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"AMELIORATING THE MICRO-CLIMATE OF URBAN AREAS:

-A CASE STUDY OF RESIDENTIAL COURTYARD BLOCK OF PATAN"

By

Grishma Aryal (075/MSCCD/08)

A THESIS

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The undersigned certify that we have certify that they have read, approved and recommended to the Institute of Engineering for acceptance, a thesis entitled **"AMELIORATING THE MICRO-CLIMATE OF URBAN AREAS: A CASE STUDY OF RESIDENTIAL COURTYARD BLOCK OF PATAN CITY"** submitted by **Grishma Aryal (075/MSCCD/08)** in partial fulfillment of the requirements for the degree of Master of Science in Climate Change and development for Final defense.

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ABSTRACT

The world is experiencing a crisis with climate change, and Nepal is among the most vulnerable nations. Urban areas, including those with heritage value, are experiencing an increase in air temperature due to the combined effects of climate change and the Urban Heat Island (UHI) effect. In order to lower UHI and raise outdoor thermal comfort, urban morphology is essential. Therefore, designers, planners or climatologists in order to make better microclimate and to improve thermal comfort consideration is necessary at planning phase.

This paper presents a study of a major open area in a densely built and populated area in the centre of Patan to improve thermal comfort conditions in open spaces. This study focuses on the temporal-spatial analysis of how the geometry and vegetation of courtyards affect the outdoor thermal conditions in a warm, humid climate. This study will help to report the thermal environmental conditions of a courtyard open space in terms of vernacular dwelling space for present and future scenarios of climate change.

This research will help to increase the comfort level of the people residing by improving indoor and outdoor thermal comfort in the courtyard with the use of appropriate construction techniques. It will also help in enhancing courtyards' thermal conditions and contributing to an improvement of the surrounding urban microclimate.

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CHAPTER ONE: INTRODUCTION

1.1.Background of the study

The rapid urbanization of hot climate cities in recent years emphasizes how important it is to provide more outdoor areas for residents to engage in a variety of activities beyond leisure or recreation. In modern architecture, open spaces typically occupy more than two thirds of the urban area; as a result, their microclimate predominates in the urban canopy layer (UCL) climate. Understanding appropriate forms and materials can greatly aid in adopting thermal environments in outdoor settings, thereby reducing energy consumption in indoor conditions. To establish an urban microclimate and attain outdoor thermal comfort, it is imperative to enhance both the exterior and indoor thermal environments of buildings through a multidisciplinary approach. Microclimatic planning/design ameliorates negative effects of global climate change. Design modifications to outdoor environments can increase thermal comfort, and in extreme cases can be lifesaving. (Robert, 2011)

The following actions are helpful at various planning sizes for enhancing the urban microclimate, lowering heat islands, and retaining water: Large open spaces and forest regions, as well as the establishment and upkeep of places with cold air and snowboards with cold air, are crucial for urban areas.

The courtyard concept is a common and ancient method in architectural design, especially in Middle Eastern countries like Iran. Understanding the enormous complexity of the microclimate and its mechanism, which greatly influences human outdoor comfort within its premises, is fundamental to understanding how courtyards function as practical solutions with their optimal form and features of traditional architecture to cope with the hot and arid climate. (Al Mansouri, 2009)

The rapid urbanization of hot climate cities in recent years emphasizes how important it is to provide more outdoor areas for residents to engage in activities other than leisure or recreation. Users' thermal perception in hot, muggy outdoor settings has not been thoroughly investigated, particularly in the early phases of design, which negatively impacts thermal comfort. This fact clarifies the necessity of taking climate into account when designing outdoor spaces for human thermal comfort. The majority of the time, site and planning design levels lack climatically sensitive landscape design. (Wesam M, Mohammad, & Germeen F, 2016)

1.2.Contextual background

Global urban systems face a serious challenge from climate change. Its effects are probably going to get worse over the next few decadesDespite the possibility that humanity can cooperate to mitigate these effects, scientific evidence indicates that some of them are already happening and will continue to do so even in the absence of additional efforts. The effects of climate change, including increased rainfall, flooding, and consequences of urban heat islands, are predicted to have an influence on global urban systems. These will have a serious effect on urban systems, the people who live there, and the services they provide. Adaptation will almost certainly be required to cope with these effects. (Heidi & Somaya, 2017)

Both natural and human-caused factors may be at play in climate change, but human activity and massive emissions of greenhouse gases (GHGs) are driving unpredictable changes in the climate. Nepal's temperature is rising at a rate that is quicker than the world average. The weather and climate are significantly impacted by rising global temperatures.

Nepal is a landlocked country in South Asia that is located between India and China at 28° North latitude and 84° East longitude. The climate is incredibly complex and varied, influenced by both regional weather systems and uneven terrain. In the Terai (southern Nepal), summer temperature exceeds 40degree Celsius and above 45 degrees Celsius in some areas, while winter temperature ranges from 7-23 degree Celsius. This paper goes through Microclimatic planning and design to ameliorate negative effects of global climate change in context of Courtyard. To find out which factors have the biggest effects on energy efficiency and thermal comfort in traditional homes and how much of an impact each variable has depends on the order in which the improvements are implemented, comparative tests of various vegetative portions are conducted.

1.3.Problem statement

Due to the increasing population density in the Kathmandu valley, which is the central hub of Nepal is constraints with small boundaries. This influences people to use different appliances and materials in a residential or commercial building to upgrade their daily life and also increase the rate of CO2 emission in the valley (R. M. Shrestha & Rajbhandari, 2010). In the current scenario, development is mainly focused on the economy and environment, due to its demand for cost-benefit ratio and climate change. However, to establish development every aspect of sustainable development should be considered. It must consider social security and access, which attracts people who are willing to live in that place having a historical background with different cultures, religious beliefs, customs, and habits. A foundation for future generations to access resources and social environments without going extinct was built by the development of the economy, environment, social interaction, and culture. The use and purpose of Courtyard is commonly studied in Nepal but the impact that vegetation can have in Courtyard design is not thoroughly studied.

1.4.Objectives of the study

The general objective of the research is studying the efficiency of courtyards as insulating barriers for coping with climate change in residential building of Patan.

Main Objective: Ameliorating the micro-climate of urban area of Patan.

Specific Objectives:

- Make it clear whether and how building courtyards can enhance urban microclimates and reduce energy use.
- To show how the presence of vegetation in the courtyards and inside the building controls the air temperature.
- To identify weather vegetation is the best solution to temperature modifier within courtyard or not.

1.5.Research questions

- What is the microclimatic impact of vegetation in Courtyard?
- How can the temperature be modified with the use of vegetation?
- Does the layout and application of effective passive cooling methods affect a courtyard's thermal properties?

1.6.Limitation of the study

- The study has been prepared considering temperature and some building material other components could also be considered for further studies.
- This research findings will not provide the solutions but helpful for the considerations a precaution required by the professionals in designing and ameliorating the effects in microclimate and role of vegetation.

CHAPTER TWO: LITERATURE REVIEW

2.1.Climate Change

Climate change is defined by the United Nations Framework Convention on Climate Change (UNFCCC) as "a change in climate that is additional to natural climate variability observed over comparable time periods and that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere." Long-term changes in temperature and weather patterns are referred to as climate change. Significant volcanic eruptions or variations in the sun's activity could be the cause of these changes. But since the 1800s, human activity—primarily the burning of fossil fuels like coal, oil, and gas—has been the main driver of climate change. As a result of the burning of fossil fuels, greenhouse gases are released into the atmosphere, enveloping the earth like a blanket and trapping solar heat, raising global temperatures. (IPCC, 2021)

Methane and carbon dioxide are the two primary greenhouse gases responsible for climate change. These arise, for example, when fuel is burned to run a car or coal is burned to heat a building. Destroying forests and clearing land can also release carbon dioxide. Methane emissions are mostly produced by the oil and gas industry and agriculture. Energy, manufacturing, transportation, construction, land use, and agriculture are the main industries that emit greenhouse gases. (UNEP, 2023)

2.1.1. Climate System

The climates of different regions of the world differ. In certain regions of the world, it rains almost daily and is very hot. They have a humid, tropical climate. Others have snowfall and year-round cold. Their climate is polar. There are numerous other climates that contribute to Earth's biodiversity and geologic legacy between the frigid poles and the steaming tropics.

A region's climate is determined by its climate system. The atmosphere, hydrosphere, cryosphere, land surface, and biosphere are the five main parts of a climate system. The component of the climate system that varies the most is the atmosphere. The composition and movement of gases surrounding the Earth can undergo significant changes due to both natural and man-made factors. Changes to the hydrosphere occur far more slowly than changes to the atmosphere. Two examples are variations in salinity and temperature.

Another component of the climate system that is generally stable is the cryosphere. Glaciers and ice sheets reflect light from the sun, and permafrost and ice's thermal conductivity have a significant impact on temperature. Additionally, the cryosphere aids in controlling thermohaline circulation. This "ocean conveyor belt" has a significant impact on biodiversity and marine ecosystems. (Lea, et al., 2014)

2.1.2. Climate Topography

Because topography and vegetation affect how the Sun's energy is used on Earth, they also affect climate. The amount of vegetation and the kind of land cover (soil, sand, or asphalt) affect temperature and evaporation. The entirety of life on Earth, or the biosphere, has a significant impact on climate. Plants contribute to the regulation of greenhouse gas flow in the atmosphere through photosynthesis. Oceans and forests act as "carbon sinks," lowering global temperatures. Living things change the environment by growing naturally and by constructing structures like mounds, burrows, and dams. The wind, erosion, and even temperature patterns in these changed landscapes can have an impact on the weather. (Wei Chun, Wei, Jiang, & Hong Bin, 2023)

2.1.3. Climate Features

Average temperature and precipitation are probably the two aspects of a region's climate that people are most familiar with. Variations in daily, nightly, and seasonal patterns also contribute to the identification of distinct climates. For instance, the annual temperatures and precipitation of Beijing, China, and San Francisco, California, are comparable. Still, San Francisco and Beijing are very different because of the daily and seasonal variations. Beijing experiences hot summers and cold winters, while San Francisco experiences winters that are not all that different from its summers. San Francisco experiences rainy winters and dry summers. Beijing experiences wet summers and dry winters due to its reversal of the wet and dry seasons. (National Geographic Society, 2022)

In addition, wind, humidity, cloud cover, air pressure, and fogginess are characteristics of the climate. Climate is greatly influenced by latitudeAdditionally, landscape can define a region's climate. Climates can be influenced by a region's elevation, land-use patterns, and distance from freshwater or the ocean.

Latitude, elevation, topography, proximity to the ocean, and geographic location within a continent are among the numerous variables that contribute to the formation of every climate. For instance, West Africa's rainy, tropical climate is shaped by its position on the western side of the continent and its proximity to the Equator (latitude). The region is situated at the intersection of moist trade winds, known as the intertropical convergence zone (ITCZ, pronounced "itch"), and enjoys year-round direct sunlight. As a result, the region's climate is warm and rainy.

2.1.4. Climate types

Climate is the average long-term weather pattern for a given area over a minimum of thirty years. Furthermore, there are many diverse kinds of climates on Earth. For instance, hotter areas are often found nearer the equator. At the equator, where the Sun shines most directly overhead, the climate is hotter. Additionally, because the Sun's heat and light are not as direct there, the North and South Poles are cold.

Wladimir Koppen, a German climate scientist, used this data to categorize the world's climates in the late 1800s and early 1900s. His classifications were based on the temperature, the quantity of precipitation, and the seasons in which it falls. The latitude of a region—the imaginary lines that measure Earth's distance from the equator to the north and south—also had an impact on the categories.

There are currently about five primary types of climates on Earth, according to climate scientists. These are:

A: Tropical. This hot, humid area experiences above-average yearly temperatures of 64°F (18°C) and above-average annual precipitation of over 59 inches.

B: Dry. Because there is very little precipitation and moisture evaporating from the air quickly, these climate zones are extremely dry.

C: Temperate. This zone usually experiences mild winters and warm, muggy summers with thunderstorms.

D. Continental. These areas experience extremely cold winters and warm to cool summers. This zone can see snowstorms, high winds, and extremely low temperatures during the winter—sometimes as low as -22°F (-30°C).

E: Polar. The polar climate zones have bitterly cold temperatures. Here, summertime temperatures never rise above 50°F (10°C).

On a globe, this is approximately where those climate zones are located:

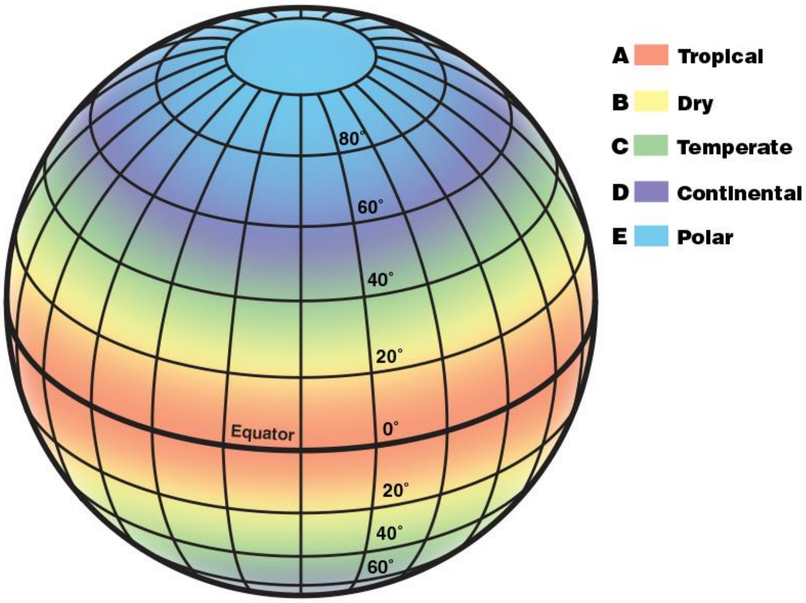


Figure 1 Climate Types

2.2.Microclimate

The unique climate of a small area, like a garden, park, valley, or portion of a city, is known as a microclimate. Temperature, precipitation, wind, humidity, and other weather variables that are specific to a microclimate may differ slightly from those that apply to the entire region and from those that could be expected under specific pressure systems or cloud cover. Indeed, the climate of a town, city, or wood is composed of a variety of slightly different microclimates.

In addition to the physical characteristics of cities, building density, environmental issues, and thermal response of buildings, and the influence of vegetation and water bodies are the primary factors influencing the microclimate of urban environments. (Giyasova, 2021).

A microclimate is a localized area with distinct atmospheric conditions that differ, typically only slightly but sometimes significantly, from the surrounding air masses. Areas as small as a few square meters or less (like a garden bed, beneath a rock, or a cave) or as big as many square kilometers can be included in the term. Because of the statistical character of climate, which implies both spatial and temporal variation of the mean values of the describing parameters, microclimates—sets of statistically distinct conditions that occur and persist over time within a region—are possible. Although microclimates are present everywhere, they are particularly noticeable in topographically dynamic regions like mountains, islands, and coastal areas.

Microclimates can be found, for instance, close to bodies of water that have the potential to cool the surrounding air or in densely populated areas where materials like brick, concrete, and asphalt absorb solar radiation, heat up, and then radiate that heat back into the surrounding air. This phenomenon is known as an urban heat island (UHI), which is further exacerbated by the area's relative lack of vegetation.

Analysing microclimates entails high-resolution spatial and temporal analysis of how architectural interventions affect local wind flow and radiative fluxes. (Graham, Graham, Turnbull, & Turnbull, 2020)

2.2.1. Urban area

Places with a dense population are called urban areas. Towns and cities contain urban areas. The primary location of employment is frequently an urban area. The majority of structures are human made in urban areas. The built environment offers opportunities for health, like public transportation and sidewalks. Air quality and sedentary commuting are two additional health risks brought on by the built environment. Metropolitan areas are made up of numerous urban areas and the socioeconomically connected communities that surround them.

Depending on their size, services provided, and functions carried out, urban centres are categorized as towns, cities, million cities, conurbations, and megalopolis.

Town: We can understand about the "town" comparing it with "village." The size of the population is not the sole factor. While there are sometimes subtle differences in the functions that towns and villages perform differently, towns are home to certain industries like manufacturing, wholesale and retail trade, and professional services.

City: A city can be considered a leading town if it has outperformed its competitors in the area or locally. As per Lewis Mumford, “the city is in fact the physical form of the highest and most complex type of associative life”. Compared to towns, cities are considerably larger and serve a wider range of economic purposes. Major financial institutions, transport terminals, and regional administrative offices are typically found there. A city is referred to as having a million residents when that number is reached.

Conurbation: When originally distinct towns or cities merged to form a larger urban area, the result was a conurbation, a term first used by Patrick Geddes in 1915. Tokyo, Chicago, Manchester, and Greater London are a few examples.

Megalopolis: This Greek term, which translates to "great city," was made popular by Jean Gottman in 1957 and denotes a region that is "super- metropolitan," meaning it is a union of conurbations. The most famous example of a megalopolis is the urban area that stretches from Boston in the north to Washington, D.C. in the south. (National Council of Educational Research and Training, 2022)

Million Cities: A city is deemed a million city once its population surpasses one million. The world's population of million cities has been rising at an unprecedented rate. By 1800, there were about 80 such cities. Paris followed suit in 1850, New York in 1860, and London in 1800.

Urban locations are just closer to one another, which makes it simpler to incorporate walking, bicycling, or taking public transportation into daily mobility plans. There are many different places to be active in urban areas, including parks and pet parks, bike lanes and walkways, green spaces, skate parks, public swimming pools, and walking and bicycling to school.

It's vital to have green space. Limited green space in cities can be rapidly consumed by new development. In urban areas with high property values, maintaining green spaces can be costly. The demand for green space can occasionally be seen in the economic market; one example is the demand for green space created by millennials or small pet owners. Some localities are mandating the inclusion of green space in larger developments. Green space preservation may benefit from zoning regulations. To incorporate green space in denser urban areas, some property owners have become inventive. A few examples of creative areas are roof-top green plazas, rain gardens for storm water drainage, and rain barrels for irrigating urban gardens. Green space has positive effects on wellbeing.

2.2.2. Courtyard

A courtyard is a fenced-in space that is frequently encircled by an open-air building or complex. Courtyards have been utilized as a common and customary architectural element by both ancient and modern architects. They are found in both Eastern and Western architectural designs. These areas in hotels and public buildings served as the main gathering spots for various groups, which gave rise to the additional meanings of the word court. The terms "court" and "yard" have the same root and refer to enclosed areas. For the relationship between this group of words, see yard and garden. Courtyards in universities are frequently referred to as quadrangles. (Jiayin, et al., 2023)

In residential architecture, courtyards—private outdoor areas encircled by walls or structures—have been used for nearly as long as people have lived in built homes. The Neolithic Yarmukian site at Sha'ar HaGolan is located on the northern bank of the Yarmouk River in the central Jordan Valley. This is particularly significant in the history of architecture since it is the first recorded example of a courtyard house, dating to approximately 6400–6000 BC (calibrated). Throughout history, people have utilized courtyards for different activities, such as gardening, preparing food, resting, working, and even keeping animals. (Garfinkel, 1993)

Prior to courtyards, open fires were maintained in the middle of homes with a tiny opening in the ceiling above them to let smoke out. These tiny apertures eventually grew larger, resulting in the creation of the centralized open courtyard that we are familiar with today. There are many different designs and constructions of courtyard homes in the world.

Temperate climates are home to a higher concentration of courtyard homes, as an open central court can help keep a home cool during hot weather. But for centuries, courtyard homes have also been found in more arid regions. People almost always want their housing to have the following comforts: air, light, privacy, security, and tranquility. These are all provided by a courtyard. Natural materials are used in almost all courtyards.

The courtyard homes of the Middle East are a reflection of the region's nomadic lifestyle. Throughout the year, cooking, sleeping, and other activities were moved to accommodate variations in temperature and sun position, rather than having formal rooms assigned for these purposes. In warm weather, these buildings' flat rooftops were frequently used for sleeping. Private courtyards were the only areas outside where women could unwind covertly in some Islamic societies. It has also been observed that in the Middle East, convective cooling occurs through transition spaces between buildings with multiple courtyards. (Ford & Ernest, 2012)

A courtyard in the center of your home can be transformed into a lovely outdoor space thanks to its central location. Compared to other outdoor areas like patios, decks, verandas, and terraces, they offer greater privacy. Houses have included courtyards for centuries. They were widely used in homes and buildings and were widespread throughout the world. Nowadays, some areas of homes no longer have as many courtyards as possible. They are more common in institutional and commercial buildings, such as workplaces, malls, and colleges. A courtyard makes a wonderful place to socialize and unwind. Still, having a courtyard in a home is becoming more and more common. People use courtyards to enhance their homes' interior rooms as they seek out more opportunities to engage with outdoor environments. (Fawzi, 2018)

2.2.2.1. Benefits of a Courtyard

1. Natural Ventilation

One of the main considerations in tropical house design is natural ventilation. Optimizing cross-ventilation or the flow of wind through a building or residence is the ideal approach. To accomplish this, it is ideal for the wind to have a relatively short path within a room. But in a house, it's typical for breezes to pass through a few rooms before emerging on the other side. This can be reduced by placing a courtyard in the center of the house. It creates an outdoor space in a floor plan layout that may have been too deep. The wind can therefore travel shorter distances through a courtyard in the center of a house.

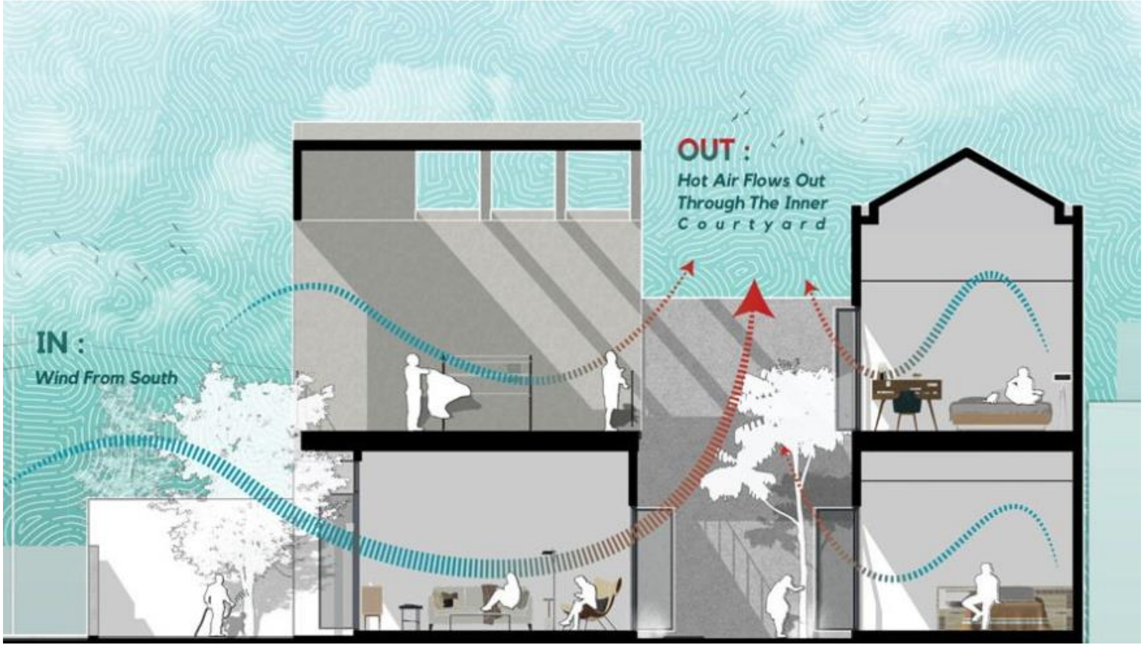


Figure 2 Wind Flowing in a courtyard

They also give warm air in the house a way to escape. There's a way for warm air to escape the house from the rooms facing the courtyard. resulting in a reduction of the interior temperature.

2. Natural Light

Sometimes you are forced to design a dense floor plan layout when you have a large house on a small lot. Because of this, there may be areas of the house that are distant from doors and windows in the outer walls. They may therefore be distant from sources of natural light.

Courtyards can provide some natural light to those enclosed areas. Furthermore, a courtyard can frequently supply internal rooms with natural, indirect light. Because of the sun's angle, tall, narrow courtyards may block out direct sunlight from entering a room. On the other hand, indirect light from sunlight bouncing off the courtyard walls can enter lower interior rooms. Thus, enjoys the advantages of natural light without the heat that comes with it. A courtyard can also be covered by a pergola or other latticed structure. Helping to screen or filter direct sunlight entering the courtyard and house is one of its advantages. permits natural light strips to pass through as well. Nevertheless, depending on the time of day, courtyards may add more direct sunlight and heat to the house.

3. Connection with Nature

There is a psychological bond between humans and nature. Viewing natural features like plants, trees, and water has been linked to several health advantages, according to studies. This is among a courtyard's additional advantages.

One excellent way to bring these natural elements into interior rooms that might not have access is to create a courtyard in the center of your home. Because courtyards can receive both sunlight and precipitation, they are often designed with gardens. Depending on the size of the courtyard, gardens may contain big trees or little plants. Water features can also be found in many courtyards. Among these water features is a fountain and pond. Furthermore, some courtyards have a swimming pool included in them. Water's sound and visual effects are frequently soothing and create a pleasant atmosphere. Therefore, adding a water feature to the center of your house can improve the interior rooms there.

4. Indoor-Outdoor Connection

Having a courtyard in the center of your home also strengthens the bond between your interior and outdoor areas, which is another advantage. As was already mentioned, a central courtyard makes you feel more connected to nature and adds an open, outdoor area right in the middle of your home. This configuration can give your home's interior a airier and more welcoming feel. Interior rooms are divided by a courtyard, which also links them to wonderful outdoor areas. With the help of large doors and window openings, the rooms that border the courtyard can open completely onto it.

5. Additional Room

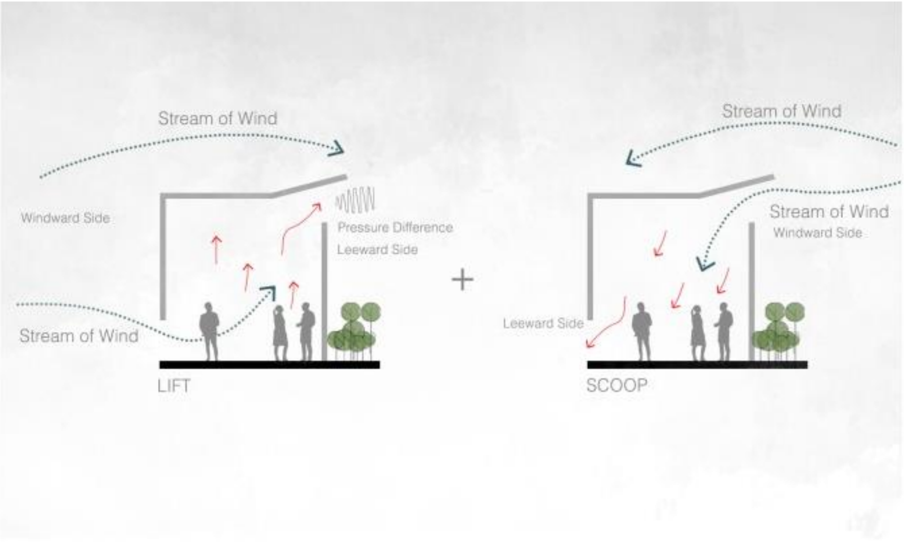
It is easy for a courtyard to feel more like a room because it frequently has rooms surrounding it, either completely or partially. This space could be used for eating, relaxing, or as a kids' play area. Given that it won't have a floor or roof, this additional room might also result in cheaper construction costs. It might, however, necessitate a few extra exterior windows and doors as well as structural walls.

6. Private Outdoor Space

A courtyard's potential to provide more seclusion than other outdoor areas is another advantage. Some places have patios, which are popular and excellent for taking in the scenery. Nevertheless, depending on where they are in the house, they may not provide much privacy.

7. Secured Exterior Area

Another great way to create an outdoor space without having to worry about intruders is with a courtyard. This is a critical issue for ground floor rooms. A courtyard that is open to the sky won't deter those monkeys from entering, though.



The Lift And Scoop Courtyard
The house uses a system of lift to remove the stale air from the inside when the courtyard is on the leeward side of the wind. The same courtyard reverses its function to act as a wind scoop to bring in fresh air when the courtyard is on the windward side.

Figure 3Function of courtyard orientation in direction of wind

To create a climate-responsive design, bioclimatology integrates microclimate and architecture with human thermal comfort. A courtyard can locally produce microclimate under particular climatic conditions, serving as a "moderator" function. A microclimate is a small area that has a unique climate that is different from the surrounding area, typically with a horizontal range of less than 1 km and an upper limit of 2 km. The primary determinants of the microclimate's physical characteristics are air temperature, relative humidity, solar radiation, and wind patterns.

Outdoor thermal comfort is influenced by a variety of meteorological factors, including air temperature, relative humidity, wind speed, and mean radiation temperature, as well as human factors, including clothing selection and level of activity. Air temperature, wind speed, relative humidity, albedo (K.K.L, Lindberg, & S., 2015) are the typical input data used by the software to evaluate comfort indexes such as the Predicted Mean Vote (PMV), the Physiological Effective Temperature (PET), Mean radiation temperature (MRT) (A.S & M, 2016), the Universal Thermal Climate Index (UTCI), effective Temperature (ET*) and the index of thermal stress (ITS), Software for simulating microclimate are Envi-met, CFD, RayMan and EnergyPlus,.Envi-met is a three- microclimate model and was used for simulating outdoor air temperature, mean radiant temperature wind speed and relative humidity.

2.2.3. Thermal Comfort in Courtyards

A common feature in traditional architecture across many cultures is the courtyard, which serves as a living area in addition to an outdoor area for the building's lighting and ventilation. These days, courtyards are viewed as a passive approach to improving a building's energy efficiency because the microclimate they create regulates the outside temperature. By reducing energy losses through surfaces that come into contact with the courtyard space, this lowers the energy demands of buildings and consequently lowers the consumption of the conditioning systems. Since the courtyard has the potential to offer better thermal comfort than other outdoor spaces—especially in hot and dry climates like the Mediterranean—we concentrate on the advantages of the courtyard as an inhabited outdoor space in this study.

2.2.4. Types of courtyard in Nepal

The terms "nani" or "chok" are commonly used to refer to the larger court types. It should be noted that the majority of Patan's population consists of Buddhist communities, the largest of which are the Sakya, Vajracharya, and Maharjan communities. Within the quarter of these communities, the resident community's utilitarian and religious facilities are constructed, and settlement quarters are arranged around spacious quadrangular courts. Buddhist monasteries are one type of such place of worship; they frequently serve as the hub of the settlement area.

The court of Nabahal nani

Situated in the western part of the city, the Nabahal quarter is a part of the Na-tole neighborhood and is recognized as a branch of Bubahal, one of Patan's sixteen principal monasteries. The four sides of Nabahal Nani's open court are square and closely spaced from one another.Located roughly north of south, the court can be accessed from the city's main east-west street. The square court's entrance lane is located precisely in the middle.

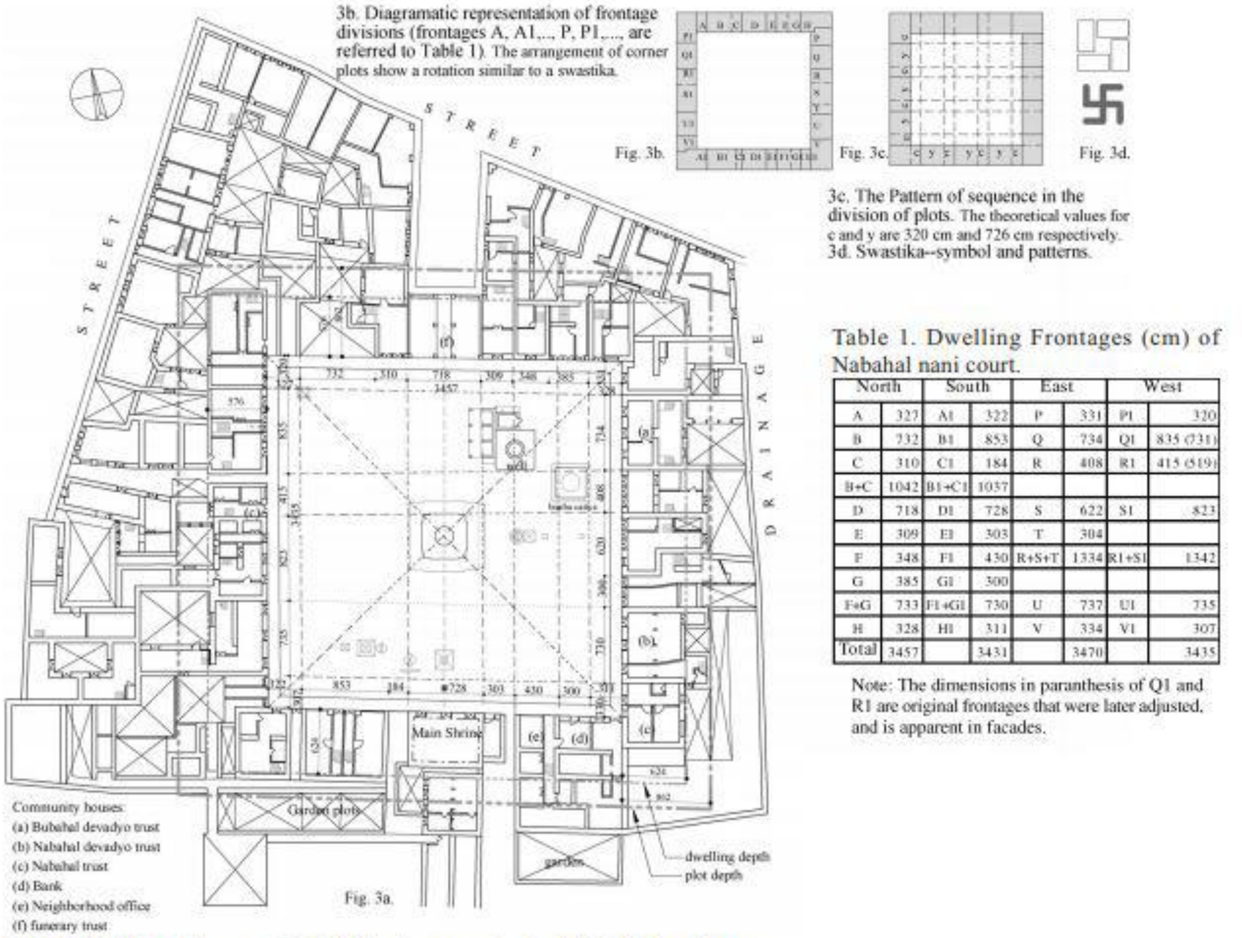


Table 1. Dwelling Frontages (cm) of Nabahal nani court.

North		South		East		West	
A	327	A1	322	P	331	P1	320
B	732	B1	853	Q	734	Q1	835 (731)
C	310	C1	184	R	408	R1	415 (519)
B+C	1042	B1+C1	1037				
D	718	D1	728	S	622	S1	823
E	309	E1	303	T	304		
F	348	F1	430	R+S+T	1334	R1+S1	1342
G	385	G1	300				
F+G	733	F1+G1	730	U	737	U1	735
H	328	H1	311	V	334	V1	307
Total	3457		3431		3470		3435

Note: The dimensions in paranthesis of Q1 and R1 are original frontages that were later adjusted, and is apparent in facades.

Fig.3. Nabahal nani quarter. 3a. Bulding frontages (cm) of Nabahal nani court.

Figure 4 Plan of Nabahal Nani.

The Court of Elanani, Nakhachuk and Nagbahal

Elanani Quarter is a part of the Nagbahal neighborhood, which is situated in the city's northwest. At its southeast corner is Kwabahal, one of Patan's principal monasteries, popularly known as the Golden Temple. Elanani's spatial and socioreligious organization is part of a larger settlement block that has two additional courtyards: Saraswati nani and Kwabahal to the east, and Nakachuk and Nagbahal to the west.

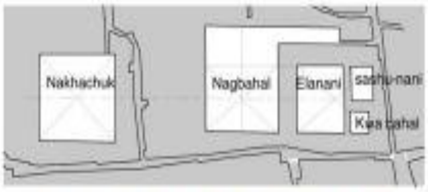


Fig.4. Spatial relationship of Elanani, Nagbahal and Nakhachuk.

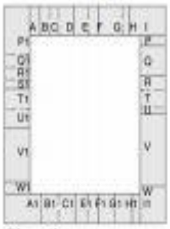
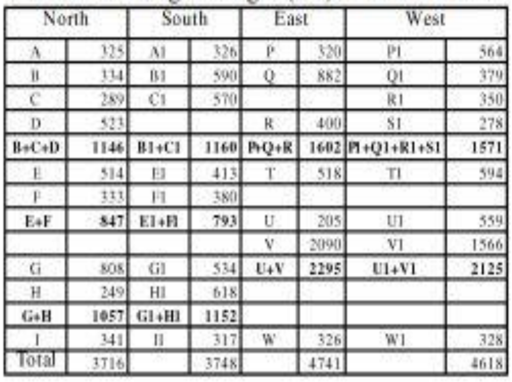


Fig. 5b.

Fig. 5c.

5b. Diagramatic representation of frontage division. (frontages A, B,.., A1, B1,..., are referred to Table 2)
5c. Pattern of sequence in the division of plots.

Table 2. Dwelling frontages (cm) of Elanani court.



North		South		East		West	
A	325	A1	326	P	320	P1	564
B	334	B1	590	Q	882	Q1	379
C	289	C1	570			R1	350
D	523			R	400	S1	278
B+C+D	**1146**	**B1+C1**	**1160**	**P+Q+R**	**1602**	**P1+Q1+R1+S1**	**1571**
E	514	E1	413	T	518	T1	594
F	333	F1	380				
E+F	**847**	**E1+F1**	**793**	U	205	U1	559
				V	2090	V1	1566
G	808	G1	534	**U+V**	**2295**	**U1+V1**	**2125**
H	249	H1	618				
G+H	**1057**	**G1+H1**	**1152**				
I	341	I1	317	W	326	W1	328
Total	3716		3748		4741		4618

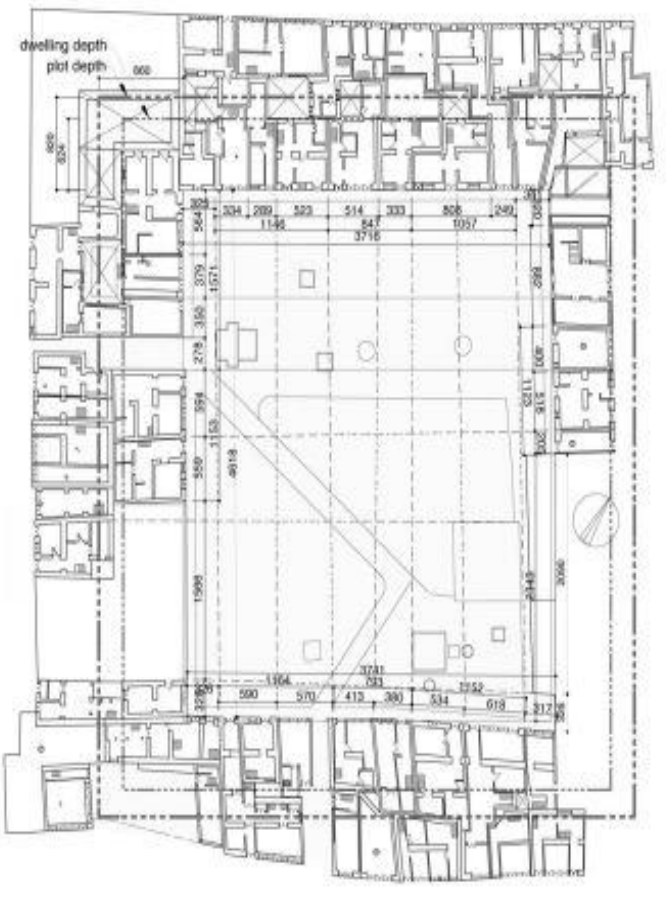


Fig.5. Elanani Court: 5a. Dimensions of dwelling frontages (cm).

Figure 5 Plan of Nakhachuk

2.2.5. Courtyards without Trees

Courtyard offers comforts including parameters like air, light, privacy, security, and tranquility. Absence of evaporative heat loss

2.2.6. Courtyards with Trees

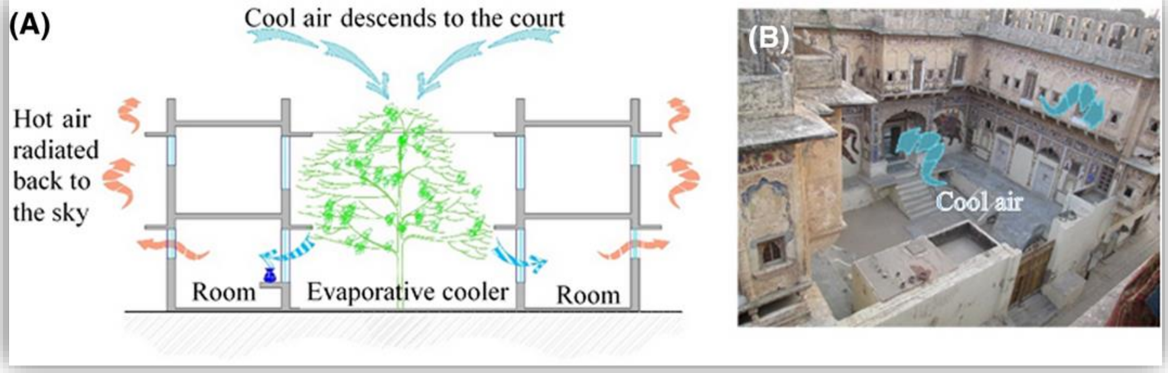


Figure 6 Evaporative cooling of courtyard

2.3.Study area-Courtyard

Newari traditional courtyard house. It may vary in size and shape depending on the place of residence.the calculation of width of the façade of courtyard is (y+c)+c=w where w stands for wide of the courtyard, c stands for the corner frontage and y stands for the width of the longer frontage of the courtyard

2.4.Sustainable approach

Material used is mud mortar (comfortable indoor environment). Outer special backed brick is (dachi-appa) and inner is sun dried brick that transfer heat in indoor. Roof is red burnt tiles which is resilient to weather. Ideology is placed at the center of court to eliminate the uncomfortable climatic condition within the building.This is 10-20% energy consumption saving. *(Source: (Korn, 1977)) North American Academic Research, Volume 3, Issue 03; March, 2020;)*

The elements of courtyard design include material, opening characteristics, geometry, proportion, and orientation. Indicators of energy consumption, indoor and outdoor temperatures, solar radiation, and natural ventilation in various climates include shading devices, vegetation, and water pools. The three main microclimatic functions of courtyards are natural ventilation, humidity, and solar gain.

2.5.Courtyard Design Variants and Microclimate Performance

The courtyard serves as a microclimate modifier, enhancing the ambient comfort levels. The enclosed space is becoming more and more common in urban architectural design because of its good potential for natural ventilation and ease of creation of a relatively independent outdoor microclimate. Kotzen states that a tree can alter the microclimate in the landscape in four main ways: temperature, relative humidity, wind (velocity, direction), and solar radiation modification of terrestrial radiation from the ground and other surfaces.

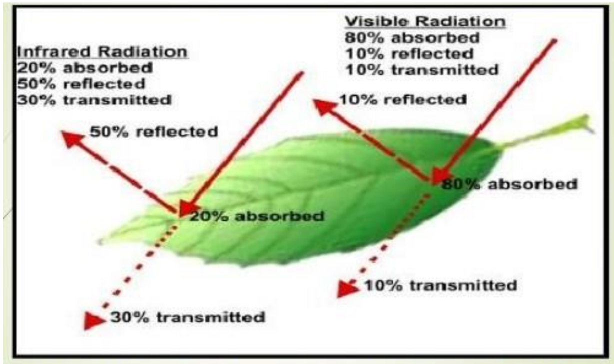


Fig:-1 Leaf Absorption, Transmission and Reflection of Solar Radiatior
(source- Brown and Gillespie, 1995)

Figure 7 leaf function

A courtyard is frequently thought of as a microclimate modifier that enhances the comfort of the surroundings. The enclosed space is becoming more and more common in urban modern architectural design because of its good natural ventilation potential and ease of creating a relatively independent outdoor microclimate. Trees are considered a basic element in microclimate modification. Kotzen states that a tree can alter the microclimate in the landscape in four main ways: by changing the wind (its direction and speed), temperature, relative humidity, solar radiation, and the amount of terrestrial radiation it receives from the ground and other surfaces. The two most crucial factors in modifying a microclimate are the amount of radiation received from the sun and the earth (Kotzen, 2003). Radiation blocking capacity of trees varies according to their level of shade. Gómez-Muñoz et al. (2010) state that the amount of shade varies throughout the day depending on the age, species, and orientation of the trees. The shape, depth, and distribution of leaf area, as well as the distance between trees and other growth factors like irrigation and cultivation, all influence the shade cast by a tree canopy (Shashua-Bar and Hoffman, 2000). On the other hand, Huang et al. (2008) investigated the impact of various ground cover types on lowering air temperature. They discovered that, during the day, the highest air temperature was recorded in the following order: bare concrete, lawn, water areas, wood, or the shade of trees. This order was reversed during the night. Climbers vary, though, in how much shade they offer. Lam (2007) states that a variety of factors, including growth rate, leaf size, climber height, tolerance to winter temperatures, maintenance, orientation (sun preference), weather tolerance, soil type, and climbing pattern, should be taken into account before choosing the best climbers for shade.

2.6. Climate Change projections

- Trends and variability
- Representative Concentration Pathway (RCP)
- Shared Socioeconomic Pathways

The IPCC adopted the Representative Concentration Pathway (RCP), a trajectory for greenhouse gas concentrations rather than emissions. For the 2014 IPCC Fifth Assessment Report (AR5), four research and modeling pathways were used.

The various climate futures depicted by the pathways are all thought to be feasible given the amount of greenhouse gases (GHG) released in the years to come.

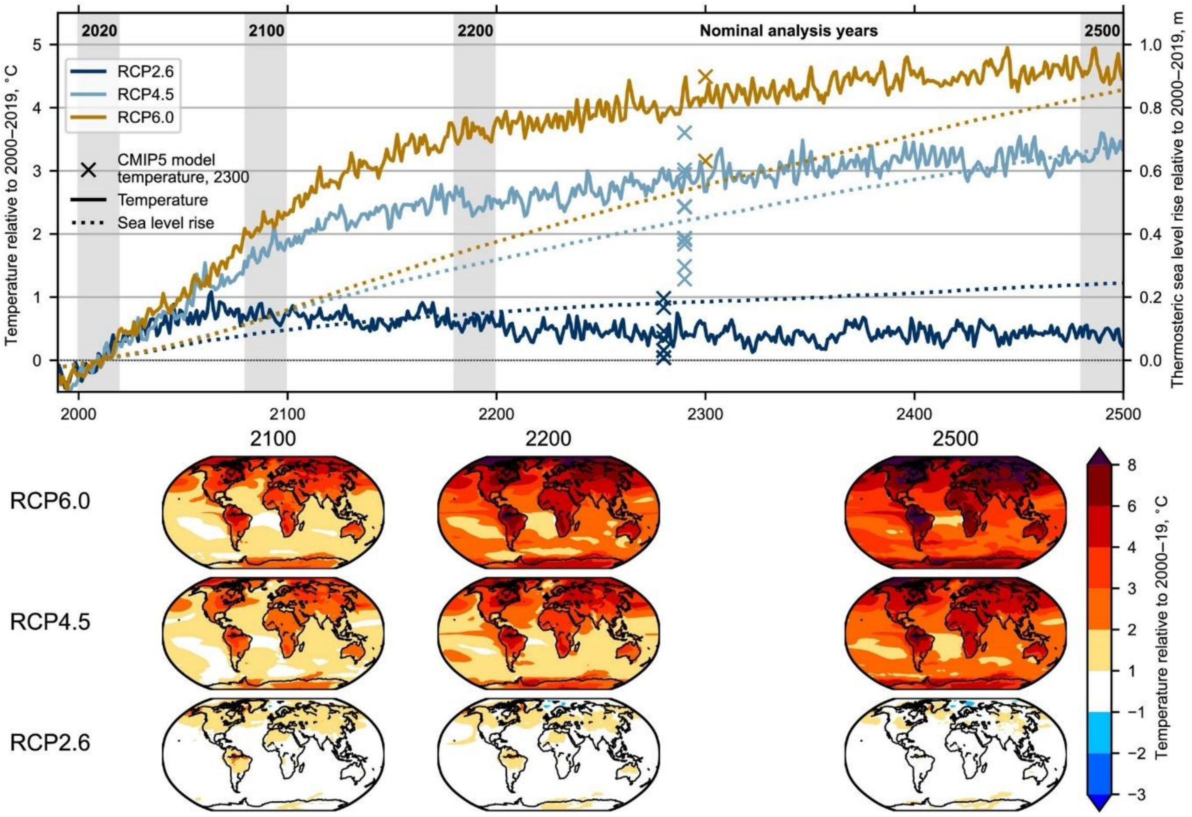


Figure 8 Representative Concentration Pathway (RCP)

2.6.1. RCP 1.9

RCP 1.9 is a pathway that limits global warming to below 1.5 °C, the aspirational goal of the Paris Agreement

2.6.2. RCP 2.6

RCP 2.6 is a "very stringent" pathway. According to the IPCC, RCP 2.6 requires that carbon dioxide (CO2) emissions start declining by 2020 and go to zero by 2100.

2.6.3. RCP 3.4

RCP 3.4 represents an intermediate pathway between the "very stringent" RCP2.6 and less stringent mitigation efforts associated with RCP4.5

2.6.4. RCP 4.5

RCP 4.5 is described by the IPCC as an intermediate scenario. Emissions in RCP 4.5 peak around 2040, then decline.

2.6.5. RCP 6

In RCP 6, emissions peak around 2080, then decline.

2.6.6. RCP 7

RCP7 is a baseline outcome rather than a mitigation target.

2.6.7. RCP 8.5

RCP8.5, generally taken as the basis for worst-case climate change scenarios, was based on what proved to be overestimation of projected coal outputs.

2.6.8. Climate change scenarios of Nepal.

For adaptation to be successful, it is essential to project future climate change. Four scenarios, or Representative Concentration Pathways (RCPs), were identified in the Fifth Assessment Report: RCP2.6, RCP4.5, RCP6, and RCP8.5. Each of them represents different volumes of greenhouse gas emissions, and hence varied levels of their concentrations in the atmosphere in the year 2100, implying a particular development trajectory taken. The total radiative forcing, or energy imbalance, expressed in watts per meter squared, for each RCP in the year 2100 relative to 1750 is its unique symbol. RCP4.5, for example, indicates a radiative forcing of 4.5 Wm-2. The amount of radiative forcing and the ultimate long-term average warming are directly causally related.

Of these four RCPs, two possible trajectories – RCP4.5 and RCP8.5 – were chosen as representations of extreme future scenarios based on different socioeconomic and developmental trajectories. Future climate change scenarios were analysed for the medium- term period (2016–2045) and the long-term period (2036- 2065) – periods corresponding with the 2030s and 2050s respectively.

Table 1 Multi model ensemble mean of change in precipitation and temperature in the medium-term and the long-term periods for the whole Nepal

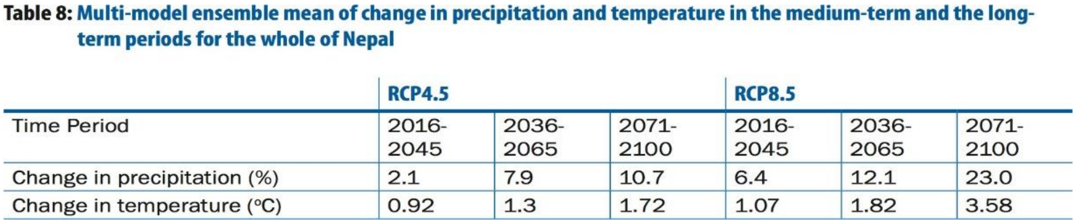


Table 8: Multi-model ensemble mean of change in precipitation and temperature in the medium-term and the long-term periods for the whole of Nepal

	RCP4.5			RCP8.5		
Time Period	2016-2045	2036-2065	2071-2100	2016-2045	2036-2065	2071-2100
Change in precipitation (%)	2.1	7.9	10.7	6.4	12.1	23.0
Change in temperature (°C)	0.92	1.3	1.72	1.07	1.82	3.58

Source: climate change scenarios for Nepal, NAP 2019

2.7.Shared Socioeconomic Pathways

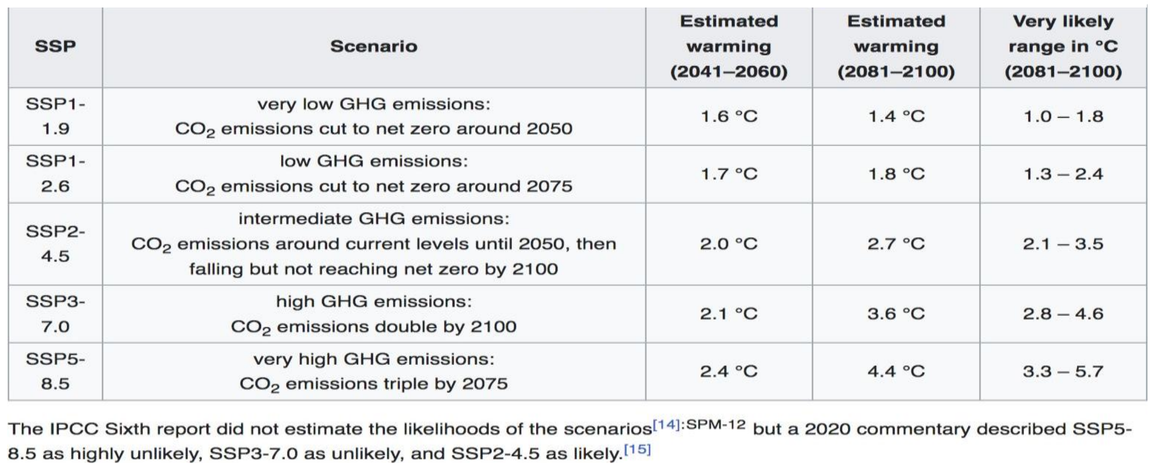
SSPs, or shared socioeconomic pathways, represent scenarios of anticipated global socioeconomic shifts through the year 2100. They are employed in generating scenarios of greenhouse gas emissions under various climate policies.

The scenarios are:

- SSP1: Sustainability (Taking the Green Road)
- SSP2: Middle of the Road
- SSP3: Regional Rivalry (A Rocky Road)
- SSP4: Inequality (A Road divided)
- SSP5: Fossil-fuelled Development (Taking the Highway)

The IPCC Sixth Assessment Report on Climate Change, which was released on August 9, 2021, was produced in part with their assistance.

Table 2 Shared Socioeconomic Pathways in the IPCC Sixth Assessment Report



SSP	Scenario	Estimated warming (2041–2060)	Estimated warming (2081–2100)	Very likely range in °C (2081–2100)
SSP1-1.9	very low GHG emissions: CO_2 emissions cut to net zero around 2050	1.6 °C	1.4 °C	1.0 – 1.8
SSP1-2.6	low GHG emissions: CO_2 emissions cut to net zero around 2075	1.7 °C	1.8 °C	1.3 – 2.4
SSP2-4.5	intermediate GHG emissions: CO_2 emissions around current levels until 2050, then falling but not reaching net zero by 2100	2.0 °C	2.7 °C	2.1 – 3.5
SSP3-7.0	high GHG emissions: CO_2 emissions double by 2100	2.1 °C	3.6 °C	2.8 – 4.6
SSP5-8.5	very high GHG emissions: CO_2 emissions triple by 2075	2.4 °C	4.4 °C	3.3 – 5.7

The IPCC Sixth report did not estimate the likelihoods of the scenarios[14]:SPM-12 but a 2020 commentary described SSP5-8.5 as highly unlikely, SSP3-7.0 as unlikely, and SSP2-4.5 as likely.[15]

Source:Shared Socioeconomic Pathways in IPCC Sixth Assessment Report

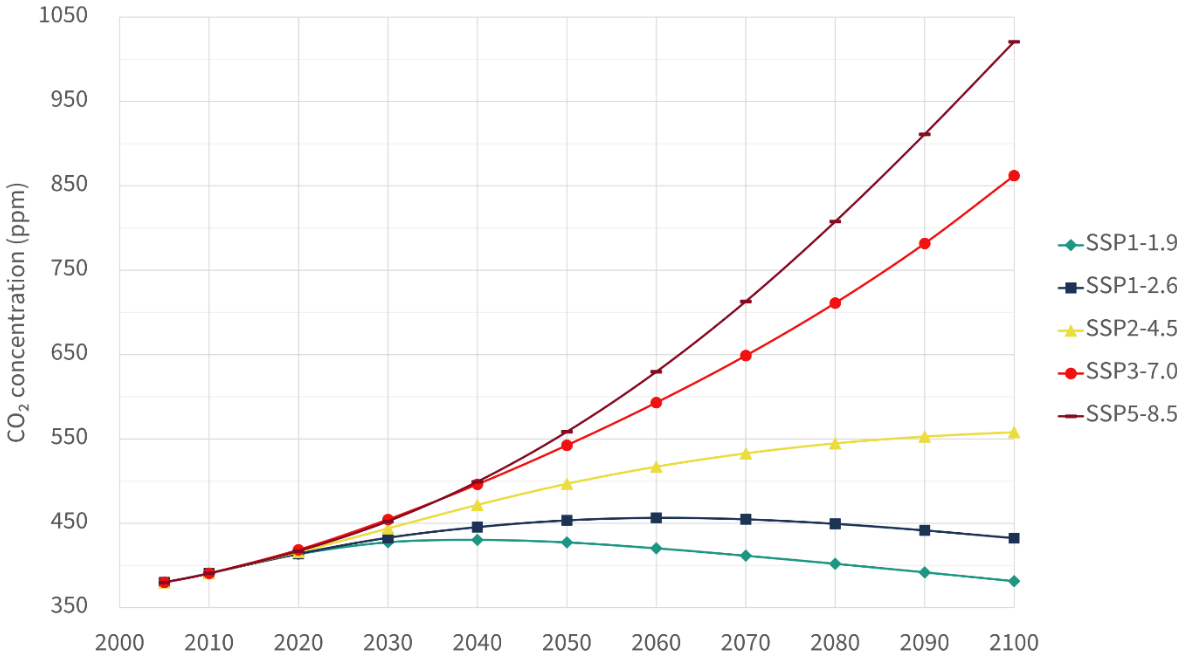


Figure 9 Concentration of CO2 from 2000 - 2100

Source www.wikipedia.org

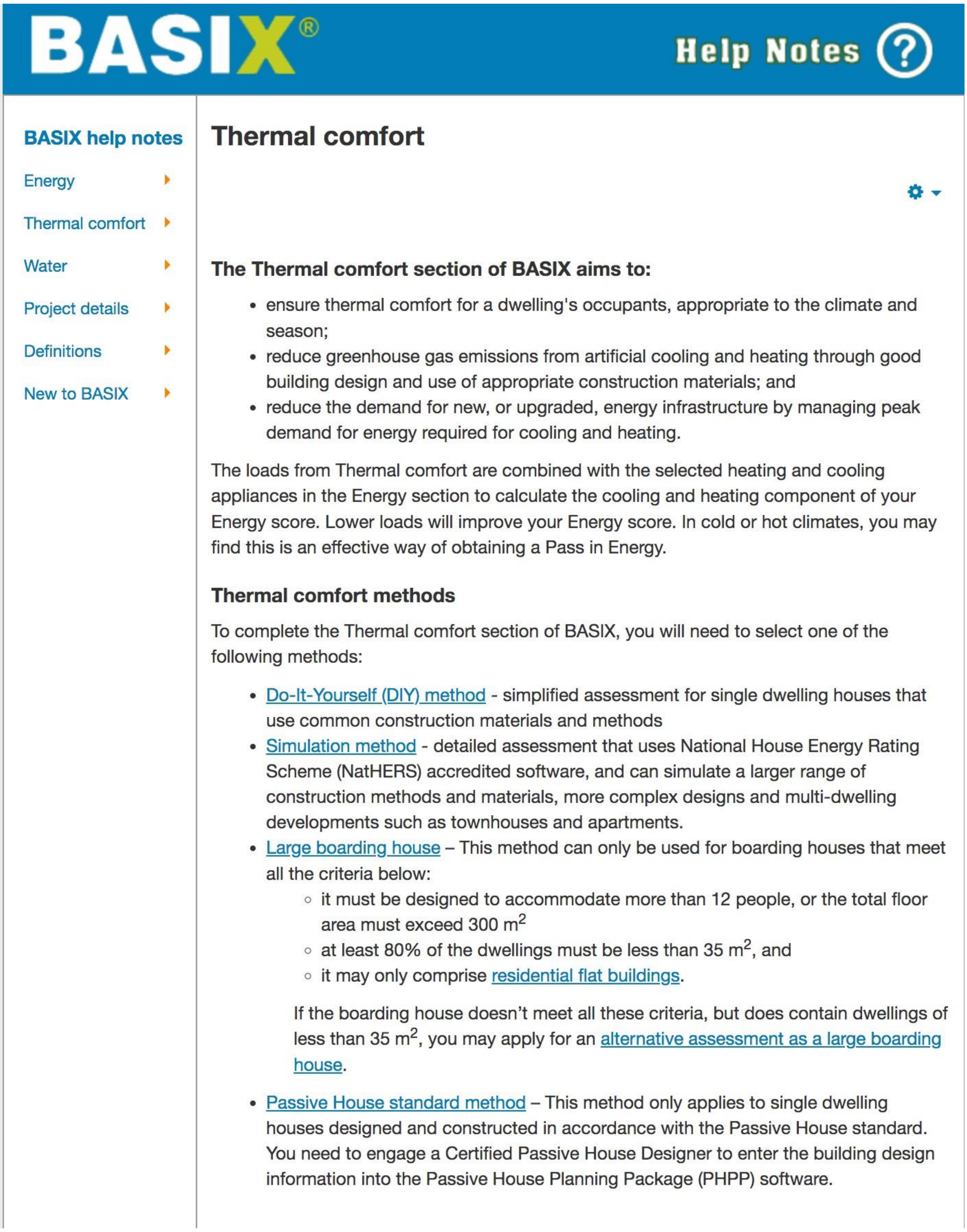
2.8.BASIX

Across the state, the Building Sustainability Index (BASIX) seeks to provide fair and efficient water and greenhouse gas reductions. One of the most effective sustainable planning initiatives in Australia is BASIX.

Under the Environmental Planning and Assessment Act, BASIX is implemented as an integrated part of the planning system. BASIX is a component of the NSW development application process that is applicable to all types of residential dwellings.

BASIX is assessed online using the BASIX assessment tool. The tool compares a proposed design's components to sustainability goals.

Homes in NSW use less water and energy thanks to BASIX. In addition to saving the homeowner money over time, these environmental benefits also make a significant contribution to our communities' sustainable future.



Thermal comfort

The Thermal comfort section of BASIX aims to:

- ensure thermal comfort for a dwelling's occupants, appropriate to the climate and season;
- reduce greenhouse gas emissions from artificial cooling and heating through good building design and use of appropriate construction materials; and
- reduce the demand for new, or upgraded, energy infrastructure by managing peak demand for energy required for cooling and heating.

The loads from Thermal comfort are combined with the selected heating and cooling appliances in the Energy section to calculate the cooling and heating component of your Energy score. Lower loads will improve your Energy score. In cold or hot climates, you may find this is an effective way of obtaining a Pass in Energy.

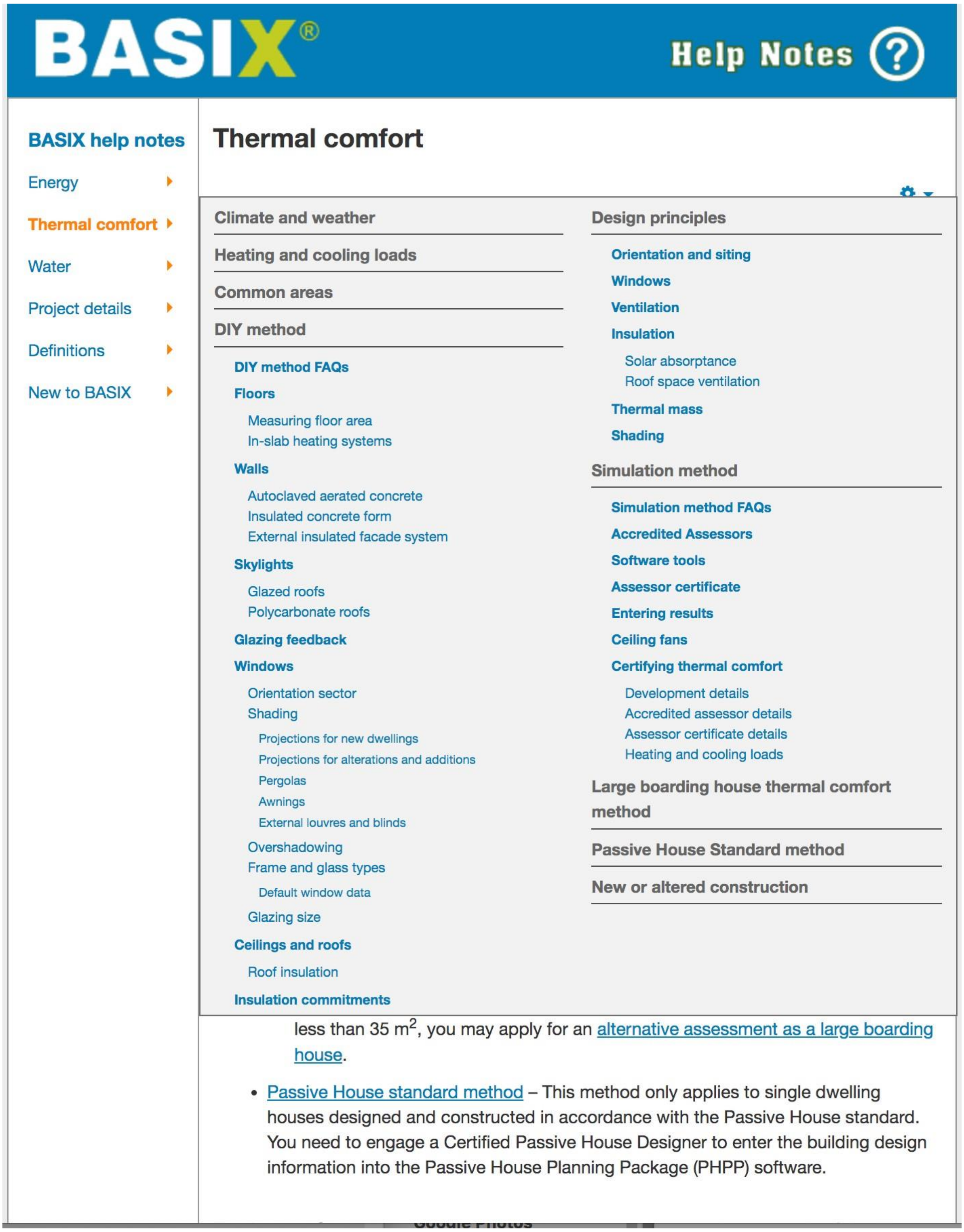
Thermal comfort methods

To complete the Thermal comfort section of BASIX, you will need to select one of the following methods:

- Do-It-Yourself (DIY) method - simplified assessment for single dwelling houses that use common construction materials and methods
- Simulation method - detailed assessment that uses National House Energy Rating Scheme (NatHERS) accredited software, and can simulate a larger range of construction methods and materials, more complex designs and multi-dwelling developments such as townhouses and apartments.
- Large boarding house – This method can only be used for boarding houses that meet all the criteria below:
  - it must be designed to accommodate more than 12 people, or the total floor area must exceed 300 m^2
  - at least 80% of the dwellings must be less than 35 m^2, and
  - it may only comprise residential flat buildings.

  If the boarding house doesn’t meet all these criteria, but does contain dwellings of less than 35 m^2, you may apply for an alternative assessment as a large boarding house.

- Passive House standard method – This method only applies to single dwelling houses designed and constructed in accordance with the Passive House standard. You need to engage a Certified Passive House Designer to enter the building design information into the Passive House Planning Package (PHPP) software.



BASIX help notes

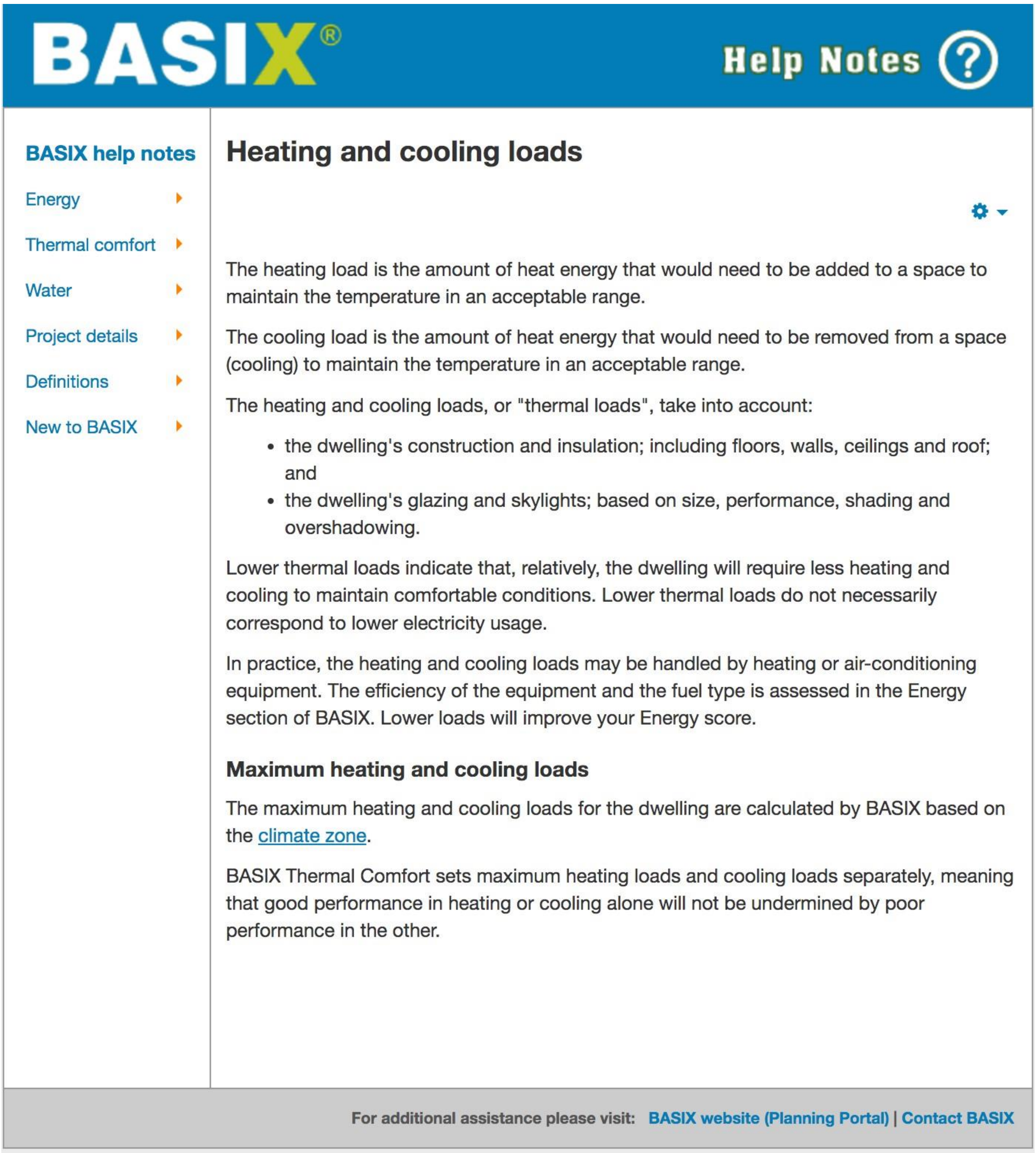
- Energy
- Thermal comfort
- Water
- Project details
- Definitions
- New to BASIX

Thermal comfort

- Climate and weather
- Heating and cooling loads
- Common areas
- DIY method
  - DIY method FAQs
  - Floors
    - Measuring floor area
    - In-slab heating systems
  - Walls
    - Autoclaved aerated concrete
    - Insulated concrete form
    - External insulated facade system
  - Skylights
    - Glazed roofs
    - Polycarbonate roofs
  - Glazing feedback
  - Windows
    - Orientation sector
    - Shading
      - Projections for new dwellings
      - Projections for alterations and additions
      - Pergolas
      - Awnings
      - External louvres and blinds
    - Overshadowing
    - Frame and glass types
      - Default window data
    - Glazing size
  - Ceilings and roofs
    - Roof insulation
  - Insulation commitments
- Design principles
  - Orientation and siting
  - Windows
  - Ventilation
  - Insulation
    - Solar absorptance
    - Roof space ventilation
  - Thermal mass
  - Shading
- Simulation method
  - Simulation method FAQs
  - Accredited Assessors
  - Software tools
  - Assessor certificate
  - Entering results
  - Ceiling fans
  - Certifying thermal comfort
    - Development details
    - Accredited assessor details
    - Assessor certificate details
    - Heating and cooling loads
- Large boarding house thermal comfort method
- Passive House Standard method
- New or altered construction

less than 35 m^2, you may apply for an alternative assessment as a large boarding house.

- Passive House standard method – This method only applies to single dwelling houses designed and constructed in accordance with the Passive House standard. You need to engage a Certified Passive House Designer to enter the building design information into the Passive House Planning Package (PHPP) software.



Heating and cooling loads

The heating load is the amount of heat energy that would need to be added to a space to maintain the temperature in an acceptable range.

The cooling load is the amount of heat energy that would need to be removed from a space (cooling) to maintain the temperature in an acceptable range.

The heating and cooling loads, or "thermal loads", take into account:

- the dwelling's construction and insulation; including floors, walls, ceilings and roof; and
- the dwelling's glazing and skylights; based on size, performance, shading and overshadowing.

Lower thermal loads indicate that, relatively, the dwelling will require less heating and cooling to maintain comfortable conditions. Lower thermal loads do not necessarily correspond to lower electricity usage.

In practice, the heating and cooling loads may be handled by heating or air-conditioning equipment. The efficiency of the equipment and the fuel type is assessed in the Energy section of BASIX. Lower loads will improve your Energy score.

Maximum heating and cooling loads

The maximum heating and cooling loads for the dwelling are calculated by BASIX based on the climate zone.

BASIX Thermal Comfort sets maximum heating loads and cooling loads separately, meaning that good performance in heating or cooling alone will not be undermined by poor performance in the other.

For additional assistance please visit: BASIX website (Planning Portal) | Contact BASIX

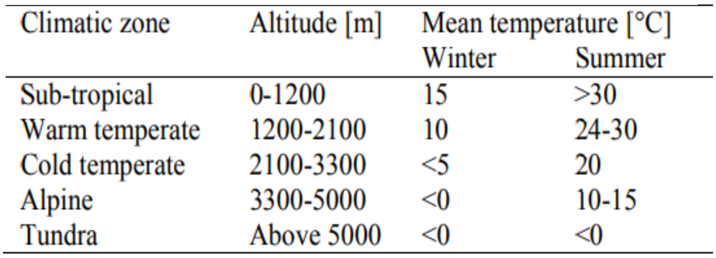
2.9.Comfort analysis in Nepal

Nepal's varied topography contributes to its wide range of climates (CBS 2014a). The Terai region, located in the country's tropical south, has a warm, humid subtropical climate. With the exception of the chilly winter evenings, the mid-land regions enjoy a temperate climate. The alpine to arctic tundra climate of the northern mountain regions is characterized by extremely low mean temperatures. In Nepal, there are two or four distinct seasons. Winter and summer are the two main seasons, with a wet and dry period in the summer according to Shrestha's 2007 definition.

Summer lasts from April to September, and winter lasts from October to March. Other states that the four main seasons in Nepal are winter from December to February, autumn from September to November, summer from June to August, and spring from March to May (CBS 2014a). Before the monsoon arrives, spring is a gloomy season with sporadic showers and steadily rising temperatures. The Terai region, the midland region, and the lower Himalayan regions receive the majority of the rains that the monsoon brings with it from India during the summer. Clear skies and comfortable temperatures are hallmarks of autumn. While the subtropical regions experience year-round warmth, the midland regions typically experience lower temperatures and higher altitudes during winter.

Nepal's climate varies greatly, ranging from a hot subtropical environment to a frigid tundra. The country's climate is influenced by various geographical factors, including vegetation, latitude, altitude, slope orientation, and both prevailing and local winds. (S. Bodach, 2016). In the Terai (southern Nepal), summer temperature exceeds 40degree Celsius and above 45 degrees Celsius in some areas, while winter temperature ranges from 7-23 degree Celsius. Located south of the Sivalik Hills and north of the Indo-Gangetic Plain, the Terai, also known as the Tarai, is a lowland area in northern India and southern Nepal. This lowland belt is characterized by tall grasslands, scrub savannah, sal forests, and clay-rich swamps. The Terai region of northern India stretches eastward from the Yamuna River, encompassing the states of West Bengal, Uttarakhand, Uttar Pradesh, Bihar, and Haryana.

Table 3 Climatic Zones in Nepal



Climatic zone	Altitude [m]	Mean temperature [°C]	
		Winter	Summer
Sub-tropical	0-1200	15	>30
Warm temperate	1200-2100	10	24-30
Cold temperate	2100-3300	<5	20
Alpine	3300-5000	<0	10-15
Tundra	Above 5000	<0	<0

2.10. Climate of Nepal

In the south of Nepal, summers are hot and winters are mild to cold, but in the north, summers are cool and winters are severe. The five seasons in Nepal are spring, summer, monsoon, autumn, and winter.

While winter temperatures in the Terai (southern Nepal) range from 7°C to 23°C, summer temperatures there often surpass 40°C and even 45°C in certain places. Summers in hilly areas are moderate, but winter lows can reach below zero in valleys and hills. The average summer temperature in the Kathmandu Valley is between 20°C and 35°C, while the average winter temperature is between 2°C and 12°C. In Nepal, the average temperature decreases by 6°C for every 1,000 meters of altitude gain.

The Himalayas serve as both the northern limit of the monsoon rains and a shield against the chilly winds that originate in Central Asia during the winter. Certain locations, such as Manang and Mustang, are primarily dry because they are shaded by the mountains from the rain. In Nepal, the monsoon season (June through September) accounts for 80% of the country's annual precipitation. The western hills experience more intense winter rains. Rainfall varies by ecoclimatic zone, with an average of 1,600 mm in Pokhara and less than 300 mm in Mustang.

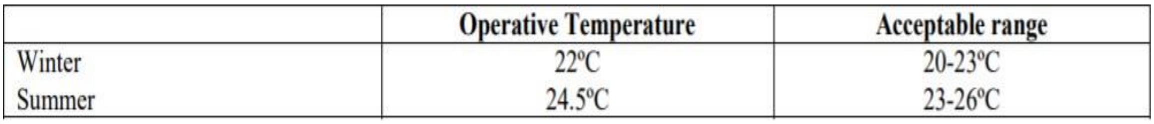
2.11. Thermal comfort

Thermal comfort has a major influence on health and safety and is one of the primary considerations in the artificial climate design process within the building. According to certain studies, there is a direct correlation between the cause of certain morbidities and the ambient temperature. In addition to being influenced by sociodemographic and pollution factors, the lag effect of hot temperatures on morbidity was less than that of cold temperatures. There is sufficient research to conclude that heat and cold waves are linked to mortality (Ye et al., 2012). There is a link between heat exposure and a higher risk of respiratory, cardiovascular, and cerebrovascular death. Young people and the elderly were more susceptible to cold-induced cardiovascular morbidity (Songet et al., 2017).

As a thermally comfortable range for humans, the ASHRAE Standard 55-2004 suggests 20°C to 24°C in the winter and 24°C to 26°C in the summer, with an indoor air relative humidity of 50%.

The state of mind that conveys satisfaction with the thermal environment is known as thermal comfort (ANSI/ASHRAE 55 Standard-2000R (2001)). The primary factors determining thermal comfort for the human body in its entirety are classified as personal factors such as clothing and metabolic rate (activity) and environmental factors such as air temperature, humidity, mean radiant temperature, and air velocity. Other environmental factors that can lead to localized heat discomfort include radiant temperature asymmetry, warm or cold floors, draughts, and a high vertical temperature differential between the head and feet.

Table 4 ASHRAE Standard recommendations.



	Operative Temperature	Acceptable range
Winter	22°C	20-23°C
Summer	24.5°C	23-26°C

2.12. Ecotect simulation

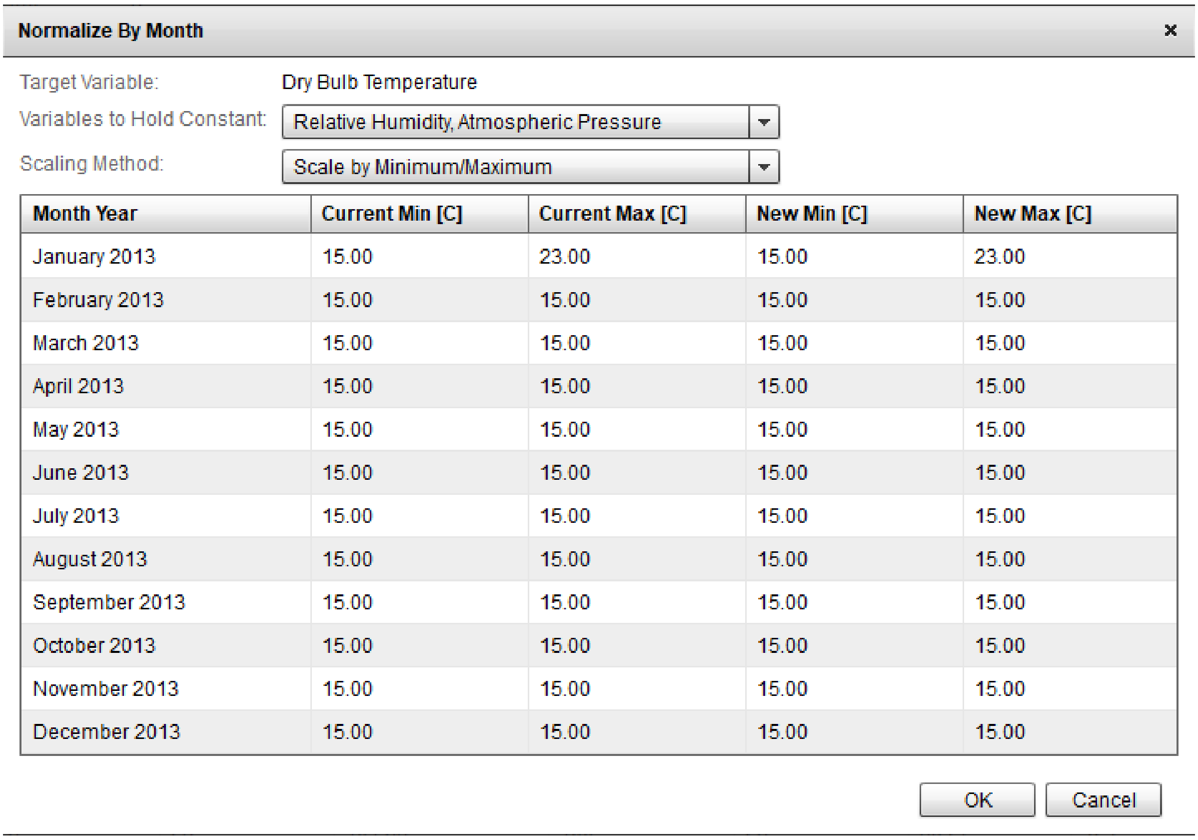
Autodesk Ecotect Analysis is a building environment analysis tool that allows designers to simulate building performance while designing a building. It analyses and interacts with the building function. It gives the option to choose various materials and finishes to the building with varying properties.

2.13. Elements

A cross-platform, free, open-source program called Elements can be used to create and modify unique weather files for building energy modeling. The project's objective is to create a complete, integrated application that can manage every routine task related to weather files.

Accurate energy consumption assessments in building energy simulation necessitate site-specific meteorological data. There are many different sources of weather data, but building energy modelers frequently need to verify the accuracy of the data and modify the weather file for different uses, like applying weather data from a nearby site to a site that lacks weather data. Different energy modelers approach this task in different ways, which leads to the re-implementation of different strategies in numerous Excel spreadsheets, script files, etc.

Elements seeks to create a single, useful tool that does all of the work involved in browsing and processing weather data files. Elements facilitate the visualization and manipulation of meteorological data loaded from multiple file formats, allowing for the conversion of meteorological data between different formats. Since weather is the primary driving force behind all building models, annual weather data is an essential component of building energy modeling. Typically, the energy modeler will look for a suitable weather file for the planned building location before starting to build the building model. Finding the accurate weather file is frequently a simple task. Thousands of weather data files covering numerous global cities are currently accessible. You can download a lot of these files for free from the internet. For a fair price, you can now purchase a weather file from certain internet services.



Target Variable: Dry Bulb Temperature

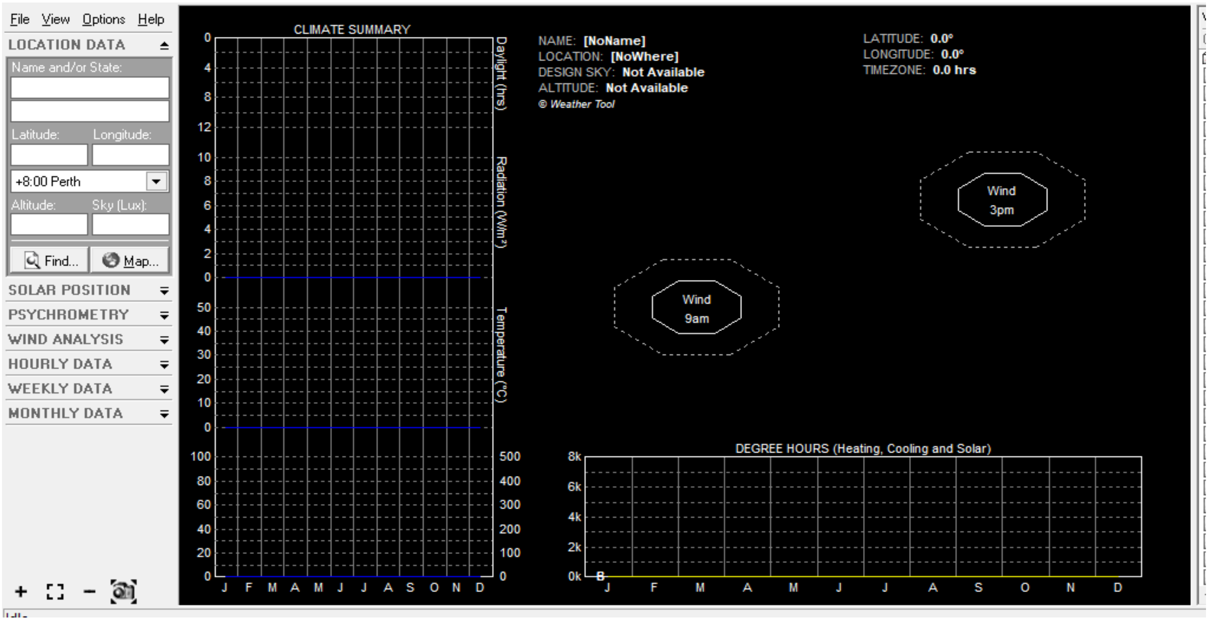
Variables to Hold Constant: Relative Humidity, Atmospheric Pressure

Scaling Method: Scale by Minimum/Maximum

Month Year	Current Min [C]	Current Max [C]	New Min [C]	New Max [C]
January 2013	15.00	23.00	15.00	23.00
February 2013	15.00	15.00	15.00	15.00
March 2013	15.00	15.00	15.00	15.00
April 2013	15.00	15.00	15.00	15.00
May 2013	15.00	15.00	15.00	15.00
June 2013	15.00	15.00	15.00	15.00
July 2013	15.00	15.00	15.00	15.00
August 2013	15.00	15.00	15.00	15.00
September 2013	15.00	15.00	15.00	15.00
October 2013	15.00	15.00	15.00	15.00
November 2013	15.00	15.00	15.00	15.00
December 2013	15.00	15.00	15.00	15.00

2.14. Weather Tool

Convert TMY or EPW weather files into WEA format for Ecotect Analysis



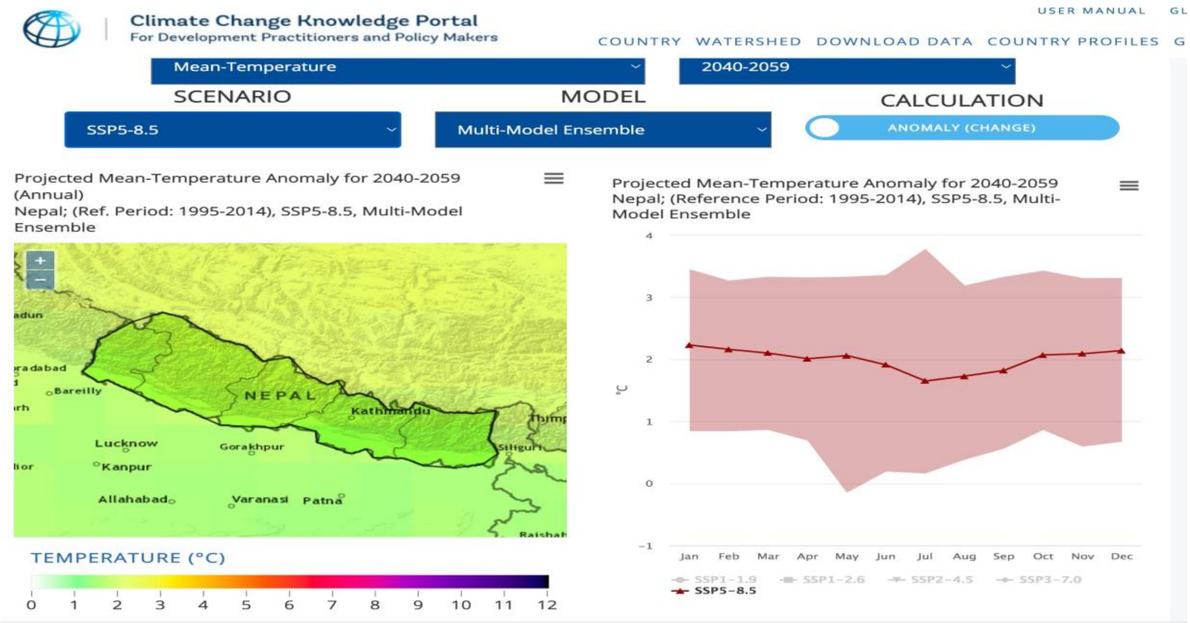
+8:00 Perth

NAME: **[NoName]**
LOCATION: **[NoWhere]**
DESIGN SKY: **Not Available**
ALTITUDE: **Not Available**
© Weather Tool

LATITUDE: **0.0°**
LONGITUDE: **0.0°**
TIMEZONE: **0.0 hrs**

2.15. Climate change knowledge portal

Global information about past, present, and future climate, vulnerabilities, and impacts is available through the Climate Change Knowledge Portal (CCKP). Use the Country and Watershed views to investigate them. See the compiled Country Profiles for more in-depth information on climate risk and adaptation strategies.



Mean-Temperature
2040-2059
SCENARIO: SSP5-8.5
MODEL: Multi-Model Ensemble
CALCULATION: ANOMALY (CHANGE)

Projected Mean-Temperature Anomaly for 2040-2059 (Annual)
Nepal; (Ref. Period: 1995-2014), SSP5-8.5, Multi-Model Ensemble

Projected Mean-Temperature Anomaly for 2040-2059
Nepal; (Reference Period: 1995-2014), SSP5-8.5, Multi-Model Ensemble

CHAPTER THREE: RESEARCH METHODOLOGY

The study method was designed in order to assess microclimate of urban areas. For this, the research site was selected, and sampling procedure was formulated along with the site measurement and measure drawings. This also included sample size, sampling technique identification, data sources, survey design and data collection methodology, and data analysis methods and techniques. The other qualitative and quantitative measurements were also done.

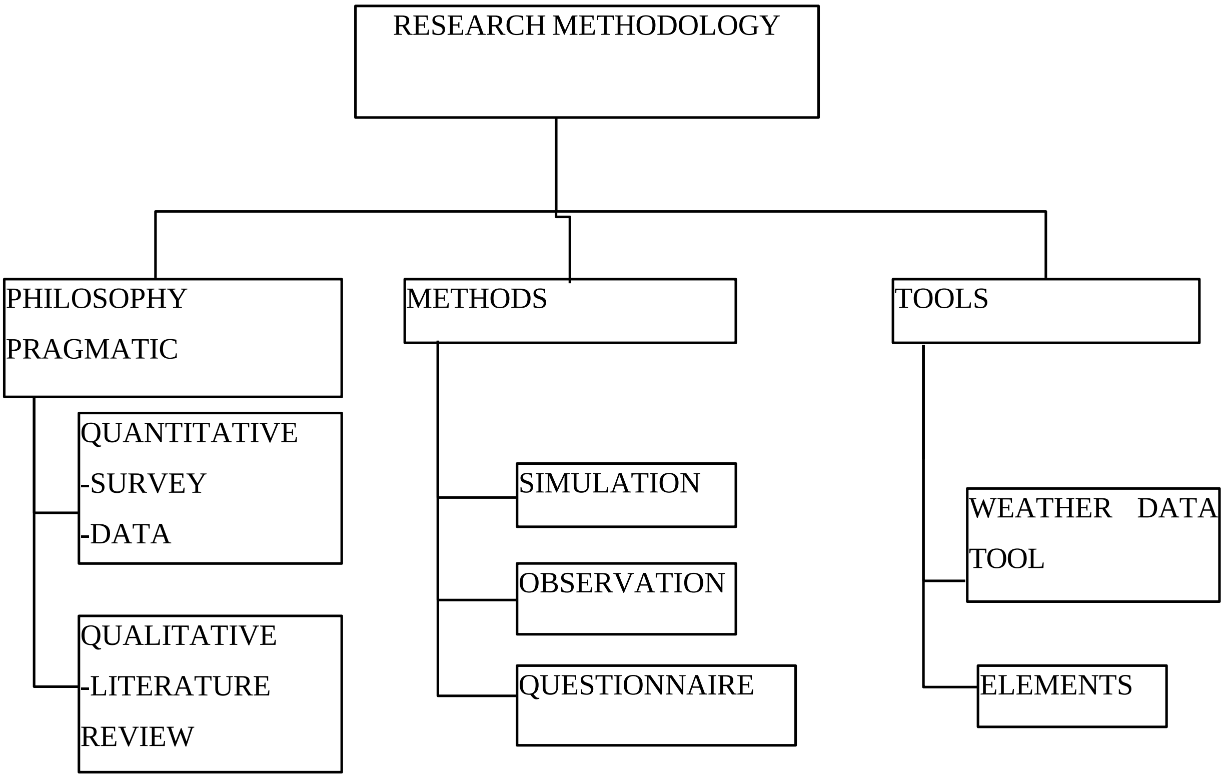


Figure 10 Research Methodology

3.1.Conceptual Framework of research

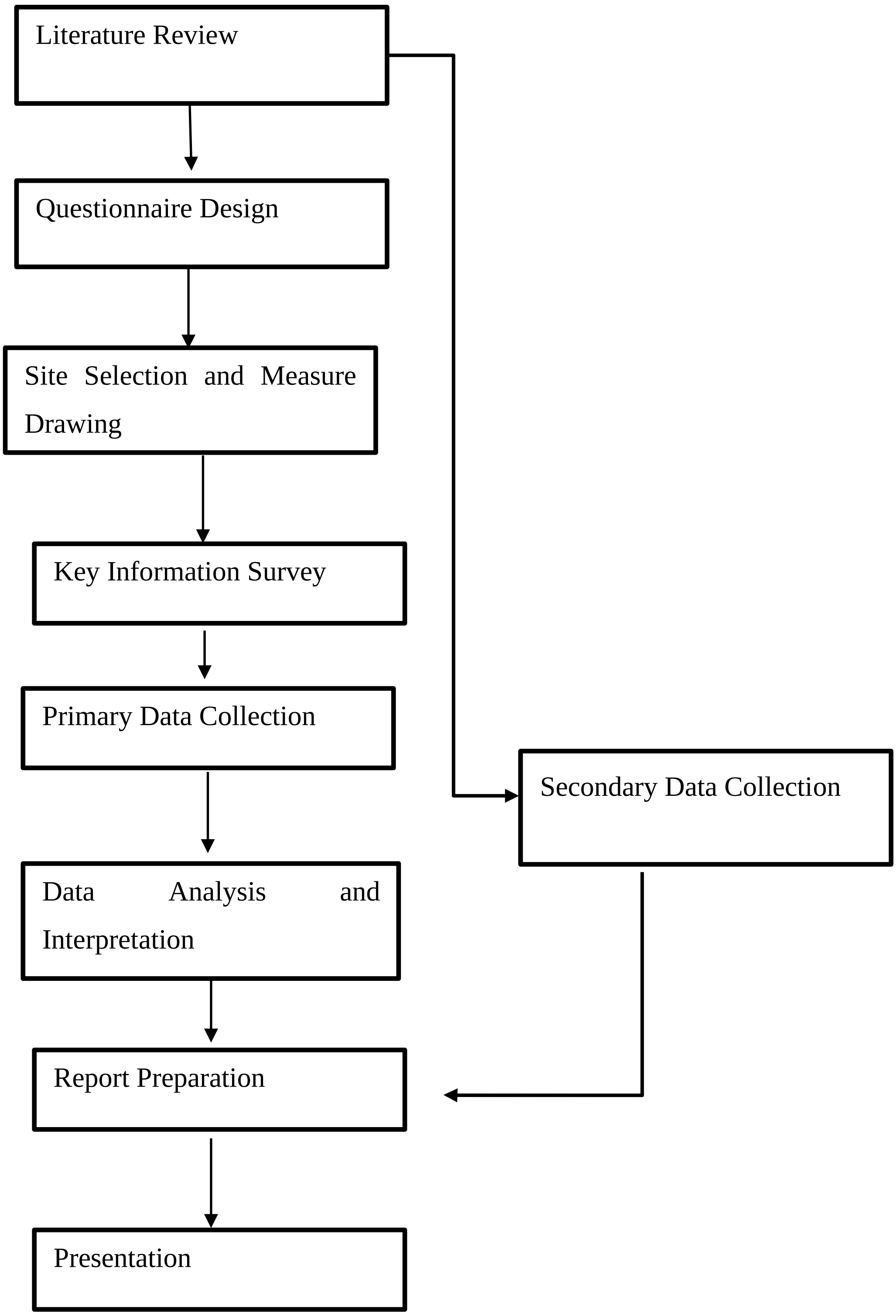


Figure 11 Conceptual framework for research

3.2. Research site

According to the 2021 census, Lalitpur Metropolitan is the fourth most populous metropolitan area in Nepal, home to 299,843 people living in 49, 044 households. At an elevation of 1,400 meters (4,600 feet), it is situated in the south-central portion of the Kathmandu Valley, a sizable valley in the high plateaus of central Nepal.

About 350 years old, Newa Chen is a traditional Newari home that has been renovated as part of a UNESCO project to serve as a tourist destination. It gives people an opportunity to encounter traditional Newari values and way of life, which are distinct from those of the contemporary, materialistic world. The property was recognized by UNESCO as one of Patan's most exquisite and well-preserved private homes.

The Research area is focused on the courtyard-house of Kathmandu Valley. Residential Courtyard Block of Patan City of Devendra Shrestha (House Owner) is analyzed for the pattern of courtyard and layout design which includes field measurement. *"This house reminds me of my ancestry and childhood days. These walls have not only survived the 2015 earthquake but the earthquake of 1934 as well. This building is a living example of our rich heritage ":Devendra Shrestha for My Republica.*

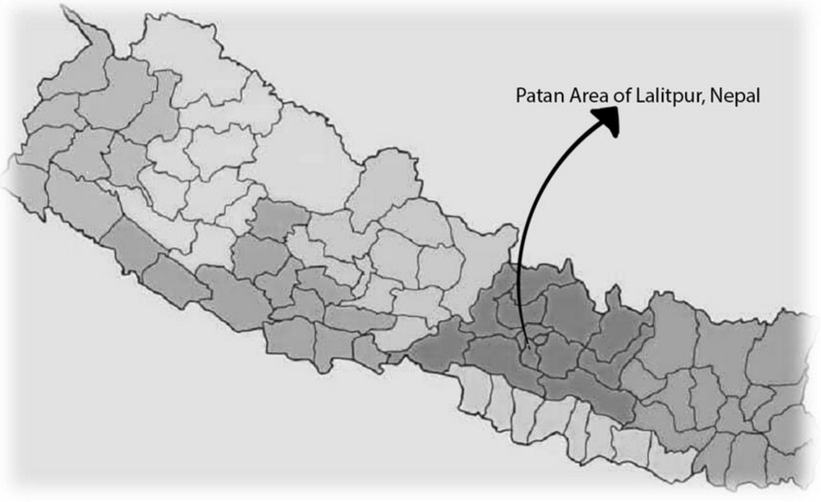


Figure 12 Map of the Research site.

Source: Survey Department, GoM, 2020

Residential Courtyard Block of Patan City of Devendra Shrestha (House Owner) will be analyzed for the pattern of courtyard and layout design which includes field measurement.

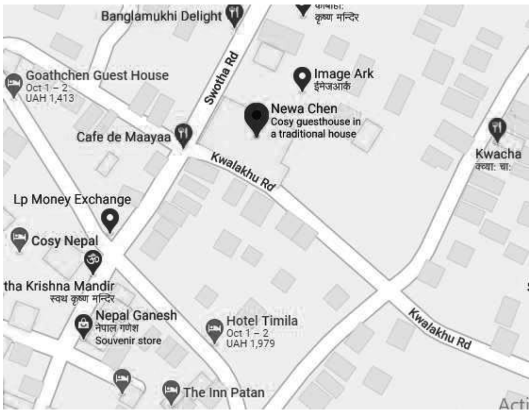


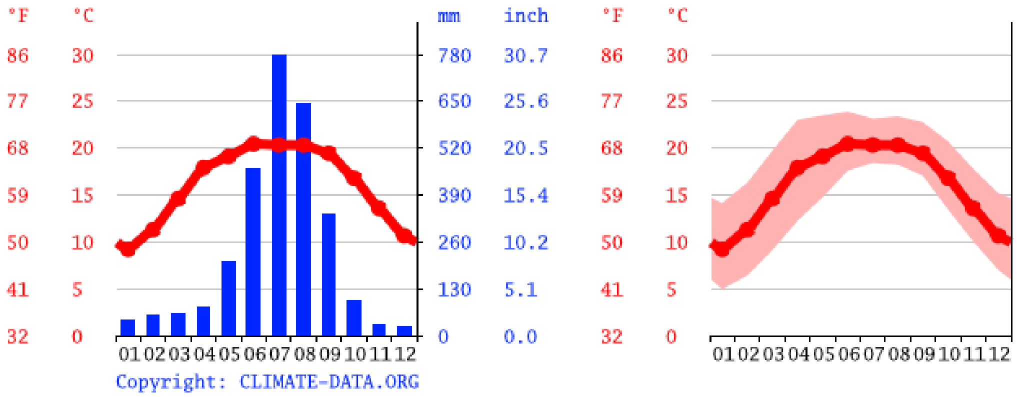
Figure 13 Location of Research site

Figure 14 Newa Chen

3.3. Study area-courtyard- newa chen

Courtyard is with humid subtropical climates which results in temperate summers and dry winters. The average annual temperature (winter) -18.3 degree. The significant change in day and night temperature is 3 to -7.7 degree Celsius. The summer temperatures varies from 27.3 to 11 degrees. Spring and autumn temperature is more or less the same with temperatures ranging from 27.3 to 11 and from 26 to 12.3 degree Celsius. The average precipitation is 1343 mm and average sunshine is 2556 hours per/year (Adam Peterson, 2018, Nov 01; Köppen-Geiger classification, 2019).

3.4. Climatic condition



Copyright: CLIMATE-DATA.ORG

Figure 15 Temperature Data

Patan, located at 28°23'50.50" N and 84°07'32.74" E, was the study's location. This region has a warm, temperate climate. Summertime rainfall in Patan is greater than wintertime rainfall. According to the Köppen-Geiger classification, this area's current weather is classified as Cwb. Based on available data, the average annual temperature in Patan is 16.1 °C, or 61.1 °F. An annual total of 2812 mm or 110.7 in of rainfall is experienced.

This area experiences a temperate, mild climate that is typically warm. Lalitpur experiences significantly more winter rainfall than summer rainfall. The Köppen-Geiger classification places the current climate in this area under the Csa category. Based on statistical analysis, the temperature at this location is approximately 25.3 °C | 77.5 °F. Here, there is roughly 953 mm (37.5 in) of precipitation annually. The summers in Lalitpur are ill-defined, and the city has a moderate climate. March, September, October, and November are the best months.

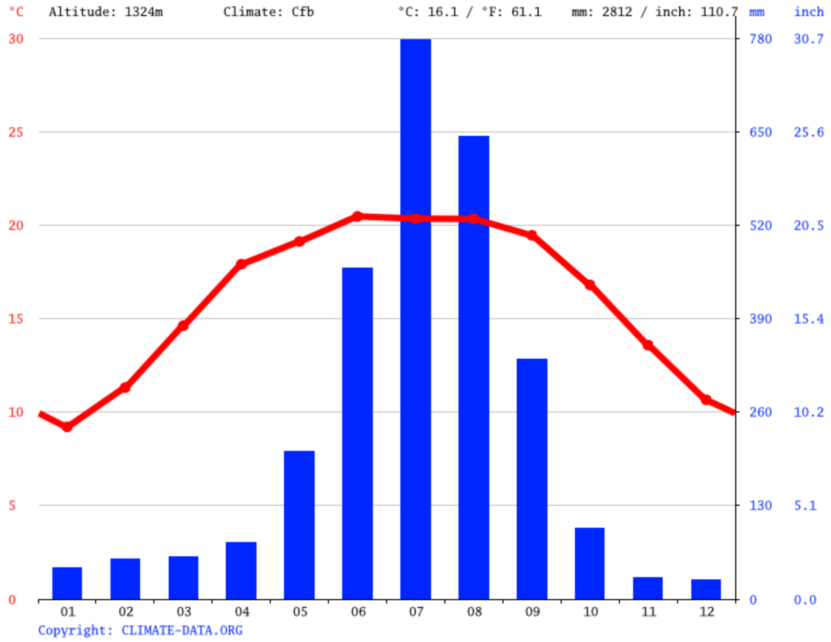


Figure 16 Temperature and precipitation data

The amount of precipitation drops to just 26 mm | 1.0 inch in December. It is officially the driest month of the year. July typically receives the most rainfall, with a mean value of 778 mm (30.6 in).

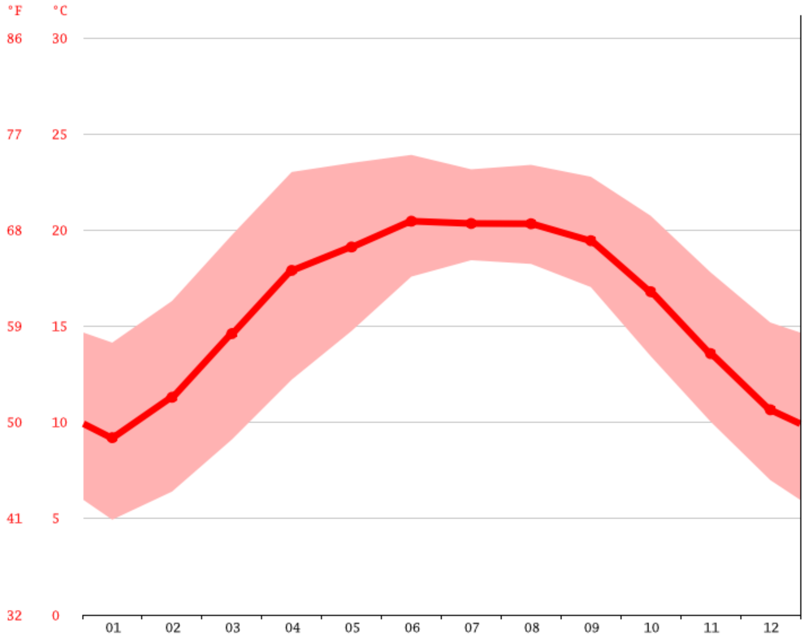
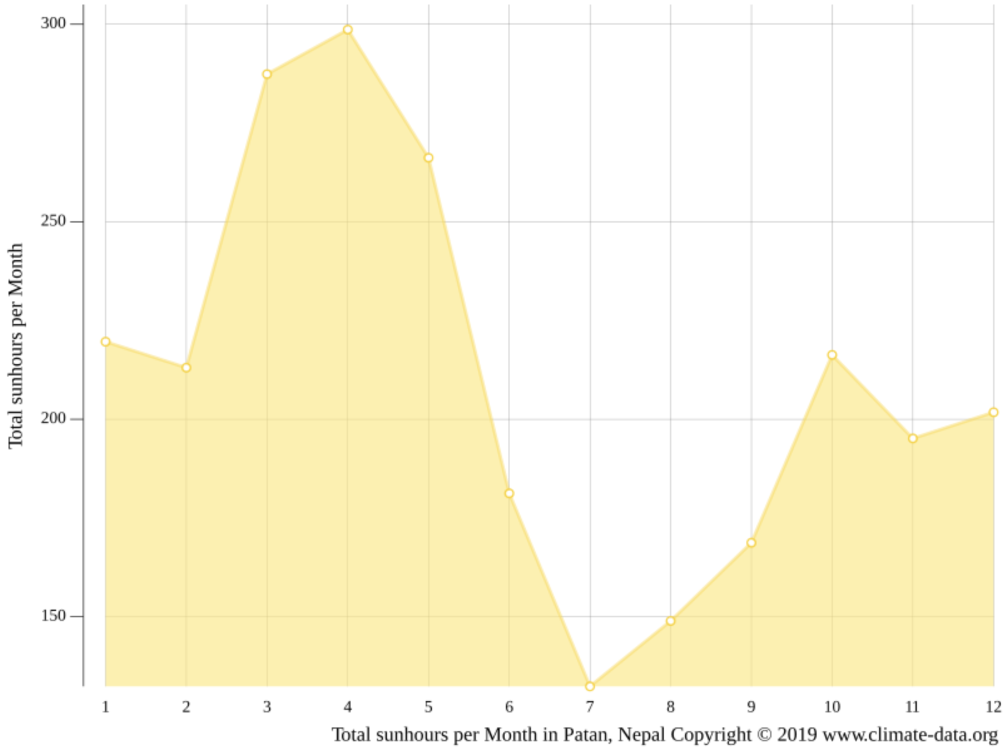


Figure 17 Temperature data

The month of highest temperature is June during which the average temperature reaches up to 20.5 °C | 68.8 °F. On average, the month of January is considered to be the coldest time of year with temperatures averaging at around 9.2 °C | 48.6 °F.

The precipitation variance between the months with the lowest and highest levels of rainfall is 752 mm | 30 inch. The fluctuation of temperatures across the seasons is referred to as 11.3 °C | 20.3 °F. July has the highest relative humidity of any month at 54.28 percent. April has the lowest relative humidity of any month at 54.28%. July records the most days with rainfall (28.97 days), while December records the fewest days with precipitation (4.87).



Total sunhours per Month in Patan, Nepal Copyright © 2019 www.climate-data.org

Figure 18 Sunhours temperature data

In the region of Patan, it has been observed that April is the month which experiences maximum daily sunshine hours, with an average duration of approximately 9.95. The total number of sunlit hours during this period amounts to a staggering sum of about 298.63. The location of Patan experiences the least amount of daily sunshine hours during January, with an average duration of only 4.27. This month, there were 132.38 hours of sunshine overall that were recorded.

It is estimated that Patan experiences 2529.35 hours of sunshine on average per year. This corresponds to an approximately 83.24 hour monthly average, on a consistent basis.

3.5.Analysis

This involves measuring the temperature in a courtyard with 75% vegetation, 25% vegetation, and no vegetation. This study aims to assess the effect of this vegetation on the courtyard's air temperature. Our expected findings might be that Courtyard with 75% Vegetation will be cooler than that of Courtyard with 25% Vegetation. Also, Courtyard with 25% vegetation might be cooler than Courtyard with no Vegetation. Courtyard is analyzed with the scenarios of Vegetation.

- With no vegetation
- With 25% of Vegetation
- With 75% of Vegetation

Wall of Newa Chen is subjected with different sets of vegetation; Temperature within building is then measured to analyze the effect of vegetation in the wall. This measurement is taken as an average of month and the final data is studied to take the outcomes of the study.Field measurement and measure drawing is done. The justification for selecting Newa Chen is because of the significance of that Newari vernacular architecture and also to study role of courtyard as temperature modifier.

3.6. Climate change prediction and its effect on annual heating and cooling effect in a courtyard

Table 5 Temperature of Patan 2021

Temp □c	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
min	1	1.4	2.3	9.3	11.3	15.4	20.2	19.4	16.5	10.9	6.8	2.3
max	23	27.1	28.8	31.3	31.5	30.1	31.2	31.9	29.8	31.1	27.5	26.1
average	10.8	12.9	16.6	21.0	22.5	23.8	24.0	23.9	22.8	20.5	15.2	12.2

Source: Department of Hydrology and Meteorology

Climate change scenario SSP5 has been used to determine the future climate for the years (2040-2059) and (2060-2079).

Table 6 Predicted Temperature of Patan (2040-2059) using climate change knowledge portal

Temp □c	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
min	3.98	4.13	5.1	12.05	13.84	17.66	22.16	21.38	18.87	13.41	9.56	5.21
max	26.22	29.9	31.4	33.52	33.46	31.86	32.86	33.9	31.88	33.47	30.21	29.27
average	13.76	15.58	19.28	23.5	24.7	26.09	26.06	26.04	24.97	23.04	17.83	15.04

Table 7 Predicted Temperature of Patan (2060-2079) using climate change knowledge portal

Temp □c	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
min	4.44	4.91	5.59	12.45	14.52	18.6	22.7	22.37	19.29	14.37	10.41	5.97
max	26.47	30.51	32.25	34.39	34.36	32.5	32	34.26	32.33	33.74	30.55	29.53
average	14.28	16.25	19.92	24.31	25.44	26.05	26.25	26.4	25.44	23.53	18.45	15.64

EPW (Energy Plus Weather Format) file of PAtan is edited using the Elements tool. Monthly maximum, minimum and average temperature from future scenario. is then inserted to produce weather file for (2040-2059) and (2060-2079)

With the help of weather data tool from ecotect, EWP file is changed to weather file.

The annual heating and cooling load is computed for the best case and least best-case scenarios using the weather files for 2040–2059 and 2060–2079. It is then compared with the current result and the conclusion is made.

3.7.Study area

The study was conducted in Patan (28°23'50.50" N 84°07'32.74" EThis region is known for its warm, temperate climate. Summertime rainfall in Patan is greater than wintertime rainfall. According to the Köppen-Geiger classification, this area's current weather is classified as Cwb. Based on available data, the average annual temperature in Patan is 16.1 °C, or 61.1 °F. An annual total of 2812 mm or 110.7 in of rainfall is experienced.

This area experiences a temperate, mild climate that is typically warm. Lalitpur experiences significantly more winter rainfall than summer rainfall. The Köppen-Geiger classification places the current climate in this area under the Csa category. Based on statistical analysis, the temperature at this location is approximately 25.3 °C | 77.5 °F. Here, there is roughly 953 mm (37.5 in) of precipitation annually. The summers in Lalitpur are ill-defined, and the city has a moderate climate. March, September, October, and November are the best months.

3.8.Selection of courtyard to be studied

The research is carried out in residential Courtyard Block of Patan City of Devendra Shrestha (House Owner) will be analyzed for the pattern of courtyard and layout design which includes field measurement.

3.8.1. Courtyard Description

- Location: Patan, 150m from Durbar Square
- Type: social enterprise
- Site Plan: Flexible site plan for all type designs

This building used as hotels during the measurement and occupied by some group of tourist.

- Size of courtyard (12.6 x10.4) m
- Floor area=368.10 sq m
- Two way slope roof profile
- Total floor area=1104.3 sq m
- Total site area=515 sq m

3.8.2. Features:

- Openings on East, North and South facade
- Ideology at center of courtyard
- U type courtyard planning
- Wall outside dachi-appa and sun dried inside with mud mortar
- Floors: traditional timber floor with mud motar
- Door and windows: wooden
- Roof: red burnt tiles
- 3 storey building

Table 8 Features of Site

Element	Description	Details
External walls	Total area: - Room area :60sq.ft Wall thickness: 16” Insulation:	sun dried and burnt clay bricks and between 70cm thickness
Roof	Total area: sq.ft thickness: 7" tiles Insulation: no	125 mm red burnt tiles
Floor	Ground floor area: sq.ft First floor area: sq.ft Room floor area: sq.ft Description:	Terracotta finishing
Windows	Total window area = sq.ft No of win in a selected room= no window area= 54 sq.ft	Central sahn jhya
Room Height	2.3m	

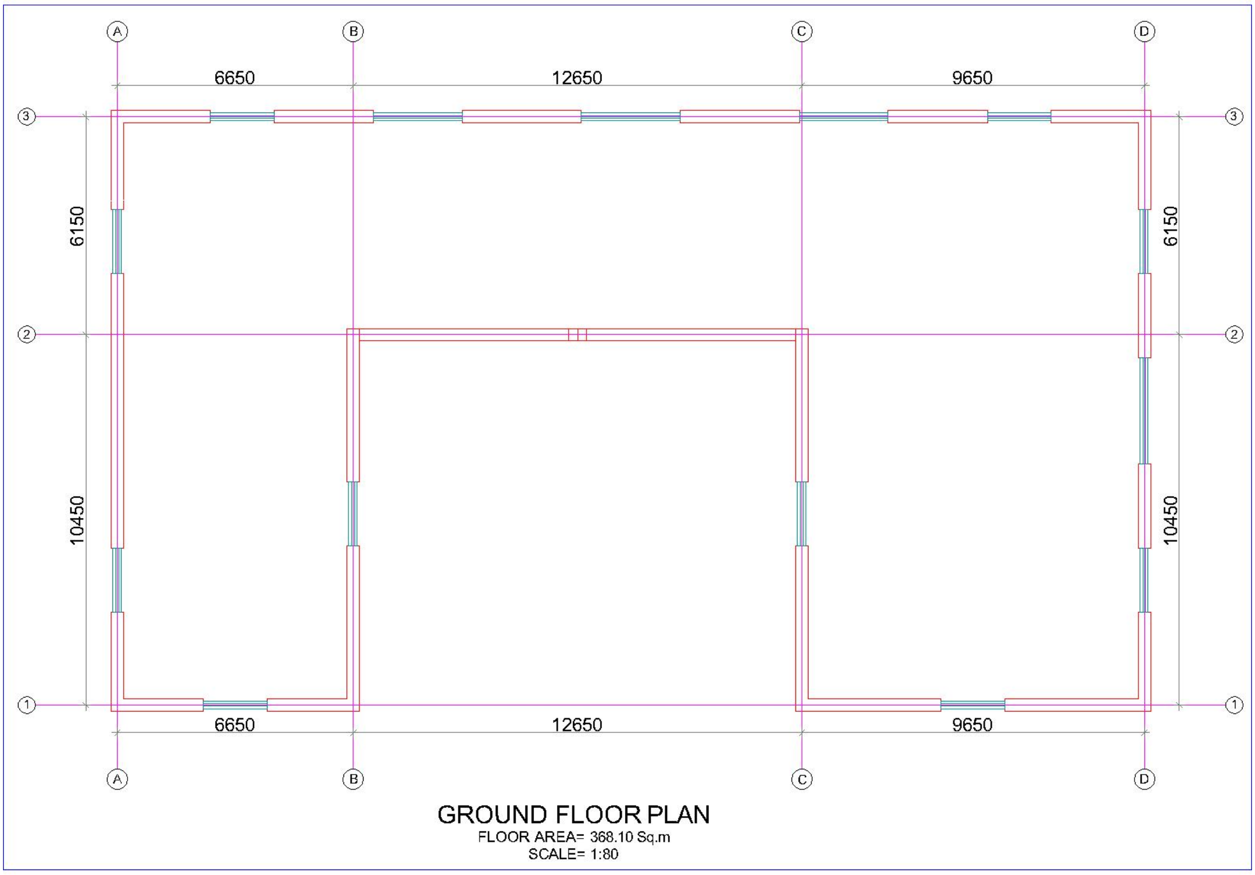


Figure 19 Ground floor plan of Newa Chen

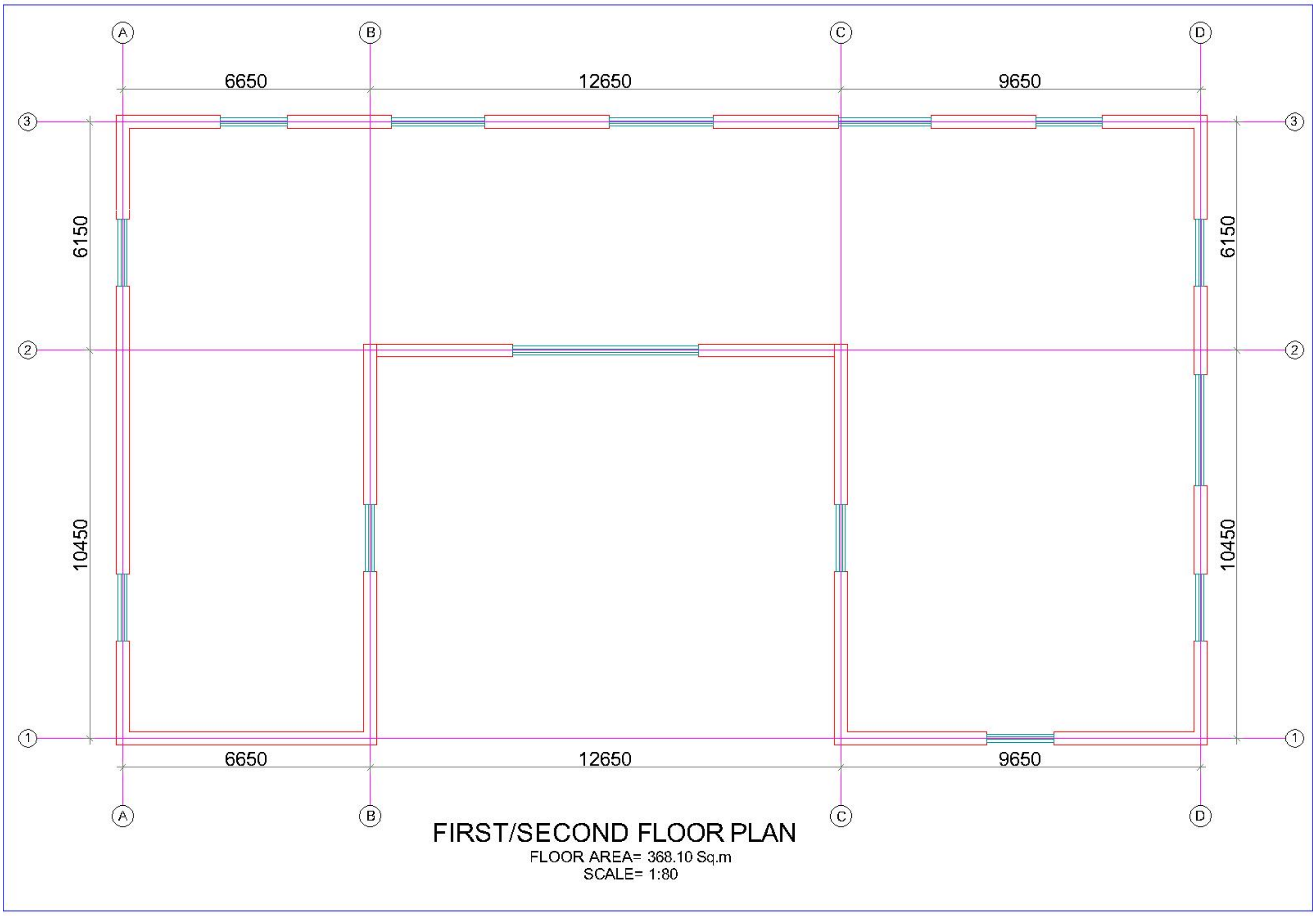


Figure 20 First/ Second floor plan of Newa Chen

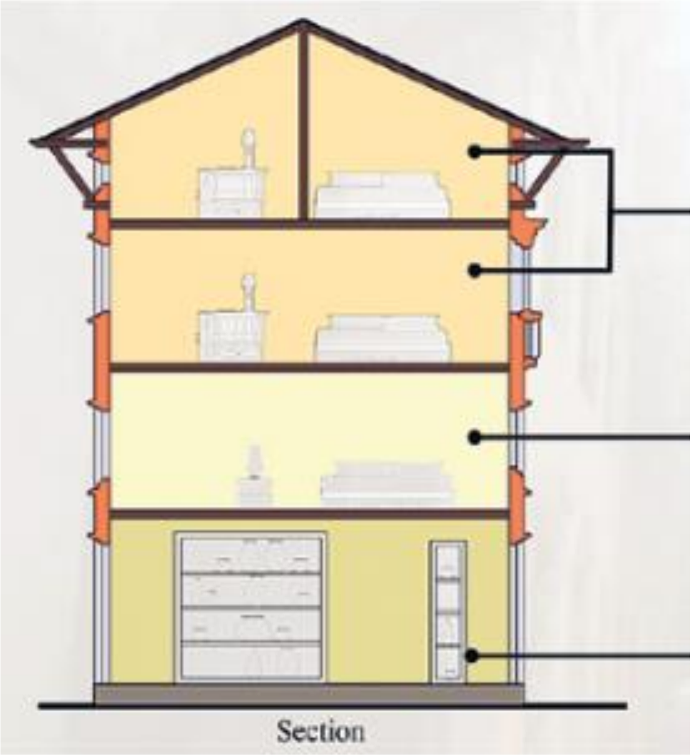


Figure 21 sectional view of Newa Chen

3.8.3. Thermal comfort analysis

Value range from 2.4-3.4 pmv (Predicted Mean Vote)

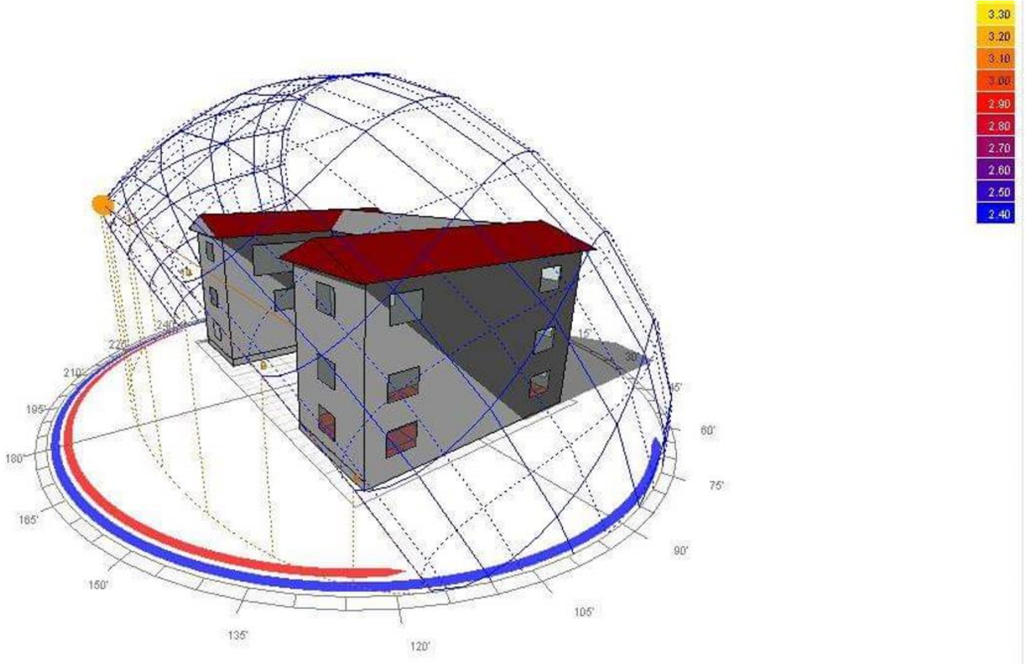


Figure 22 Calculating thermal comfort in courtyard building during sunny day.

Analysis of Building with atmospheric temperature and pressure resembled the (2.4-3.4) KW of PMV. This analysis concludes that the temperature within building is moderate in sunny day but lags behind in thermal comfort when sun sets.

3.8.4. Rayman Model analysis

Mean values of air temperature, relative humidity, solar radiation, and wind speed, for a typical winter and summer day were used with a time resolution of one hour, as input parameters for the RayMan model (Matzarakis, Rutz, & Mayer, 2010). Wind speed measured at 10 m above ground level was reduced to the height of 1.1 m according to the generally adopted empirical formula (Kuttler & Stadklima, 2000) (Matzarakis, Najjar, & De Rocco, 2009) (Eq. 1):

$$WS1.1 = WSh * (1.1/h) \alpha \ \alpha = 0.12 * z0 + 0.18$$

(WSh): wind speed at 10 meters from the ground

(α): empirical exponent which depends on the surface roughness

($z0$) is the roughness length

The values ($\alpha = 0.30$) and ($z0 = 1$) correspond to the walls’ characteristics of the selected courtyards in the study area. A cloudless sky was assumed in the simulations.

CHAPTER FOUR: DATA ANALYSIS, RESULTS AND DISCUSSION

4.1.Data collection and data types

Various sources and techniques were considered for collection of data required for the study. Primary data was collected through site survey, climate change knowledge portal and secondary data was collected through articles, websites and Department of Hydrology and Meteorology (DHM).

4.2.Data analysis

Data analysis will be done through various assistive media used for the qualitative and quantitative analysis of data like SPSS and Excel. All the quantitative data will be entered in these assistive media for data processing, analysis and interpretation. Other descriptive statistics like graphs, charts and other such tools will be used to present the data.

Data collection for Temperature, Relative Humidity and Atmospheric Pressure collected from meteorological department at normal ATP. Then, modelling of samples conducted with normal ATP and with vegetation. The particular site will be subjected to 25% of vegetation for 1 week and again with 75% of vegetation for next one week. A more appropriate function is an exponential decay function:

$$T=a-be-ctT=a-be-ct$$

Since this is a non-linear function, obtaining the fitting parameters a, b, and c will involve some kind of iterative procedure. Still, it isn't too difficult to perform. Using a least squares algorithm in conjunction with a Newton-Raphson root finding algorithm is the basic idea.

4.3.Analysis for courtyard

The purpose of this analysis is to identify the best method for preserving human comfort.

- Analysis of building without subjecting to any vegetation
- Analysis with 25 percent vegetation
- Analysis with 75 percent vegetation

Scenario 1 (Analysis of building without subjecting to any vegetation)

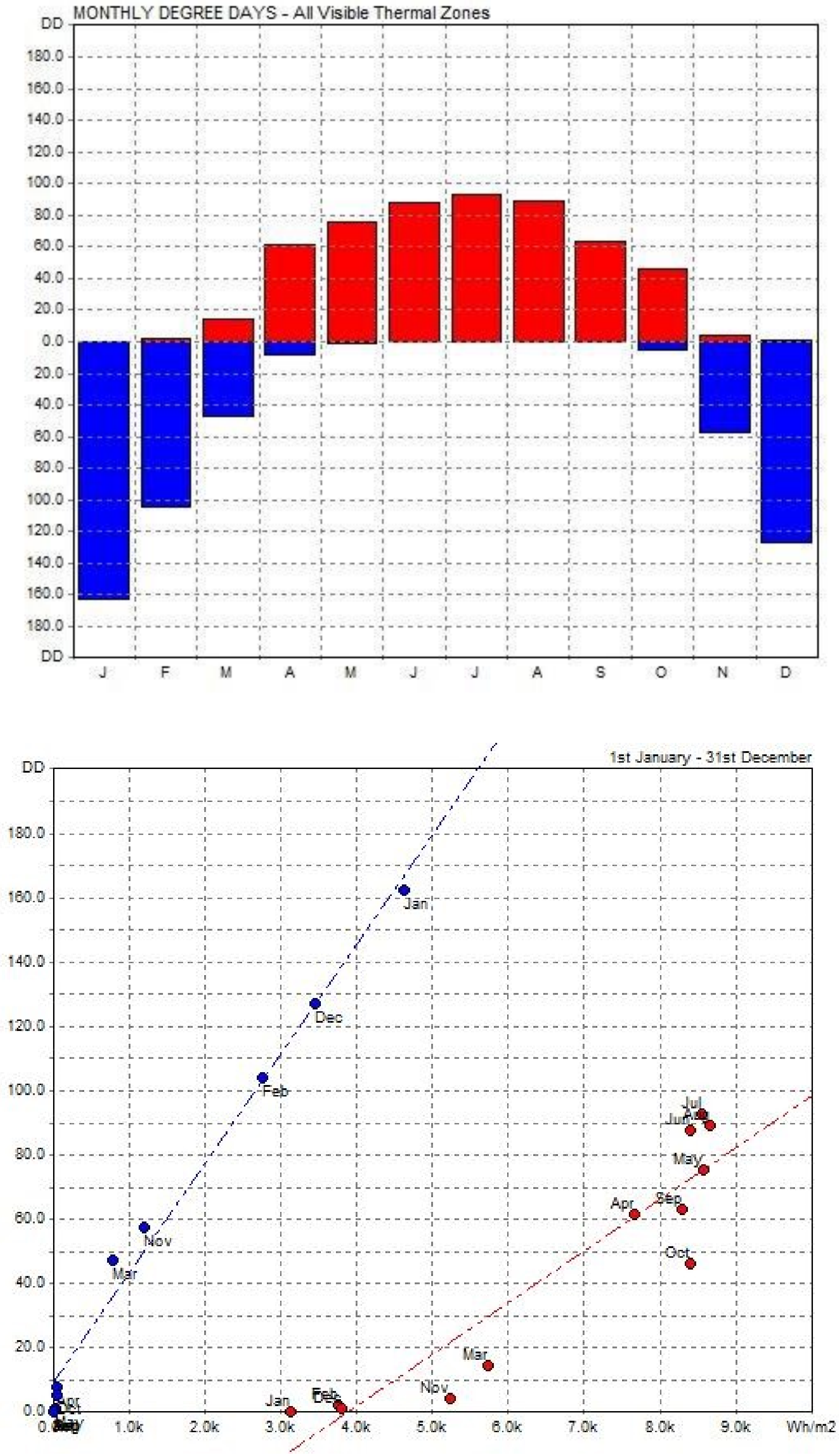
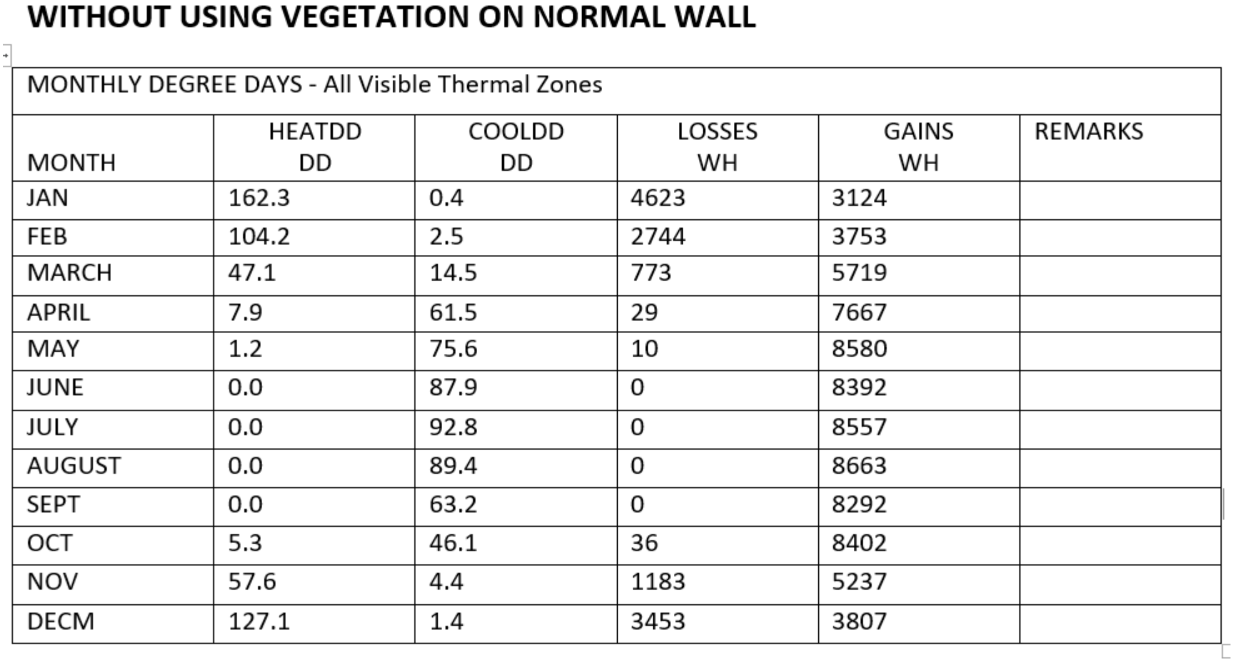


Figure 23 Thermal analysis of building and presenting it in graph to represent yearly data

Table 9 Table representing Thermal Analysis of building without any vegetation.



WITHOUT USING VEGETATION ON NORMAL WALL

MONTHLY DEGREE DAYS - All Visible Thermal Zones					
MONTH	HEATDD DD	COOLDD DD	LOSSES WH	GAINS WH	REMARKS
JAN	162.3	0.4	4623	3124	
FEB	104.2	2.5	2744	3753	
MARCH	47.1	14.5	773	5719	
APRIL	7.9	61.5	29	7667	
MAY	1.2	75.6	10	8580	
JUNE	0.0	87.9	0	8392	
JULY	0.0	92.8	0	8557	
AUGUST	0.0	89.4	0	8663	
SEPT	0.0	63.2	0	8292	
OCT	5.3	46.1	36	8402	
NOV	57.6	4.4	1183	5237	
DECM	127.1	1.4	3453	3807	

The following data says that the

- Opening size maintained as same in all months, the result shows that maximum amount of heat loss is seen in month of January i.e. 4623WH while, maximum amount of heat gain is seen in the month of August i.e. 8663WH.
- Building shows no heat loss in four months of season, June to September.
- Building shows minimum amount of heat gain in the month of January i.e.,3124WH.

From May to October heat gain is continuously high and has the maximum value raising above 8000WH margin.

Scenario 2(Analysis of Building By Subjecting To 25% Of Vegetation**)**

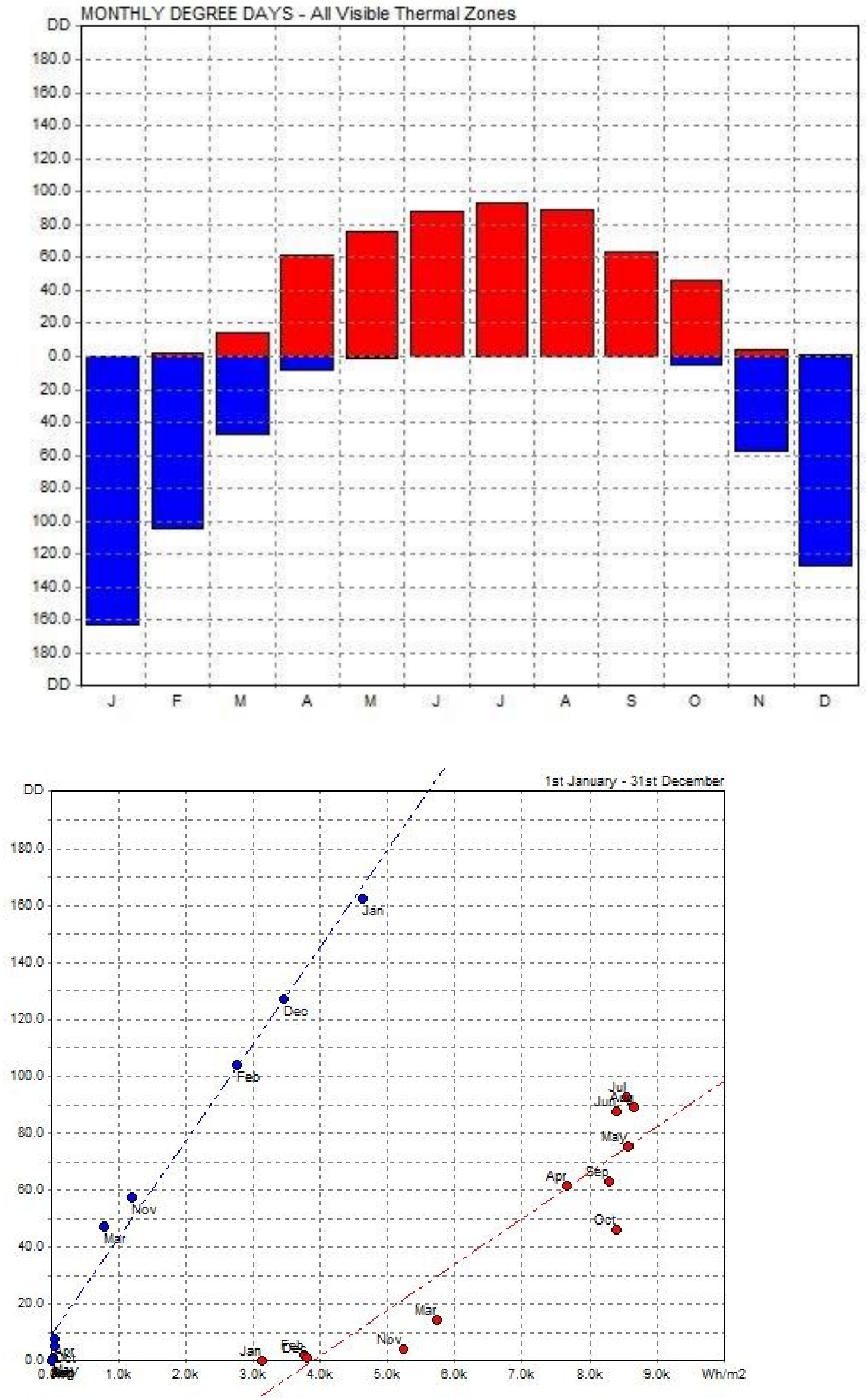
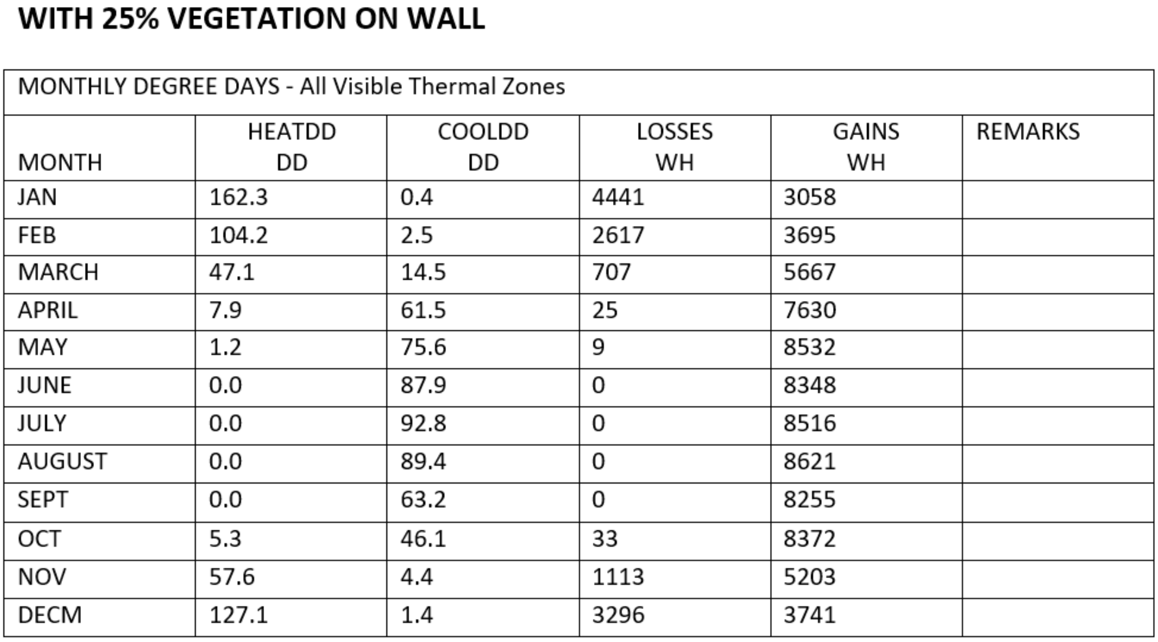


Figure 24 Thermal analysis of building and presenting it in graph to represent yearly data.

Table 10 Table representing Thermal Analysis of building with 25 percent vegetation.



WITH 25% VEGETATION ON WALL

MONTHLY DEGREE DAYS - All Visible Thermal Zones					
MONTH	HEATDD DD	COOLDD DD	LOSSES WH	GAINS WH	REMARKS
JAN	162.3	0.4	4441	3058	
FEB	104.2	2.5	2617	3695	
MARCH	47.1	14.5	707	5667	
APRIL	7.9	61.5	25	7630	
MAY	1.2	75.6	9	8532	
JUNE	0.0	87.9	0	8348	
JULY	0.0	92.8	0	8516	
AUGUST	0.0	89.4	0	8621	
SEPT	0.0	63.2	0	8255	
OCT	5.3	46.1	33	8372	
NOV	57.6	4.4	1113	5203	
DECM	127.1	1.4	3296	3741	

The data says that.

- Opening size maintained as same in all months, the result shows that maximum amount of heat loss is seen in month of January i.e. 4441WH while, maximum amount of heat gain is seen in the month of August i.e. 8621WH.
- Considerable amount of difference in Heat loss is seen in these two analyses. Subjecting 25% of vegetation in building has reduced the heat loss from 4623WH to 4441WH, (i.e., 182WH) in the month of January.
- Building shows no heat loss in four months of season, June to September as earlier with no vegetation.
- Building shows minimum amount of heat gain in the month of January i.e.,3058WH.
- From May to October heat gain is continuously high and has the maximum value raising above 8000WH margin but the amount of heat gain is considerably lower than that of building with no vegetation.

Scenario 3(Analysis of Building By Subjecting To 75% Of Vegetation**)**

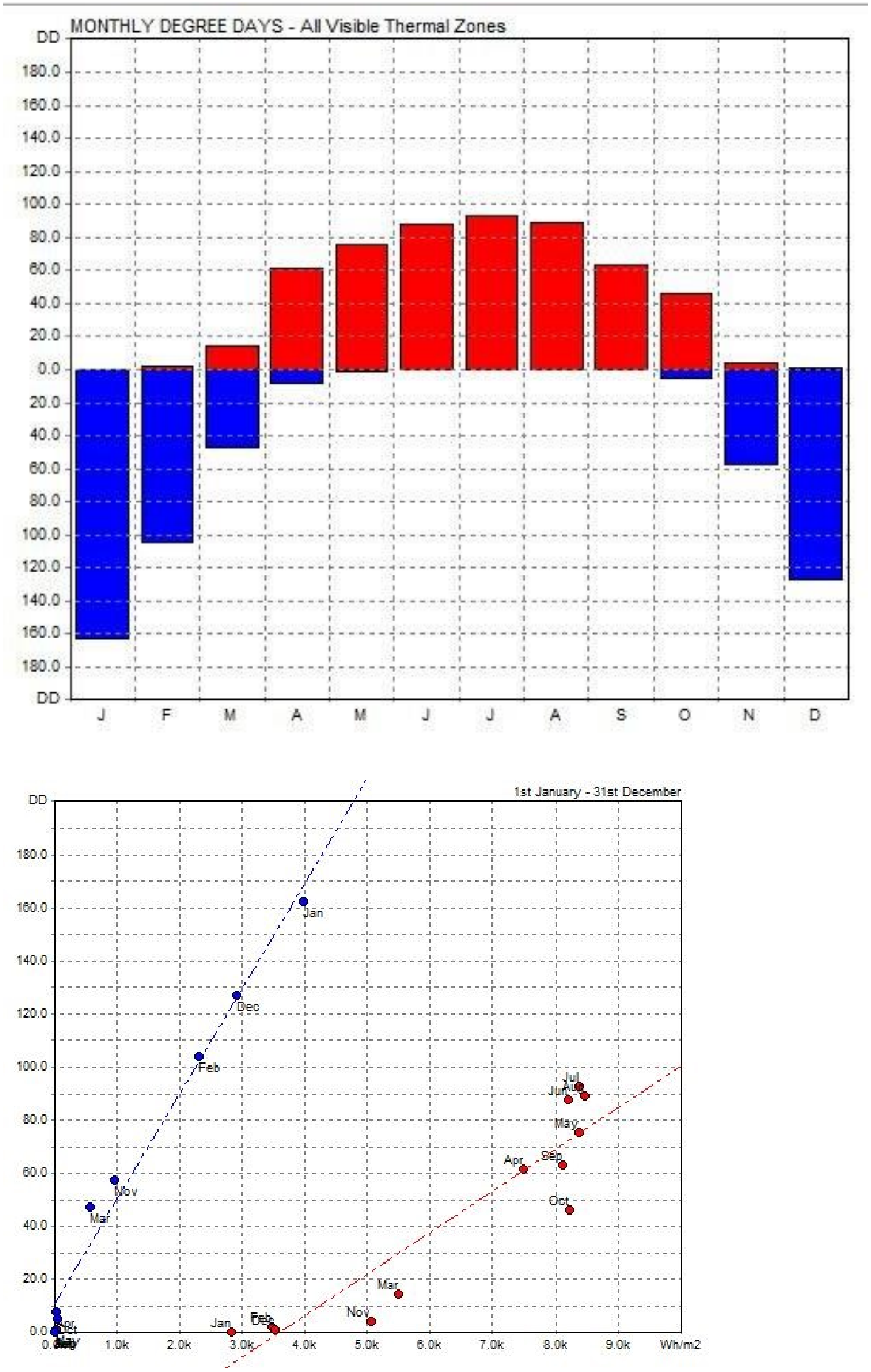
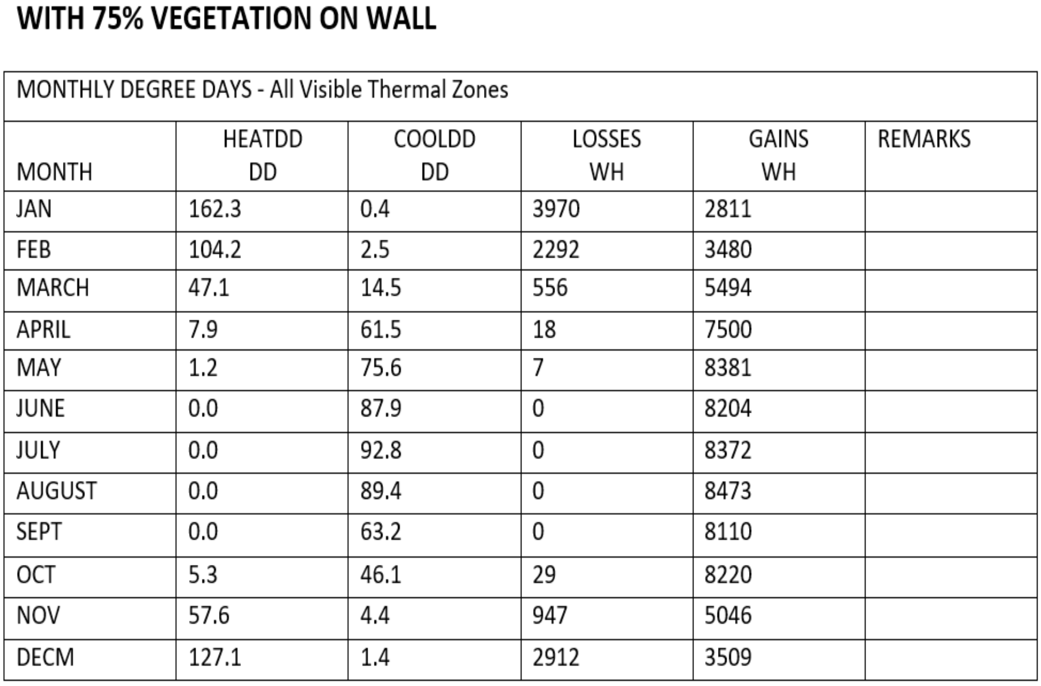


Figure 25 Thermal analysis of building and presenting it in graph to represent yearly data

Table 11 Table representing Thermal Analysis of building with 75 percent vegetation



WITH 75% VEGETATION ON WALL

MONTHLY DEGREE DAYS - All Visible Thermal Zones					
MONTH	HEATDD DD	COOLDD DD	LOSSES WH	GAINS WH	REMARKS
JAN	162.3	0.4	3970	2811	
FEB	104.2	2.5	2292	3480	
MARCH	47.1	14.5	556	5494	
APRIL	7.9	61.5	18	7500	
MAY	1.2	75.6	7	8381	
JUNE	0.0	87.9	0	8204	
JULY	0.0	92.8	0	8372	
AUGUST	0.0	89.4	0	8473	
SEPT	0.0	63.2	0	8110	
OCT	5.3	46.1	29	8220	
NOV	57.6	4.4	947	5046	
DECM	127.1	1.4	2912	3509	

The data says that.

- Opening size maintained as same in all months, the result shows that maximum amount of heat loss is seen in month of January i.e. 3970WH while, maximum amount of heat gain is seen in the month of August i.e. 8473WH.
- Considerable amount of difference in Heat loss is seen in these three analyses. Subjecting 25% of vegetation in building has reduced the heat loss from 4623WH to 4441WH, (i.e. 182WH) in the month of January. Also, subjecting 75% of vegetation has shown that the heat loss has reduced to 3970WH, a total reduction of (4623-3970) = 653WH.
- Building shows no heat loss in four months of season, June to September as earlier with no vegetation.
- Building shows minimum amount of heat gain in the month of January i.e.,2811WH.
- From May to October heat gain is continuously high and has the maximum value raising above 8000WH margin but the amount of heat gain is considerably lower than that of building with no vegetation.

- Both heat gain and heat loss is reduced while subjecting building to vegetation but this will lead to energy neutral structure which finally can be effective for temperature resilient design.

4.4.Rayman Model Analysis

Patan, located at 28°23'50.50" N and 84°07'32.74" E, was the study's location. This region has a warm, temperate climate. Summertime rainfall in Patan is greater than wintertime rainfall. According to the Köppen-Geiger classification, this area's current weather is classified as Cwb. Based on available data, the average annual temperature in Patan is 16.1 °C, or 61.1 °F. An annual total of 2812 mm or 110.7 in of rainfall is experienced.

The climate here is mild, and generally warm and temperate. Lalitpur experiences significantly more winter rainfall than summer rainfall. The Köppen-Geiger classification places the current climate in this area under the Csa category. Based on statistical analysis, the temperature at this location is approximately 25.3 °C | 77.5 °F. Here, there is roughly 953 mm (37.5 in) of precipitation annually. Lalitpur experiences a moderate climate, and the summers are not easy to define. The best time is March, September, October, November.

The RayMan model's input parameters were the average air temperature, relative humidity, solar radiation, and wind speed for a typical winter and summer day, with an hourly time resolution (Matzarakis, Rutz, & Mayer, 2010). The generally accepted empirical formula reduced the wind speed measured at 10 m above ground level to 1.1 m (Kuttler & Stadklima, 2000) (Matzarakis, Najjar, & De Rocco, 2009) (Eq. 1):

$WS1.1 = WSh * (1.1/h) \alpha \ \alpha = 0.12 * z0 + 0.18$

(WSh): wind speed at 10 meters from the ground

(α): empirical exponent which depends on the surface roughness.

(z0) is the roughness length.

The study area's chosen courtyards' wall characteristics are reflected in the values ($\alpha = 0.30$) and ($z0 = 1$). The simulations assumed a cloudless sky.

Wind speed is calculated at different heights, using this formula.

Table 12 Wind speed calculated at different heights

S.N	**Height (m)**	**WS=WSh*(1.1/h)a (m/s)**
1	1.10	2.81
2	1.50	2.75
3	2.00	2.77
4	2.50	2.80
5	3.00	2.85

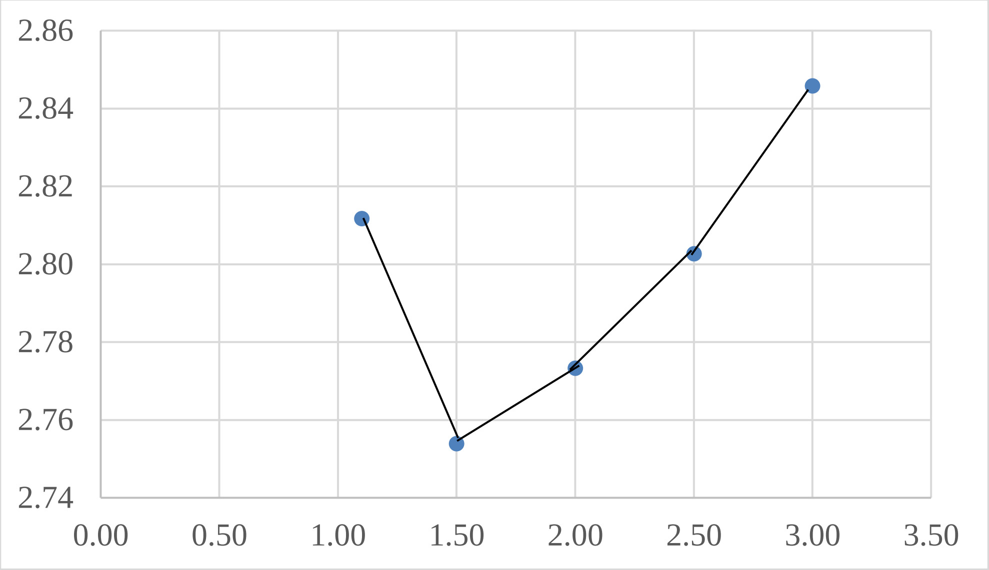


Figure 26 Windspeed obtained at different heights.

The above graph shows wind speed obtained at different heights. The wind speed is seen to decrease, when we change the height from 1.1m to 1.5m, then the wind speed gradually increases as we increase the height from 1.5m to 3m.

The table below, shows the calculation of Ws, when height is taken as 1.1m, we obtain average wind speed of 2.81m/s.

Table 13 Calculation for Wind speed when h=1.1m

S.N	**WSh(mps)**	**h(m)**	**a=.12*zo+.18**	**WS=WSh*(1.1/h)a**
1	4.35	10	0.3	2.24
2	4.97	10	0.3	2.56
3	4.35	10	0.3	2.24
4	4.35	10	0.3	2.24
5	3.73	10	0.3	1.92
6	4.97	10	0.3	2.56
7	3.11	10	0.3	1.60
8	4.35	10	0.3	2.24
9	8.08	10	0.3	4.17
10	4.97	10	0.3	2.56
11	7.46	10	0.3	3.85
12	4.97	10	0.3	2.56
13	6.21	10	0.3	3.20
14	4.97	10	0.3	2.56
15	4.35	10	0.3	2.24
16	3.73	10	0.3	1.92
17	4.97	10	0.3	2.56
18	4.35	10	0.3	2.24
19	4.97	10	0.3	2.56
20	3.73	10	0.3	1.92
21	6.21	10	0.3	3.20
22	8.08	10	0.3	4.17
23	8.08	10	0.3	4.17
24	7.46	10	0.3	3.85
25	4.35	10	0.3	2.24
26	4.35	10	0.3	2.24
27	6.21	10	0.3	3.20
28	5.59	10	0.3	2.88
29	7.46	10	0.3	3.85
30	4.97	10	0.3	2.56
31	9.32	10	0.3	4.81
total				**87.16**
avgerage				**2.81**

The table below, shows the calculation of Ws, when height is taken as 1.5m, we obtain average wind speed of 2.75 m/s.

Table 14 Calculation for Wind speed when h =1.5m

S.N	**WSh(mps)**	**h(m)**	**a=.12*zo+.18** **a=0.36**	**WS=WSh*(1.5/h)a**
1	4.35	10	0.36	2.20
2	4.97	10	0.36	2.51
3	4.35	10	0.36	2.20
4	4.35	10	0.36	2.20
5	3.73	10	0.36	1.88
6	4.97	10	0.36	2.51
7	3.11	10	0.36	1.57
8	4.35	10	0.36	2.20
9	8.08	10	0.36	4.08
10	4.97	10	0.36	2.51
11	7.46	10	0.36	3.77
12	4.97	10	0.36	2.51
13	6.21	10	0.36	3.14
14	4.97	10	0.36	2.51
15	4.35	10	0.36	2.20
16	3.73	10	0.36	1.88
17	4.97	10	0.36	2.51
18	4.35	10	0.36	2.20
19	4.97	10	0.36	2.51
20	3.73	10	0.36	1.88
21	6.21	10	0.36	3.14
22	8.08	10	0.36	4.08
23	8.08	10	0.36	4.08
24	7.46	10	0.36	3.77
25	4.35	10	0.36	2.20
26	4.35	10	0.36	2.20
27	6.21	10	0.36	3.14
28	5.59	10	0.36	2.82
29	7.46	10	0.36	3.77
30	4.97	10	0.36	2.51
31	9.32	10	0.36	4.71
total				**85.37**
avgerage				**2.75**

The table below, shows the calculation of Ws, when height is taken as 2m, we obtain average wind speed of 2.77 m/s.

Table 15 Calculation for Wind speed when h=2m

S.N	**WSh(mps)**	**h(m)**	**a=.12*zo+.18 a=0.42**	**WS=WSh*(2/h)a**
1	4.35	10	0.42	2.21
2	4.97	10	0.42	2.53
3	4.35	10	0.42	2.21
4	4.35	10	0.42	2.21
5	3.73	10	0.42	1.90
6	4.97	10	0.42	2.53
7	3.11	10	0.42	1.58
8	4.35	10	0.42	2.21
9	8.08	10	0.42	4.11
10	4.97	10	0.42	2.53
11	7.46	10	0.42	3.79
12	4.97	10	0.42	2.53
13	6.21	10	0.42	3.16
14	4.97	10	0.42	2.53
15	4.35	10	0.42	2.21
16	3.73	10	0.42	1.90
17	4.97	10	0.42	2.53
18	4.35	10	0.42	2.21
19	4.97	10	0.42	2.53
20	3.73	10	0.42	1.90
21	6.21	10	0.42	3.16
22	8.08	10	0.42	4.11
23	8.08	10	0.42	4.11
24	7.46	10	0.42	3.79
25	4.35	10	0.42	2.21
26	4.35	10	0.42	2.21
27	6.21	10	0.42	3.16
28	5.59	10	0.42	2.84
29	7.46	10	0.42	3.79
30	4.97	10	0.42	2.53
31	9.32	10	0.42	4.74
total				**85.97**
avgerage				**2.77**

The table below, shows the calculation of Ws, when height is taken as 2.5m, we obtain average wind speed of 2.8 m/s.

Table 16 Calculation for Wind speed when h =2.5m

S.N	WSh(mps)	h(m)	a=.12*zo+.18 a=0.48	WS=WSh*(2.5/h)a
1	4.35	10	0.42	2.24
2	4.97	10	0.42	2.56
3	4.35	10	0.42	2.24
4	4.35	10	0.42	2.24
5	3.73	10	0.42	1.92
6	4.97	10	0.42	2.56
7	3.11	10	0.42	1.60
8	4.35	10	0.42	2.24
9	8.08	10	0.42	4.15
10	4.97	10	0.42	2.56
11	7.46	10	0.42	3.83
12	4.97	10	0.42	2.56
13	6.21	10	0.42	3.19
14	4.97	10	0.42	2.56
15	4.35	10	0.42	2.24
16	3.73	10	0.42	1.92
17	4.97	10	0.42	2.56
18	4.35	10	0.42	2.24
19	4.97	10	0.42	2.56
20	3.73	10	0.42	1.92
21	6.21	10	0.42	3.19
22	8.08	10	0.42	4.15
23	8.08	10	0.42	4.15
24	7.46	10	0.42	3.83
25	4.35	10	0.42	2.24
26	4.35	10	0.42	2.24
27	6.21	10	0.42	3.19
28	5.59	10	0.42	2.87
29	7.46	10	0.42	3.83
30	4.97	10	0.42	2.56
31	9.32	10	0.42	4.79
total				**86.88**
avgerage				**2.80**

The table below, shows the calculation of Ws, when height is taken as 3m, we obtain average wind speed of 2.85 m/s.

Table 17 Calculation for Wind speed when h=3m

S.N	**WSh(mps)**	**h(m)**	**a=.12*zo+.18 a=0.54**	**WS=WSh*(3/h)a**
1	4.35	10	0.54	2.27
2	4.97	10	0.54	2.59
3	4.35	10	0.54	2.27
4	4.35	10	0.54	2.27
5	3.73	10	0.54	1.95
6	4.97	10	0.54	2.59
7	3.11	10	0.54	1.62
8	4.35	10	0.54	2.27
9	8.08	10	0.54	4.22
10	4.97	10	0.54	2.59
11	7.46	10	0.54	3.89
12	4.97	10	0.54	2.59
13	6.21	10	0.54	3.24
14	4.97	10	0.54	2.59
15	4.35	10	0.54	2.27
16	3.73	10	0.54	1.95
17	4.97	10	0.54	2.59
18	4.35	10	0.54	2.27
19	4.97	10	0.54	2.59
20	3.73	10	0.54	1.95
21	6.21	10	0.54	3.24
22	8.08	10	0.54	4.22
23	8.08	10	0.54	4.22
24	7.46	10	0.54	3.89
25	4.35	10	0.54	2.27
26	4.35	10	0.54	2.27
27	6.21	10	0.54	3.24
28	5.59	10	0.54	2.92
29	7.46	10	0.54	3.89
30	4.97	10	0.54	2.59
31	9.32	10	0.54	4.87
total				**88.22**
avgerage				**2.85**

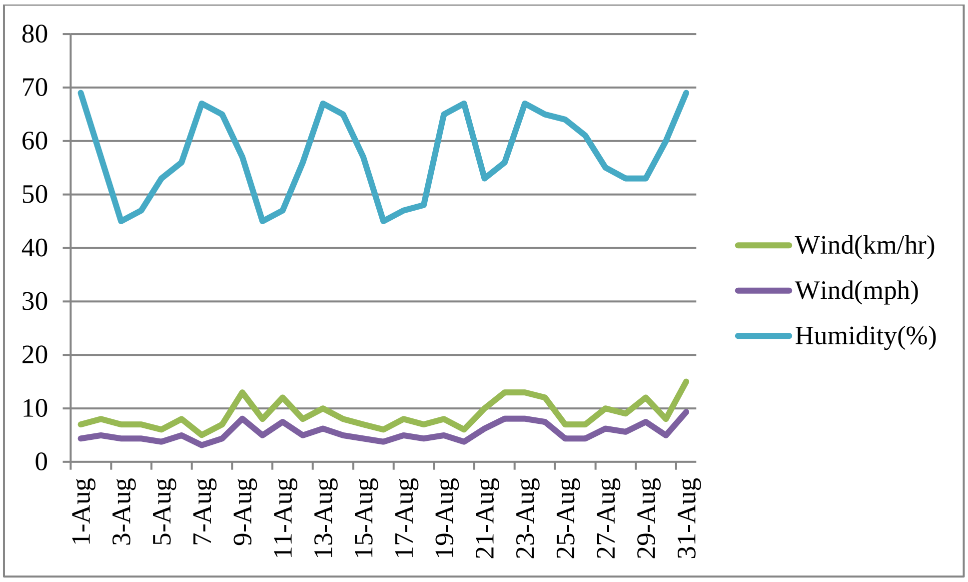


Figure 27 Wind and Humidity chart

Table 18 Wind and Humidity Measurement for site

month	**Wind(km/hr)**	**Wind(mph)**	**Humidity (%)**
1-Aug	7	4.35	69.00
2-Aug	8	4.97	57.00
3-Aug	7	4.35	45.00
4-Aug	7	4.35	47
5-Aug	6	3.73	53
6-Aug	8	4.97	56
7-Aug	5	3.11	67
8-Aug	7	4.35	65
9-Aug	13	8.08	57
10-Aug	8	4.97	45
11-Aug	12	7.46	47
12-Aug	8	4.97	56
13-Aug	10	6.21	67
14-Aug	8	4.97	65
15-Aug	7	4.35	57
16-Aug	6	3.73	45
17-Aug	8	4.97	47
18-Aug	7	4.35	48
19-Aug	8	4.97	65
20-Aug	6	3.73	67
21-Aug	10	6.21	53

month	**Wind(km/hr)**	**Wind(mph)**	**Humidity (%)**
22-Aug	13	8.08	56
23-Aug	13	8.08	67
24-Aug	12	7.46	65
25-Aug	7	4.35	64
26-Aug	7	4.35	61
27-Aug	10	6.21	55
28-Aug	9	5.59	53
29-Aug	12	7.46	53
30-Aug	8	4.97	60
31-Aug	15	9.32	69
Total	**272**	**169.01**	
avg	**8.77**	**5.45**	

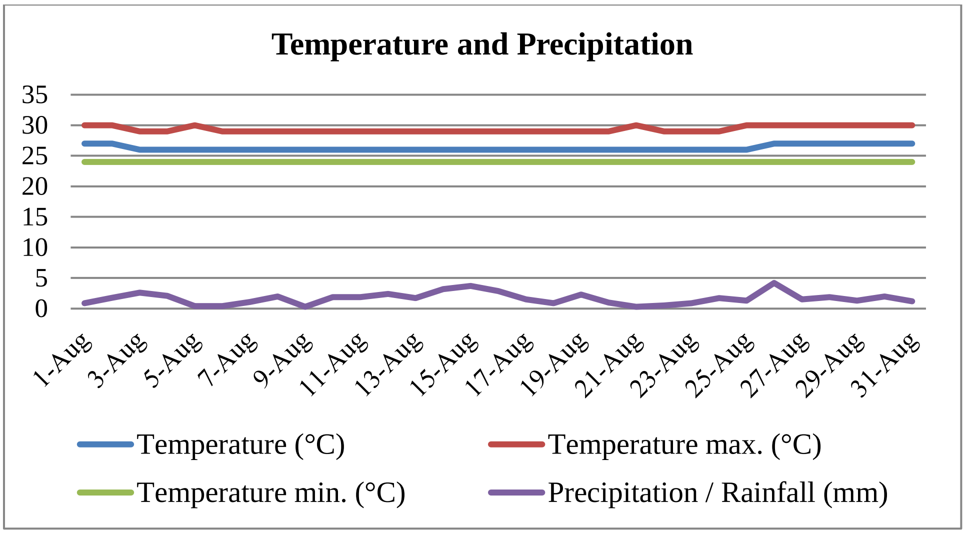


Figure 28Precipitation and Temperature Chart

Table 19 Precipitation and Temperature Measurement

Day	**Temperature (°C)**	**Temperature max. (°C)**	**Temperature min. (°C)**	**Precipitation / Rainfall (mm)**
1-Aug	27	30	24	0.9
2-Aug	27	30	24	1.8
3-Aug	26	29	24	2.6
4-Aug	26	29	24	2.1
5-Aug	26	30	24	0.4
6-Aug	26	29	24	0.4
7-Aug	26	29	24	1.1
8-Aug	26	29	24	2
9-Aug	26	29	24	0.3
10-Aug	26	29	24	1.9
11-Aug	26	29	24	1.9
12-Aug	26	29	24	2.4
13-Aug	26	29	24	1.7
14-Aug	26	29	24	3.2
15-Aug	26	29	24	3.7
16-Aug	26	29	24	2.9
17-Aug	26	29	24	1.5
18-Aug	26	29	24	0.9
19-Aug	26	29	24	2.3
20-Aug	26	29	24	1
21-Aug	26	30	24	0.3
22-Aug	26	29	24	0.5
23-Aug	26	29	24	0.9
24-Aug	26	29	24	1.7
25-Aug	26	30	24	1.3
26-Aug	27	30	24	4.2
27-Aug	27	30	24	1.5
28-Aug	27	30	24	1.9
29-Aug	27	30	24	1.3
30-Aug	27	30	24	2
31-Aug	27	30	24	1.2

4.5.Discussion and Data Validation:

The analysis of building without subjecting to any vegetation (Scenario 1) shows that, maximum amount of heat loss is 4623 WH in the month of January, and maximum amount of heat gain is 8663 WH in the month of August. Likewise, the analysis of building without subjecting to 25% of vegetation (Scenario 2) shows that, maximum amount of heat loss is 4441 WH in the month of January, and maximum amount of heat gain is 8621 WH in the month of August. The analysis of building without subjecting to 75% of vegetation (Scenario 3) shows that, maximum amount of heat loss is 3970 WH in the month of January, and maximum amount of heat gain is 8473 WH in the month of August. Both heat gain and heat loss are reduced while subjecting building to vegetation, but this will lead to energy neutral structure which finally can be effective for temperature resilient design. This finding is relevant to the research and comes within the scope of (Zakaria & Kubota, 2014).

While using Rayman Model, the wind speed at different heights is obtained. The wind speed is 2.81m/s at height =1.1m, 2.75 m/s, at height =1.5m, 2.77m/s at height =2m, 2.8m/s at height = 2.5m and 2.85m/s at height =3m. The wind speeds is seen to decrease, when we change the height from 1.1m to 1.5m, then the wind speed gradually increases as we increase the height from 1.5m to 3m. The similar results are obtained in the research of (Charalampopoulos & Matzarakis, 2013).

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Microclimate modification through design can be done. While evergreen trees may offer more wind shelter but will also block winter sun, deciduous tree plantations offer the benefit of summer shade while also having the advantage of not limiting solar radiation in winter. In addition, using cool materials for building envelopes and pavements lowers ambient temperatures, lowers summertime air conditioning costs, mitigates the urban heat island effect, lowers CO2 emissions and ensuing air pollution, and lengthens the material's lifespan.

Urban areas' microclimate can be improved by up to 108C by decreasing the pavement temperature by 54 degrees by increasing the solar reflectance of the pavement by 0.25. By providing shade and allowing for evapotranspiration, trees and other vegetation, or "green spaces," help to cool urban climates.. After a certain depth, the ground's high thermal capacity acts as a cooling source, keeping soil temperatures significantly below that of the surrounding air. Higher air flows are often achieved with pipe arrays.

Therefore, reducing the impact of heat islands in cities is essential, and this can be accomplished by enhancing the urban microclimate. Four such measures were necessary due to the main focus: (a) cool materials; (b) green spaces; (c) intensive solar control; and (d) earth to air heat exchangers. Hence, traditional house saves energy up to 10-20% during summer and winter seasons.

5.2. Recommendation

- Only a partial analysis and the thermal conditions of the courtyard in terms of Tmrt are covered in this study.
- Further research is necessary to ascertain how courtyard aspect ratios and orientations impact wind conditions.
- The nearby buildings' year-round thermal comfort during the day and at night.
- To provide more comprehensive recommendations, specific aspects of courtyard design (such as vegetation, surface materials, albedo, and emissivity) must also be considered.

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