additionally, data on the wall-to-window ratio was collected. Lastly, interviewers captured two photographs of the building.

Figure 30: Survey questionnaire breakdown



The third section of the questionnaire focused on aspects related to energy consumption. It involved gathering information about the source of energy, with specific attention to various uses such as space heating, space cooling, water heating, lighting, and cooling. The questionnaire then detailed the devices utilized for these purposes. Following the identification of different sources, data was collected regarding the cost of energy use, measured in terms of monthly electricity consumption. This information aided in understanding seasonal energy consumption patterns. Cost-related details were also obtained from other sources by inquiring about the monthly or seasonal usage of alternative fuels.

The final segment of the questionnaire concentrated on renewable energy sources, retrofitting measures, and the respondent's willingness to transition to passive energy sources.

4.5 Cross validation of data

The final dataset underwent rigorous cross-validation to ensure the utmost reliability of the research findings. This validation process involveda comprehensive review of existing literature and case studies, aligning the new data with established knowledge in the field. Furthermore, data triangulation was employed to provide additional layers of confidence in the results. For each key finding, extensive comparisons were made with existing datasets, encompassing not only prior research from scholars and students but also specific references to prior investigations conducted at the Institute of Energy Efficiency (IOE) and the Master of Science in Energy Efficient Building. These comparisons helped contextualize the findings within the broader academic landscape. The consultant also cross-checked the census data to verify the distribution of constructed buildings in municipalities. For instance, many mud houses were recorded in Manang and Mustang Districts, snd these findings were subsequently verified by census data.

In addition, the rates associated with the research, such as electricity rates, were cross-referenced with the standards set by the Nepal Electricity Authority (NEA). This ensured that the rates used in the analysis were up-to-date and consistent with official data. The consultant took a proactive approach to verify the data, going beyond the conventional methods. For instance, when discrepancies in biomass energy consumption data inButwal, the consultant initiated direct contact with the participants to gain further insights and clarify any ambiguities. This hands-on approach ensured that the findings were as accurate as possible.

Furthermore, when dealing with the physical characteristics of the building, such asits area and layout, maps and drawings were compared to the collected data. For certain hotel buildings, the consultant even crosschecked the area usingGoogle Earth Imagery to add an extra layer of data validity. This step not only enhanced the precision of the analysis but alsoconfirmed that the data accurately represented the real-world context.

In summary, the research process incorporated a comprehensive approach to data validation involving cross-referencing with census data, prior research, official rates, and direct communication with participants, all of which collectively strengthened the integrity of the research findings.

4.6 Data quality, processing, and analysis

4.6.1 Data quality

Data quality was ensured throughout thesurvey, questionnaire preparation, data collection and analysis stages. Team leaders hecked and verified the surveys in the field, contributing to the overall quality assurance process and increasing the validity of the study. The establishment of a proper database, alongwith the time evidence of data and data triangulation, further strengthened the validity of the study.

The following outlines the Consultant's approach to the project. Drawing on its extensive experience in providing consultancy services for similar projects, and the Consultant's general approach is based on:

- Development of close working relationship with the selected municipalities
- Supervision of all works by team leader
- Ensuring the completionof work within the allocated time
- Maintaining all necessary records, books, diaries and other site and project documentation, including all correspondence, test records and accounts
- Undertaking inspections and measurements of the works as necessary to confirm claims.

4.6.2 Data processing

The raw data of the survey was downloaded from Kobo in XML format. Subsequently, the XML data underwent processingusingExcel. Relevant elements were identified, and a filter was created to extract the required information. The extracted data was saved in a separate fileand further cleaned by the consultant in Excel.

Inconsistencies, missing values, and formatting issues were addressed using Excel's built-in data cleaning functions. Outliers, errors, and discrepancies were reviewed and corrected to ensure data accuracy. Finally, the data was properly formatted with appropriate data types.

Verification of entries wascarried out. The cleaned data underwent further verification, for local rates of electricity and firewood were confirmed. Columns containing rate information were identified, and validation criteria were defined. Excel's functions and formulas were utilized to compare the rates against reference rates and highlight any discrepancies. Manual review and adjustments were made to ensure accurate rates.

In case of discrepancies further confirmation with users was conducted. For example, when the energy consumption cost was lower than usual rates, the consultant rechecked the data with enumerators and in some cases the survey participants themselves. Similarly, in instances where the area mentioned in the survey was smaller than shown in uploaded floor plans, cross checking was also performed.

4.6.3 Data analysis

The analytical framework for data analysis was formulated with consideration of the project documents and project result matrix. Data analysis, for the baseline was planned to align with the project requirements. After completing data collection and cleaning, the final data sets were further cross tabulated and analyzed. Quantitative data collected in the survey underwent analysis using Excel. Using Excel's analytical packages, he collected data facilitated descriptive as well as multivariate causal analysis on key quantitative indicators.

Quantitative data

Simple statistical tools such as mean, range, and percentage were employed to analyze quantitative data. Graphics including diagrams and photographs were used whenever appropriate to enhance information presentation in the report. Results were analyzed and presented through trend analysis, graphs, and charts, utilizing descriptive statistics based on the nature of data. Through out the data analysis process, team members focused on evidence generation.

The data analysis included the following aspects:

(a) Climatic zones analysis –Survey outcomes were disaggregated based on the four climatic zones mentioned above to understand differential baseline status among different climatic regions.

(b) Energy consumption analysis –Comparative analysis of energy consumption in three types of buildings was conducted, namely, Day-use office buildings, hotels and residential buildings.

4.7 Key outputs from data analysis

The data analysis from the survey produces various outputs, and the extensive data collected can serve as a valuable resource for numerous studies. Nevertheless, for the purpose of this project, the following outputs are discussed:

- Building Distribution: Investigates how the surveyed buildings are distributed in different climatic zones and municipalities.
- Building Characteristics: Explores characteristics such as the area of the building, construction techniques, wall thickness, roof thickness, window types and shading strategies. These findings will be used to correlate against energy use age and EPI in further analyses.
- Annual Energy Consumption: Examines the different sources of energy used in different types of buildings in context of the survey. Provide information regarding the annual consumption of different types of energy sources and cost expenditures.
- End Uses: Refers to different activities for which energy is utilized, including space heating, space cooling, lighting, provides a better insights into major areas of energy consumptionand suggests how cost-effective technologies can minimize operational costs in different sectors.
- Types of Devices: Investigates the devices used for different end uses. The Use of devices can be correlated with energy consumption, and the identification of high energy consuming devices can guide policy-making for replacements.
- Energy Performance Index (EPI): Measure of the annual cost of energy used per square meters of the building area. Correlates EPI with different building characteristics to understand efficient construction techniques in terms of energy consumption..

- Use of Solar PV: Provide a better insight into the increasing trend of using solar energy as an energy source. By comparing this data with previous data, predictions about the future use of solar energy in Nepal can be made, guiding policy formulation.
- Use of Solar Water Heating: Offers insight into how renewable energy, specifically solar energy, is being used for water heating.
- Awareness about energy awareness: Measures how informed respondents are about incorporating energy-efficient measures in buildings. The report also studies the incorporation of energy awareness measures.

The data comprises over 100 variables, offering the opportunity for cross-tabulation and correlated among them. An example of a crucial dataset is the EPI, which can be cross-tabulated with various housing typologies, construction technologies, bio-climatic zones or even based on the built-up area. Similarly, variables like wall thickness or roof thickness can be cross evaluated with the need for space cooling or heating. The comprehensive nature of the data, with disintegrated information, allows the study team to extract data as per the specific needs and objectives of the study.

4.8 GESI integration in survey

Since the research is based on the survey method, it was crucial to hear all the voices and include everyone in the process. Without integrating every voice the study could be biased, considering the considerable divide of energy sources and consumption with respect to gender, caste, ethnicity, and economic disparities. The Consultant adopted the following strategies to integrate GESI in the survey:

Inclusive team formation: The consultant established an inclusive team of experts for the project, and in a later stage, enumerators were also recruited from a diverse pool, including members from GESI community. The team's composition reflects the diversity of the communities the survey is intended to serve. The consultant ensured a supportive and collaborative work environment, fostering the safety and participation of individuals from different backgrounds, castes, ethnicities, and genders at various stages of the project.

Prioritization in data collection: The consultant prioritized women-led businesses, women-led households, and members from marginalized groups when collecting data for the survey. Prioritizing diverse groups essential to understand different perspectives on energy consumption.

Open ended discussions: The consultant also conducted open-ended discussions to comprehend the scenario of energy access, and availability among marginalized groups and communities. While quantitative questions facilitated data collection, open-ended interviews enhanced the understanding of the biases in the energy scenario within different groups in the context of Nepal.

4.9 Sustainable approaches in the survey

The study on energy consumption in the building construction sector aims to find sustainable solutions. Therefore, it was equally important to conduct the survey in a sustainable manner whenever possible.

The consultant designed the survey to be sustainable using the following methods:

Use of electronic devices for the survey: To minimize the use of paper and reduce the environmental impact of the survey, the consultant opted for electronic devices such as tablets or laptops to conduct the survey. This involved setting up the survey on an electronic platform and training enumerators on how to use the devices for administering the survey.

Safe disposal of any waste: Any electronic waste or other forms of waste generated during the survey were safely disposed of in accordance with local regulations and best practices. Recyclable materials were separated and recycled as much as possible.

Conduct in-depth study: To gather in-depth information about energy consumption scenarios, the consultant conducted interviews and focus group discussions with relevant stakeholders. This involved developing a list of questions to ask, scheduling and conducting the interviews or focus groups, and analyzing the data gathered.

Protect the environment: The consultant took measures to ensure that any study activity did not harm environmental resources, such as trees or water sources.

Use of public transport: To reduce the environmental impact of transportation, the consultant used public transport as much as possible instead of private vehicles. This involved planning the travel routes to take advantage of available public transport options and coordinating with relevant parties to arrange transportation.

SURVEY RESULTS AND ANALYSIS: RESIDENTIAL BUILDINGS

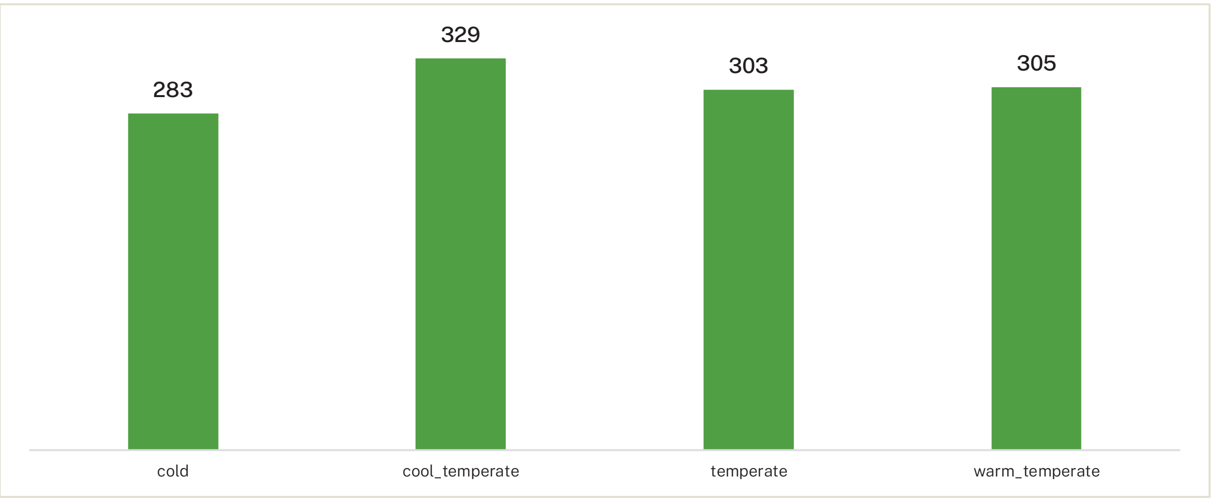
A total of 1220 residential buildings are surveyed. They are further classified in terms of bio-climatic zone, building typology, year of construction, etc. The outputs of the survey are presented in terms of different charts and tables in two sections: building characteristics and energy consumption.

Section I: Building Characteristics

5.1 Surveyed household distribution among bio-climatic zones and building typologies

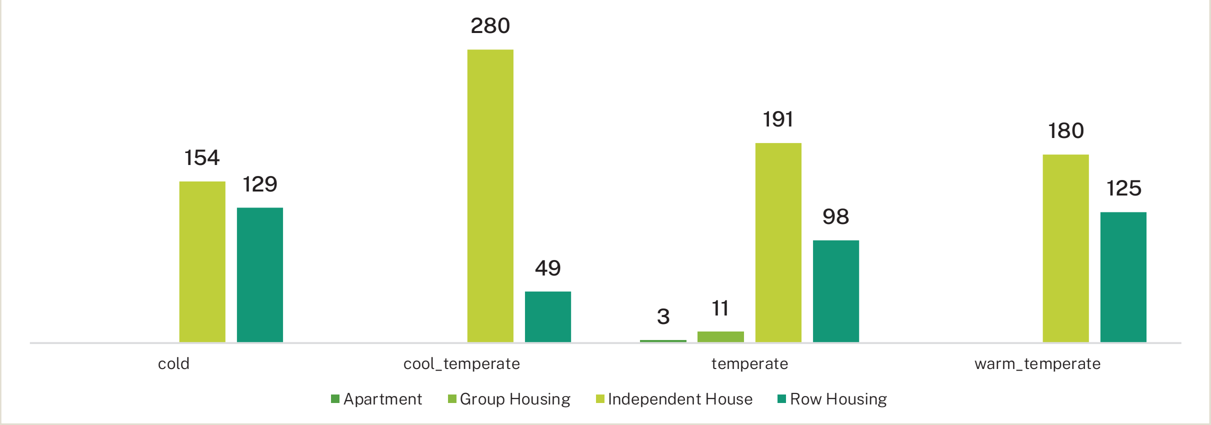
Figure 31 shows the distribution of a total of 1220 surveyed households among the bio-climatic zones, i.e., Cold, Cool temperate, Temperate, and Warm temperate. The survey was designed to have a uniform distribution of samples in each bio-climatic zone for comprehensive data collection. It varied between a minimum of 23% for cold and 27% for the cool temperate bio-climatic zone.

Figure 31: Distribution of surveyed households as per bio-climatic zone



The surveyed houses were divided into four typologies-row housing, independent housing, group housing, and apartment. Figure 32 shows the distribution of a total of surveyed households based on building typology for each bio-climatic zone. Among surveyed households, 'independent house' was the predominant typology with an overall share of 66%, while 'row housing' was 33% of the total sample. Considering the availability and difficulties in getting permission for apartment and group housing, only limited samples were surveyed.

Figure 32: Distribution of households as per building typology for each bio-climatic zone



5.2 Year of construction of surveyed households

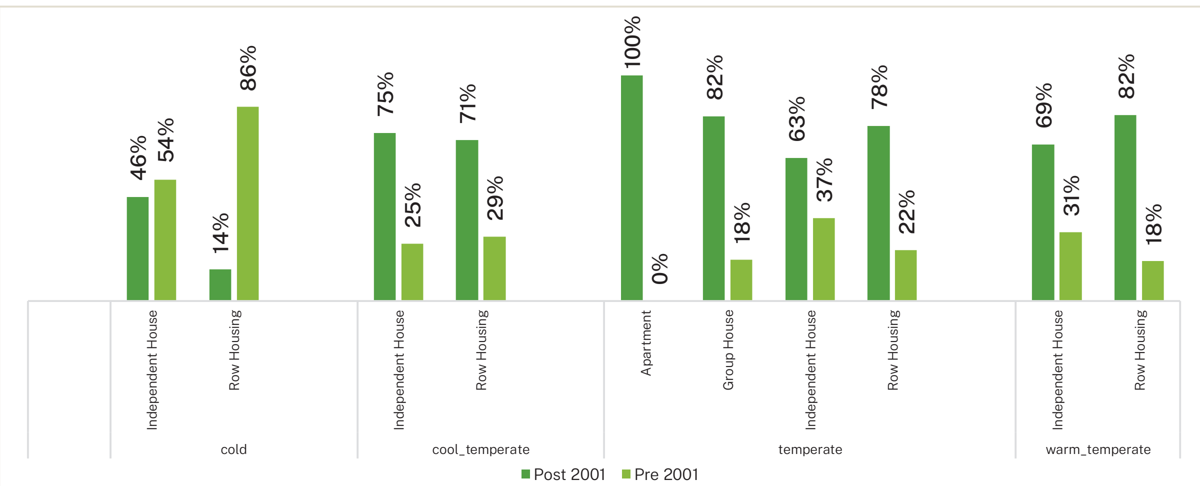
Table 7 and Figure 33 show the distribution of the residential buildings based on the year of construction for each bio-climatic zone and building typology.

Table 7: Distribution of residential buildings based on year of construction

Climate	Typology	1751-1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010	2011-2020	2021-2030
Cold	Independent House	13%	8%	7%	5%	12%	9%	19%	22%	7%
	Row Housing	42%	13%	8%	7%	10%	5%	10%	4%	0%
Cool temperate	Independent House	3%	1%	4%	4%	6%	9%	12%	53%	8%
	Row Housing	4%	0%	2%	8%	6%	10%	12%	48%	10%
Temperate	Apartment	0%	0%	0%	0%	0%	0%	0%	100%	0%
	Group House	0%	0%	0%	0%	0%	18%	36%	45%	0%
	Independent House	1%	0%	1%	3%	9%	24%	32%	24%	6%
	Row Housing	7%	0%	0%	1%	6%	15%	31%	36%	3%
Warm temperate	Independent House	0%	0%	1%	2%	6%	20%	33%	29%	9%
	Row Housing	0%	0%	0%	1%	2%	13%	40%	38%	7%

In cold climates, 42% of the surveyed row houses were found to be built before 1950, which provided a glance into vernacular mountain architecture. However, in other climate zones, most of the surveyed houses were found to have been built in the last 30 years. Also, about 40% of the total surveyed houses were constructed after 2011.

Figure 33: Pre-Post 2001 year of construction distribution based on different typologies and climate zones



Consolidated data of the year range further shows that in cold climates most of the surveyed buildings were pre-2001 in both typologies. However, in other bio-climate zones surveys revealed that post-2001 houses are more likely to be found.

5.3 Built-up area

Table 8 shows the distribution of surveyed households as per the built-up area range for all the bio-climatic zones. It was found that the predominant size for the household varied from 501–1750 ft^2 for the surveyed households in each climatic zone and building typology as 65% of the surveyed households were in this range. The top four area ranges (contributing to more than 50%) for each typology and climatic zone are highlighted. Since a small sample of Apartments and Group Housing data was collected in the survey, the area ranges are not shown here.

Table 8: Predominant built-up area range in different bio-climatic zones and typologies

Area (ft^2)	Cold		Cool_Temperate		Temperate		Warm_Temperate	
	Independent House	Row Housing	Independent House	Row Housing	Independent House	Row Housing	Independent House	Row Housing
0-250	1%	2%	0%	0%	0%	0%	1%	5%
0251-500	12%	8%	8%	4%	1%	1%	6%	6%
0501-750	13%	17%	15%	6%	8%	15%	22%	10%
0751-1000	9%	14%	17%	20%	14%	14%	17%	14%
1001-1250	15%	16%	16%	22%	15%	15%	11%	11%
1251-1500	13%	10%	12%	8%	12%	13%	12%	10%
1501-1750	8%	6%	9%	10%	14%	13%	6%	14%
1751-2000	10%	7%	10%	8%	8%	8%	11%	7%
2001-2250	4%	6%	3%	4%	7%	9%	6%	5%
2251-2500	5%	4%	5%	8%	6%	3%	4%	6%
2501-2750	0%	4%	3%	4%	5%	3%	1%	3%
2751-3000	4%	3%	1%	0%	2%	1%	3%	3%
3001-3500	2%	1%	0%	0%	7%	1%	1%	2%
3501-4000	1%	1%	1%	2%	1%	0%	0%	2%
4001-4500	1%	1%	0%	2%	1%	1%	1%	1%
4501-5000	1%	1%	0%	0%	0%	0%	0%	0%
5001-5500	1%	0%	0%	0%	1%	0%	0%	0%
5501-6000	1%	0%	0%	0%	0%	0%	0%	1%
6501-7000	0%	0%	0%	0%	0%	1%	0%	0%

5.4 Spatial configuration

Most of the surveyed houses had one living room, one kitchen and 2 or 3 bedrooms. So, for both the typologies 2 bhk and 3 bhk spatial configurations were predominantly found, which corresponds to the predominant area ranges.

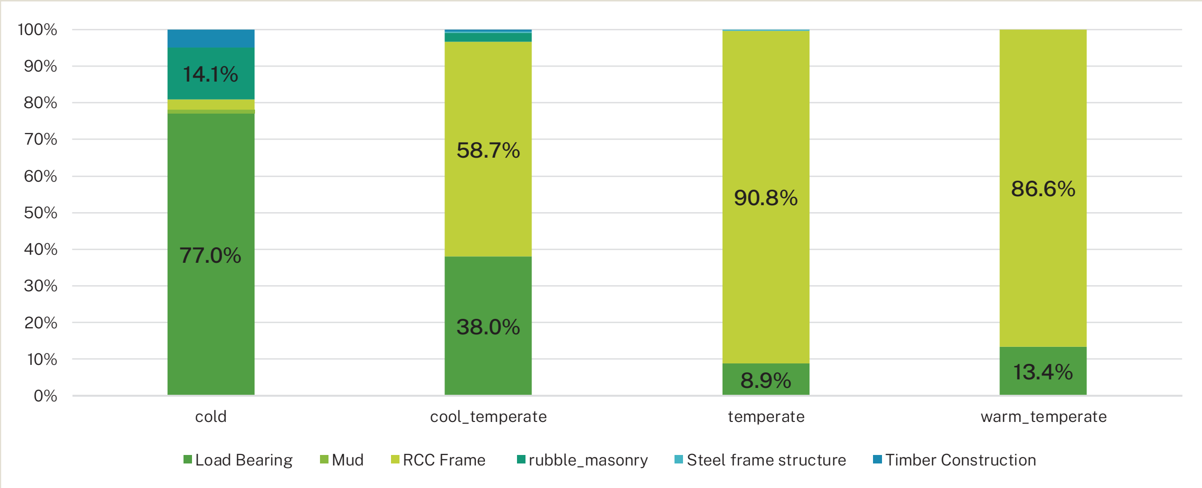
5.5 Construction technology

Figure 34 shows the construction practices as per the bio-climatic zones. Load-bearing construction was predominant (77%) in the cold climate, followed by rubble masonry. Temperate and warm temperate climates predominantly had RCC frame constructions (90.8% and 86.6% respectively), followed by a small share of load-bearing constructions. Cool temperate also had predominantly RCC frame constructions (58.7%), however, it also had a significant share of load-bearing constructions (38%).

As a large number of buildings surveyed in the Cold region were constructed before 2001, they represented old buildings with vernacular technology. Load-bearing thick walls have been used in the cold region which have large thermal mass and provide better insulation.

Within specific climatic zones, the construction practice for row housing and independent houses remained similar. However, the apartment and group housing typology (only in temperate climates), mostly had RCC frame constructions. It was also found that the overall RCC frame construction technology remained dominant as it represented 61% of the total surveyed houses and out of those, 81% were constructed post-2001, which also shows that in recent years, the trend is towards using RCC frame constructions.

Figure 34: Construction practices as per bio-climatic zone



5.6 Exterior Wall Assembly

The houses in cold and cool temperate regions had thicker walls; the wall thickness reduced at lower altitudes. The predominant wall assemblies found in different climatic zones are presented in Table 9. Out of the large number of wall assemblies reported in the survey, only predominant assemblies are presented in Table 10.

Table 9: Predominant exterior wall assembly in bio-climatic zone

Bio-climatic zone	Predominant wall assembly layers and its thickness	Share in the sample size for the climate
Cold	Overall ~465 mm: Lime/Mud/Cement Plaster (15-20 mm) Stone Masonry (~430 mm) Lime/Mud/Cement Plaster (15-20 mm)	35%
Cool Temperate	Overall 254 mm: Cement Plaster (12 mm) Solid Burnt Brick (230 mm) Cement Plaster (12 mm)	40%
Temperate	Overall 254 mm: Cement Plaster (12 mm) Solid Burnt Brick (230 mm) Cement Plaster (12 mm)	43%
	Overall 312 mm: Stone cladding (20 mm) Screed (50 mm) Solid Burnt Brick (230 mm) Cement Plaster (12 mm)	27%
Warm Temperate	Overall 254 mm: Cement Plaster (12 mm) Solid Burnt Brick (230 mm) Cement Plaster (12 mm)	88%

The survey also revealed that three-layer walls are most common in Nepal. Stone masonry was found to be predominant in-cold climates, while in other climates solid burnt brick masonry was the predominant practices for external walls.

5.7 Roof assembly

5.7.1 Predominant roof type

Table 14 shows the distribution of the type of roof for the four bio-climatic zones. Flat roofs were found to be the predominant roof construction in all the bio-climates followed by inclined roofs. In the cool temperate zone, a substantial percentage (30%) of the roofs were of inclined roof type.

Table 10: Roof type based on bio-climatic zones

Bio-climatic Zone	Dormer	Dutch Roof	Flat CGI Roof	Flat Roof	Gable Roof	Inclined Roof
Cold	0.4%	0.0%	0.0%	83.7%	1.1%	14.8%
Cool temperate	0.0%	0.0%	0.0%	67.8%	2.1%	30.1%
Temperate	0.0%	0.3%	0.0%	94.1%	0.7%	5.0%
Warm temperate	0.0%	0.0%	0.3%	83.0%	0.0%	16.7%

5.7.2 Predominant roof assembly

Table 11 gives the predominant type of roof assembly for each bio-climatic zone. Two layered roofs of Mud + Wooden plank have the highest share (34%) in cold climates. RCC slab with cement plaster was found to be the predominant roof construction in temperate and warm temperate climates.

Cool temperate climate showed a mix of roof assembly; RCC + cement plaster and Corrugated Galvanised Iron (CGI) + Wood Plank. While the roof thickness will vary as per its assembly, the average roof thickness of the houses in different bio-climatic zones remained in a narrow (130-180 mm) band; contrary to wall thickness which had larger variations.

Table 11: Predominant roof assembly in bio-climatic zone

Bio-climatic zone	Predominant wall assembly layers and its thickness	Share in the sample size for the climate
Cold	Overall 175 mm:Mud (125 mm) wooden plank (50 mm)	34%
Cool Temperate	Overall 77 mm:CGI (2 mm) Wood Plank(75 mm)	11%
	Overall 137 mm:RCC Slab (125 mm) Cement Plaster (12 mm)	12%
	Overall 187 mm: Screed (50 mm) RCC Slab (125 mm) Cement Plaster (12 mm)	10%
Temperate	Overall 192 mm:Ceramic Tiles (5 mm) Screed (50 mm) +RCC Slab (125 mm) Cement Plaster (12 mm)	19%
	Overall 150 mm: Cement Plaster (12 mm) RCC Slab (125 mm) Cement Plaster (12 mm)	15%
Warm Temperate	Overall 187 mm: Screed (50 mm) RCC Slab (125 mm) Cement Plaster (12 mm)	34%

5.8 Window to Wall Ratio (WWR)

Figure 35 shows the distribution of surveyed households as per the WWR range for different bio-climatic zones. Cold climate houses had lower WWR, with 73% of the houses having WWR less than 20%. The lower WWR in cold climate houses can be attributed to an attempt to minimize the heat loss from the windows as well as a very low requirement for natural ventilation for thermal comfort. In the cool-temperate climate, the WWR increased with 71% of the houses having WWR ranging between 10-30%. The temperate and warm-temperate climates which require more natural ventilation for thermal comfort had the highest WWR, with 64% and 61% houses having WWR ranging between 20-40%, respectively.

Figure 35: Distribution of surveyed households as per WWR range for different bio-climatic zones

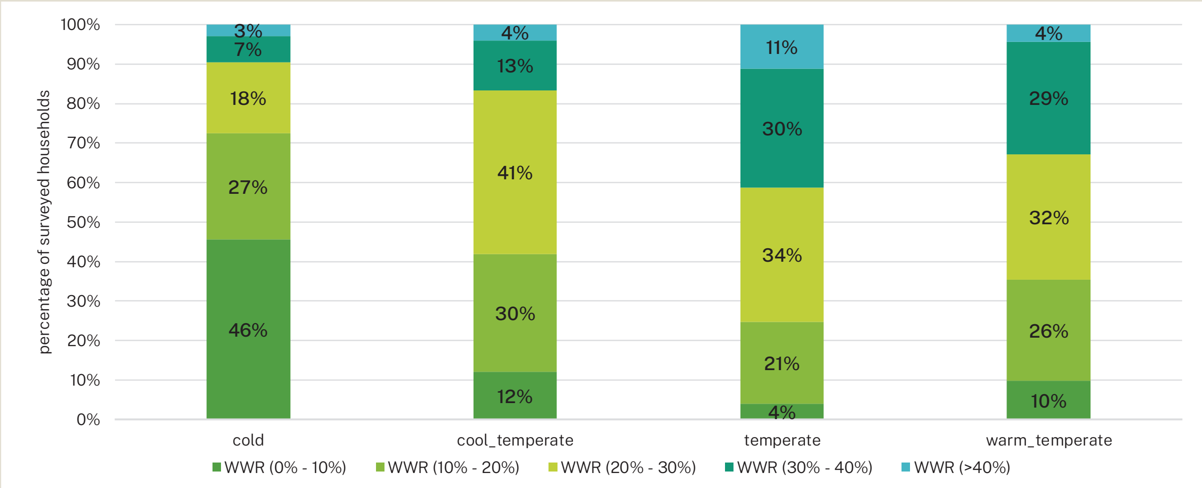
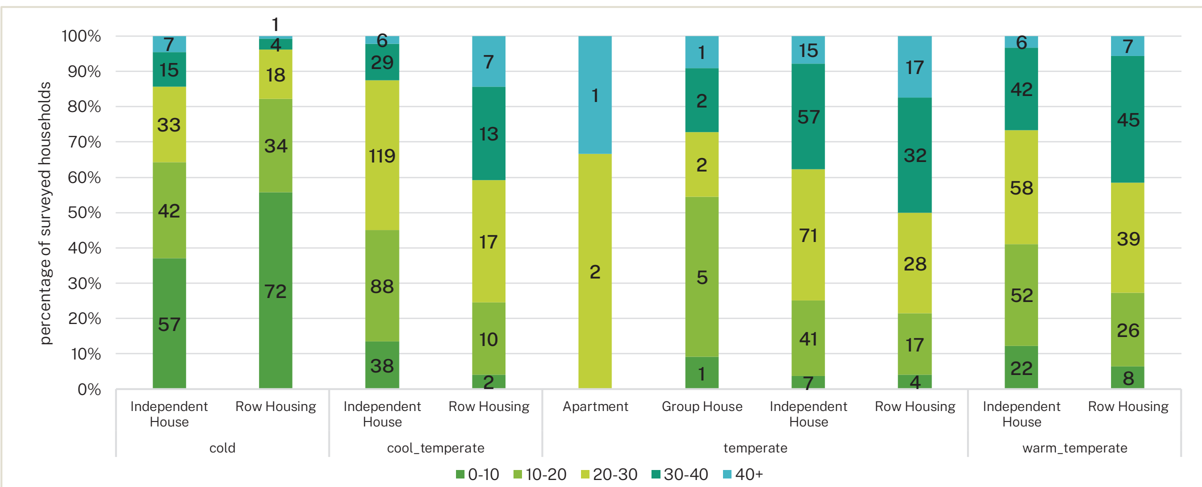


Figure 36 shows the distribution of surveyed households as per the WWR range for different typologies under each bio-climatic zone. While the general trends for the climate are followed for different typologies; some variations were also observed among building typologies. For example, row housing in cold climates showed lower WWR trends as compared to independent houses, while row housing in other climates showed higher WWR trends as compared to independent houses. A higher WWR in row housing in cool temperate, temperate, and warm temperate climates can be attributed to the less exposed wall area available which also needs to accommodate sufficient windows to allow required daylight and ventilation.

Figure 36: Distribution of surveyed households as per WWR range for different typologies under each bio-climatic zone



5.9 Window type

Table 12 shows the window type for different bio-climatic zones. The surveyed data among 1220 households showed that casement window is the predominant window type(86.4% of the total). Around 3/4th of the casement windows had glass panes, while the remaining 1/4th had wooden shutters. The use of wooden shutters is found more in cold climates. Apart from the casement window, a sliding window is another significant type. Overall, 11.1% of houses had sliding windows. Except for the cold climate, sliding windows were found in all t three other climate zones. The trends among building typologies (independent house and row housing) within the bio-climatic zones, followed the same trends.

Table 12: Window type

Bio-climate	Casement-Glass	Casement - Wooden Shutter	Fix Window	Grilled Opening	No Window	Pivot	Sky Light	Sliding	Traditional Window
cold	50.5%	41.3%	1.8%	0.0%	3.9%	0.4%	0.7%	0.0%	1.4%
cool temperate	57.1%	24.9%	0.6%	0.0%	0.0%	0.6%	0.0%	16.7%	0.0%
temperate	81.5%	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%	0.0%
warm temperate	78.0%	6.6%	0.0%	1.6%	0.0%	0.0%	0.0%	13.8%	0.0%
Overall	66.9%	19.4%	0.6%	0.4%	0.9%	0.2%	0.2%	11.1%	0.3%

5.10 Window glazing and framing

Table 13 shows window glazing and framing assembly for all bio-climatic zones for the predominant type, i.e., "Casement – Glass".It clearly shows that the casement window with a wooden frame and single clear glass is the predominant window assembly for all bio-climatic zones. The cold climate had a significant share of wooden windows with no glass, which is also found in cool temperate climates. The use of tinted glass is found more in cool temperate and warm temperate (22-24%) climates. For framing, except in cold climates, aluminum was the second preference after wooden framing.

Table 13: Window glazing and framing assembly for all bio-climatic zones

1.1.1.1.1	Clear Glass	No Glass	Tinted Glass
Cold	**152**	**128**	**3**
No window		10	
Wooden	152	118	3
Cool temperate	**182**	**74**	**73**
Aluminum	22		33
Mild steel			1
PVC UPVC	5		4
Wooden	155	74	35
Temperate	**261**	**6**	**36**
Aluminum	30		11
Mild steel	1		
PVC UPVC	4		
Wooden	226	6	25
Warm temperate	**213**	**18**	**74**
Aluminum	17		26
Wooden	196	18	48

5.11 Window shading

Table 14 shows the different types of shading used as per the bio-climatic zones. The predominant type of shading used across all climates is the continuous overhang.

Further, Table 15 shows the average depth of the continuous overhang shading for different orientations for all climatic zones. In terms of orientation, no predominant orientation is found;however, the depth of the shading in the south direction has been slightly more than in other orientations. The average depth of shading progressively increases as we move down the altitude, from ~325 mm in a cold climate to ~725 mm in a warm temperate climate,thiscan be attributed to the use of deeper shading in relatively warmer and humid climates to reduce the solar heat gains and provide protection from rain, i.e., more shading in the houses in Terai region having warm temperate climate.Whereas, in cold climates the rainfall is muchless, and less shading is preferred to allow solar gains, hence, there is no shading in around ~30% of houses and also the depth is only 320 mm.

Table 14: Shading type with bio-climatic zone

Bio-Climate	Continuous Overhang	No Shading	Overhang Over Windows
Cold	68.60%	30.40%	1.10%
Cool temperate	91.20%	6.70%	2.10%
Temperate	91.40%	5.90%	2.60%
Warm temperate	76.70%	8.50%	14.80%

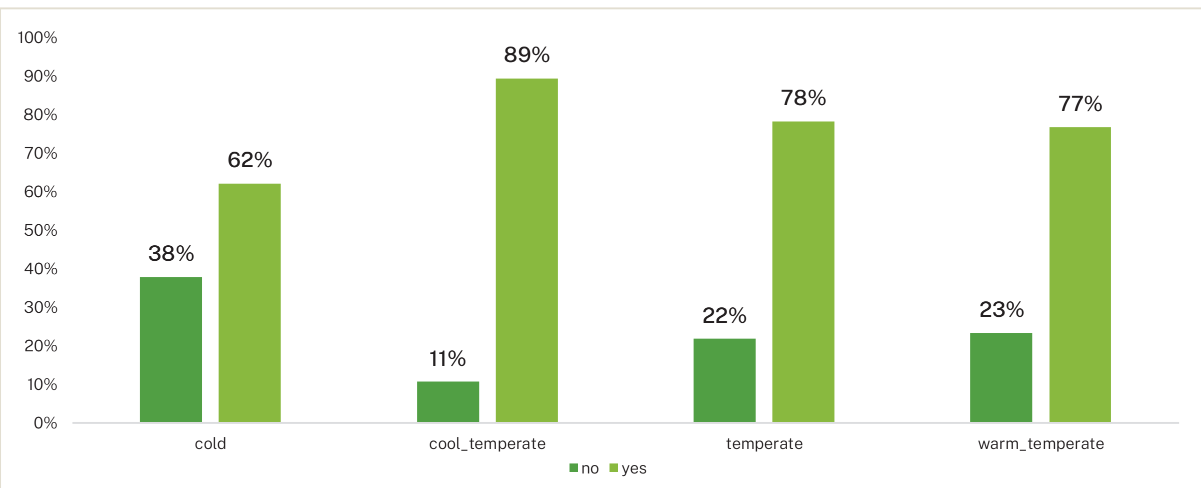
Table 15: Average shading depth with bio-climatic zone

Bio-Climate	Average depth of continuous overhang shading (mm)			
	North	South	East	West
Cold	320	355	308	320
Cool temperate	543	652	566	531
Temperate	631	673	668	618
Warm temperate	734	724	724	719

5.12 Perception of respondents on daylight, ventilation, and air infiltration.

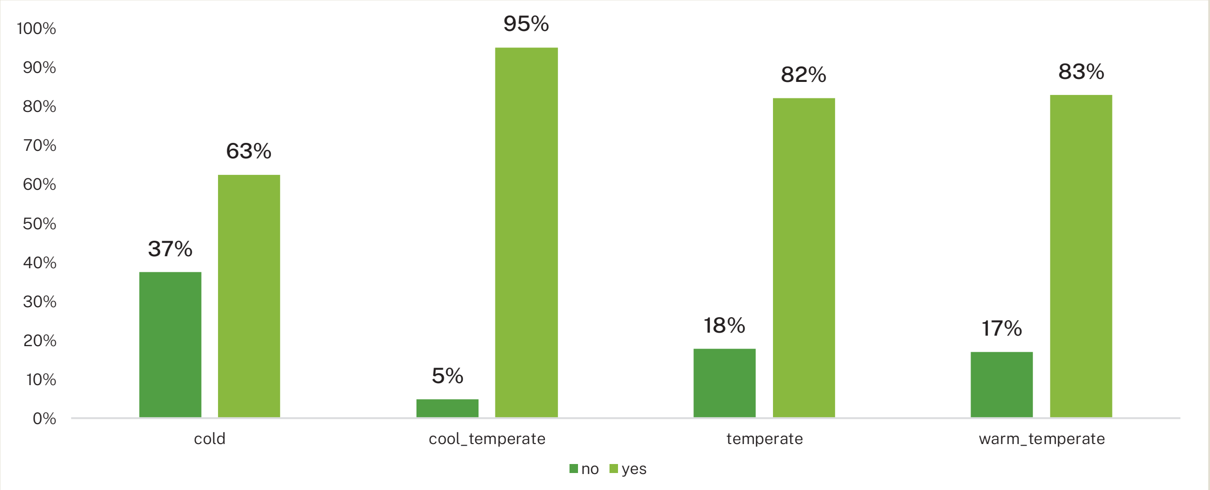
During the survey, the respondents were asked if they get sufficient daylight inside the regularly occupied spaces during the daytime. Figure 37 shows their responses for each climatic zone. It shows that except for the cold climate, most of the respondents in other climates found daylight to be sufficient. In cold climates, 38% of the respondents said that daylight is not sufficient, which can be attributed to the lower WWR and higher use of wooden (no glass) windows.

Figure 37: Daylight sufficiency perception



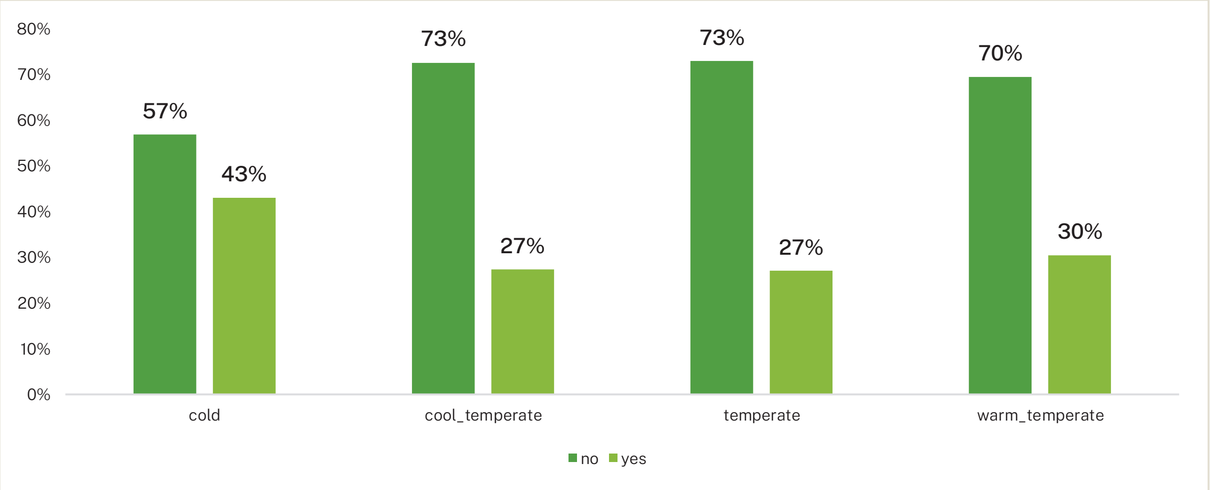
During the survey, the respondents were asked if they get sufficient ventilation during the summer months. Figure 38 shows their responses for each climatic zone. It shows that except for the cold climate, most of the respondents in other climates said ventilation was sufficient. While in cold climates, having lower WWR, 37% of the respondents said that ventilation is not sufficient.

Figure 38: Ventilation sufficiency perception



During the survey, the respondents were asked if they experience cold air infiltration during winter months while the windows are closed. Figure 39 shows their responses for each climatic zone. While most of the respondents said they do not experience cold air infiltration; still there is a good share (27-43%) of respondents who experienced it, in all climate zones. This can be attributed to the use of wooden framing (which was found to be the predominant practice) with inadequate sealing of windows. In cold climates, more respondents (43%) experienced air infiltration, which can be attributed to the lower air temperature which gives a higher sensation of cooling.This suggests that measures to mitigate cold air infiltration are necessary in cold climates to enhance thermal comfort and energy efficiency in households.

Figure 39: Cold air infiltration perception



Based on these three perception ideas cool temperate zone is shown to have a better construction practice for sufficient daylight, sufficient ventilation, and lesser perceived cold air filtration. On further analysis based on a gender perspective, no significant difference in perception was observed. Around 77.7% of females and 76.5% of males reported sufficient daylight and 82.1% of females and 80.4% of male respondents reported sufficient ventilation.

Table 16 shows the cold air infiltration perception based on the construction technology. A higher number of respondents from load-bearing houses reported infiltration issues. Also, higher infiltration was found in Timber houses which may have resulted from the fact that timber houses are constructed without proper workmanship.

Table 16: Cold air infiltration perception based on construction technology

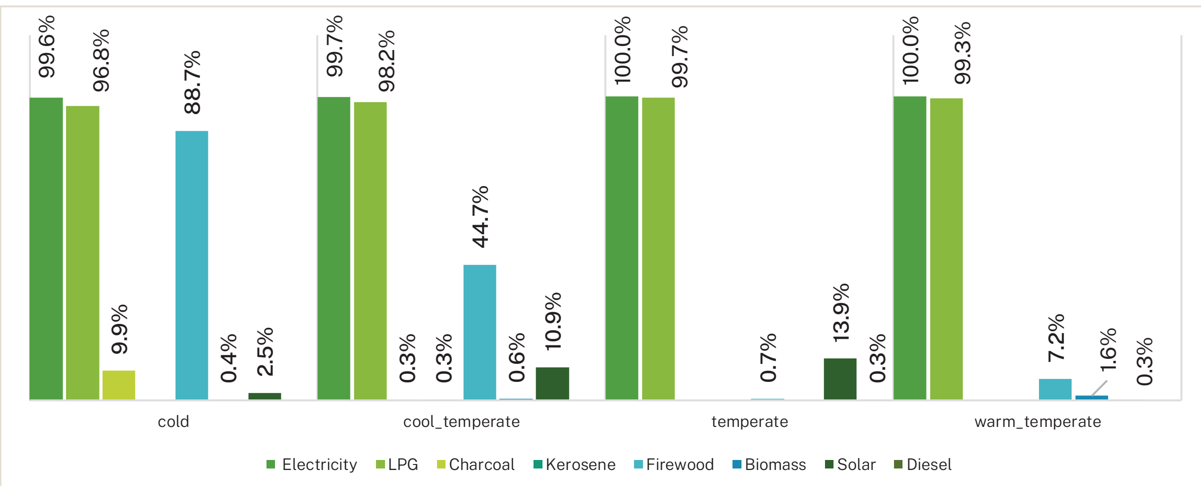
Construction Technology	Total Sample	Infiltration - Yes
Load Bearing	411	41%
Mud	3	33%
RCC Frame	740	25%
rubble masonry	48	35%
Steel frame structure	2	50%
Timber Construction	16	75%

Section II: Energy Consumption

5.13 Distribution of different fuel types based on the climate zone

The use of different fuels in various bio-climatic zones was examined, highlighting the percentage of households relying on each fuel type (refer Figure 40). Electricity and LPG are the most common energy sources which are used by ~100% of the houses in all bio-climatic zones. Firewood is used extensively (88.7% of the houses) in the cold bio-climatic zone, moderately (44.7% of the houses) in the cool temperate bio-climatic zone, and small (7.2% of the houses) in the warm temperate bio-climatic zone. The highest use of solar energy is found in temperate (13.9% of the houses) and cool temperate bio-climatic zone (10.9% of the houses), while a small fraction of the houses used solar energy in the cold bio-climatic zone (2.5%). The use of charcoal (9.9%) is only found in the cold bio-climatic zone.

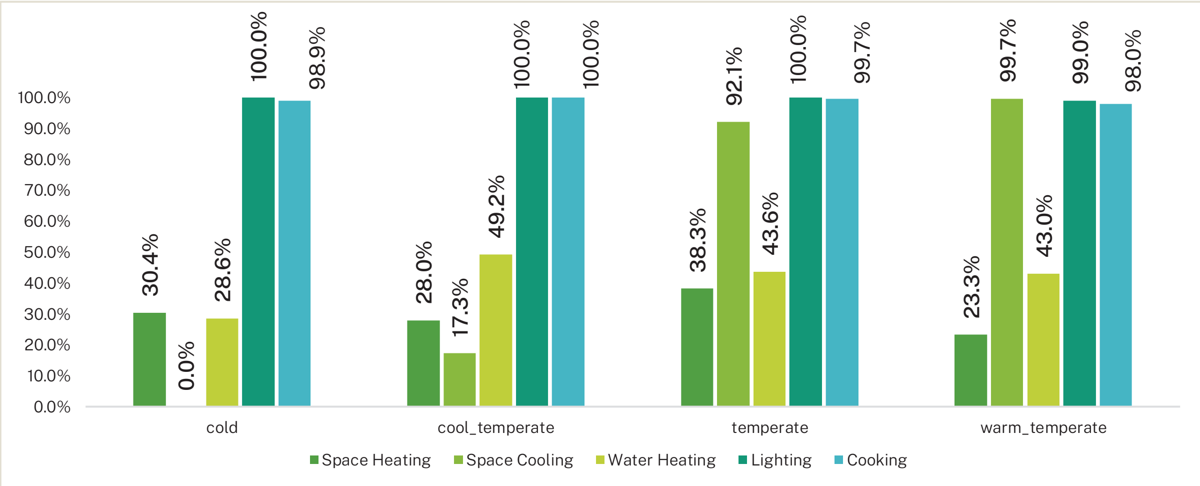
Figure 40: Use of different fuel/energy based on the bio-climatic zone



5.14 Type of fuel for all different end-uses

5.14.1 End-use of energy

Figure 41: Percentage of houses using energy for key end-uses in different bio-climatic zones



Lighting and cooking are the most common uses of energy, which has been reported in all bio-climatic zones. Warm temperate and temperate climates had very high use of energy for cooling, which also included the use of fans for cooling (refer Figure 41). In the cold climate zone, while no use of space cooling is reported; the use for space heating and water heating is reported low. It is anticipated that the cooking system using firewood for cooking, also serves for space heating and water heating end-uses in the cold climate. Therefore, it may not have been reported separately and would need further investigation. The trends among building typologies (independent house and row housing) within the bio-climatic zones, followed the same trends.

5.14.2 Distribution of energy source for end-use

Survey results (refer Table 17) clearly show that firewood is the predominant energy source for space heating in cold climate, while electricity is in cool temperate, temperate, and warm temperate climates.

Table 17: Distribution of energy source used for space heating in bio-climatic zones

Bioclimatic Zones	Electricity	LPG	Charcoal	Kerosene	Firewood
Cold	21%	0%	0%	17%	79%
cool temperate	85%	1%	0%	1%	17%
Temperate	99%	7%	0%	0%	0%
warm temperate	99%	4%	0%	0%	4%

Note: The percentages are given only for the houses which reported space heating as an end-use of energy. Some houses reported more than one energy source; hence, the total can exceed 100%.

For space cooling,electricity is the predominant energy source with 100% of the houses using it in the cool temperate, temperate, and warm temperate climate.

Survey results (refer Table 18) showed that multiple energy sources are being used for water heating in all bio-climatic zones. Electricity is predominantly used for water heating in cool temperate, temperate, and warm temperate climates whereas in cold climates, firewood is predominantly used for water heating closely followed by electricity. The use of solar water heating systems for water heating was also evident in cool and temperate zones.

Table 18: Distribution of energy source used for water heating in bio-climatic zones

Bioclimatic Zones	Electricity	LPG	Firewood	Solar
cold	48%	26%	51%	6%
cool temperate	53%	24%	20%	22%
temperate	61%	33%	0%	30%
warm temperate	74%	34%	0%	1%

5.15 Predominant device and their usage for different end uses

5.15.1 Predominant device for different end uses

Based on the predominant energy source for different end-uses (as per the previous section), the survey was further analyzed to show the corresponding devices that are used for end-use and the predominant combination for each bio-climatic zone. Table 19 shows that fireplaces and smokeless stoves are the predominant devices used for space heating in cold climates, while radiant heaters in cool temperate, temperate, and warm temperate climates. Table 20 shows that table/ceiling fans are the predominant devices used for space cooling in cool temperate, temperate, and warm temperate climates. Table 21 shows that improved cook stoves are the predominant devices used for water heating in cold climates, while electric kettles are in cool temperate, temperate, and warm temperate climates.

Table 19: Predominant device for space heating as per predominant energy source for different climates

Bio-Climatic Zone	Energy Source	Predominant Device	Percentage Use of Predominant Device
Cold	Firewood	Fireplace	37%
Cold	Firewood	Smokeless stoves	37%
Cool Temperate	Electricity	Radiant heater	72%
Temperate	Electricity	Radiant heater	73%
Warm Temperate	Electricity	Radiant heater	51%

Table 20: Predominant device for space cooling as per predominant energy source for different climates

Bio-Climatic Zone	Energy Source	Predominant Device	Percentage Use of Predominant Device
Cool Temperate	Electricity	Table fan	51%
Temperate	Electricity	Ceiling fan	80%
Warm Temperate	Electricity	Ceiling fan	99%

Table 21: Predominant device for water heating as per predominant energy source for different climates

Bio-Climatic Zone	Energy Source	Predominant Device	Percentage Use of Predominant Device
Cold	Firewood	Improved cook stove	54%
Cool Temperate	Electricity	Electric kettle	63%
Temperate	Electricity	Electric kettle	40%
Warm Temperate	Electricity	Electric kettle	49%

5.15.2 Usage of the predominant device for different end uses

Table 22, Table 23, and Table 24 show the usage schedule (month-wise and average usage hours per day) for the combination of predominant energy source and device for each bio-climatic zone. All the numbers (hours per day and percentages) shown in the tables are calculated considering only the selected households.

Space heating: In cold climates, space heating is operated at a minimum of 50% of the household round-the-year, while the peak usage found is found in Nov-Feb. In cold climates, it was observed that fireplaces and smokeless stoves are generally operated for both cooking and space-heating purposes. For the other three climates, the usage month also remained Nov-Feb while peak usage was found in Dec-Jan. Interestingly, the usage hours per day havenot changed significantly among the climate zones.

Table 22: Operational schedule for predominant devices for space heating

Bio-climatic zone / Energy source / Predominant device	Average usage (h/d)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cold / Firewood / Fireplace	2.9	100%	88%	88%	88%	88%	72%	72%	72%	76%	84%	100%	100%
Cold / Firewood / Smokeless stoves	2.9	92%	92%	67%	63%	58%	50%	54%	58%	67%	79%	100%	100%
Cool Temperate / Electricity /Radiant heater	2.3	96%	72%	6%	2%	0%	0%	0%	2%	8%	20%	86%	100%
Temperate / Electricity / Radiant heater	2.7	97%	72%	8%	0%	0%	0%	0%	0%	1%	18%	76%	100%
Warm Temperate / Electricity / Radiant heater	2.6	95%	51%	0%	0%	0%	0%	0%	0%	0%	3%	59%	100%

Explanatory note: The table shows value as 86% for the November month for the Cool Temperate / Electricity /Radiant heater combination. This percentage is calculated based on the total number of surveyed buildings which use space heating in cool temperate climate using electricity based radiant heater. The number 86% for November means that 86% of that specific total uses it.

Space cooling: Warm temperate had high usage in Mar-Sep with highest average usage hours per day. Temperate and cool temperate climate had usage in Apr-Sep and Apr-Aug, respectively. The average usage hours per day are in line with the climate conditions.

Table 23: Operational schedule for predominant devices for Space Cooling

Bio-climatic zone / Energy source / Predominant device	Average usage (h/d)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cool Temperate / Electricity / Table fan	2.0	0%	0%	17%	67%	100%	96%	79%	38%	8%	0%	0%	0%
Temperate / Electricity / Ceiling fan	4.2	0%	0%	13%	69%	84%	100%	97%	81%	47%	4%	1%	0%
Warm Temperate / Electricity / Ceiling fan	8.7	1%	11%	49%	100%	100%	100%	97%	91%	77%	33%	9%	1%

Water heating: In cold climates, space heating is operated at a minimum of 50% of the household round-the-year, while the peak usage found is found in Nov-Feb. The temperate climate also showed considerable usage of water heating around the year, however, the usage hours per day were almost half as compared to cold. The cool temperate climate also had peak usage in Nov-Feb. Warm temperate had high use in Dec-Jan.

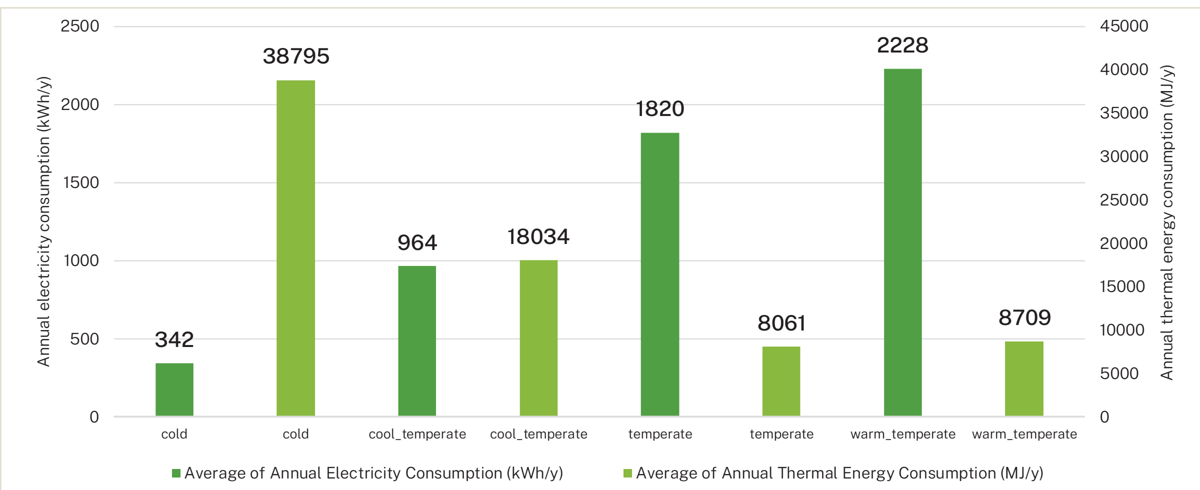
Table 24: Operational schedule for predominant devices for water heating

Bio-climatic zone / Energy source / Predominant device	Average usage (h/d)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cold / Firewood / Improved cook stove	1.9	90%	90%	75%	75%	75%	60%	60%	60%	70%	85%	100%	100%
Cool Temperate / Electricity / Electric kettle	1.2	96%	93%	44%	26%	26%	26%	26%	26%	30%	63%	93%	100%
Temperate / Electricity / Electric kettle	1.0	96%	68%	44%	40%	44%	52%	52%	48%	52%	60%	88%	100%
Warm Temperate / Electricity / Electric kettle	1.3	100%	43%	4%	4%	4%	4%	6%	4%	4%	6%	42%	81%

5.16 Overall electrical and thermal energy consumption

Figure 42 shows the annual average electrical and thermal energy consumption per household as per climate. Depending on the types of fuel used, the proportion of electrical and thermal energy changes as per the bio-climatic zone.These variations in energy consumption in different bio-climatic zones highlight the influence of climate, end-use, local energy availability, device efficiency, and financial feasibility of different energy sources.

Figure 42: Annual average electrical and thermal energy consumption per household as per bio-climatic zone

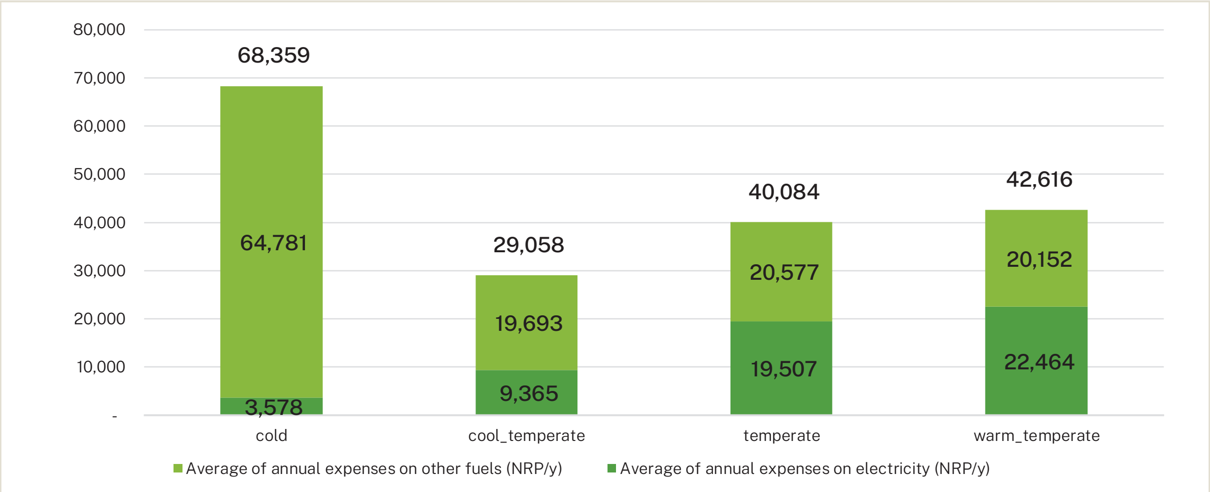


In cold bio-climatic zone, in addition to cooking the thermal energy requirement for end-uses like space heating and water heating is higher and fuels like firewood and charcoal are used in devices having low thermal efficiency, resulting in higher thermal energy consumption. Electricity consumption islow in the cold bio-climatic zone as it is mainly used for lighting only. In temperate and warm temperate bio-climatic zones in addition to the use of electricity for lighting, electricity is also used for space cooling (e.g.fans) for several months in a year, resulting in higher electricity consumption. The use of thermal energy is restricted only to cooking for which LPG is the main fuel which is used in devices having higher thermal efficiencyhence the thermal energy consumption is low. Inthe cool temperate bio-climatic zone, there is a good mix of electrical and thermal energy consumption, due to a mix of fuel availability and end-uses.

5.17 Total annual energy expenses

Based on the energy source, its consumption, and prevailing electricity/fuel rates, estimation was made for the total annual energy expenses per household. Figure 43 shows the average total annual energy expenses per household for all bio-climatic zones. The maximum annual expenditure on energy is for households located in the cold bio-climatic zone, mainly due to high energy requirements due to extreme weather conditions. The lowest expenditure is for the cool temperate bio-climatic zone, as this zone has more energy supply options and relatively lower requirements for energy for thermal comfort.

Figure 43: Average of total annual energy expenses per household for all bio-climatic zones



5.18 Per capita energy consumption and expenditure

Table 25 gives the average annual consumption[17] of electrical energy, thermal energy, and estimated energy expenses per capita per year for all bio-climatic zones. The trends among the climatic zones follow the same trend as given for the total energy expenses.

Table 25: Average of energy expenses per capita per year

Bio-climatic zone	Annual electricity consumption per capita (kWh/y.person)	Annual thermal energy consumption per capita (MJ/y.person)	Annual energy expenses per capita (NPR/y.person)
cold	82	9320	16,422
cool_temperate	189	3544	5,711
temperate	320	1419	7,057
warm_temperate	443	1732	8,473

5.19 Energy Performance Index (EPI) – Electrical and Thermal

Figure 44 and Figure 45 shows the average electrical EPI[18] and thermal EPI, respectively, as well as its spread (box and whisker plot[19]) as per bio-climatic zones. The numbers in the middle of the box show the average values. The spread shows that with the higher average EPI, the spread also increases. The overall trend for electrical and thermal EPI is in line with the explanation given in the section 5.16.

17 For each bio-climatic zone, annual electricity consumption per capita = (total electricity consumption by all houses in that bio-climatic zone) / (total number of persons in all houses in that bio-climatic zone) Similar, calculations are done for “annual thermal energy consumption per capita” and “annual energy expenses per capita”.

18 For each bio-climatic zone, average electrical EPI = (sum of EPI of all houses in that bio-climatic zone) / (total number of houses in that bio-climatic zone) Similar, calculations are done for “average thermal EPI”.

19 The box is at the center and the whiskers are the two lines above and below the box. The box represents the distance between the 1st(25thpercentile) and 3rd(75th percentile) quartiles OR the InterQuartile Range (IQR=Q3-Q1).The box has the median (50th percentile) marked within the box as a line. The whiskers are 1.5*IQR or the highest / lowest point within the range. Any data points which are outside (lower or higher) the whisker are taken as ‘outlier points’ and are not shown here.

Figure 44: Electrical EPI for residential buildings as per bio-climatic zone

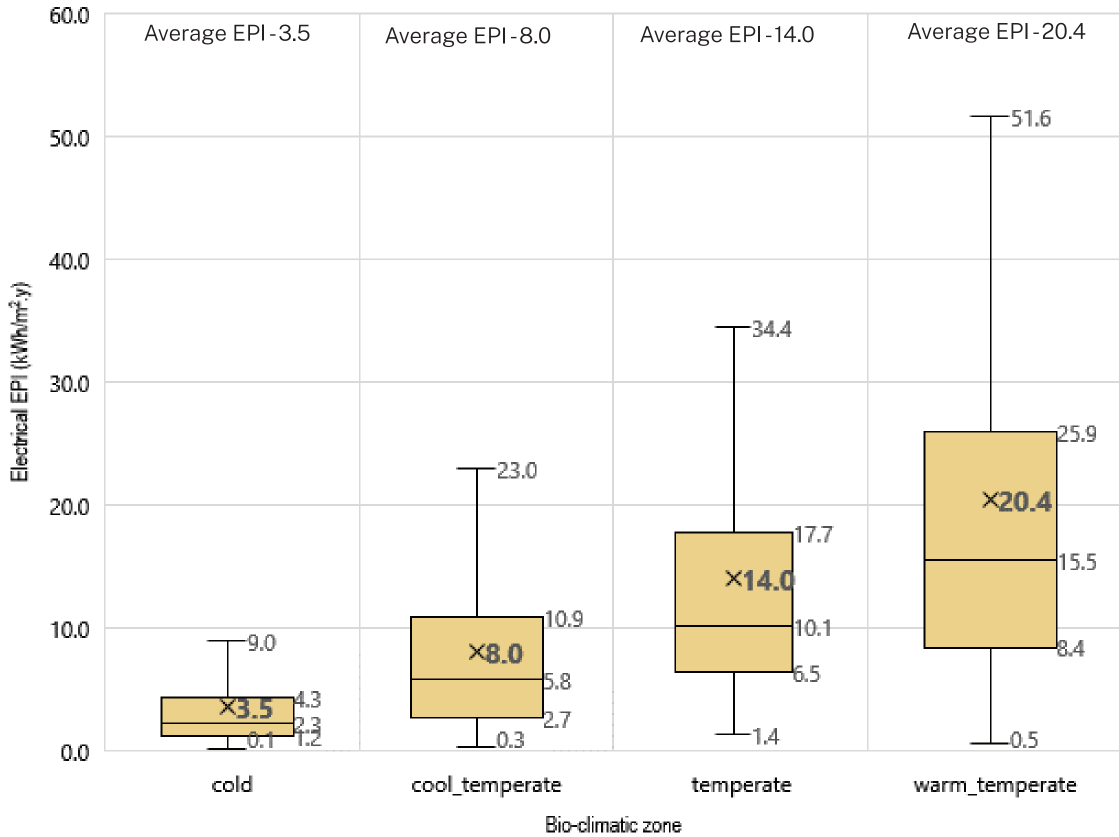


Figure 45: Thermal EPI for residential buildings as per bio-climatic zone

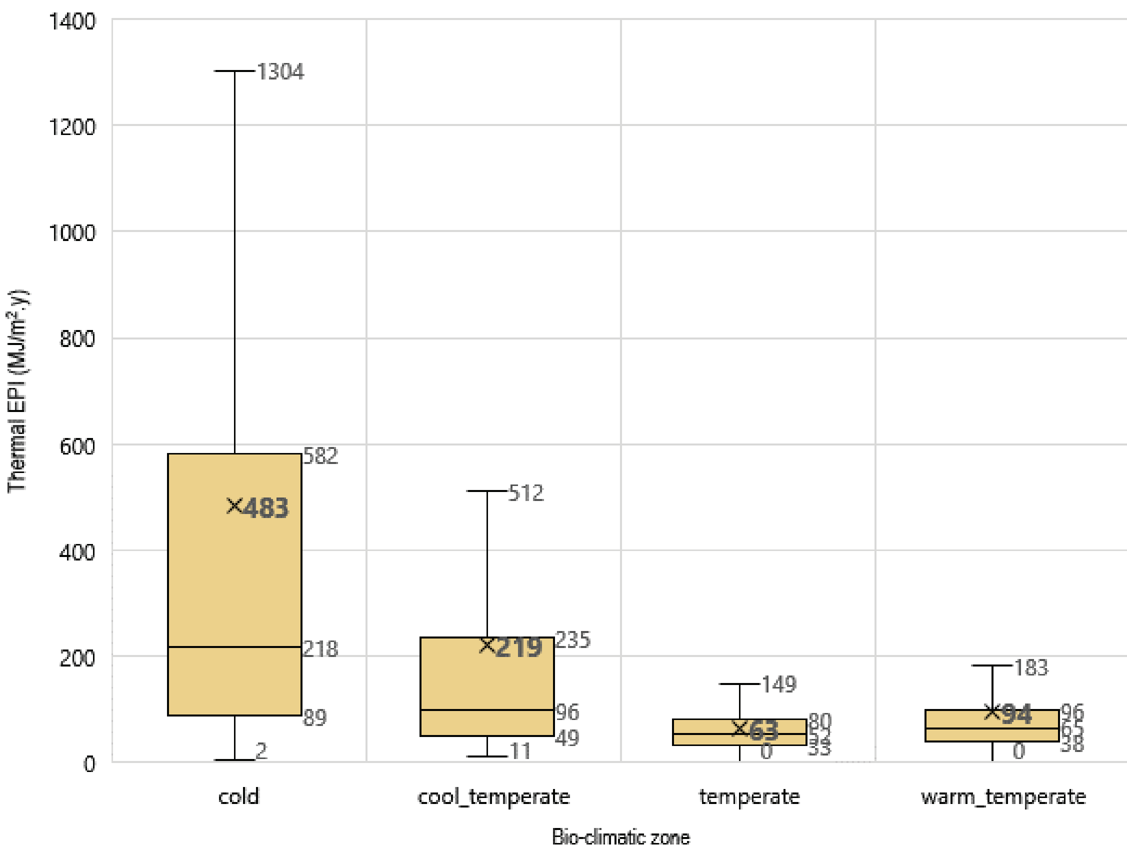


Table 26: Electrical and thermal EPI based on the building typologies

Climate / Typology	Average of Electrical EPI (kWh/m².y)	Average of Thermal EPI (MJ/m².y)
Cold	**3.5**	**483**
Independent House	3.3	584
Row Housing	3.8	363
Cool_temperate	**8.0**	**219**
Independent House	7.8	238
Row Housing	9.2	111
Temperate	**14.0**	**63**
Independent House	14.5	65
Row Housing	12.4	60
Warm_temperate	**20.4**	**94**
Independent House	20.4	101
Row Housing	20.5	84

The Electrical EPI valuesrange from 3.5 to 20.4kWh/m^2.y, represent the average electrical energy consumption patterns within each climatic zone (refer Table 26). These values are influenced by various factors, notably the prevailing climate and associated energy needs. Let's delve into the explanations for these differences:

Energy Source Utilization: In the cold zone, where the Electrical EPI is the lowest at 3.5kWh/m^2.y, the predominant use of firewood for space heating and water heating contributes to reduced reliance on electricity. Firewood is a traditional and often more accessible source of thermal energy in colder regions. In contrast, the cool temperate, temperate, and warm temperate zones exhibit progressively higher Electrical EPI values, suggesting a shift towards greater utilization of electricity for heating purposes due to the potential limitations of other thermal energy sources like firewood.

Space Cooling Demand: The increase in Electrical EPI as we move from cold to warm temperate zones can be attributed to the demand for space cooling. In temperate and warm temperate regions, the higher Electrical EPI values might be a consequence of increased electricity consumption for air conditioning and cooling systems. This is particularly relevant in urban areas with higher socio-economic conditions, where greater access to modern amenities leads to more widespread usage of cooling technologies.

Infrastructure and Socio-economic Factors: The availability and reliability of electricity infrastructure play a crucial role in energy consumption patterns. Regions with well-established and widespread electricity distribution systems are more likely to have higher Electrical EPI values. This is often the case in urban areas characterized by better socio-economic conditions. As urban areas tend to have higher energy demands due to increased commercial activities, residential comfort needs, and advanced technologies, this can contribute to the observed trend of higher Electrical EPI in these zones.

Diverse End Uses of Electricity: The warm temperate zone stands out with the highest Electrical EPI of 20.4kWh/m^2.y. This could be due to a combination of factors, including a broader spectrum of electricity end uses. In addition to space cooling, electricity might be used for various purposes such as heating, lighting, appliances, and industrial processes. The mix of urban infrastructure, economic prosperity, and lifestyle choices in this zone likely contributes to this multifaceted electricity consumption pattern.

In conclusion, the variation in average Electrical EPI across different climatic zones can be attributed to a combination of energy source availability, demand for space cooling, electricity infrastructure, socio-economic conditions, and the diversity of electricity end uses. The interplay of these factors shapes the energy consumption patterns in each zone and underscores the importance of understanding regional context when analyzing energy usage.

The variation in the average EPI across distinct climate zones aligns with the prevailing energy consumption patterns. In the cold climate zone, the higher average Thermal EPI of 483MJ/m^2.yunderscores the increased reliance on thermal energy sources like firewood, necessary for space and water heating in colder conditions. Transitioning to the cool temperate climate, the average Thermal EPI of 219 MJ/m^2.ysuggests a more optimized use of thermal energy, likely owing to improved efficiency measures. The temperate climate zone maintains a lower average Thermal EPI of 63MJ/m^2.y, indicative of reduced consumption of thermal energy fuels, possibly due to milder climate conditions. Meanwhile, the warm temperate climate zone records an average Thermal EPI of

94MJ/m^2.y, higher than the temperate zone but still below cold and cool temperate zones. This can be attributed to the utilization of firewood, particularly during colder winters in these regions.

5.20 Solar water heating and Solar PV

5.20.1 Distribution of buildings (in %) with and without Solar PV installation based on the bioclimatic zone.

Table 27: Availability of Solar PV

Bio-climatic zones	No	Yes
Cold	78%	22%
Cool temperate	90%	10%
Temperate	84%	17%
Warm temperate	95%	5%
Grand Total	**87%**	**13%**

Table 27 shows only 13% of the households were using Solar PV systems. The cold (22%) and temperate (17%) showed higher use of Solar PV.

5.20.2 Distribution of type of Solar PV (standalone, grid-connected) based on the bioclimatic zone.

Among households that were using Solar PV systems (refer Table 28), an overwhelming majority (89%) had standalone Solar PV systems with batteries, whereas only 11% were grid connected solar PV.

Table 28: Type of Solar PV

Bio-Climate	Grid Connected	Standalone System
Cold	11%	89%
Cool temperate	3%	97%
Temperate	20%	80%
Warm temperate	0%	100%
Grand Total	11%	89%

5.20.3 Distribution of buildings (in %) with and without Solar water heater installation based on the bioclimatic zone.

The temperate zone had the highest penetration (28% of the households) of solar water heating systems while no household in warm temperate reported using solar water heaters (refer Table 29). While the hot water demand is maximum in cold climates, the solar water heating system has low penetration, which may be due to cheaper (e.g. firewood) alternatives available and also may be due tothe non-availability of affordable SWH which works in cold climates (addressing insulation, freezing issues).

Table 29: Use of Solar Water Heating Devices

Bio-Climate	No	Yes
Cold	94%	6%
Cool temperate	84%	16%
Temperate	72%	28%
Warm Temperate	100%	0%
Grand Total	87%	13%

5.20.4 Distribution of type of Solar Water heating system based on the bioclimatic zone

Evacuated tube collector is the main type of solar water heater technology used in all bio-climatic zones. In addition to the evacuated tube collector technology the use of curved solar heater technology was reported in the cold bio-climatic zone and that of flat plate solar water heater technology in cool temperate and temperate climates (refer Table 30).

Table 30: Type of solar water heating system installed

Bio-Climate	Curve Solar Heater	Evacuated Tube Collector	Flat Plate Solar Water Heater
cold	31%	63%	6%
Cool temperate	0%	89%	11%
temperate	0%	65%	35%

5.20.5 Predominant Capacity of the Solar Water heating system based on the building typologies.

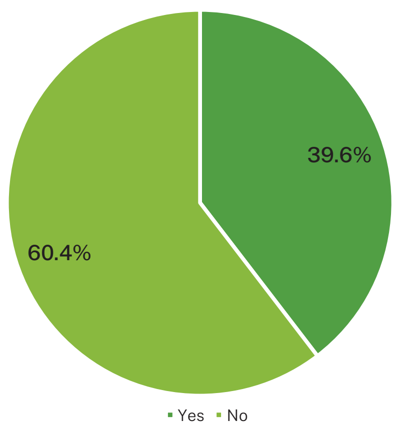
The predominant capacity for Solar Water heating systemswas found to be:

- Independent houses: 200 liters per day (lpd)
- Row Housing: 100 lpd

5.21 Energy efficiency awareness

5.21.1 Awareness of energy efficiency measure

Figure 46: Awareness of building energy efficiency measures



Out of the surveyed total households, 39.6% responded (refer Figure 46) to have awareness regarding energy awareness measures. The count of energy awareness was found to be slightly higher in male respondents at 46.4%,while it was 33.2 % for female respondents.

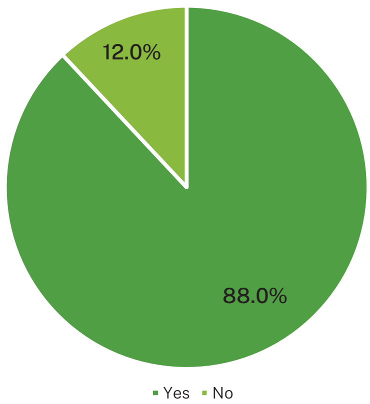
Table 31: Awareness of Energy Efficiency Measures based on Bio-climatic Zones

Bio-Climatic Zones	No	Yes
cold	55%	45%
cool temperate	61%	39%
temperate	59%	41%
warm temperate	66%	34%

Based on bio-climatic zones awareness of energy efficiency was found to be highest in cold climates (refer Table 31). This may be due to the harsh weather climate conditions and the use of vernacular technologies to follow climate-responsive design.

5.21.2 Out of the total, how many percent of the people have incorporated energy efficiency measures in their buildings?

Figure 47: Use of Energy efficiency measures



Despite only 39.6 % of people knowing energy efficiency measures, more than 88% of households have been using energy efficiency measures (refer Figure 47). Cool temperate zone reported the least use of energy efficiency measures.Among the various energy efficiency measures being used LED light is predominantly used, with more than 80% of households using LED lights for lighting purposes. Table 32 shows the percentage distribution of lack of use of any energy efficiency measures.

Table 32: Percentage distribution of lack of use of any energy efficiency measures

Bio-Climatic Zones	Energy Efficiency Measures
cold	14%
cool temperate	38%
temperate	23%
warm temperate	25%

Upon being asked about the willingness to incorporate energy efficiency measures provided technical and financial assistance is provided, 83.28% revealed their willingness. The cold climate which had the maximum expenditure per household on energy reported the highest willingness to incorporate energy efficiency measures. The willingness was reported equally in both genders. Table 33 shows the willingness to implement energy efficiency measures based on bio-climatic zones.

Table 33: Willingness to implement energy efficiency measures based on bio-climatic zones

Bio-Climatic Zones	No	Yes
cold	10%	90%
cool temperate	13%	87%
temperate	25%	75%
warm temperate	18%	82%

5.22 Summary of results

Table 34 gives an overall summary of the key survey results which are already shown in the details in the above sections of this Chapter. The results are mainly shown as per the bio-climatic zones, while some parameters are also shown as per building typology.

Table 34: Summary of baseline survey results for residential buildings

Parameter (Predominant)	Typology	cold	cool_temperate	temperate	warm_ temperate
Building construction					
Spatial configuration	All	2 or 3 BHK	2 or 3 BHK	2 or 3 BHK	2 or 3 BHK
Construction practices	All	Load bearing	RCC frame	RCC frame	RCC frame
Buil-up area (ft2)	Independent	500-1500	500-1500	750-1750	500-1500
	Row housing	500-1500	750-1750	500-1500	750-1750
Construction practices	All	Load bearing	RCC frame	RCC frame	RCC frame
Wall construction	All	Overall ~465 mm: Lime/Mud/ Cement Plaster (15-20 mm) + Stone Masonry (~430 mm) + Lime/Mud/ Cement Plaster (15-20 mm)	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	a. Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm) b. Overall 312 mm: Stone cladding (20 mm) + screed (50 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)
Roof construction	All	Overall 175 mm: Mud (125 mm) + wooden plank (50 mm)	a. Overall 77 mm: CGI (2 mm) + Wood Plank (75 mm) b. Overall 137 mm: RCC Slab (125 mm) + Cement Plaster (12 mm) c. Overall 187 mm: Screed (50 mm) + RCC Slab (125 mm) + Cement Plaster (12 mm)	a. Overall 192 mm: Ceramic Tiles (5 mm) + Screed (50 mm) + RCC Slab (125 mm) + Cement Plaster (12 mm) b. Overall 150 mm: Cement Plaster (12 mm) + RCC Slab (125 mm) + Cement Plaster (12 mm)	Overall 187 mm: Screed (50 mm) + RCC Slab (125 mm) + Cement Plaster (12 mm)
WWR range (%)	Independent	0-10	20-30	20-30	20-30
	Row housing	0-10	20-30	30-40	30-40
Window type	All	Casement with Glass or wooden Shutter	Casement with Glass	Casement with Glass	Casement with Glass
Window glazing and framing	All	Wooden frame with clear glass or wood	Wooden frame with clear glass	Wooden frame with clear glass	Wooden frame with clear glass
Window shading	All	Continuous overhang on all sides ~325 mm	Continuous overhang on all sides ~570 mm	Continuous overhang on all sides ~650 mm	Continuous overhang on all sides ~725 mm
Daylight sufficiency perception (%)	All	62	89	78	77
Ventilation sufficiency perception (%)	All	63	95	82	83

Parameter (Predominant)	Typology	cold	cool_temperate	temperate	warm_ temperate
Cold air infiltration perception (%)	All	43	27	27	30
Energy use in building					
Energy source	All	Electricity, LPG, Firewood	Electricity, LPG, Firewood	Electricity, LPG, Solar	Electricity, LPG
Annual electricity consumption (kWh/y) per household	All	342	964	1,820	2,228
Annual thermal energy consumption (MJ/y) per household	All	38,795	18,034	8,061	8,709
Annual energy expenses, total (NPR/y) per household	All	68,359	29,058	40,084	42,616
Annual energy expenses, electricity (NPR/y) per household	All	3,578	9,365	19,507	22,464
Annual energy expenses, other fuels (NPR/y) per household	All	64,781	19,693	20,577	20,152
Annual energy expenses per capita (NPR/y. person)	All	16,422	5,711	7,057	8,473
Electrical EPI, average (kWh/ m^2.y)	Independent	3.3	7.8	14.5	20.4
	Row housing	3.8	9.2	12.4	20.5
Thermal EPI, average (MJ/ m^2.y)	Independent	584	238	65	101
	Row housing	363	111	60	84
End-use: Space heating					
Energy source	All	Firewood	Electricity	Electricity	Electricity
Device used	All	Fireplace, Smokeless stoves	Radiant heater	Radiant heater	Radiant heater
Usage months	All	All months	Jan-Feb, Nov-Dec	Jan-Feb, Nov-Dec	Jan-Feb, Nov-Dec
Usage hours per day	All	2.9	2.3	2.7	2.6
End-use: Space cooling					
Energy source	All	-	Electricity	Electricity	Electricity
Device used	All	-	Table fan	Ceiling fan	Ceiling fan
Usage months	All	-	Apr-Jul	Apr-Aug	Apr-Sep
Usage hours per day	All	-	2.0	4.2	8.7

Parameter (Predominant)	Typology	cold	cool_temperate	temperate	warm_ temperate
End-use: Water heating					
Energy source	All	Firewood, Electricity	Electricity	Electricity	Electricity
Device used	All	Improved cook stove	Electric kettle	Electric kettle	Electric kettle
Usage months	All	All months	Jan-Feb, Oct-Dec	Jan-Feb, Jun-Jul, Sep-Dec	Jan, Dec
Usage hours per day	All	1.9	1.2	1.0	1.3
Renewable energy use and awareness on energy efficiency					
Houses using Solar PV (%)	All	22	10	17	5
Houses using solar water heater (%)	All	6	16	28	0
Houses aware about energy efficiency measure (%)	All	45	39	41	34
Houses implemented energy efficiency measure (%)	All	14	38	23	25

SURVEY RESULTS AND ANALYSIS: OFFICE BUILDINGS

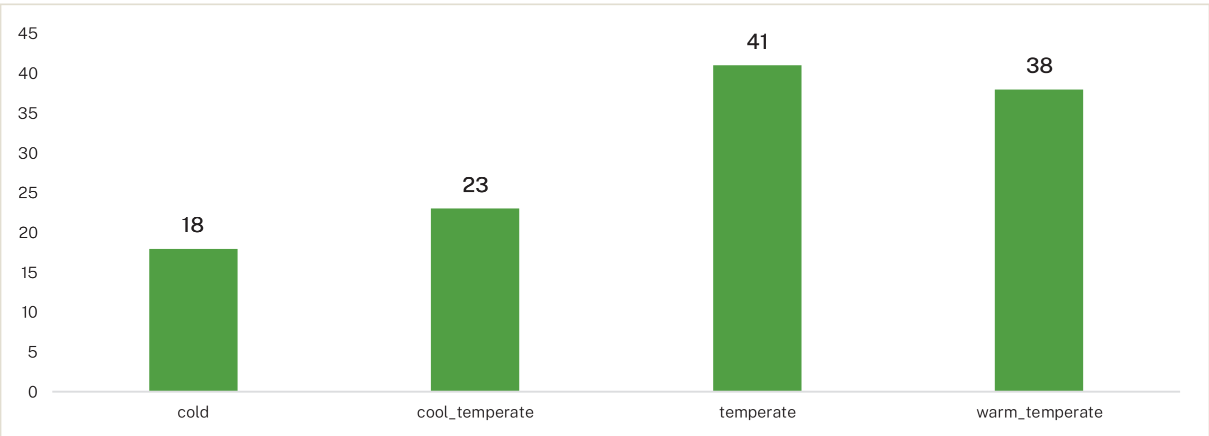
A total of 120 different office buildings were surveyed during this study. The outputs of the survey are presented in terms of different charts and tables in two sections: building characteristics and energy consumption. They are further classified in terms of bio-climatic zone and building typology.

Section I: Building Characteristics

6.1 Surveyed office distribution among bio-climatic zones and building typologies

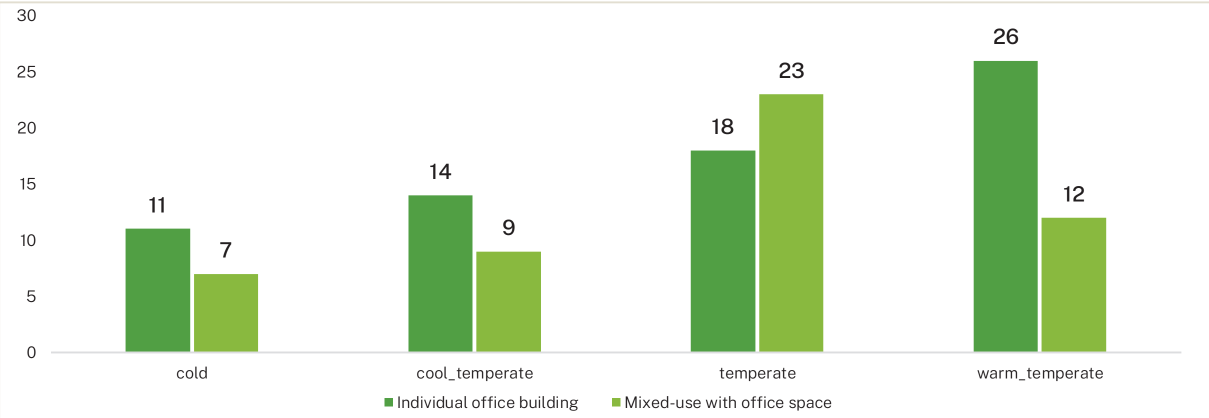
Figure 48 shows the distribution of a total of 120 surveyed offices among the bio-climatic zones, i.e., Cold, Cool temperate, Temperate, and Warm temperate. Among the surveyed buildings 34% were surveyed in the temperate climate whereas only 15% were surveyed in the cold climate. The sample size for the climate zone varied based on the overall number of buildings as well as their availability for the survey.

Figure 48: Distribution of surveyed offices as per bio-climatic zone



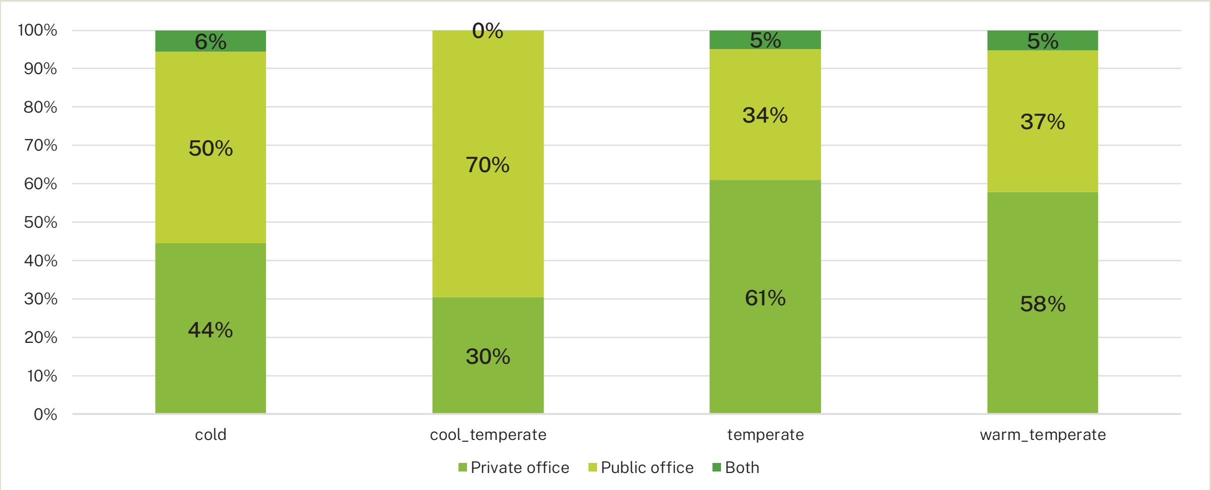
Office buildings were further divided into typologies based on individual and mixed-use spaces. Individual use office buildings were surveyed in large numbers in cold, cool, and warm temperate zones whereas in temperate zones higher numbers of mixed-use spaces were surveyed as shown in Figure 49.

Figure 49: Distribution of offices as per building typology for each bio-climatic zone



The surveyed office buildings were also categorized based on the office type (refer Figure 50). The share of public offices was more in cold and cool temperate zones, which can be attributed to the higher altitudes where public offices have to be there to deliver essential services, while due to fewer economic activities, the number of private enterprises and officesis less. Private offices were predominantly found in warm temperate and temperate zones having larger populations and economic activities.

Figure 50: Distribution of office type with bio-climatic zone



6.2 Year of construction of surveyed offices

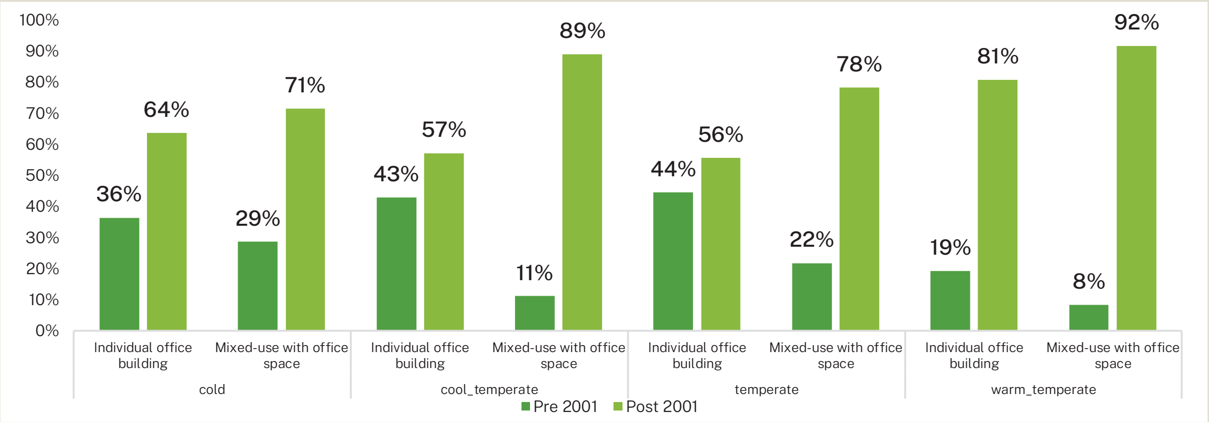
Table 35 and Figure 51 show the distribution of the office buildings based on the year of construction for each bio-climatic zone and building typology.

Table 35: Distribution of office buildings based on year of construction

Climate	Typology	1901-1950	1951-1990	1991-2000	2001-2010	2011-2020	2021-2030
Cold	Individual office building	0%	18%	18%	27%	36%	0%
	Mixed-use with office space	14%	0%	14%	29%	43%	0%
Cool temperate	Individual office building	0%	21%	21%	7%	43%	7%
	Mixed-use with office space	0%	0%	11%	22%	56%	11%
Temperate	Individual office building	0%	11%	33%	17%	39%	0%
	Mixed-use with office space	4%	0%	17%	35%	30%	13%
Warm temperate	Individual office building	0%	12%	8%	23%	42%	15%
	Mixed-use with office space	0%	0%	8%	50%	33%	8%

A majority of the office buildings were found to have been constructed post-2001, and in most climates, the largest proportion of office buildings were constructed post-2011.

Figure 51: Pre-Post 2001 year of construction distribution based on different typologies and climate zones



As shown in the figure above, a higher percentage of buildings were found to be post-2001, at each bio-climatic zone and building typology. In cool temperate and temperate the share of pre 2001 individual office buildings was found comparable to post-2001 buildings.

6.3 Site setback

The distribution of setback configurations in different bio-climatic zones reveals notable patterns. In cold climates, significant percentages (44%) of buildings have setbacks on one side, while cool temperate climates predominantly feature buildings with setbacks on all sides (52%) (Refer Table 36). In temperate climates, buildings exhibit more diversity. Warm temperate climates primarily showcase buildings with setbacks on all sides (39%). These variations reflect the influence of climate, altitude, and regional building practices on the preferred setback configurations across different bio-climatic zones.

Table 36: Distribution of setback based on Bio-climatic zones

Bio-Climatic Zones	No Setback	One Side	Two Side	Three Side	All Side
Cold	0%	44%	11%	11%	33%
Cool Temperate	4%	22%	17%	4%	52%
Temperate	5%	24%	29%	12%	29%
Warm Temperate	0%	21%	24%	16%	39%

Similarly, in the case of individual office buildings, maximum buildings were found to have setbacks on all sides, whereas mixed-use office buildings were found to have setbacks on one or two sides predominantly. Public office buildings which are built on large site areas are mostly individually used,thatmay be the reason for this finding.

6.4 Built-up area

Table 37 shows the average built-up area in different bio-climatic zones and typologies for the surveyed offices while Table 38 shows the distribution of surveyed offices as per the built-up area range for all the bio-climatic zones and the building typologies.

Table 37: Average built-up area in different bio-climatic zones and typologies

Climate	Typology	Average Area (ft^2)
Cold	Individual office building	1,375
	Mixed-use with office space	911
Cool temperate	Individual office building	2,446
	Mixed-use with office space	2,069
Temperate	Individual office building	3,500
	Mixed-use with office space	1,766
Warm temperate	Individual office building	4,244
	Mixed-use with office space	1,792

The average sizes in the cold climate were to be the smallest for both typologies. The individual offices had more built-up area and were found to be maximum in warm temperate climates.

Table 38: Predominant built-up area range in different bio-climatic zones and typologies

Area Range (ft²)	Cold		Cool Temperate		Temperate		Warm Temperate	
	Individual Office Building	Mixed-Use With Office Space	Individual Office Building	Mixed-Use With Office Space	Individual Office Building	Mixed-Use With Office Space	Individual Office Building	Mixed-Use With Office Space
0-250	-	14%	-	-	-	-	-	-
0251-500	9%	43%	-	-	-	-	-	-
0501-750	9%	14%	7%	11%	-	-	-	-
0751-1000	18%	-	14%	-	-	-	-	-
1001-1250	27%	-	14%	-	-	9%	12%	17%
1251-1500	-	-	-	-	-	9%	19%	-
1501-1750	9%	14%	-	33%	11%	43%	23%	67%
1751-2000	-	-	-	-	6%	17%	12%	-
2001-2250	9%	-	-	-	6%	13%	4%	-
2251-2500	9%	-	7%	22%	17%	4%	8%	8%
2501-2750	-	-	-	22%	6%	-	-	-
2751-3000	9%	14%	7%	-	6%	-	15%	-
3001-3250	-	-	36%	11%	17%	4%	4%	-
3251-3500	-	-	-	-	6%	-	-	-
3501-3750	-	-	7%	-	-	-	-	-
3751-4000	-	-	-	-	-	-	-	8%
5001-5250	-	-	7%	-	6%	-	-	-
5251-5500	-	-	-	-	11%	-	-	-
6751-7000	-	-	-	-	6%	-	-	-
7501-7750	-	-	-	-	6%	-	-	-
7750+	-	-	-	-	-	-	4%	-

While the area range varied a lot among building typology and the climate zone, still there were some dominant ranges found in some categories, e.g., the 1501-1750 ft² range was the predominant area range in mixed-use office buildings in temperate and warm temperate zones. In general, individual offices showed a wider range as compared to the mixed-use buildings.

6.5 Office usage

6.5.1 Public and private office

Table 39: Distribution of office with typology and usage

Type	Individual Office Building	Mixed-Use With Office Space
Both	3	2
Private office	23	39
Public office	43	10

Public offices generally have their own building; while private offices are found more in mixed-use buildings with office spaces (refer Table 39).

6.5.2 Number of occupants

Table 40: Number of occupants in different bio-climatic zones and typologies

Climate	Typology	Number of Occupants		
		Average	Min	Max
Cold	Individual office building	7	2	17
	Mixed-use with office space	4	1	8
Cool temperate	Individual office building	16	3	70
	Mixed-use with office space	10	2	28
Temperate	Individual office building	33	6	150
	Mixed-use with office space	11	4	34
Warm temperate	Individual office building	16	5	129
	Mixed-use with office space	7	4	15

While the number of occupants varied among different climate zones and typologies (refer Table 40), the predominant range was found to be 5-10 occupants.

6.5.3 Occupancy schedule

The office occupancy schedule didn't vary much as per the climate type and building typology as shown in the table. The predominant opening and closing timings of the offices were found to be 10 am and 5 pm, respectively. The schedule is also coincident with the public office schedule of the country (refer Table 41).

Table 41: Office opening and closing timings

Opening Time	Closing Time						
	04:00:00 PM	05:00:00 PM	05:30:00 PM	06:00:00 PM	06:30:00 PM	07:00:00 PM	08:00:00 PM
06:00:00 AM							1
07:00:00 AM						2	
08:00:00 AM		1					
09:00:00 AM		10	3	1			
09:30:00 AM	1	3	14	4	1	3	
10:00:00 AM	5	55	2	8			

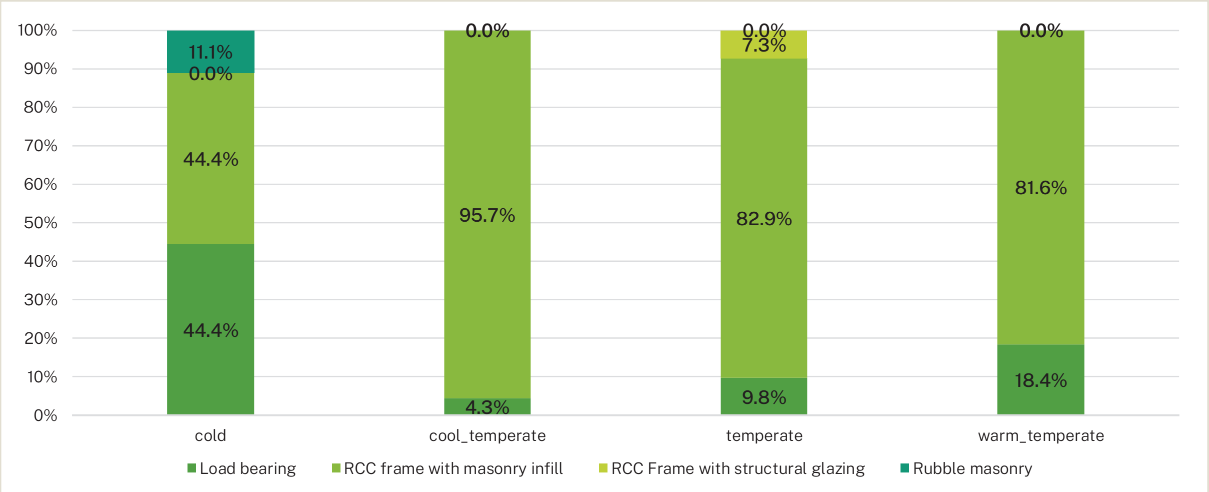
However, the differences in timings were found based on whether it was a private or public office building. While the public offices followed the predominant trend of 10 am-5 pm (7 hours working), the private offices reported 8 hours working, i.e., opening time 9-10 am and closing time 5-6 pm.

The majority (93%) of the surveyed offices reported a weekly operation schedule of 6 working days per week.

6.6 Construction technology

Figure 52 shows the construction practices as per the bio-climatic zones. Overall, RCC frame construction with masonry infill is found to be a predominant practice. However, in cold climates, an equal mix of load-bearing and RCC frames with masonry infill constructions was found. The cold climate also had rubble masonry constructions. The other three climates had RCC frame constructions with masonry infill as the predominant practice, with a small share of load-bearing constructions. Temperate climates also had few RCC frame constructions with structural glazing.

Figure 52: Predominant construction technology based on the bio-climatic zone



Considering the building typologies within the climatic zones, individual office buildings and mixed-use office space did not show any significant differences. RCC frame with masonry infill is found to be the predominant practice with 76.8% of individual office buildings, and 82.4% mixed-use office spaces.

Out of the surveyed buildings constructed pre-2001, 34% had load bearing while 59% had RCC frame constructions. In post-2001 constructed surveyed buildings, the share of load bearing reduced to 10% while the share of RCC increased to 86%. This shows the increasing popularity of RCC frame constructionsin Nepal.

6.7 Exterior wall assembly

Among the surveyed offices, it was found that the offices in cold regions had thicker walls, whereas wall thickness was reduced for the other climates. The vernacular technologies for better thermal insulation due to the construction of thicker walls in higher altitude regions are the reason for that.

Table 42: Predominant exterior wall assembly in bio-climatic zone

Bio-climatic zone	Predominant wall assembly layers and its thickness	Share in the sample size for the climate
Cold	Overall ~475 mm: Cement Plaster (12 mm) + Stone Masonry (~450 mm) + Cement Plaster (12 mm)	61%
Cool Temperate	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	74%
Temperate	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	61%
Warm Temperate	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	84%

Table 42 shows the predominant wall assembly found in different climatic zones. As so many layers combination was observed in the survey for wall assembly only predominant combinations are shown here. The survey also revealed that three-layer walls are most common in Nepal. Stone masonry was found to be predominant in the cold climate, while other climates had solid burnt brick as the predominant practice for external walls.

6.8 Roof Assembly

6.8.1 Predominant roof type

Table 43 shows the distribution of the type of roof for all the bio-climatic zones. Flat roofs were found to be the predominant roof construction in all the bio-climates. A higher percentage of inclined roof 30% was found in warm temperate zones.

Table 43: Roof type based on bio-climatic zones

Bio-Climatic Zone	Flat Roof	Gable Roof	Inclined Roof
Cold	72%	6%	22%
Cool temperate	87%	0%	13%
Temperate	93%	0%	7%
Warm temperate	76%	0%	24%

6.8.2 Predominant roof assembly

Table 44 gives the predominant type of roof assembly for each bio-climatic zone. Cold climate showed a variety of roof construction, which varied from RCC slab and wooden planks. While for the other climates,125 mm RCC slabswere found to be the main roof construction, while the composition of additional layers (plaster, screed) found some variations.

Table 44: Predominant roof assembly in bio-climatic zone

Bio-climatic zone	Predominant roof assembly layers and its thickness	Share in the sample size for the climate
Cold	Overall 137mm:RCC slab (125 mm) + Cement plaster (12 mm)	33%
	Overall 250 mm:Mud (130 mm) + Wood Plank (20 mm) + Wooden rafter (100 mm)	28%
	Overall 26 mm (without cavity) -625 mm (with cavity): CGI (0.6 mm) Air cavity (600) + Wood Plank (25 mm)	28%
Cool Temperate	Overall 210 mm: Cement plaster (12 mm) + Screed (60 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	30%
Temperate	Overall 187 mm: Screed (50 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	27%
Warm Temperate	Overall 187 mm: Screed (50 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	32%

6.9 Window to Wall Ratio (WWR)

Figure 53 shows the distribution of surveyed offices as per WWR range for different bio-climatic zones. Compared to residential buildings, office buildings were found to have higher WWR. In all the climates, more than 50% of the office buildings had a WWR -of over 30%. The predominant WWR range in cold and warm temperate climates was 30-40%, while for cool temperate and temperate climates, it was >40%.

Cold-climate offices had comparatively lower WWR as compared to offices in other climates. The lower WWR in cold climate offices can be attributed to an attempt to minimize the heat loss from the windows as well as the very low requirement for natural ventilation for thermal comfort. On the contrary, temperate climate offices showed a trend towards higher WWR, which can be mostly attributed to the potential of natural ventilation for thermal comfort in this climate and higher WWR helps in achieving the suitability of more ventilation for thermal comfort. The other two bio-climate zones cool temperate and warm temperate showed an overall WWR slightly lower as compared to temperate and much higher as compared to cold.

Figure 53: Distribution of surveyed office as per WWR range for different bio-climatic zones

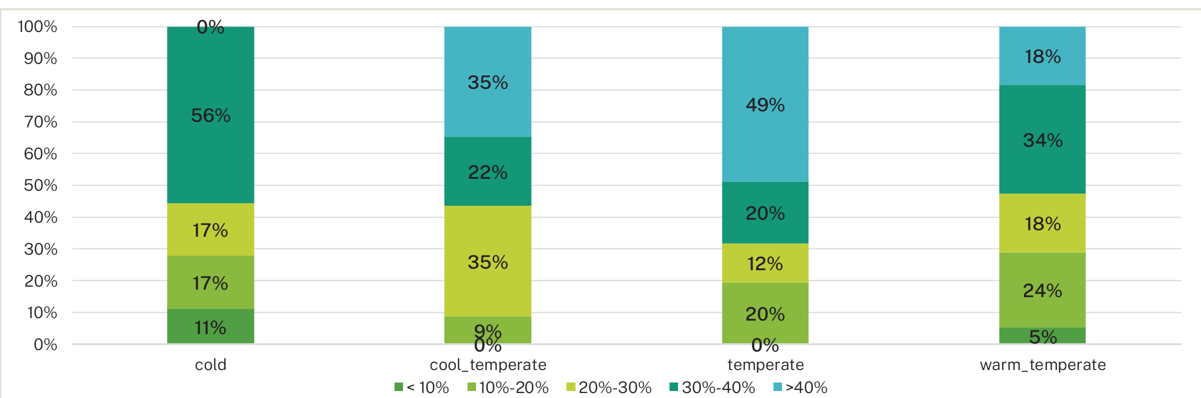
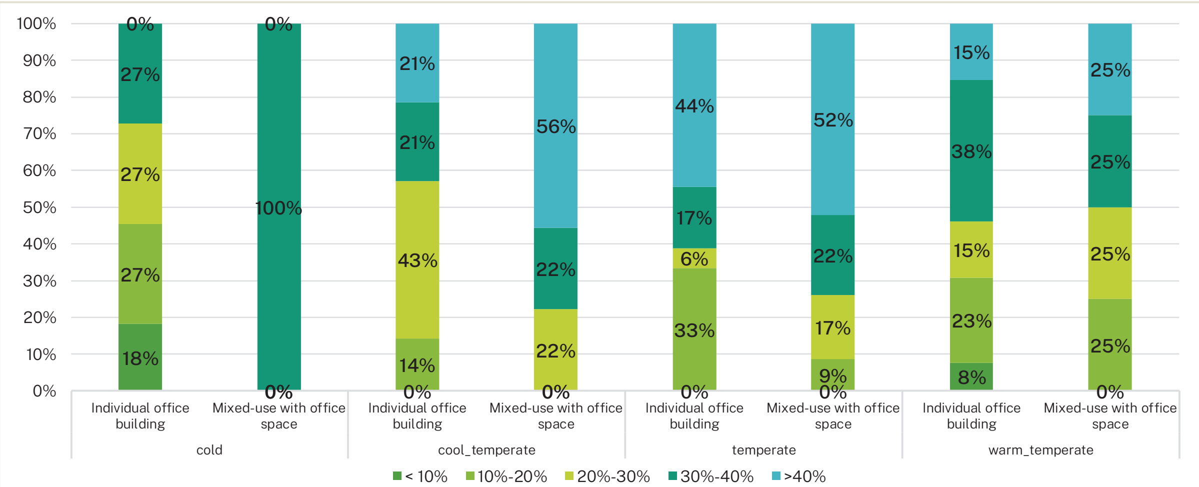


Figure 54 shows the distribution of surveyed offices as per WWR range for different typologies under each bio-climatic zone. In all climatic zones, it was found that the 'mixed-use with office space' building typology had higher WWR as compared to 'individual office building'. For the cold climate, all the offices under 'mixed-use with office space' found to be in the 30-40% WWR range. Low WWR (<10%) was found only in a cold and warm temperate climate in 'individual office building'. A higher WWR in the 'mixed-use with office space'building typology can be attributed to the less exposed wall area available (as compared to 'individual office building') which also needs to accommodate sufficient windows to allow required daylight and ventilation.

Figure 54: Distribution of surveyed offices as per WWR range for different typologies under each bio-climatic zone



6.10 Window type

Table 45 shows the window type for different bio-climatic zones. The surveyed data among 120 offices showed that overall, the casement window is the predominant window type. Sliding windows were almost equally popular in cool temperate and warm temperate climates. In temperate climates, 'Glass Glazing with few openings' was also found a popular window type. The wooden shutter is only found in cold climates. The trends among building typologies within the bio-climatic zones followed similar trends. However, in a cool temperate climate, 'mixed-use with office space' typology had more sliding windows, whereas the 'individual office building' had more casement windows.

Table 45: Predominant window type

Bio-Climate	Casement Window	Glass Glazing With Few Openings	Pivoted Window, Hung Window	Sliding Window	Structural Glazing	Fixed Glass Window	Wooden Shutter
Cold	78%	0%	0%	11%	0%	0%	11%
Cool temperate	48%	4%	0%	48%	0%	0%	0%
Temperate	39%	32%	0%	15%	12%	2%	0%
Warm temperate	45%	8%	3%	39%	3%	3%	0%
Overall	48%	14%	1%	28%	5%	2%	2%

6.11 Window glazing and framing

Table 46 shows window glazing and framing assembly for all bio-climatic zones. Overall, it shows that the single clear glass is predominant for glazing, while for window framing, both wooden and aluminum frames are used. For cold climates, wooden framing was predominant, whereas for the other three climate zones, aluminum framing was predominant. The use of 'single tinted glass' has been predominantly observedin the temperate and warm temperate climates along with aluminum framing.

Table 46: Window glazing and framing assembly for all bio-climatic zones

1.1.1.1.2	Single Clear Glass Panes	Single Tinted Glass	No Glass	Grand Total
Cold	15		3	18
Aluminum	2			2
Wooden	13		3	16
Cool_temperate	20	3		23
Aluminum	10	3		13
Wooden	10			10
Temperate	23	18		41
Aluminum	8	14		22
Mild steel	1			1
Pvc/upvcs		3		3
Wooden	14	1		15
Warm_temperate	24	13	1	38
Aluminum	10	10		20
Pvc/upvcs		1		1
Wooden	14	2	1	17
Grand total	82	34	4	120

Table 47 shows the overall predominant window type, framing, and glazing combinations, observed within the surveyed office buildings.

Table 47: Predominant window assembly is based on the bioclimatic zone

Window Assembly	Cold	Cool Temperate	Temperate	Warm Temperate
Casement window+ Wooden+ Single clear glass panes	72.2%	43.5%	31.7%	36.8%
Sliding window+ Aluminium+ Single clear glass panes	11.1%	39.1%	12.2%	21.1%
Sample size	18	23	41	38

6.12 Window shading

Table 48 shows the different types of shading used as per the bio-climatic zones. The survey data shows that the predominant type of shading used across all climates is the continuous overhang (at roof level). Further, Table 49 shows the average depth of the continuous overhang (at roof level) shading for different orientations for all climatic zones. The average shading depth is found to be minimal for cool temperate climates, while the maximum is for warm temperate climates. Higher depth of shading in warm temperate can attributed to higher temperature and better control to reduce the solar heat gain. In terms of direction, higher shading depth is found in the south direction followed by the west direction.

Table 48: Shading type with bio-climatic zone

Bio-Climate	Continuous Overhang(at roof level)	No Shading	Overhang Over Windows
Cold	56%	33%	11%
Cool temperate	78%	9%	13%
Temperate	63%	34%	2%
Warm temperate	66%	32%	3%

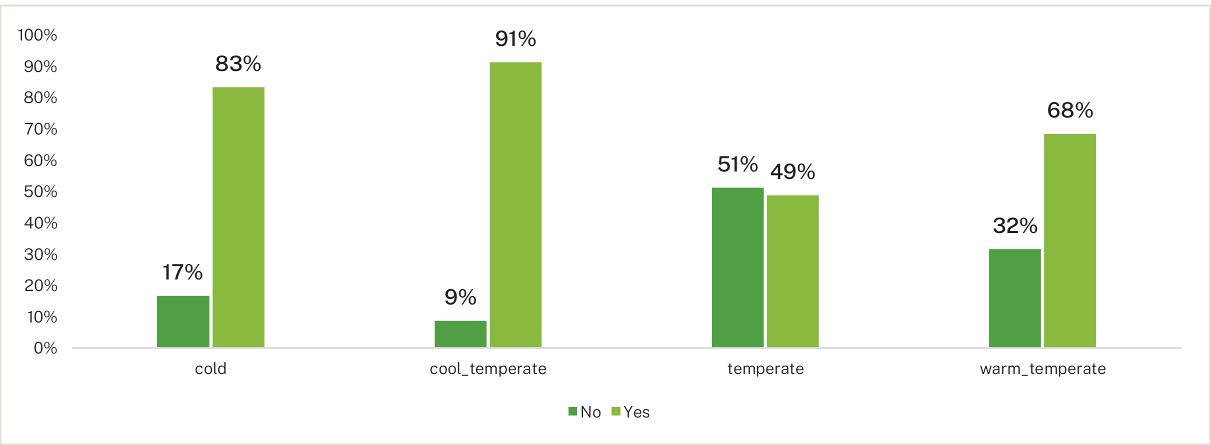
Table 49: Predominant shading depth with bio-climatic zone

Bio-Climate	Average depth of continuous overhang shading (mm)			
	North	South	East	West
Cold	500	669	470	475
Cool temperate	427	445	416	382
Temperate	491	543	532	609
Warm temperate	575	675	450	650

6.13 Perception of respondents on daylight, ventilation, and air infiltration

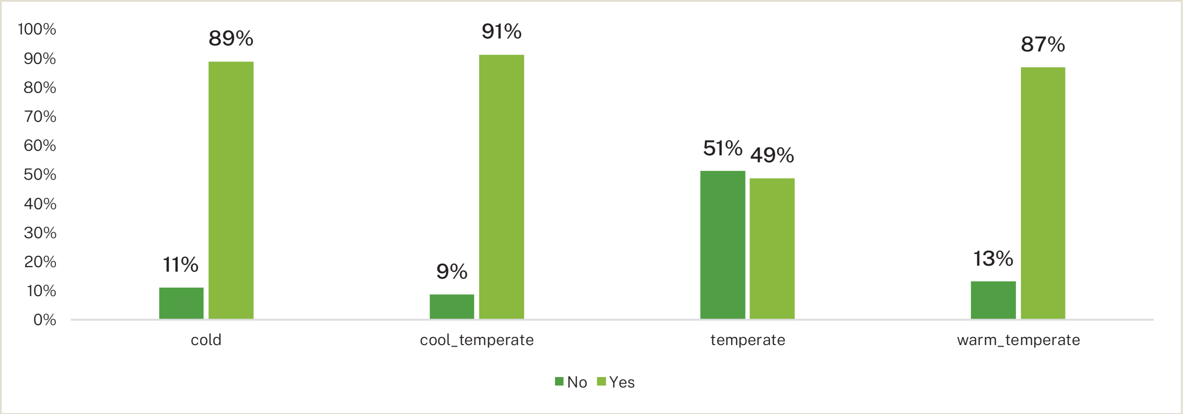
During the survey, the respondents were asked if they get sufficient daylight inside the regularly occupied spaces during the daytime. Figure 55 shows their responses for each climatic zone. It shows that for the cold and cold temperate climate, most of the respondents said that daylight is sufficient except, which can be attributed to the use of clear glass (with high visual light transmission) along with sufficient WWR. In temperate and warm temperate climates, a significant number of respondents reported that daylight is not sufficient, which can be attributed the use of tinted glass (44% of buildings in temperate and 34% of buildings in warm temperate) allowing less light transmission.

Figure 55: Daylight sufficiency perception



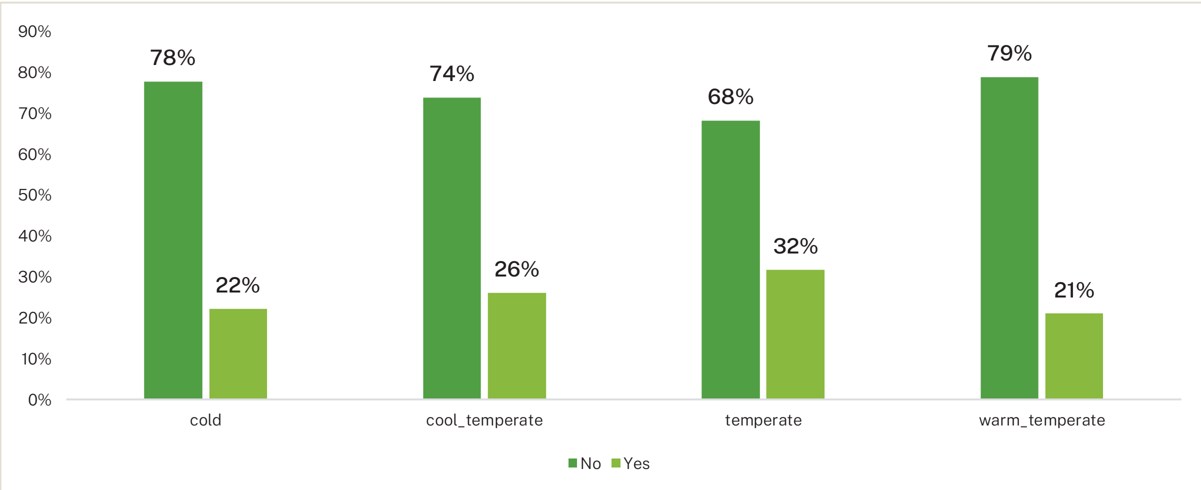
During the survey, the respondents were asked if they get sufficient ventilation during the summer months. Figure 56 shows their responses for each climatic zone. It shows that except for the temperate climate, most of the respondents in other climates found ventilation to be sufficient. While in temperate climates, 51% of the respondents found that ventilation is not sufficient, which can be attributed to the 59% of the buildings having window type (glass glazing with few openings, sliding windows and structural glazing) which allows no/low ventilation in the building.

Figure 56: Ventilation sufficiency perception



During the survey, the respondents were asked if they experience cold air infiltration during winter months while the windows are closed. Figure 57 shows their responses for each climatic zone. While most of the respondents said they do not experience cold air infiltration; still there is a good share of respondents who experienced it, in all climate zones. This can be attributed to the inadequacy of proper sealing of windows, which allows more infiltration in those buildings. It also suggested that the proper sealing of windows needs to be practiced to minimize the infiltration.

Figure 57: Cold air infiltration perception



Looking at the construction technology, it was found that higher infiltration is found in the buildings with rubble masonry as construction technology (refer Table 50).

Table 50: Construction technology-wise perception of cold air infiltration

Construction Technology	No	Yes
Load bearing	75.00%	25.00%
RCC frame with masonry infill	74.74%	25.26%
RCC Frame with structural glazing	66.67%	33.33%
Rubble masonry	50.00%	50.00%

Based on these three perception ideas, it suggests that the office buildings in the temperate climates need better building design to better manage daylight, ventilation, and infiltration.

On further analysis based on gender perspective (refer Table 51), a relatively smaller number of female respondents reported daylight and ventilation sufficiency as compared to males, while more male respondents reported cold air infiltration.

Table 51: Gender-wise response on daylight, ventilation, and infiltration

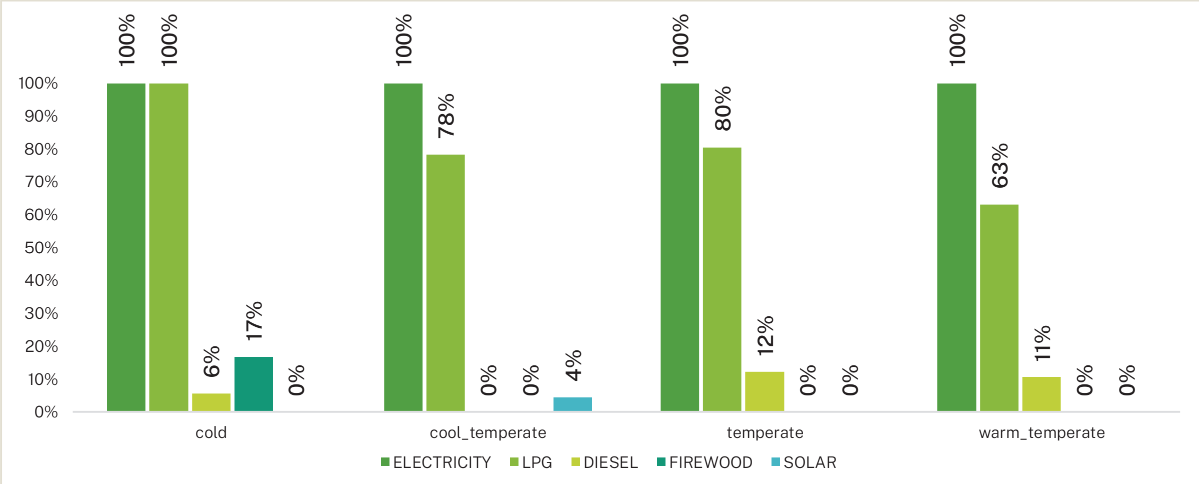
Gender	Daylight is Sufficient	Ventilation if Sufficient	Has Cold Air Infiltration
Female	63%	68%	20%
Male	71%	79%	29%

Section II: Energy Consumption

6.14 Distribution of different fuel types based on the climate zone

The use of different fuels in various bio-climatic zones was examined, highlighting the percentage of offices relying on each fuel type (refer Figure 58). Electricity is the most common energy source which is used by 100% of the offices in all bio-climatic zones. Use of LPG is 100% in cold climates but slightly reduced in other regions. Firewood was also found in 17% of total surveyed buildings in cold climatic zones only. Diesel as a power backup fuel is also used in 12% and 11% of the surveyed buildings in temperate and warm temperate climates, respectively. The use of solar energy is observed only in very few buildings in cool temperate climate zones.

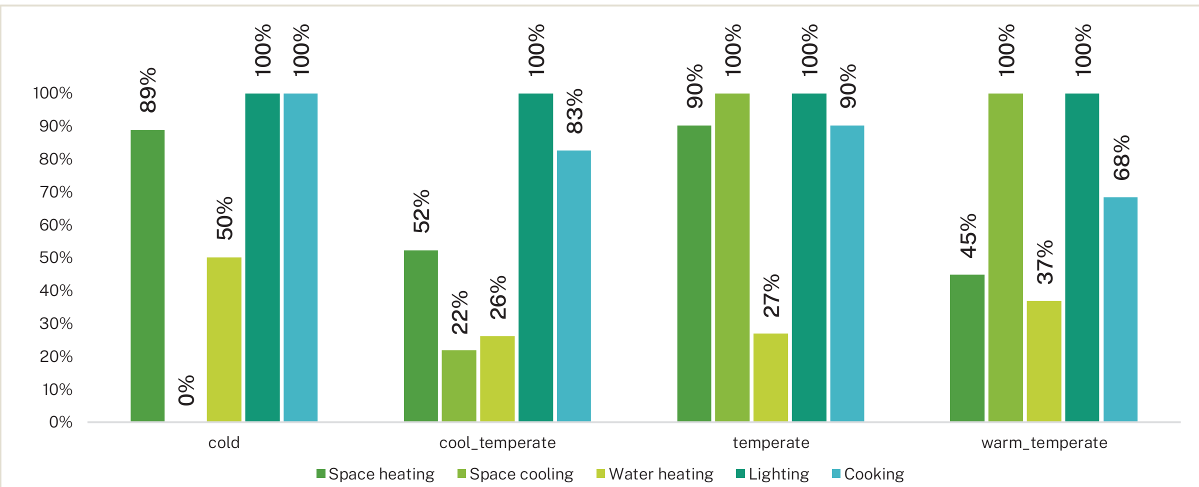
Figure 58: Use of different fuel/energy based on the bio-climatic zone



6.15 Type of fuel for all different end-uses

6.15.1 End-use of energy

Figure 59: Percentage of offices using energy for key end-uses in different bio-climatic zones



Lighting is an essential requirement which is found to be 100% in climatic zones, while cooking is also found significantly high percentages considering office buildings (refer Figure 59). Space heating had a varied trend that did not follow the climatic conditions and may need further investigation. Water heating was found to be maximum in cold climates and lower for other regions. Space cooling trends followed the climatic conditions and were quite logical.

The use of different end uses also depends on the sophistication of office spaces. The temperate climate has the highest percentage of buildings using space heating as the government units selected in this climate are more of anurban nature.

6.15.2 Distribution of energy source for end-use

Survey results (refer Table 52) clearly show that electricity is the predominant energy source for space heating in all climatic zones. Use of firewood is also found in cold climates, while LPG is also used in a few offices.

Table 52: Distribution of energy source used for space heating in bio-climatic zones

Bioclimatic Zones	Electricity	LPG	Firewood
cold	94%	6%	13%
cool_temperate	100%	8%	0%
temperate	97%	8%	0%
warm_temperate	100%	0%	0%

Note: The percentages are given only for the offices which reported space heating as an end-use of energy. Some offices reported more than one energy source; hence, the total can exceed 100%.

For space cooling, electricity is the predominant energy source with 100% of the offices using it in the cool temperate, temperate, and warm temperate climate.

Survey results (refer Table 53) showed that multiple energy sources are being used for water heating in all bio-climatic zones. Electricity is predominantly used for water heating in all climatic zones. The second predominant fuel for water heating was LPG which also had some share in all climatic zones. The use of solar systems for water heating was only reported in temperate climates.

Table 53: Distribution of energy source used for water heating in bio-climatic zones

Bioclimatic Zones	Electricity	LPG	Solar	Firewood
cold	89%	22%	0%	22%
cool_temperate	67%	17%	0%	17%
temperate	73%	27%	9%	9%
warm_temperate	93%	7%	0%	0%

6.16 Predominant device and their usage for different end uses

6.16.1 Predominant device for different end uses

Based on the predominant energy source for different end-uses (as per the previous section), the survey was further analyzed to show the corresponding devices that are used for end-use and the predominant combination for each bio-climatic zone. Table 54 shows that radiant heaters are the predominant devices used for space heating in cold and temperate climates, while AC in warm temperate climates and electric convection heaters in cool temperate climates. Table 55 shows that split AC and ceiling fans are the predominant devices used for space cooling in cool temperate, temperate and warm temperate climates. Table 56 shows electric kettle is the predominant device used for water heating in all climatic zones.

Table 54: Predominant device for space heating as per predominant energy source for different climates

Bio-Climatic Zone	Energy Source	Predominant Device	Percentage Use of Predominant Device
Cold	Electricity	Radiant heater	87%
Cool Temperate	Electricity	Electric Convention heater	75%
Temperate	Electricity	Radiant heater	56%
	Electricity	AC	50%
Warm Temperate	Electricity	AC	65%

Table 55: Predominant device for space cooling as per predominant energy source for different climates

Bio-Climatic Zone	Energy Source	Predominant Device	Percentage Use of Predominant Device
Cool Temperate	Electricity	Split AC	80%
Temperate	Electricity	Split AC	54%
	Electricity	Ceiling fan	51%
Warm Temperate	Electricity	Ceiling fan	74%
	Electricity	Split AC	50%

Table 56: Predominant device for water heating as per predominant energy source for different climates

Bio-Climatic Zone	Energy Source	Predominant Device	Percentage Use of Predominant Device
Cold	Electricity	Electric kettle	56%
Cool Temperate	Electricity	Electric kettle	50%
Temperate	Electricity	Electric kettle	45%
Warm Temperate	Electricity	Electric kettle	43%

6.16.2 Usage of the predominant device for different end uses

Table 57, Table 58 and Table 59 show the usage schedule (month-wise and average usage hours per day) for the combination of the predominant energy source and device for each bio-climatic zone. All the numbers (hours per day and percentages) shown are calculated considering only the selected offices.

Space heating: In a cold climate, space heating is operated was observed round-the-year with few offices, while more usage (>50% offices) was found during Aug-Jan. In cool temperate climates, the peak usage was found duringNov-Feb, while average usage hours were more as compared to the cold climates. It was observed that in offices in temperate and warm temperate climate zones, the heating is in a few offices around the year, the peak usage was observed during Nov-Feb. Interestingly, the usage hours per day was higher in temperate climates, which might need further investigation. While using AC for heating in temperate and warm temperate zones, the predominant set-point for space heating is found to be 28-30°C.

Table 57: Operational schedule for predominant devices for space heating

Bio-climatic zone / Energy source / Predominant device	Average usage (h/d)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cold / Electricity / Radiant heater	4.4	62%	46%	46%	31%	23%	15%	15%	62%	77%	85%	100%	100%
Cool Temperate / Electricity / Electric Convention heater	5.7	100%	100%	44%	0%	0%	0%	0%	0%	11%	44%	67%	100%
Temperate / Electricity / Radiant heater	4.6	85%	50%	0%	0%	0%	0%	0%	0%	0%	10%	85%	100%
Temperate / Electricity / AC	7.6	100%	89%	50%	39%	39%	44%	44%	44%	33%	83%	94%	100%
Warm Temperate / Electricity / AC	4.8	100%	100%	44%	44%	44%	44%	44%	44%	44%	44%	56%	100%

Space cooling: Space cooling in warm temperate climates had high usage in Mar-Oct with the highest average usage hours per day. The temperate climate had usage in Mar-Sep, with average usage hours very close to the warm temperate climate. For cool temperate climates, usage was observed round the year, however, the sample size (4 nos.) was very small and the usage hours were less. The predominant temperature set for the cooling range was found to be 18-20°C for both temperate and warm temperate zones.

Table 58: Operational schedule for predominant devices for space cooling

Bio-climatic zone / Energy source / Predominant device	Average usage (h/d)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cool Temperate / Electricity / Split AC	4.1	50%	50%	50%	100%	100%	100%	50%	50%	50%	25%	50%	50%
Temperate / Electricity / Split AC	6.2	32%	32%	41%	82%	95%	100%	100%	82%	55%	27%	32%	32%
Temperate / Electricity / Ceiling fan	5.6	0%	0%	38%	81%	90%	100%	95%	76%	19%	0%	0%	0%
Warm Temperate / Electricity / Ceiling fan	6.5	0%	14%	79%	100%	100%	100%	100%	93%	86%	54%	4%	0%
Warm Temperate / Electricity / Split AC	5.5	44%	44%	72%	100%	100%	100%	100%	89%	67%	56%	50%	44%

Water heating: In cold and cool temperate climates, water heating is operated aroundtheyear. For temperate and warm temperate climates, the peak usage was in Nov-Feb.

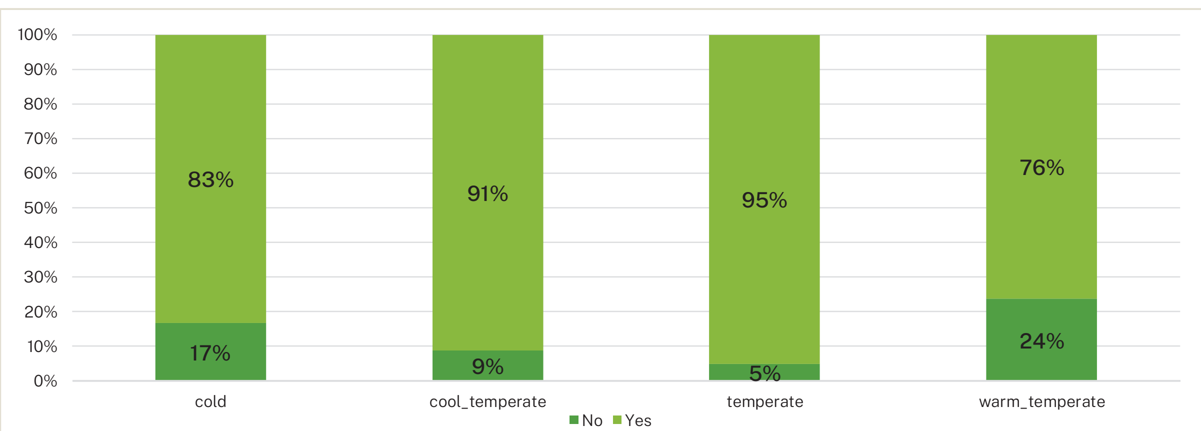
Table 59: Operational schedule for predominant devices for water heating

Bio-climatic zone / Energy source / Predominant device	Average usage (h/d)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cold / Electricity / Electric kettle	3.2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Cool Temperate / Electricity / Electric kettle	2.0	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Temperate / Electricity / Electric kettle	2.8	80%	80%	40%	40%	40%	40%	40%	40%	40%	40%	80%	100%
Warm Temperate / Electricity / Electric kettle	4.1	83%	50%	17%	0%	0%	0%	0%	0%	17%	33%	67%	100%

6.17 Power backup system

6.17.1 Distribution of building with power backup system based on bio-climatic zone

Figure 60: Provision of Power Back-up System based on bio-climatic zones



Being commercial buildings, the majority of the offices in all the climatic zones had a provision of backup system. The maximum percentage was found in temperate climates while the minimum was in warm temperate climates (refer Figure 60). These differences might be due to the electricity supply conditions in the locations where the offices were surveyed.

6.17.2 Predominant power backup system

Figure 61: Predominant Power backup system based on bio-climatic zones

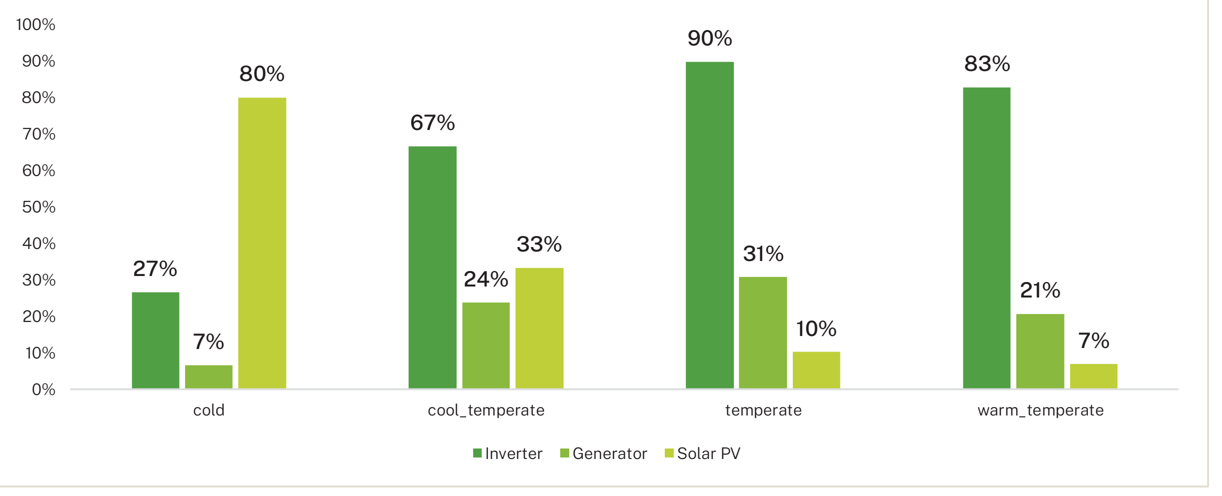
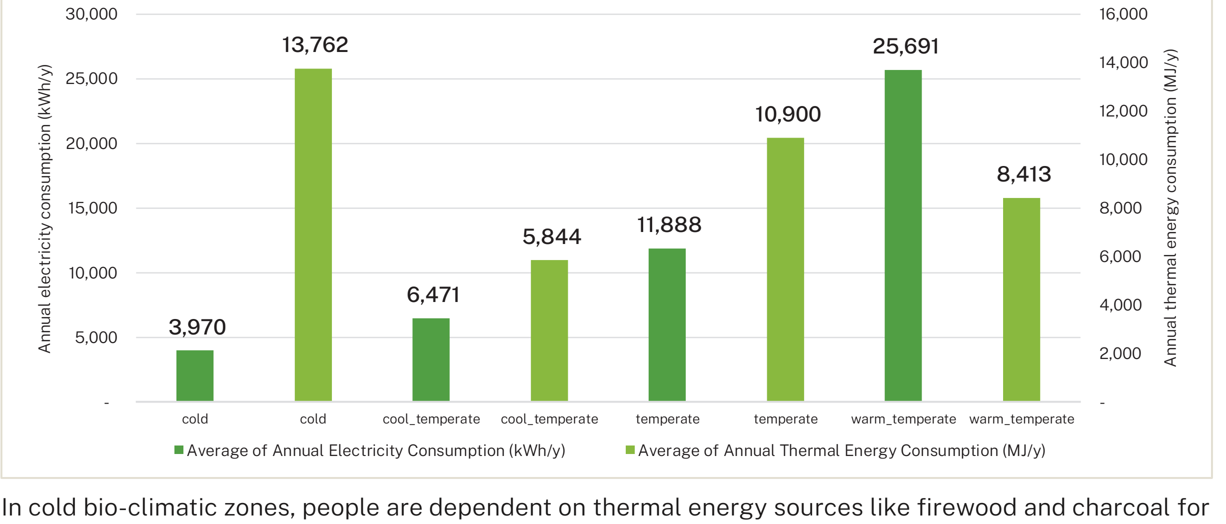


Figure 61 shows the usage of power backup devices among the offices that have a power backup system in place, as per the climatic zone. The total may exceed 100% of value as many offices use multiple devices for power backup. There is a good penetration of solar PV systems in the cold climate (~80%) observed in the surveyed offices. For the other three climates, invertersare reported as the predominant device for power backup in the surveyed offices.

6.18 Overall electrical and thermal energy consumption

Figure 62 shows the annual average electrical and thermal energy consumption per office building as per climate. Depending on the types of fuels used the proportion of electrical and thermal energy changes as per the bio-climatic zone. These variations in energy consumption in different bio-climatic zones highlight the influence of climate, end-use, local energy availability, and feasibility of alternative energy sources.

Figure 62: Annual average electrical and thermal energy consumption per office building as per bio-climatic zone

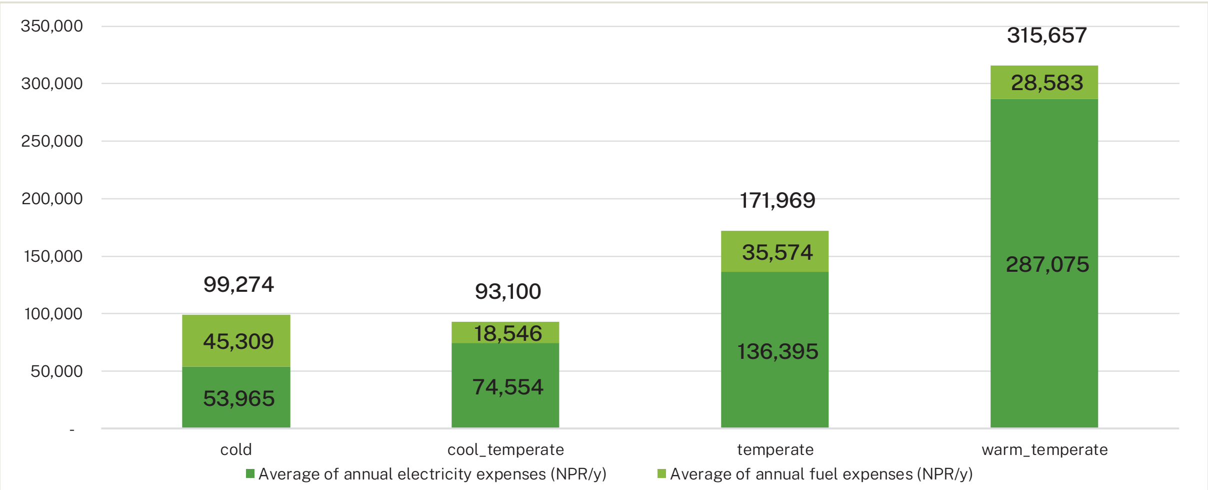


In cold bio-climatic zones, people are dependent on thermal energy sources like firewood and charcoal for space heating, cooking, and water heating purposes, which leads the higher thermal energy consumption. Also, electrical energy is mainly used for lighting in the cold bio-climatic zone, leading to lower consumption. As we move towards warmer climates i.e. temperate and warm temperate bio-climatic zones, the use of electricity-based space cooling devices for thermal comfort increases, and therefore electrical energy consumption is more. In the case of the cool temperate and temperate bio-climatic zone, there is a good mix of electrical and thermal energy consumption, due to a mix of fuel availability and end-uses.

6.19 Total annual energy expenses

Based on the energy source, its consumption, and prevailing electricity/fuel rates, estimation was made for the total annual energy expenses. Figure 63 shows the average total annual energy expenses per office building for all bio-climatic zones. The maximum is for the warm temperate bio-climatic zone, mainly due to the high energy requirements for air-conditioning due to extreme weather conditions. The lowest is for the cool temperate bio-climatic zone, as this zone has more energy supply options and relatively lower requirements for thermal comfort.

Figure 63: Average of total annual energy expenses for all bio-climatic zones



6.20 Per capita energy consumption and expenditure

Table 60 gives the average annual consumption[20] of electrical energy, thermal energy, and estimated energy expenses per capita per year for all bio-climatic zones. The trends among the climatic zones follow the same trend as given for the total energy expenses. In cold climates, firewood is the major energy source for thermal energy consumption. While the consumption is higher, the firewood is sourced locally and a large part of it is collected manually which does not add to the expenses.

Table 60: Average of energy expenses per capita per year

Bio-climatic zone	Annual electricity consumption per capita (kWh/y.person)	Annual thermal energy consumption per capita (MJ/y.person)	Annual energy expenses per capita (NPR/y.person)
Cold	643	2,228	16,073
Cool_temperate	189	417	6,650
Temperate	320	639	10,085
Warm_temperate	443	637	23,884

20 For each bio-climatic zone, annual electricity consumption per capita = (total electricity consumption by all offices in that bio-climatic zone) / (total number of persons in all offices in that bio-climatic zone) Similar, calculations are done for "annual thermal energy consumption per capita" and "annual energy expenses per capita".

6.21 Energy Performance Index (EPI) – Electrical and Thermal

Figure 64 and Figure 65 show the average electrical EPI[21] and thermal EPI, respectively, as well as its spread (box and whisker plot) as per bio-climatic zones. The numbers in the middle of the box show the average values. The spread shows that with the higher average EPI, the spread also increases.

The overall trend for electrical and thermal EPI is in line with the explanation given in the previous section. While the total electricity consumption showed an increasing trend from cold to cool temperate zone, the EPI doesn't follow the same. This is mainly due to the smaller office sizes in the cold climate which led to higher EPI.Survey results also showed that there are offices in cool temperate, temperate, and warm temperate climatic zones that only rely on electricity and no other fuel is used (primarily absence of LPG used for cooking).Thermal EPI is the highest in cold climate zones, followed by temperate climates. Dependency on diesel was observed higher in temperate zones as a result of increased thermal EPI.

Figure 64: Electrical EPI for office buildings as per bio-climatic zone

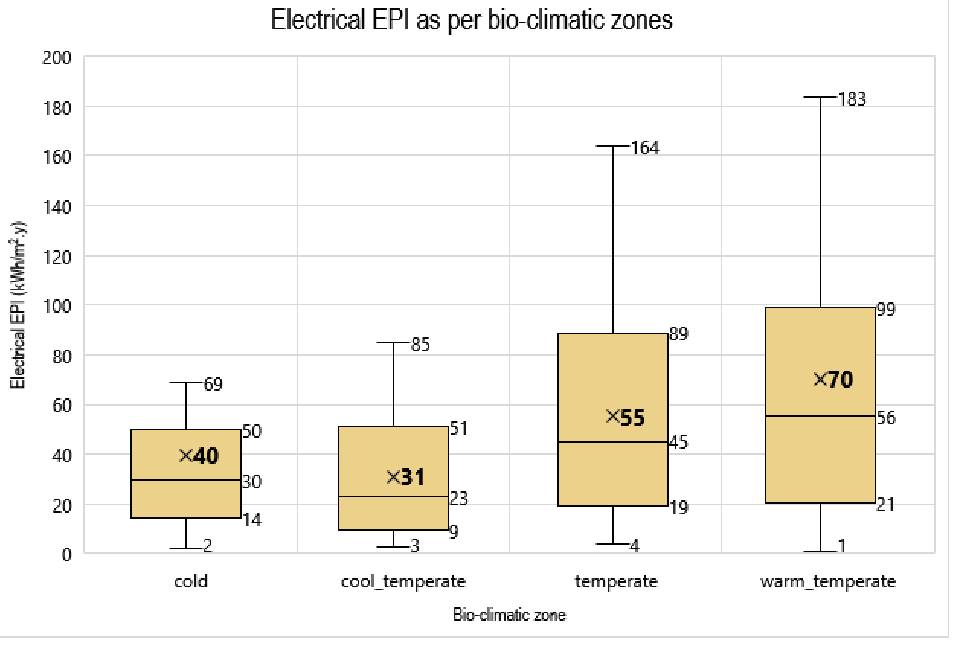
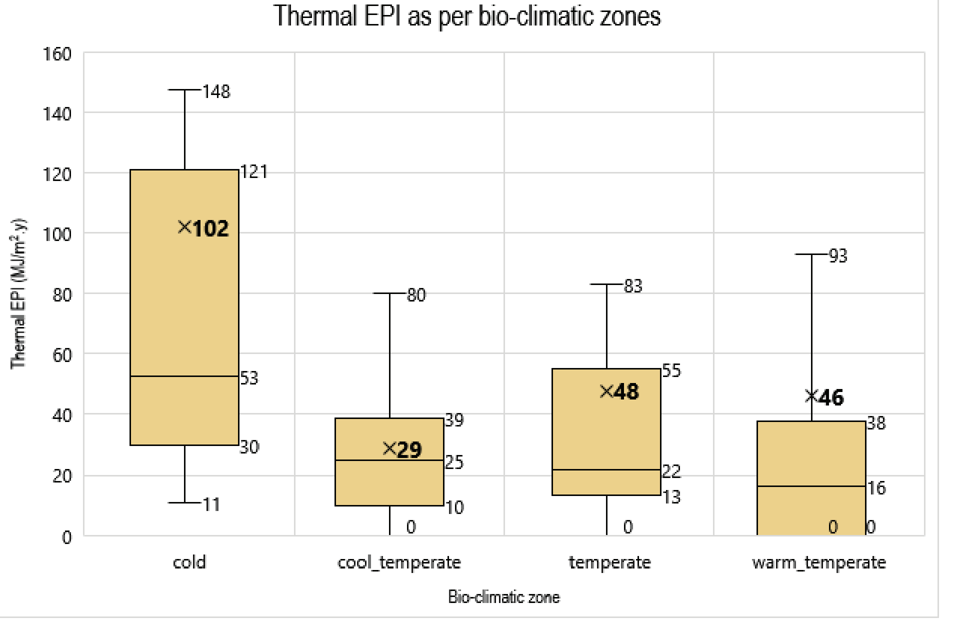


Figure 65: Thermal EPI for office buildings as per bio-climatic zone



21 For each bio-climatic zone, average electrical EPI = (sum of EPI of all offices in that bio-climatic zone) / (total number of offices in that bio-climatic zone) Similar, calculations are done for "average thermal EPI".

Table 61: Electrical and thermal EPI based on the building typologies

Climate / Typology	Average of Electrical EPI (kWh/m².y)	Average of Thermal EPI (MJ/m².y)
Cold	**40**	**102**
Individual office building	44	103
Mixed-use with office space	31	100
Cool_temperate	**31**	**29**
Individual office building	26	27
Mixed-use with office space	39	32
Temperate	**55**	**48**
Individual office building	54	79
Mixed-use with office space	56	25
Warm_temperate	**70**	**46**
Individual office building	67	50
Mixed-use with office space	78	37

While some of the explanations are given for climatic zones, the building typologies did not follow any predominant trend for electrical and thermal EPI (refer Table 61). The Electrical EPI values, range from 31 to 70 kWh/m².y, represent the average electrical energy consumption patterns within each climatic zone. The EPI variations are influenced by various factors, notably the prevailing climate and associated energy needs which are explained in the subsequent sections.

6.22 Solar water heating and Solar PV

6.22.1 Distribution of buildings (in %) with and without Solar PV installation based on the bioclimatic zone

Table 62: Availability of Solar PV

Bio-Climatic Zones	No	Yes
Cold	33%	67%
Cool temperate	78%	22%
Temperate	90%	10%
Warm temperate	95%	5%
Grand Total	**81%**	**19%**

The cold climate had good penetration of solar PV as 2/3rd of the surveyed offices are using it. Most respondents in temperate and warm temperate climatic zones said that solar PV is not used in their offices. Slightly higher use of solar PV was observed in cool temperate climates. These findings suggest that solar PV installations increase as we move to the colder region (refer Table 62).

6.22.2 Distribution of type of Solar PV (standalone, grid-connected) based on the bioclimatic zone

Table 63: Type of Solar PV

Bio-Climate	Grid Connected	Standalone System
Cold	42%	58%
Cool temperate	20%	80%
Temperate	50%	50%
Warm temperate	0%	100%
Grand Total	**35%**	**65%**

The use of a standalone type of Solar PV is more common in cool temperate and warm temperate climates, while in cold and temperate climates both types are being used (refer Table 63). Overall, standalone-type solar PV systems are found in 2/3rd of the surveyed houses ,that have solar PV.

6.22.3 Distribution of buildings (in %) with and without solar water heater installation based on the bioclimatic zone.

Table 64: Use of solar water heating services

Bio-Climate	No	Yes
Cold	78%	22%
Cool temperate	96%	4%
Temperate	98%	2%
Warm Temperate	100%	0%
Grand Total	**95%**	**5%**

Except for cold climates, all other climates had no or very low penetration of solar water heating systems. Overall, solar water heating systems had only 5% penetration among surveyed offices, with a maximum of 22% in the cold climate (refer Table 64). These findings also suggest that solar water heater installations increase as we move towards colder regions.

6.22.4 Distribution of type of solar water heating system (flat plate, evacuated tube) based on the bioclimatic zone.

Table 65: Type of solar water heating system installed

Bio-Climate	Evacuated Tube Collector	Flat Plate Solar Water Heater
Cold	75%	25%
Cool temperate	100%	0%
Temperate	0%	100%
Grand Total	**67%**	**33%**

Evacuated tube collector is the predominant type used in cold and cool temperate climates while flat plate collectors in temperate climates. Overall, evacuated tube collectors are found to be the predominant type (refer Table 65).

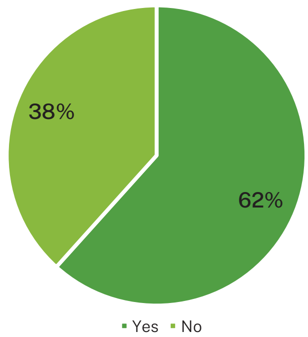
6.22.5 Predominant capacity of the solar water heating system based on the building typologies

In terms of building typologies, no mixed-use office space was found to be using solar water heating services. The average capacity for individual office space was found to be ~320LPD.

6.23 Energy efficiency Awareness and Use

6.23.1 Energy Efficiency Awareness

Figure 66: Energy efficiency awareness



Among the total surveyed office buildings, 62% responded to have awareness about energy efficiency measures (refer Figure 66). The count of energy awareness was found to be slightly higher in female respondents at 65%, while it was 60% for male respondents. Table 66 shows the awareness of energy efficiency measures based on bio-climatic zones.

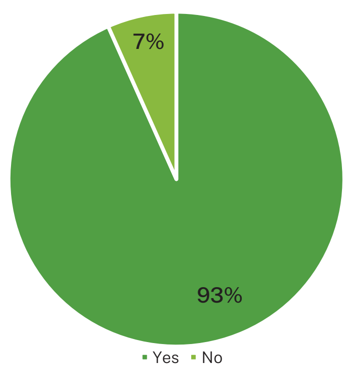
Table 66: Awareness of energy efficiency measures based on bio-climatic zones

Bio-Climatic Zones	No	Yes
cold	17%	83%
cool temperate	78%	22%
temperate	24%	76%
warm temperate	39%	61%

Based on bio-climatic zones awareness of energy efficiency was found to be highest in cold climates. This may be due to the harsh weather climate conditions and the use of vernacular technologies to follow climate-responsive design.

6.23.2 Incorporation of Energy Efficiency Measures

Figure 67: Incorporation of different energy efficiency measures



Out of all surveyed buildings, 93% have incorporated energy efficiency measures (refer Figure 67), which is mainly the use of LED lights. Table 67 shows the use of different energy efficiency measures.

Table 67: Use of different energy efficiency measures

Energy Efficiency Measures	Percentage of offices using it
Building Management System	0.9%
Card Based Lighting	1.8%
Double Glazed Windows	2.7%
LED Lights	98.2%
Sub Metering	2.7%
Roof Insulation	2.7%

Out of the office using energy efficiency measures, 98% are using LED lights. Some offices reported double glazing, sub-metering and roof insulation as well. Table 68 shows the use of energy efficiency measure by bio-climate.

Table 68: Use of energy efficiency measure by bio-climate

Climate Zone	No	Yes
cold	0%	100%
cool temperate	9%	91%
temperate	0%	100%
warm temperate	16%	84%

The use of energy efficiency measure was found to be 100% in cold climates and temperate climates. Higher awareness of energy efficiency measures may have led to higher use in such conditions.

About 88% of the participants expressed their willingness to implement energy efficiency measures if technical and financial assistance was provided. The willingness was highest in the cold bio-climatic zone with 100% and the lowest in the warm temperate zone.

6.24 Summary of results

Table 69 gives an overall summary of the key survey results which are already shown in the details in the above sections of this Chapter. The results parameters are mainly shown as per the bio-climatic zones, while some parameters are also shown as per building typology.

Table 69: Summary of baseline survey results for office buildings

<table>
<tr><th>Parameter (Predominant)</th><th>Typology</th><th>cold</th><th>cool_temperate</th><th>temperate</th><th>warm_ temperate</th></tr>
<tr><td colspan="6">Building construction</td></tr>
<tr><td>Construction practices</td><td>All</td><td>Load bearing, RCC frame</td><td>RCC frame</td><td>RCC frame</td><td>RCC frame</td></tr>
<tr><td rowspan="2">Built-up area (ft2)</td><td>Individual office building</td><td>1001-1250</td><td>3001-3250</td><td>2251-2500
3001-3250</td><td>1501-1750</td></tr>
<tr><td>Mixed-use with office space</td><td>251-500</td><td>1501-1750</td><td>1501-1750</td><td>1501-1750</td></tr>
<tr><td>Buildings with setback (%)</td><td>All</td><td>44
(One side)</td><td>52
(All side)</td><td>29
(All side)</td><td>39
(All side)</td></tr>
<tr><td rowspan="2">Average number of occupants</td><td>Individual office building</td><td>7</td><td>16</td><td>33</td><td>16</td></tr>
<tr><td>Mixed-use with office space</td><td>4</td><td>10</td><td>11</td><td>7</td></tr>
<tr><td>Opening and Closing time</td><td>All</td><td>10:00 AM – 5:00 PM</td><td>10:00 AM – 5:00 PM</td><td>10:00 AM – 5:00 PM</td><td>10:00 AM – 5:00 PM</td></tr>
</table>

Parameter (Predominant)	Typology	cold	cool_temperate	temperate	warm_ temperate
Wall construction	All	Overall ~475 mm: Cement Plaster (12 mm) + Stone Masonry (~450 mm) + Cement Plaster (12 mm)	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)
Roof type	All	Flat roof	Flat roof	Flat roof	Flat roof
Roof construction	All	a. Overall 137 mm:RCC slab (125 mm) + Cement plaster (12 mm) b. Overall 250 mm:Mud (130 mm) + Wood Plank (20 mm) + Wooden rafter (100 mm) c.Overall 26 mm (without cavity) -625 mm (with cavity): CGI (0.6 mm) Air cavity (600) + Wood Plank (25 mm)	Overall 210 mm: Cement plaster (12 mm) + Screed (60 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	Overall 187 mm: Screed (50 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	Overall 187 mm: Screed (50 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)
WWR range (%)	Individual office building	10-20 20-30 30-40	20-30	>40	30-40
	Mixed-use with office space	30-40	>40	>40	10-20 20-30 30-40 >40
Window type	All	Casement window	Casement window or Sliding window	Casement window or Glass Glazing with few openings	Casement window or Sliding window
Window glazing and framing	All	Wooden frame with single clear glass	a. Wooden frame with single clear glass b. Aluminumframe with single clear glass	a. Wooden frame with single clear glass b. Aluminum frame with single tinted glass	a. Wooden frame with single clear glass b. Aluminumframe with single clear glass c. Aluminum frame with single tinted glass
Window shading	All	Continuous overhang on all sides ~530 mm	Continuous overhang on all sides ~420 mm	Continuous overhang on all sides ~545 mm	Continuous overhang on all sides ~590 mm
Daylight sufficiency perception (%)	All	83	91	49	68
Ventilation sufficiency perception (%)	All	89	91	49	87
Cold air infiltration perception (%)	All	22	26	32	21

Parameter (Predominant)	Typology	cold	cool_temperate	temperate	warm_ temperate
Energy use in building					
Energy source	All	Electricity, LPG	Electricity, LPG	Electricity, LPG	Electricity, LPG
Annual electricity consumption (kWh/y) per office	All	3,970	6,471	11,888	25,691
Annual thermal energy consumption (MJ/y) per office	All	13,762	5,844	10,900	8,413
Annual energy expenses, total (NPR/y) per office	All	99,274	93,100	1,71,969	3,15,657
Annual energy expenses, electricity (NPR/y) per office	All	53,965	74,554	1,36,395	2,87,075
Annual energy expenses, other fuels (NPR/y) per office	All	45,309	18,546	35,574	28,583
Annual energy expenses per capita (NPR/y.person)	All	16,073	6,650	10,085	23,884
Electrical EPI, average ($kWh/m^2.y$)	Individual office building	44	26	54	67
	Mixed-use with office space	31	39	56	78
Thermal EPI, average ($MJ/m^2.y$)	Individual office building	103	27	79	50
	Mixed-use with office space	100	32	25	37
End-use: Space heating					
Energy source	All	Electricity	Electricity	Electricity	Electricity
Device used	All	Radiant heater	Electric Convention heater	Radiant heater, AC	AC
Usage months	All	Jan, Aug-Dec	Jan-Feb, Nov-Dec	Jan-Feb, Oct-Dec	Jan-Feb, Nov-Dec
Usage hours per day	All	4.4	5.7	4.6 (Radiant heater), 7.6 (AC)	4.8
End-use: Space cooling					
Energy source	All	-	Electricity	Electricity	Electricity
Device used	All	-	Split AC	Split AC, Ceiling fan	Ceiling fan, Split AC
Usage months	All	-	Apr-Jun	Apr-Aug	Mar-Sep
Usage hours per day	All	-	4.1	6.2 (Split AC), 5.6 (Ceiling fan)	6.5 (Ceiling fan), 5.5 (Split AC)
End-use: Water heating					
Energy source	All	Electricity	Electricity	Electricity	Electricity
Device used	All	Electric kettle	Electric kettle	Electric kettle	Electric kettle
Usage months	All	All months	All months	Jan-Feb, Nov-Dec	Jan-Feb, Nov-Dec
Usage hours per day	All	3.2	2.0	2.8	4.1

Parameter (Predominant)	Typology	cold	cool_temperate	temperate	warm_ temperate
Power back-up system					
Provision of power back up system (%)	All	83	91	95	76
Power backup system	All	Solar PV	Inverter	Inverter	Inverter
Renewable energy use and awareness on energy efficiency					
Houses using Solar PV (%)	All	67	22	10	5
Houses using solar water heater (%)	All	22	4	2	0
Houses aware about energy efficiency measure (%)	All	83	22	76	61
Houses implemented energy efficiency measure (%)	All	100	91	100	84

SURVEY RESULTS AND ANALYSIS: HOTEL BUILDINGS

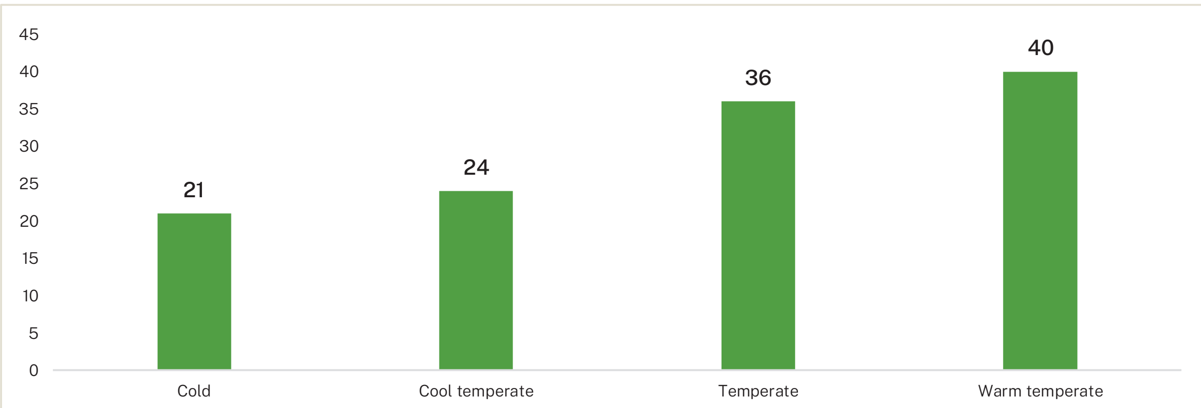
A total of 121 different hotel buildings were surveyed during this study. The outputs of the survey are presented in terms of different charts and tables in two sections: building characteristics and energy consumption. They are further classified in terms of bio-climatic zone and building typology.

Section I: Building Characteristics

7.1 Surveyed hotel distribution among bio-climatic zones and building typologies

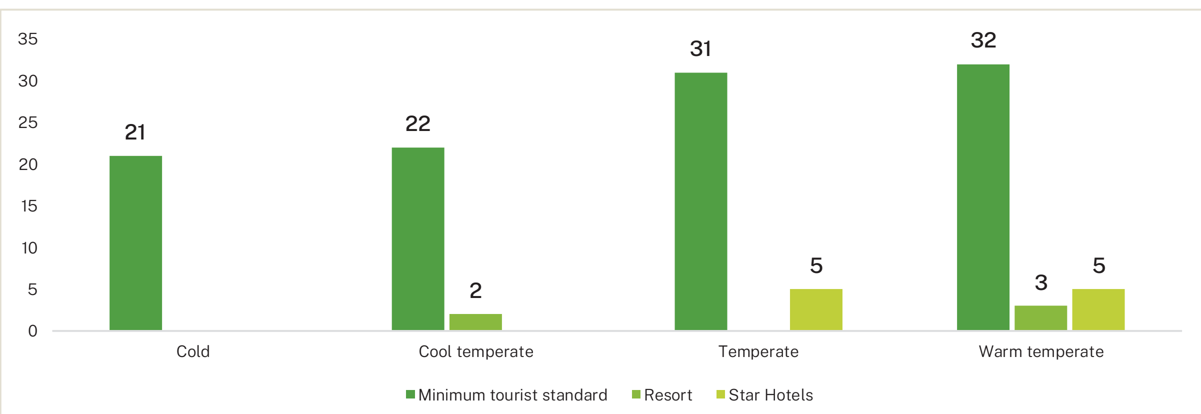
Figure 68 shows the distribution of a total of 121 surveyed hotels among the bio-climatic zones, i.e., Cold, Cool temperate, Temperate, and Warm temperate. Among the surveyed buildings, 33% were surveyed in the warm temperate climate whereas only 17% were surveyed in the cold climates. The sample size for the climate zone varied based on the overall number of buildings as well as their availability for the survey.

Figure 68: Distribution of surveyed hotels as per bio-climatic zone



Hotel buildings were further divided into three typologies, i.e., minimum tourist standard, resort and star hotels. The minimum tourist standard type was found to be the predominant type among the surveyed hotels in all climate zones. Among surveyed hotels, small samples of the 'resort' typology included cold temperate and warm temperate climates; whereas, the star hotels typology included temperate, and warm temperate climates (refer Figure 69).

Figure 69: Distribution of hotels as per building typology for each bio-climatic zone



Out of 106 minimum tourist standard hotel buildings surveyed, 92 were of lodge type, 12 were of Home Stay and 2 were Motel.

7.2 Year of construction

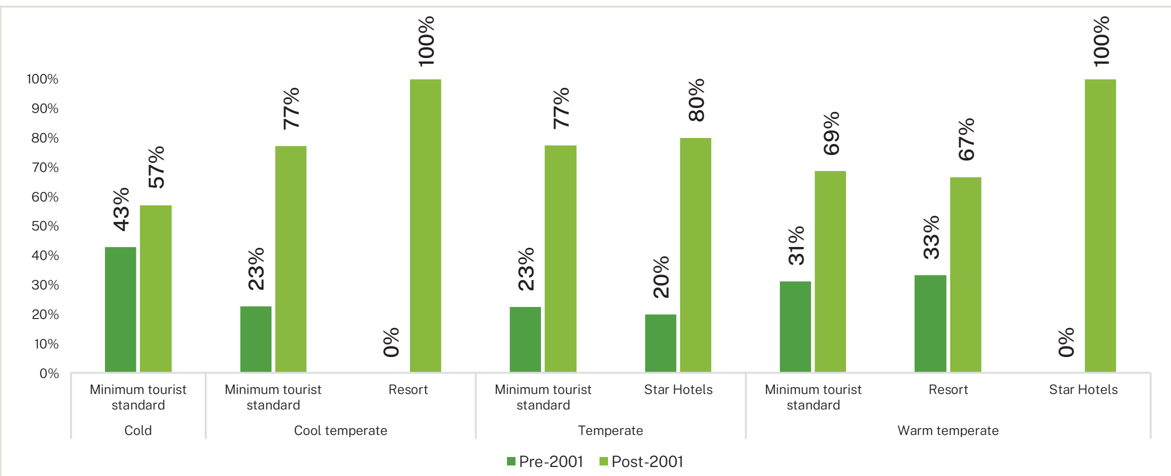
Table 70 and Figure 70 show the distribution of the hotel buildings based on the year of construction for each bioclimatic zone and building typology.

Table 70: Distribution of hotel buildings based on year of construction

Climate	Typology	1951-90	1991-2000	2001-10	2011-20	2021-30
Cold	Minimum tourist standard	10%	33%	19%	38%	0%
Cool temperate	Minimum tourist standard	9%	14%	14%	64%	0%
	Resort	0%	0%	0%	100%	0%
Temperate	Minimum tourist standard	13%	10%	29%	39%	10%
	Star Hotels	0%	20%	0%	80%	0%
Warm temperate	Minimum tourist standard	9%	22%	25%	44%	0%
	Resort	33%	0%	33%	33%	0%
	Star Hotels	0%	0%	20%	60%	20%

Among surveyed buildings, the majority of them were constructed in 2011-2020, for climate and typologies. The cold climate had a good share of older hotel buildings as compared to other climate zones. While the share of minimum tourist standard hotels is prevalent, the share of resorts and star hotels has also increased in recent years.

Figure 70: Pre-Post 2001 year of construction distribution based on different typologies and climate zones



As shown in the figure above, a higher percentage of buildings were found to be post-2001, at each bio-climatic zone and building typology. In cold the share of pre-2001 minimum tourist standard hotels were found comparable to post-2001 buildings.

7.3 Site setback

The distribution of setback configurations in different bio-climatic zones reveals notable patterns. In cold climates, the majority of hotels had setbacks on all sides or three sides (refer Table 71). For cool temperate climates, the setbacks were distributed in two, three, or all sides. Temperate climates had all types of possible setbacks and didn't show any predominant practice. In warm temperate climates, the majority of hotels had setbacks on one or two sides.

Table 71: Distribution of setbacks based on bio-climatic zones

Bio-Climatic Zones	No Setback	One Side	Two Side	Three Side	All Side
Cold	5%	14%	14%	24%	43%
Cool Temperate	0%	13%	29%	25%	33%
Temperate	11%	22%	17%	25%	25%
Warm Temperate	3%	28%	43%	10%	18%

The resort-type hotel buildings in cool temperate and warm temperate climates predominantly had setbacks on all sides. Star hotels in temperate climates had three or all side setbacks, while in warm temperate climates, setbacks were found on two or all sides.

7.4 Built-up area

Table 72 shows the average built-up area in different bio-climatic zones and typologies for the surveyed hotels while Table 73 shows the distribution of surveyed hotels as per the built-up area range for all the bio-climatic zones and the building typologies.

Table 72: Average built-up area in different bio-climatic zones and typologies

Climate	Typology	Average area (ft²)
Cold	Minimum tourist standard	4,719
Cool temperate	Minimum tourist standard	3,493
	Resort	6,017
Temperate	Minimum tourist standard	7,251
	Star Hotels	29,193
Warm temperate	Minimum tourist standard	5,123
	Resort	17,200
	Star Hotels	23,899

The average size of the hotels under the minimum tourist standard typology was found to-vary between ~3,500 ft² (for cool temperate climate) to ~7,250 ft² (for temperate climate). Star hotels had the maximum area out of three typologies, while resorts had large variations in the average area among climate zones.

Table 73: Built-up area ranges as per climatic zone and building typology

Area range (ft²)	Cold	Cool temperate		Temperate		Warm temperate		
	Minimum tourist standard	Minimum tourist standard	Resort	Minimum tourist standard	Star Hotels	Minimum tourist standard	Resort	Star Hotels
1000-2000	24%	9%	-	6%	-	9%	-	-
2000-3000	14%	41%	-	13%	-	16%	33%	-
3000-4000	10%	23%	-	13%	-	13%	-	-
4000-5000	24%	14%	-	16%	-	9%	-	-
5000-6000	5%	5%	-	16%	-	16%	-	-
6000-7000	10%	5%	100%	3%	-	16%	-	-
7000-8000	-	-	-	-	-	9%	-	-
8000-9000	-	5%	-	3%	-	6%	-	-
9000-10000	-	-	-	6%	40%	-	-	-
10000-15000	14%	-	-	13%	20%	6%	-	60%
15000-20000	-	-	-	3%	20%	-	-	-
20000-50000	-	-	-	6%	-	-	67%	20%
50000+	-	-	-	-	20%	-	-	20%

While the area range varied a lot among building typology and the climate zone, still there were some dominant ranges found in some categories, e.g., the 2000-3000 ft² range was the predominant area range in minimum tourist standard type in a cool temperate climate.

7.5 Spatial configuration

The survey also identified the predominant spatial configuration types for hotel buildings based on different bioclimatic zones. Overall, the majority of the buildings were either single-loaded or double-loaded type in all climate zones (refer Table 74); while cold climate had single-loaded as predominant and also had few buildings with courtyard type. The warm temperate climate had a small share of buildings with open courtyards. Single-loaded type buildings are where rooms are arranged along a single corridor or side of the building; while in double-loaded configuration, rooms are there on both sides of a corridor. Open Courtyard configuration incorporated an open space or courtyard into the design. It's important to note that these percentages represent the predominant configurations, and other types may also exist.

Table 74: Spatial Configuration based on the bio-climatic zone

Bio-Climatic Zones	Courtyard	Double Loaded	Open Courtyard	Single Loaded
Cold climate	10%	24%	0%	67%
Cool Temperate Climate	0%	54%	0%	46%
Temperate Climate	0%	53%	0%	47%
Warm temperate climate	0%	55%	3%	43%
Overall	**2%**	**49%**	**1%**	**49%**

Table 75 further gives the spatial configuration of all building typologies under each climatic zone, highlighting the predominant share of spatial configuration.

Table 75: Spatial Configuration based on the building typologies for each climate

Climate	Typology	Courtyard	Double Loaded	Open Courtyard	Single Loaded
Cold	Minimum tourist standard	10%	24%	0%	67%
Cool temperate	Minimum tourist standard	0%	59%	0%	41%
	Resort	0%	0%	0%	100%
Temperate	Minimum tourist standard	0%	48%	0%	52%
	Star Hotels	0%	80%	0%	20%
Warm temperate	Minimum tourist standard	0%	50%	0%	50%
	Resort	0%	67%	33%	0%
	Star Hotels	0%	80%	0%	20%

7.6 Guest Rooms

Table 76 gives the average number of guest rooms and their area for each climatic zone and each typology within the climate zone. The minimum tourist standard hotels have no large variation average number of guest rooms (minimum 10 for cool temperate climate and maximum 18 for temperate climate) as well as the average area of guest rooms (minimum 142 ft^2 for cold climate and maximum 177 ft^2 for temperate climate). Star hotels had more guest rooms (42-43) and also had bigger guest rooms (~240 ft^2). Resorts had a similar number of guest rooms among climates, but their size varied significantly with the climatic zone.

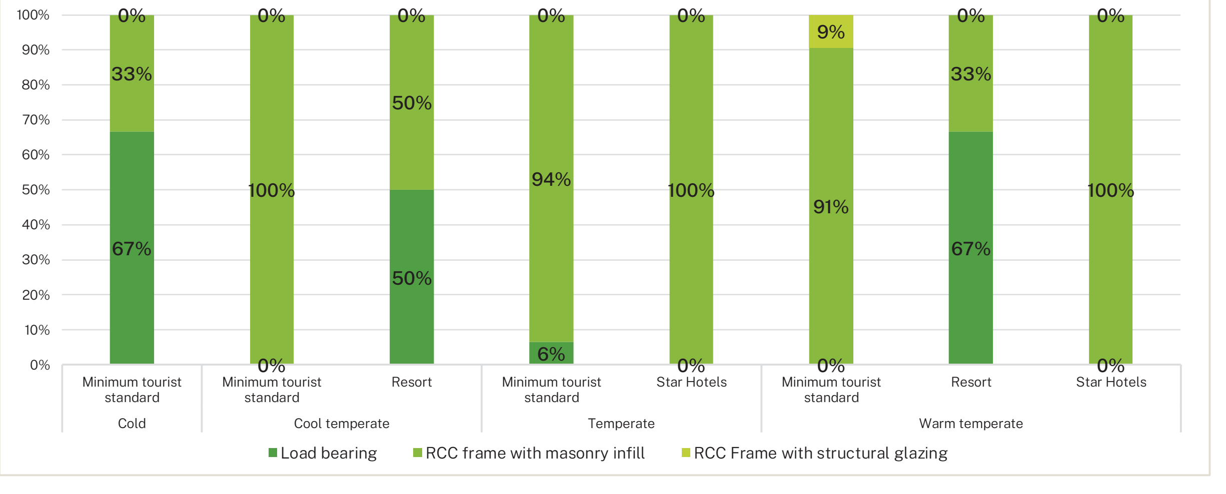
Table 76: Guest rooms and their area based on bio-climatic zone and building typology

Bio-Climatic Zone	Average of Number of Guest Rooms	Average of Area of Guest Rooms (ft²)
Cold	13	142
Minimum tourist standard	13	142
Cool temperate	12	147
Minimum tourist standard	10	149
Resort	26	120
Temperate	22	185
Minimum tourist standard	18	177
Star Hotels	43	233
Warm temperate	20	168
Minimum tourist standard	17	145
Resort	24	294
Star Hotels	42	243

7.7 Construction technology

Figure 71 presents the distribution of construction technology for different typologies of hotel buildings under each climatic zone. It is very clear that the "RCC frame with masonry infill" is the overall predominant practice. However, the minimum tourist standard hotel in a cold climate had "load bearing" as the predominant construction technology. For resorts, load-bearing construction technology was predominant in warm temperate climates and matched equally with the "RCC frame with masonry infill" construction technology in cool temperate climates. "RCC frame with structural glazing" construction technology has been reported only in warm temperate climates in very few buildings.

Figure 71: Construction technology based on bio-climatic zone and building typology

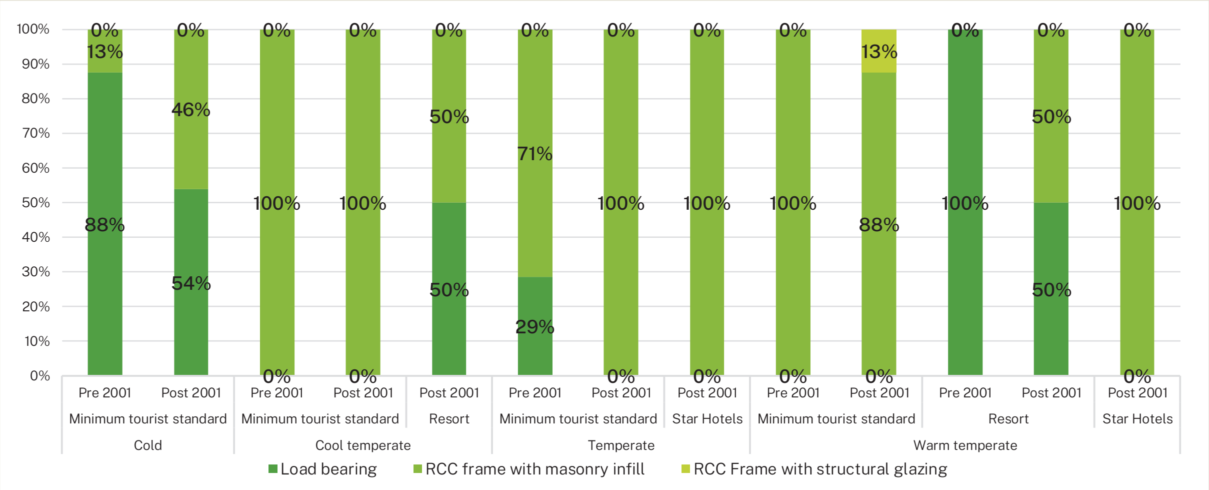


In analyzing the data, load-bearing construction is more prevalent in colder climates, where the structural integrity and insulation provided by this method are advantageous. RCC frame with masonry infill is the dominant approach in most bio-climatic zones, indicating its wide-ranging suitability and popularity for construction. RCC frame with structural glazing is used sparingly across all climates, suggesting it may have specific applications or is less preferred due to potential limitations or higher costs. The distribution of construction methods reflects the consideration of climate factors and the varying requirements for structural stability, insulation, and aesthetics.

Figure 72 shows the pre and post-2001 construction trends among building typology in different climatic zones. Some of the categories, e.g., minimum tourist standard in cold and temperate climates, and resorts in warm temperate climates observed a shift from "load bearing" to "RCC frame with masonry infill construction technology.

Also, "RCC frame with structural glazing" construction technology is being introduced in the minimum tourist standard typology in warm temperate climates.

Figure 72: Pre and post 2001 distribution based on construction technologies



7.8 Exterior wall assembly

Among the surveyed hotels, it was found that the hotels in cold regions had thicker walls, whereas wall thickness was reduced for the other climates. The vernacular technologies for better thermal insulation due to the construction of thicker walls in higher altitude regions are the reason for that.

Table 77: Predominant exterior wall assembly in bio-climatic zone

Bio-Climatic Zone	Predominant Wall Assembly Layers and its Thickness	Share in the Sample Size for the Climate
Cold	Overall ~480 mm: Cement Plaster (~20 mm) + Stone Masonry (~440 mm) + Cement Plaster (~20 mm)	57%
Cool Temperate	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	58%
Temperate	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	47%
Warm Temperate	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	60%

Table 77 shows the predominant wall assembly found in different climatic zones. As so many layers combination was observed in the survey for wall assembly only predominant combinations are shown here. The survey also revealed that three-layered walls are most common in hotels. Stone masonry was found to be predominant in the cold climate, while other climates had solid burnt brick as the predominant practice for external walls. This suggests that these wall assemblies have demonstrated suitability and effectiveness in their respective climates. The use of solid burnt brick in combination with cement plaster may indicate a preference for durability, thermal insulation, and overall structural integrity. The choice of wall assembly in each bio-climatic zone reflects the consideration of local climate conditions and the need for appropriate building materials and techniques to ensure comfort and efficiency.

7.9 Roof assembly

7.9.1 Predominant roof type

Table 78 shows the distribution of type of roof for all the bio-climatic zones. Flat roofs were found to be the predominant roof construction in all the bio-climates. A higher percentage of inclined roofs 24% was found in cold climates. Flat roofs are widely adopted due to their ease of construction, cost-effectiveness, and potential for additional usable space. The preference for inclined roofs in cold climates may be attributed to their ability to shed snow and facilitate drainage. The absence of gable and flat roofs and pyramidal roofs in most climates indicates their less common or specialized use. The choice of roof type in each bio-climatic zone reflects considerations of climate, aesthetics, and practicality in addressing weather conditions and achieving optimal performance of the building envelope.

Table 78: Roof type based on bio-climatic zones

Bio-Climatic Zone	Flat Roof	Gable And Flat Roof	Inclined Roof	Pyramidal
Cold	71%	5%	24%	0%
Cool temperate	83%	0%	17%	0%
Temperate	97%	0%	0%	3%
Warm temperate	88%	0%	12%	0%

7.9.2 Predominant roof assembly

Table 79 gives the predominant type of roof assembly for each bio-climatic zone. A variety of roof constructions ranging from RCC slabs and wooden planks were found in cold climates.For the other climates, a125 mm RCC slab was found to be the main roof construction, while the composition of additional layers (plaster, screed) found some variations.

Table 79: Predominant roof assembly in bio-climatic zone

Bio-Climatic Zone	Predominant Roof Assembly Layers and its Thickness	Share in the Sample Size for the Climate
Cold	Overall ~175mm:Mud (~125 mm) + Wooden roof (~50 mm)	33%
	Overall ~137mm:RCC slab (125 mm) + Cement plaster (12 mm)	29%
Cool Temperate	Overall ~210 mm: Cement plaster (12 mm) + Screed (60 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	42%
Temperate	Overall ~150 mm: Cement plaster (12 mm) + RCC Slab (125 mm) +Cement Plaster (12 mm)	22%
	Overall 187 mm: Screed (50 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	22%
Warm Temperate	Overall 187 mm: Screed (50 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	38%

7.10 Window to wall ratio (WWR)

Figure 73 shows the distribution of surveyed hotels as per the WWR range for different bio-climatic zones. Cold and cool temperate climate hotels had comparatively lower WWR as compared to other climates. The predominant WWR range also remains 20-30% in cold and cool temperate climates. For the temperate climate, the predominant range for WWR remained 20-40%. For the warm temperate the WWR range was highest and observed a large variation. The lower WWR in cold and cool temperate climate hotels can be attributed to an attempt to minimize the heat loss from the windows as well as the very low requirement for natural ventilation for thermal comfort. On the contrary, warm temperate climate hotels showed a trend towards higher WWR, which can be mostly attributed to the potential of natural ventilation for thermal comfort in this climate and higher WWR helps in achieving the suitability of more ventilation for thermal comfort.

Figure 73: Distribution of surveyed hotels as per WWR range for different bio-climatic zones

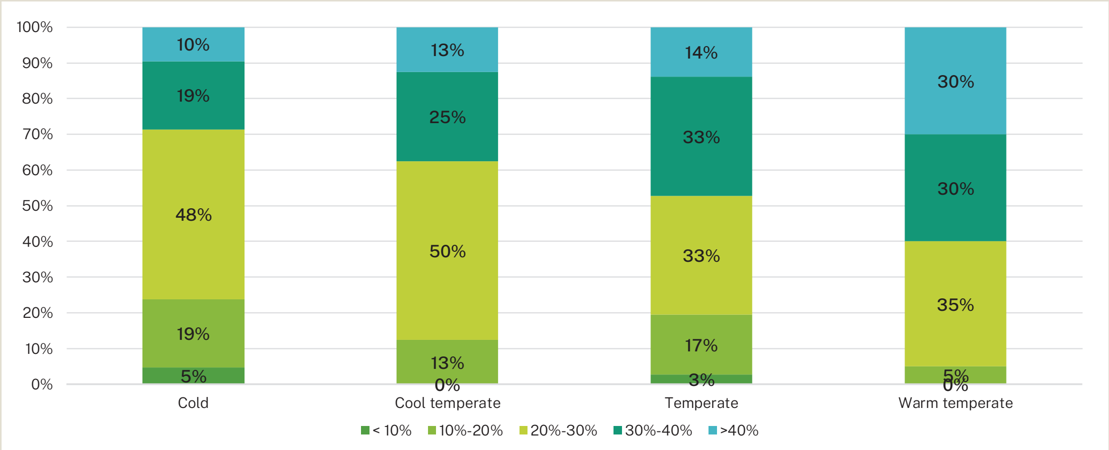
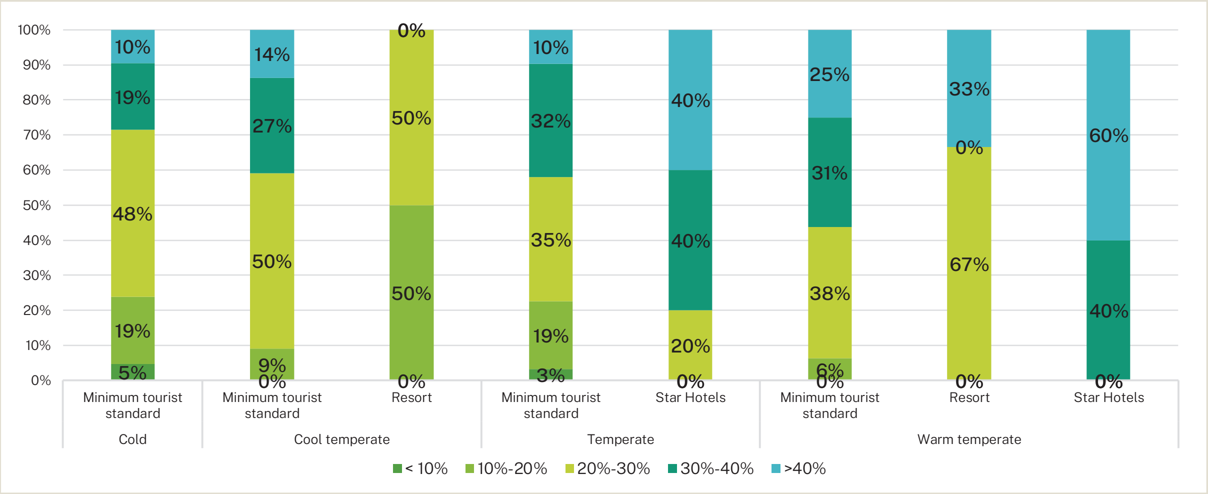


Figure 74 shows the distribution of surveyed hotels as per the WWR range for different typologies under each bio-climatic zone. For the 'minimum tourist standard' building typology, the predominant WWR in all climatic zones remained 20-30%. For the 'resort' building typology the predominant WWR range in cool temperate remained 10-30%, while it was 20-30% for the warm temperate climate. For the 'star hotels' building typology, the WWR remained higher as compared to other typologies as the predominant WWR range in warm temperate remained >40%, while it was 30-40% &>40% for the temperate climate.

Figure 74: Distribution of surveyed hotels as per WWR range for different typologies under each bio-climatic zone



7.11 Window type

Table 80 shows the window type for different bio-climatic zones. The surveyed data among 121 hotels showed that overall, the casement window is the predominant window type, closely followed by the sliding windows, except for the cold climate. Among all climate zones, the warm temperate climate found a larger variation in the window type.

The trends among building typologies within the bio-climatic zones followed similar trends for the 'minimum tourist standard' and 'resort' typologies. For the 'star hotels 'typology, sliding windows were found to be the predominant window type.

Table 80: Predominant window type

Bio-Climate	Casement Window	Glass Glazing With Few Openings	Pivoted Window, Hung Window	Sliding Window	Structural Glazing
Cold	86%	10%	0%	5%	0%
Cool temperate	58%	4%	0%	38%	0%
Temperate	56%	0%	0%	42%	3%
Warm temperate	53%	8%	10%	30%	0%
Overall	**60%**	**5%**	**3%**	**31%**	**1%**

7.12 Window glazing and framing

Table 81 shows window glazing and framing assembly for all bio-climatic zones. Overall, it shows that the single clear glass is predominant for glazing in all climatic zones. The window framing, both wooden and aluminum frames are used, except for the cold climate, where wooden framing was predominant. The use of 'single tinted glass' has been predominantly observed in the warm temperate climate along with aluminum framing, which may be a strategy to reduce the heat gain from the windows and/or for aesthetic reasons.

Table 81: Window glazing and framing assembly for all bio-climatic zones

Row Labels	Single Clear Glass Panes	Single Tinted Glass	Double Glass	Others	Grand Total
Cold	**21**				**21**
Aluminum	1				1
Wooden	20				20
Cool temperate	**17**	**6**		**1**	**24**
Aluminum	5	4			9
PVC/UPVCs	3				3
Wooden	9	2		1	12
Temperate	**30**	**5**	**1**		**36**
Aluminum	14	5	1		20
PVC/UPVCs	1				1
Wooden	15				15
Warm temperate	**24**	**16**			**40**
Aluminum	5	12			17
PVC/UPVCs		2			2
Wooden	19	2			21
Grand Total	**92**	**27**	**1**	**1**	**121**

Table 82 shows the overall predominant window type, framing, and glazing combinations, observed within the surveyed hotel buildings.

Table 82: Predominant window assembly is based on the bioclimatic zone

Window Assembly	Cold	Cool Temperate	Temperate	Warm Temperate
Casement window+ Wooden+ Single clear glass panes	86%	38%	42%	45%
Sliding window+ Aluminium+ Single clear glass panes	5%		22%	
Sliding window+ Aluminium+ Single tinted glass panes		17%		15%
Sample size	21	24	36	40

7.13 Window shading

Table 83 shows the different types of shading used as per the bio-climatic zones. The survey data shows that the predominant type of shading used across all climates is the continuous overhang (at roof level). For warm temperate climates, the share of buildings with 'no shading' is also significant.

Table 83: Shading type with bio-climatic zone

Bio-Climate	Continuous Overhang(at roof level)	No Shading	Overhang Over Windows
Cold	90%	0%	10%
Cool temperate	83%	13%	4%
Temperate	86%	8%	6%
Warm temperate	63%	38%	0%

While the continuous overhang (at roof level) was the predominant shading, it was not applied in all the orientations and its application varied as per the orientation. Table 84 shows the percentage of shading applied in a particular direction that had continuous overhang (at roof level).

Table 84: Percentage of buildings having continuous overhang (at roof level)shading applied in each direction

Bio-Climate	North	South	East	West
Cold	89%	79%	79%	89%
Cool temperate	55%	65%	65%	55%
Temperate	81%	84%	74%	55%
Warm temperate	28%	60%	44%	24%

Further, Table 85 shows the average depth of the continuous overhang (at roof level) shading for different orientations for all climatic zones. The average shading depth is found to be minimal for cold climates, while the maximum is for warm temperate climates. Higher depth of shading in warm temperate climates can be attributed to higher temperatures and better control to reduce the solar heat gain. In terms of direction, higher shading depth is found in the north direction which doesn't seem to be helping if the shading is being used for reducing the heat gains in warm climates and neither helping in getting more heat in cold climates.

Table 85: Predominant shading depth with bio-climatic zone

Bio-Climate	Average Depth of Continuous Overhang Shading (mm)			
	North	South	East	West
Cold	461	365	422	375
Cool temperate	718	739	509	595
Temperate	625	656	549	628
Warm temperate	786	543	701	700

The different building typologies within the climate zone overall followed the same trends as that for the overall climate zone.

Section II: Energy Consumption

7.14 Amenities and facilities

The available surveyed data informs us about the availability of facilities in each typology where all categories offer guest accommodations, which was the basic criteria for the identification of hotels. However, the percentages for other facilities vary across the typologies.

In terms of restaurants, 84% of the "Minimum tourist standard" hotels have this facility, while 80% of resorts and 90% of star hotels offer on-site dining options. This suggests that higher-end hotels tend to provide a higher proportion of restaurants for their guests. Banquet halls are available in only 15% of the "Minimum tourist standard" hotels, but they are found in 100% of resorts and 70% of star hotels. This indicates that resorts and star hotels are more likely to cater to events and functions by providing banquet facilities.

Swimming pools are relatively less common in all typologies, with only 3% of "Minimum tourist standard" hotels, 60% of resorts, and 70% of star hotels having this amenity. The higher percentage in resorts and star hotels suggests a greater emphasis on recreational amenities. Laundry facilities are available in 25% of "Minimum tourist standard" hotels, and 40% of star hotels, but surprisingly not in any of the resorts. This could indicate that resorts might rely on external laundry services or other arrangements for their guests' laundry needs.

Shops are only present in 8% of "Minimum tourist standard" hotels, while none of the resorts have such facilities. However, 10% of star hotels offer on-site shopping options, suggesting a higher level of convenience for their guests. Gym/spa facilities are least prevalent in the "Minimum tourist standard" category, with only 2% of hotels providing them. In contrast, 40% of star hotels offer gym/spa amenities, indicating a greater focus on wellness and fitness services.

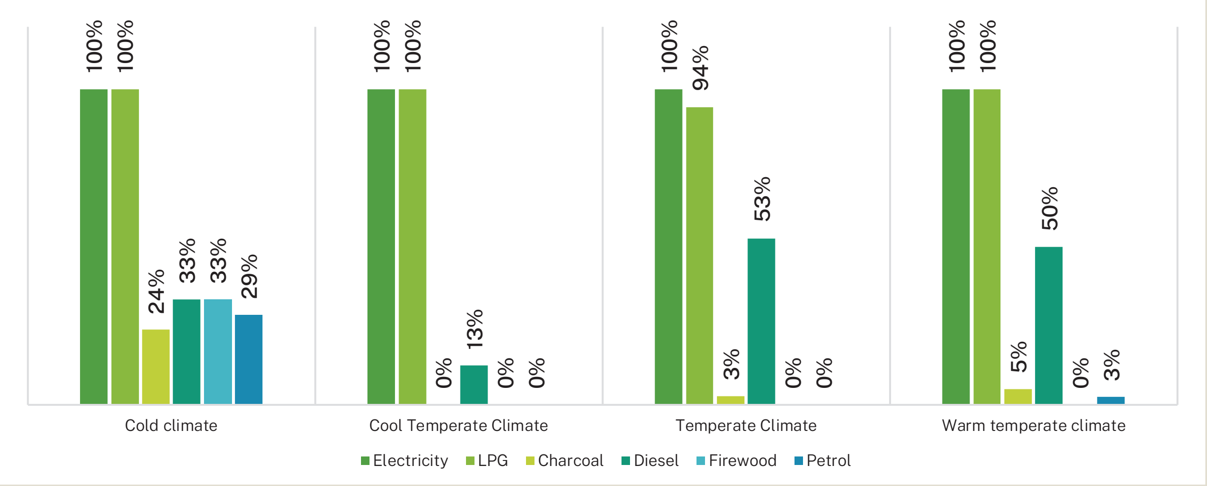
Finally, backhand offices (administrative or support offices) are present in 13% of "Minimum tourist standard" hotels, 20% of resorts, and 80% of star hotels. This suggests that star hotels prioritize having internal support structures for their operations.

In summary, the survey reveals that the availability of facilities varies across different typologies of hotels. Higher-end hotels like resorts and star hotels tend to offer a wider range of amenities such as restaurants, banquet halls, swimming pools, gym/spa facilities, and backhand offices, while the "Minimum tourist standard" hotels have more limited offerings. These findings can help in understanding the different features and services provided by hotels in each category, allowing stakeholders to make informed decisions based on their specific needs and preferences.

7.15 Distribution of different fuel types based on the climate zone

Figure 75 shows the use of different fuels in various bio-climatic zones, highlighting the percentage of hotels relying on each fuel type.The surveyed data shows that electricity is widely used, with 100% of hotel buildings relying on it as their primary energy source. Additionally, LPG (liquefied petroleum gas) is utilized by all hotels in each climate zone, especially for cooking purposes. The cold climate had a wide range of energy sources, including charcoal, diesel, firewood, and petrol in considerable hotels. Hotels in all other climate zones (cool temperate, temperate, and warm temperate) rely on diesel, mainly as a power backup, in addition to the main energy sources.

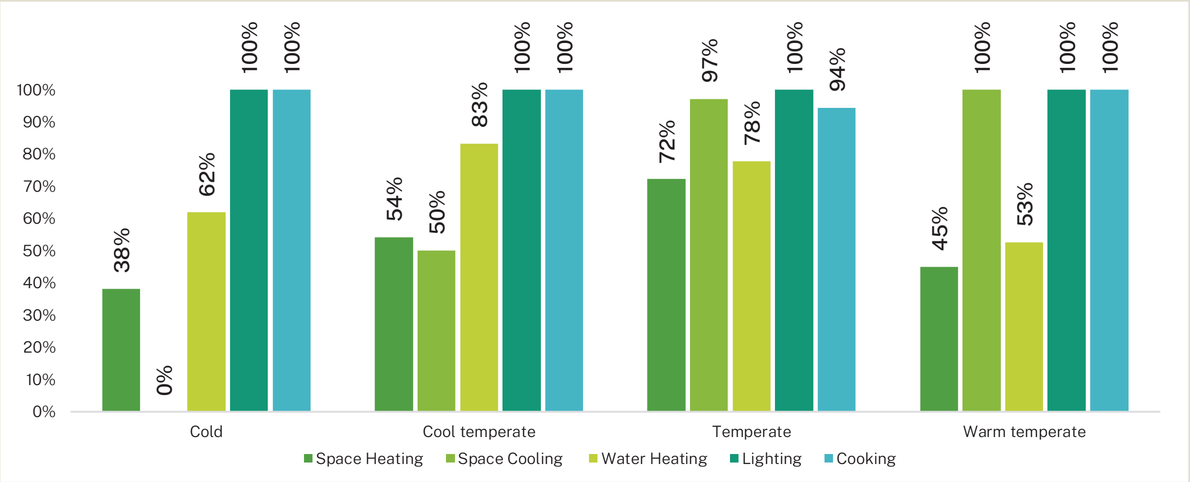
Figure 75: Use of different fuel/energy based on the bio-climatic zone



7.16 Type of fuel for all different end-uses

7.16.1 End-use of energy

Figure 76: Percentage of offices using energy for key end-uses in different bio-climatic zones



Lighting is an essential requirement which is found to be 100% in all climatic zones, while cooking was also found significantly high percentages considering a hotel building and food as a key service (refer Figure 76). Space heating had a varied trend that did not follow the climatic conditions and may need further investigation. Similarly, lower water heating usage in cold climates as compared to cool temperate and temperate climates, also needs further investigations. Space cooling trends followed the climatic conditions and were quite logical.

7.16.2 Distribution of energy source for end-use

Survey results (refer Table 86) clearly show that electricity is the predominant energy source for space heating in all climatic zones, except the cold climate. Use is firewood is found to be predominant for space heating in the cold climate.

Table 86: Distribution of energy source used for space heating in bio-climatic zones

Bioclimatic Zones	Electricity	Firewood	LPG
cold	38%	63%	13%
cool_temperate	100%	0%	0%
temperate	100%	0%	0%
warm_temperate	100%	0%	0%

Note: The percentages are given only for the hotels which reported space heating as an end-use of energy. Some hotels reported more than one energy source; hence, the total can exceed 100%.

For space cooling, electricity is the predominant energy source with 100% of the hotels using it in the cool temperate, temperate, and warm temperate climate.

Survey results (refer Table 87) showed that multiple energy sources are being used for water heating in all bio-climatic zones. Overall, electricity is the predominant energy source used for water heating. In cool temperate climates, solar is the largest shared for water heating.. In cold climates, multiple energy sources were used as the hot water demand was high. LPG was found as the second predominant fuel for water heating in temperate and warm temperate climates.

Table 87: Distribution of energy source used for water heating in bio-climatic zones

Bioclimatic Zones	Electricity	LPG	Firewood	Solar
Cold	62%	62%	38%	0%
Cool_temperate	55%	5%	0%	60%
Temperate	86%	18%	4%	14%
Warm_temperate	76%	24%	0%	5%

7.17 Predominant device and their usage for different end uses

7.17.1 Predominant device for different end uses

Based on the predominant energy source for different end-uses (as per the previous section), the survey data was further analyzed to show the corresponding devices which are used for end-use and the predominant combination for each bio-climatic zone. Table 88 shows that the firewood chimney was the predominant device used for space heating in cold climates, while Split AC was in the other three climates. For cool temperate climates, radiant electric heaters and convection heaters also observed significant usage. Table 89 shows that split AC and ceiling fans are predominant devices used for space cooling in cool temperate, temperate, and warm temperate climates. Table 90 shows the predominant device for water heating and energy source both varied a lot among the climate zones.

Table 88: Predominant device for space heating as per predominant energy source for different climates

Bio-Climatic Zone	Energy Source	Predominant Device	Percentage Use of Predominant Device
Cold	Firewood	Firewood Chimney	80%
Cool Temperate	Electricity	Split AC	42%
Temperate	Electricity	Split AC	89%
Warm Temperate	Electricity	Split AC	94%

Table 89: Predominant device for space cooling as per predominant energy source for different climates

Bio-Climatic Zone	Energy Source	Predominant Device	Percentage Use of Predominant Device
Cool Temperate	Electricity	Split AC	42%
Temperate	Electricity	Split AC	63%
	Electricity	Ceiling fan	49%
Warm Temperate	Electricity	Ceiling fan	85%
	Electricity	Split AC	60%

Table 90: Predominant device for water heating as per predominant energy source for different climates

Bio-Climatic Zone	Energy Source	Predominant Device	Percentage Use of Predominant Device
Cold	LPG	LPG Geyser	88%
Cool Temperate	Solar	Solar Heating	100%
Temperate	Electricity	Heat Pump	46%
Warm Temperate	Electricity	Instant Geyser	56%

7.17.2 Usage of the predominant device for different end uses

The Table 91, Table 92 and Table 93 show the usage schedule (month-wise and average usage hours per day) for the combination of predominant energy source and device for each bio-climatic zone. All the numbers (hours per day and percentages) shown below are calculated considering only these selected hotels.

Space heating: In cold climates, space heating operation was observed round-the-year in most of the hotels. In cool temperate, the peak usage found in Nov-Feb and significant usage in Mar-Jul, while average usage hours were slightly more as compared to cold climates. Hotels in temperate climates used space heating in Oct-Mar while in warm temperate climates, it was mainly in Dec-Jan. Interestingly, the usage hours per day were higher in temperate climates, which might need further investigation. Regarding the set point of temperature,28-30°C was observed to be predominant in a temperate climate, whereas in a warm temperate climate, 26-28°C was found to be predominant.

Table 91: Operational schedule for predominant devices for space heating

Bio-climatic zone / Energy source / Predominant device	Average usage (h/d)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cold / Firewood / Firewood Chimney	6.5	100%	75%	75%	75%	75%	75%	75%	75%	100%	100%	100%	100%
Cool Temperate / Electricity / Split AC	6.8	100%	100%	80%	80%	80%	60%	60%	20%	20%	40%	100%	100%
Temperate / Electricity / Split AC	7.8	100%	92%	56%	36%	36%	36%	36%	36%	32%	60%	96%	100%
Warm Temperate / Electricity / Split AC	7.6	82%	47%	47%	53%	53%	53%	53%	53%	59%	53%	53%	82%

Space cooling: Warm temperate climate had high usage of split AC in Mar-Oct with highest average usage hours per day. The temperate climate had usage in Mar-Sep, with average usage hours very close to the warm temperate climate. For cool temperate climate, usage was observed in Nov-Aug. The predominant cooling temperature set point range was found to be 18-20°C for the cool temperate, temperate, and warm temperate zones.

Table 92: Operational schedule for predominant devices for space cooling

Bio-climatic zone / Energy source / Predominant device	Average usage (h/d)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cool Temperate / Electricity / Split AC	8.3	75%	75%	75%	100%	100%	100%	100%	50%	25%	25%	75%	75%
Temperate / Electricity / Split AC	8.0	25%	25%	50%	88%	88%	100%	96%	88%	50%	38%	25%	25%
Temperate / Electricity / Ceiling fan	5.2	0%	0%	29%	88%	94%	100%	88%	71%	24%	0%	0%	0%
Warm Temperate / Electricity / Ceiling fan	9.7	9%	21%	68%	100%	100%	100%	100%	97%	71%	38%	18%	12%
Warm Temperate / Electricity / Split AC	9.8	42%	33%	75%	96%	100%	100%	100%	100%	79%	50%	42%	42%

Water heating: In cold and temperate climates, water heating is operated round-the-year. For cool temperate the peak usage was found in Oct-Mar, while for the warm temperate climate, it was in Nov-Feb.

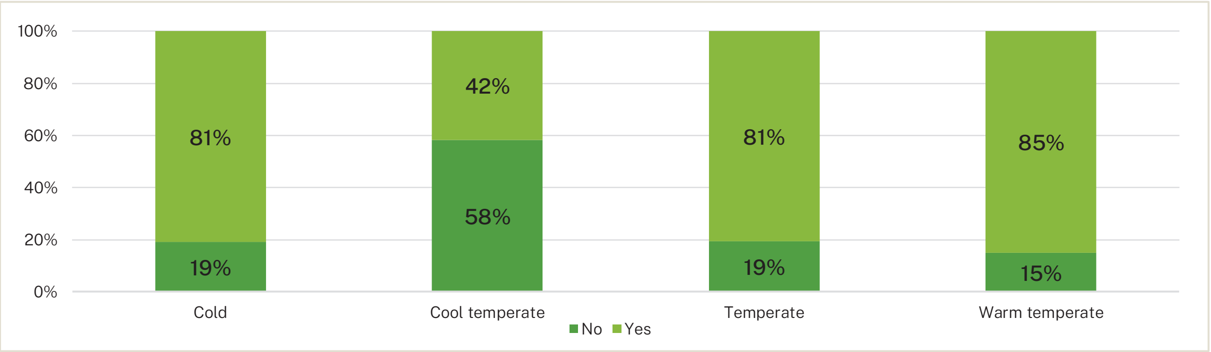
Table 93: Operational schedule for predominant devices for water heating

Bio-climatic zone / Energy source / Predominant device	Average usage (h/d)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cold / LPG / LPG Geyser	4.0	100%	86%	71%	71%	71%	71%	71%	71%	86%	100%	100%	100%
Cool Temperate / Solar / Solar Heating	5.3	100%	100%	71%	29%	29%	29%	29%	29%	43%	100%	100%	100%
Temperate / Electricity / Heat Pump	16.8	100%	100%	100%	92%	83%	83%	83%	83%	92%	100%	100%	92%
Warm Temperate / Electricity / Instant Geyser	4.2	100%	67%	11%	11%	11%	11%	11%	11%	11%	22%	78%	100%

7.18 Power backup system

7.18.1 Distribution of building with power back up system based on bio-climatic zone

Figure 77: Provision of power back-up system based on bio-climatic zones



Except for the cool temperate climate, the majority of the hotels in all the other three climatic zones (cold, temperate, and warm temperate climate) had a provision of a power backup system. For a cool temperate climate, there might be much better electricity supply conditions, which might be the reason for the lower requirement for power backup. Overall, across all regions, 74% of hotels have a power backup system in place, indicating a relatively high percentage of hotels prepared for power cut-offs (refer Figure 77).

7.18.2 Predominant power backup system

Figure 78: Predominant power backup system based on bio-climatic zones

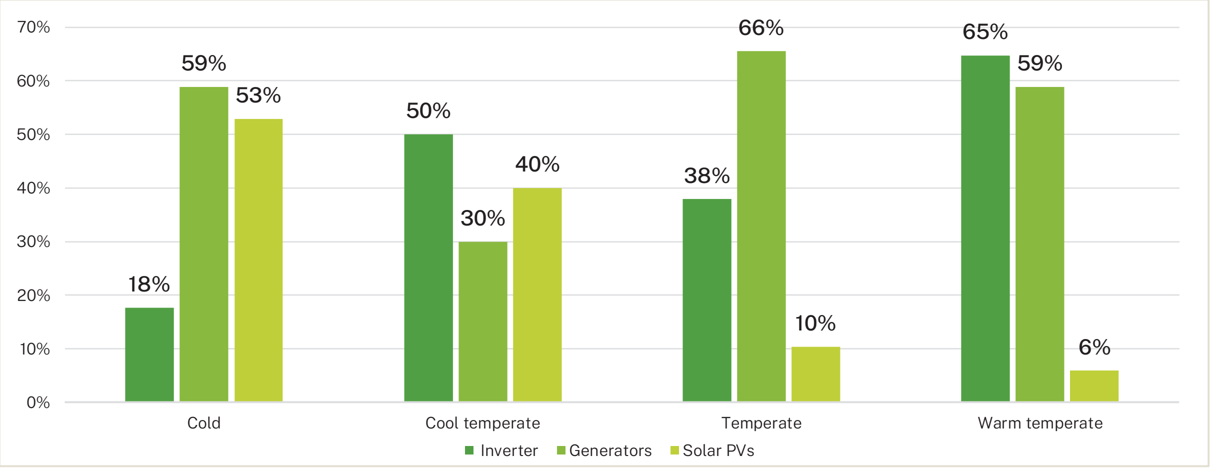
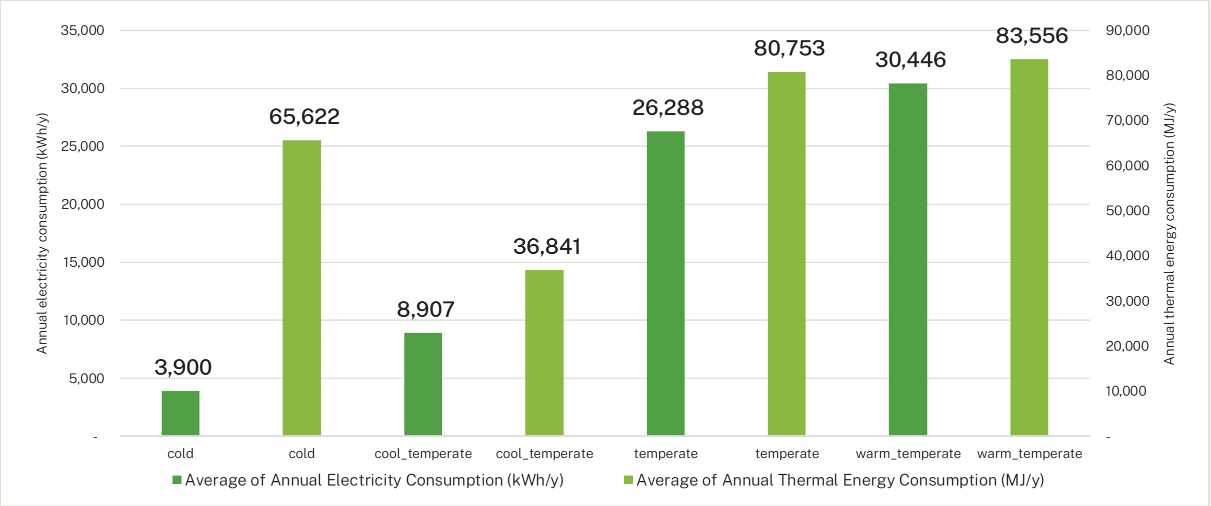


Figure 78 shows the usage of power backup devices among the hotels which have a power backup system in place, as per the climatic zone. The total may exceed 100% of value as many hotels use multiple devices for power backup. There is a good penetration of solar PV systems in the cold climate (~53%) and cool temperate climate (~40%) among the surveyed hotels. Inverters and Generators are found to be the predominant power backup devices in all the bio-climatic zones. In cold climate and temperate climates, generators are used predominantly whereas in cool and warm temperate climates, inverters were found to be used predominantly in the surveyed hotel buildings.

7.19 Overall electrical and thermal energy consumption

Figure 79 shows the annual average electrical and thermal energy consumption for minimum tourist standard hotels for each climate zone. Depending on the types of fuel used the proportion of electrical and thermal energy changes as per the bio-climatic zone. These variations in energy consumption in different bio-climatic zones highlight the influence of climate, end-use, local energy availability and feasibility of alternative energy sources.

Figure 79: Annual average electrical and thermal energy consumption per office building as per bio-climatic zone



In cold bio-climatic zones, hotels are more dependent on thermal energy sources like firewood and charcoal for space heating, cooking, and water heating purposes, which leads the higher thermal energy consumption. Also, electrical energy is mainly used for lighting in the cold bio-climatic zone, leading to lower consumption. As we move towards warmer climates i.e. temperate and warm temperate bio-climatic zones, the use of electricity-based space cooling devices for thermal comfort increases, and therefore electrical energy consumption is more. Except for the cold climate, all other bio-climatic zones have a good mix of electrical and thermal energy consumption, due to a mix of fuel availability and end-uses. Thermal energy in hotel buildings is mainly consumed in cooking compared to other typologies. The need for energy for cooking is directly dependent on the level of facilities. Thermal energy consumption is higher in cold and cool climates for residential and hotel typologies, however, when it comes to hotels, higher consumption was observed in temperate and warm temperate climate. The facilities in the temperate and warm temperate regarding hotel buildings are sophisticated and a higher amount of diesel consumption was also observed in these regions.

Considering the smaller sample size, the electrical and thermal energy consumption for resorts and star hotels are shown separately (refer Table 94). As these are the bigger buildings, the energy consumption number is much higher as compared to minimum tourist standard hotels.

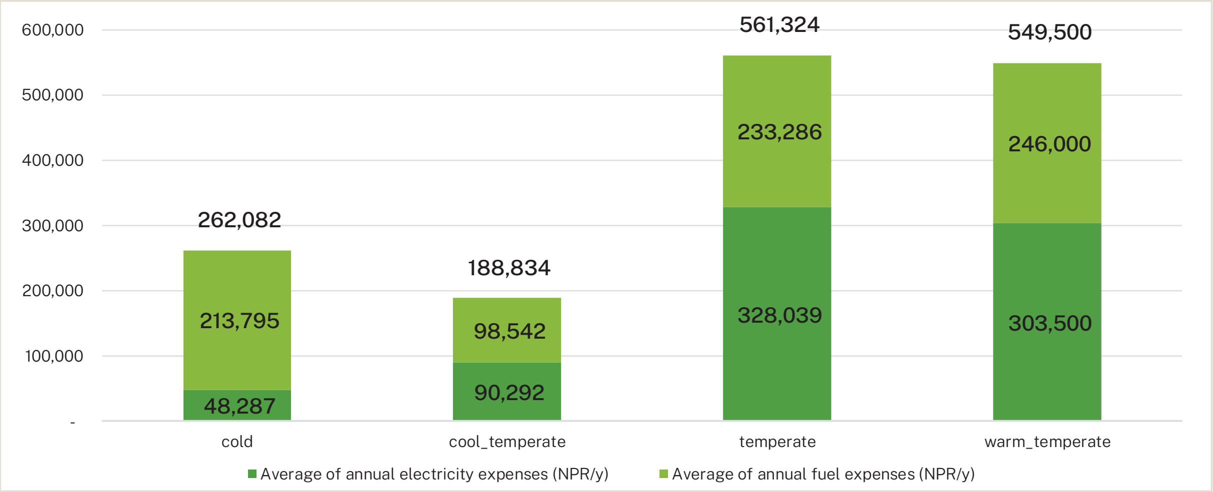
Table 94: Annual electrical and thermal energy consumption for resorts and star hotels

1.1.1.1.3	Average of Annual electricity consumption (kWh/y)	Average of Annual thermal energy consumption (MJ/y)
Resort	**90,320**	**1,86,573**
Cool temperate	16,500	1,66,398
Warm temperate	1,39,533	2,00,023
Star Hotels	**2,69,790**	**5,83,497**
Temperate	2,93,065	5,87,900
Warm temperate	2,46,514	5,79,095

7.20 Total annual energy expenses

Based on the energy source, its consumption, and prevailing electricity/fuel rates, an estimation was made for the total annual energy expenses. Figure 80 shows the average total annual energy expenses for minimum tourist standard hotels for each climate zone. The minimum is for the cool temperate climate as the energy requirement for heating and cooling is likely to be minimal in this climate as compared to other three climates.

Figure 80: Average of total annual energy expenses for all bio-climatic zones



Similar numbers for the resort and star hotel building typologies are shown in Table 95. In these bigger buildings, the annual energy expenses are much higher as compared to minimum tourist standard hotels.

Table 95: Annual expenses on energy for resorts and star hotels (NPR/y)

1.1.1.1.4	Average of Annual electricity expenses (NPR/y)	Average of Annual fuel expenses (NPR/y)
Resort	9,55,200	5,69,425
Cool temperate	2,35,000	6,37,500
Warm temperate	14,35,333	5,24,042
Star Hotels	34,20,500	19,24,130
Temperate	45,00,000	20,07,100
Warm temperate	23,41,000	18,41,160

7.21 Per guest room energy consumption and expenditure

Table 96 gives the average annual consumption of electrical energy, thermal energy and estimated energy expenses per guest room for all bio-climatic zones and building typologies. The trends among the climatic zones follow the same trend as given for the total energy expenses.

Table 96: Average of energy consumption and total expenses per guest room per year

Climate & typology	Average of Annual electricity consumption per room (kWh/y.room)	Average of Annual thermal energy consumption per room (MJ/y.room)	Average of Annual energy expenses per room (NPR/y.room)
Cold	262	6,160	23,481
Minimum tourist standard	262	6,160	23,481
Cool temperate	815	3,788	18,781
Minimum tourist standard	838	3,638	18,001
Resort	556	5,439	27,367
Temperate	1,678	5,571	37,952
Minimum tourist standard	1,252	4,983	29,134
Star Hotels	4,234	9,098	90,860

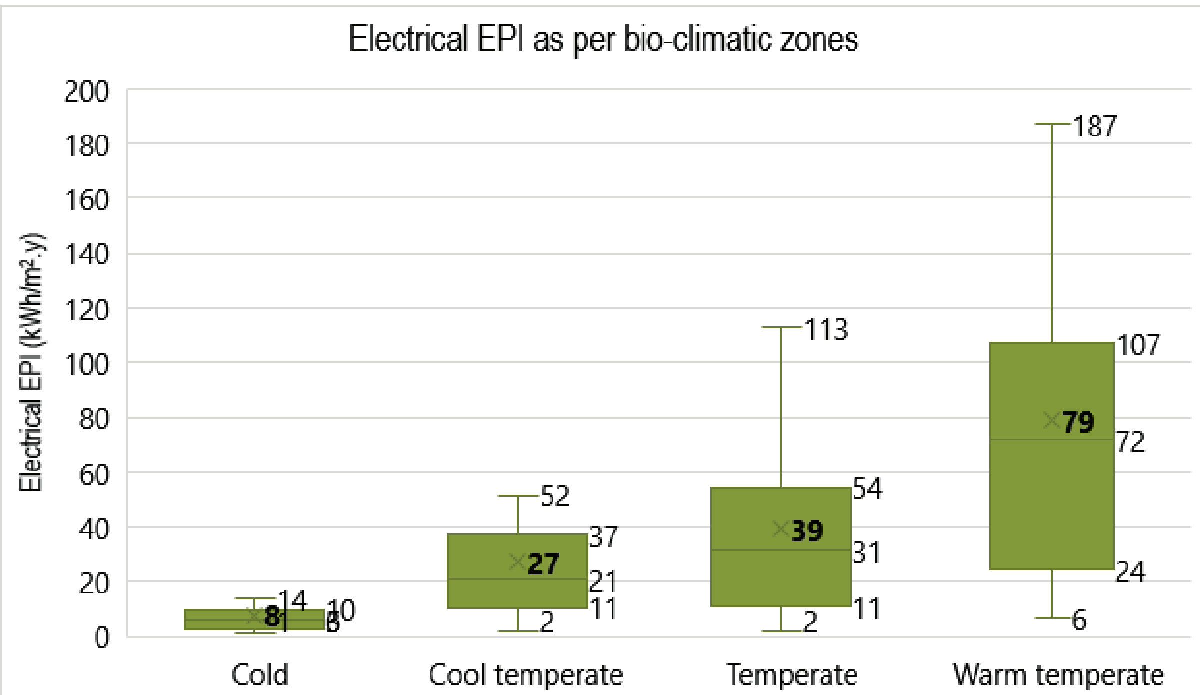
Climate & typology	Average of Annual electricity consumption per room (kWh/y.room)	Average of Annual thermal energy consumption per room (MJ/y.room)	Average of Annual energy expenses per room (NPR/y. room)
Warm temperate	2,621	6,232	44,327
Minimum tourist standard	1,756	4,802	31,298
Resort	7,015	7,860	93,811
Star Hotels	5,522	14,407	98,027

7.22 Energy Performance Index (EPI) – Electrical and Thermal

Figure 81 and Figure 82 show the average electrical EPI[22] and thermal EPI, respectively, as well as its spread (box and whisker plot) as per bio-climatic zones. The numbers in the middle of the box show the average values. The spread shows that with the higher average EPI, the spread also increases.

The overall trend for electrical and thermal EPI is in line with the explanation given in the previous section. The electrical EPI increases as we move from the colder to warmer climate, indicating the higher use of electricity for air-conditioning. Thermal EPI is the highest for the cold climate suggesting a higher fuel usage for space heating and water heating applications, as the requirement is higher. Higher thermal EPI in warm temperate climates could be associated with higher usage for cooking and power backup.

Figure 81: Electrical EPI for hotel buildings as per bio-climatic zone



22 For each bio-climatic zone, average electrical EPI = (sum of EPI of all offices in that bio-climatic zone) / (total number of hotels in that bio-climatic zone) Similar, calculations are done for "average thermal EPI".

Figure 82: Thermal EPI for office buildings as per bio-climatic zone

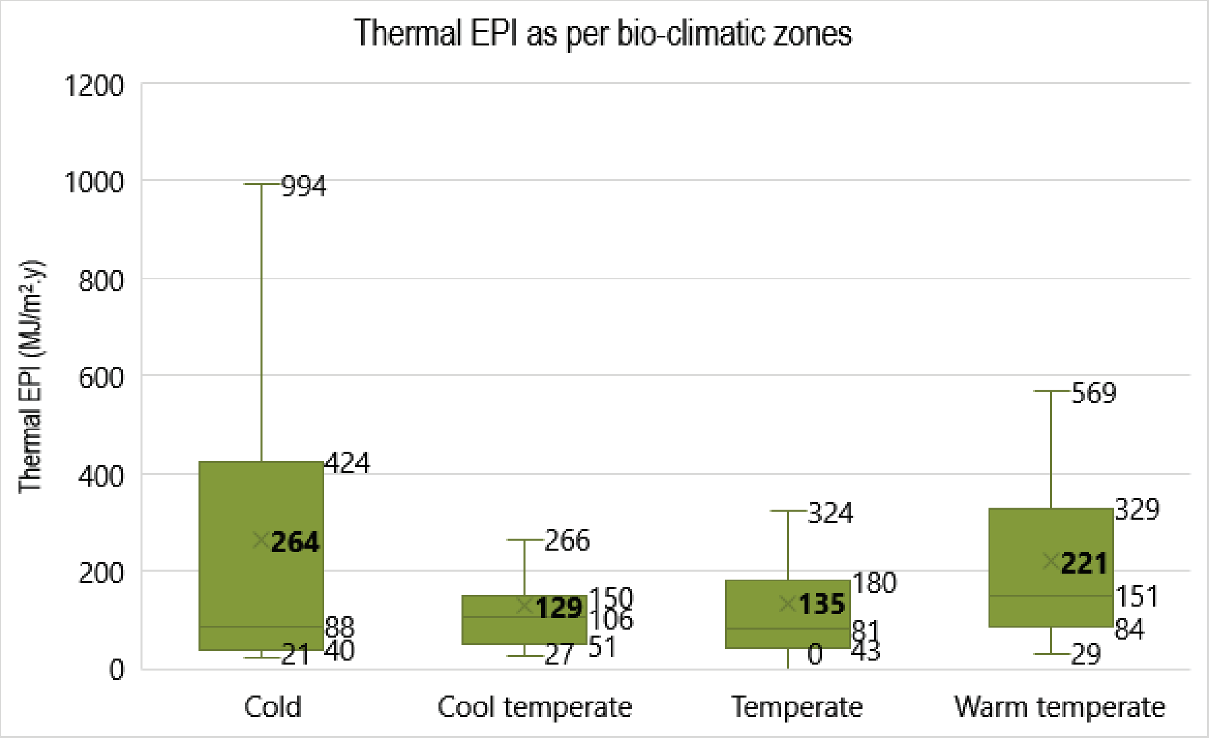


Table 97: Electrical and thermal EPI based on the building typologies

Climate / Typology	Average of Electrical EPI (kWh/m².y)	Average of Thermal EPI (MJ/m².y)
Cold	8	264
Minimum tourist standard	8	264
Cool temperate	27	129
Minimum tourist standard	27	113
Resort	29	297
Temperate	39	135
Minimum tourist standard	33	129
Star Hotels	77	174
Warm temperate	79	221
Minimum tourist standard	70	200
Resort	115	177
Star Hotels	114	385
Grand Total	45	185

The building typologies for the predominant building typology, i.e., minimum tourist standard, followed the same trend as that for the climate. 'Star Hotels' building typology had higher electrical and thermal EPI as compared to the other two typologies. Resort building typology had varied trends in cool temperate and warm temperate climates. The EPI variations are influenced by various factors, notably the prevailing climate and associated energy needs which are explained in the subsequent sections (refer Table 97).

7.23 Solar water heating and solar PV

7.23.1 Distribution of buildings (in %) with and without Solar PV installation based on the bio-climatic zone

Table 98: Availability of solar PV

Bio-Climatic Zones	Yes	No
Cold	43%	57%
Cool temperate	17%	83%
Temperate	8%	92%
Warm temperate	5%	95%
Grand Total	**15%**	**85%**

The cold climate had good penetration of solar PV as 43% of the surveyed hotelsare using it (refer Table 98). Most respondents in temperate and warm temperate climatic zones responded that solar PV is not used in their hotels. Slightly higher use of solar PV was observed in cool temperate climates. These findings suggest that solar PV installations increase as we move to the colder regions.

7.23.2 Distribution of type of Solar PV (standalone, grid-connected) based on the bioclimatic zone

Table 99: Type of Solar PV

Bio-Climate	Standalone System	Grid Connected
Cold	67%	33%
Cool temperate	100%	0%
Temperate	100%	0%
Warm temperate	50%	50%
Grand Total	**78%**	**22%**

Overall, the standalone system is more common, which is 100% for cool temperate and temperate climates (refer Table 99). For warm temperate climates, the solar system is uniformly distributed among standalone and grid-connected types.

7.23.3 Distribution of buildings (in %) with and without solar water heater installation based on the bio-climatic zone.

Table 100: Use of solar water heating devices

Bio-Climate	No	Yes
Cold	48%	52%
Cool temperate	38%	63%
Temperate	56%	44%
Warm Temperate	98%	3%
Grand Total	**64%**	**36%**

Penetration of SWH systems in hotels in cold, cool temperate, and temperate climates is quite good (overall 44-63%), while the warm temperate climate had very low SWH penetration. Overall, the SWH penetration (36%) was found to be more than the Solar PV (22%), showing a preference for renewable energy-based hot water systems over electricity generation (refer Table 100).

7.23.4 Distribution of type of solar water heating system (Flat plate, evacuated tube) based on the bio-climatic zone

Table 101: Type of solar water heating system installed

Bio-Climate	Evacuated Tube Collector	Flat Plate Solar Water Heater
Cold	82%	18%
Cool temperate	60%	40%
Temperate	31%	69%
Warm temperate	0%	100%
Grand Total	**53%**	**47%**

Overall, evacuated tube collectors and flat plate collectors both are being used in the hotel buildings. While in cold and cool temperate climates, evacuated tube collector was predominant; flat plate collector was the predominant type used in temperate and warm temperate climates (refer Table 101).

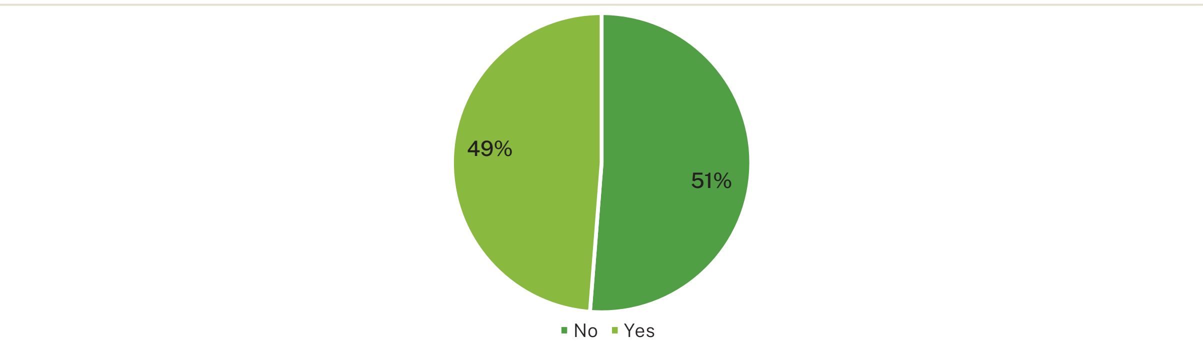
7.23.5 Predominant capacity of the solar water heating system based on the building typologies

In terms of building typologies, minimum tourist standard hotels had an average SWH capacity of 1000 LPD, while for star hotels building typology, the average size was 1500 LPD.

7.24 Energy efficiency awareness and use

7.24.1 Energy efficiency awareness

Figure 83: Energy efficiency awareness



Among the total surveyed hotel buildings, 49% responded to have awareness about energy efficiency measures (refer Figure 83). However, with or without knowledge, more than 93% of hotel buildings are using energy efficiency measures. Regarding the awareness of the energy efficiency in energy awareness level, male respondents reported to have higher awareness as compared to female respondents.

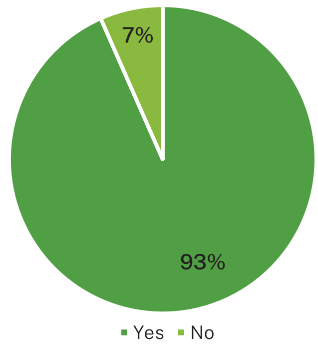
Table 102: Awareness of energy efficiency measures based on Bio-climatic Zones

Bio-Climatic Zones	No	Yes
Cold	38%	62%
Cool temperate	75%	25%
Temperate	47%	53%
Warm temperate	48%	53%

Based on bio-climatic zones, awareness of energy efficiency was found to be the highest in cold climates (refer Table 102). This may be due to the harsh weather climate conditions and the use of vernacular technologies to follow climate-responsive design.

7.24.2 Incorporation of energy efficiency measures

Figure 84: Incorporation of different energy efficiency measures



Out of all surveyed buildings, 93% have incorporated energy efficiency measures, which is mainly the use of LED lights (refer Figure 84).

Table 103: Use of different energy efficiency measures

Energy Efficiency Measures	Percentage of Offices Using it
Wall Insulation	1%
Roof Insulation	5%
Floor Insulation	2%
Double Gazed/Low E Glass	2%
LED Lighting	88%
Card Switches lighting control	5%
Sensor-based lighting control (occupancy sensors, dimmers)	2%
Sub metering for the end uses	3%
Building management system	1%

Out of the hotels using energy efficiency measures, 88% are using LED lights. The next sets of energy efficiency measures include roof insulation and card switch-lighting controls (refer Table 103).

7.25 Summary of results

Table 104 gives an overall summary of the key survey results which are already shown in the details in the above sections of this Chapter. The results parameters are mainly shown as per the bio-climatic zones, while some parameters are also shown as per building typology.

Table 104: Summary of baseline survey results for hotel buildings

Parameter (Predominant)	Typology	Cold	Cool_temperate	Temperate	Warm_ temperate
Building construction					
Construction practices	Minimum tourist standard	Load bearing	RCC frame with masonry infill	RCC frame with masonry infill	RCC frame with masonry infill
	Resort	-	RCC frame with masonry infill, Load bearing	-	Load bearing
	Star Hotels	-	-	RCC frame with masonry infill	RCC frame with masonry infill
Built-up area (ft2)	Minimum tourist standard	1000-2000 4000-5000	2000-3000	4000-5000 5000-6000	2000-3000 5000-6000 6000-7000
	Resort	-	6000-7000	-	20000-50000
	Star Hotels	-	-	9000-10000	10000-15000
Buildings with setback (%)	All	43 (All side)	33 (All side)	25 (All side)	43 (Two side)
Spatial Configuration	Minimum tourist standard	67% Single loaded	59% Double loaded	52% Single loaded	50% Single loaded 50% Double loaded
	Resort	-	100% Single loaded	-	67% Double loaded
	Star Hotels	-	-	80% Double loaded	80% Double loaded
Guest Rooms	Minimum tourist standard	13	10	18	17
	Resort	-	26	-	24
	Star Hotels	-	-	43	42
Wall construction	All	Overall ~480 mm: Cement Plaster (~20 mm) + Stone Masonry (~440 mm) + Cement Plaster (~20 mm)	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)	Overall 254 mm: Cement Plaster (12 mm) + Solid Burnt Brick (230 mm) + Cement Plaster (12 mm)
Roof type	All	Flat roof	Flat roof	Flat roof	Flat roof
Roof construction	All	a. Overall ~175 mm:Mud (~125 mm) + Wooden roof (~50 mm) b. Overall ~137 mm:RCC slab (125 mm) + Cement plaster (12 mm)	Overall ~210 mm: Cement plaster (12 mm) + Screed (60 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	a. Overall ~150 mm: Cement plaster (12 mm) + RCC Slab (125 mm) +Cement Plaster (12 mm) b. Overall 187 mm: Screed (50 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)	Overall 187 mm: Screed (50 mm) +RCC Slab (125 mm) +Cement Plaster (12 mm)

Parameter (Predominant)	Typology	Cold	Cool_temperate	Temperate	Warm_ temperate
WWR range (%)	Minimum tourist standard	20-30%	20-30%	20-30%	20-30%
	Resort	-	10-30%	-	20-30%
	Star Hotels	-	-	30-40%, >40%	>40%
Window type	All	Casement window	Casement window or Sliding window	Casement window or Sliding window	Casement window or Sliding window
Window glazing and framing	All	Wooden frame with single clear glass	Wooden frame with single clear glass	a. Wooden frame with single clear glass b. Aluminium frame with single clear glass	a. Wooden frame with single clear glass b. Aluminium frame with single tinted glass
Window shading	All	Continuous Overhang (at roof level)	Continuous Overhang (at roof level)	Continuous Overhang (at roof level)	a. Continuous Overhang (at roof level) b. No shading
Energy use in building					
Energy source	All	a. Electricity, LPG b. Firewood, Diesel, Petrol, Charcoal	Electricity, LPG	a. Electricity, LPG b. Diesel	a. Electricity, LPG b. Diesel
Annual electricity consumption (kWh/y) per hotel	Minimum tourist standard	3,900	8,907	26,288	30,446
	Resort	-	16,500	-	1,39,533
	Star Hotels	-	-	2,93,065	2,46,514
Annual thermal energy consumption (MJ/y) per hotel	Minimum tourist standard	65,622	36,841	80,753	83,556
	Resort	-	1,66,398	-	2,00,023
	Star Hotels	-	-	5,87,900	5,79,095
Annual energy expenses, total (NPR/y) per hotel	Minimum tourist standard	2,62,082	1,88,834	5,61,324	5,49,500
	Resort	-	8,72,500	-	19,59,375
	Star Hotels	-	-	65,07,100	41,82,160
Annual energy expenses, electricity (NPR/y) per hotel	Minimum tourist standard	48,287	90,292	3,28,039	3,03,500
	Resort	-	2,35,000	-	14,35,333
	Star Hotels	-	-	45,00,000	23,41,000
Annual energy expenses, other fuels (NPR/y) per hotel	Minimum tourist standard	2,13,795	98,542	2,33,286	2,46,000
	Resort	-	6,37,500	-	5,24,042
	Star Hotels	-	-	20,07,100	18,41,160

Parameter (Predominant)	Typology	Cold	Cool_temperate	Temperate	Warm_ temperate
Annual energy expenses per room (NPR/y.room)	Minimum tourist standard	23,481	18,001	29,134	31,298
	Resort	-	27,367	-	93,811
	Star Hotels	-	-	90,860	98,027
Electrical EPI, average (kWh/m^2.y)	Minimum tourist standard	8	27	33	70
	Resort	-	29	-	115
	Star Hotels	-	-	77	114
Thermal EPI, average (MJ/m^2.y)	Minimum tourist standard	264	113	129	200
	Resort	-	297	-	177
	Star Hotels	-	-	174	385
End-use: Space heating					
Energy source	All	Firewood	Electricity	Electricity	Electricity
Device used	All	Firewood Chimney	Split AC	Split AC	Split AC
Usage months	All	round-the-year	Nov-Jul	Oct-Mar	Dec-Jan
Usage hours per day	All	6.5	6.8	7.8	7.6
End-use: Space cooling					
Energy source	All	-	Electricity	Electricity	Electricity
Device used	All	-	Split AC	a. Split AC b. Ceiling fan	a. Ceiling fan b. Split AC
Usage months	All	-	Nov-Jul	Apr-Aug	Mar-Sep
Usage hours per day	All	-	8.3	8.0 (Split AC), 5.2 (Ceiling fan)	9.7 (Ceiling fan), 9.8 (Split AC)
End-use: Water heating					
Energy source	All	LPG	Solar	Electricity	Electricity
Device used	All	LPG Geyser	Solar water heater	Heat pump	Instant Geyser
Usage months	All	All months	Oct-Mar	All months	Nov-Feb
Usage hours per day	All	4.0	5.3	16.8	4.2
Power back-up system					
Provision of power back up system (%)	All	81	42	81	85
Power backup system	All	Generator	Inverter	Generator	Inverter
Renewable energy use and awareness on energy efficiency					
Houses using Solar PV (%)	All	43	17	8	5
Houses using solar water heater (%)	All	52	63	44	3
Houses aware about energy efficiency measure (%)	All	62	25	53	53

CONCLUSION AND RECOMMENDATIONS

8.1 Challenges and mitigations

Some of the challenges that the consultant faced during the survey and the possible mitigation measures to be adopted by the consultant were:

- Accessibility: Some rural and hilly areas may be difficult to reach due to poor roads or lack of transportation infrastructure. To mitigate this challenge, the consultant planned the survey route and arranged for reliable transportation.
- Language barriers: Survey teams encountered language barriers in some cases as they were not fluent in the local language or dialect. However, it was well communicated with the enumerators that all the information should be collected with sensitivity. Enumerators collected -accurate information by seeking help from local stakeholders in some cases.
- The TOR mentioned that consultants get a no-objection letter from each municipality before starting the survey. However, it was a time-consuming process and not feasible in many municipalities. The consultant deployed enumerators with a signed letter from the consultant in case of any objection. Rapport building with the municipalities was achieved by contacting local focal persons in the respective municipalities.

Despite all the challenges by being prepared and flexible, and by engaging with local authorities, community leaders, and experts, the consultant ensured that the survey was conducted effectively.

8.2 Conclusion

The baseline study was carried out to understand the overall operational energy of the buildings across various bio-climatic zones and building typologies.

The data analysis shows a high dependency on active devices for space cooling and space heating purposes.

Apart from the use of LED light, building efficiency measures are not popular in many cases. Electricity and LPG are still the popular mode of energy used for various purposes in the country. As the country continues to excel in hydroelectricity production, reduced tariffs on electricity can lead to a reduction of dependency on fossil fuels.

The research also revealed that as construction practices shift from traditional to modern, especially in temperate and warm temperate zones, the demand for space cooling has increased. Space cooling in warm temperate climates is used more than space heating in cold climates. While water heating is used almost uniformly in most of the bio-climatic zones, the increasing energy for space cooling is certainly one area that can be intervened. Innovative construction materials and passive cooling systems can be promoted to minimize energy consumption. Similarly, solar energy is seen as a popular choice of alternative energy sources. The government can thus introduce policies to promote cheaper electricity and solar devices to reduce the burden of high energy costs.

8.3 Further action required

The findings from the baseline survey, presented in the form of a report, are intended to serve as the foundational document for the development of the manual for the BEEN Project. Nevertheless, there is still a need for further actions, as identified below:

- Simulation-based approach for the further analysis of the typologies of buildings in the selected representative municipalities needs to be carried out to know the in-depth energy usage patterns, performance of construction technologies, and materials and equipment used in the particular bio-climatic zones.
- The study of the potential of Energy Conservation Measures (ECM) can be carried out based on the outcomes of the report.
- The cost-effectiveness, as well as return on investment, for efficient envelope components should be calculated for the surveyed typologies to determine the exact requirements for bio-climatic zones. This would help in the development of guidelines for building envelope design to achieve optimum consumer benefits and assist in policy-making aimed at saving energy.

- This survey will also provide a platform for comparison surveys in the future regarding energy efficiency and consumption scenarios. The survey can be extended to other provinces and municipalities as well. In order to obtain a broader overview and capture diverse perspectives, the survey can be extended to include the eastern and far western parts as well.
- The survey has been confined only to the three typologies of buildings, residence, day-use office, and hotel buildings. The survey can be done in other energy-intensive buildings like departmental stores, hospitals, etc.

ANNEX

9.1 Building plans, photographs and sketches

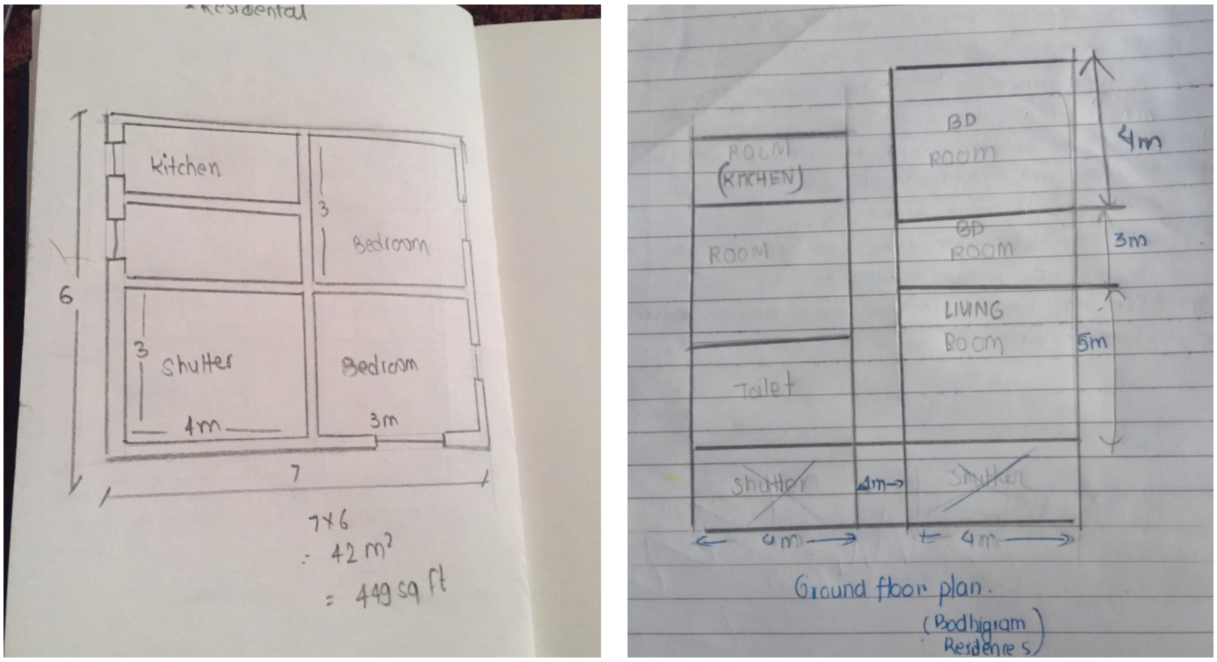
Figure 85: Hotel Building at Annapurna Rural Municipality

Figure 86: Surveyers at Chame, Manang

Figure 87: Curved solar water heater being used at Mustang

Figure 88: Traditional house at Mustang

Figure 89: Residential plans



9.2 Energy bills

Figure 90: Bills collected in the survey

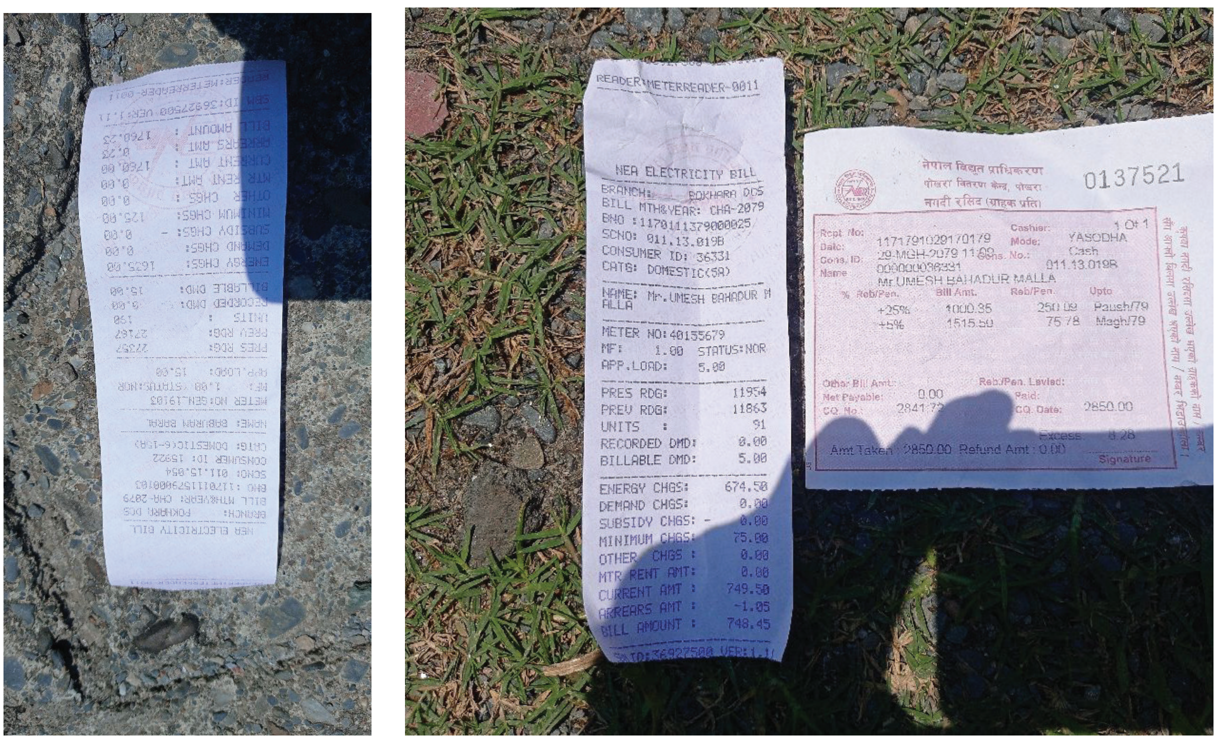


Figure 91: Bills verification sample 1

नेपाल विद्युत प्राधिकरण
Nepal Electricity Authority

TRANSACTIONS DATED FROM : 03/01/2022 TO 03/01/2023

Consumer Detail

Customer Name	Mrs.ANITA RAI RANA	SC No	052.12.041B
NEA Location	POKHARA DCS	Consumer Id	68502

Bill Detail

SNO	STATUS	DUE BILL OF	BILL DATE	CONSUMED UNITS	BILL AMT	REBATE	RATE	PAYABLE AMOUNT	PAID AMOUNT	PAID VIA MERCHANT	MERCHANT PARTNER TXN ID	PAID DATE
1	PAID				0.0000		0	0.0000	1586.0000		esewa87464434	3/1/2022 3:14:55 PM
2	PAID	Falgun/2078	24-FEB-22	175	1618.0000	REBATE	2	1586.0000		ESEWA Company	esewa87464434	3/1/2022 3:14:55 PM
3	PAID				0.0000		0	0.0000	1757.0000		esewa92701016	4/27/2022 12:32:52 PM
4	PAID	Chaitra/2078	26-MAR-22	173	1597.0000	PENALTY	10	1757.0000		ESEWA Company	esewa92701016	4/27/2022 12:32:52 PM
5	PAID				0.0000		0	0.0000	2844.0000		esewa96140289	6/5/2022 3:49:28 PM
6	PAID	Baisakh/2079	25-APR-22	152	1399.0000	PENALTY	25	1749.0000		ESEWA Company	esewa96140289	6/5/2022 3:49:28 PM
7	PAID	Jestha/2079	26-MAY-22	120	1095.0000	NO REBATE OR PENALTY	0	1095.0000		ESEWA Company	esewa96140289	6/5/2022 3:49:28 PM
8	PAID				0.0000		0	0.0000	1493.0000		esewa98641911	6/27/2022 8:20:35 PM
9	PAID	Ashad/2079	26-JUN-22	165	1523.0000	REBATE	2	1493.0000		ESEWA Company	esewa98641911	6/27/2022 8:20:35 PM
10	PAID				0.0000		0	0.0000	1892.0000		esewa103164857	8/3/2022 5:22:33 PM
11	PAID	Shrawan/2079	28-JUL-22	208	1930.0000	REBATE	2	1892.0000		ESEWA Company	esewa103164857	8/3/2022 5:22:33 PM
12	PAID				0.0000		0	0.0000	2163.0000		esewa106722527	9/1/2022 9:49:38 PM
13	PAID	Bhadra/2079	28-AUG-22	237	2207.0000	REBATE	2	2163.0000		ESEWA Company	esewa106722527	9/1/2022 9:49:38 PM
14	PAID				0.0000		0	0.0000	1724.0000		esewa111382977	10/7/2022 8:14:05 PM
15	PAID	Ashwin/2079	28-SEP-22	190	1759.0000	REBATE	2	1724.0000		ESEWA Company	esewa111382977	10/7/2022 8:14:05 PM
16	PAID				0.0000		0	0.0000	1632.0000		esewa114754408	11/2/2022 1:18:39 PM
17	PAID	Kartik/2079	29-OCT-22	180	1665.0000	REBATE	2	1632.0000		ESEWA Company	esewa114754408	11/2/2022 1:18:39 PM
18	PAID				0.0000		0	0.0000	1741.0000		esewa119172876	12/5/2022 7:59:15 PM
19	PAID	Mangsir/2079	28-NOV-22	188	1741.0000	NO REBATE OR PENALTY	0	1741.0000		ESEWA Company	esewa119172876	12/5/2022 7:59:15 PM
20	PAID				0.0000		0	0.0000	2945.0000		esewa127262253	2/2/2023 5:05:32 PM
21	PAID	Magh/2079	26-JAN-23	302	2945.0000	NO REBATE OR PENALTY	0	2945.0000		ESEWA Company	esewa127262253	2/2/2023 5:05:32 PM
22	PAID				0.0000		0	0.0000	2220.0000		esewa130629247	2/27/2023 7:32:39 PM
23	PAID	Falgun/2079	24-FEB-23	243	2264.0000	REBATE	2	2219.0000		ESEWA Company	esewa130629247	2/27/2023 7:32:39 PM
24	PAID	ARREARS	27-FEB-23	0	0.4100	NO REBATE OR PENALTY	0	1.0000		ESEWA Company	esewa130629247	2/27/2023 7:32:39 PM
	PAID		TOTAL		21743.4100			21997.0000	21997.0000			
25	PAY ADVANCE	ADVANCE	16-JUN-23	0	-0.5300	NO REBATE OR PENALTY	0	0.0000				
26	PAY ADVANCE	PAID UPTO 2080-02		0	0.0000	NO REBATE OR PENALTY	0	0.0000				
	PAY ADVANCE		TOTAL		-0.5300			0.0000				

Figure 92: Bill verification sample 2

SNO	STATUS	DUE BILL OF	BILL DATE	CONSUMED UNITS	BILL AMT	REBATE	RATE	PAYABLE AMOUNT	PAID AMOUNT	PAID VIA MERCHANT	MERCHANT PARTNER TXN ID	PAID DATE
1	PAID				0.0000		0	0.0000	13168.0000		esewa93653691	5/8/2022 2:44:21 PM
2	PAID	Baisakh/2079	05-MAY-22	1251	13436.0000	REBATE	2	13168.0000		ESEWA Company	esewa93653691	5/8/2022 2:44:21 PM
3	PAID				0.0000		0	0.0000	14352.0000		esewa96835319	6/12/2022 4:16:36 PM
4	PAID	Jestha/2079	05-JUN-22	1361	14644.0000	REBATE	2	14352.0000		ESEWA Company	esewa96835319	6/12/2022 4:16:36 PM
5	PAID				0.0000		0	0.0000	10807.0000		esewa100138470	7/10/2022 11:53:30 AM
6	PAID	Ashad/2079	06-JUL-22	1032	11027.0000	REBATE	2	10807.0000		ESEWA Company	esewa100138470	7/10/2022 11:53:30 AM
7	PAID				0.0000		0	0.0000	12768.0000		esewa104500505	8/14/2022 10:57:55 AM
8	PAID	Shrawan/2079	07-AUG-22	1214	13028.0000	REBATE	2	12768.0000		ESEWA Company	esewa104500505	8/14/2022 10:57:55 AM
9	PAID				0.0000		0	0.0000	11896.0000		esewa107951862	9/10/2022 12:36:19 PM
10	PAID	Bhadra/2079	07-SEP-22	1133	12138.0000	REBATE	2	11896.0000		ESEWA Company	esewa107951862	9/10/2022 12:36:19 PM
11	PAID				0.0000		0	0.0000	20571.0000		esewa116149619	11/11/2022 1:43:15 PM
12	PAID	Ashwin/2079	08-OCT-22	849	9013.0000	PENALTY	10	9915.0000		ESEWA Company	esewa116149619	11/11/2022 1:43:15 PM
13	PAID	Kartik/2079	08-NOV-22	1018	10873.0000	REBATE	2	10656.0000		ESEWA Company	esewa116149619	11/11/2022 1:43:15 PM
14	PAID				0.0000		0	0.0000	6838.0000		esewa119969451	12/12/2022 10:42:58 AM
15	PAID	Mangsir/2079	08-DEC-22	664	6977.0000	REBATE	2	6838.0000		ESEWA Company	esewa119969451	12/12/2022 10:42:58 AM
16	PAID				0.0000		0	0.0000	7177.0000		esewa124791976	1/16/2023 12:07:53 PM
17	PAID	Poush/2079	06-JAN-23	682	7177.0000	NO REBATE OR PENALTY	0	7177.0000		ESEWA Company	esewa124791976	1/16/2023 12:07:53 PM
18	PAID				0.0000		0	0.0000	5816.0000		esewa127965925	2/8/2023 10:40:21 AM
19	PAID	Magh/2079	05-FEB-23	569	5934.0000	REBATE	2	5816.0000		ESEWA Company	esewa127965925	2/8/2023 10:40:21 AM
20	PAID				0.0000		0	0.0000	6820.0000		esewa133109612	3/22/2023 1:05:11 PM
21	PAID	Falgun/2079	06-MAR-23	620	6495.0000	PENALTY	5	6820.0000		ESEWA Company	esewa133109612	3/22/2023 1:05:11 PM
22	PAID				0.0000		0	0.0000	7205.0000		esewa135338692	4/9/2023 12:08:44 PM
23	PAID	Chaitra/2079	05-APR-23	698	7352.0000	REBATE	2	7205.0000		ESEWA Company	esewa135338692	4/9/2023 12:08:44 PM
24	PAID				0.0000		0	0.0000	10182.0000		esewa138412259	5/2/2023 10:08:07 AM
25	PAID	ADVANCE	02-MAY-23	0	-0.2800	NO REBATE OR PENALTY	0	0.0000		ESEWA Company	esewa138412259	5/2/2023 10:08:07 AM
26	PAID	Baisakh/2080	05-MAY-23	974	10389.0000	REBATE	2	10182.0000		ESEWA Company	esewa138412259	5/2/2023 10:08:07 AM
	PAID		TOTAL		128482.7200			127600.0000	127600.0000			

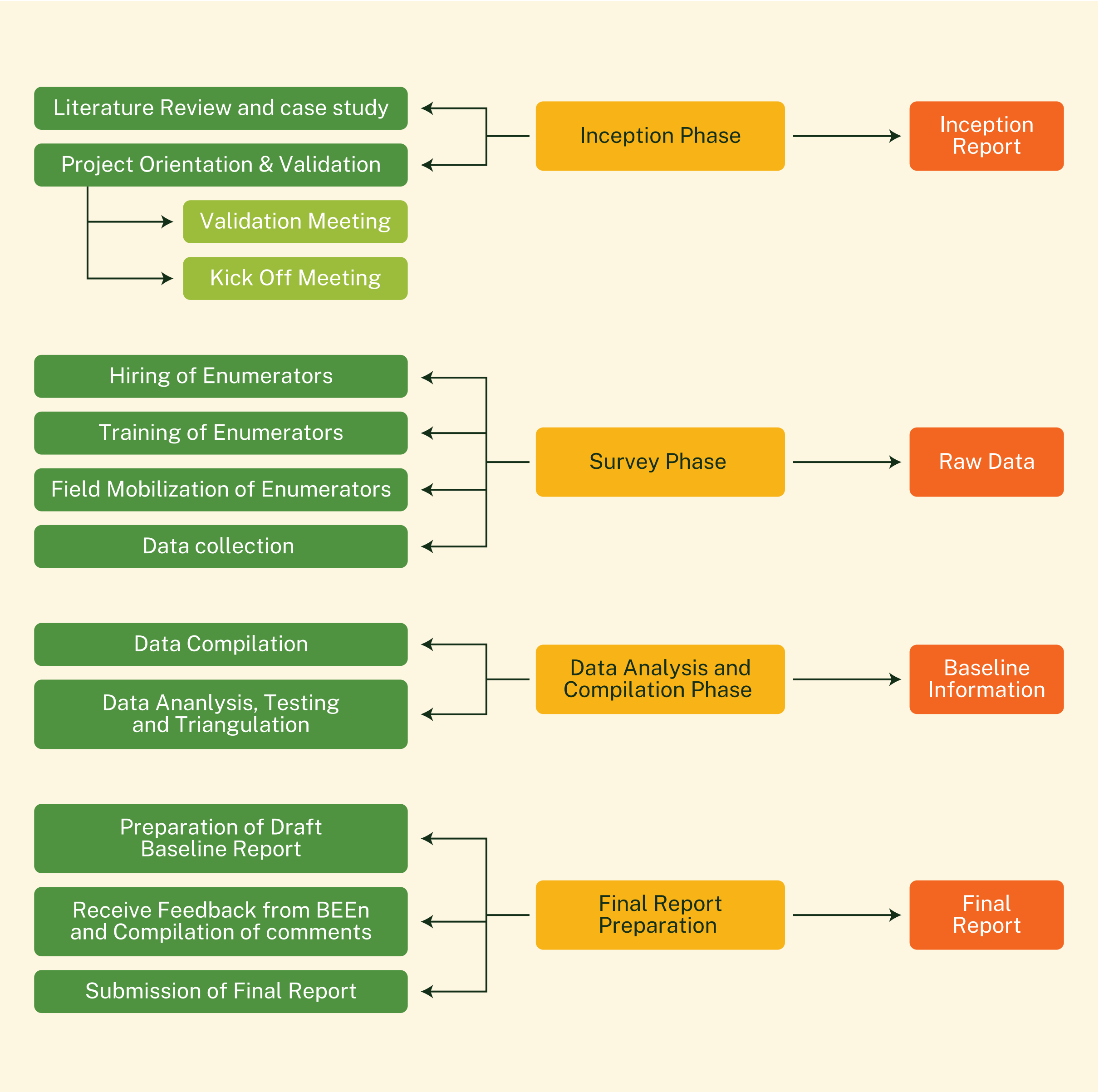
9.3 EPI calculation method

Electrical EPI = Annual Energy Consumption (kWh)/ Livable Building Area (Square Meters)

Thermal EPI= Summation of Thermal Energy Consumption (Mega Joule)/ Livable Building Area (Sq Meters)

9.4 Standard methodology

Figure 93: Standard Adopted Methodology



9.5 Team formation for the project

SN	List of Expert	Proposed Name	Highest Education	General Experience	Specific Experience	Nationality
1	Energy Efficient Building Design Expert/Advisor	Ujjwal Man Shakya	Master of Science in Architecture from Belarusian National Technical University, Minsk, Byelorussia in 1985	37	37	Nepali
2	Team Leader	Apil KC	M. Sc in Urban Planning in 2015 from Institute of Engineering, Pulchowk Campus, T.U. Nepal. Bachelor's in Architecture Engineering in 2012 from Institute of Engineering, Pulchowk Campus, T.U. Nepal.	10	7	Nepali
3	Data Analyst	Hari Prasad Pandey	MSc in Statistics from TU Nepal in 2018 BSc in Statistics from Trichandra Campus in 2013	9	9	Nepali
4	Survey Supervisor	Sampada Thapa Magar	Bachelor of Architecture 2017 from Institute of Engineering, Pulchowk Campus, T.U. Masters in Urban Planning,2021 Institute of Engineering, Pulchowk Campus, T.U.	5	5	Nepali
5	Survey Supervisor	Shreya Maharjan	Bachelor of Engineering (Civil) form Institute of Engineering Thapathali Campus in 2016 MSC in Construction Management (running)	6	6	Nepali
6	Survey Supervisor	Upashna Poudel	Bachelor of Architecture 2017 from Institute of Engineering, Pulchowk Campus, T.U. Masters in Energy Efficient Building ,2021 Institute of Engineering, Pulchowk Campus, T.U.	5	5	Nepali

Table 105: Summary of socio-economic data of selected municipalities

Municipality	Total Population	No. of Households	Avg. Household Size	Predominant Construction Material (%)	Predominant Wall Type (%)	Predominant Roof Type (%)	Primary Drinking Water Source (%)	Primary Cooking Fuel (%)	Primary Toilet Facility (%)
Bharatpur Met. City	369,268	96,591	3.82	Cement-bonded Brick/Stone (50.8%)	Cement-bonded Brick (92%)	CGI Sheets (49.7%)	Tap/Piped Water (52.1%)	LPG (88.0%)	Varied
Lalitpur Met. City	294,098	77,159	3.80	RCC Brick/ Stone (50.9%)	Cement-bonded Brick (52.2%)	RCC Slab (83.6%)	Tap/Piped Water (45.1%)	LPG (93.6%)	Flush Toilet -Septic (61.5%)
Dhulikhel Municipality	33,726	8,570	3.93	RCC Frames (41.3%)	Cement-bonded Brick (69.6%)	RCC Slab (61.9%)	Tap/Piped Water (61.4%)	LPG (75.9%)	Flush Toilet -Septic (73.1%)
Gosainkunda Rural Municipality	7,788	2,038	3.82	Mud-bonded Brick/Stone (35.5%)	Cement-bonded Brick (56.4%)	CGI (63.5%)	Tap/Piped Water (53.0%)	LPG (59.4%)	Flush Toilet -Septic (38.4%)
Butwal Sub-Metropolitan City	194,335	50,565	4.76	Cement-bonded Brick/Stone (34.3%)	Cement-bonded Brick (95.6%)	RCC Slab (77.8%)	Tap/Piped Water (65.2%)	LPG (94.2%)	Flush Toilet -Septic (82.6%)
Nepalgunj Sub-Metropolitan City	164,444	34,565	4.76	Cement-bonded Brick/Stone (48.9%)	Cement-bonded Brick (78.5%)	RCC Slab (75.3%)	Tap/Piped Water (35.0%)	LPG (77.8%)	Flush Toilet -Septic (67.5%)
Tulsipur Sub-Metropolitan City	179,755	46,018	3.91	Mud-bonded Brick/Stone (50.7%)	Cement-bonded Brick (49.6%)	CGI (41.1%)	Tap/Piped Water (74.8%)	Wood (44.8%)	Flush Toilet -Septic (74.3%)
Pokhara Metropolitan City	513,504	140,459	3.66	Cement-bonded Brick/Stone (45.7%)	Cement-bonded Brick (90.6%)	RCC Slab (62.8%)	Tap/Piped Water (65.2%)	LPG (90.8%)	Flush Toilet -Septic (90.6%)
Annapurna Rural Municipality	22,099	6,049	3.65	Mud-bonded Brick/Stone (66.7%)	Mud-bonded Brick (62.5%)	CGI (56.8%)	Tap/Piped Water (76.2%)	Wood (68.9%)	Flush Toilet -Septic (86.9%)
Gharapjhong Rural Municipality	7,788	2,038	3.29	Mud-bonded Brick/Stone (82.3%)	Mud-bonded Brick (85.9%)	Mud Roof (70.5%)	Tap/Piped Water (50.2%)	LPG (67.6%)	Flush Toilet -Septic (87.1%)
Varagung Muktichhetra Rural Municipality	2,036	723	2.82	Mud-bonded Brick/Stone (86.3%)	Mud-bonded Brick (85.9%)	Mud Roof (82.2%)	Tap/Piped Water (50.2%)	LPG (29.0%)	Flush Toilet -Septic (87.1%)
Chame Rural Municipality	1,276	389	3.28	Mud-bonded Brick/Stone (64.0%)	Mud-bonded Brick (49.1%)	CGI (87.9%)	Tap/Piped Water (65.3%)	Wood (71.0%)	Flush Toilet -Septic (88.9%)

BUILDING ENERGY EFFICIENCY IN NEPAL

Dakshinkali Chowk, Manbhawan
Lalitpur 44700

+ (977) 1-5421760
+ (977) 1-5421317

info@beenproject.org
https://been.minergynepal.com