TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

THESIS NO.: 074/MSCCD/014

An Analysis on Building Energy Consumption by Using Simulation Tool: A Case Study of Existing Office Building in Kathmandu Valley

by

Roshani Mandal

A THESIS

SUBMITTED TO THE DEPARTMENT OF APPLIED SCIENCE AND CHEMICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CLIMATE CHANGE AND DEVELOPMENT

DEPARTMENT OF APPLIED SCIENCE AND CHEMICAL ENGINEERING

LALITPUR, NEPAL

MARCH, 2022

TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

DEPARTMENT OF APPLIED SCIENCE AND CHEMICAL ENGINEERING

This is to verify that the thesis entitled "**An Analysis on Building Energy Consumption by Using Simulation Tool: A Case Study of Existing Office Building in Kathmandu Valley**" submitted by **Roshani Mandal (074MSCCD014)** has been examined and is accepted, in partial fulfillment of the requirements for the degree of Master Science in Climate Change and Development of Tribhuvan University.

Supervisor: ________________________________

Asst. Prof. Neeraj Adhikari
Department of Mechanical and Aerospace Engineering
IOE, Pulchowk Campus

External Examiner: ________________________________

Dr. Nawaraj Bhattarai
Department of Mechanical and Aerospace Engineering
IOE, Pulchowk Campus

Program Coordinator: ________________________________

Prof. Dr. Khem Narayan Paudyal
Climate Change and Development Program
IOE, Pulchowk Campus

Committee Chairperson: ________________________________

Prof. Dr. Ram Kumar Sharma
Head of Department
Department of Applied Science and Chemical Engineering
IOE, Pulchowk Campus

Date: March, 2022

ABSTRACT

Concerns about climate change are driving an increase in the demand for energy conservation. Buildings are large energy consumers in all countries, thus studying the impact of climate change on building energy performance is important. Building energy simulation software is a useful tool in this regard. A suitable set of typical weather files plays an important role in the success of building energy simulation.

The objective of this research is to evaluate the impact of climate change on energy consumption mainly due to atmospheric temperature change in the future. This study reports the work of developing a set of weather data files for Kathmandu, taking into the effects of future climate change. An existing Typical meteorological year (TMY) weather file of period 1973-1996 composed of weather data by the SWERA project was assumed as the baseline climate in this study. The monthly average temperature for future periods was predicted by SDSM (statistical downscaling model) under different emission scenarios, was further downscaled to hourly temperature data using the downscaling method, morphing. This shows that the annual average temperature of the atmosphere from baseline will increase by 0.6^0C, 1.5^0C & 2.4^0C for the different future scenarios i.e. RCP2.6, RCP4.5 & RCP8.5 respectively. A typical office building was modeled using the building simulation program eQUEST. Hourly building simulations were carried out for all the future scenarios including baseline year. The simulated results indicate that there will be a substantial increase in total energy consumption under the different RCPs future scenarios i.e. RCP2.6, RCP4.5 & RCP 8.5, ranging from 0.53%, 1.43% & 15.2% for the office building respectively from the baseline year whereas Space Cooling load increased by 31.69%, 34.16% & 100%. The study has also shown the comparison of building energy consumption with and without insulating material which results that insulating a building will decrease energy consumption. There will be a decrease in the cooling energy consumption by 5.23%, 3.01%, 6.59% & 15.64% in the baseline year, RCP2.6, RCP4.5 & RCP 8.5 respectively after the addition of insulation material insulator board.

Keywords: Building, energy consumption, TMY, RCPs, simulation, eQuest.

ACKNOWLEDGEMENT

First of all, I would like to thank my thesis supervisor Asst. Prof. Neeraj Adhikari for his constant guidance, supervision, comments, and inspiration throughout the study. I would also like to express my sincere gratitude to the Department of Applied Science and Chemical Engineering, Institute of Engineering for providing the opportunity to carry out thesis work as partial fulfillment of the Master of Science in Climate Change and Development.

I would like to express my gratitude to Prof. Dr. Ram Kumar Sharma, HOD, Department of Applied Science and Chemical Engineering, Prof. Dr. Khem Narayan Poudyal, Program Coordinator of “Climate Change and Development” for their guidance and encouragement and continuous support throughout the study. Also, I am indebted to my senior Mr. Sameer Pandit, for his continuous support in my thesis.

I am also grateful to the staff of Nirdhan Bhawan of Naxal for their cooperation during the study and for providing a sound environment for the study, without their support this thesis would not have been complete. Furthermore, I would also like to acknowledge the help from my friend Nirab Shrestha for providing the necessary information required for the study area.

Lastly, I would like to extend my appreciation to all my friends and family for their constant support to bring this research together.

Roshani Mandal

074/MSCCD/014

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ASHRAE = American Society of Heating, Refrigeration and Air-conditioning Engineers

DOE = Department of Energy

EPA = Environmental Protection Agency

EQUEST = Quick Energy Simulation Tool

GCM = General Circulation Model

GHG = Green House Gas

GISS = Goddard Institute for Space Studies

GON = Government of Nepal

HVAC = Heating, ventilating and Air Conditioning

IEA = International Energy Agency

IPCC = Intergovernmental Panel on Climate Change

NASA = National Aeronautics and Space Administration

RCMs = Regional Climate Model

RCPs = Representative Concentration Pathways

SDSM = Statistical Downscaling Model

SWERA = Solar and Wind Energy Resource Assessment

TMY = Typical Meteorological Year

CHAPTER ONE: INTRODUCTION

1.1 Background

Climate change is defined as a change in the condition of the climate that may be detected (e.g., using statistical tests) by changes in the mean and/or variability of its properties over time, generally decades or more (IPCC, 2012). There will be an unavoidable impact on most human activity and living, including buildings and their occupation patterns, as global mean temperatures and extreme occurrences are predicted to rise. (Waddicor et al., 2016). The building sector is one of the largest GHG contributors to global GHG emissions. According to Ürge-Vorsatz et al., (2014), the building industry accounted for 32% of worldwide final energy consumption, 19% of CO_2 emissions from energy, and 51% of global electricity consumption in 2010. Buildings have the greatest impact on climate change since they are the most common land use, aside from other land uses. One area that directly gets affected by climate change is the energy consumption for heating and cooling in buildings (Wang & Chen, 2014).

The impact of climate change on particular buildings in terms of rising temperatures is twofold. 1) Warmer temperatures have an impact on indoor temperature and thermal comfort. 2) Specific heating energy requirements per unit of area are reduced, while specific cooling energy requirements are increased if appropriately furnished. Both variables have an impact on the buildings sector's overall energy demand, either indirectly through increased demand for cooling spaces, or directly through changes in specific energy requirements. (Aebischer et al., 2007).

Buildings are built to achieve or provide a comfortable environment for people living inside. Heating and cooling in buildings has been easier as building technology have advanced, and there is less concern for climate and environment in sustaining comfortable indoor temperatures in modern buildings (Upadhyay et al., 2006). Future building energy consumption will be influenced by climate change. Building simulation is a feasible way to quantitatively evaluate this impact.

1.2 Problem Statement

Climate change has a huge impact on building design, how they are kept cool, and how they are weathered against more harsh climatic conditions, as well as on the health and well-being of individuals who live near structures. There are different parameters of building like building envelope, building equipment, orientation, ventilation, space used, passive technologies, etc. through which energy is being consumed and contributing to GHGs emissions which ultimately result in climate change. Buildings provide comfortable indoor environment conditions by operational energy. Heating and cooling are the main energy consumers in buildings and most of this energy is wasted due to improper way of operating it and these might be because of improper planning and inadequate insulation. The calculation of heating and cooling energy consumption based on the building envelope is usually ignoring climate change. Climate change is expected to alter a building's energy efficiency over its useful life. Studies on building heating and cooling energy consumption, and other aspects that contribute to climate change are lacking in the context of Nepal, so it becomes necessary to carry out an analysis of energy consumption.

1.3 Objectives

The main objective of this research is to evaluate the impact of climate change on energy consumption in a selected office building.

Specific Objectives

- To study the energy consumption pattern in different scenario
- To forecast the future climatic data using climate model
- To study the comparison in energy consumption pattern from baseline year and future year

1.4 Study Location

For this study, the office building is selected as maximum energy consumption for heating and cooling is in this type of building. This office building is located at Naxal Bhagwati Kathmandu. The office building is 5 storey in which ground floor is furniture showroom, the first floor is a bank, second floor, and the third floor is an office and the fifth floor is a conference hall.

1.5 Research Questions

The research questions are as follows:

- What will be the impact of climate changes on our buildings and are we designing them for the correct climate?

1.6 Expected Output

From the study, different parameters of building energy consumption like materials, envelopes, orientation, and building equipment for services will be studied. Energy consumption patterns of an office building will be studied and also comparison will be considered of baseline year and future year.

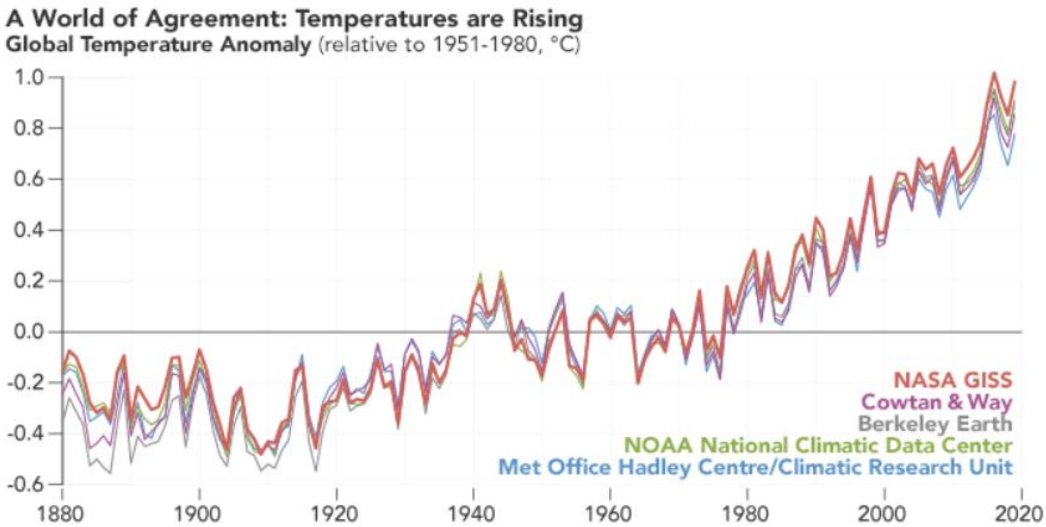
1.7 Limitations

Climate change concern leads to the decrement of energy use due to growing demand. As building is one of the largest energy-consuming sectors, it is essential to study the impact of climate change on building energy consumption. Hence instead of studying building type and design main focus of the study is to see the impact of climate change on the existing building energy consumption. Nepal is facing different climatic events like rising in atmospheric temperature, variable rainfall pattern, and seasonal changes which is ultimately affecting people. This study focuses only on the atmospheric temperature change.

CHAPTER TWO: LITERATURE REVIEW

2.1 Climate Change

Climate change is one of the most notable problems of the 21st century, human activity is responsible for the current rapid warming of the Earth's climate, which poses an unexpected threat to human civilization and the planet's ecosystems if allowed unchecked. Climate change is expected to have a number of negative effects on the environment, including increased temperatures, flooding, lesser water resources, health risks, and a reduction in biodiversity. The Earth's surface continues to be extremely hot, with recent global temperatures being the warmest in over 2,000 years. According to a study done by experts at NASA's Goddard Institute for Space Studies (GISS), the average global temperature has risen by at least 1.1 degrees Celsius since 1880. Since 1975, the majority of the warming has happened at a rate of 0.15 to 0.20°C each decade. Figure 1 shows the change in global surface temperature relative to 1951-1980 average



temperatures.

Figure 1: The global temperatures relative to 1951 to 1980.
Source: NASA's Goddard Institute for Space Studies (GISS)

Greenhouse gas emissions projections differ widely, depending on socioeconomic development and climate policies. The Representative Concentration Pathways (RCPs) explain four potential 21st-century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions, and land use, and are used to make projections based on these parameters. According to (Pandit and Bhattarai, 2018) as per Predictions cited by the Intergovernmental Panel on Climate Change (IPCC) indicate an increase in global average surface temperature in the different scenarios from 1.1 – 2.98^{0}C to 2.4 – 6.48^{0}C from a 1990s baseline at the end of the 21st century. According to the IPCC synthesis report 2014, Global surface temperature for the end of the 21st century is likely to exceed 1.5°C relatives to 1850 to 1900 for all RCPs except for RCP2.6. The increase of global mean surface temperature for 2081-2100 relative to 1986-2005 is projected to be in the ranges 0.3°C to 1.7°C under RCP2.6, 1.1°C to 2.6°C under RCP4.5, 1.4°C to 3.1°C under RCP6.0, and 2.6°C to 4.8°C under RCP8.5 (IPCC, 2014). RCP2.6 represents a scenario in which global warming is limited to less than 2°C above pre-industrial temperatures. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks (Kaito et al., 2000).

2.2 Climate Change in Nepal

Climate change is a serious threat to all developing countries. Nepal is amongst that developing countries worldwide, that has particularly susceptible to climate change because of its varied topography and social vulnerability. As a result, Nepal's adaptive capacity to cope with climate change variation is limited. Climate change has had an impact on a variety of areas, including water, forestry, biodiversity, agriculture, and the cryosphere. Impacts on these sectors are quite likely to have a negative impact on local residents' livelihoods. As suggested by IPCC (2013), climate-related changes, such as temperature changes, rainfall, and extreme weather events, can affect the environment and a wide range of sectors. Climate change is expected to put millions of Nepalese in danger, including reduced agricultural production, food shortages, strained water resources, loss of forests and biodiversity, and infrastructure damage. The impact is going to be more serious in the coming years if proper adaptive measures are not taken into consideration.

In Nepal, the temperature has risen steadily over the last few decades. Between 1978 and 1994, the maximum temperature in Nepal climbed at a rate of 0.06 °C per year, with larger rates at stations at higher altitudes (GON, 2019). Another study found that between 1975 and 2010, the daily maximum temperature climbed by 0.1 °C/decade on average, whereas the lowest temperature increased by 0.3 °C/decade (Shrestha et al., 2017). In the context of Climate change, Nepal is facing challenges in hydrological cycles and depletion of water resources.

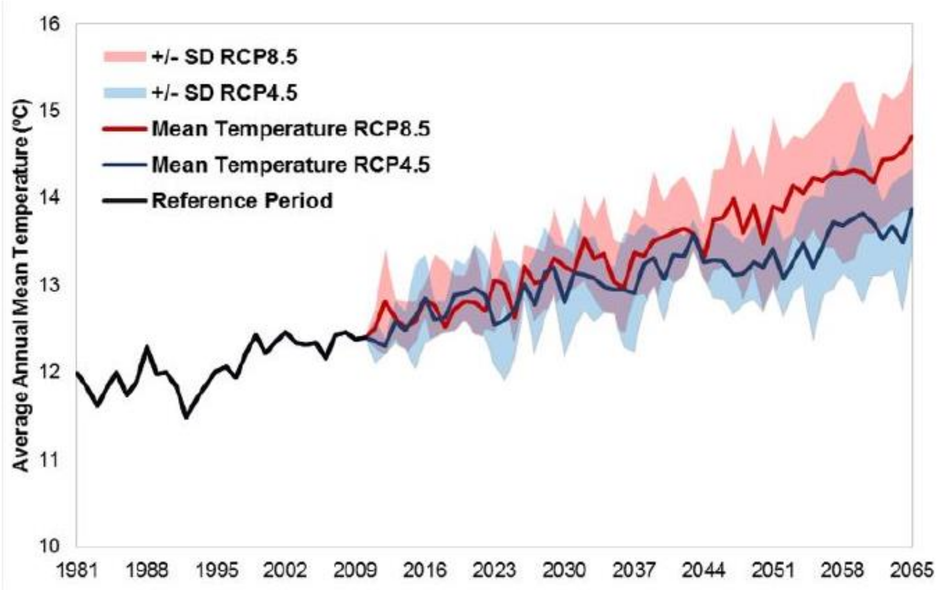


Figure 2: The average annual temperature from 1981 to 2065.

Source: (Government of Nepal, 2019)

As per the study done by the Government of Nepal in 2019, it has resulted that there will be an increase in temperature throughout the country. Fig 2 shows the findings done by GON, annual mean temperature from the period medium term: 2016-2045 to long term: 2036-2065 which shows that temperature increase by 0.9-1.1°C in the medium term and 1.3 to 1.82 °C in the long-term period (up to 2.5 °C in some places). The temperature in Nepal has risen by 1.8°C in the last 32 years. It could be because of solar radiation absorbed by glacier lakes as well as radiation absorbed by land due to snow melting in the Himalayan region (Gurung et al., 2011).

2.3 Climate Change in Buildings

The built environment is a high-priority area for climate change due to the complex and sensitive balance that it maintains with its environment. The impact of the built environment on the natural environment perhaps being the most noticeable in regard of climate change, as it gets boosted after the industrial revolution for which the emission of greenhouse gases is identified as the primary cause. As a result of population expansion, the building industry has become a priority area in climate change because of its substantial percentage of CO_2 emissions, significant energy savings prospects, and rising demands for occupant comfort. The built environment has grown in size and proportion as a result of rising income and the development of new technology, putting increasing demands on our resources.

The main objective of environmental building design is to create a comfortable yet energy-efficient internal environment for humans. The successful design of buildings relies on an appropriate understanding of the climate. Buildings are increasingly being designed to utilize passive techniques and have evolved so that they adapt to the climate. (Kinnane et al., 2016). The need to control the indoor environment to fulfill the demands of occupants evolved from the necessity to provide shelter. As a result, mechanical climate control systems were developed, which provide heating, cooling, and ventilation while operating almost completely independent of the building structure and its surroundings (Looman, 2012).

Climate change has a significant environmental impact on buildings because it switches energy demand from heating to cooling, creating HVAC system inefficiency and malfunction as a result of changing thermal operating conditions, and increasing precipitation, flooding, and wind. Extreme heatwaves are also anticipated to continue longer, get stronger, and occur more frequently, having a greater severe impact on human life and the electric grid (Dino and Akgül, 2019). As a result, it's critical to research building energy use and prospective climate change mitigation strategies.

2.4 Energy Consumption in Buildings

Buildings are big energy consumers in all countries, particularly in places with extreme climatic conditions, and a significant portion of energy is used to heat and cool them. Many cities throughout the world have witnessed rapid urbanization with little regard for the changing urban environment. This put a strain on the country's energy supply. As a result of being exposed to harsh external temperatures, the need for suitable building conditions has increased dramatically. According to the IPCC, in 2010 buildings sector accounted for 32 % of global final energy consumption and 19 % of energy-related CO_2 emissions, and 51 % of global electricity consumption was one of the largest end-use sectors worldwide. Furthermore, according to the Intergovernmental Panel on Climate Change (IPCC), the global average temperature is expected to rise by 4.1–4.8°C by 2100, and the change in carbon dioxide equivalent (CO_2-eq) emissions from 2010 to 2100 will be 74–178% if emissions continue to rise at the current rate.

(Dino and Akgül, 2019). Below Figure 3 shows that in 2010, space heating accounted for 32–34 percent of global final energy consumption in both the residential and commercial building sub-sectors. Furthermore, lighting was particularly essential in the commercial sub-sector, whereas cooking and water heating were important end-uses in residential buildings.

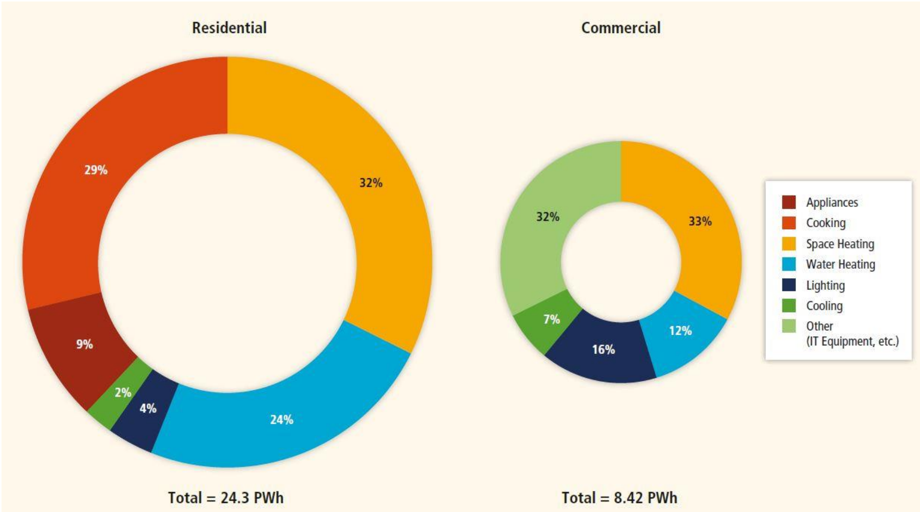


Figure 3: World building final energy consumption by end-use in 2010.
Source: (Cabeza and Jiang, 2014)

Climate change has a significant impact on the energy efficiency of buildings. The weather has a direct and significant impact on the thermal loads and energy consumption of HVAC (Heating, Ventilation, and Air Conditioning) systems. HVAC systems in commercial buildings in China account for more than half of overall building energy usage (Zhu et al., 2016). Buildings, both existing and future, will account for a significant amount of world energy demand. According to current trends, substantial increases in energy demand and related emissions are possible. As an important part of climate change studies, the forecast of building energy demand under climate change is very crucial in building energy savings, urban energy planning, urban strategy creation, and energy policy formulation.

The amount of energy used by a building is determined by a number of factors, including the environment, design, and kind of structure. In a hot climate, it is obvious that the cooling system consumes the most energy; nevertheless, in a cold climate, the heating system consumes more energy (Kamali, 2014). Furthermore, in compared to residential structures, commercial buildings consume more energy for lighting and appliances. Figure 4 illustrates the breakdown of end-use energy in office and residential buildings in the United States.

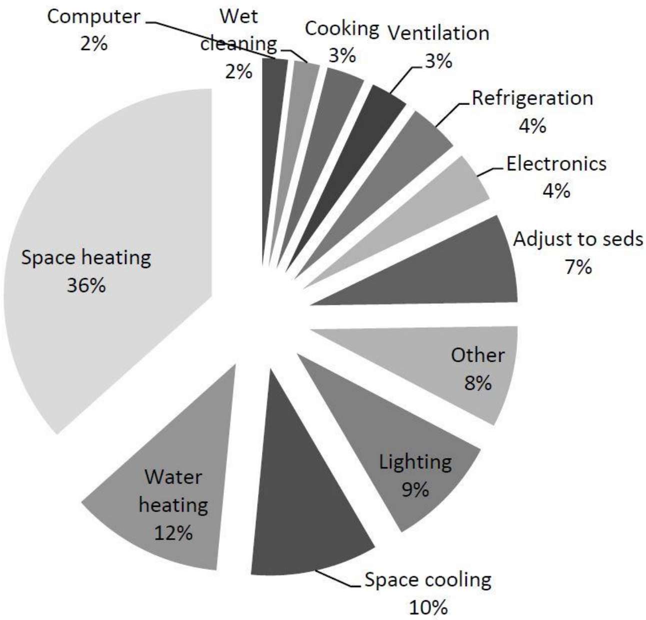


Figure 4: Breakdown of end-use energy consumption in a commercial and residential building in United State (U.S. Department of Energy, 2012) (Kamali, 2014)

Electricity and heat are two types of energy that are used for heating, cooling, lighting, air conditioning, and ventilation, among other things. In comparison to other applications, heating, cooling, and ventilation use the most energy. As a result, any energy-saving improvements to the air conditioning system and built environment result in lower building energy consumption.

2.5 Energy Consumption Pattern in Nepal

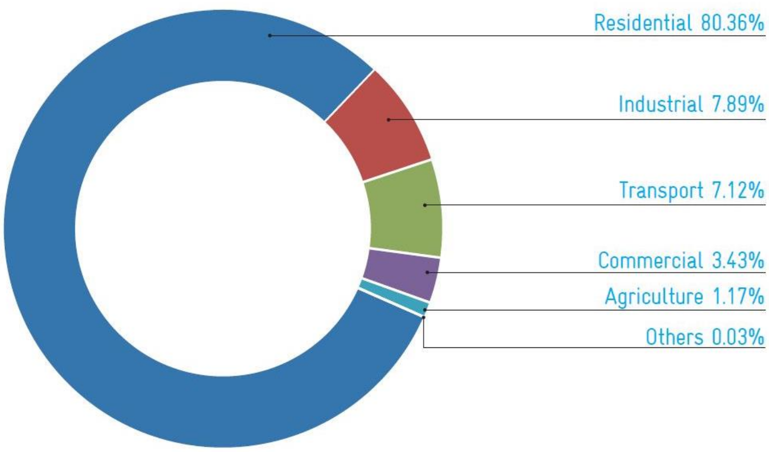


Figure 5: Energy consumption by economic sector in Nepal, 2011/12 (WECS, 2014)

Source: (GoN, 2014)

Figure 5 illustrates the energy consumption situation in Nepal for the year 2011/12 by fuel type and economic sectors. In the economic sector, the Residential sectors consumed the highest energy out of all which is almost 80%, led by industrial sectors 7.89 %, transport by 7.12%, and commercial sector is consuming around 3.43%. As the energy demand & population of the country is surging day by day, it is predictable that energy consumption is likely to increase in residential and commercial sectors.

2.6 Impact of Climate Change on Building

Concerns about climate change are causing people to reduce their energy consumption as demand grows. Buildings are one of the most energy-intensive features in any country, and they are influenced by the interaction and correlation of various distinct elements, including their physical characteristics, technical systems, equipment, inhabitants, and so on (Tam et al., 2018). The aging of a building's components, which is caused by its exterior and equipment degradation, has a major effect on its energy performance over time (Waddicor et al., 2016). Figure 6 clearly shows the different variables that influence the energy use of buildings.

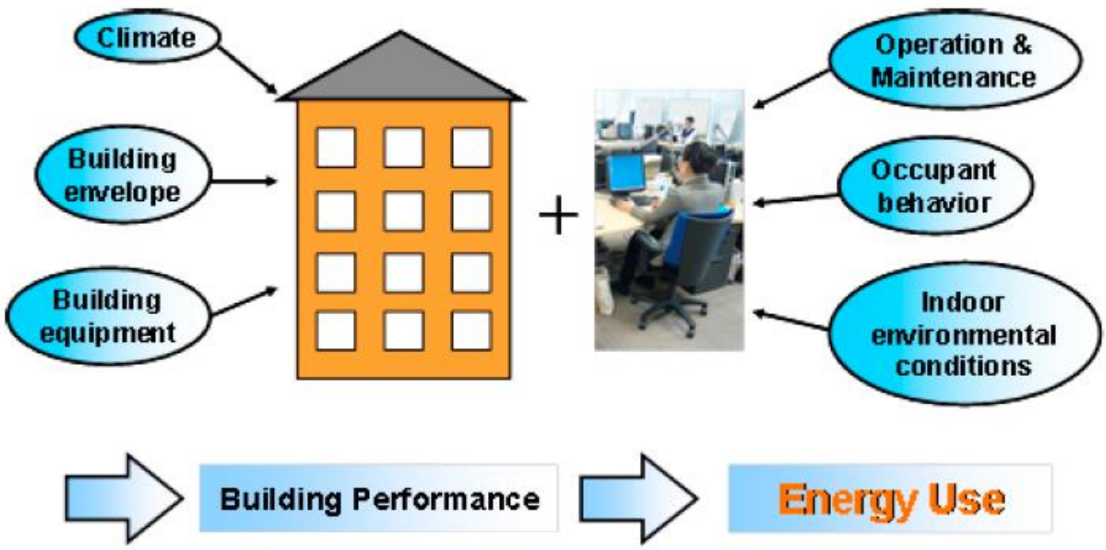


Figure 6: Six Factors influencing total energy use in buildings

Source: (Agency, 2016)

As the building is one of the large energy-consuming sectors, it is likely to be affected by climate change over its useful life. In this regard, building energy simulation is a useful tool. One simulation study done by (Invidiata & Ghisi, 2016) at the Civil Engineering Department, Federal University, Santa Catarina Brazil found that there will be an increase in the annual energy demand ranging from 19%-65% among the three cities in 2020, 56%-112% in 2050 and 112%-185% in 2080. According to this study, incorporating passive design strategies can also save up to 50% of future annual cooling and heating energy demand in Brazilian homes.

Another simulation study done by (Chan, 2011) shows that there will be substantial increase in A/C energy consumption under the impact of future climate change, ranging from 2.6% to 14.3% and from 3.7% to 24% for office building and residential flat, respectively. Similarly another energy simulation study done by (Dino and Akgül, 2019) shows that overheating will be experienced in the future which will have a strong effect on cooling energy use and occupant comfort.

As it is recognized that there will be major climate change due to global warming in the coming decades, the energy and thermal performance of buildings under future climatic conditions should be investigated and evaluated. Due to passive solar design features, the space heating, cooling, and mechanical ventilation loads and total annual energy consumption are found to be reduced in the building (Chandel and Sarkar, 2015). Renewable energy technology is an emerging tool to address the future energy demand which has no impact on the climatic properties. Some studies have demonstrated that the implementation of adaptation/mitigation techniques will be necessary to lower energy demand in buildings in order to reduce the impact of climate change in buildings. Furthermore, new buildings should be designed and constructed with efficient climate-change mitigation techniques and environmental characteristics.

2.7 Energy Demand Prediction of the Building

As an important part of climate change studies, the projection of building energy demand under climate change is directly important in building energy saving, urban energy planning, urban strategy development, and energy policy formulation. At present, the projection research of building energy demand under climate change can be divided into two groups: 1) direct prediction through statistical analysis, and 2) indirect prediction using building simulation tool (Zhu et al., 2016).

2.8 Direct prediction through statistical analysis:

A statistical analysis method is widely used for direct prediction to establish a link between local climatic factors (degree day, dry-bulb temperature/wet-bulb temperature) and specific building energy demand based on enough previously observed data. After a reasonable validation, the relationship can be used as a predictive model.

2.8.1 Indirect prediction using building Simulation Tool:

For indirect prediction, energy simulation techniques forecast the energy performance of a structure and the thermal comfort of its occupants. Building energy simulation is an analysis of the dynamic energy performance of a building using computer modeling and simulation techniques (Rallapalli, 2010). To predict a building's energy and environmental performance, an energy simulation program analyses the thermal, visual, ventilation, and other energy-consuming processes that occur within it.

To begin with, any simulation output can only be as accurate as the simulation's input data. The building dimensions, interior loads, HVAC systems and components, weather data, operating strategies and schedules, and simulation-specific factors are all used in the calculation process, as shown in Figure 7. Thermodynamic equations, principles, and assumptions are used in every energy simulation. The results of these simulations will show how alternative architectural parts or characteristics may have affected whole-building energy usage and how this may impact future net-zero energy building design (Anderson, 2016).

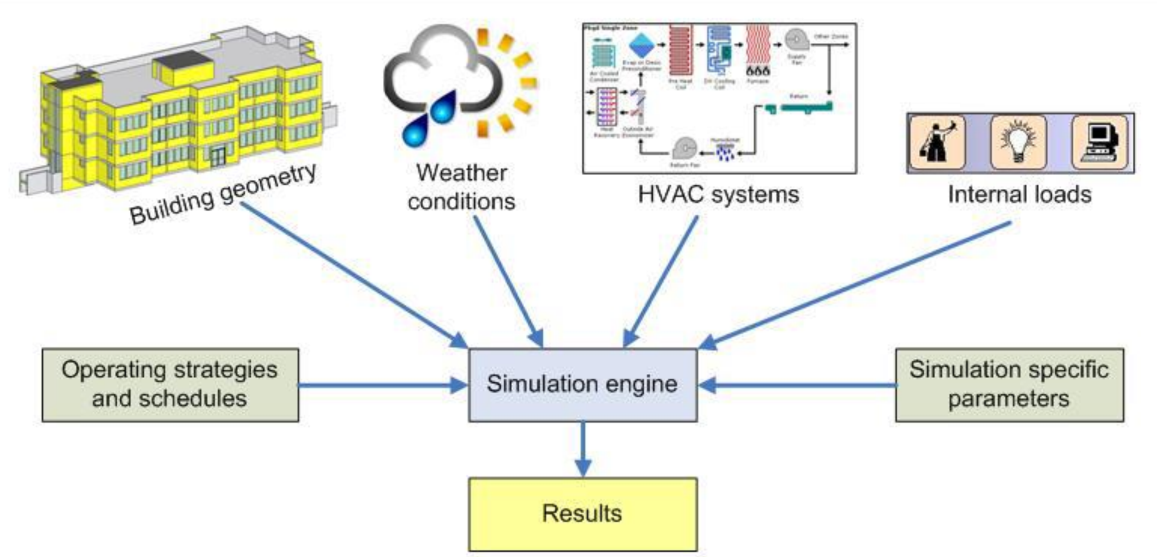


Figure 7: General data flow of simulation engines

Source: (Maile et al., 2007)

Building energy usage can be evaluated using computer-based modeling and simulation. There are many simulation software available these days for whole building performance simulation for example BLAST, DOE 2, eQUEST, TRNSYS, EnergyPlus, Energy Express, EFEN, etc (Chowdhury et al., 2007). eQUEST is a user-friendly building energy analysis program that combines a building creation wizard, an energy efficiency measure wizard, and a graphical results display module with an upgraded DOE-2.2 derived building energy simulation program to produce results. The user is guided through the process of generating a building model by the building creation wizard. DOE-2.2 uses hourly weather data for the location under consideration to perform an hourly simulation of the building over an entire year (8760 hours) based on inputs that describe its construction, occupancy patterns, equipment load, plug loads, and lighting loads, as well as heating and cooling systems, within eQUEST. eQUEST also allows users to create several simulations and compare the results side-by-side visualizations (Abdullah et al., 2014).

2.8.2 Energy Modeling Data Collection

eQUEST is interested in the walls, roof, and floor of the proposed building only in so far as they transfer or store heat (Rallapalli, 2010). The roof surfaces and above-grade walls characteristics are divided into five parts: construction, external finish and color, exterior insulation, additional insulation, and interior insulation (Zerroug and Dzelzitis, 2019). The data that is needed to include for modeling are as follows:

Building Architectural Data:

- All floor CAD drawings
- Building orientation and location
- Floor-to-floor and floor-to-ceiling heights

Building Envelope Construction Materials:

- Exterior wall, roof, and floor slab materials, windows, doors, wall insulation thickness and type, flooring material, and wall-slab construction joint type
- Fenestration details: number, size, and placement of all exterior doors and windows, as well as any overhangs, fins, blinds, or drapes on windows.

Building Operations and Scheduling:

- Building operation schedule
- Building occupancy details
- Lighting and office equipment load details

- Details of all HVAC systems, including numbers and types of AHUs and fans
- Temperature set-points for all AHUs
- Ventilation and air-flow values for all spaces
- HVAC zoning of all floors

Temperature:

The **air temperature** is the average temperature of the air surrounding the occupant, concerning location and time. Air temperature is measured with a dry-bulb thermometer and for this reason, it is also known as dry-bulb temperature.

Air temperature is one of the most essential climate variables, which has a major impact on human comfort as well as building design planning. Many elements influence the air temperature including incoming solar radiation, humidity, and geography of the nearby region (Bano & Kamal, 2016). It is important to understand the sources of temperature as it may affect workers‟ psychological state. There are no Environmental Protection Agency (EPA) standards. The American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc (ASHRAE) provides guidelines that are intended to satisfy the majority of building occupants wearing a normal amount of clothing while working at a desk. The ASHRAE guidelines recommend 68 F to 74 F (20-23.5C°) in the winter and 72 F to 80 F (23-26C°) in the summer (Northern Arizona University, 2013). According to Managing Indoor Air Quality cited by (Burroughs and Hansen, 2011), a suggested typical range for summer is 23 to 25.5 °C (73 to 78 °F), with that for winter being 20 to 23.5 °C (68 to 74 °F), depending on variations in humidity and likely clothing, although by other considerations the maximum should be below 24 °C (75 °F) and to avoid sick building syndrome, below 22 °C (72 °F).

The climate of Nepal varies not only with the season but also varies with geographical location. The Kathmandu Valley is located in the subtropical zone yet it has a composite climate due to its elevation of roughly 1200 meters above sea level. Kathmandu's climate has three distinct seasons, i.e. cool dry, hot dry, and warm wet seasons. In May and June, Kathmandu's climate is often dry and hot. The average maximum air temperature in the summer months is around 30°C, with a minimum is around 20ºC (Bajracharya, 2014).

Table 1: Climatic data of Kathmandu

1	Climatic feature	Composite climate	
2	Landscape	Relatively flat	
3	Vegetation	Abundant vegetation	
4	Solar radiation	Intense in summer & Diffused in monsoon	
5	Ambient temperature:		
	Summer	Day	mean maximum 30°C
	Night		mean minimum 20°C
	Winter	Day	mean maximum 19°C
	Night		mean minimum 3°C
	Diurnal variation	> 10°C	
6	Relative humidity	78% (Monsoon) & 50-60% (Summer & Winter)	
7	Precipitation	>1000 mm per year	
8	winds	Variable	
9	Sky conditions	Clear sky (Summer) & Generally overcast (Monsoon)	

Source: (Bajracharya, 2014)

According to Nicol's graph, the adaptive comfort temperature as being cited by (Bajracharya, 2014) the comfort temperature of Kathmandu is 15°C in winter and 26°C in summer.

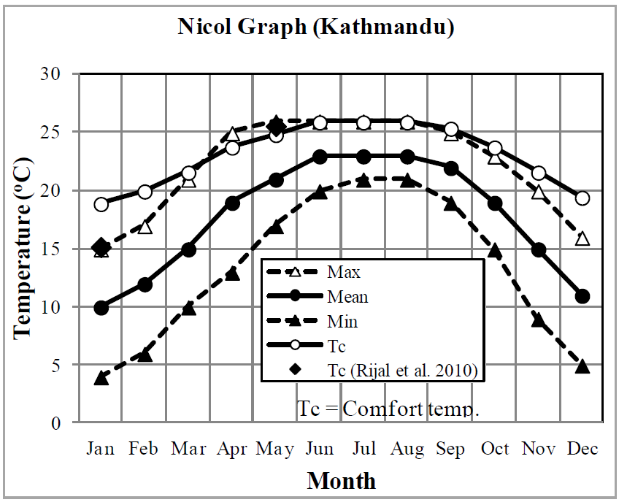


Figure 8: Outdoor air temperatures and the comfort temperature (Tc) for residential buildings of Kathmandu, Nepal.

Table 2: Adaptive Indoor Comfort Temperatures and Comfort Zone from Nicol and Rijal comfort temperature (Tc) in summer and winter for Kathmandu.

S.No.	Thermal Sensation	Thermal Scale	Nicol	Tc(ºC)	Rijal	Tc(ºC)	Comfort Category	Remark
			Summer	Winter	Summer	Winter		
1	Hot	3	32	*	32	*	Very Uncomfortable	
2	Warm	2	30	*	30	*	Uncomfortable	
3	Slightly Warm	1	28	*	28	*	Comfortable	Comfort Zone
4	Neutral	0	26	19	26	15	Very Comfortable	
5	Slightly Cool	-1	*	17	*	13	Comfortable	
6	Cool	-2	*	15	*	11	Uncomfortable	
7	Cold	-3	*	13	*	9	Very Uncomfortable	

Source: (Bajracharya, 2014)

2.9 Weather Files

The weather files used for building energy consumption simulation at a specific location that are hourly datasets in a variety of formats depending on country of origin and/or simulation package (Jiang et al., 2019). There are 20 sources available on the energy plus website from where weather data sources can be extracted out of which the typical year hourly data of Solar and Wind Energy Resource Assessment (SWERA), funded by the United Nations Environment Program, which is available for 156 locations in 14 developing countries are selected for this study.

2.10 Weather files generation for Future Climates

Climate models are the most important tools for studying the climate system's behavior to various forcing, making climate predictions on seasonal to decadal time periods, and forecasting future climate over the next century and beyond. (Kattsov et al., 2013). One of the most commonly used climate models is the global calculation model (GCM) and is capable of predicting future climatic conditions for further evaluating the changes in energy consumption in buildings (Wang et al., 2017). Since GCMs tend to ignore regional heterogeneity (such as climatic processes), their resolutions are too broad to be used for any kind of regional assessment (such as at a catchment level). As a result, these GCMs are downscaled even more to a smaller resolution. Downscaling techniques can be divided into two groups: Dynamic downscaling and empirical-statistical downscaling. Dynamic downscaling uses Regional Climate Models (RCMs).

Empirical-statistical downscaling is based on the statistical relationship between large-scale predictors (climate model data) and local-scale observations (GON, 2019). There are several methods for achieving downscaling.

2.10.1 Dynamical Downscaling

The first way is dynamical downscaling, which involves running comprehensive regional climate models that resolve small-scale atmospheric processes across a narrow spatial area with better modeling of topography and mesoscale processes, for example. However, because this technology is computationally expensive, it is unlikely to be used in building design projects.

2.10.2 Stochastic Weather Generation

A second option is the use of a 'weather generator,' in which synthetic weather time series are constructed using empirically derived statistics. Whilst this method is computationally cheap, it does require large data sets to ‘train’ the model to give appropriate statistics and fix unknown model coefficients, and the weather series it produces may not always be meteorologically consistent.

2.10.3 Interpolation

Interpolating the output from coarse resolution climate models in space and time is a third way. This method isn't commonly used to create climate change scenarios. The output of climate models is frequently biased, which is a fundamental disadvantage of this strategy. This means that even today's climate could be skewed, for example, by being warmer than measured.

SDSM (Statistical Downscaling Model) is a Windows-based decision support tool for quickly creating single site ensemble scenarios of daily weather variables under current and future regional climate forcing. It is an easy-to-use software package that uses statistical downscaling methods to generate high-resolution monthly climate data from coarse-resolution climate model (GCM) simulations. Researchers in the building industry typically use simulation software to explore future building energy demands as a result of climate change. Projected weather data and building models are among the simulation software's input files. Although there are a number mathematical approaches for forecasting future weather, the most well-known is the morphing method (Jiang et al., 2019).

2.10.4 Downscaling of Global Climate Change Model by The Morphing Method

The morphing method proposed by Belcher et al., 2005 was adopted for developing future weather data files. It has several practical advantages. First, the "baseline climate" is reliable, because it is the climate of the present-day weather series. Second, the resulting weather sequence is likely to be meteorologically consistent. Third, spatial downscaling is achieved because the present-day weather series is obtained from observations at a real location (Jiang et al., 2019).

According to studies carried out by Belcher et al., 2005; Jentsch et al., 2008, 2013; Jiang et al., 2018; Shen, 2017; Wang & Chen, 2014; Wang et al., 2010 as being cited by Jiang et al., 2019, "Morphing" methodology for weather data involves shifting and stretching the climate variables in the present day weather time series to produce new weather time series that summarize the average climate change, while preserving the physically realistic weather sequences of the source data.

The common algorithms used in the morphing process include: 1) shift; 2) linear stretch 3) combination of shift and stretch which is given below;

$$X = x_0+\Delta x_m \text{---} (1)$$

$$X = a_m x_0 \text{--} (2)$$

$$X = x_0+\Delta x_m+a_m\,(x_0-(x_0)_m) \text{---------------} (3)$$

where x_0 is the existing hourly climatic variable, Δx_m is the absolute change in monthly-mean climate variable for month m, a_m is the fractional change in monthly mean climatic variable for month m, $(x_0)_m$ is the climatic variable x_0 average over month m. This method is applied for adjusting the present-day dry bulb temperature.

CHAPTER THREE: METHODOLOGY

3.1 Overview

The research methodology outlines what research is, how it is conducted, how progress is measured, and what constitutes success (Noel). It defines how the data are collected in a research project. From a quantitative point of view, the proposed research has been developed. Quantitative approaches emphasize on objective measurements and statistical, mathematical, or numerical analysis of data obtained through polls, questionnaires, and surveys. This study lies within the post-positivist paradigm. The study involves quasi-experiment and does not include any hypotheses. The study follows the correlation method since different design parameters are correlated for the thermal performance of buildings. This research aims to determine the energy consumption for office buildings to see the impact of climate change.

3.2 Data Collection

The research methodology involves three main phases. The first phase involves the study of a wide range of literature reviews through journal articles, conference articles, and books to establish a firm base for the research findings. Likewise, the second phase is the study of the office building selected for this project. The office selected for this study is located at Naxal Bhagwati, Kathmandu. The office building is 5 storey in which ground floor is furniture showroom, the first floor is a bank, second floor, and third floor is an office and the fifth floor is a conference hall. The building footprint design is extracted from Autocad drawings of the building. Standard profiles for official buildings are used to produce occupancy profiles, lighting profiles, and other miscellaneous profiles. Building envelope profiles are based on the ASHRAE 90.1-2006 handbook.

For this study, the baseline climate was considered to be a 1973-1996 TMY weather file which was created using meteorological data from the SWERA project. The file contains hourly data on a variety of metrics. Finally, the third phase includes simulation of an office building by studying various building parameters.

3.3 Building Energy Simulation

For this study, the energy simulation tool e-QUEST was utilized, which forecasts hourly energy use and cost by running an hourly energy simulation of the building design for a year using meteorological data as input. Using hourly meteorological data for the place in question, e-QUEST can determine hourly building energy usage over the course of a year. For the same building setup, simulations are run for the baseline year and future years.

3.4 Downscaling Method for Hourly Temperature Generation

GCM data from SDSM software was used to predict future daily temperatures. It's a combination of a climate database, a stochastic weather generator, and transfer function methods. With consideration of three composite uncertainty scenarios, these future daily temperatures are converted into monthly mean temperatures. A downscaling method called Morphing was used to generate future TMY's based on an existing TMY in order to apply future monthly mean temperatures to building energy demand predictions.

3.5 Results, Discussion, and Conclusion

The result gained from the simulation was then analyzed in detail and a conclusion and recommendation was drawn from the analysis of the results.

3.6 Thesis writing, submission, and final Presentation

All the work done as part of the thesis was documented in the form of the report.

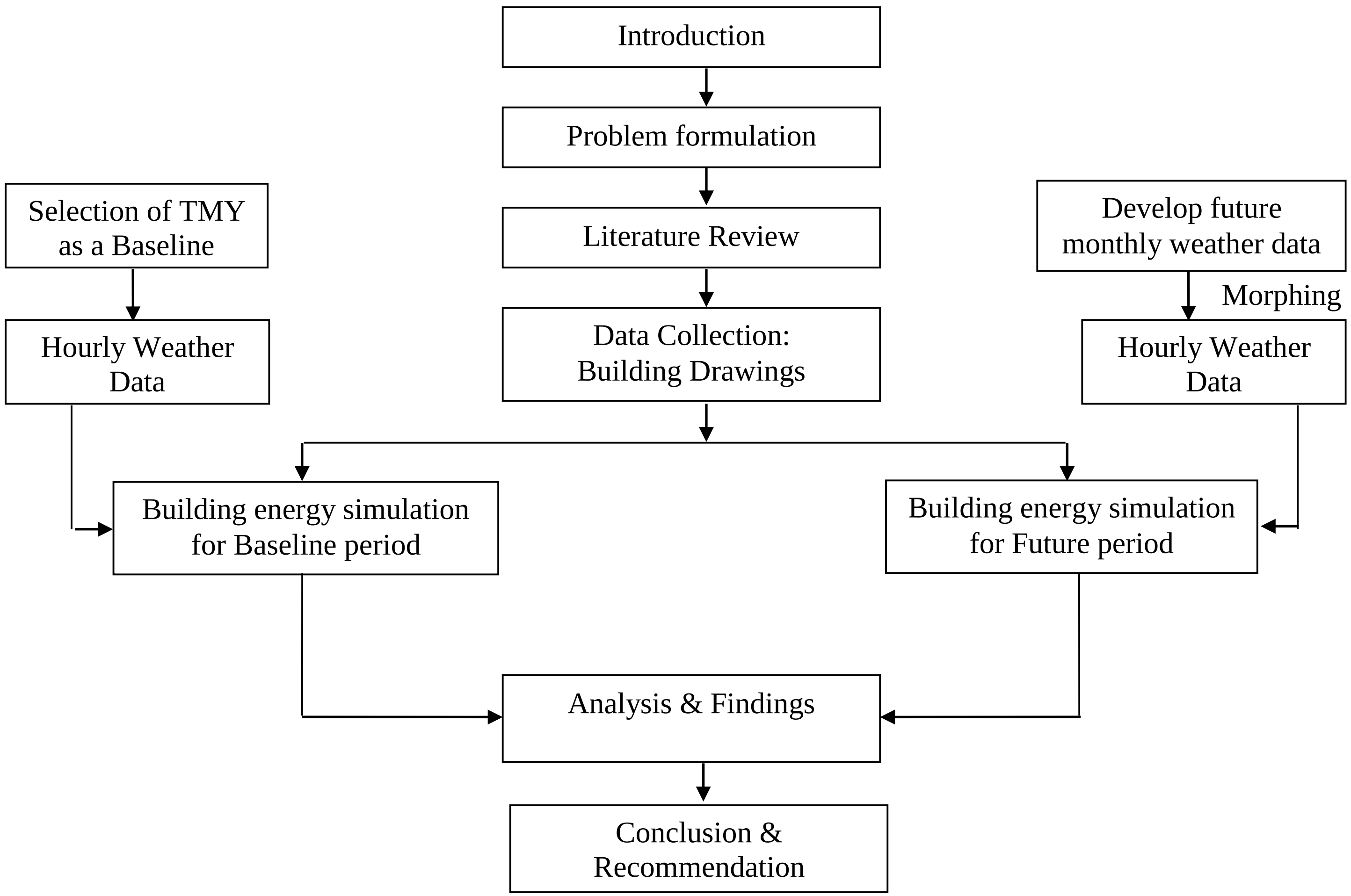


Figure 9: Flowchart of Methodology

CHAPTER 4: BUILDING DESCRIPTION AND FEATURES

4.1 Building Description

The main objective of this research is to evaluate the impact of climate change on energy use in selected building rather than their design. So one office building is selected for this purpose. This office building is located at Bhagwatibahal, Naxal, Katmandu with given planning (Refer Appendix) for modeling purposes to find out the impact of atmospheric temperature on the building energy use. For the modeling purpose following inputs are being considered of the building:

- All floor CAD drawings (Fifth storied)
- Building orientation and geographical location of the site
- Floor-to-floor and floor-to-ceiling heights
- Exterior and interior envelope construction (roofs, walls, slabs) – both, materials and insulation
- Building operation schedule
- Occupancy details
- Lighting and office equipment load details
- A simple packaged direct expansion system serves the cooling needs and packaged single zone heat pump serves the heating of the building

This building is used for an office. The building is run for 6 days a week and remains closed on Saturday. The building open from 8 am to 5 pm.

4.2 Building Geometry

Table 3: Building Geometry

Building Geometry	**Units**	**Inputs**	**Remarks**
Ground Floor area	Sq.ft	2656	As per the drawings provided
First-floor area	Sq.ft	2921	As per the drawings provided

Second-floor	Sq.ft	2921	As per the drawings provided
Third-floor	Sq.ft	2921	As per the drawings provided
Fourth-Floor	Sq.ft	2949	As per the drawings provided
Total conditioned area	Sq.ft	Only the second floor and the third floor is air-conditioned	
Number of floors above grade	No.	5	As per the drawings provided
Number of floors below grade	No.	0	As per the drawings provided
Floor to ceiling height	Ft.	10’	As per the drawings provided
Floor to floor height	Ft.	11’8”	As per the drawings provided
Plenum height	Ft.	No false ceiling	As per the drawings provided

4.3 Building Envelope

A building envelope is a physical interface between the conditioned i.e. inside and unconditioned i.e. outside environment of a building. It is one of the major inputs for the simulation of any building. These inputs include details like building characteristics and construction, frame type, and insulation status.

- Building characteristics and construction
    - Building orientation
    - Glazing orientation and cooling zones
    - Floor, wall, and ceiling construction details
    - Window and door characteristics
- Frame type

- Window and door area
- Single or double glazing, U-value
- Daylighting
- Skylights

➢ Insulation status

- Type, thickness, and location of the existing insulation

Table 4: Building Envelope

Building Envelope	**Units**	**Inputs**	**Remarks**
Roof U value	Btu/hr. sq. ft. F	0.658	Roof construction considered as per the ASHRAE 90.1-2007
Roof reflectivity			No cool roof
Wall U value	Btu/hr. sq. ft. F	0.403	9” brick wall plastered on either side
False ceiling	Btu/hr. sq. ft. F	NA	There is no false ceiling
External floor U value	Btu/hr. sq. ft. F	0.870	Clay tile flooring
Window wall ratio			
East West North South		By the building drawings provided	As per the drawings provided, the total window area to the exterior wall area
Shading			No external shading device

The U value is taken into consideration for the building chosen here in order to meet the ASHRAE 90.1-2007 standard standards. All of the proposed building's exterior walls are made of a standard brick wall with plastering on both sides.

For the construction, the most applicable materials from the eQuest library are used. The building envelope consists of an 8" common brick wall with stucco plastering on both sides and a 4" thick concrete slab with plastering on the interior face. Materials that are similar in nature are chosen from the material library and employed in the building. The resulting U value is 0.403 Btu/hr. sq. ft. F.

The Ground floor is in contact with the ground beneath. All the floors have 4” concrete with clay tile (with no insulation). Ceilings have a drywall finish, having no extra insulation. Vertical walls are framed without any extra insulation.

4.4 HVAC System

For thermal simulation models, HVAC systems and their components are a major part of the input information. These systems can be modeled to reflect the actual system if the energy simulation tool (graphical user interface and the engine) provides enough flexibility.

In the proposed building a simple package single-zone air conditioning system is used to meet the cooling requirements and for the heating packaged single zone heat pump is used. The cooling set point is maintained at 24^0C and the heating temperature set point is maintained at 22^0C. In the building, a constant speed fan with a motor efficiency of 0.9 is employed. The HVAC system fan starts one hour before the building's operational schedule and one hour after its closure.

Table 5: HVAC system properties

HVAC system	**Units**	**Inputs**	**Remarks**
HVAC system type		Packaged single-zone	A simple packaged DX system
Cooling type		DX high efficiency	
Cooling EER		8.2	
Heating type		DX coils (heat pump)	
Heating EER			COP=2.9
Supply fan control		Constant speed	
Fan on mode		Intermittent	

Fan schedule			Operate fan 1hr before open and 1hr before close
Minimum design airflow		0.5	
Motor efficiency of the fan		0.9	
Cooling setpoint	deg F	75(24^{0}C)	The comfort range is (19^{0}C-27^{0}C)
Heating setpoint	deg F	72(22^{0}C)	The comfort range is (19^{0}C-27^{0}C)
Thermostat set points Occupied unoccupied	 deg F deg F	 76 (24.4^{0}C) 70 (21.1^{0}C) 82 64	 Cool Heat Cool Heat

4.5 Loads and Profiles

Table 6: Ground floor lighting loads and profiles

Area Type	Percent area	Lighting (w/sq.ft)	Miscellaneous Loads(w/sq.ft)	Office equipment loads(w/sq.ft)
Furniture showroom	68.3	1.70	0.25	3.00
storage	15.9	0.80	0.00	0.00
Lobby (main entry and assembly)	12.8	1.30	0.25	0.00
Restrooms	3	0.90	0.1	0.00

Table 7**:** First-floor lighting loads and profiles

Area Type	**Percent area**	**Lighting (w/sq.ft)**	**Miscellaneous Loads(w/sq.ft)**	**Office equipment loads(w/sq.ft)**
Office (open plan)	41.9	1.10	0.75	3.00
Office (executive / private)	23.8	1.10	0.75	3.00
Corridor	3.8	0.5	0.00	0.00
Lobby (main entry and assembly)	13.5	1.30	0.25	0.00
Restrooms	4.7	0.9	0.10	0.00
Storeroom	6.3	0.8	0.00	0.00
Copy room(photocopying equipment)	5.9	1.50	0.70	0.30

Table 8: Second, Third-floor lighting loads and profiles

Area Type	**Percent area**	**Lighting (w/sq.ft)**	**Miscellaneous Loads(w/sq.ft)**	**Office equipment loads(w/sq.ft)**
Office (open plan)	47	1.10	0.75	1.09
Office (executive / private)	6.5	1.10	0.75	1.58
Conference room	13.7	1.30	0.10	0.75
Lobby (main entry and assembly)	13.3	1.30	0.25	0
Restrooms	4.7	0.9	0.10	0
Corridor	4.6	0.5	0.00	0
Storeroom	6.3	0.8	0.00	0
Copy room(photocopying equipment)	3.8	1.5	0.70	0.30

Table 9: Fourth-floor lighting loads and profiles

Area Type	Percent area	Lighting (w/sq.ft)	Miscellaneous Loads(w/sq.ft)	Office equipment loads(w/sq.ft)
Conference room	62.1	1.30	0.10	0.16
Storeroom	16.5	0.80	0.00	0.00
Lobby (main entry and assembly)	14.5	1.30	0.25	0.00
Corridor	3.2	0.50	0.00	0.00
Restrooms	3.7	0.90	0.10	0.00

4.5.1 Loads and Profiles

The Below graph represents the profiles for parameters like occupancy, office equipment, miscellaneous equipment, and lighting. The profiles are standard profiles selected based on building type. Hence following are the standard profiles for the official building. As the period of the day changes profile graph also changes. Office opening time is selected at 8 am and close time is 5 pm. The profiles vary accordingly with this time. At noontime, it is assumed to be a lunch break and hence there is a decrease in the percentage of full load in occupancy and office equipment.

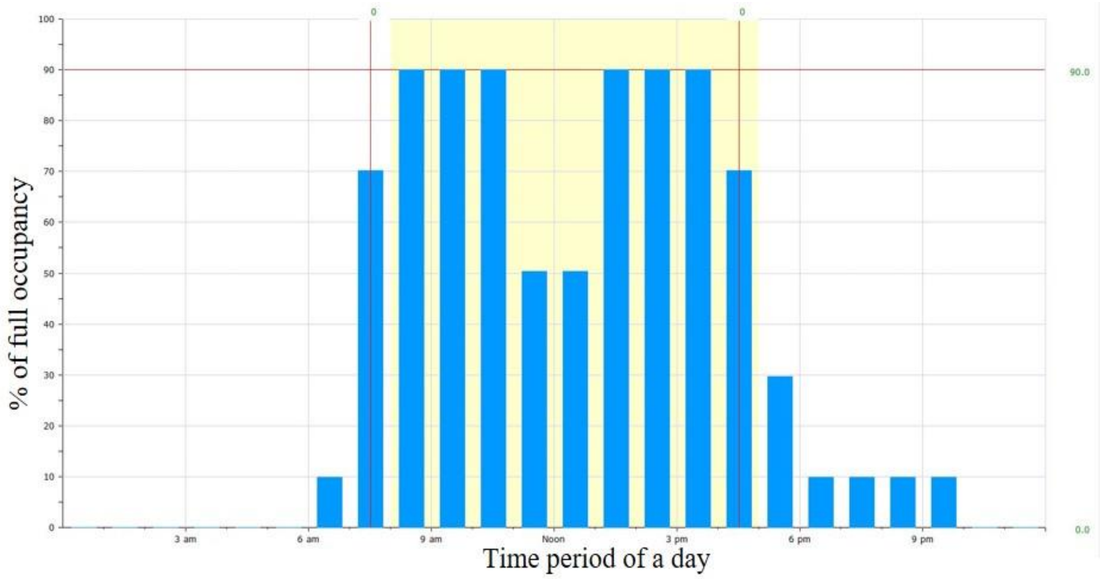


Figure 10: Occupancy Profiles

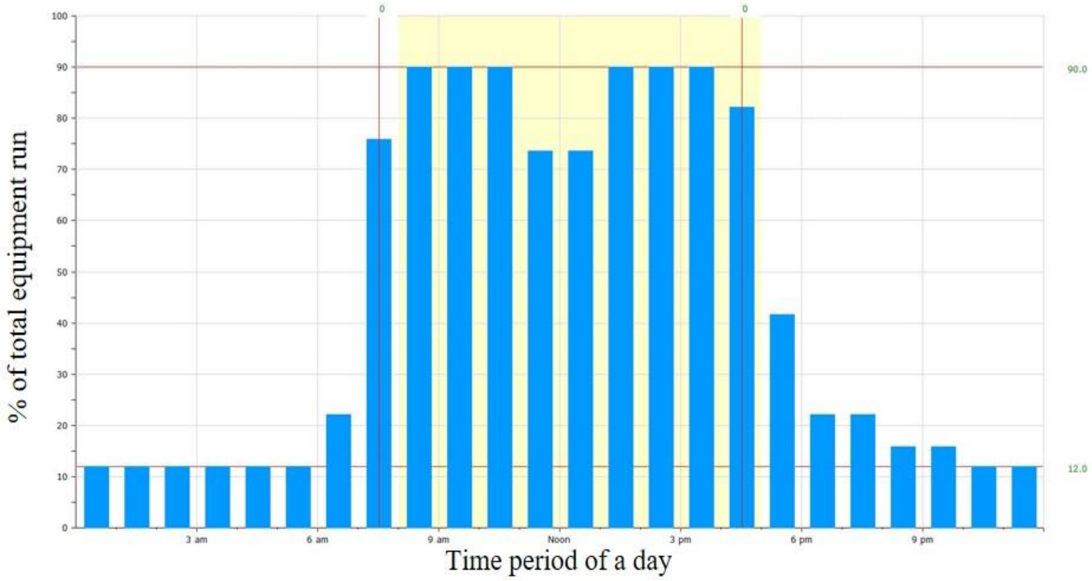


Figure 11: Office Equipment Profiles

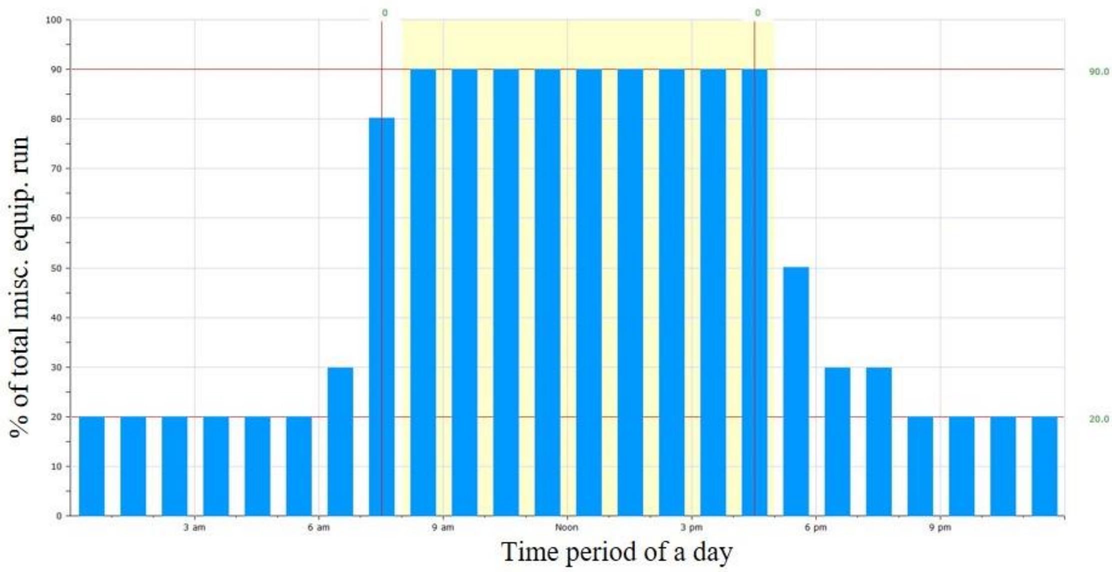


Figure 12: Miscellaneous Equipment profiles

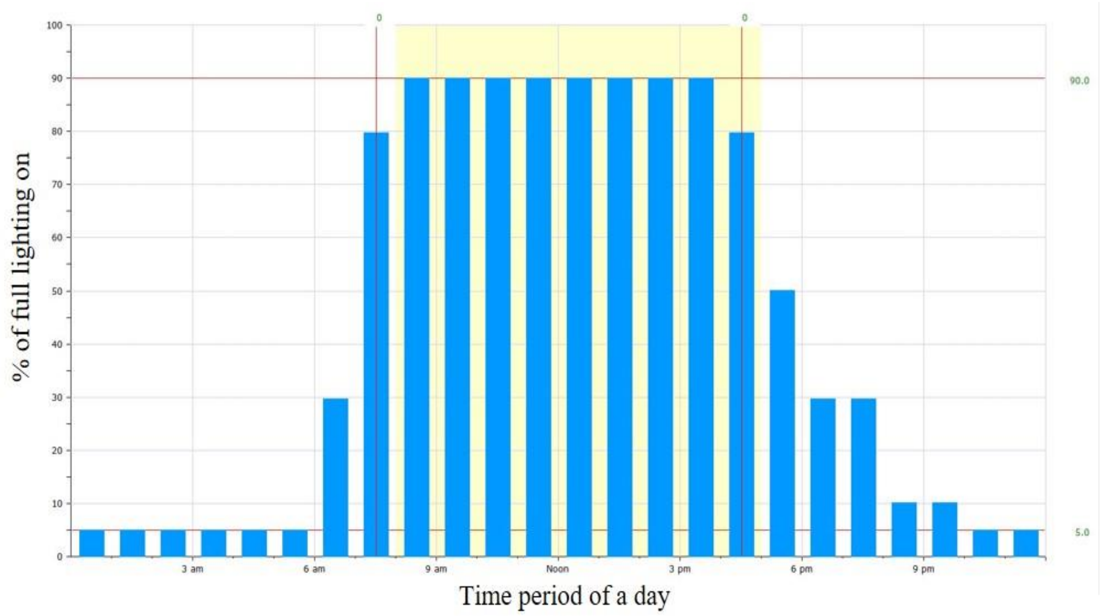


Figure 13: Ambient Lighting profiles

Above figures 12 & 13 represents the miscellaneous equipment and lighting profiles that are used for building operation. Here in the chart in vertical axis represent the percent for the parameter profile. Two vertical lines show the office shift start and end time. The horizontal line at the top of the bar is the position where the profile is maximum.

4.6 Weather Data Selection

The baseline climate for this study was based on an existing TMY weather file from 1973 to 1996, which was created using weather data from the SWERA project. The UN Environment Program-funded Solar and Wind Energy Resource Assessment (SWERA) project is generating high-quality data on solar and wind energy resources in 14 developing nations. Typical year hourly data are available for 156 locations in Belize, Brazil, China, Cuba, El Salvador, Ethiopia, Ghana, Guatemala, Honduras, Kenya, Maldives, Nicaragua, and Sri Lanka.

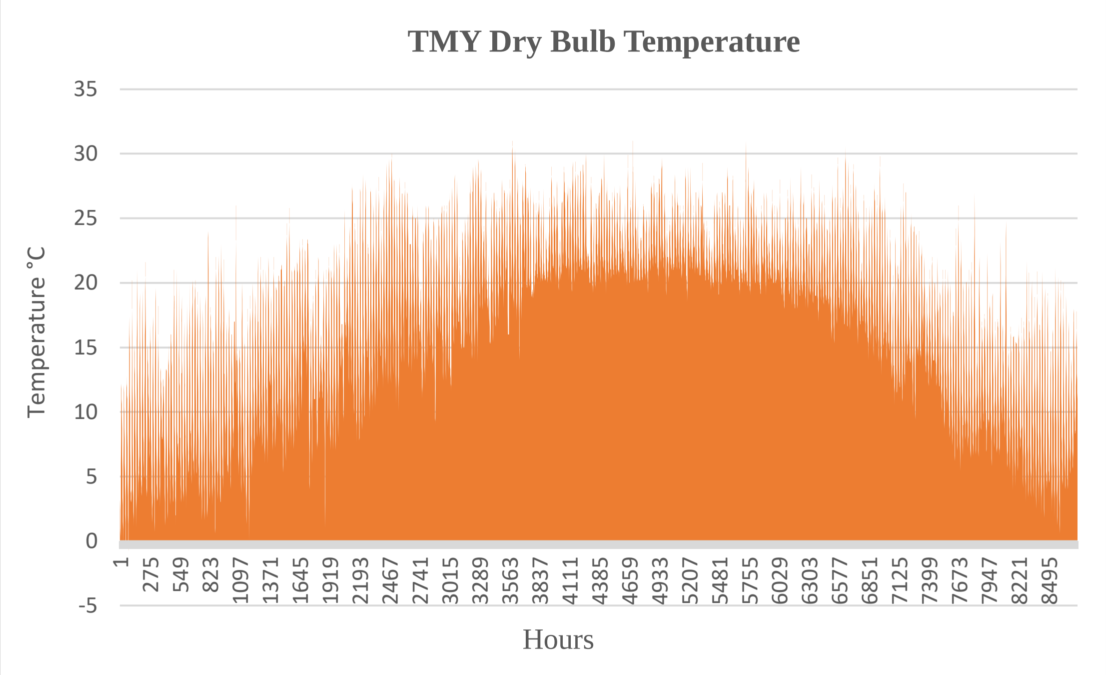


Figure 14: Temperature distribution of selected TMY (1973-1996)

Figure 14 represents the temperature distribution for the selected TMY 1973-1996 period. The temperature reading is varying from around zero degrees Celsius to about 31 degrees Celsius. Reading on the horizontal represents a particular hour time of a year of a selected period.

CHAPTER FIVE: ANALYSIS AND FINDINGS

5.1 Climate Change Data

General circulation model (GCMs) data needs to be downscaled into a higher resolution for the further analysis of regional data. The climate data is obtained from the Energy plus website (SWERA) project and the general Circulation Model file gridded from the Canadian website. These first data are the primary input data for the statistical downscaling model. This data is calibrated based on the screening variables and the GCM data are then validated and modeled to predict future data based on the various RCPs.

The GCM Data obtained from SDSM software is for 365 no. days for the different RCPs. As the weather inputs for the building simulation are the hourly TMYs, the data obtain from SDSM need to be downscaled again into hours to apply for simulation. These data are downscaled by morphing methods to generate hourly data.

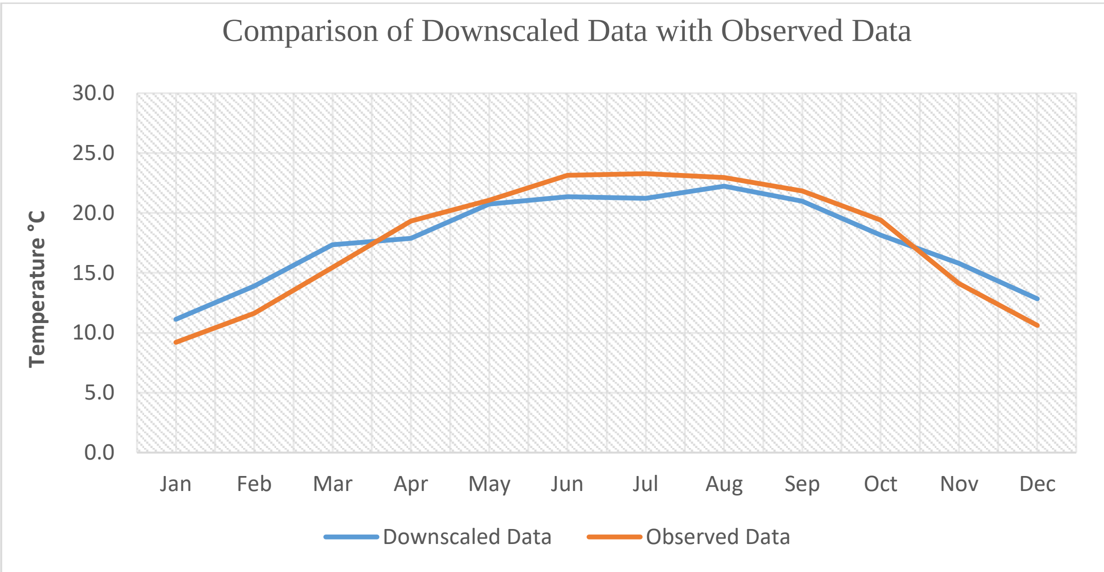


Figure 15: Comparison of Downscaled data with Observed data

Figure 15 shows the comparison of the monthly average temperatures of downscaled data and real observed data for the TMY period. The annual average temperature of real observed data is 17.7^{0}C whereas the downscaled data is 17.8^{0}C. The weather station of the real observed data is Kathmandu airport. Although an annual average of downscaled data and real data are nearly the same, monthly averages are varying.

Maximum variation is seen between June and July and the rest of the months have a nearly same monthly average temperature. This comparison supports verifying the software in the prediction of future temperature data. Also, this comparison further increases the reliability of the different scenarios temperature data that are predicted from SDSM software.

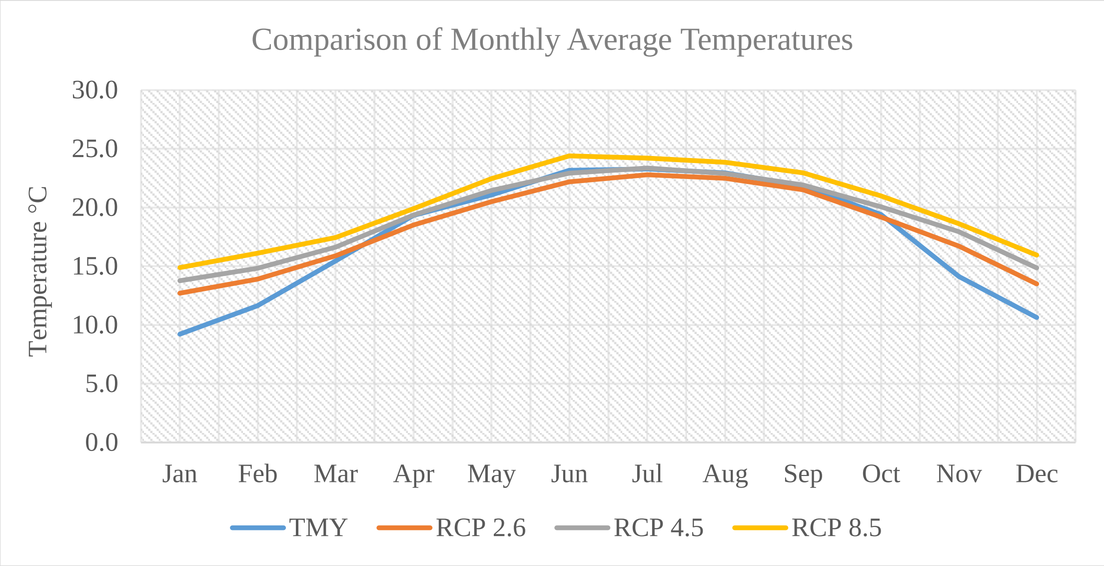


Figure 16: Comparison of Monthly Average temperatures

Figure 16 shows the comparison of the monthly average temperatures of baseline and different future scenarios. There is an increment in the temperature in different scenarios compared to the baseline period. Here the annual average temperature is increased from 17.7^{0}C to 18.3^{0}C, 19.2^{0}C & 20.1^{0}C for the scenarios RCP 2.6, RCP 4.5 & RCP8.5 respectively.

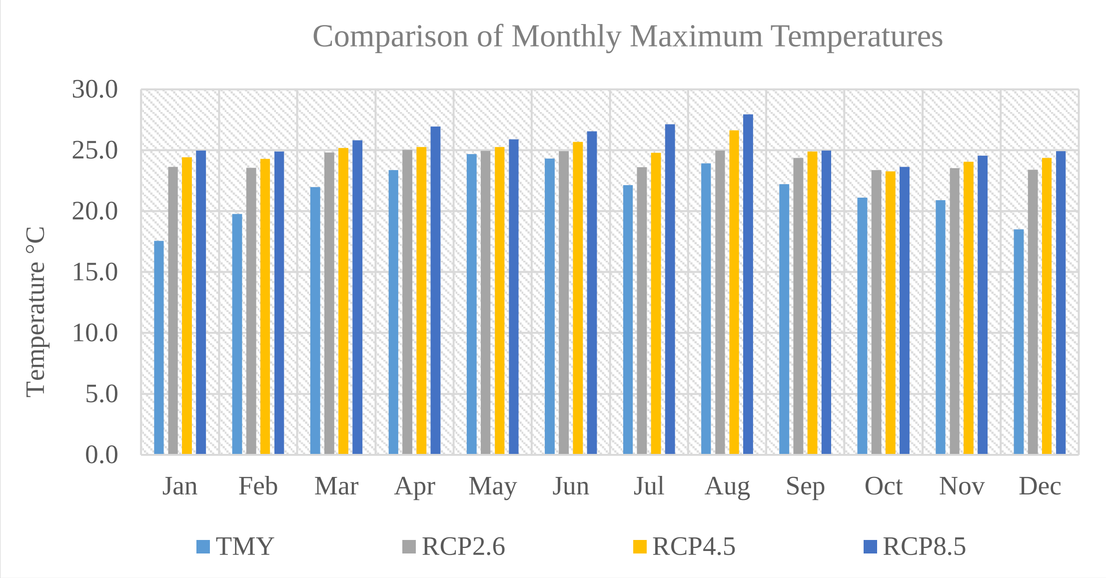


Figure 17: Comparison of Monthly Maximum Temperatures

Figure 17 shows the comparison of the monthly maximum temperatures of baseline and different future scenarios. There is an increment in the temperature in different scenarios compared to the baseline period. Here annual maximum temperature is increased from 21.7^{0}C to 24.2^{0}C, 24.8^{0}C & 25.7^{0}C for the scenarios RCP2.6, RCP4.5 & RCP8.5 respectively.

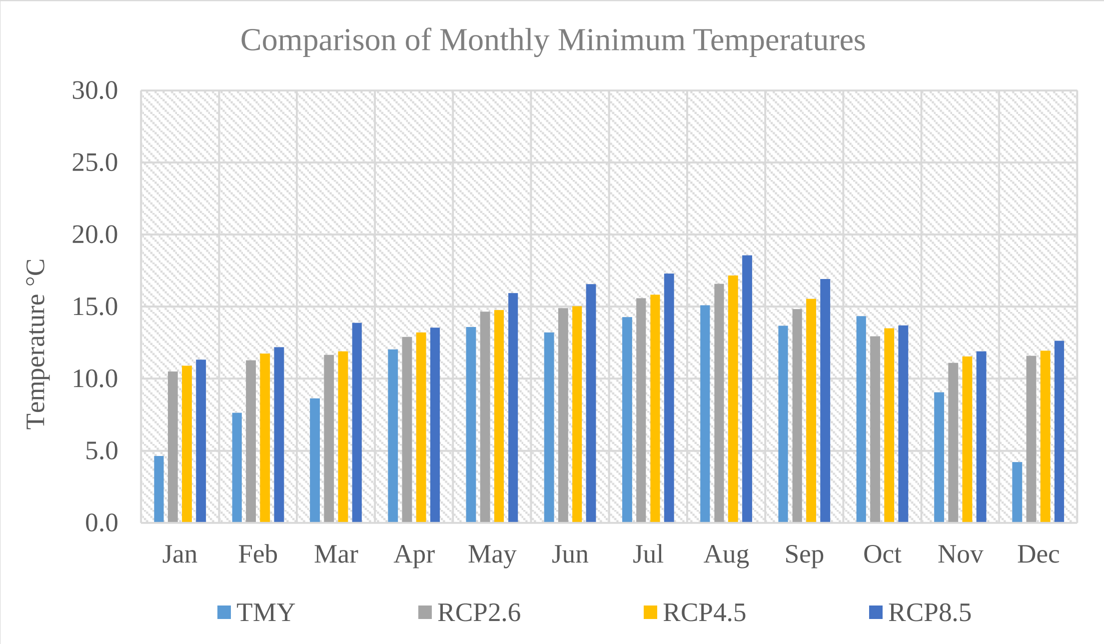


Figure 18: Comparison of Monthly Minimum Temperatures

Figure 18 shows the comparison of the monthly minimum temperatures of baseline and different future scenarios. There is an increment in the temperature in different scenarios compared to the baseline period. Here the annual minimum temperature is increased from 10.9^{0}C to 13.2^{0}C, 13.6^{0}C & 14.5^{0}C for the scenarios RCP2.6, RCP4.5 & RCP8.5 respectively.

5.2 Energy Simulation

The weather file is loaded in creating the building model along with the various parameters of the building. The details of the building design presented below are modeled in the e-quest software. After entering all the parameters of the building along with the weather file, a model of the proposed building is created. Fig 19 shows the basic layout of the e-quest tool after the building model has been created.

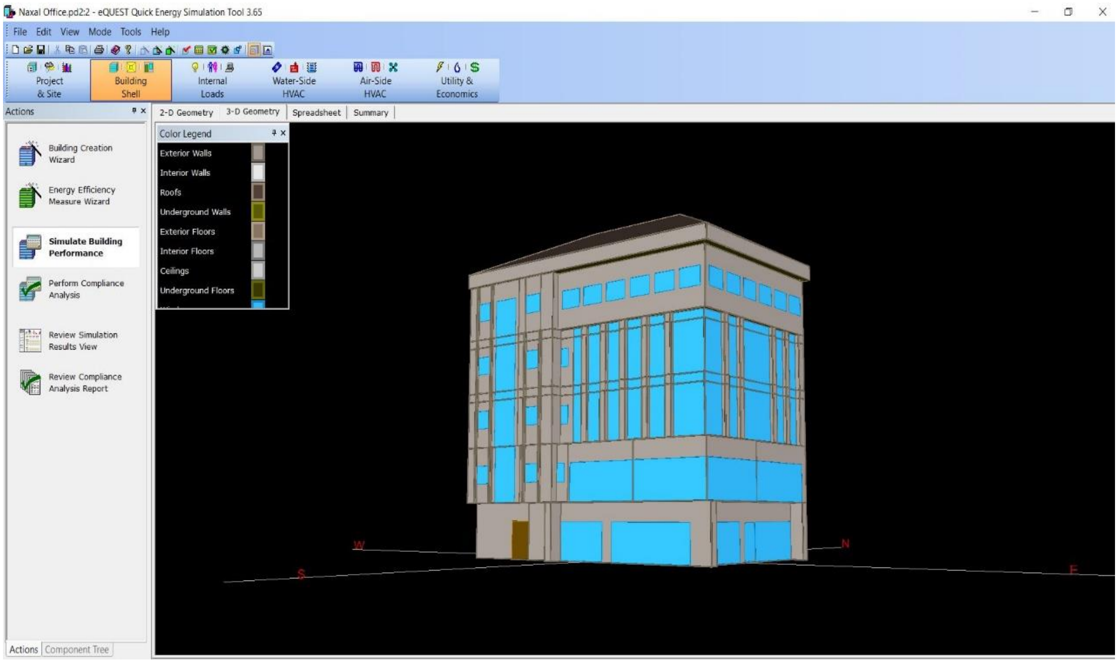


Figure 19**:** e-Quest tool basic layout

5.3 Simulation Results

Inserting all the components and weather files of the Surrounding environment simulation is performed in the e-Quest which then performed 8760 energy balances for the building, one for each hour of the year. The results obtained can be visualized in the graphical manner presented below.

5.3.1 Result for Baseline Year

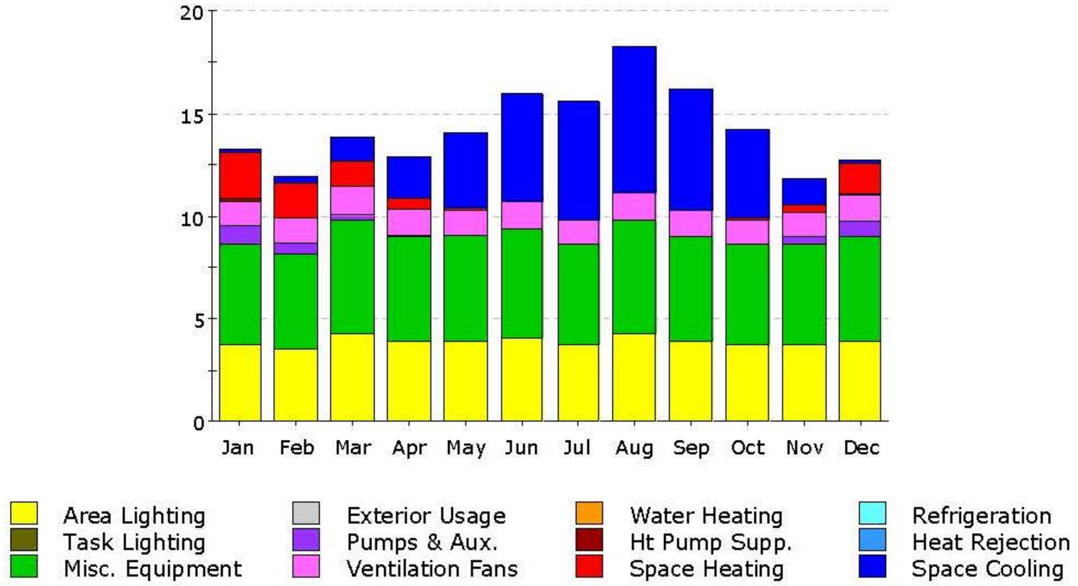


Figure 20**:** Baseline Monthly Electric Consumption

Here figure 20 shows the monthly electric consumption pattern of the proposed building for the baseline year. Starting from the month of march to august, there is an increasing pattern in energy consumption. After August there is a decrease in the energy consumption rate. Looking for the rest energy consumption, Misc. equipment consumed more than the area lighting. There is excessive consumption of energy for the space cooling of the building in the months from March to October, which has increased the overall energy demand.

Table 10: Monthly Electric Consumption (kwh x 1000)

Electric Consumption(kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.09	0.25	1.08	1.68	3.05	5.10	5.35	6.48	5.35	3.68	1.02	0.09	33.22
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	2.01	1.50	1.20	0.35	0.09	0.00	0.00	0.00	0.00	0.01	0.25	1.50	6.91
HP Supply	0.13	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.21
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	1.09	1.03	1.25	1.15	1.15	1.20	1.18	1.25	1.15	1.09	1.09	1.15	13.78
Pumps & Aux.	0.78	0.45	0.14	0.04	0.01	0	0	0	0	0	0.37	0.75	2.54
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc. Equip.	4.92	4.64	5.56	5.11	5.13	5.32	4.92	5.56	5.11	4.92	4.89	5.13	61.21
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	3.72	3.52	4.25	3.89	3.89	4.06	3.72	4.25	3.89	3.72	3.71	3.89	46.51
Total	12.74	11.45	13.48	12.22	13.32	15.68	15.17	17.54	15.5	13.42	11.33	12.53	164.38

Here Table 10 represents the monthly electric consumption. The total energy consumed by the building in the TMY period is 164,380 kWh. Out of the total energy consumed, space cooling consumed 33,220 kWh of energy which is the maximum for June, July, August, and September. In January, February, March, April, November, and December energy is consumed for Space heating which is only 6,910 kWh energy. Area lighting consumed 46,490 kWh of energy which is almost the same for each month. From the graph it can also be noticed that in a single month energy is consumed for both space cooling and heating, it is due to the temperature variations during the morning and day times. This is seen in the month January, February, March, April, November, and December.

Table 11: Annual Electric Consumption by end-use

Parameters	Electricity (kWh)
Space cool	33,220
Space Heat	6,910
HP supply	210
Vent. Fans	13,781
Pumps and Aux.	2,540
Misc. Equipment	61,210
Area Lights	46,510
Total	1,64,380

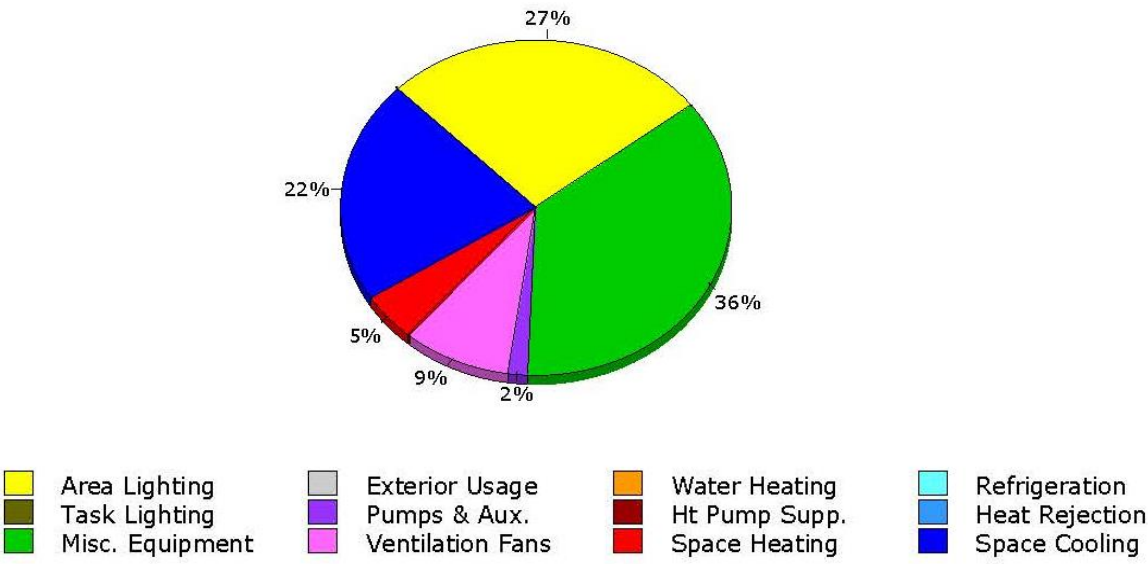


Figure 21: Baseline Annual energy consumption by End-Use

Table 11 & Figure 21 shows the annual energy consumption of the baseline period in which almost 36% of total energy is consumed by misc. equipment which equals 61,210 kWh of energy, 27% is consumed by space lighting equals 46,510 kWh of energy and 22% is consumed by space cooling which is 33,220 kWh of energy.

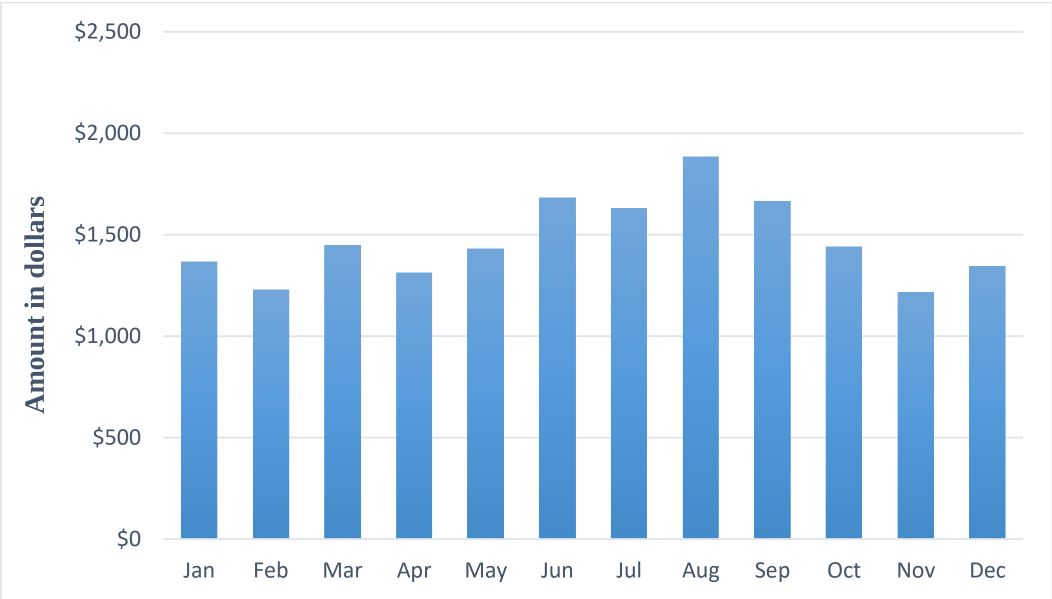


Figure 22: Total Annual bill of baseline 1973-1996 year

Figure 22 shows the total annual bill for running the building. Total amount of electric bill is Rs. 2,120,502. Here a unit is assumed to cost Rs. 12.9 and 1$ equal to Rs.120.1

5.3.2 Result for RCP 2.6_2006-2100 Year

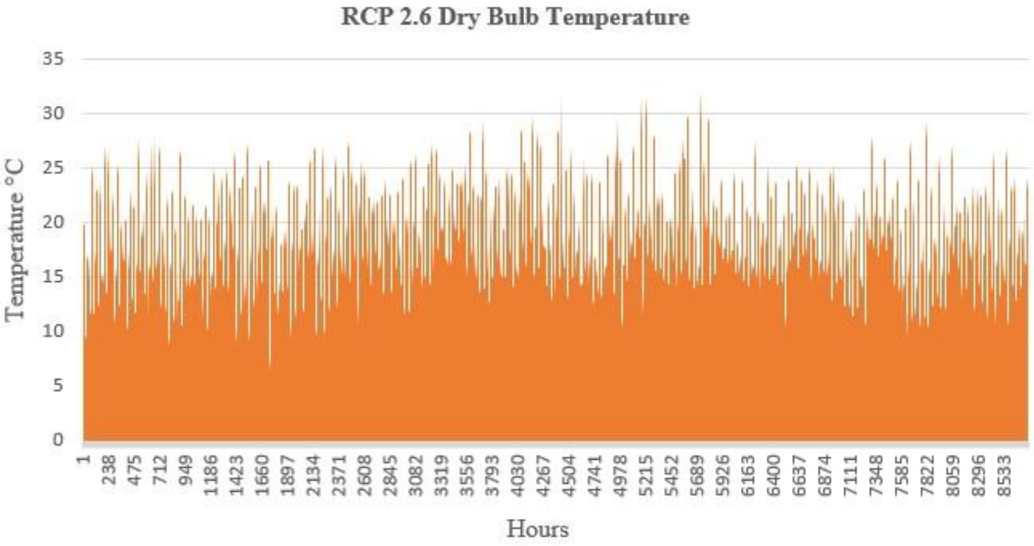


Figure 23: Temperature distribution of RCP 2.6 (2006-2100) year

Figure 23 represents the temperature distribution for the selected RCP 2.6 (2006-2100) scenario. The temperature reading is varying from around zero degrees Celsius to about 32 degrees Celsius. Reading on the horizontal represents a particular hour time of a year of a selected period.

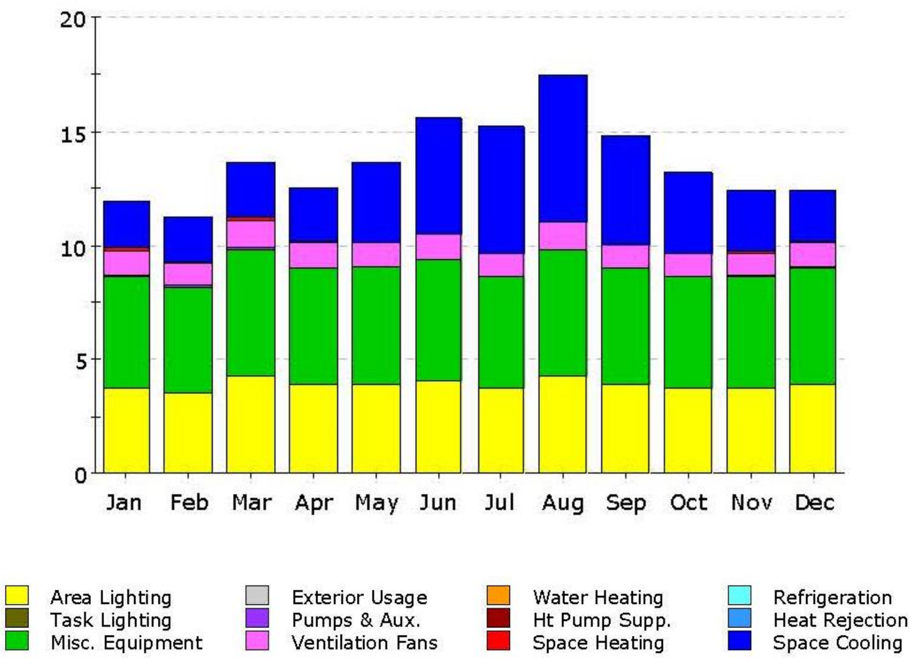


Figure 24: Monthly electric consumption of RCP 2.6 Scenario

Here figure 24 shows the monthly electric consumption pattern of the proposed building for the RCP 2.6 scenario. Starting from the month of march to august, there is an increasing pattern in energy consumption. After August there is a decrease in the energy consumption rate. Looking for the rest energy consumption, Misc. equipment consumed more than the area lighting. There is excessive consumption of energy for the space cooling of the building in the months from March to October, which has increased the overall energy demand.

Table 12: Monthly Electric Consumption (kwh x 1000)

Electric Consumption(kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.37	2.25	2.75	2.52	3.54	5.04	5.25	6.16	4.82	3.7	2.85	2.5	43.75
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Space Heat	0.15	0.12	0.15	0.07	0.00	0	0	0	0	0.00	0.04	0.06	0.61
HP Supply	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Vent. Fans	1.03	0.98	1.18	1.08	1.08	1.13	1.03	1.18	1.08	1.03	1.03	1.08	12.91
Pumps & Aux.	0.04	0.04	0.08	0.03	0	0	0	0	0	0.01	0.05	0.01	0.26
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Misc. Equip.	4.92	4.64	5.56	5.11	5.13	5.32	4.92	5.56	5.11	4.92	4.89	5.13	61.21
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Area Lights	3.72	3.52	4.25	3.89	3.89	4.06	3.72	4.25	3.89	3.72	3.71	3.89	46.51
Total	12.23	11.55	13.97	12.7	13.65	15.55	14.92	17.15	14.9	13.39	12.57	12.67	165.25

Here Table 12 represents the monthly electric consumption. The total energy consumed by the building in the RCP 2.6 scenario is about 165,253 kWh of energy. Out of the total energy consumed, space cooling consumed 43,750 kWh of energy which is the maximum for June, July, August, and September. In January, February, March, April, November, and December energy is consumed for Space heating which is only 613 kWh of energy. Area lighting consumed a total of 46,510 kWh of energy which is almost the same for each month.

Table 13: Annual Electric Consumption (kWh x 1000)

Parameters	Electricity (kWh)
Space cool	43,750
Space Heat	613
HP supply	0
Vent. Fans	12,910
Pumps and Aux.	260
Misc. Equipment	61,210
Area Lights	46,510
Total	165,253

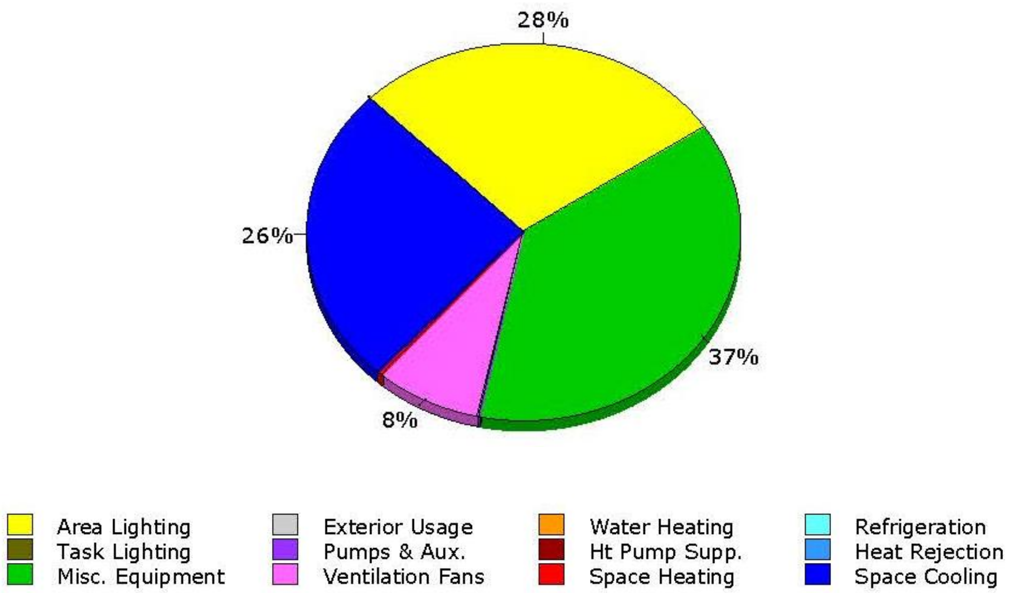


Figure 25**:** Annual energy consumption of RCP 2.6 Scenario

Table 13 and figure 25 represent the annual energy consumption by end-use of the RCP 2.6 scenario. Almost 37% of energy is used for the Misc. Equipment which is 61,210 kWh energy followed by space lighting which is 46,510 kWh of energy i.e. 28% of total energy. Space cooling consumed 43,750 kWh of energy which is almost 26% of the total energy.

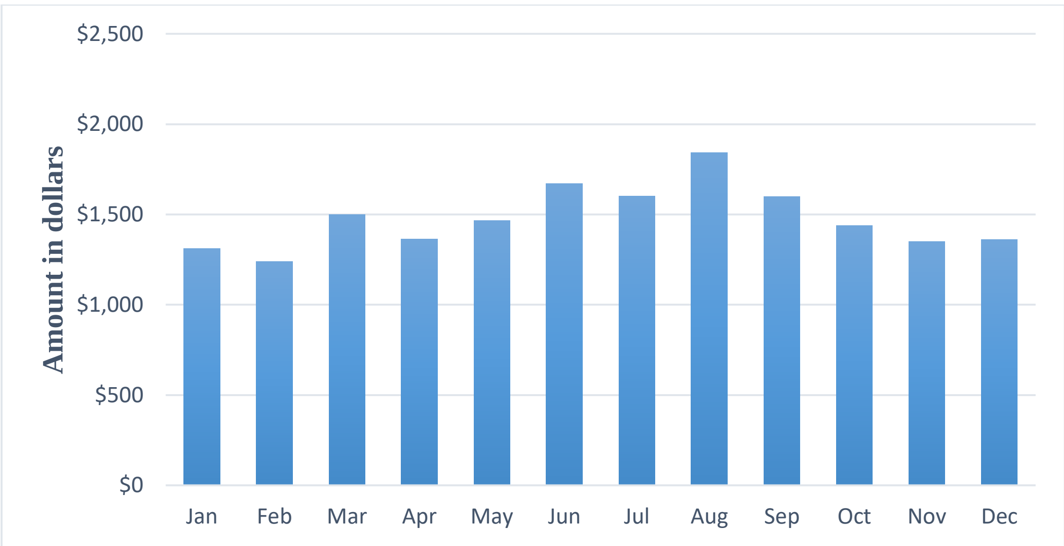


Figure 26**:** Total Annual bill of RCP 2.6 Scenario

Figure 26 shows the total annual bill for running the building. Total amount of electric bill is Rs. 2,131,725. Here a unit is assumed to cost Rs. 12.9 and 1$ equal to Rs.120.17.

5.3.3 Result for RCP 4.5_2006-2100 Year

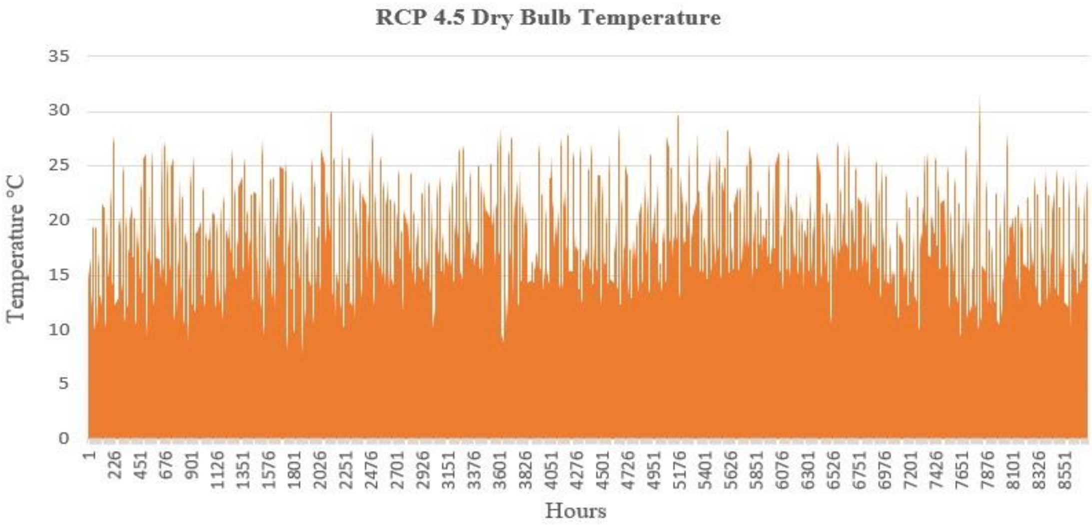


Figure 27: Temperature distribution of RCP 4.5 (2006-2100) year

Figure 27 represents the temperature distribution for the selected RCP 4.5 (2006-2100) scenario. The temperature reading is varying from around zero degrees Celsius to about 33.2 degrees Celsius. Reading on the horizontal represents a particular hour time of a year of a selected period.

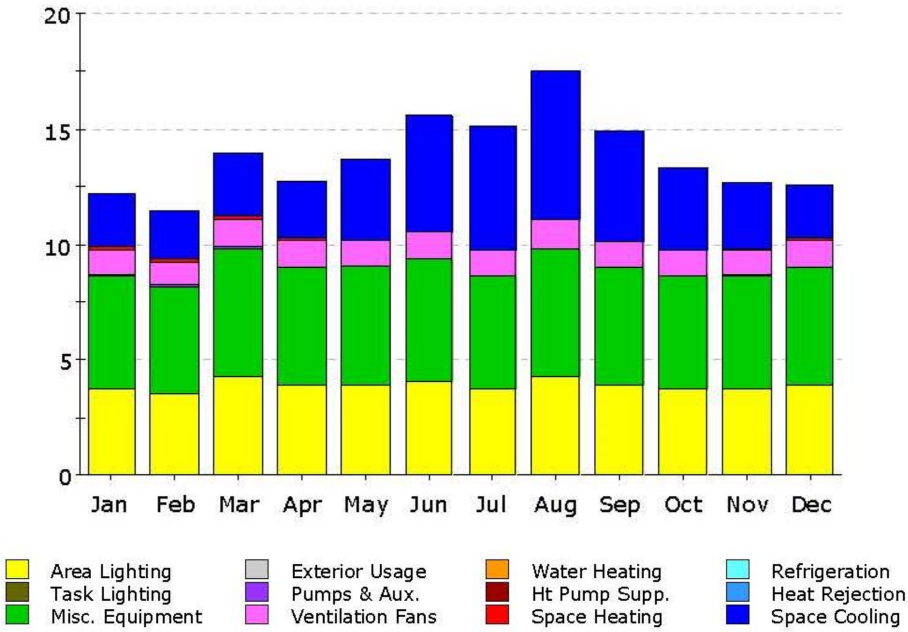


Figure 28: Monthly electric consumption of RCP 4.5 Scenario

Here figure 28 shows the monthly electric consumption pattern for the RCP 4.5 scenario. Comparing to the RCP 2.6 scenario, the cooling energy will increase starting from the month of march to august. After August there is a decrease in the energy consumption rate.

Table 14: Monthly Electric Consumption (kwh x 1000)

Electric Consumption (kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.45	2.28	2.75	2.68	3.58	5.11	5.40	6.44	4.92	3.75	2.88	2.33	44.57
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Space Heat	0.13	0.11	0.13	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.54
HP Supply	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Hot water	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Vent.Fans	1.09	1.03	1.25	1.14	1.14	1.20	1.09	1.25	1.14	1.09	1.09	1.14	13.65
Pumps & Aux.	0.04	0.04	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.26
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Misc. Equip.	4.92	4.64	5.56	5.11	5.13	5.32	4.92	5.56	5.11	4.92	4.89	5.13	61.21
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Area lights	3.72	3.52	4.25	3.89	3.89	4.06	3.72	4.25	3.89	3.72	3.71	3.89	46.51
Total	12.35	11.62	14.00	12.91	13.75	15.69	15.13	17.50	15.06	13.50	12.68	12.55	166.74

Here Table 14 represents the monthly electric consumption. The total energy consumed by the building in the RCP 4.5 scenario is 166,740 kWh of energy. Out of the total energy consumed, space cooling consumed 44,570 kWh of energy which is the maximum for June, July, August, and September.

Table 15: Annual Electric Consumption (kwh x 1000)

Parameters	Electricity (kWh)
Space cool	44,570
Space Heat	540
HP supply	0
Vent. Fans	13,650
Pumps and Aux.	260
Misc. Equipment	61,210
Area Lights	46,510
Total	166,740

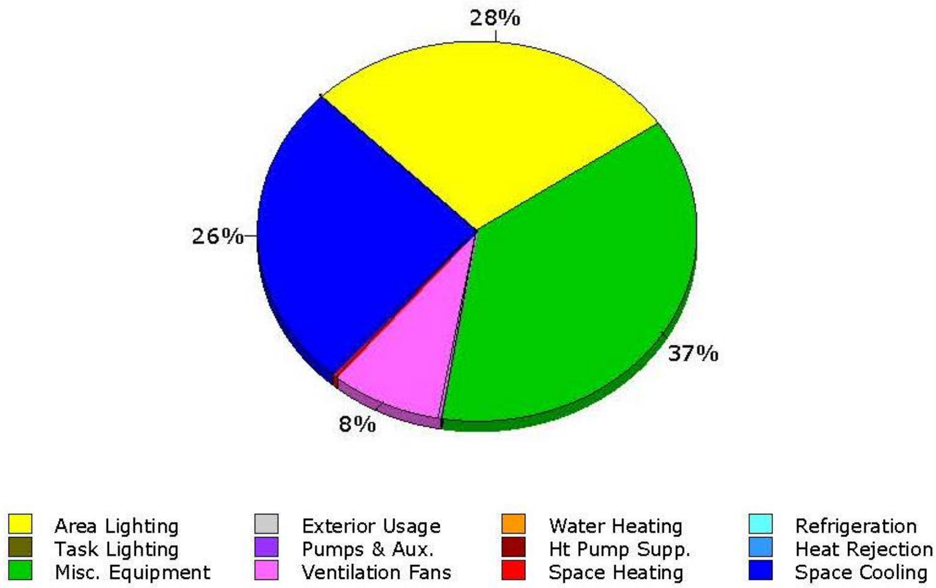


Figure 29**:** Annual energy consumption of RCP 4.5 Scenario

Table 15 and figure 29 represent the annual energy consumption by end-use of the RCP 4.5 scenario. The total annual energy consumption will be 1,66,740 kWh. Out of this, 37% of energy is consumed for the Misc. Equipment followed by space lighting which is 28% of total energy. Space heating energy consumption will be reduced from 613 to 540 kWh of energy comparing with the RCP 2.6 scenario.

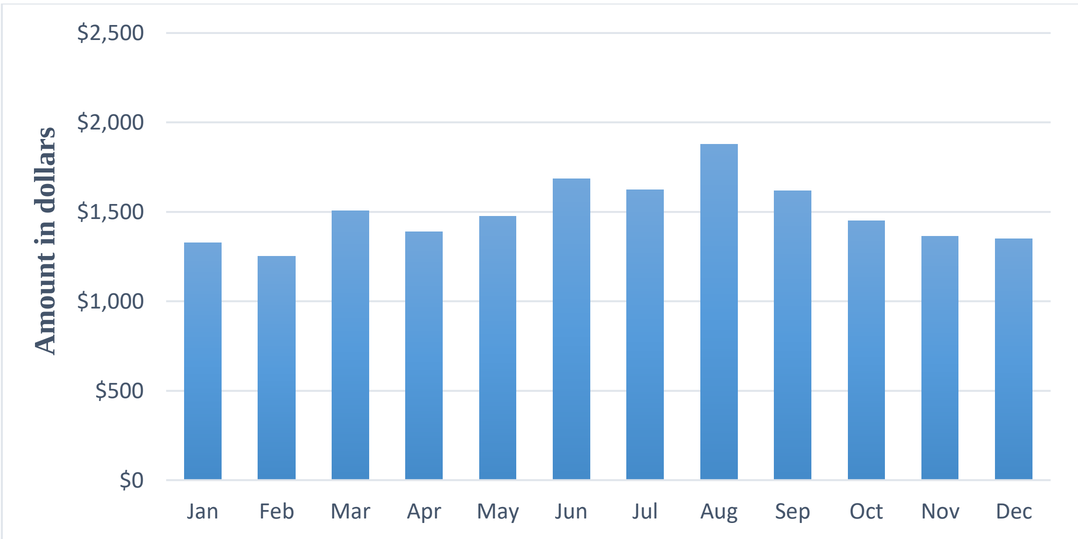


Figure 30**:** Total Annual bill of RCP 4.5 Scenario

Figure 30 shows the total annual bill for running of the building. Total amount of electric bill is Rs. 2,152,881. Here a unit is assumed to cost Rs. 12.9 and 1$ equal to Rs.120.17.

5.3.4 Result for RCP 8.5_2006-2100 Year

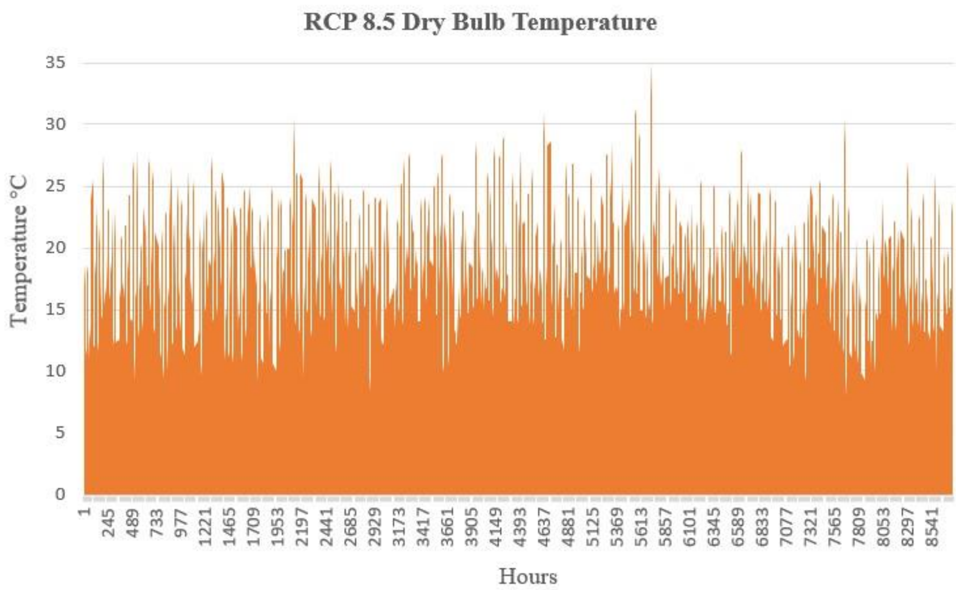


Figure 31**:** Temperature distribution of RCP 4.5 (2006-2100) year

Figure 31 represents the temperature distribution for the selected RCP 8.5 (2006-2100) scenario. The temperature reading is varying from around zero degrees Celsius to about 35 degrees Celsius. Reading on the horizontal represents a particular hour time of a year of a selected period.

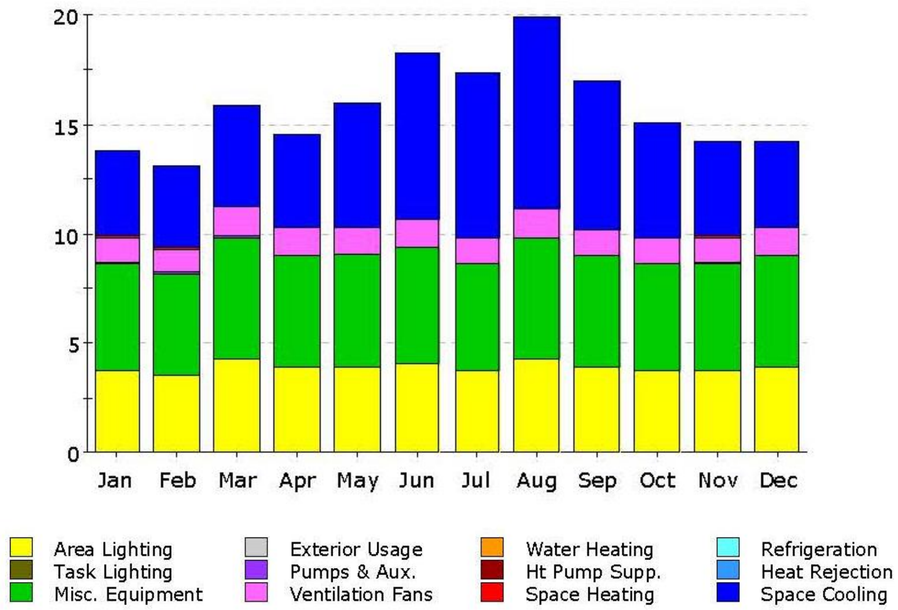


Figure 32**:** Monthly electric consumption of RCP 8.5 Scenario

Here figure 32 shows the monthly electric consumption pattern for the RCP 8.5 scenario. Comparing with baseline and other scenario energy consumption Space heating energy consumption will be decreased to a negligible figure. Space cooling consumed maximum energy compare to rest scenarios.

Table 16: Monthly Electric Consumption (kwh x 1000)

Electric Consumption (kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	3.89	3.76	4.66	4.32	5.71	7.59	7.60	8.75	6.79	5.25	4.34	3.96	66.63
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.15
HP Supply	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	1.17	1.11	1.34	1.22	1.22	1.28	1.17	1.34	1.22	1.17	1.17	1.22	14.62
Pumps & Aux.	0.04	0.05	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.26
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc. Equip.	4.92	4.64	5.56	5.11	5.13	5.32	4.92	5.56	5.11	4.92	4.89	5.13	61.21
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area lights	3.72	3.52	4.25	3.89	3.89	4.06	3.72	4.25	3.89	3.72	3.71	3.89	46.51
Total	13.77	13.11	15.88	14.57	15.96	18.26	17.40	19.89	17.01	15.07	14.22	14.23	189.37

Here Table 16 represents the monthly electric consumption for the 8.5 scenario. The total energy consumed by the building in the RCP 8.5 scenario is about 166,890 kWh of energy. Out of the total energy consumed, space cooling consumed 66,636 kWh of energy which is the maximum for May, June, July, August, September, and October. In January, February, March, November, and December energy is consumed for Space heating which is only 145 kWh of energy.

Table 17: Annual Electric Consumption (kwh x 1000)

Parameters	Electricity (kWh)
Space cool	66,636
Space Heat	145
HP supply	0
Vent. Fans	14,621
Pumps and Aux.	260
Misc. Equipment	61,210
Area Lights	46,510
Total	189,367

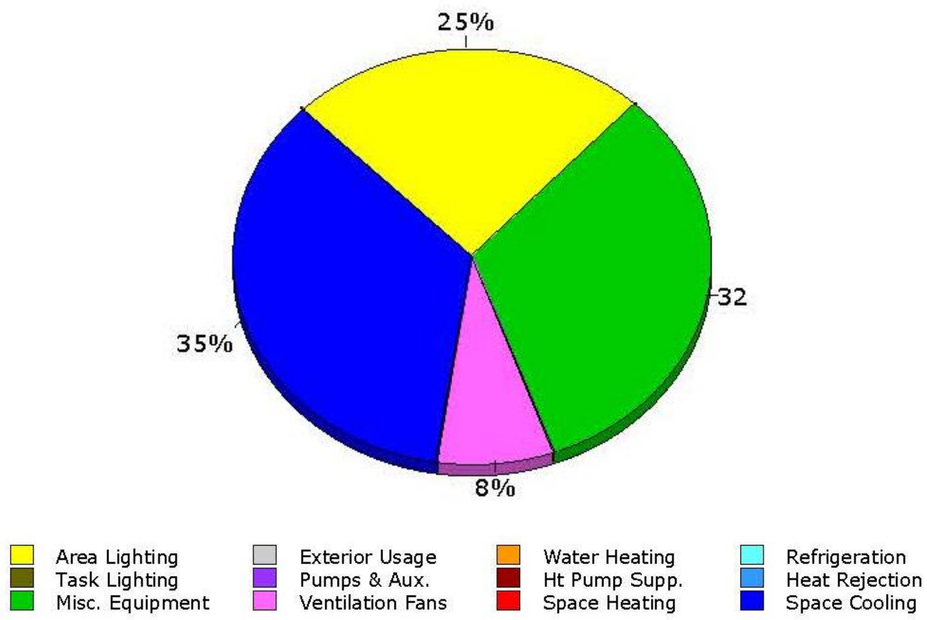


Figure 33**:** Annual energy consumption of RCP 8.5 Scenario

Table 17 and figure 33 represent the annual energy consumption by end-use. Almost 32% of energy is used for the Misc. Equipment which is 61,210 kWh energy followed by space lighting which is 46,510 kWh of energy i.e. 25% of total energy. Space cooling consumed 66,636 kWh of energy which is almost 35% of the total energy.

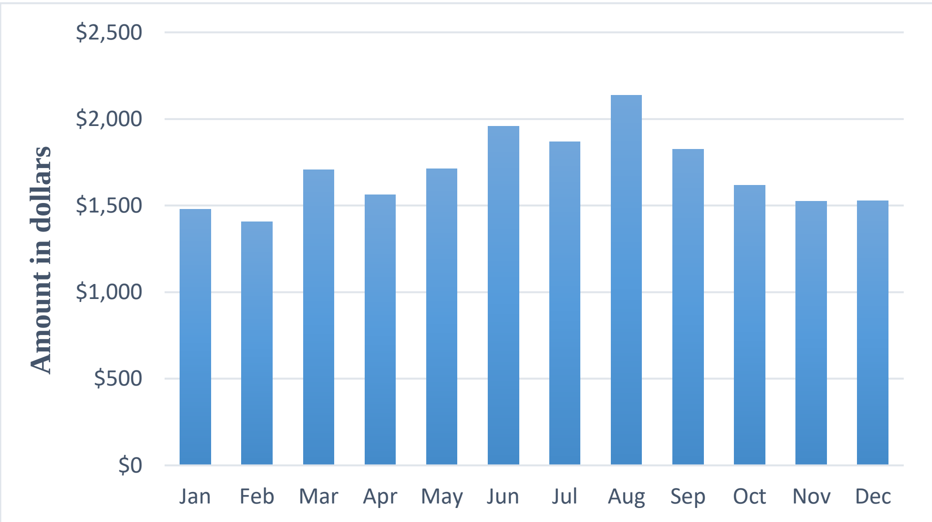


Figure 34**:** Total Annual bill of RCP 8.5 Scenario

Figure 34 shows the total annual bill for running of the building. The total amount of the electric bill is Rs. 2,442,770. Here a unit is assumed to cost Rs. 12.9 and 1$ equal to Rs.120.17.

5.4 Result Analysis

Table 18: Result analysis of different Scenario

	Parameters	Scenario			
		Baseline	RCP 2.6	RCP 4.5	RCP 8.5
Energy Consumption (kWh)	Space Cooling	33,220	43,750	44,570	66,636
	Changes from the baseline year		+31.69%	+34.16%	+100%
	Space Heating	6910	613	540	145
	Changes from the baseline year		-91.1%	-92.18%	-97.90%
	Heat Pump Supplies	210	0	0	0
	Changes from the baseline year		Negligible	Negligible	Negligible
	Ventilation Fans	13,781	12,910	13,650	14,621

	Changes from the baseline year		-6.32%	-0.95%	+6.09%
	Pumps and Aux.	2,540	260	260	260
	Changes from the baseline year		Negligible	Negligible	Negligible
	Miscellaneous Equipment	61,210	61,210	61,210	61,210
	Changes from the baseline year		Negligible	Negligible	Negligible
	Area Lights	46,510	46,510	46,510	46,510
	Changes from the baseline year		Negligible	Negligible	Negligible
	Total	1,64,380	1,65,253	1,66,740	1,89,367
	Changes from the baseline year		+0.53%	+1.43%	+15.2%

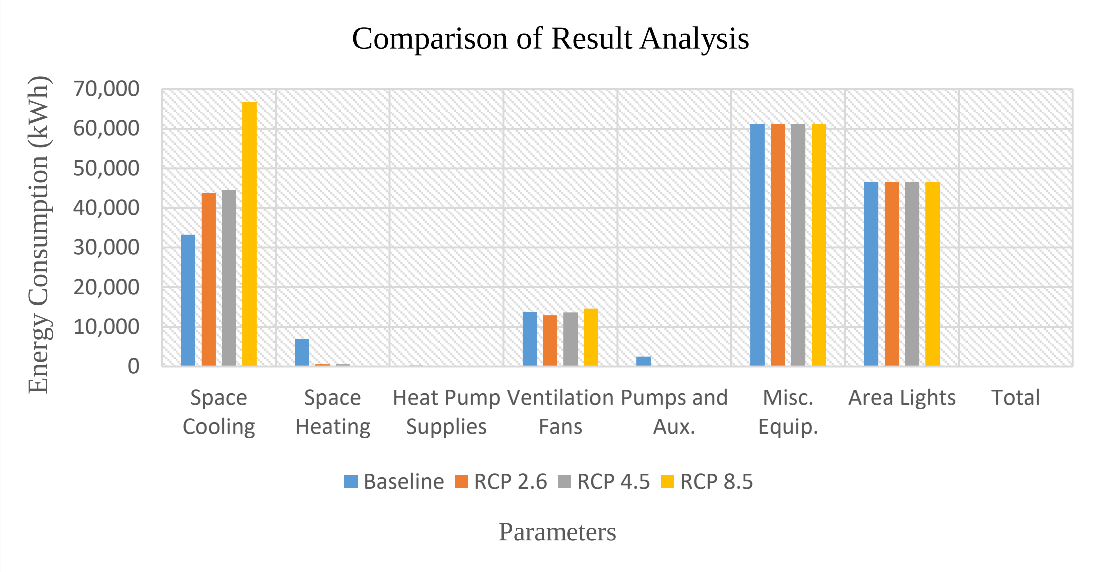


Figure 35: Comparison of Parameters in different Scenario

Here table 18 and figure 35 show the comparison of different parameters in all Scenarios. This result shows that there will be an increase in energy consumption in the future from the baseline period, especially for the space cooling than space heating. Rest parameters remain almost the same in all scenarios.

5.5 Result Analysis after Insulation

After the result analysis for a different scenario, insulating material is added to all the exterior walls and roof. Insulating material selected from the e-Quest library is Insulator board, Shingle backer of thickness 4.5 inches with total thermal insulation value. The material is then added inside the vertical wall surfaces, roof and then again building energy simulation is performed. After the simulation runs, it is found that there is a decrease in energy consumption of the building. The detailed analysis is presented in the table below.

Table 19: Result analysis with and without insulation

Scenario		Space Cooling	% Change after Insulation	Space Heating	% Change after Insulation	Total	% Change after Insulation
TMY	Without Insulation	33,220	-5.23%	6,910	-8.97%	1,64,380	-1.43%
	With Insulation	31,480		6,290		1,62,020	
RCP 2.6	Without Insulation	43,750	-3.01%	613	-39.64%	1,65,253	-1.23%
	With Insulation	42,430		370		1,63,210	
RCP 4.5	Without Insulation	44,570	-6.59%	540	-22.22%	1,66,740	-2.0%
	With Insulation	41,630		420		1,63,420	
RCP 8.5	Without Insulation	66,636	-15.64%	145	-51.72%	1,89,367	-5.73%
	With Insulation	56,210		70		1,78,515	

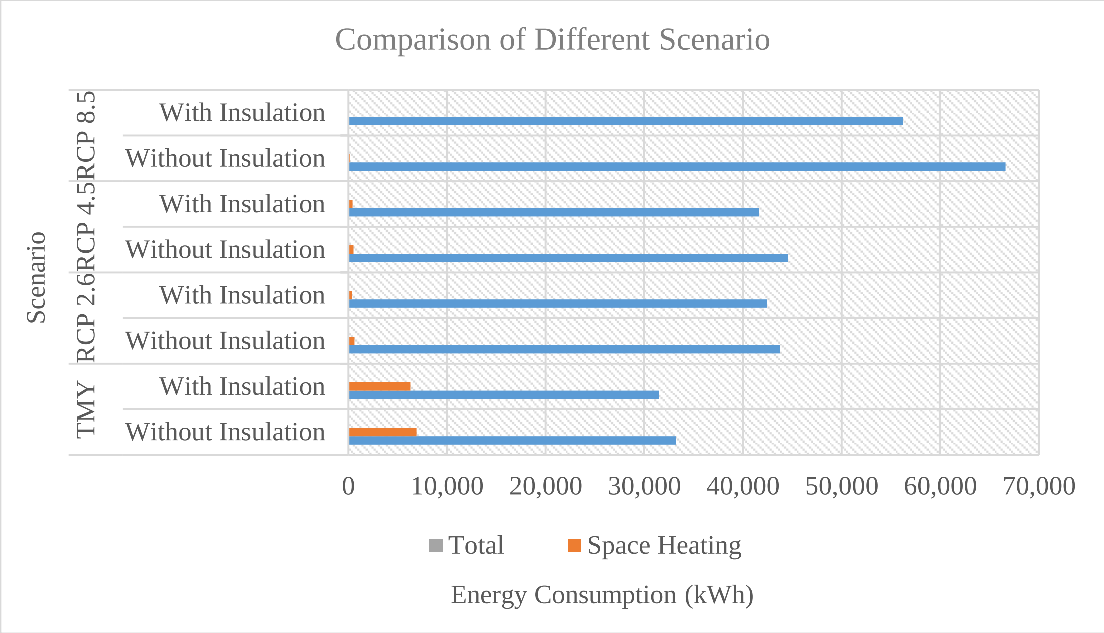


Figure 36**:** Comparison of Result analysis with and without insulation

Here table 19 and figure 36 show the result after adding insulation in the building. It shows the consumption of energy in different scenarios. It is found that after the addition of an insulating board in the building there is a decrease in energy consumption compared to without insulation inside the building. This result shows that to reduce the energy consumption in any type of building insulating material plays an important role.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The annual average temperature of Kathmandu valley is 17.7^{0}C for the selected baseline period(TMY). Weather data obtained from SDSM was downscaled to hourly data which shows that the annual average temperature of the atmosphere from baseline (17.7^{0}C) will increase to 18.3^{0}C, 19.2^{0}C & 20.1^{0}C for the different future scenarios i.e. RCP2.6, RCP4.5 & RCP8.5 respectively. Based on literature review and guidance to meet objectives, this research was conducted with the main purpose of evaluating the energy consumption in selected office building considering various building features, materials, electrical and mechanical systems, occupancy, and operating schedules by using the simulation tools. It has been found that there will be an increase in the total building's energy consumption under the different RCPs future scenarios i.e. RCP2.6, RCP4.5 & RCP 8.5, ranging from 0.53%, 1.43% & 15.2% respectively whereas Space Cooling load increased from 33,220kWh to 43,750kWh, 44,570kWh and 66,636kWh by 31.69%, 34.16% & 100% respectively. Also, there will be a decrease in the space heat consumption from 6910kWh to 613kwh, 540kwh, 145kwh by 91.1%, 92.18% & 97.90% for the RCP2.6, RCP4.5 & RCP 8.5 respectively. Although the reduction in heating load has a higher percentage value than the increase in cooling load, the increase in cooling load is much more than the decrease in heating load. Since the building operation and other schedules are kept the same, other parameters of energy consumption have remained almost the same. The study has also shown the comparison of building energy consumption with and without insulating material which results that insulating a building will decrease energy consumption.

Thus, the study concludes that annual cooling loads will increase at a much greater rate than heating loads. This analysis shows the potential for reducing the energy use of building quantitatively and therefore improving building design.

6.2 Recommendations

Buildings are influenced by a various factor which is responsible for energy consumption. To reduce energy consumption in any building, insulation plays an important role. From the study, it is concluded that adding insulation on vertical walls and roofs can reduce energy consumption so further studies on other factors that can reduce energy consumption can be done. This research has been based on the increment of dry-bulb temperatures only so other weather parameters can also be considered for further studies. This study can be carried out for different types of building in different geographic locations using different climate models so that it can help designers to design buildings as per the future energy demand and also helpful for comparative result analysis of the models.

REFERENCES:

- Abdullah, A., Cross, B., & Will, P. (2014). Whole Building Energy Analysis : A Comparative Study of Different Simulation Tools and Applications in Architectural Design. 1–12.
- Aebischer, B., Giacomo, C., & Martin, J. (2007). Impact of climate change on thermal comfort , heating and cooling energy demand in Europe. ECEEE 2007 Summer Study Saving Energy - Just Do It!, (March 2017), 859–870. https://doi.org/10.1016/j.enbuild.2016.07.067
- Agency, I. E. (2016). Final Report Annex 53. Total energy use in buildings Analysis and evaluation methods. International Energy Agency Programme on Energy in Buildings and Communities, (June), 132. https://doi.org/10.1136/bmj.e6533
- Anderson, J. (2016). Modelling and performance evaluation of net zero energy buildings. 169.
- Bajracharya, S. B. (2014). The Thermal Performance of Traditional Residential Buildings in Kathmandu Valley. Journal of the Institute of Engineering, 10(1), 172–183. https://doi.org/10.3126/jie.v10i1.10898
- Bano, F., & Kamal, M. A. (2016). Examining the Role of Building Envelope for Energy Efficiency in Office Buildings in India. Architecture Research, 6(5), 107–115. https://doi.org/10.5923/j.arch.20160605.01
- Chan, A. L. S. (2011). Developing future hourly weather files for studying the impact of climate change on building energy performance in Hong Kong. Energy and Buildings, 43(10), 2860–2868. https://doi.org/10.1016/j.enbuild.2011.07.003
- Chandel, S. S., & Sarkar, A. (2015). Performance assessment of a passive solar building for thermal comfort and energy saving in a hilly terrain of India. Energy and Buildings, 86, 873–885. https://doi.org/10.1016/j.enbuild.2014.10.035
- Chowdhury, A. A., Rasul, M. G., & Khan, M. M. K. (2007). Modelling and simulation of building energy consumption: A case study on an institutional building in central queensland, australia. IBPSA 2007 - International Building Performance Simulation Association 2007, (Krarti 2000), 1916–1923.
- Dino, I. G., & Meral Akgül, C. (2019a). Impact of climate change on the existing residential building stock in Turkey: An analysis on energy use, greenhouse gas emissions and occupant comfort. Renewable Energy, 141, 828–846. https://doi.org/10.1016/j.renene.2019.03.150

- Dino, I. G., & Meral Akgül, C. (2019b). Impact of climate change on the existing residential building stock in Turkey: An analysis on energy use, greenhouse gas emissions and occupant comfort. Renewable Energy, 141, 828–846. https://doi.org/10.1016/j.renene.2019.03.150
- GoN. (2014). Energy Data Sheet. Water and Energy Commission Secretariat, (June 2014), 6. Retrieved from http://energyefficiency.gov.np/downloadthis/final_data_book__11_june_2014.pdf
- Government of Nepal. (2019). Climate Change Scenarios for Nepal. Ministry of Forests and Environment, (February), 66. Retrieved from http://mofe.gov.np/downloadfile/MOFE_2019_Climate change scenarios for Nepal_NAP_1562647620.pdf
- Gurung, T. B., Pokharel, P. K., & Wright, I. (2011). Climate Change : Livestock Sector Vulnerability and Adaptation in Nepal. Changes, (August), 105. https://doi.org/10.13140/RG.2.1.1548.6887
- Invidiata, A., & Ghisi, E. (2016). Impact of climate change on heating and cooling energy demand in houses in Brazil. Energy and Buildings, 130(March 2017), 20–32. https://doi.org/10.1016/j.enbuild.2016.07.067
- IPCC. (2012). Glossary of Terms. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, 555–564. https://doi.org/10.1177/1403494813515131
- Jiang, A., Liu, X., Czarnecki, E., & Zhang, C. (2019). Hourly weather data projection due to climate change for impact assessment on building and infrastructure. Sustainable Cities and Society, 50(February), 101688. https://doi.org/10.1016/j.scs.2019.101688
- Kaito, C., Ito, A., Kimura, S., Kimura, Y., Saito, Y., & Nakada, T. (2000). Topotactical growth of indium sulfide by evaporation of metal onto molybdenite. In Journal of Crystal Growth (Vol. 218). https://doi.org/10.1016/S0022-0248(00)00575-3
- Kamali, S. (2014a). Improving Thermal Comfort in Building and Reducing the Indoor Air Temperature Fluctuation in Cyprus by Utilizing the Phase Change Materials. (October). https://doi.org/10.13140/2.1.3332.4480
- Kamali, S. (2014b). Improving Thermal Comfort in Building and Reducing the Indoor Air Temperature Fluctuation in Cyprus by Utilizing the Phase Change

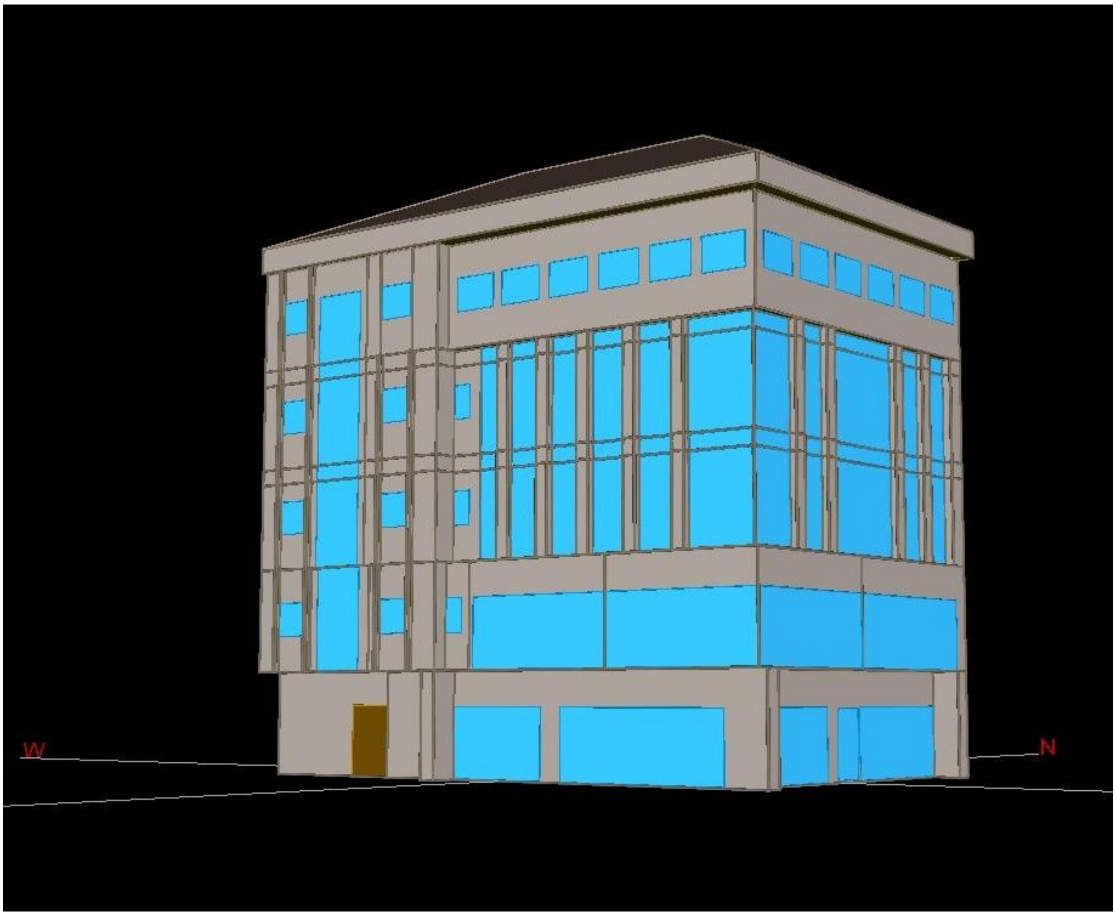
Materials. (October). https://doi.org/10.13140/2.1.3332.4480

- Kattsov, V., Federation, R., Reason, C., Africa, S., Uk, A. A., Uk, T. A., … Uk, A. S. (2013). Evaluation of climate models. Climate Change 2013 the Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 9781107057, 741–866. https://doi.org/10.1017/CBO9781107415324.020
- Kinnane, O., Grey, T., & Dyer, M. (2016). Adaptable housing design for climate change adaptation. Proceedings of the Institution of Civil Engineers - Engineering Sustainability, (April). https://doi.org/10.1680/jensu.15.00029
- Looman, R. (n.d.). Climate - responsive building elements implementation of climate - responsive building elements.
- Maile, T., Fischer, M., & Bazjanac, V. (2007). Building Energy Performance Simulation Tools - a Life-Cycle and Interoperable Perspective. Wp107, (December), 1–49. Retrieved from cife.stanford.edu/sites/default/files/WP107.pdf
- H.E. Burroughs, S. J. Hansen. (2011). Managing Indoor Air Quality, fifth edition
- Northern Arizona University. (2013). Thermal Comfort (Relative Humidity (RH) and Air Temperature). Retrieved from https://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_ThermalComfort.pdf%0Ahttp://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_ThermalComfort.pdf
- Pandit, S., & Bhattarai, N. (2018). Impact of Rise in Atmosphere Temperature on an Official Building's Energy Consumption in Kathmandu. Journal of the Institute of Engineering, 13(1), 102–107. https://doi.org/10.3126/jie.v13i1.20354
- Rise, S. (2000). Climate Change Scenarios for the. Changes, 1998(February).
- Shrestha, A. B., Bajracharya, S. R., Sharma, A. R., Duo, C., & Kulkarni, A. (2017). Observed trends and changes in daily temperature and precipitation extremes over the Koshi river basin 1975–2010. International Journal of Climatology, 37(2), 1066–1083. https://doi.org/10.1002/joc.4761
- Tam, V. W. Y., Almeida, L., & Le, K. (2018). Energy-related occupant behaviour and its implications in energy use: A chronological review. Sustainability (Switzerland), 10(8), 1–20. https://doi.org/10.3390/su10082635
- Upadhyay, A. K., Yoshida, H., & Rijal, H. B. (2006). Climate Responsive Building Design in the Kathmandu Valley. Journal of Asian Architecture and Building Engineering, 5(1), 169–176. https://doi.org/10.3130/jaabe.5.169
- Ürge-Vorsatz, D., Lucon, O., Zain Ahmed, A., Akbari, H., Bertoldi, P., Cabeza, L.

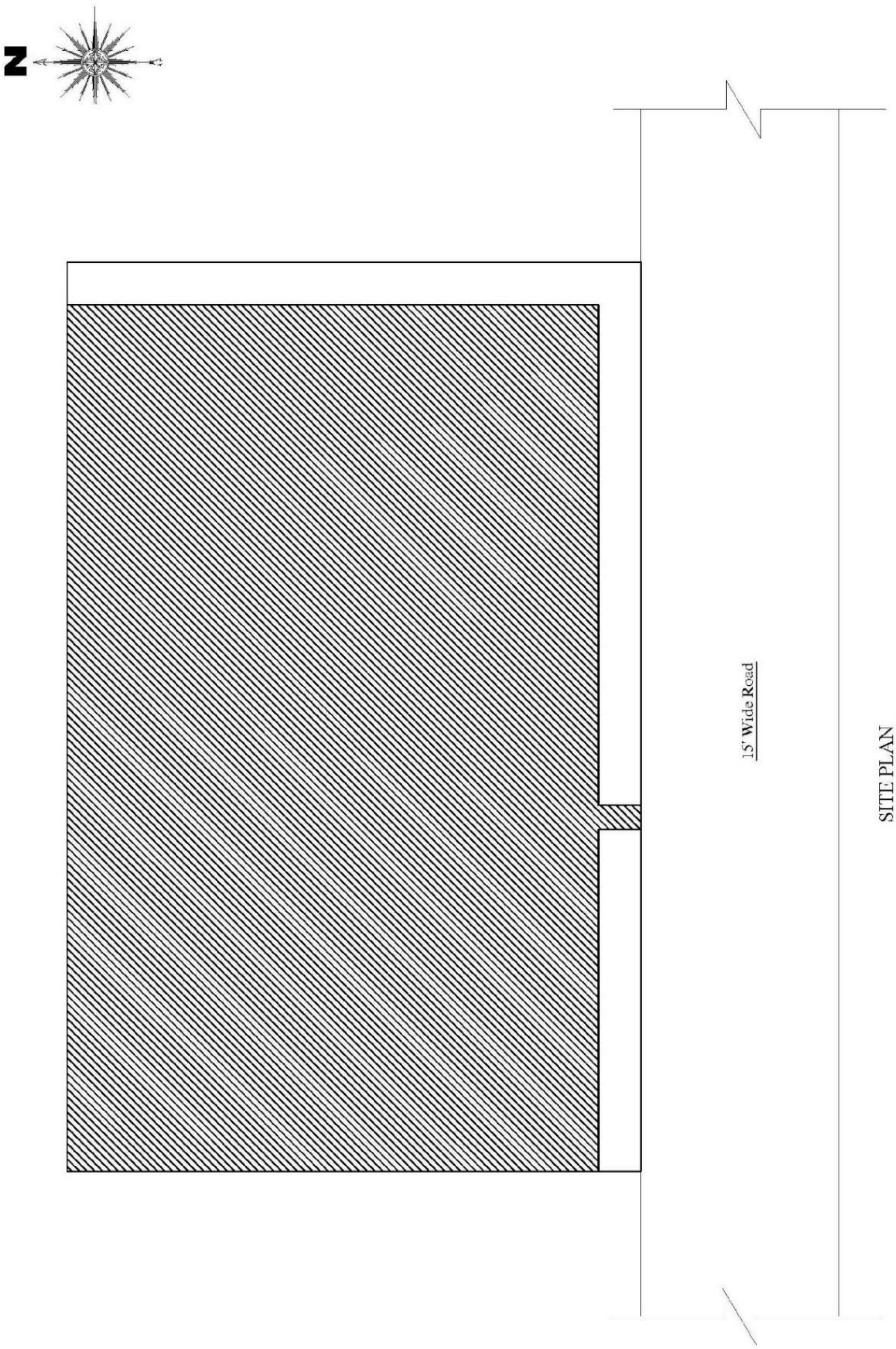
F., … Vilariño, M. V. (2014). Buildings. In: Mitigation. Working Group III contribution to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change. 671–738.

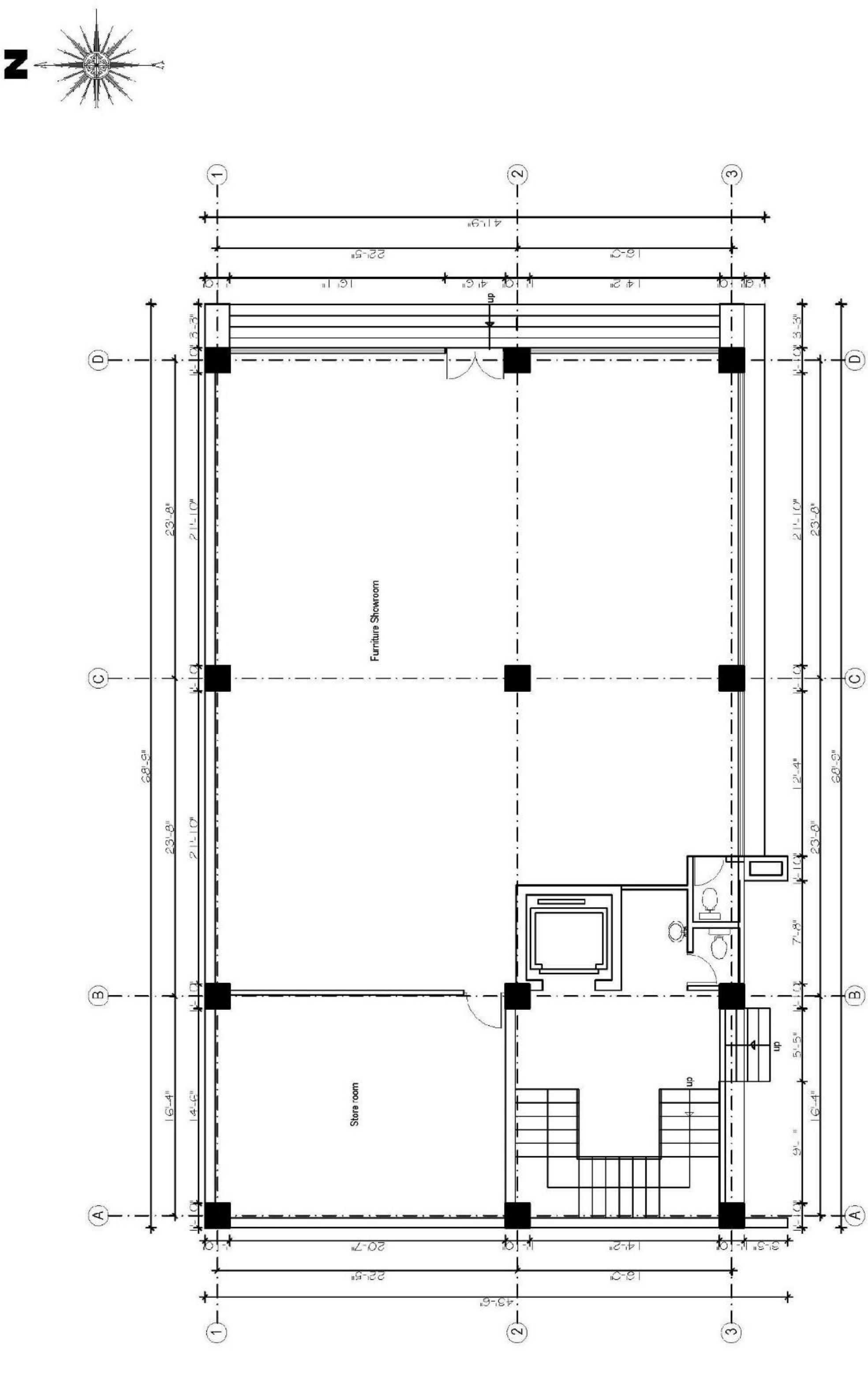
- Waddicor, D. A., Fuentes, E., Sisó, L., Salom, J., Favre, B., Jiménez, C., & Azar, M. (2016). Climate change and building ageing impact on building energy performance and mitigation measures application: A case study in Turin, northern Italy. Building and Environment, 102, 13–25. https://doi.org/10.1016/j.buildenv.2016.03.003
- Wang, H., & Chen, Q. (2014). Impact of climate change heating and cooling energy use in buildings in the United States. Energy and Buildings, 82(2014), 428–436. https://doi.org/10.1016/j.enbuild.2014.07.034
- Wang, Y., Lin, H., Wang, W., Liu, Y., Wennersten, R., & Sun, Q. (2017). ScienceDirect ScienceDirect buildings differences between occupants with different age Assessing the feasibility of using the heat demand-outdoor a long-term district heat demand forecast.
- Zerroug, A., & Dzelzitis, E. (2019). Analysis of different building exterior walls insulations using eQUEST. E3S Web of Conferences, 111(201 9), 0–5. https://doi.org/10.1051/e3sconf/201911106032
- Zhu, M., Pan, Y., Huang, Z., & Xu, P. (2016). An alternative method to predict future weather data for building energy demand simulation under global climate change. Energy & Buildings, 113, 74–86. https://doi.org/10.1016/j.enbuild.2015.12.020
- Government of Nepal, 2019: “Change Scenarios for Nepal”
- R. Spiegel, D. Meadows (2010), ‘Green Building Materials: A Guide to Product Selection and Specification’.
- https://climate-scenarios.canada.ca/?page=pred-canesm2
- https://energyplus.net/weatherlocation/asia_wmo_region_2/NPL/NPL_Kathmandu.444540_SWERA

APPENDIX

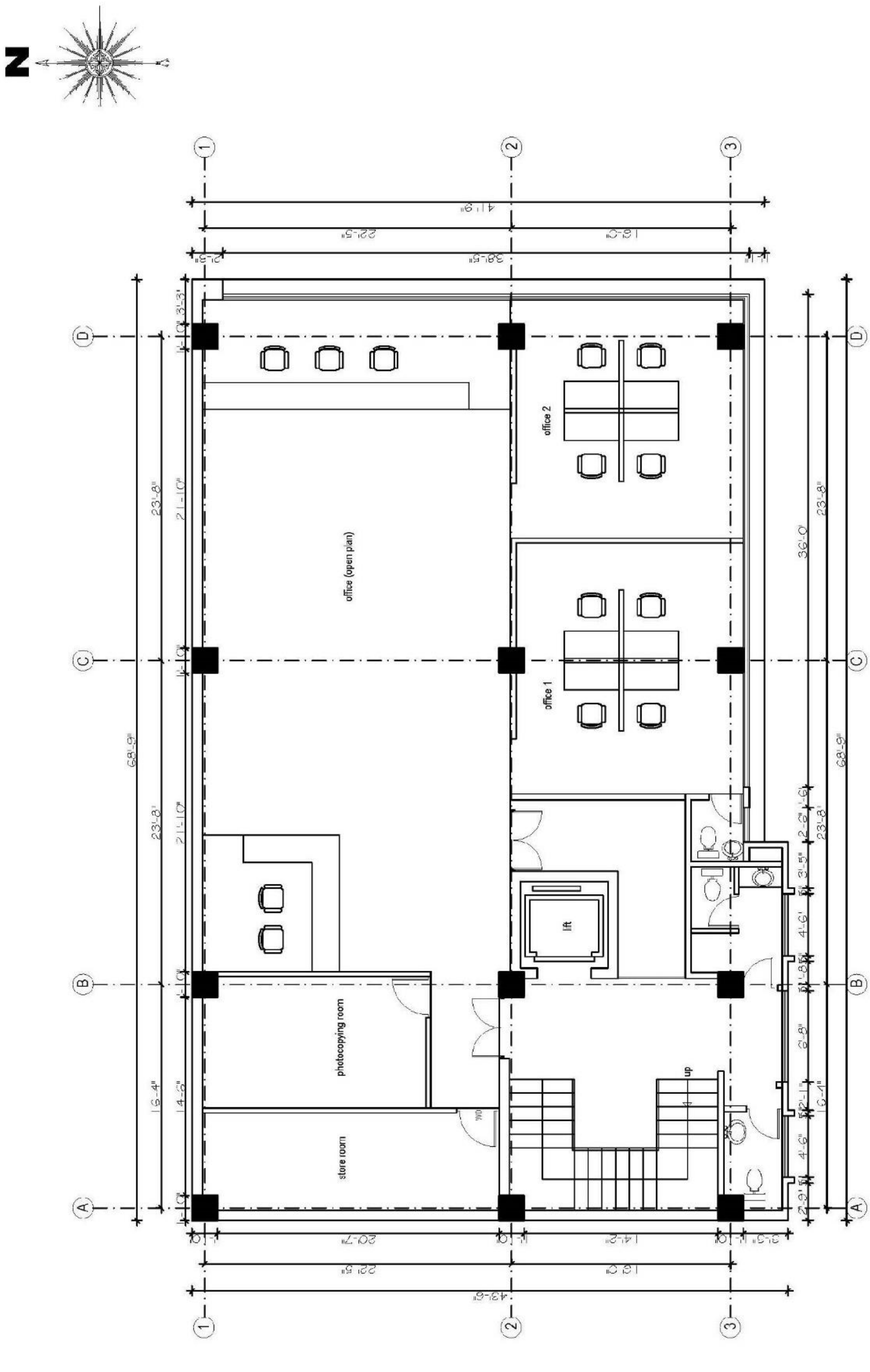


Model of the proposed building created on e-quest

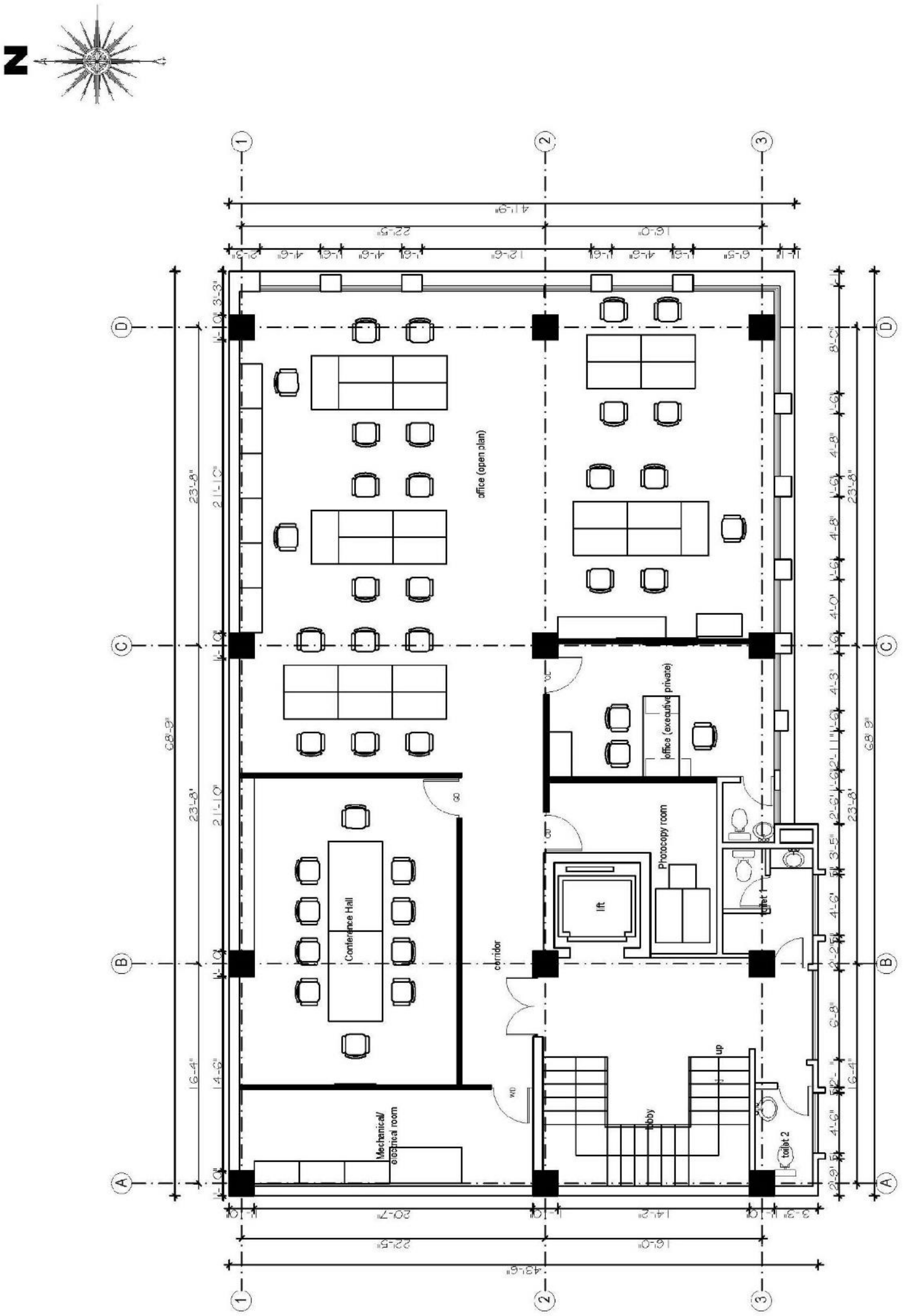

N
15' Wide Road
SITE PLAN
AREA: 2991.70 SQ.FT



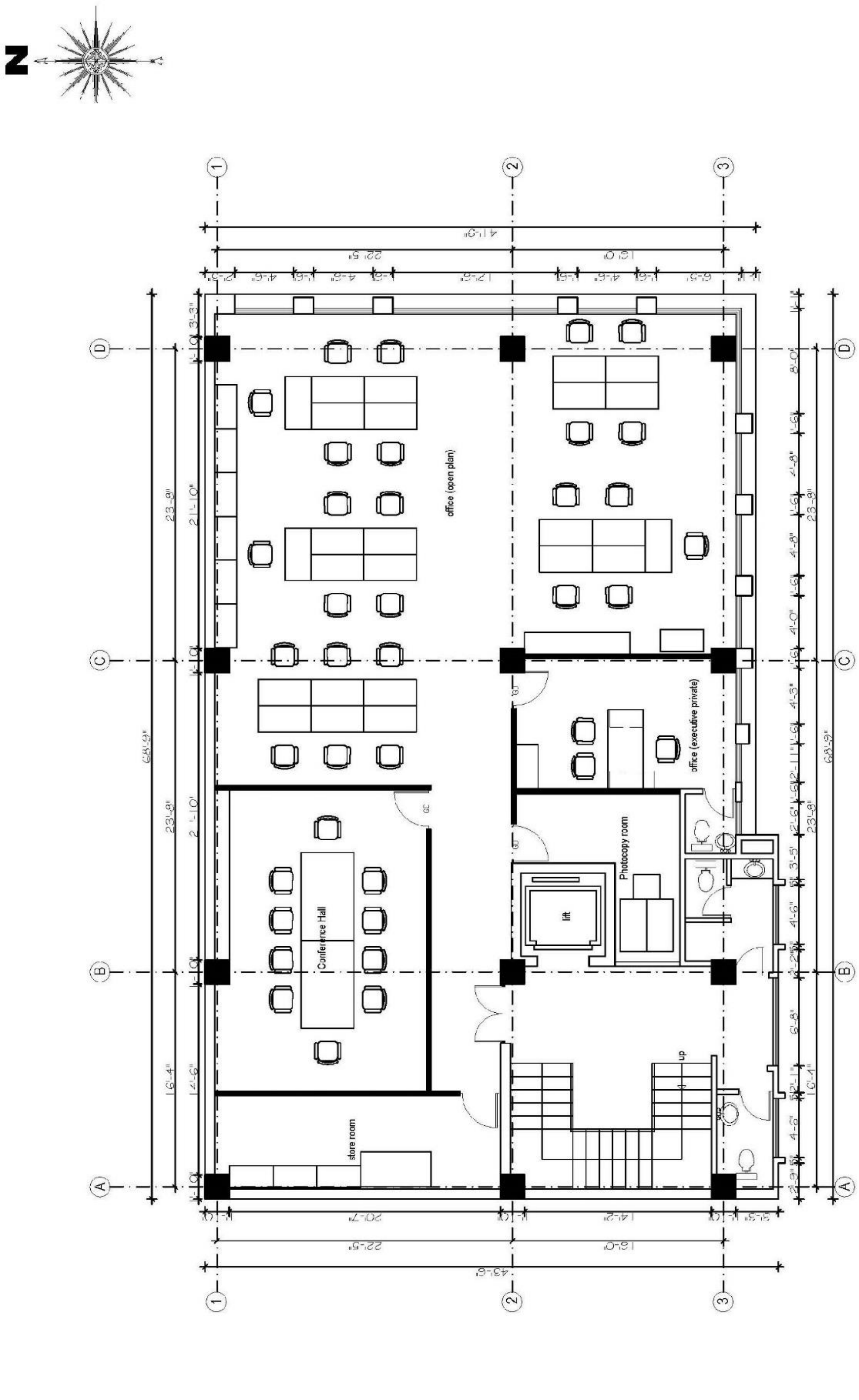
GROUND FLOOR PLAN
AREA: 2656 SQ.FT



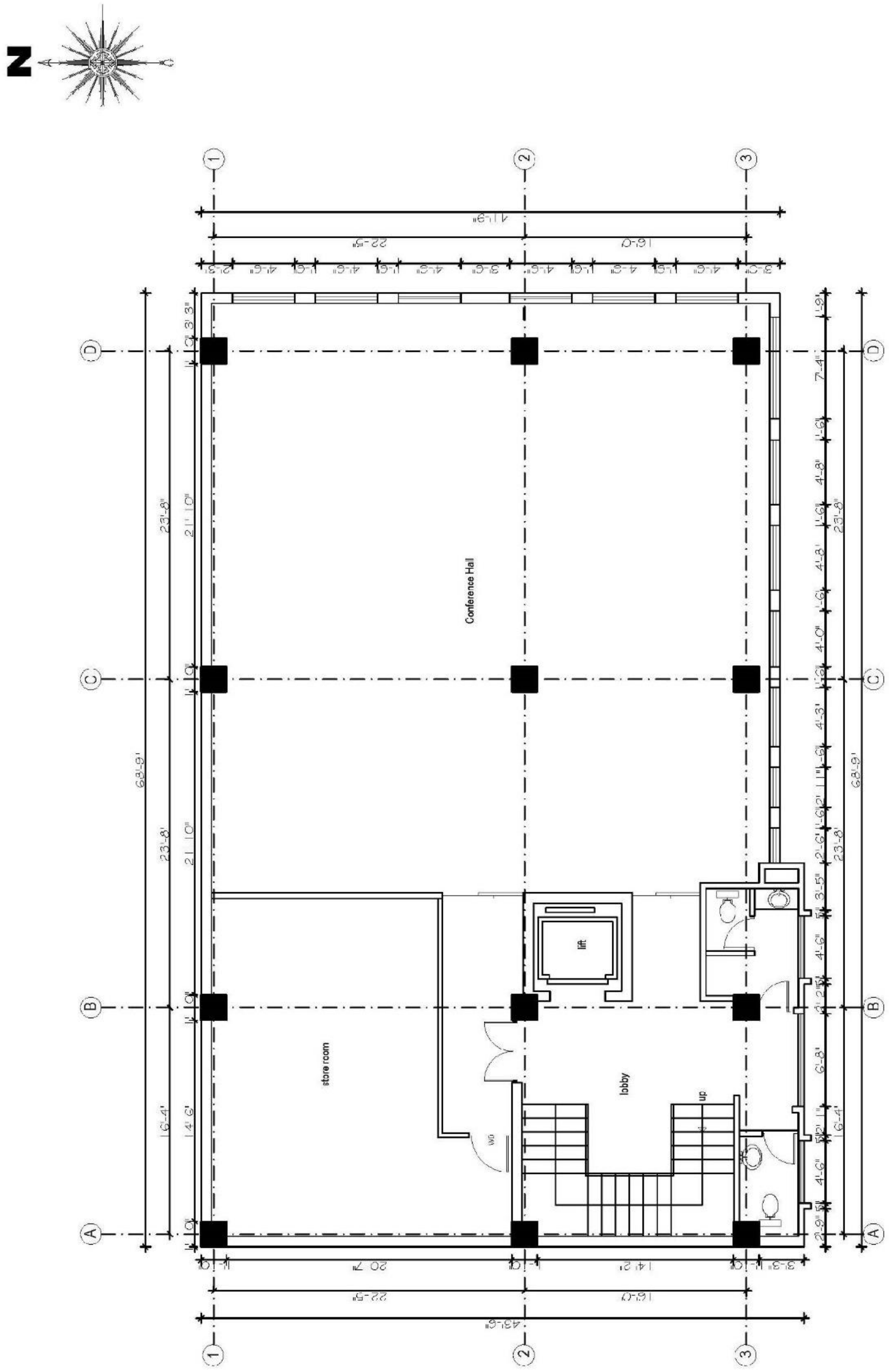
FIRST FLOOR PLAN
AREA: 2921 SQ.FT



SECOND FLOOR PLAN
AREA: 2921 SQ.FT



THIRD FLOOR PLAN
AREA: 2921 SQ.FT



FOURTH FLOOR PLAN
AREA: 2948 SQ.FT