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The role of Green Buildings in Climate Adaptation: An investigation on Corporate Buildings in Kathmandu

by

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APPROVAL PAGE

The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, thesis entitled "**The role of Green Buildings in Climate Adaptation: An investigation on Corporate Buildings in Kathmandu”** submitted by **Pratima Panthi (074/MSCCD/013)** in partial fulfilment of the requirements for the degree of M.Sc. in Climate Change and Development.

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ABSTRACT

Climate Change has an impact on building performance and human comfort which also highly contribute to final energy consumption. The final building design has to meet a variety of design objectives (such as comfortable indoor climate, healthy environment, life-cycle costs, resource use, environmental loading, functionality and architectural expression) that interrelate with each other. Green buildings can significantly reduce the energy consumption of a building by providing more affordable and clean energy and contributing to climate-responsive or climate adaptable buildings. Adaptation in buildings refers to physical properties and its flexibility to handle change in use, function and volume.

The study highlights the significance of adaptive measures and the energy efficiency of the building. The purpose of the research is to study the parameters of climate adaptive building and its energy efficiency by selecting the corporate buildings inside Kathmandu Valley. Two buildings that attempted green design strategies and one conventional type of building was selected to study the physical and functional attributes and to do comparative analysis for its energy efficiency. The adaptive capacity of the building was investigated by observing the physical and functional parameters like building geometry, orientation, form, materials used, lighting, services, thermal performance, internal layouts, passive/ active designs and energy efficiency. Data obtained from the field observation, drawings, literature and interview were analyzed and co-related with the help of AutoCAD, Sketch-Up, Microsoft Excel, VELUX Daylight Visualizer etc. The result confirms that the proper design consideration, technologies used and suitable building materials aid to improve the adaptive capacity and energy efficiency of the buildings. The buildings with green design strategies are found to be more energy-efficient and climate adaptable, so it is recommended to integrate such strategies in upcoming design and constructions works.

Keywords: Building Design, Green Building, Adaptive Measures, Energy Efficiency, Parameters.

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LIST OF ABBREVIATIONS

GHG	Green House Gas
CABS	Climate Adaptive Building Shell
LEED	Leadership in Energy and Environmental Design
IPCC	Intergovernmental Panel on Climate Change
SCGSA	SONA Committee on Green and Sustainable Architecture
SONA	Society of Nepalese Architects
BPC	Butwal Power Company
VRV	Variable Refrigent Volume
HVAC	Heating Ventilation Air Conditioning
EAT	Earth Air Tunnel
AHU	Air Handling Unit
TFAS	Treated Fresh Air System

CHAPTER ONE: INTRODUCTION

1.1 Background

“Climate change” means a change in the climate which is directly or indirectly attributed to human activities that alter the configuration of the global atmosphere and which is in addition to natural climate unpredictability observed over equivalent periods (‘UNFCCC’, 1992). The impacts of Climate Change are the consequences of natural as well as human activities. Climate change has also a substantial impact on buildings and how they are kept cool and how they are weathered against more extreme climatic conditions and these consequences to people around buildings and their health and well-being (Kinnane et al., 2016).

Greenhouse gas emissions from buildings mainly arise from their consumption of fossil-fuel-based energy, both through the direct use of fossil fuels and through the use of electricity that has been spawned from fossil fuels. Buildings are responsible for more than 40 per cent of global energy consumption and one-third of global greenhouse gas emissions, both in developed and developing countries (IPCC, 2014).

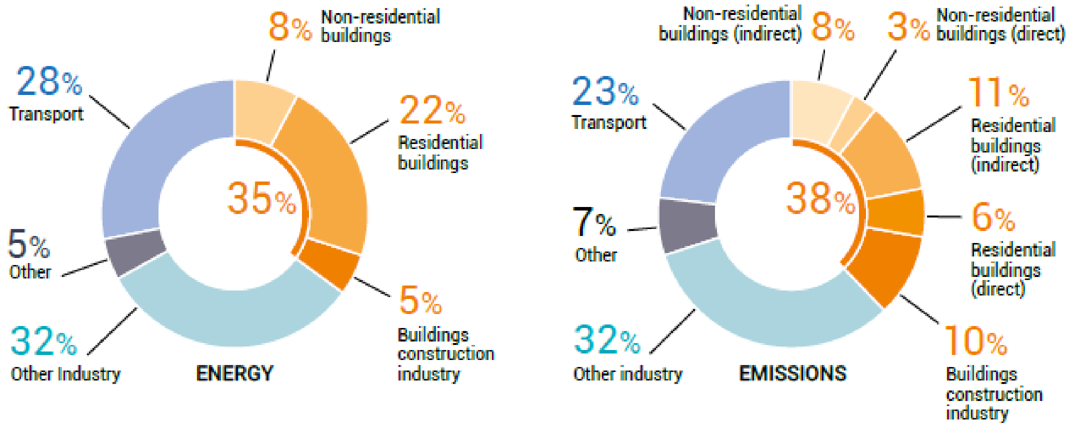


Figure 1: Global share of buildings and construction final energy and emissions, 2019

The building sector has the most prospective for delivering significant and cost-effective GHG emission declines. Fourth Assessment Report shows that the potential for greenhouse gas reductions from buildings is common to both developed and developing countries and countries with economies in transition (IPCC, 2014). In Nepal, the energy consumption by buildings accounts for 89% of the total energy consumption of national consumption (WECS, 2014).

Green building refers to the construction and using a process that is environmentally responsible and resource-efficient throughout a building's life-cycle: from site to design, construction, operation, maintenance, renovation, and demolition (Vij et al., 2010). The building sector has considerable possibilities for the positive change to become more efficient in terms of resource use, less environmentally exhaustive and more profitable by implementing green building design strategies (Adagala, 2012). Climate Change adaptation in buildings refers to the building's physical properties and its flexibility to handle change in use, function and volume (Grynning et al., 2017).

The description of CABS made by Loonen et al says that: A climate adaptive building shell can constantly and reversibly change some of its functions, features or behaviour over time in response to changing performance requirements and variable boundary conditions, and does this to improve overall building performance (en.wikepedia.org).

1.2 Problem Statement

Buildings are accountable for more than 40 per cent of global energy use which contributes to climate change. Rapidly increasing climate change has an impact on building performance and human comfort which also highly contribute to the final energy consumption. It is known that building design is a very complex practice. The final building design has to encounter a variety of design purposes (such as comfortable indoor climate, healthy environment, life-cycle costs, resource use, environmental loading, functionality and architectural expression) that interrelate with each other. Green buildings can considerably reduce the energy consumption of a building by providing more affordable and clean energy and contributing to climate-responsive or climate adaptable buildings.

1.3 Objectives

The main objective of this research is to study the attributes of building adaptation and evaluate the contribution of green building to energy efficiency in the context of Kathmandu Valley.

Specific Objectives:

- To study the existing green building in terms of its design based on the energy efficiency of the building.
- To examine the adaptability of selected buildings in changing climate.
- To compare the green building with a conventional building in terms of its adaptive measures and energy efficiency.

1.4 Project Justification

Climate Change poses one of the most significant challenges in building design, human comfort, and access to natural resources. The projected rate of climate change will result in unpredictable and unfamiliar environmental impacts requiring building systems to be adapted according to the climate. Climate change is expected to cause impacts on the built environment, physical infrastructure and buildings, so to be prepared for these changes we will require an adaptation strategy that demands a shift from current practices and demands. Because the building sector contributes the largest source of emissions, green building practices could reduce the overall environmental impact and increase the efficiency of energy, water, and another resource. The reduction in energy consumption of the buildings is connected to the reduction of future GHG emissions. Hence, the utilization of advanced passive technologies in buildings may offer human comfort and comparatively reduce energy demand and carbon footprint. So, the research focuses on energy efficiency, building design, materials that have properties to respond to climate leading to the climate-responsive building.

1.5 Expected Outcome

From the study, physical and functional attributes of adaptable buildings like energy efficiency, thermal performance, buildings design, building orientation, building services, internal layouts and building materials will be studied for the selected corporate buildings inside Kathmandu valley to find out the final result. Furthermore, the energy consumption of corporate buildings will also be studied and a comparison will be carried out to find out the contribution to final energy consumption.

1.6 Study Location

The region for the research of the project is Kathmandu Valley. For this corporate building **Hama Iron Steel Building** located at Kamaladi, Kathmandu, **Butwal Power Company** located at Buddhanagar, Kathamandu which has attempted (LEED) green building strategies and a (Conventional Corporate Building) **Nepal Stock House** located at Kalikasthan, Kathmandu will be studied in the context of its design, attributes and energy efficiency.

1.7 Scope and Limitations of Research

The scope of the study is to identify the existing corporate buildings in Kathmandu Valley in the context of their design, functions and energy efficiency for adaptation. This could be identified by studying and observing the planning, design, technologies used for the construction of the study area. In the building construction process, it is important to consider the impact of adaptation as well so that it is more efficient in adapting to the changing climate. The study would include the technologies and building materials that can be adopted for the building's energy efficiency, which also contributes to the energy consumption in building sectors. The study shall be based on Primary and Secondary Sources.

1.8 Research Questions

The research questions are as follows:

- What will be the impact of green buildings on changing climate and is this a good option for climate adaptable buildings?
- Can green building helps to combat climate change?

CHAPTER TWO: LITERATURE REVIEW

2.1 Building and Climate Change

In both industrialized and developing countries, buildings account for more than 40% of world energy consumption and one-third of global greenhouse gas emissions (UNEP, 2009). According to the IPCC, the building industry has the greatest potential for reducing GHG emissions in a cost-effective manner in order to adapt to future climate change. Energy use is the primary source of greenhouse gas emissions from buildings. While industrialized countries have historically emitted the majority of emissions, it is projected that the level of emissions from buildings will rapidly rise in the near future (UNEP, 2009).

In comparison to other major polluting industries, the building sector has the greatest potential for dramatically decreasing greenhouse gas emissions. This capability is relatively unaffected by the cost per ton of CO2 produced (Reay et al., 2007). Buildings emit greenhouse gases primarily as a result of their consumption of fossil-fuel-based energy, which includes both direct uses of fossil fuels and electricity generated from fossil fuels (Reay et al., 2007). Construction materials, particularly insulating materials, as well as refrigeration and cooling systems, contribute significantly to greenhouse gas emissions. Energy is consumed in general during the following activities:

- manufacturing of building materials (‘embedded’ or ‘embodied’ energy)
- transport of these materials from production plants to building sites (‘grey’ energy);
- construction of the building (‘induced’ energy);
- operation of the building (‘operational’ energy); and
- Demolition of the building (and recycling of their parts, where this occurs) (Reay et al., 2007).

According to data from the United Nations (UN), in 2050 around 68% of humanity will live in cities (United Nations, 2021). Although they only cover 3% of the planet's area, they utilize 78 per cent of the planet's energy and emit 60% of greenhouse gas emissions. As a result, the United Nations improved the New Urban Agenda in 2016 to help countries with their urbanization processes and make cities more livable, inclusive, healthy, resilient, and sustainable. The building sector's energy usage has increased as a result of increased urbanization and modern lifestyles. Furthermore, energy consumption is raised as a result of the inadequate thermal architecture of buildings that do not consider climate and do not meet the comfort limits of the occupants. The traditional and vernacular architecture was developed and designed in response to climate change all around the world (Salman, 2019). Energy use in buildings currently accounts for about 32% of the global total final energy consumption in the world from which 40 % is consumed by traditional buildings (IPCC, 2014). As a result, many architects have proposed the construction of a Green Building or a Zero Energy Building. (Shakya & Bajracharya, 2015).

In the case of Nepal also ancient traditional buildings of the Lichchhavi and Malla periods are found to be good examples of climate-responsive buildings. In research, it is found that traditional residential buildings are a minimum of one to degrees cooler in summer and warmer in winter compared to contemporary residential buildings of Kathmandu valley which is also preferable for future climate change (Bajracharya, 2014).

2.2 Climate Adaptable Buildings

Adaptation is the process of implementing adjustments to our physical environment, infrastructure, and social systems in response to real or anticipated climatic phenomena or their impacts, including measures to mitigate harm and reap advantages. (Reay et al., 2007). A building that can adapt or react to changes in environmental conditions is known as an adaptable building. Climate-responsive building elements are those that expressly address these characteristics. (Looman, 2007). The geometry, orientation, size and height of the building, structural durability, internal layout, building envelope, and services are all physical attributes that must be considered when dealing with building adaptation. Thermal, acoustical, and lighting requirements, as well as fire protection, occupant comfort, safety, and security, are all functional attributes that influence adaptation. Each of these characteristics must be addressed in order to address building adaptation (Aysha & Mani, 2017). Any sustainable adaptation strategy that is implemented for individual buildings will be region-specific. As a response, adaptation strategies should be local rather than global, given the wide range of responses to climate change among systems (Kinnane et al., 2016).

However, some of the following measures can be used to investigate the possibilities of building adaption. Using appropriate insulation and functional windows in building design, orienting buildings to get as much light and heat from the sun, and energy-saving (Nick Gromicko and Rob London, 2006).

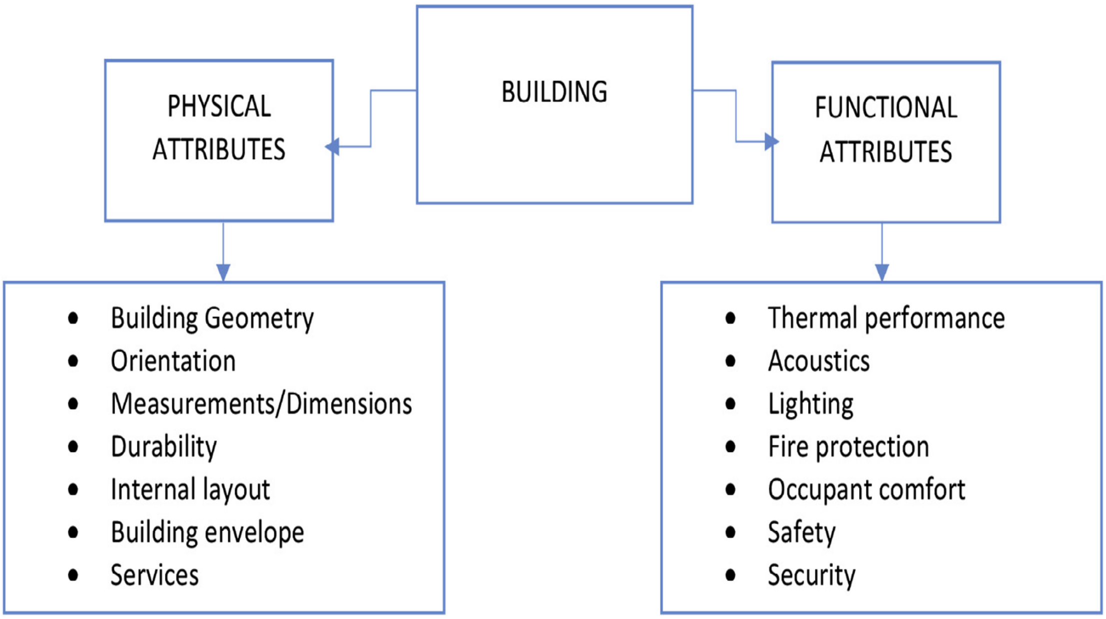


Figure 2: Attributes of building adaptation(Source: (Aysha & Mani, 2017))

2.2.1 Physical Attributes of Buildings

Physical attributes are the characteristics of the fabricated structures on a site, including the design, materials, scale, features, quality and other items that define a building or structure. These include the building's geometric form in response to the solar geometry of the geographic location, the material configuration defining the building envelope, cultural preferences, local resources and skill, and modularity and adaptation/changes amenability (Aysha & Mani, 2017). Externally, the building shape and envelope demonstrate adaptation to existing climatic conditions and other environmental vagaries through the use of local materials/resources, development of necessary skill, durability, and resilience (Aysha & Mani, 2017).

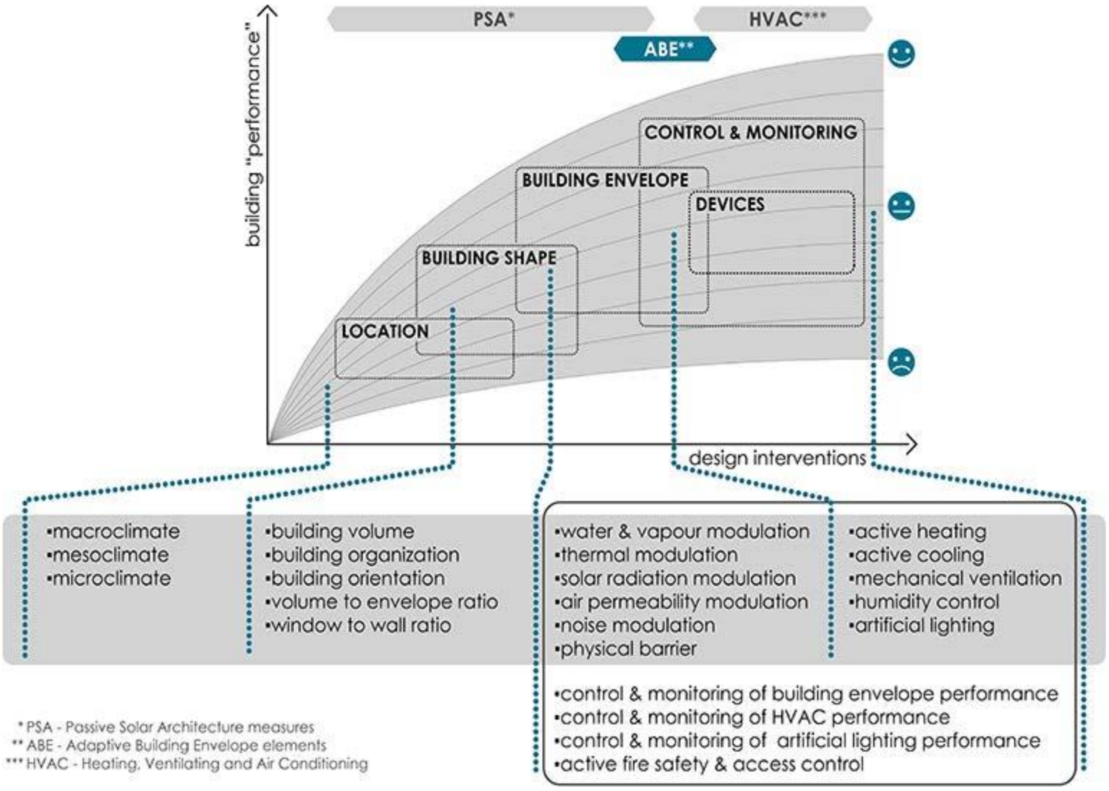


Figure 3: Adaptive Building Envelope (Drahansky et al., 2016)

- **Building Geometry**

The possibilities of vertical and horizontal openings are determined by the building's shape. It also controls how much of the floor area will be illuminated by natural light. With a variation of glazing areas and orientations, the shape of the buildings has an impact on energy usage. (Simulation, 2011).

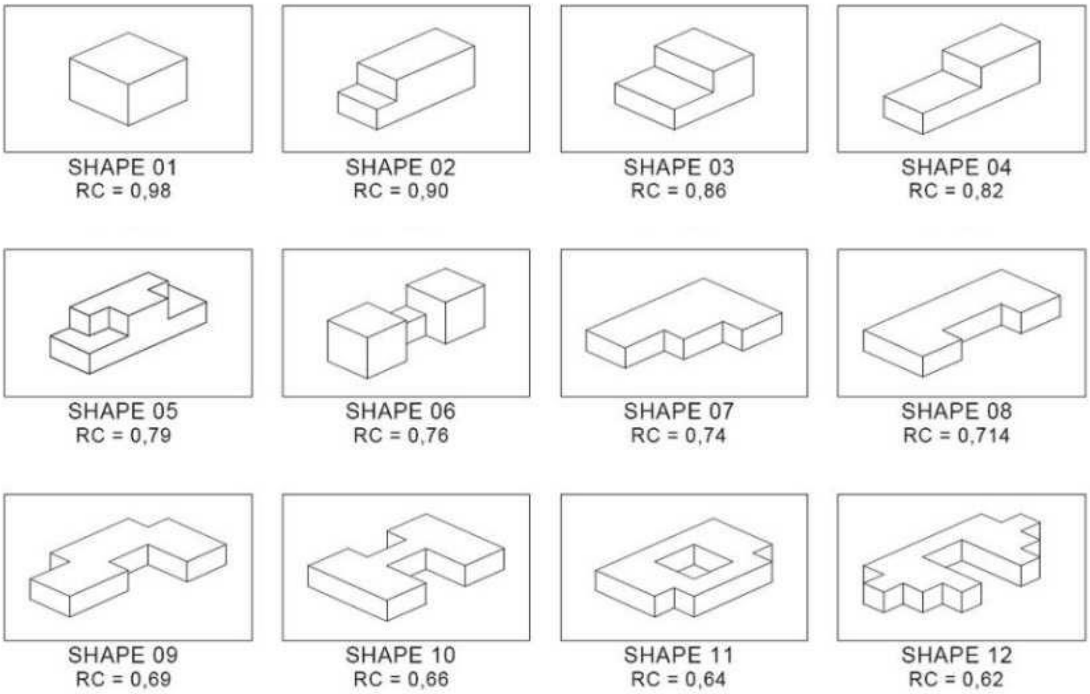


Figure 4: Different building shapes (Simulation, 2011)

- **Orientation**

The proper orientation of the building is the design starts for a good day. The amount of solar radiation falling on the surfaces of different orientations varies considerably depending on the view or exposure to the sun (Nick Gromicko and Rob London, 2006).

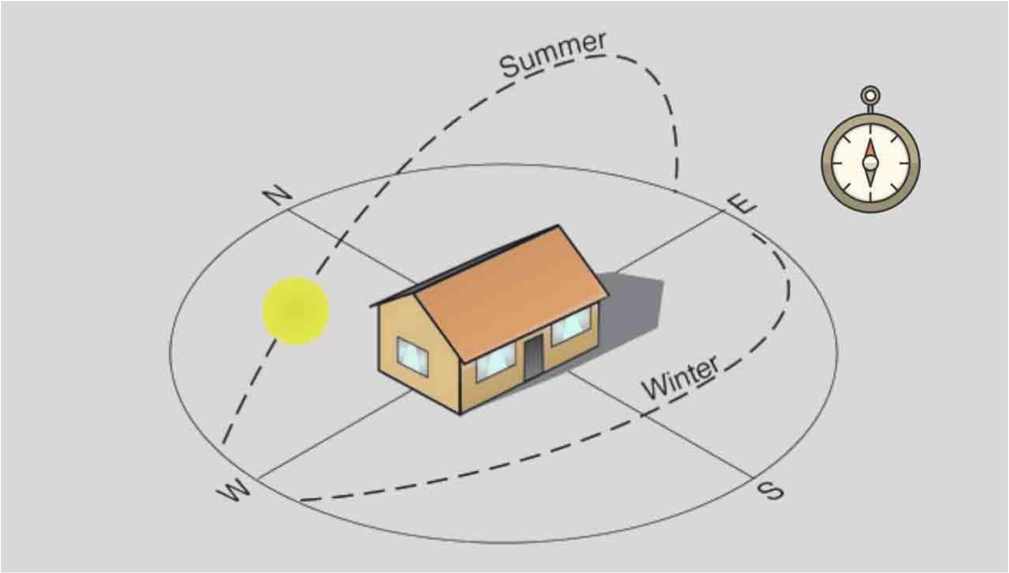


Figure 5: Showing Building Orientation for optimum Day Lighting (Now, n.d.)

At the building level, orientation is considered as per the surrounding built form. Orientation may affect the daylight factor, increasing the reflected radiation component and thus overshadowing and diverting winds. Orienting the majority of the glazing north-south and minimizing east west-facing glass helps to control the use of external window treatment strategies (Now, n.d.).

- **South orientation:**

  Since the solar radiation received in this façade is easily adjustable, it is ideal for daylighting. The building's south façade is the best as it absorbs the steadiest sunlight throughout the day and year.

- **North orientation:**

  Due to the obvious stability of the light, the north is the second-best orientation for daylighting. Although the quantity of north light is low, the quality is excellent.

- **East & West orientation:**

  These are the worst orientations since they only receive half of the day's sunlight, which is difficult to control. Summer, rather than winter, has the most sunlight. The sun is low in the sky from the east and west, causing severe glare issues.

- **Measurements/Dimensions**

The ratio of total floor area, numbers of the floors, floor height are the measurements of buildings that affect the daylight factor. The window area, also known as the window-to-wall ratio (WWR), is an important factor that influences a building's energy efficiency. (Troup et al., 2019).

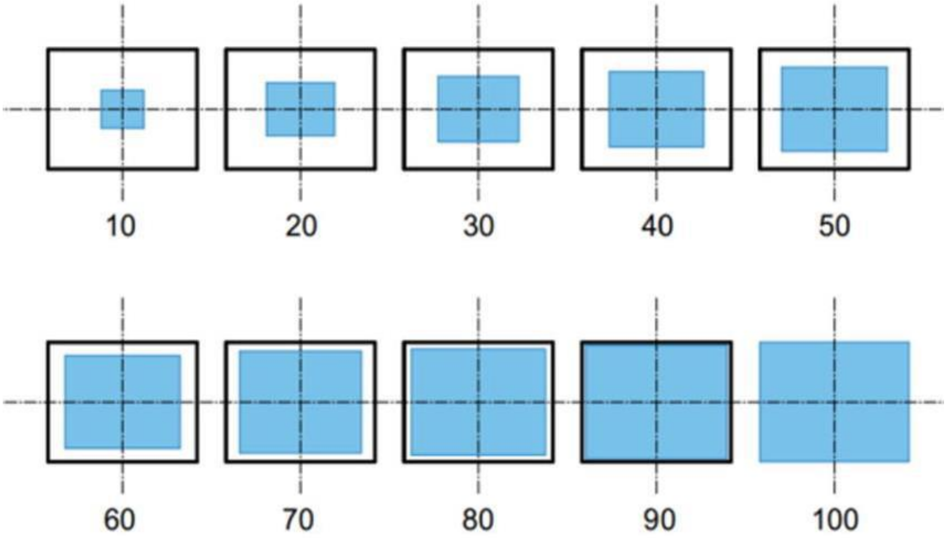


Figure 6: Glazing to wall ratio examined by (Alwetaishi, 2019)

The window-wall ratio is the percentage area calculated by dividing the total glass area of a building by the exterior envelope wall area. Window area will determine the building's heating, cooling, lighting, and how it interacts with the natural environment in terms of daylight, ventilation, and sights. (Alwetaishi, 2019).

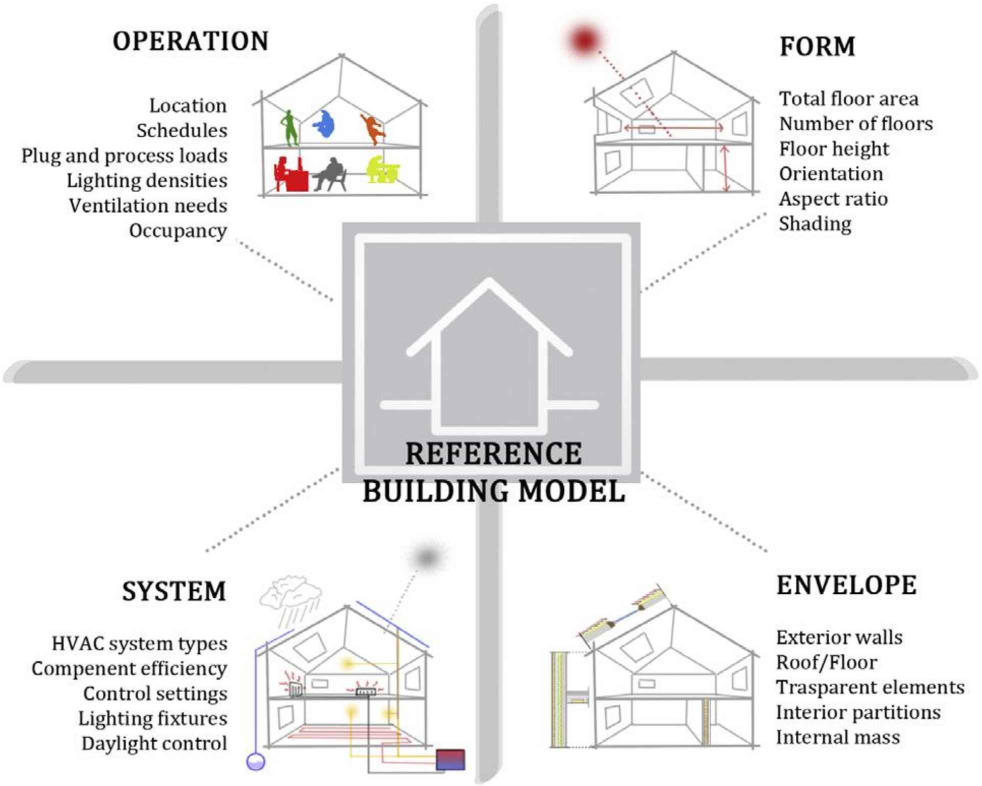


Figure 7: Showing Measurements and physical dimensions (Corgnati et al., 2013).

- **Durability**

Durable materials and little supplementary finishes (particularly glued rather than mechanically fastened finishes) can go a long way toward ensuring the building's durability; durable materials don't need to be scraped out and replaced nearly as frequently. (Guy, 2015). Durable materials can also possibly have another life if mechanically affixed (Figure 8). They also require less maintenance over the duration of the building's life, lowering operating expenses. They can also better withstand the forces of nature, enhancing their endurance. Taking climate change into account when considering durability; excessive heat and other harsh conditions may alter your perception of what is "durable." (Adaptability, n.d.)."

Figure 8: Dixon Water Foundation Josey Pavilion is constructed using durable materials(Adaptability, n.d.)

- **Internal Layout**

The interior design is built on providing the occupant with a healthy, social, and high-quality lifestyle. The internal layout of the design can lower the energy requirements of buildings. The need for heating energy can be decreased by making the most of the sun's radiation. (Delzendeh et al., 2017). These communal rooms require better heating, whereas places with a lower heating demand, such as the pantry, bathroom, and toilet, can be utilized as buffer areas, minimizing heat transfer to the external by positioning them in heat loss areas. By accumulating solar radiation, spaces such as sunrooms on the south facades of buildings contribute to the building's heating and energy savings. (Yüksek; I.; & Karadayi; T. T, n.d.).

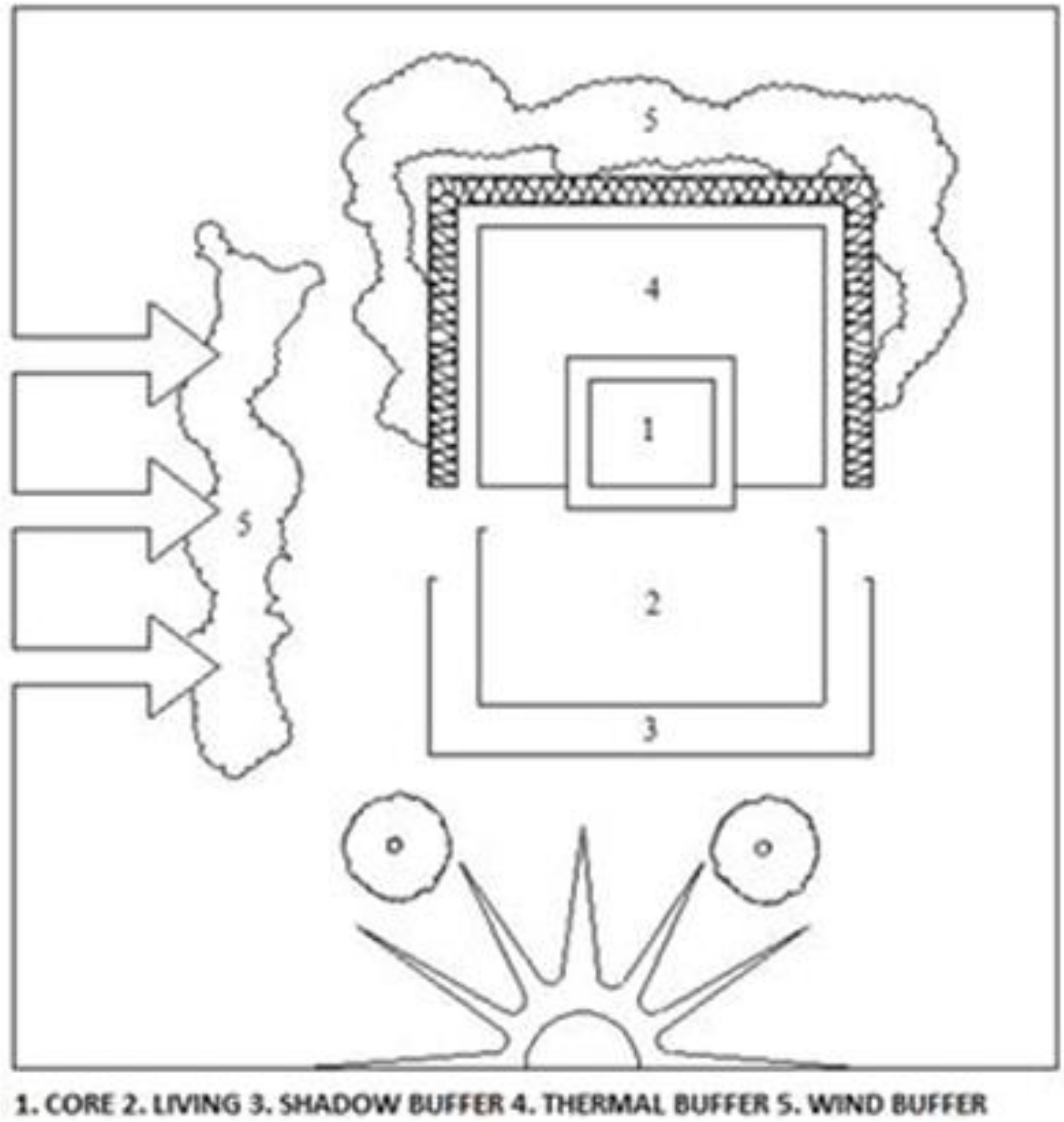


Figure 9: Spatial Zoning (Yüksek; I.; & Karadayi; T. T, n.d.)

- **Building Envelope**

The building envelope, which comprises walls, windows, doors, roofs, and floor surfaces, is made up of structural materials and finishes that enclose space and separate inside from outside (Shinde et al., 2013). Green building envelopes differ from conventional building envelopes in that they strive to achieve a broader range of goals and work differently. The following are some of the characteristics of green building envelopes (Gibberd, 2014):

– **Responsive:** Green building envelopes are designed to respond to their local context and work with external and internal conditions to achieve optimum environments within and around the building. For example, in areas that receive noise from external environments and have strong visual and physical connections (through balconies, windows, and external doors) where external light and thermal conditions support human comfort, the building envelope may have additional acoustic treatment (Gibberd, 2014).

– **Dynamic:** Green building envelopes are dynamic and react to changing conditions in order to maintain optimal conditions. In order to reduce undesired heat gains, more of the building envelope may be shaded in the summer than in the winter. In the winter, the envelope may allow more sunshine into the building than in the summer, allowing the building to warm up. (Gibberd, 2014).

– **Controllable:** In most green buildings, providing users with more control over their surroundings is a key technique. As a result, building envelopes are likely to contain a significant number of moveable windows that occupants may easily open and close. They may also include external solar screening and controlled internal blinds, which can be used to improve internal daylight quality while reducing glare and solar gain. Providing users with greater control over local environments is a central strategy in most green buildings. Building envelopes, therefore, are likely to have large numbers of operable windows that can be easily opened and closed by occupants. They may also have controllable internal blinds and external solar shading which can be used to maximize internal daylight quality and avoid glare and solar gain (Gibberd, 2014).

- **Ecological:** Green building envelopes strive to assist the growth of ecosystems and plant and animal life around the building, and the roof and balconies can be planted to provide habitat for creatures such as birds. (Gibberd, 2014).

- **Breathing walls:** Green building designers frequently strive for the same performance qualities seen in good outdoor apparel. The building envelope's outermost covering, like a raincoat or an umbrella, protects against the elements such as wind and rain. Warmth and thermal insulation are provided by the middle layer, which includes shirts and jerseys. The inner layer, similar to a vest, is soft to the touch and wicks away perspiration. (Gibberd, 2014).

- **Microclimate:** The building envelope is utilized to encourage the growth of local microclimates. As a result, envelopes can be employed to create sheltered, sunny amenity zones for building inhabitants. They can also be used to create shaded, vegetated spaces where cool, fresh air can be pulled inside the building. (Gibberd, 2014).

- **Energy:** Building envelopes offer excellent prospects for generating renewable energy for use in the structure. Photovoltaic and solar water heating panels, as well as wind turbines, are used to accomplish this. These are best integrated with the building envelope design to increase the building's aesthetic quality and reduce material requirements. (Gibberd, 2014).

- **Services**

Building services play an important role in the design of a building, not only in terms of overall strategies and standards to be met, but also in terms of fenestration engineering, the weights, sizes, and locations of major plant and equipment, the position of vertical service risers, horizontal service distribution routes, drainage, energy sources, sustainability, and so on (National & Pillars, n.d.). The systems installed in buildings to make them comfortable, functional, efficient, and safe are known as building services. It refers to any system or piece of equipment in a structure that makes the space more pleasant and secure. Building services assist in the creation of environments where people can live and work with the least amount of environmental effect feasible (Yoko, 2019).

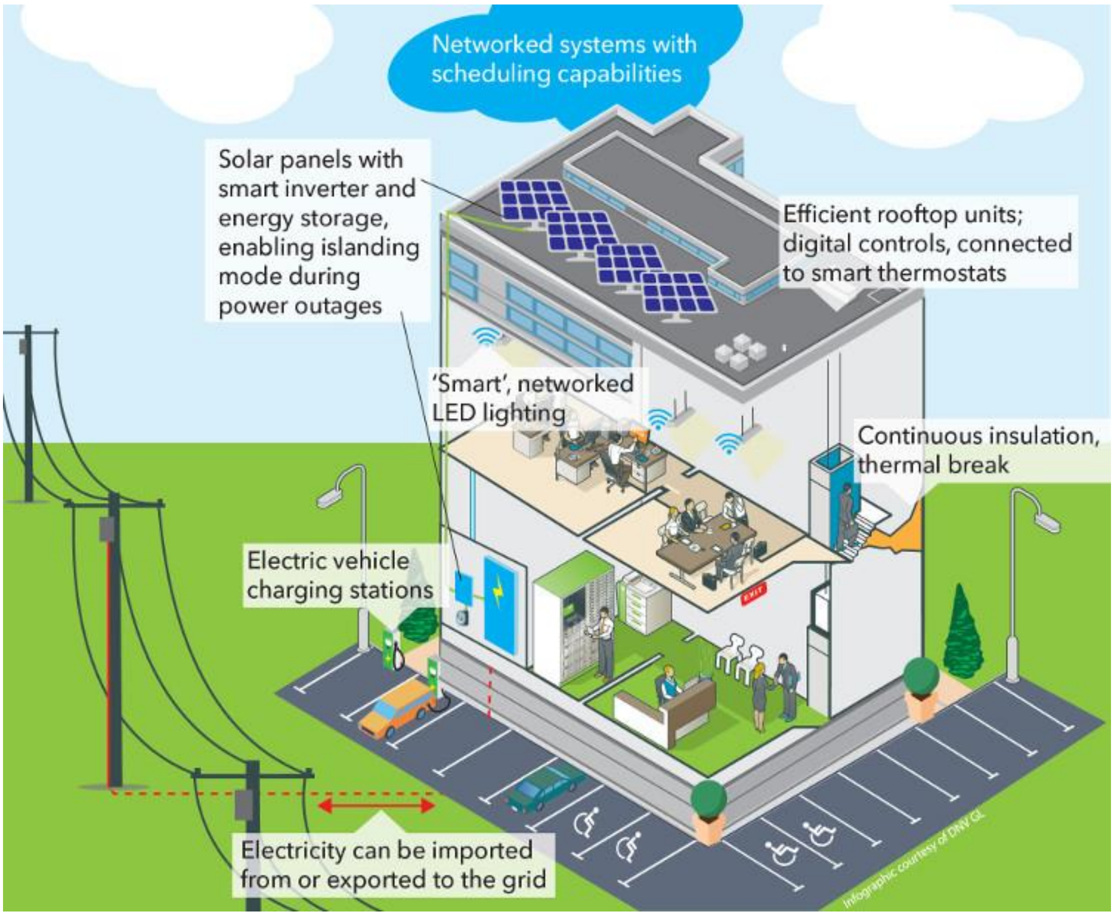


Figure 10: Showing building Services (Yoko, 2019)

2.2.2 Functional Attributes of Buildings

Functional attributes are the characteristic of the interior spaces, including space utilization, weathering & durability, thermal comfort, lighting & acoustics and items which defines the functional performance. Internally, the indoor living (thermal) environment demonstrates the constructed form's ability to sustain a favourable and productive atmosphere in reaction to exterior climatic circumstances (Aysha & Mani, 2017).

- **Thermal Performance**

Heat gains or losses through various structural elements such as walls, windows, and floors, internal heat loads, and rate of ventilation are all aspects that influence the thermal performance of office buildings (Aye et al., 2006). The thermal performance of a building is determined by its ability to resist air penetration and inhibit heat exchange across the structure, according to the Joseph Rowntree Housing Trust (JRHT) (El-Darwish & Gomaa, 2017). Figure 11: The heat flow of an un-insulated cool-climate building is depicted.

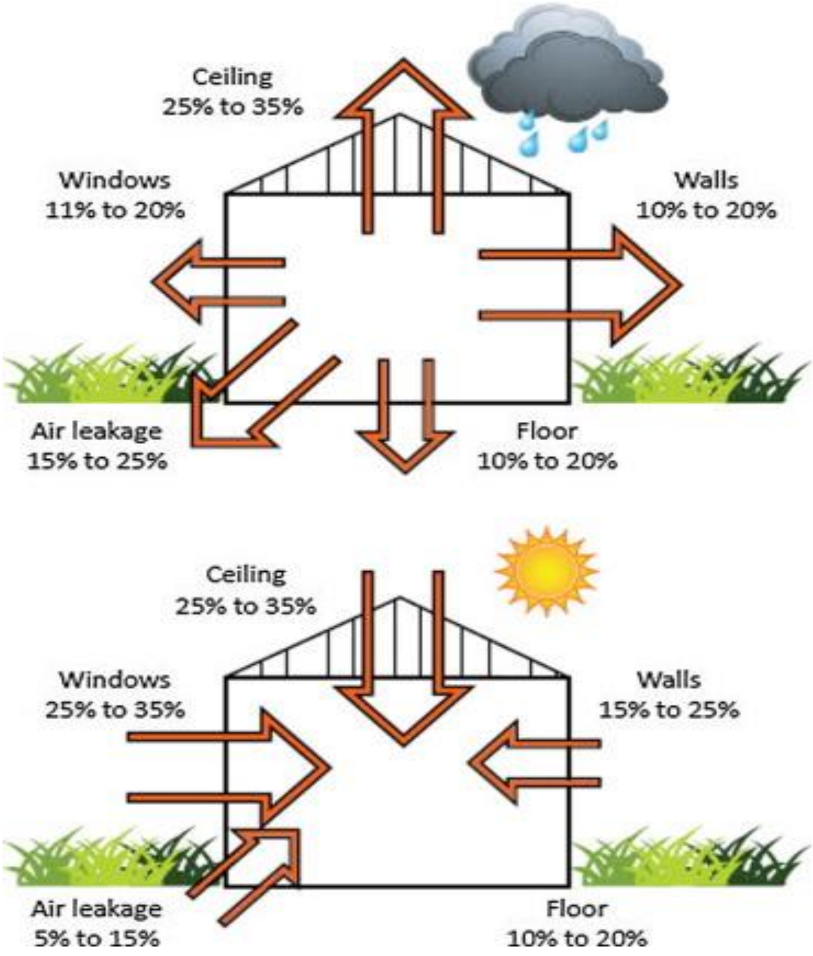
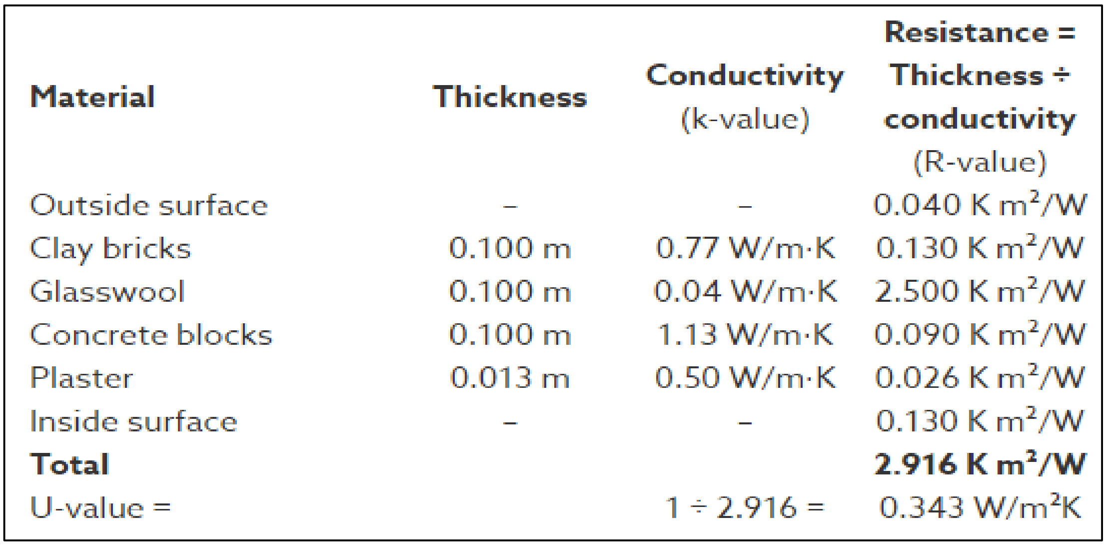


Figure 11: Thermal Performance in Building (El-Darwish & Gomaa, 2017)

In a study by Farmer et al. on off-the-shelf solutions to the retrofit challenge, specifically on thermal performance, it was discovered that with proper attention to detail in design, specification, and installation, off-the-shelf thermal upgrade measures can achieve the anticipated reduction in U-values, and thus can significantly reduce space heat requirements and CO2 emissions (El-Darwish & Gomaa, 2017).

U-Value – The rate of heat transfers through a structure (which can be a single material or a composite) divided by the temperature differential across that structure is known as thermal transmittance, also known as U-value. W/m2K is the unit of measurement. (El-Darwish & Gomaa, 2017). Simple U-value calculations can be done in the following manner, by layering the structure of the building element. However, this does not account for cold bridging (for example, by wall ties), air gaps surrounding insulation, or the varying thermal characteristics of different types of mortar joints. A cavity wall is used in this scenario (Anthony Lymath, n.d.):

Table 1: U-Value of materials (Anthony Lymath, n.d.)



Material	**Thickness**	**Conductivity** (k-value)	**Resistance = Thickness ÷ conductivity** (R-value)
Outside surface	–	–	0.040 K m^2/W
Clay bricks	0.100 m	0.77 W/m·K	0.130 K m^2/W
Glasswool	0.100 m	0.04 W/m·K	2.500 K m^2/W
Concrete blocks	0.100 m	1.13 W/m·K	0.090 K m^2/W
Plaster	0.013 m	0.50 W/m·K	0.026 K m^2/W
Inside surface	–	–	0.130 K m^2/W
Total			**2.916 K m^2/W**
U-value =		1 ÷ 2.916 =	0.343 W/m^2K

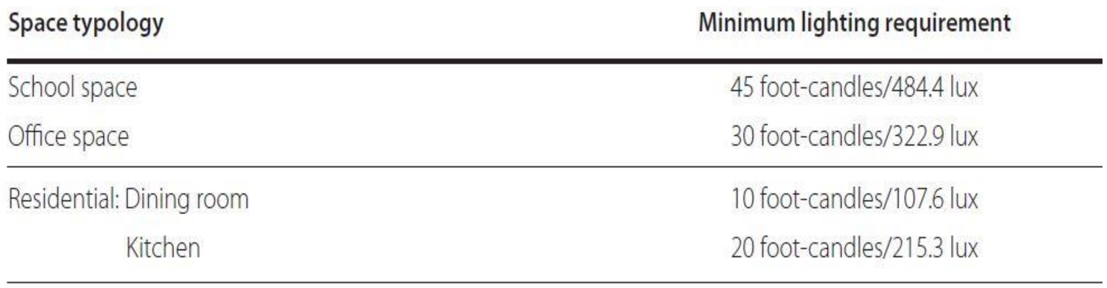
- **Acoustics**

Today's comfortable atmosphere entails more than just warmth and security. Noise pollution from cities, planes, and automobiles can have an impact on our level of comfort, productivity, and sleep. As a result, acoustics is a crucial structural factor to consider (Drechsler et al., 2009). Many of today's plastic foams are not only excellent insulators, sealants, and vapour barriers, but they can also be used for sound absorption and noise control. Insulation, an air barrier, and sound control can all be achieved with a low-density SPF (Drechsler et al., 2009).

- **Lighting**

The lighting system alone accounts for about 15% of the total energy demand of the structure (Chuck, 2010). Light levels are higher than necessary in 50 to 60% of work locations. Time scheduling, occupancy sensors, and light-level adjustments for daylight dimming can all be controlled with electronics. Daylighting can also be controlled in excessively illuminated areas by using automatically controlled blinds and window coverings on all solar exposed windows (Tech & Management, 2020).

Varied places require different illumination, therefore it's crucial to assess the requirements for residential, commercial, and work environments. As indicated in Figure 12, the US Occupational Health and Safety Administration (OSHA) has established minimum illumination criteria (Ochs et al., 2015).



Space typology	Minimum lighting requirement
School space	45 foot-candles/484.4 lux
Office space	30 foot-candles/322.9 lux
Residential: Dining room	10 foot-candles/107.6 lux
Kitchen	20 foot-candles/215.3 lux

Figure 12: Minimum Lighting Requirements (Ochs et al., 2015)

- **Fire Protection**

Buildings should be designed such that occupants may evacuate on their own in the event of a fire (Paulo & Brazil, 1993). A wide range of connected design and use issues must be considered in order to offer a sufficient level of fire safety in buildings and other structures. The safe installation and use of heat-producing and energy-consuming devices, as well as the safe performance of actions that may include the risk of igniting, are critical components of this system (Paulo & Brazil, 1993). Fire extinguishers, fire hose reels, fire hydrants, hydrant valves, fire blankets, automatic fire detection and alarm systems, automatic fire sprinkler systems, and emergency warning and intercommunication systems are all examples of fire protection systems.

- **Occupant Comfort**

The thermal interaction of human bodies with the environment is influenced by a variety of factors, including (Aye et al., 2006):

- The air in the surrounding (air temperature, air velocity and relative humidity)
- The immediate environment's surfaces (mean radiant temperature)
- Heat loss due to evaporation (from skin), Inhalation and Exhalation (sensible heat loss and evaporative heat loss due to respiration)
- Surface that is exposed (temperature of clothing surface, intrinsic clothing thermal efficiency, and emissivity)
- Clothes (clothing and change due to clothing)
- Sweat (saturated water vapour pressure at skin temperature and moisture)
- Skin (skin temperature, surface area of nude body and sensible heat loss)

2.3 Green Buildings

A green or sustainable building is one that, due to its design and features, can help to preserve or improve the quality of life in the area where it is located. Green Building is a term used to describe a structure that is ecologically responsible and resource-efficient throughout its life cycle, from site selection to design, construction, operation, maintenance, renovation, and demolition (Shinde et al., 2013).

A green building uses design strategies, materials, and technologies to reduce its total environmental and human health implications. Better siting, design, material selection, building, maintenance, removal, and possible reuse are all ways to achieve this. The major consequences are less site disruption, lower fossil fuel consumption, lower water consumption, and fewer pollutants utilized and discharged throughout the building's construction, occupancy, and disposal (The Economic and Social Commission for Asia and the Pacific, 2012).

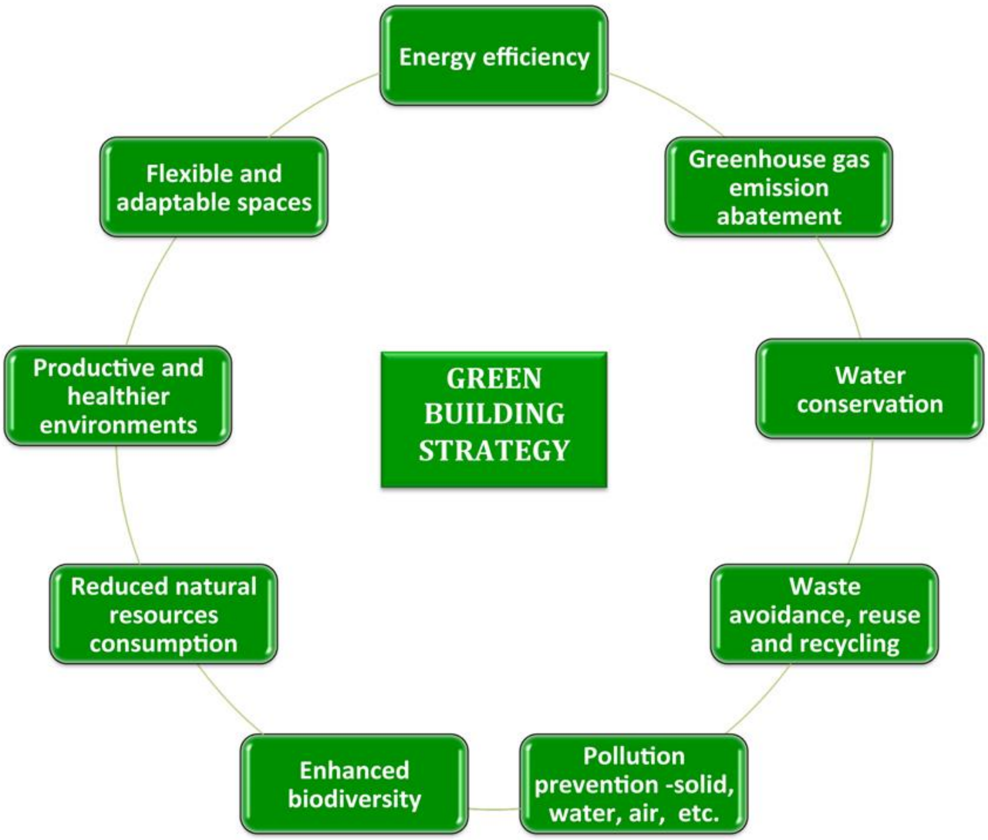


Figure 13: Green building strategy (Source: (The Economic and Social Commission for Asia and the Pacific, 2012))

The terms "energy-efficient" and "high performance" buildings refer to energy efficiency specifically, whereas "green" buildings refer to a building's overall environmental considerations, including energy efficiency. Energy price volatility and the negative effects of climate change make Asian and Pacific countries susceptible (The Economic and Social Commission for Asia and the Pacific, 2012).

2.3.1 Characteristics of Green Buildings

Superior air quality, plentiful natural light, access to views, and noise management are all features of green buildings that benefit building occupants, making them better places to work or live. The lot design and development efficiency, energy and water efficiency, resource efficiency, indoor environmental quality, and the building's total influence on the environment are the primary aspects taken into account (Building, 2019).

In practically all green building programs, energy efficiency is one of the most critical components. The use of clean energy-powered heating/cooling systems, careful window selection, building envelope air sealing, duct sealing, adequate placement of air and vapour barriers, and the use of energy-efficient heating/cooling systems all contribute to an energy-efficient structure. The utilization of renewable energy to meet energy needs, such as solar, wind, or biomass energy, can greatly lower the carbon footprint of such structures (Building, 2019).

Green buildings help to reduce building-related environmental consequences while also generating healthier and more pleasurable environments for people. Throughout its life cycle, these are designed to save energy and resources, recycle materials, and reduce harmful substance emissions (Bhatia, 2014).

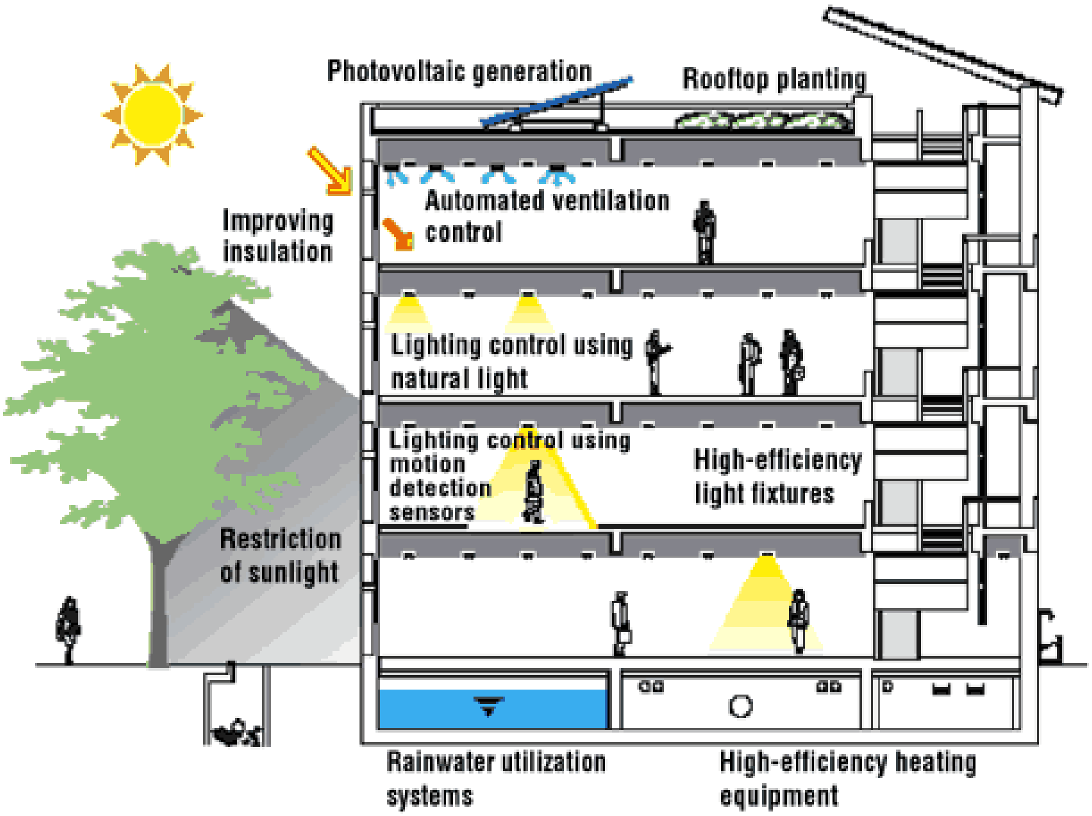


Figure 14: Features of Green Buildings (Building, 2019)

Green building's major goal is to harmonize with the local climate, traditions, culture, and environment so that it can sustain and improve human existence while also sustaining the ecosystem's capacity on a local and global scale. The other performance goals are listed in the table below:

Table 2: Performance objectives for green building envelopes (Gibberd, 2014)

Aspect	**Performance Objective**
Daylight	The building envelope is designed to provide an average daylight factor (DF) of 2.5 per cent in all inhabited (living and working) portions of the building.
Ventilation	The building's architecture allows for natural ventilation of the spaces. Natural ventilation is given by a minimum openable space of at least 5% of the internal floor area within the external envelope.
Sunlight	In-office environments, direct sunlight is avoided, especially where VDUs are employed. Sunlight is only permitted into the building if it is used as part of a direct gain passive solar approach that helps to warm the building during the winter.
Airtightness	The building envelope is airtight to prevent undesired cold or hot air from infiltrating the structure. Airtightness criteria are higher than SANS 204's minimal requirements.
Noise	Internal noise levels do not exceed good practice guidelines, and there is no obtrusive external noise from traffic or other sources (i.e. ambient sound levels do not exceed 45dBAeq in open-plan offices)
Habitat and vegetation	Vegetation covers at least 10% of the external building envelope. Green roofs, window boxes, planted terraces and balconies, and wall creepers can all help with this. This is also utilized to help in animal habitat creation.
Thermal comfort	The envelope is designed to meet best-practice internal thermal comfort levels, as defined by ISO Standard 7730, Ergonomics of the Thermal Environment, and quantified using the Predicted Mean Vote.

Energy	The building envelope contributes to an overall integrated design strategy that meets good practice energy consumption targets and notably exceeds SANS 204 minimum energy efficiency standards (SABS, 2011).
Car parking	Natural ventilation is provided in all covered car parking areas.
Renewable energy	Renewable energy generation such as photovoltaic, wind turbines, and solar water heaters are included in the building envelope, and these sources provide 10% of the building's energy requirements.
Views	Every working space is within 7 meters of a window with a direct view of the outside.
East and West elevations	To reduce undesirable solar gain, windows on the east and west elevations are minimized, and suitable solar shade is given where it exists.
Openable windows	Openable windows are installed in locations where they may be easily operated by anyone in the vicinity. In occupied areas, at least one openable window per 5 running meters of the building envelope is provided.
Internal blinds	Internal blinds are installed on all windows in working areas.
Rainwater harvesting	Roofs are utilized to gather rainwater, and a goal of a 50% reduction in mains potable water consumption (compared to conventional buildings) is accomplished.
Cool roofs	To avoid undesired heat gains, roofs, big exterior balconies and terraces, and large external balconies and terraces are constructed of a material with an absorptance value of less than 0.55 (are light-colored).
Insulation	The building's insulation levels are higher than the SANS 204 minimum criteria .
Passive environmental control	By providing suitably distributed and proportioned openings, thermal mass, and other features, the building envelopes support passive environmental control solutions.

- **Integrated Design Approach**

Green building covers a broad range of issues, not just on the material level, but also on the cultural, economic, and spiritual levels. Not only must natural lighting, solar power generation, sewage recycling, and other variables be considered in green building design, but also the natural integration of the building and the surrounding environment concerning man and nature, among other expects (Wang & Zhang, 2016).

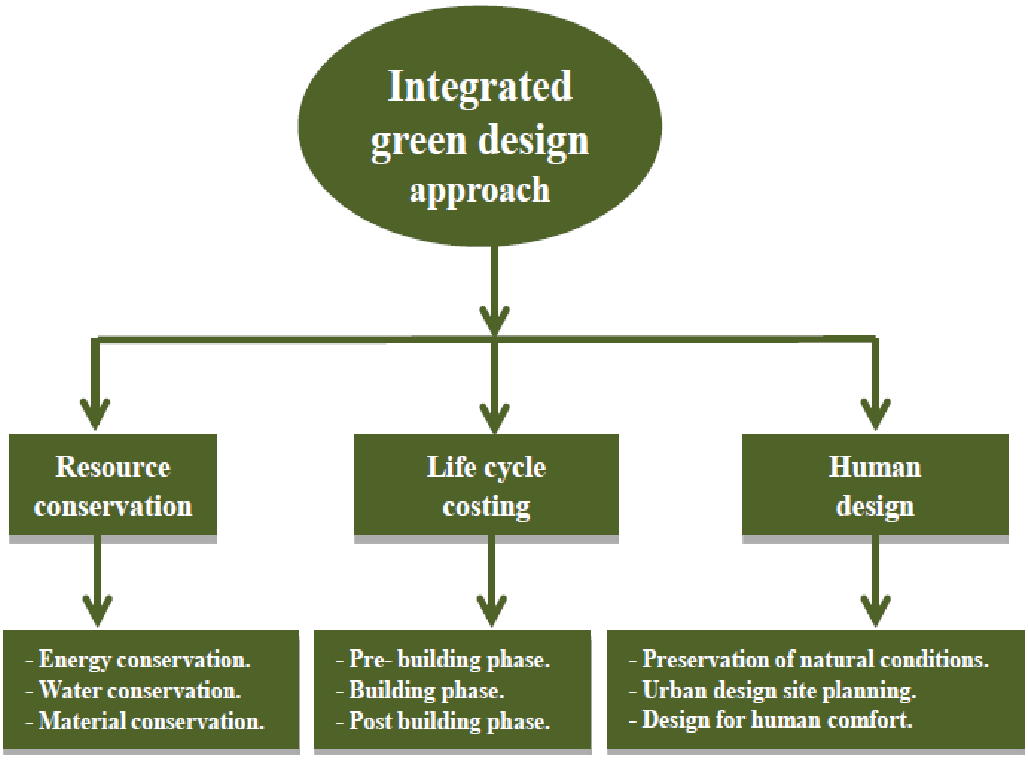
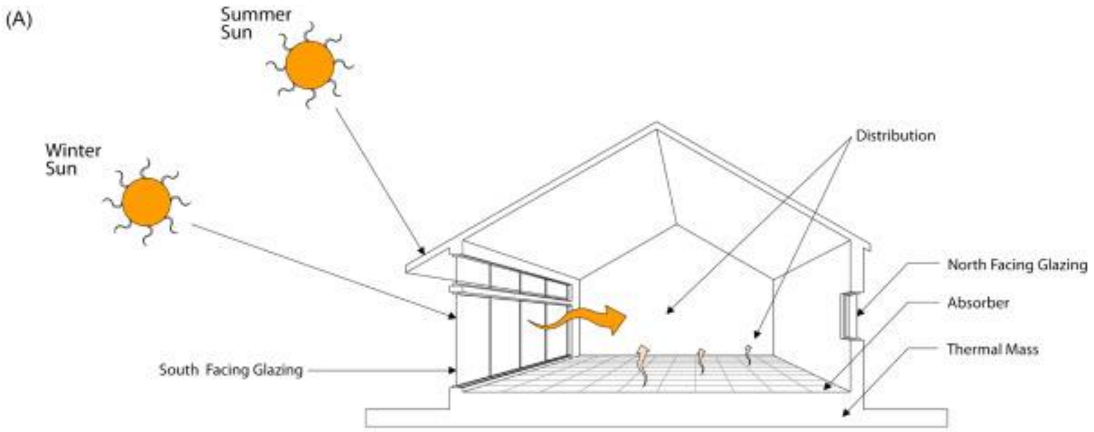


Figure 15: Integrated Design Approach (Badawy et al., 2021)

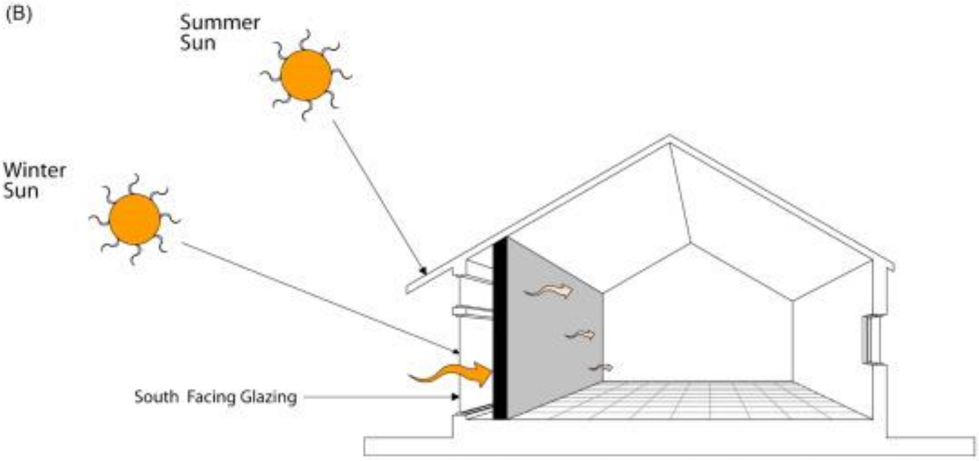
- **Passive and Active design**

A system or structure that uses natural energy such as sunshine, wind, temperature variations, or gravity to achieve a result without the need for power or fuel using the basic elements of the design such as insulation, airtightness, natural light, solar gain and solar ventilation is known as passive design (Kumar, 2014). The integration of principles of good passive design in building suitable for climate effectively locks in thermal comfort, suitable daylighting and reduced greenhouse gas emissions

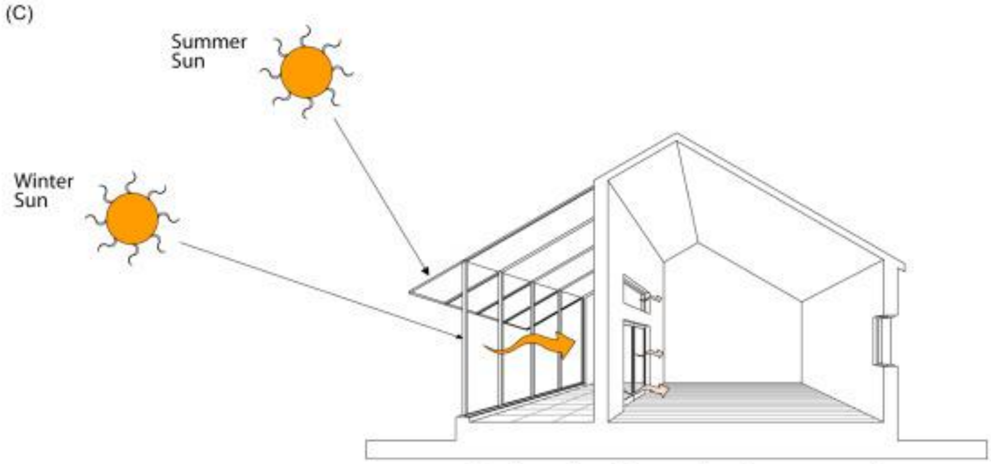
(Heckeroth & McLees, 1994). The passive design needs active users who makes effort to regulate adjustable shading, open windows as per needs etc. (Mahar et al., 2020).



Direct solar gain



Indirect solar gain (Tormbe wall)



Isolated solar gain (sunspace)

Figure 16: Passive Space Heating (Guedes, 2013)

A system or structure that uses or produces electricity is known as active design. Because they require electricity, most products and infrastructure have an active design. Solar panels, Wind turbines, district heating, etc. are some of the examples of active design (Chel & Kaushik, 2018).

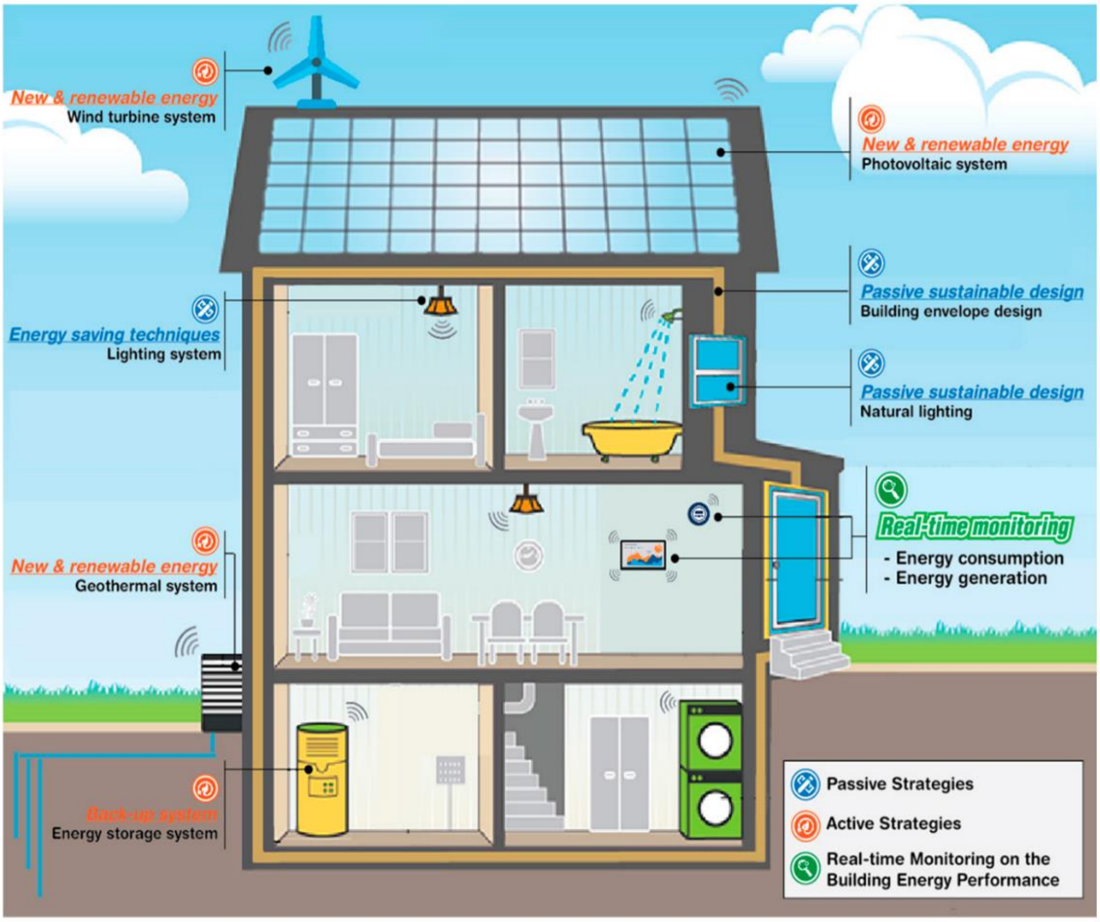


Figure 17: Active and Passive design in building (Oh et al., 2017)

Passive solar buildings with proper design and construction offer various advantages to building owners and occupants, including (Shinde et al., 2013):

-**Energy Efficiency:** Lower your energy bills all year long.

-**Investment:** On a life-cycle cost basis, a high economic return on incremental investment and increased financial freedom from future increases in energy costs. These factors can contribute to improved tenant retention and satisfaction, as well as increased building value and reduced risk.

-**Comfort:** Greater thermal comfort, less reliance on loud mechanical systems, solid construction (more thermal mass), sunny interiors, and open floor patterns are all advantages.

- **Productivity:** Increasing daylighting, upgrading lighting systems, and reducing glare can boost worker productivity and lower absenteeism.

-**Low Maintenance:** Less reliance on mechanical systems means lower building maintenance expenses.

- **Environmental advantages:** include lower energy consumption and reliance on fossil fuels.

- **Materials and Resources Efficiency**

Choosing the appropriate items can make a big difference in terms of sustainability. Extraction, processing, and transportation are all processes in the material processing process that can damage the air and water and deplete natural resources. Using recycled or salvaged materials can assist reduce waste while choosing local or lightweight materials can help lessen transportation's environmental impact. (Michaelis, 2014).

- **Green Building Materials**

Lumber from forests that have been certified to a third-party forest standard, rapidly renewable plant materials like bamboo and straw, insulating concrete forms, dimension stone, recycled stone, recycled metal, and other non-toxic, reusable, renewable, and/or recyclable products (e.g. Linoleum, sheep wool, panels made from paper flakes, compressed earth block, adobe, baked earth, rammed earth, clay, etc.) are typically considered 'green' building materials. (Shiva J, 2011).

- **Energy Efficiency**

Green buildings frequently contain methods to reduce energy consumption - both the embodied energy necessary to extract, process, transport, and install building materials, as well as the operating energy required to supply services such as heating and equipment power. (Shoubi et al., 2015). High-efficiency windows and insulation in walls, ceilings, and floors boost the effectiveness of the building envelope, reducing operating energy use (the barrier between conditioned and unconditioned space) (Shiva J, 2011).

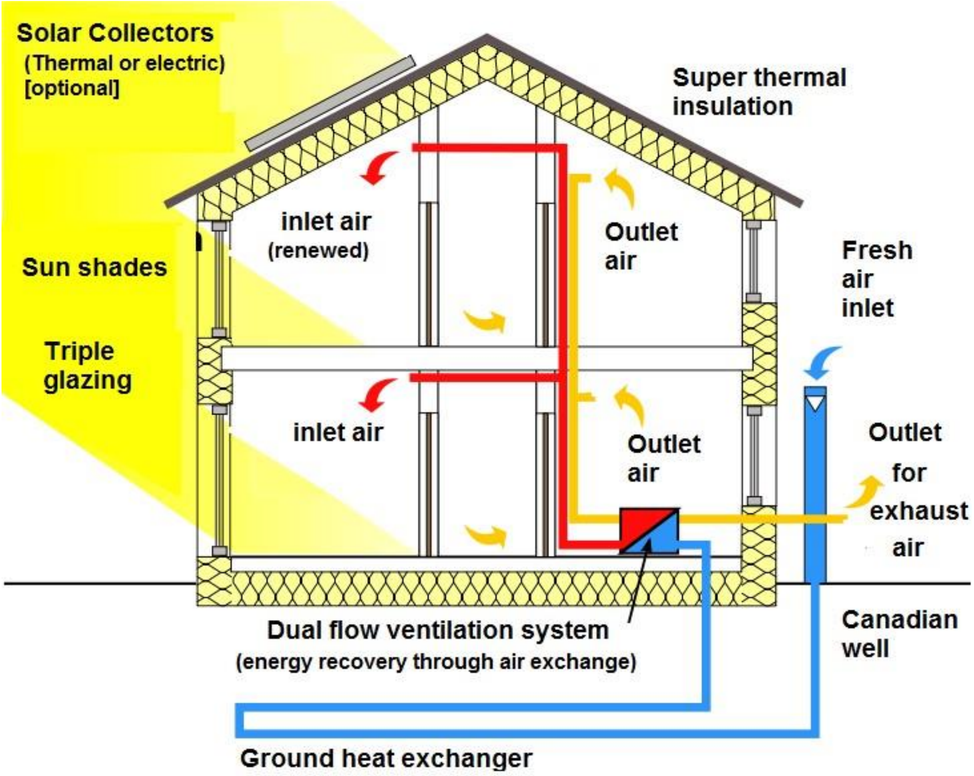


Figure 18: Reducing energy use through intelligent design (Source: pngegg.com)

The passive solar building design is another approach that is frequently used in low-energy buildings. Designers position awnings, porches, and trees to shade windows and roofs during the summer while optimizing solar gain during the winter. Furthermore, efficient window arrangement (daylighting) can give more natural light during the day and reduce the need for electric lighting. Solar water heating lowers energy bills even more (Shiva J, 2011).

2.3.2 Green Building Rating Systems

National efforts have been made to establish public or private voluntary green building rating systems with the goal of evaluating buildings against a set of performance criteria and recognizing better environmental performance. Rating programs like these help with the design. (The Economic and Social Commission for Asia and the Pacific, 2012)). To accomplish so, it is necessary to reach a high level of efficiency: lowering energy, water, and other resource use reduce pollution.

The British Building Research Establishment Environment Assessment Method, or BREEAN, was established in 1990, and it was the first of three major certification systems to emerge in the 1990s. In 1996, the French certification system, HQE (High Environmental Quality), was introduced (The Economic and Social Commission for Asia and the Pacific, 2012)). Perhaps the LEED certificate (Leadership in Energy and Environmental Design) developed by the United States Green Building Council (USGBC) in 1998 is the internationally recognized formal recognition that determines if a structure is worthy of being classified as sustainable (Bhatia, 2014).

Figure 19: LEED Rating Systems (USGBC, 2019)

LEED certification develops a scoring system based on many parts pertaining to design and construction, which we shall cover below, to evaluate a building's sustainability. (USGBC, 2019):

- **Sustainable sites: 26 points**

  Protect and preserve natural habitats, limit pollution and natural resource consumption, and make it easier to interact with environment.
- **Efficient use of water: 10 points**

  Lower the amount of water used during construction and create solutions to reduce the water footprint of the building.

- **Energy and atmosphere: 35 points**
  To reduce pollution, reduce energy consumption, use renewable energy, and improve energy efficiency.
- **Materials and resources: 14 points**
  During construction, incorporate recycling systems, use sustainable materials, and conserve as many resources as feasible.
- **Indoor environmental quality: 15 points**
  Consider the space's occupants' comfort, such as air quality, temperature control, and noise pollution.
- **Design innovation: 6 points**
  During construction, implement novel sustainability techniques.
- **Regional priority: 4 points**
  Achieve environmental, social equality, and public health gains in the area where it is located. (Bhatia, 2014).

2.4 Green Building and Climate Adaptable Buildings

Climate-responsive building elements, which refer to the responsiveness to internal and external climatic circumstances as well as occupant intervention, are those that particularly address the environmental condition. Buildings that adjust to climate change help to maintain a comfortable environment while also improving energy efficiency. (Looman, 2007). The use of these adaptable buildings reverts to the original combined role of a building structure to meet both the function it was established to offer comfort and the original combined role of a building structure to meet both the function it was created to provide comfort. As a result, an integrated building concept combining adaptive building elements with green building techniques and sustainable building systems for climate control could be a feasible design option for optimal performance on both comfort and energy issues (Looman, 2007).

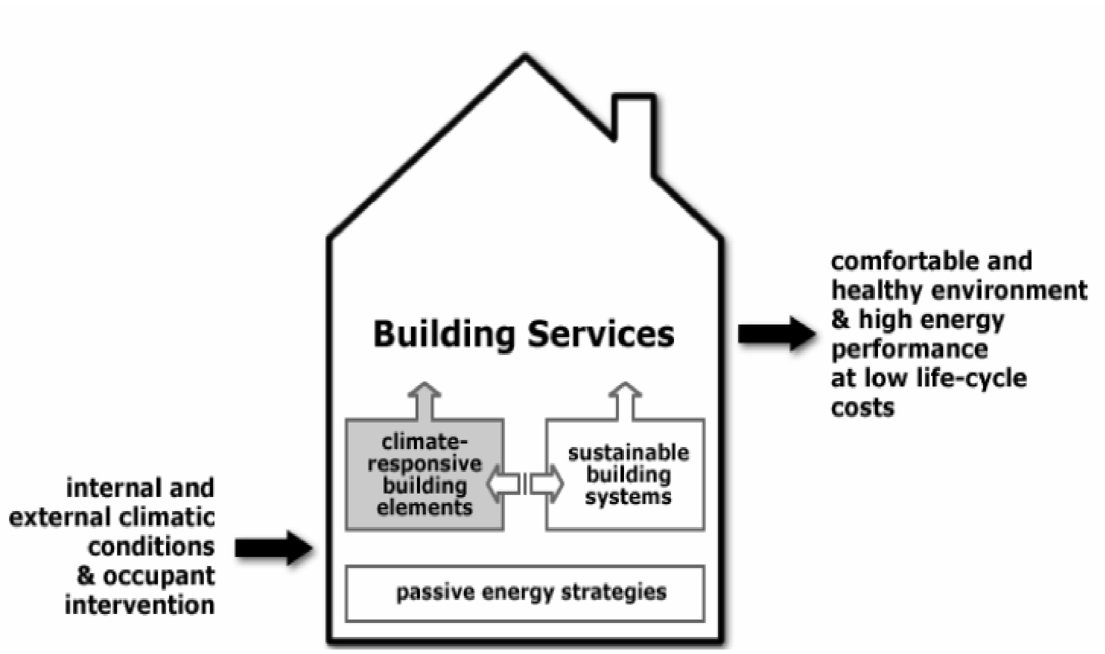


Figure 20: Integrated building concept (Source: (Looman, 2007)

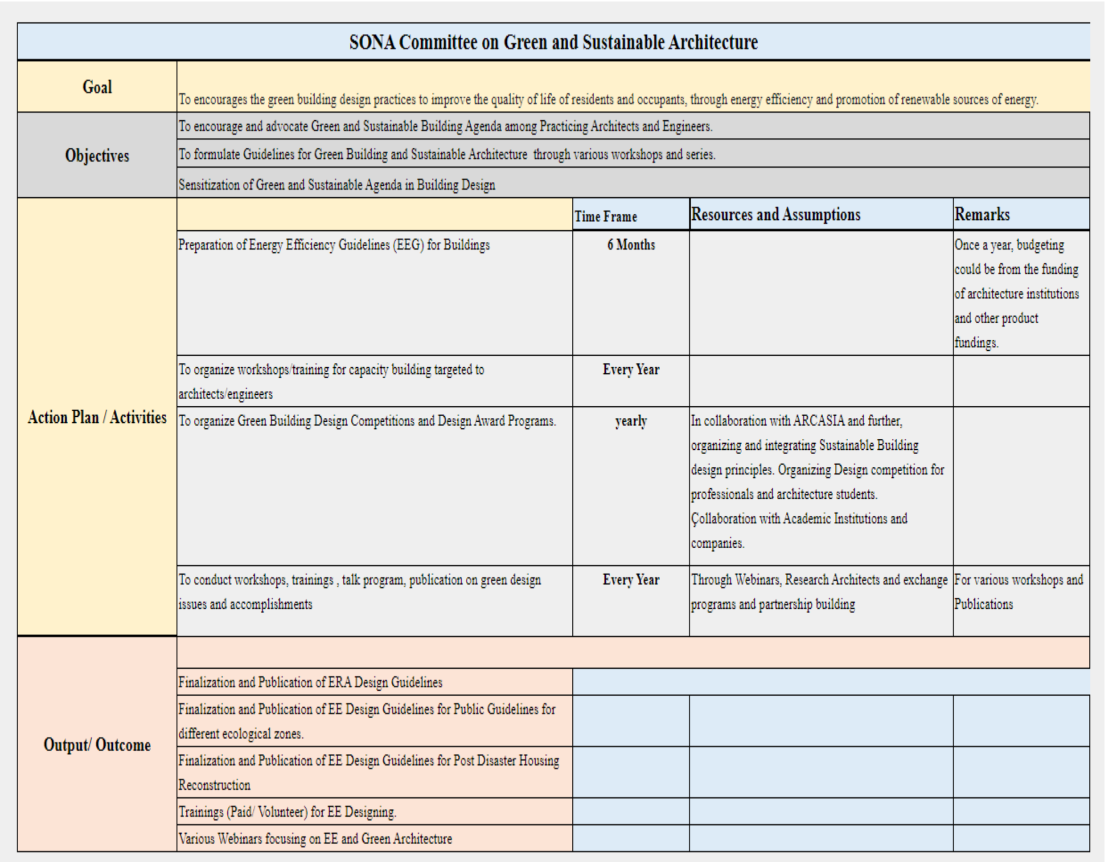
Green buildings are designed to address a variety of building components that emit greenhouse gases. Renewable energy generation, land cover change, energy efficiency, water use and treatment efficiency, eco-conscious materials, and interior environmental quality are some of the most important components and challenges (Tichaona Dande, 2018). As a result, the green buildings examined the correlation between energy efficiency and adaptability to climate change.

2.5 Green Buildings Practices in Nepal

2.5.1 SONA Committee on Green and Sustainable Architecture (SCGSA)

The SCGSA's mission is to promote and advocate for green and sustainable building initiatives among practising architects and engineers. For the years 2021 and 2022, the 14th SCGSA has set three goals, five objectives, and a list of activities. Its goal is to develop Green Building and Sustainable Architecture Guidelines through a series of workshops and lectures. Promotional, sensitization, and information dissemination efforts are also included (sona.org.np).

Table 3: Objectives of SCGSA



SONA Committee on Green and Sustainable Architecture				
Goal	To encourages the green building design practices to improve the quality of life of residents and occupants, through energy efficiency and promotion of renewable sources of energy.			
Objectives	To encourage and advocate Green and Sustainable Building Agenda among Practicing Architects and Engineers.			
	To formulate Guidelines for Green Building and Sustainable Architecture through various workshops and series.			
	Sensitization of Green and Sustainable Agenda in Building Design			
Action Plan / Activities		**Time Frame**	**Resources and Assumptions**	**Remarks**
	Preparation of Energy Efficiency Guidelines (EEG) for Buildings	**6 Months**		Once a year, budgeting could be from the funding of architecture institutions and other product fundings.
	To organize workshops/training for capacity building targeted to architects/engineers	**Every Year**		
	To organize Green Building Design Competitions and Design Award Programs.	**yearly**	In collaboration with ARCASIA and further, organizing and integrating Sustainable Building design principles. Organizing Design competition for professionals and architecture students. Çollaboration with Academic Institutions and companies.	
	To conduct workshops, trainings , talk program, publication on green design issues and accomplishments	**Every Year**	Through Webinars, Research Architects and exchange programs and partnership building	For various workshops and Publications
Output/ Outcome				
	Finalization and Publication of ERA Design Guidelines			
	Finalization and Publication of EE Design Guidelines for Public Guidelines for different ecological zones.			
	Finalization and Publication of EE Design Guidelines for Post Disaster Housing Reconstruction			
	Trainings (Paid/ Volunteer) for EE Designing.			
	Various Webinars focusing on EE and Green Architecture			

(SOURCE: sona.org.np)

2.5.2 UN-Habitat NEPAL

Green Homes Project was launched in Nepal by UN-Habitat with the backing of the European Union, with the goal of promoting sustainable housing concepts in Nepal. The concept of sustainable housing focuses on lowering the housing system's negative impact on natural resources and carbon emissions. Eco-friendly techniques help to reduce energy consumption in the housing sector while also helping to lessen the effects of global climate change, resulting in a healthier lifestyle. UN-Habitat and its implementing partners (Federation of Nepalese Chambers of Commerce and Industry (FNCCI) (Clean Energy Nepal (CEN), Environment and Public Health Organization (ENPHO), Institute of Housing and Urban Development Studies (IHS), and Shelter and Local Technology Development Center (SLTDC)) are working on the Green Homes Project (fncci.org).

The project's particular goals are to:

- Create an enabling policy environment for sustainable housing;
- Strengthen sustainable housing supply chains and build SMEs' capacity to deliver household-level green technologies and services.
- Boost demand for environmentally friendly housing.

Existing SMEs in Nepal's sustainable housing sector are lacking in technical and management expertise. Recognizing the relevance of SMEs' strength and capacity, UN-Habitat, in collaboration with FNCCI, is striving to develop the supply chain for sustainable housing products and services through the Green Homes Project (fncci.org).

Figure 21: Green Homes Model by UN habitat (fncci.org)

Green Home Projects Have Five Components:

- Passive Solar Design
- Energy Efficiency
- Waste Management
- Water Conservation
- Green Construction Materials

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Overview

The research methodology defines the activity of research, how it was proceeding, the progress measured and what institutes success (Noel). It defines how the data were collected in a research project. The proposed research is based on an inductive research approach. Moving from individual findings to bigger generalizations is how inductive inquiry works. This study uses both qualitative and quantitative methods of data collection for the study.

The research area will be observed and interpreted using a case study research strategy. Case study methodology helps to study in-depth and explore the reality. The area under research will be studied to obtain detailed information in the context of the physical and functional attributes of the building complex. This study will also identify adaptation practices of the green buildings in comparison with conventional types of buildings, which aids in making the climate adaptive buildings more climate-resilient.

3.2 Data Collection

The primary data collection includes field observation, interviews and surroundings of the selected area. A visual assessment of the existing scenario and discussions with the concerned person has been made. The drawings, reports and data related to selected buildings were collected. Visual inspection, analysis about the physical and functional attributes of the buildings like building elements, construction type, thermal and lighting systems, the surrounding settlements etc. were generally observed on the site.

Secondary Data collection is done for secondary information base maps, technical data, drawings, specifications and photographs were collected through related institutions and personnel. It includes a collection of published research materials, journals, articles, green building strategies, reports and papers from several websites and the concerned authorities.

3.3 Research Methodology

The research methodology involves three main phases. The first phase involves the study of a wide range of literature reviews through journal articles, conference papers, and books to provide a solid foundation for research findings. Likewise, the second phase is the study of the corporate buildings selected for this project in the context of their adaptive capacity. For these, the attributes of climate adaptable buildings have been studied through the designs and drawings of the buildings. The final phase includes data analysis and findings to conclude.

The proposed research is based on qualitative as well as quantitative processes which lie within the post-positivist paradigm. The process includes literature review, questionnaires survey and data analysis. The study also follows the correlation method since different design parameters will be correlated.

The study area is Hama Steel Complex, Butwal Power Company and Nepal Stock House inside Kathmandu Valley. Hama and BPC are considered iconic green building and has been listed in Leadership in Energy and Environmental Design (LEED) as they both attempted LEED strategies. First, a reconnaissance survey of the proposed area was conducted for the study of overall planning, design and construction, orientation and pattern, building materials used for efficient planning and other basic services of green building. Then an interview was carried out with a list of questions to study various parameters (Appendix I). The parameters will determine at which level is the study area resilient to cope with adaptation and what we are lacking in the construction process to achieve it. Finally, the third phase includes a desk study for the second time, this time using qualitative and quantitative methodologies to examine and assess the data from the first and second phase investigations. However, the research will identify the existing level of energy efficiency in the selected building and the potential of climate adaptive building.

A conceptual framework drawn for further methodology process is given below:

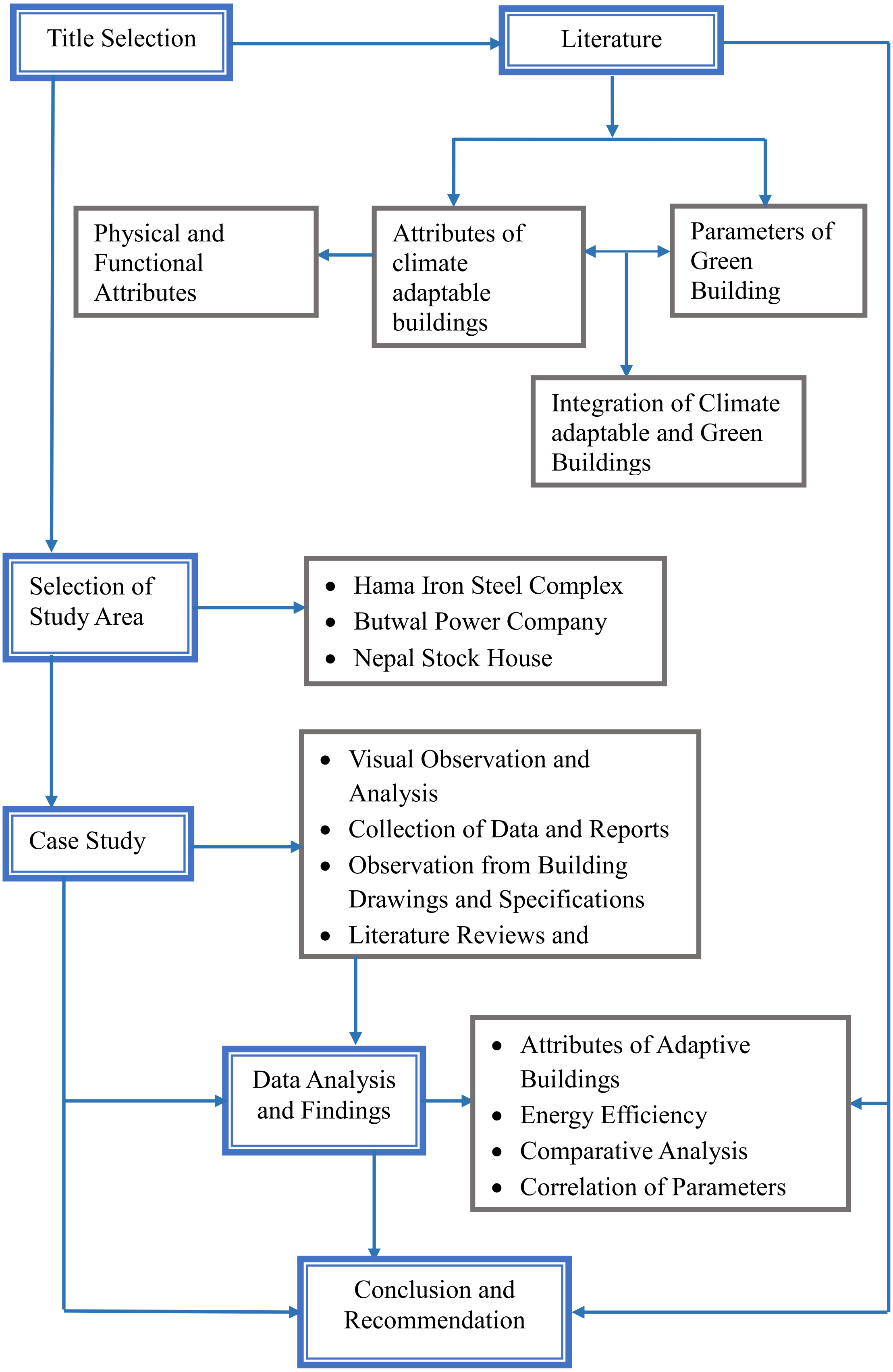


Figure 22: Theoretical Framework of Study

CHAPTER FOUR: CASE STUDY

4.1 Introduction

The concept of "green building" is gaining importance in a number of nations, including Nepal. According to experts in the field, these are buildings that certify that waste is eliminated at every stage of the building's construction and operation, resulting in lower costs. In Nepal, Many Architect follows LEED standards but have no certificate for the buildings. Nepal also has several codes to be monitored for building construction but doesn’t have any rating systems or mandatory for green constructions.

This paper aims to study the selected corporate buildings in the context of energy efficiency their climate adaptive capacity. The region for the research for the project is the Kathmandu Valley, the capital city of Nepal. For this corporate buildings **(Hama Iron Steel Complex)** located at Kamaladi, Kathmandu, **(Butwal Power Company)** located at Buddhanagar, Kathmandu and **(Nepal Stock House)** located at Kalikasthan, Kathmandu was selected. The building design and construction of Hama and BPC have followed the guidelines of LEED aiming at maximum use of renewable energy sources resulting in sustainability and adaptability with energy-efficient features. The main reason to choose these buildings as the case study is to demonstrate its efficient building features that are relatively better practised in the construction industry of Nepal.

4.2 Hama Iron Steel Complex

Project Details: **Hama Iron Steel Complex**
Location: Kamaladi, Ganesthan, Kathmandu
Consultant: Technical Interface Pvt. Ltd.
Chief Architect: Ar. Bibhutiman Singh
Total Coverage Area of the Building: 353 sq. m.
Design: Contemporary, Green Building Concept (LEED Attempted)
No. Of Storey: 12 Floors + 2 Basement (Top three floors were designed for an apartment but used as office space)

Figure 23: Location Map of Hama Iron Steel Complex

Hama Steel Complex is the building that has attempted LEED standards inside Kathmandu Valley. The major topics of a green building, such as sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, design innovation, and regional priority, have been effectively addressed and performed in the design, construction, and operation of this building. In this project, certain experiments are done, including building materials and other features that are innovative and environmentally responsive.

The concept, design and planning were strictly focused on the green features, most specifically in planning for the construction of the building minimizing destructiveness to the environment as far as possible and making the complex, energy and resource-efficient. The use of different green building materials that are relatively inventive in the market, makes the building more prior and energy-efficient.

4.2.1 Green Features of the Hama Iron Steel Complex

The major green features of this building are passive solar energy, active solar energy, Variable Refrigerant Volume (VRV) and Cristopia Heating Ventilation Air Conditioning (HVAC) System. The maximum use of renewable energy is one of the major features applied in this building.

The other attempts of green building designs observed in Hama Iron Steel Buildings are:

- Sustainable Site: Located in a commercial zone, have proximity to amenities, alternative transportation, low emitting/ fuel-efficient vehicle parking (parking for electric vehicles and green roofs.
- Water efficiency: Use of water-efficient fixtures and hydroponics (the process of growing plants in sand, gravel, or liquid, with added nutrients but without soil) but hydroponics is not in practice currently.
- Energy optimization: Use of energy-efficient lighting systems, maximum use of natural light, high-speed regenerative elevator, Use of Insulating materials in walls, renewable energy generation (use of photovoltaic system, solar water heating system).
- Materials & resource efficiency: Storage and Collection of Recyclables.
- Indoor Environment Quality: Increased ventilation, maximum use of daylight at working space.
- Innovative Design: Water treatment exposed in building facade.

4.3 Butwal Power Company

Project Details: **Butwal Power Company**

Location: Buddhanagar, Gangadevi Marga, Kathmandu

Consultant: Innovative Createers Pvt. Ltd.

Construction: MRB & Associates

Total Coverage Area of the Building: 571 sq. m.

Design: Contemporary, Green Building Concept (LEED Attempted)

No. Of Storey: 8 Floors + 1 Basement +1 Attic Floor (All floors are used as office space)

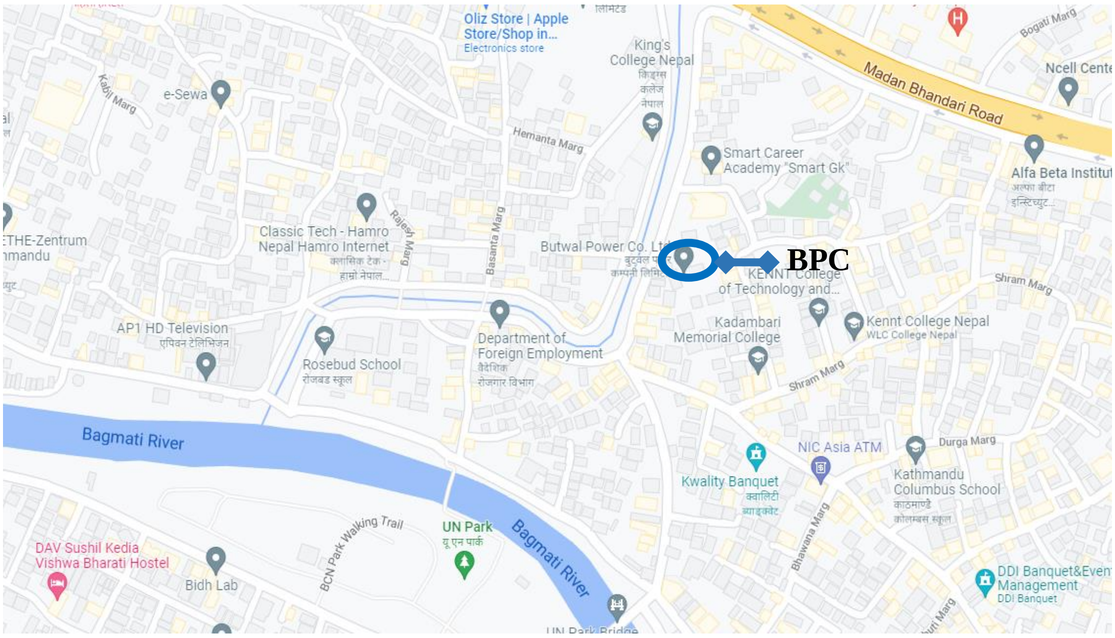


Figure 24: Location Map of Butwal Power Company

BPC is also the prevailing building inside Kathmandu Valley which has attempted LEED standards for the design and construction. The building is designed and constructed using the standards of green building to make it energy-efficient and self-sufficient. The use of renewable sources of energy like solar water, photovoltaic cells, earth air tunnel systems etc. makes building material resource-efficient as well.

4.3.1 Green Features of the BPC

The major green features of this building are passive solar energy, active solar energy, Earth Air Tunnel System (EAT) for heating and cooling. The maximum use of renewable energy is one of the major features applied in this building.

The other attempts of green building designs observed in Butwal Power Company are:

- Sustainable Site: Located in a commercial zone, have proximity to amenities, alternative transportation, environment-friendly material used and green roofs.
- Water efficiency: Use of water-efficient fixtures and rainwater harvesting connected with the underground water charging system.
- Energy optimization: Use of energy-efficient lighting systems, maximum use of natural light, treated air from Earth Air Tunnel (EAT), Use of Insulating materials in walls, renewable energy generation (use of photovoltaic system, solar water heating system).

- Materials & resource efficiency: Storage and Collection of Recyclables.
- Indoor Environment Quality: Treated Fresh Air System (TFAS) is incorporated in the HVAC system to improve indoor environment quality.
- Innovative Design: Green Roofs to reduce heat island effect.

4.4 Nepal Stock House

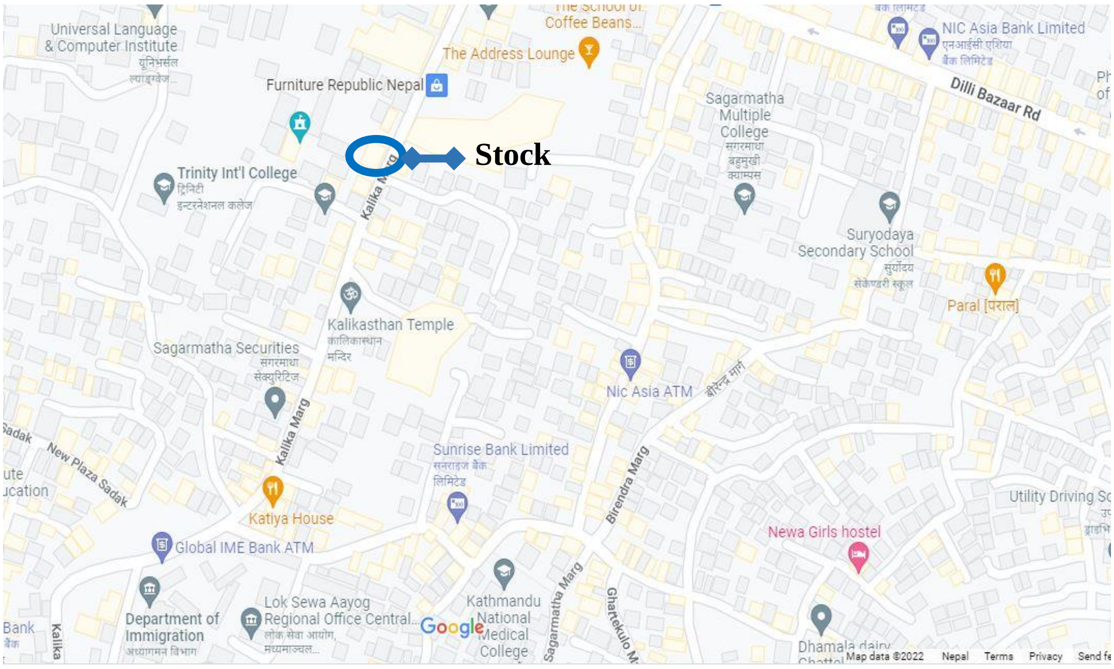


Figure 25: Location Map of Nepal Stock House

Project Details: **Nepal Stock House**

Location: Kalikasthan, Kathmandu

Total Coverage Area of the Building: 187.52 sq. m.

Total Site Area: 369.54 sq.m.

Design: Contemporary (Corporate Building)

No. of Storey: 7 Floors + 1 Basement (All floors are used as office space)

The corporate building (Nepal Stock House) selected does not include any kind of passive technologies and it is one of the examples of the commercial building inside Kathmandu. The construction materials and the techniques followed in this corporate office and most of the commercial buildings in Kathmandu is similar. Ground Floor is used for parking and other floors are used for offices.

CHAPTER FIVE: ANALYSIS AND FINDINGS

The adaptive capacity of the building was investigated by observing the physical and functional parameters of climate adaptive building like building geometry, orientation, form, materials used, lighting, services, thermal performance, internal layouts, passive & active designs and energy efficiency which are co-related to the components of green buildings as well. Data obtained from the field observation, drawings, literature and interview were analyzed with the help of AutoCAD, Sketch-Up, Microsoft Excel, VELUX Daylight Visualizer etc. Different line graphs, tables and charts were formulated for the results obtained.

5.1 Building Geometry, Orientation and Form

5.1.1 Building Geometry, Orientation and Form- Hama Complex

The building geometry is rectangular having a length of 24.65 meters, a breadth of 15.22 meters and the total height of the building is 46.42 meters having each floor of the height of 3.7 meters. To maximize the solar gain through the South, the long axis of the building is oriented toward is from East-West.

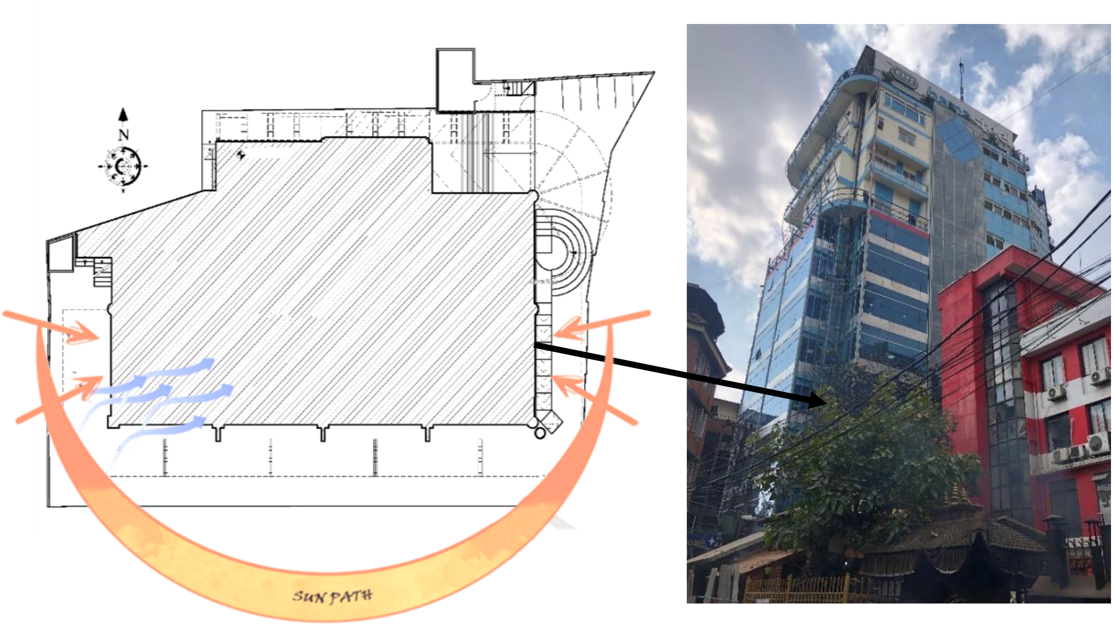


Figure 26: Showing Building Form and Orientation along with Sun Path- Hama

The building orientation is designed to capture the daylight as much as possible facing the most usable rooms towards the south.

The geometry of the building and the floor height ratio is sufficient for the proper access of daylight through the vertical and horizontal openings. The window to wall ratio of the Hama Complex is shown the Figure 29.

5.1.2 Building Geometry, Orientation and Form- BPC

The building geometry is rectangular and the main orientation of the building is towards the north direction. Though the building is oriented towards the north the building has access to daylight through south, east and west directions as well and the long axis of the building is from East-West.

Figure 27: Showing Building Form and Orientation along with Sun Path- BPC

The building orientation is designed to capture the daylight as much as possible facing the most usable rooms towards the north and south direction. The building is intended to face south and is oriented east-west.

It is advantageous for optimum solar gain in the winter and reduced penetration of undesired, unpleasant sunlight in the summer. The location of stairwells and restrooms on the west side of the building reduces the building's summer solar exposure.

The building measures 33.89 meters in length, 19.89 meters in breadth and the total height of the building is 41.31 meters. The floor height is 3.8 meters which are sufficient for the proper access of daylight through the vertical and horizontal openings. The window to wall ratio of BPC is shown the Figure 29.

5.1.3 Building Geometry, Orientation and Form- Stock House

The building geometry is rectangular and the main orientation of the building is towards the east direction. To maximize the solar gain through the East, the long axis of the building is from North-South.

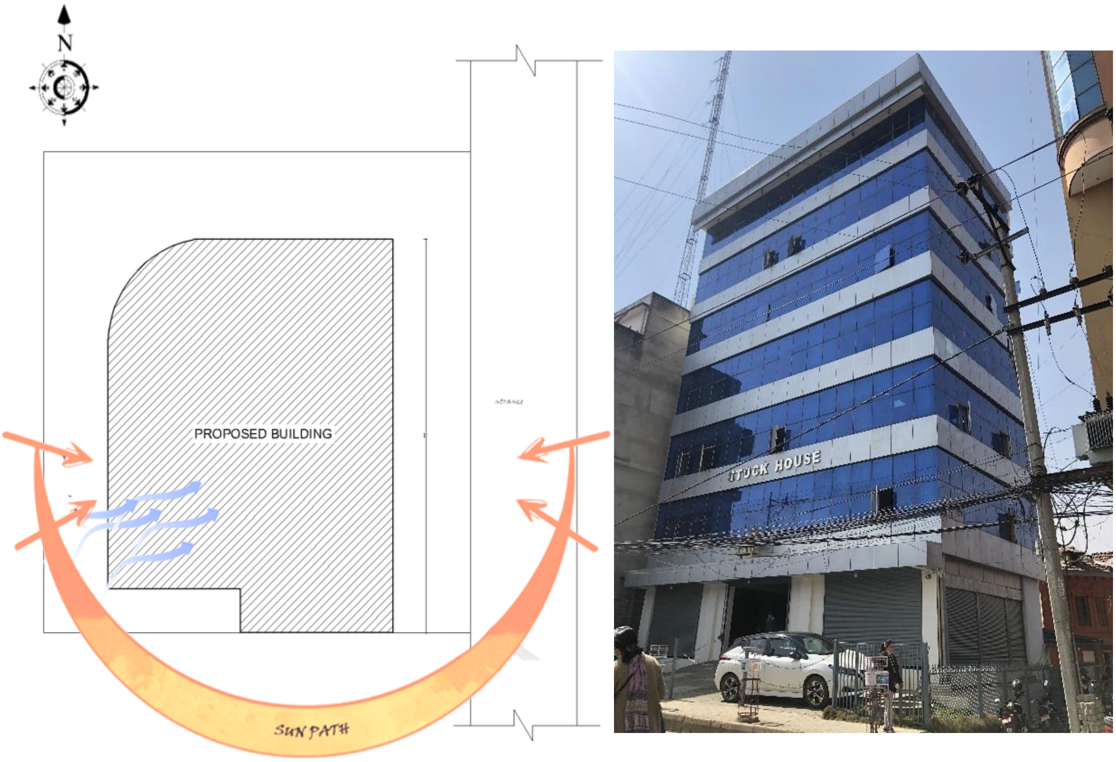


Figure 28: Showing Building Form and Orientation along with Sun Path- Stock House

The building orientation is designed to capture the daylight as much as possible from north, west and east directions. The geometry of the building and the floor height ratio is sufficient for the proper access of daylight through the vertical and horizontal openings.

The building measures 16.56 meters in length, 12.34 meters in breadth and the total height of the building is 28.2 meters. The floor height of 3.6 meters is provided for the proper access of daylight through the vertical and horizontal openings. The window to wall ratio of the building is shown the Figure 29.

Openings and Wall Ratio

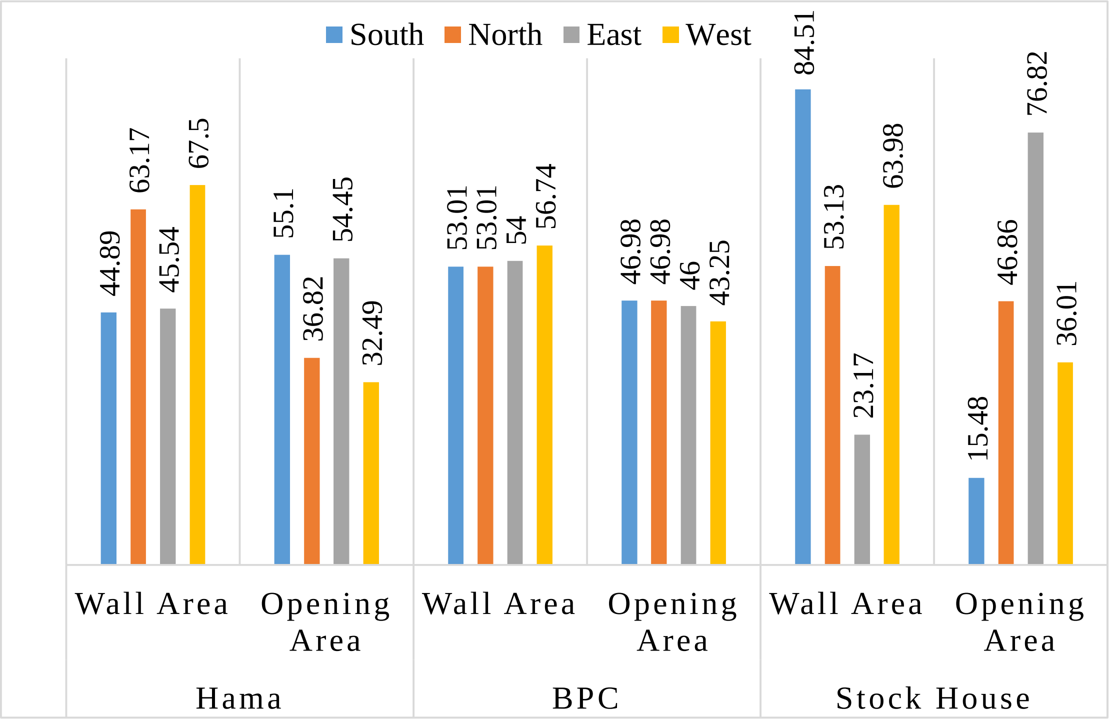


Figure 29: Comparison of Openings and Wall Ratio in Percentage

As per Standards the openings and wall ratio has implications on how much internal area will have access to daylight, its thermal efficiency which would save the energy used for internal lighting and space heating/ cooling of the building. As shown in Figure 29 all the buildings have openings in all four directions but in the Stock house, minimal openings (15.48 %) is provided in south directions. BPC has uniform openings in all four directions. It shows that the internal areas of all the buildings have proper access to natural daylight.

Hama Complex is found to be more focused on the East and South direction for openings whereas in BPC maximum openings are provided in north and south for cross ventilation during the summer seasons which provide thermal comfort during summer seasons whereas in Hama and Stock House building South and East direction are focused which is a solar orientation that provides thermal comfort in winters. Hence, BPC and Hama are found to have maximum vertical and horizontal openings through all four directions which provide indoor comfort as well as daylight in maximum interior spaces resulting in saving energy.

5.2 Building Envelope

5.2.1 Building Envelope- Hama Complex

The main structure of the building is frame structure and is constructed in conventional method using RCC but the use of green concrete and other various green building materials have reduced the overall carbon emission production and embodied energy while constructing the building.

A detailed description of the building materials and other elements used in the Hama Steel complex is given as follows:

Table 4: Building Materials in Hama Steel Complex

S.N.	Building Materials	Description
1	Fibre Cement Board	-Used for wall structure of the building replaced by the fired burnt clay bricks. -This replacement of the board with the brick helps to reduce a lot of carbon emission and embodied energy. -Lighter in weight and time-efficient too which is a prefabricated product and are installed on the site in lesser time.
2	Fly Ash in Concrete	-Is a by-product produced during the operation of coal-fired power plants. -More than 20% of OPC is replaced by fly ash and 2-5 % micro silica.

		-Fly Ash Used in construction has saved energy consumed.
3	Rubber Insulation	-1” thick rubber insulation is placed below the laminated flooring which makes the floor weight lighter, environment friendly and act as a very good insulator. -Provide better thermal performance inside the building.
4	Steel Structure	-Usage of Steel can be seen in the exterior part of the building, especially in the staircase area and the balconies which comparatively reduce the production of embodied energy and carbon emission.
5	Active Solar Energy	-Placed in the terrace to acquire the sunlight and convert it into electricity purposes which saves energy consumption.
6	Passive Solar Energy VRV	-Used in the building for heating and cooling around the interior spaces which results in better thermal performance.
7	Double Pane Windows	-Double pane windows are used as window panels that prevent direct sunlight glare and provide visual comfort.
8	High-Speed Regenerative Elevator	-Optimize the Energy performance of the building as well as a good option in high-rise buildings as it saves time due to its high speed.

Some building materials in this complex help to maintain the guidelines of LEED and also the material used in the building is efficient as well. These materials are also found to be a good option for energy saving in the building construction sector and adaptive to climate as well.

5.2.2 Building Envelope- BPC

Building main structure is frame structure as in Hama Complex but the use of concrete in external walls and various green building materials has helped in reducing the overall energy consumption during the construction period.

A detailed description of the building materials and other elements used in the Butwal Power Company is given as follows:

Table 5: Building Materials used in BPC

S.N.	**Building Materials**	**Description**
1	Polystyrene Boards	-Used to protect heat loss through walls and roofs which provide thermal comfort in interior spaces.
2	Sensor Devices	-Light and motor sensors are used for lighting efficiency. -Provided indoors for easy access.
3	Active Solar Energy	- 60 numbers of solar panels are used to produce Solar Energy to save energy consumption.
4	Passive Solar Energy VRV	- Used in the building for heating and cooling around the interior spaces which results in better thermal performance.
5	Wind Turbine	-It is placed at the top of the building, Kinetic energy from wind is converted to electricity (produces 2KW of energy).
6	Double Pane Windows	-Double pane windows are used as window panels that prevent direct sunlight glare and provide visual comfort.
7	EAT (Earth Air Tunnel)	-Earth Air Tunnel (EAT) is connected with an HVAC duct system and equipped with a heat pump (AHU) which is operated through Solar Air Collector. -EAT also supplies cold air during summer through the concrete tunnel of size 42mx0.9mx0.6m in 5 separates below the ground level.
8	Permeable pavement systems (PPS)	-Used in front yard space and open parking areas to collect, treat and infiltrate freely any surface runoff to support groundwater recharge.
9	TFAS	-Treated Fresh Air System (TFAS) is incorporated in the HVAC system for a better Indoor Environment.

The building materials used in BPC are also found to be energy efficient which follows the standards and guidelines of LEED. The material and technology used are resource-efficient, flexible as well as the building result in optimization of energy use.

5.2.3 Building Envelope- Stock House

Building main structure is the RCC frame structure as in general types of buildings in Kathmandu.

A detailed description of the building materials and other elements used in the Stock House is given as follows:

Table 6: Building Materials used in Stock House

S.N.	**Building Materials**	**Description**
1	Bricks Wall	-Used in external Walls
2	Fibre Cement Board	-Used as partition walls in interior spaces of office areas. - Lighter in weight and time-efficient too which is a prefabricated product and are installed on the site in lesser time.
3	Plaster Boards	- Used in False ceilings with the air gap.
4	Single Pane Windows	-Single pane windows are used as window panels for openings.

The building materials used in Stock House are not found to be energy efficient and do not follows any standards and guideline for energy efficiency except the electrical fixture (LED light, CFL Lamps etc.). The material and technology used are general and is maximally used for building construction inside Kathmandu Valley.

5.3 Lighting

5.3.1 Lighting- Hama Complex

The orientation and the internal layout determines the access of light inside the building, in Hama Complex most usable room are oriented toward the south and east direction to gain maximum daylight through these directions.

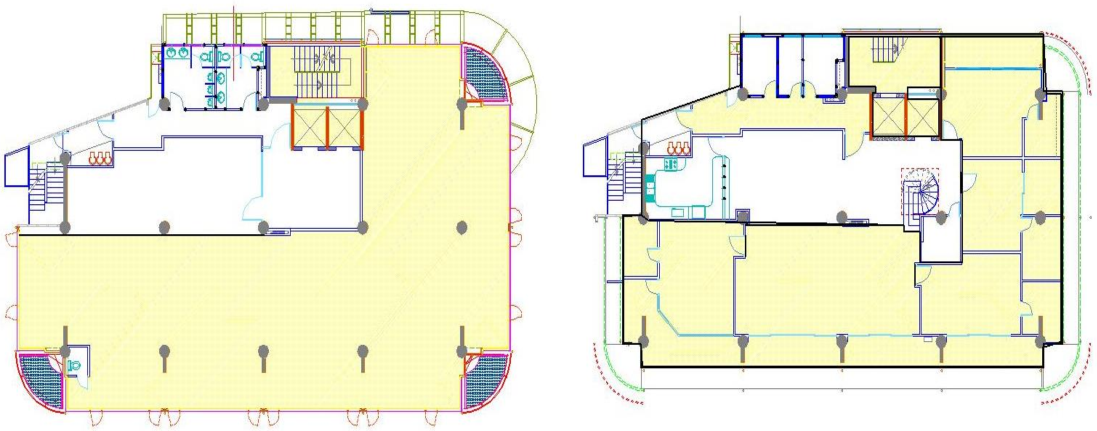


Figure 30: Showing Access of daylight in interior spaces

The shaded area as shown in Figure 30 captures daylight through the glazing maximum through the south- direction and other areas also have proper access to daylight through the east, west and north direction.

Figure 31: Daylight at Meeting Hall and Staircase areas

Maximization of daylight through the glazed wall helps to minimize the artificial lighting bill, high-speed lift with natural daylight use helps to save time and energy. In the building also solar PV panels are used for internal lighting and an energy star rated VRF air conditioning system is used for internal comfort.

Figure 32: Daylight and Skylight in Working Spaces

5.3.2 Lighting- BPC

In BPC maximum of office, areas are oriented towards the north direction to gain maximum daylight through the horizontal and vertical openings. The internal layout and half partition in working areas have captured the maximum daylight in the interior spaces.

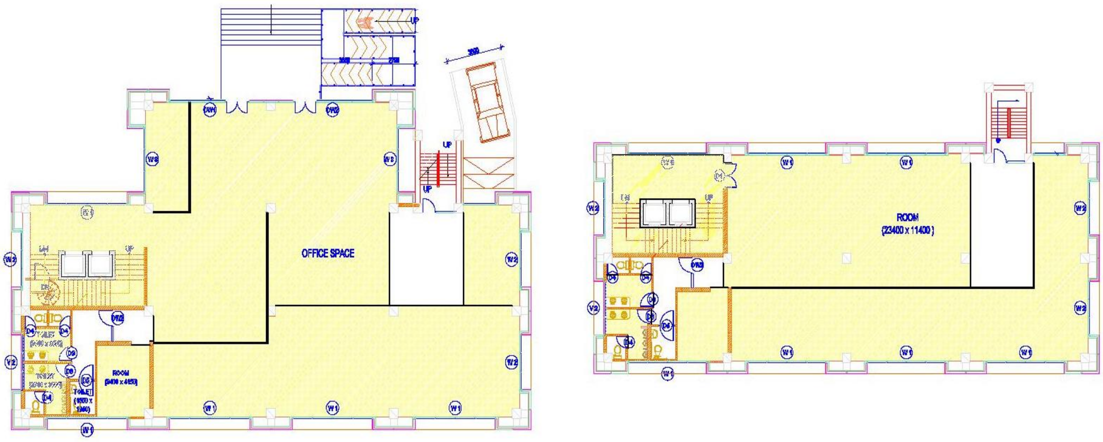


Figure 33: Showing Access of daylight in interior spaces

The shaded area as shown in Figure 33 captures the daylight through the glazing maximum through the north and south- direction and other areas also have proper access to daylight through the east and west direction. As observed almost all area has access to daylight, only in the lift there is no access to daylight.

Figure 34: Daylight at Working Spaces and Staircase Areas

Meeting Room and Cabins are oriented towards the South direction and these areas also have access to proper daylight through the South. Double glazed windows have helped to reduce sunlight glare at working areas.

Figure 35: Daylight at Cabin and Passage Areas

Stairways and Passage areas are also provided with large openings to avoid the use of artificial light which has helped in reducing energy use. Separate outdoor lighting units with photovoltaic cells are used for exterior lighting systems.

5.3.3 Lighting- Stock House

In Stock House maximum of office, areas are oriented towards the east and north direction to gain maximum daylight through the horizontal and vertical openings. Maximum of light enters in the interior through east direction as it is main orientation and on the roadside, so there is no obstruction through other buildings as well. Enough setback at North and West direction has made to have proper daylight in Staircase and Office areas.

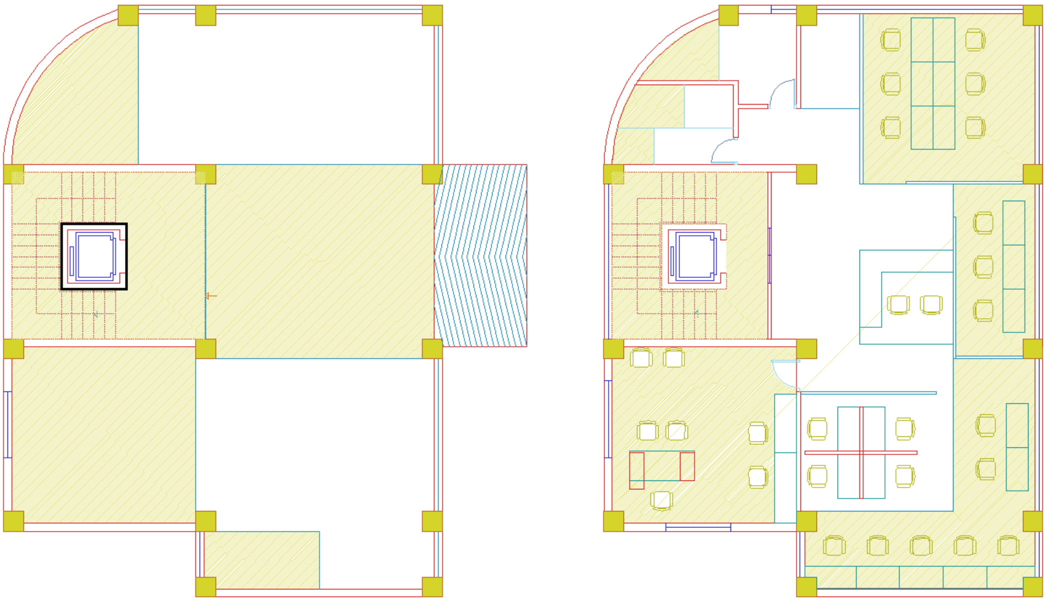


Figure 36: Showing Access of daylight in interior spaces

The shaded area as shown in Figure 36 captures the daylight through the glazing maximum through the north and east- direction and other areas also have proper access to daylight through the west direction.

Figure 38: Lighting at Office and Staircase Areas

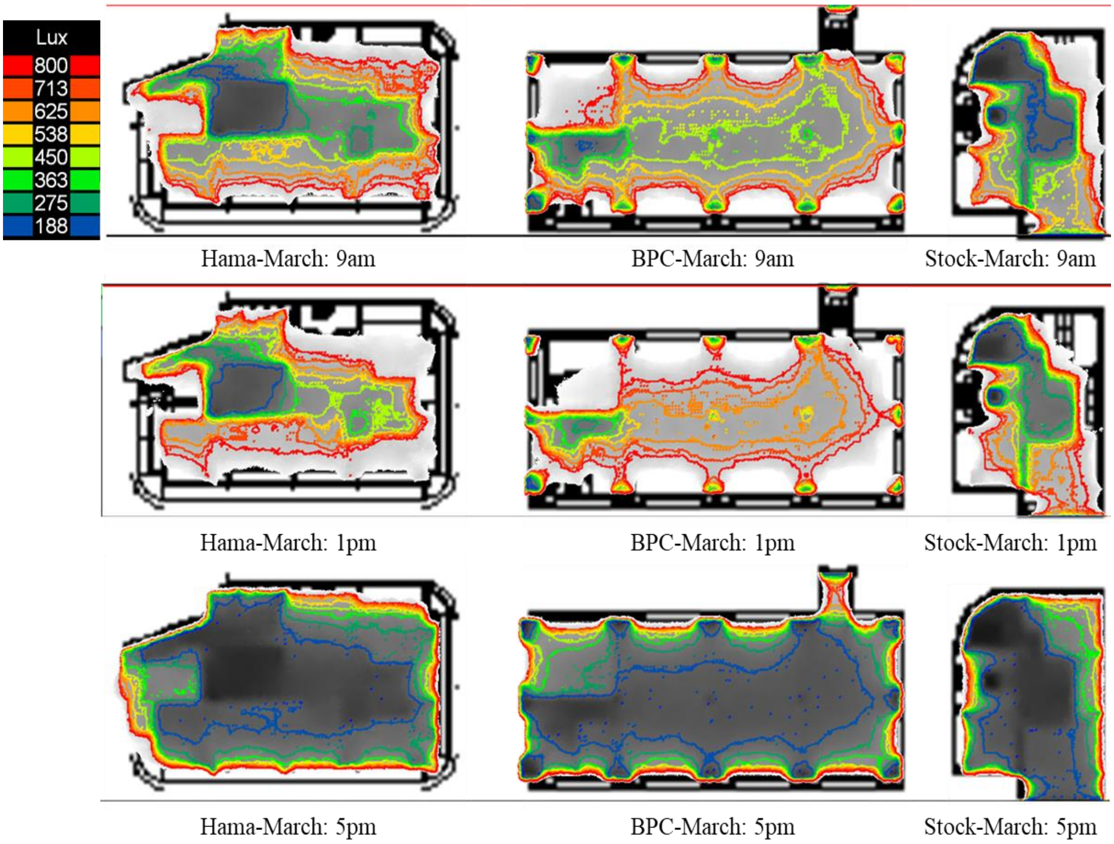
As the observed maximum area has access to daylight, only in lift and central areas (reception) there is the use of artificial light for internal lighting. Also in toilet areas, the light is not much sufficient but almost all other workings areas have access to proper daylight.

Figure 37: Showing Lighting at Reception and Working Spaces

Figure 37 shows the usage of daylighting in staircase areas and office areas where is there is not sufficient daylight. At the reception area also there is no sufficient light as shown in Figure 38.

Analysis for Day-Lighting

The daylight of three corporate building Hama Complex, BPC and Stock House was analyzed using the software VELUX Daylight Visualizer. The analysis was made for three different time interval for the month of March as shown in the Figure 39.



Hama-March: 9am BPC-March: 9am Stock-March: 9am

Hama-March: 1pm BPC-March: 1pm Stock-March: 1pm

Hama-March: 5pm BPC-March: 5pm Stock-March: 5pm

Figure 39: Daylight imitation with the VELUX Daylight Visualizer

Figure shows the ISO contour image indicating the distribution of daylight in interior spaces, where there is the sufficient natural light i.e. above 300 lux for office building and where there is need of artificial light i.e. below 300 lux. BPC is found to have less use of artificial light as per case study photographs and analysis. BPC found to have use of artificial light in enclosed spaces of lift and corner (approximately 8 % area) during daytime. If we compare all three buildings, then conventional building (Stock house) has maximum need of artificial lighting which increases the electricity bills as well the final energy uses of the building. The use of half partitions in working areas are found to be a good example for proper use of daylight as observed in BPC. So, passive buildings have comparatively low energy consumption for lighting purposes which shows the lighting efficiency of these buildings. As per standards also the minimum lux required for office working area is 300 lux, this shows the sufficient daylight in BPC comparatively. Hence adaptive measure like daylight has made the passive building more adaptive and energy-efficient in comparison with Stock house.

5.4 Building Services

5.4.1 Building Services- Hama Complex

Major Services like Rainwater harvesting, Sewage Treatment Plant, Services lifts are provided to make the building functional, efficient and self-sufficient.

- **Rainwater harvesting**

  Rainwater harvesting is proceeding in the building for water management. Kathmandu Valley is well known for the shortage of water in spring. So, to overcome this problem and to not depend on the regular drinking water supply of Nepal drinking water authority, this feature has been made for the building occupiers.

Figure 40: Storage for Rain Water and Separate Service Lift at West

The storage capacity for rainwater is 60000 litres and this rainwater stored is used in basins and all other purposes. For drinking purposes, boring water is used.

- **Services Lift**

  As shown in the Figure the services lift is provided on the west side for the building to transfer the heavy equipment inside the building without disturbing internal functions.

- **Sewage Treatment Plant (STP)**

  The sewage treatment plant is also another special feature of this high rise building. The process leads to three different treatments: Primary, Secondary and Tertiary. Sedimentation of wastewater and sludge, as well as their basic treatment in septic tanks, are part of the primary treatment. This device produces 5m3 of biogas per day by treating black water and organic materials. Both black and greywater are treated in a chambered Anaerobic Baffled Reactor in the Secondary unit (ABR). The ABR uses anaerobic digestion inside the chambers to reduce biological and chemical oxygen consumption. The recycled grey water is then used to meet the requirements for toilet flushing.

5.4.2 Building Services- BPC

The major services provided in BPC are Rainwater harvesting, EAT (Earth Tunnel System) and Fire Safety which has helped in making the building functional, efficient and self-sufficient.

- **Rainwater harvesting**

  Rainwater harvesting having storage of 70000 litres (Underground Reservoir Tanks) is proceeding in the building for water management. The stored rainwater is sufficient for 3-4 months during monsoon time but not for all seasons to the building has also access to main supply line from external sources. The stored rainwater during the monsoon is used for toilets for flushing and growing plants at the roof gardens.

- **EAT (Earth Tunnel System)**

  EAT is connected to an HVAC duct system which is operated by Solar Air Collector. The main purpose of EAT is to provide thermal comfort inside the interior spaces. It is used for space heating and cooling inside the building which is explained in detail in the thermal performance of BPC (5.5.2 Thermal Performance-BPC).

- **Fire Safety and Emergency Exits**

  There is the provision of a Powered Fire Extinguisher as a fire retardant on each floor for safety during fires. The stairways at North-West Corner and South-East Corner performs as emergency exits in the building.

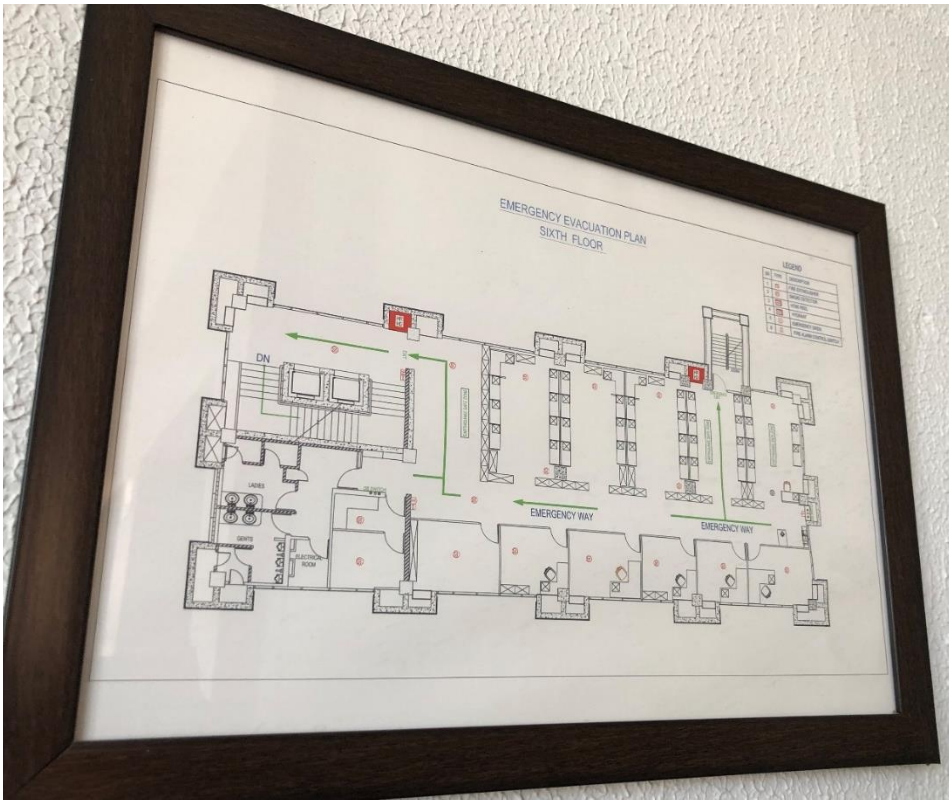


Figure 41: Showing Emergency Evacuations Plan in Each Floors

5.4.3 Building Services- Stock House

The services in the building are general services like a staircase, lift etc. which are very essentials but there are no other services found which makes building more functional, self-sufficient and energy-efficient.

5.5 Thermal Performance

5.5.1 Thermal Performance- Hama Complex

Light Weight Concrete Very few amount of OPC is used with the huge quantity of granular foam for making cement concrete and is poured in between the fibre cement boards to form the wall. This lightweight concrete is not only energy efficient but is also very good for thermal as well as sound insulation. Double glazed window pane also provides thermal comfort inside the building and also act as a good sound insulator as it reduces the sound that arises from traffic and other mediums. Rubber insulation and polystyrene insulation are being used in the flooring and interior walls.

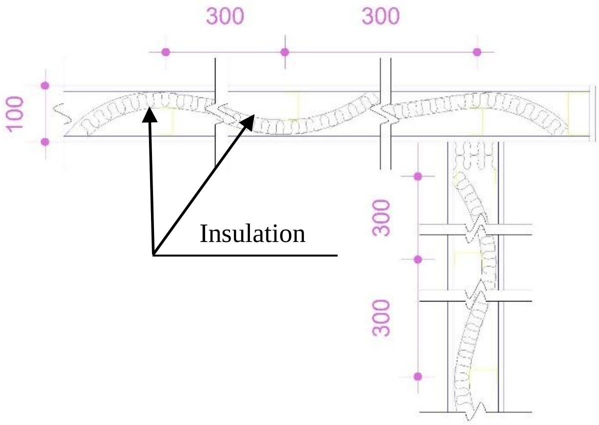


Figure 42: Insulation in Interior Walls

The rubber insulation layers of approximately 1” height are placed below the laminated flooring which makes the floor weight less heavy, environment friendly and act as a very good thermal insulator. Double Grid ACP panel with a thermo-coal sheet at back for both sound and thermal insulation.

5.5.2 Thermal Performance- BPC

As in Hama Complex use of Double glazed window pane and use of polystyrene boards to protect heat loss through walls and roofs which provide thermal comfort in interior spaces has been observed. An innovative renewable energy system had been developed to meet the thermal comfort of the building. A combination of EAT (Earth Air Tunnel) and Solar Air Heating System is designed for heating and cooling of the building as shown in Figure 43.

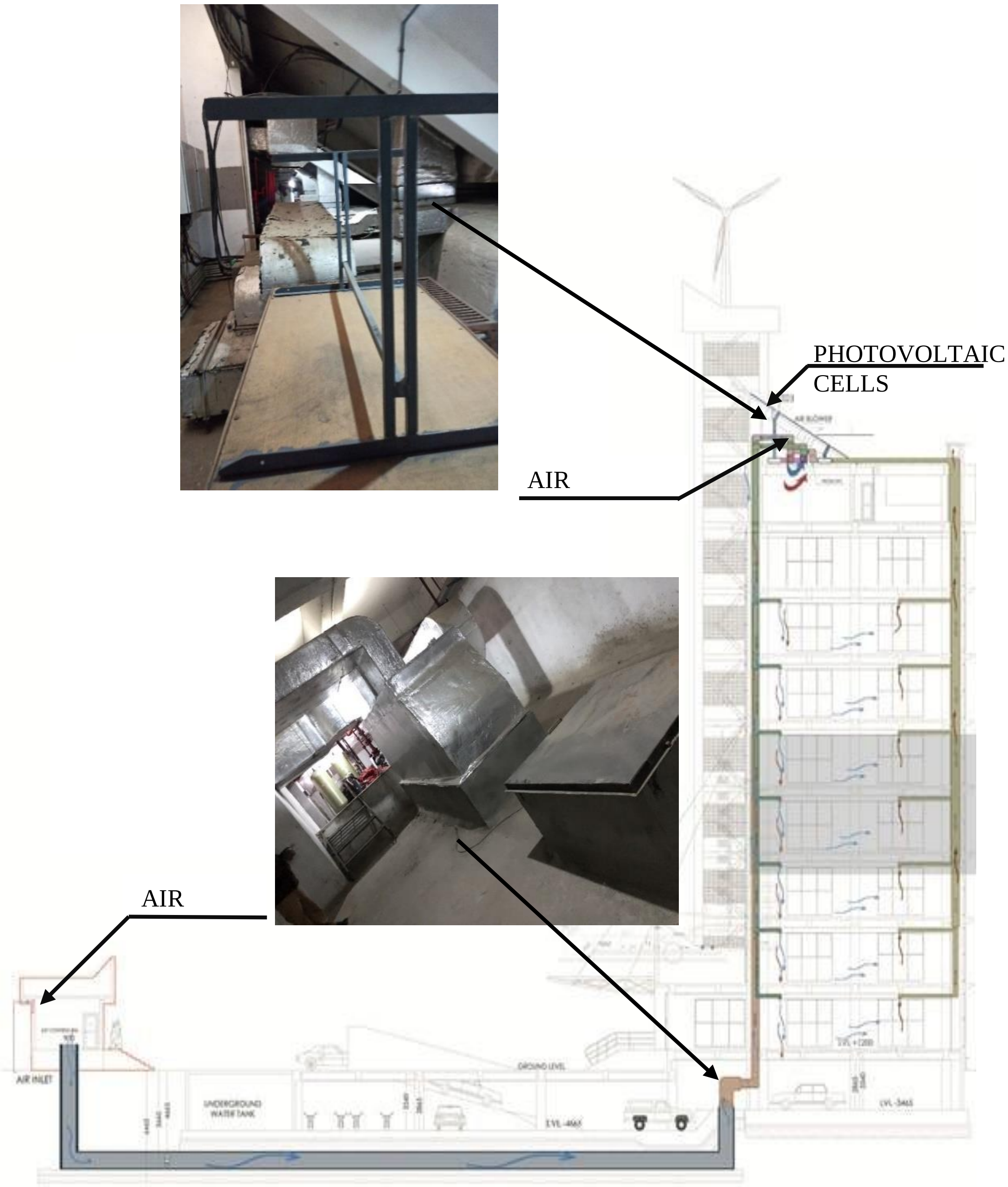


Figure 43: Section Showing Earth Air Tunnel (Source: archinect.com)

EAT consists of a total of five separators of size 42mx0.9mx0.6m which are placed 4.6m below the ground level i.e. below the basement parking level as shown in Figure 43. In BPC, the temperature of the earth below 4.6m is 18°C which remains constant throughout the air so here, cooling/heating takes place due to the temperature differences of the soil. Each tunnel is connected with an HVAC duct system and fortified with a heat pump (AHU) which is operated through Solar Air Collector. To supply hot air total 60 numbers of Solar Panels are used which produces 30KW of energy.

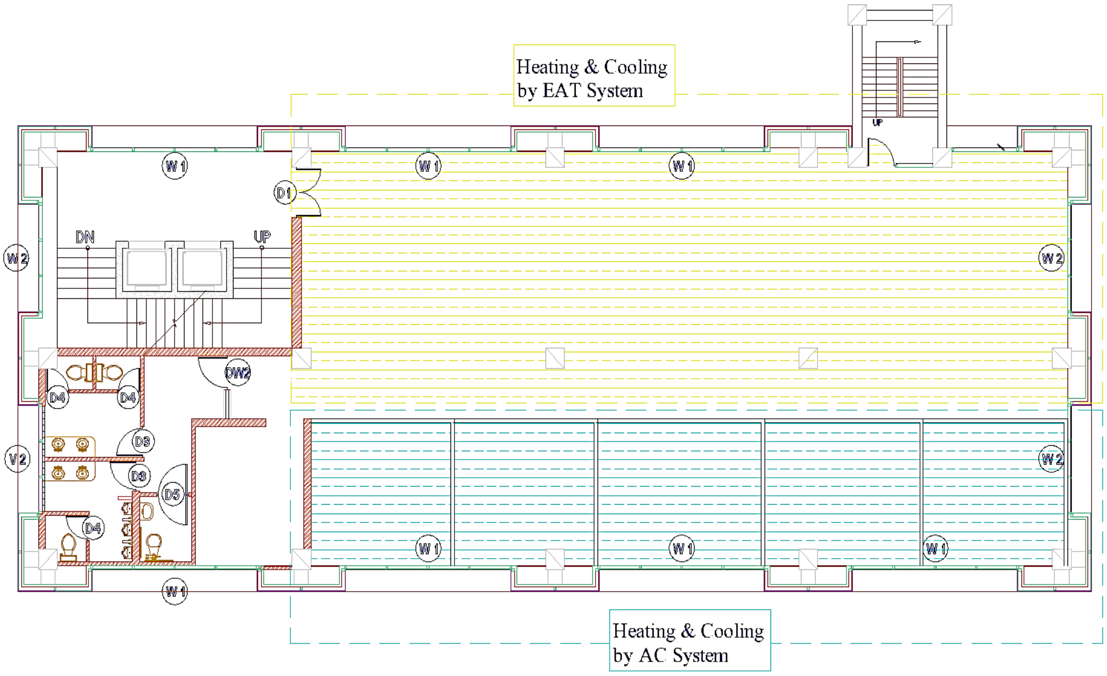


Figure 44: Floor Plan Showing access to EAT and AC System

For Space Heating and Cooling 60%of Working Areas at North Orientation is provided with EAT (Earth Tunnel System) and the remaining 40% of areas with Cabins and Meeting Rooms are oriented towards the South which is provided with AC System (VRF, VRF-DC Inverter Type) for Space Heating and Cooling. So, this building has saved 60% of the energy needed for Space heating and cooling in the working areas (which is the maximum used in this building) by providing active solar energy for space heating and cooling. Figure 44 shows the areas where there is provision for EAT System and the areas with the provision of an AC System for space heating and cooling.

5.5.3 Thermal Performance- Stock House

For Space Heating and Cooling in the building, there is the provision of an AC system using electricity from the external main supply line of NEA for all seasons. No other specific technologies or special kinds of insulating materials are used to make building thermally comfortable. The use of electricity for heating, cooling has increased the electricity bills and energy consumption comparatively.

5.5.4 Comparison of U-Value of Building Surfaces

The comparison of U-Value of Building Surfaces of Hama, BPC and Stock House was calculated to examine the thermal conductivity of the building surfaces. The U-values of Wall, Window, Floors and Ceiling were calculated using U-Value Calculator. The calculated U-Values along with the Building Material Used in Hama Complex, BPC and Stock House are shown in Table 7, Table 8 and Table 9 correspondingly.

Table 7: U-Value Calculation for Hama Complex

Building Elements	**Description of Material Used**	**U-Value (W/m2K)**
Wall	10 mm Cement Fibre Board both sides with 50mm thick polystyrene insulation slab in between with air gap	0.25
Window	Double Glazed window	3.06
Floors	125mm suspended Concrete with rubber insulation	0.35
Ceiling	10mm plastered board with 50mm polystyrene insulation and framed wall as air gap	2.04

Table 8: U-Value Calculation for BPC

Building Elements	**Description of Material Used**	**U-Value (W/m2K)**
Wall	230 mm Concrete Wall with polystyrene board with the air gap	0.41
Window	Double Glazed Window	3.06
Floors	125mm suspended Concrete with air cavity	1.89
Ceiling	10mm plastered board with 50mm polystyrene insulation boards with an air gap	2.04

Table 9: U-Value Calculation for Stock House

Building Elements	**Description of Material Used**	**U-Value (W/m2K)**
Wall	230 mm Brick Wall	1.9
Window	Single Plane Glass	5
Floors	125mm suspended Concrete Floors	3.6
Ceiling	Suspended Concrete Ceiling with the false ceiling of plastered cement board	4.7

Comparison of U-Value

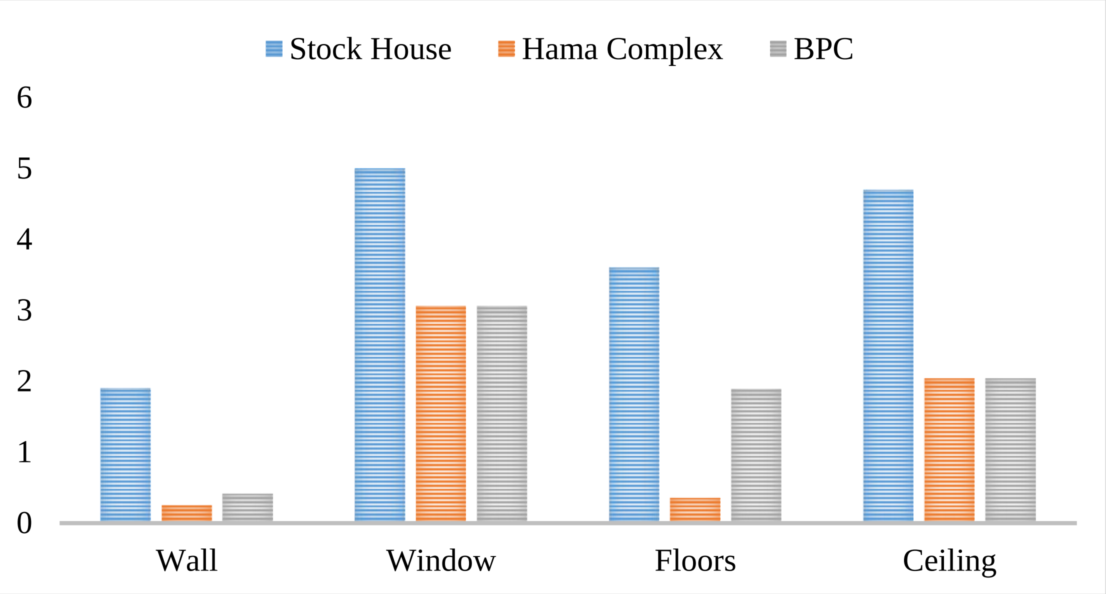


Figure 45: Comparison of U-Value

The overall U-value of Green buildings is lower than all conventional types of buildings, according to an analysis of the U-values of Stock House, Hama Complex, and BPC. It means that passive buildings provide a comfortable environment in both the winter and summer. As a result, when compared to conventional building, the thermal performance of passive buildings (Hama and BPC) demonstrates that energy is conserved for heating and cooling. Through the use of insulation, the selection of building materials, and passive technology, these buildings have reduced their energy consumption.

5.6 Internal Layouts

5.6.1 Internal Layouts- Hama Complex

The building is used for commercial purposes and the internal layout of almost all floors is similar which is similar in layout as shown in Figure 46. The internal layout is designed to capture the daylight as much as possible by facing the most usable rooms towards the south and east side. Large openings with double panes are provided for daylight and a better environment inside the rooms.

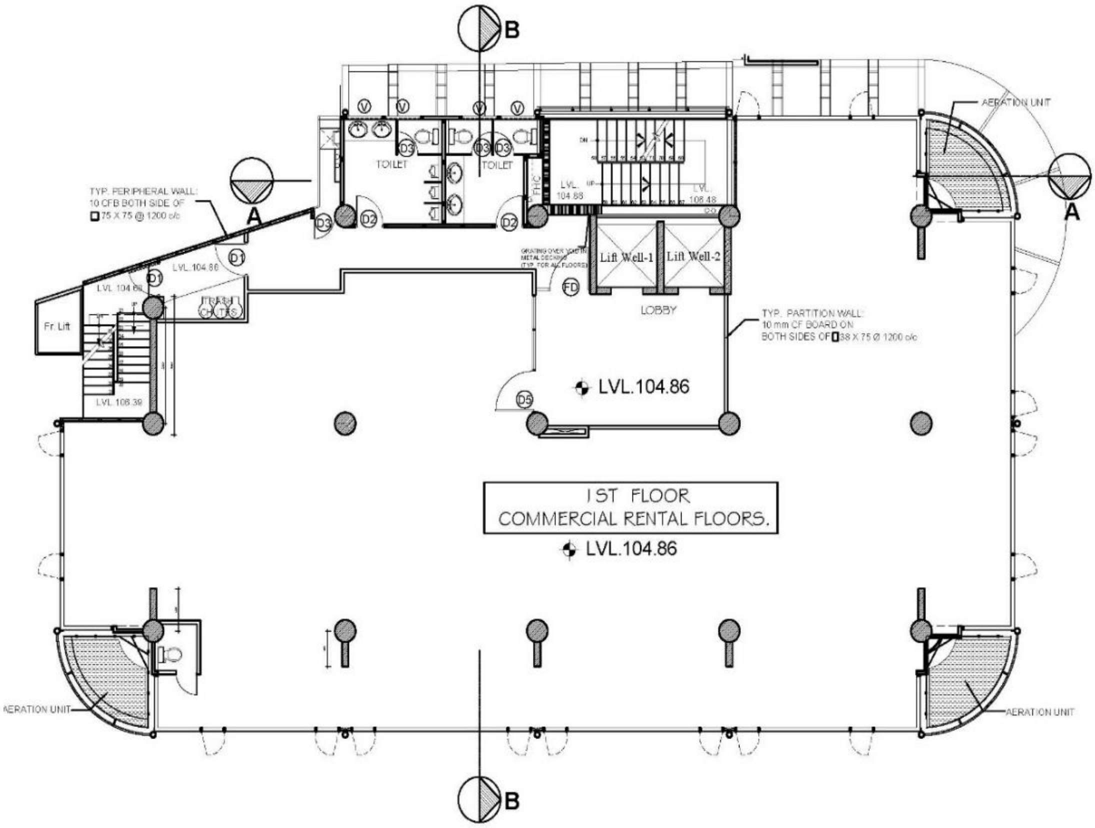


Figure 46: Typical Floor Plan of Hama Building

5.6.2 Internal Layouts- BPC

The internal layout for all floors is similar where the ground to seventh floors are used as office areas and the eighth floor as a cafeteria. On the west side of the building toilet, staircase and lift are placed and the office area is placed at the north, south and east sides.

So, the maximum of daylight is a capture from south, north and east direction for usable office areas. Half partitions in interior spaces for furnishing have helped in capturing maximum daylight in almost all areas of the office.

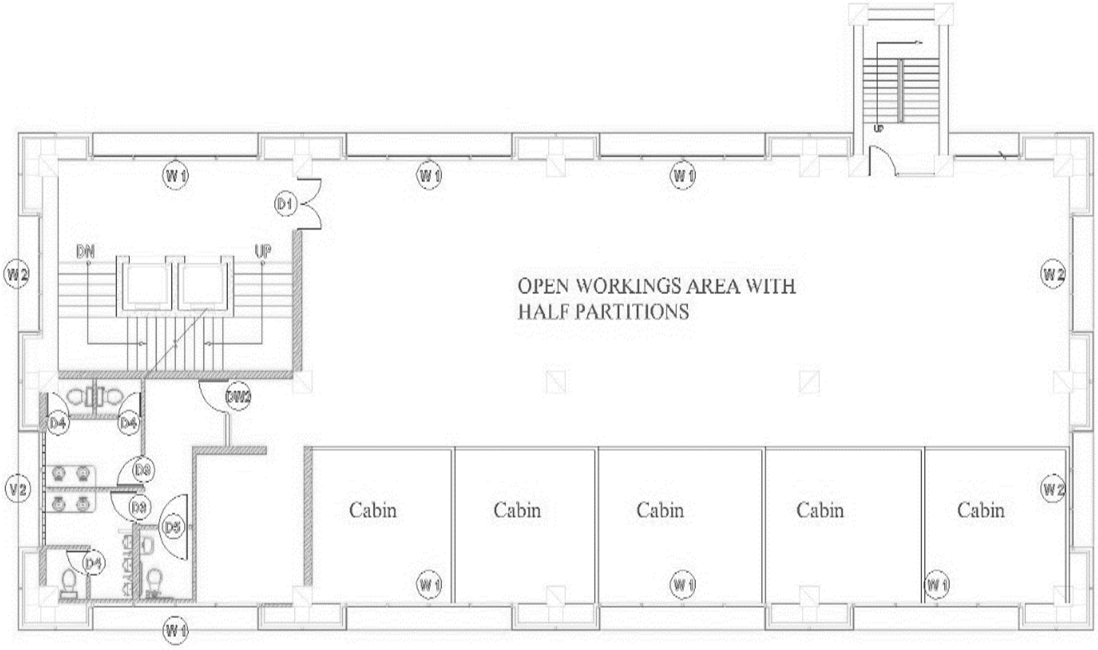


Figure 47: Typical Floor Plan of BPC Building

5.6.3 Internal Layouts- Stock House

The internal layout for almost all floors is similar where the ground floor is used as a parking area, first to sixth floors are used as office areas. On the west side of the building toilet, staircase and lift are placed and the office area is placed at the north, south and east sides. So, the maximum of daylight is a capture from the north and east direction for usable office areas.

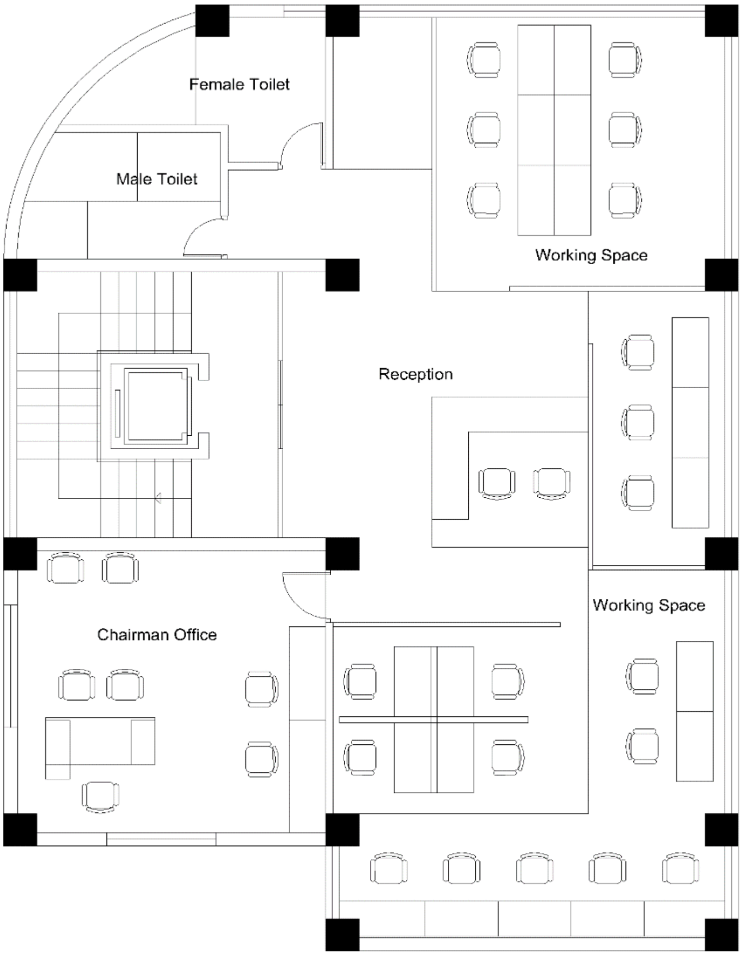


Figure 48: Typical Floor Plan of Stock House

5.7 Indoor Environment Quality

5.7.1 Indoor Environment Quality- Hama Complex

Increased numbers of ventilation in the buildings help to improve the indoor environment quality of the interior spaces. Energy Star Rated VRF air conditioning system has also been used for internal comfort. Double glazed windows in the building facade also prevent the direct glare of sunlight.

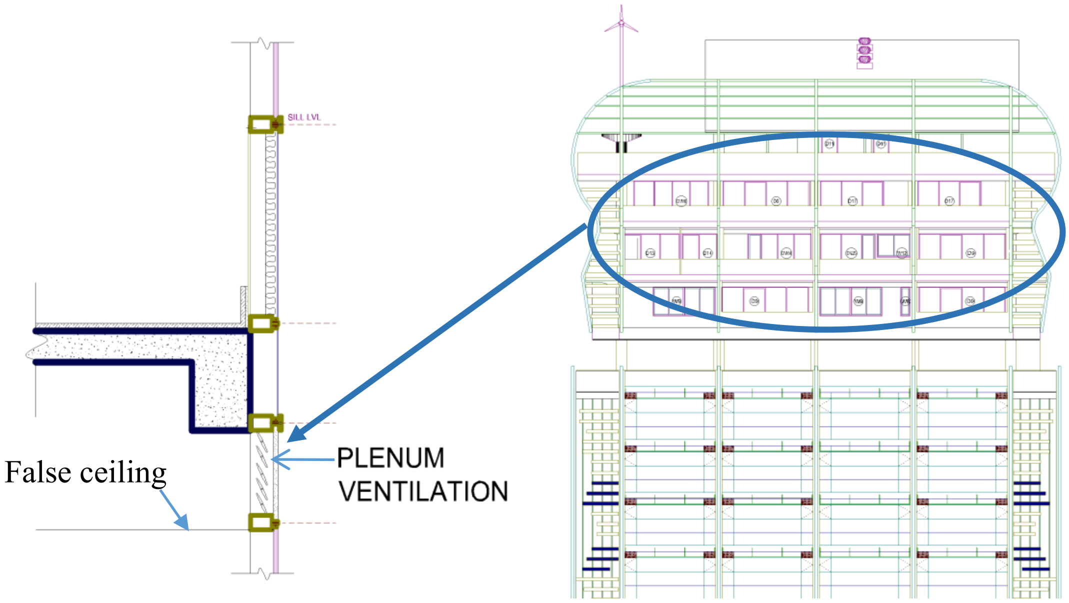


Figure 49: Ventilation at top

Plenum ventilation is used for cross ventilation and proper airflow throughout the building. This system helps for the natural airflow and helps to throw out the inner unwanted air from the building and provides fresh air inside.

The building has a double basement with ventilation based on appropriate CO_2 levels (Photographs in Annex V). There is always a chance of having a high-level CO_2 in the basement because of the absence of air circulation and also due to the number of vehicles for this, sufficient ventilation is provided which balance the level of CO_2.

5.7.2 Indoor Environment Quality- BPC

Increased openings at South and North Orientation has helped to improve indoor environment quality through cross ventilation. Treated Fresh Air System (TFAS) is also incorporated in the HVAC system for a better Indoor Environment. Double glazed windows have helped to prevent the direct glare of sunlight.

EAT system as explained in the thermal performance of BPC (5.5.2 Thermal Performance-BPC) has helped to improve thermal comfort and indoor environment quality by providing fresh air in the interior spaces.

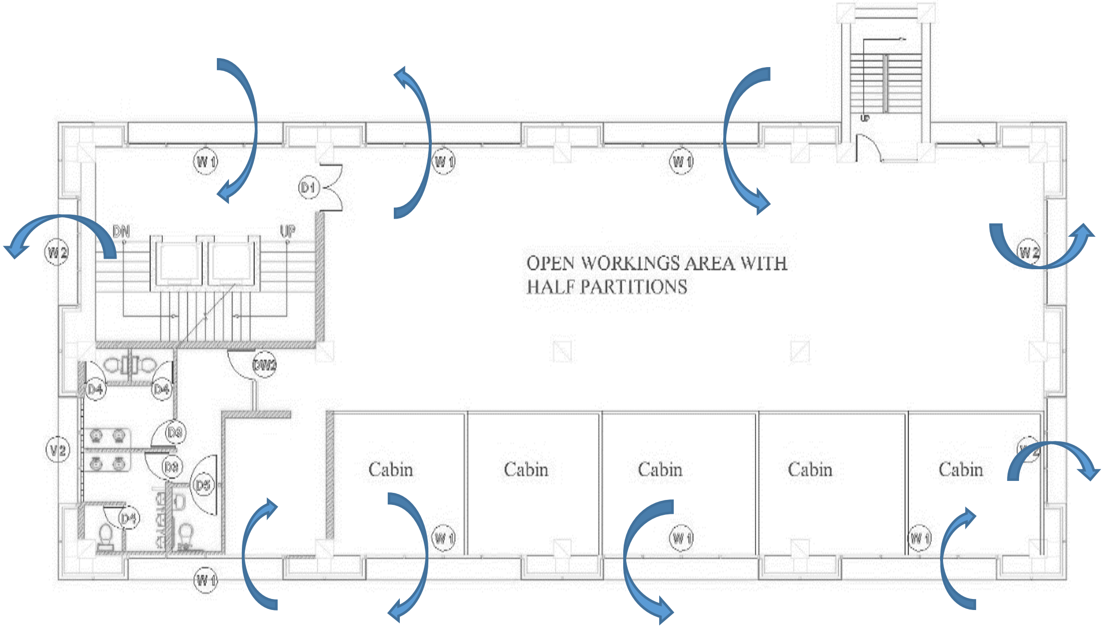


Figure 50: Plan Showing Cross-Ventilation

Half Partitions in interior spaces allows has helped for free air movement and cross-ventilation in interior spaces as shown in Figure 50. Increased numbers of Windows and Openings through all directions has also helped to improve the indoor environment quality.

The indoor environment quality of BPC is found to be better if compared with Hama Complex as it has integrated TFAS also in the building. As per standards also for building to be more functional and adaptive parameters like Indoor Environment Quality should be integrated into Building. So, Hama and BPC are attempting to provide better indoor environment quality whereas in Stock House there are no attempts made to improve the indoor environment except the windows.

5.8 Passive and Active Designs

5.8.1 Passive and Active Designs- Hama Complex

Passive Solar Energy VRV HVAC System VRV (Variable Refrigerant Volume) has been used in the building for heating and cooling around the interior spaces. This system's primary concept is that a huge outside unit serves several indoor units. To match the demand of the space it serves, each indoor unit employs an LEV (electronic liquid expansion valve) to control its refrigerant delivery. The output of the outdoor unit fluctuates to meet the communal demands of the interior units it feeds.

Figure 51: Active Design in Hama Building

Active Solar Energy- 48 numbers of total Solar Panels are placed on the terrace which acquires the sunlight and converts it into electricity for different uses. As per Mr Raju Kumar Thapa (General Manager of Hama Steel) approximately, the total panels have the capacity of 14 KW energy production per day and when it was in operation it fulfilled the requirement of internal lighting in the building. Currently, the Solar Panels are not in operation due to the need for repair and maintenance but in near future, they will be in operation again.

The maximum use of renewable energy is one of the major objectives of green buildings and hence this complex follows the rule by installing these devices for the maximum utilization of renewable energy resources. The use of passive and active designs in the building also results in the energy efficiency of a building.

5.8.2 Passive and Active Designs- BPC

The major portion of the terrace roof is covered with a roof garden (Green Roofs), which is acting like and heat insulation layer and contributes to reducing the heat island effect in the building. Solar water heating and Space heating has reduced the energy requirement of the building.

Figure 52: Showing Solar Panel Placed on the Terrace (Source: archinect.com)

Active Solar Energy- 60 Numbers of Solar Panels are placed on the terrace which produces 30KW electricity is supplied for the HVAC System in the interior spaces and a Wind Turbine of 2KW is provided at the topmost portions of the emergency exit. This active solar energy fulfils 60% of the energy required for space heating and cooling of the building and the remaining 40% is provided with the AC (VRF, VRF-DC Inverter Type) system.

5.9 Energy Efficiency

The major source of energy is electricity in corporate buildings, so for the analysis of energy efficiency of the building the bill of electricity of 12 months i.e. last one year was collected and also comparative analysis is made based on these bills. The monthly bill collected is presented in tabular form which is attached in Appendix IV.

5.9.1 Energy Efficiency- Hama Complex

Maximum use of renewable sources of energy for internal lighting, energy star rated VRF air conditioning for internal comfort, rainwater harvesting system with a water treatment plant in the building shows the efficiency of energy in Hama Complex.

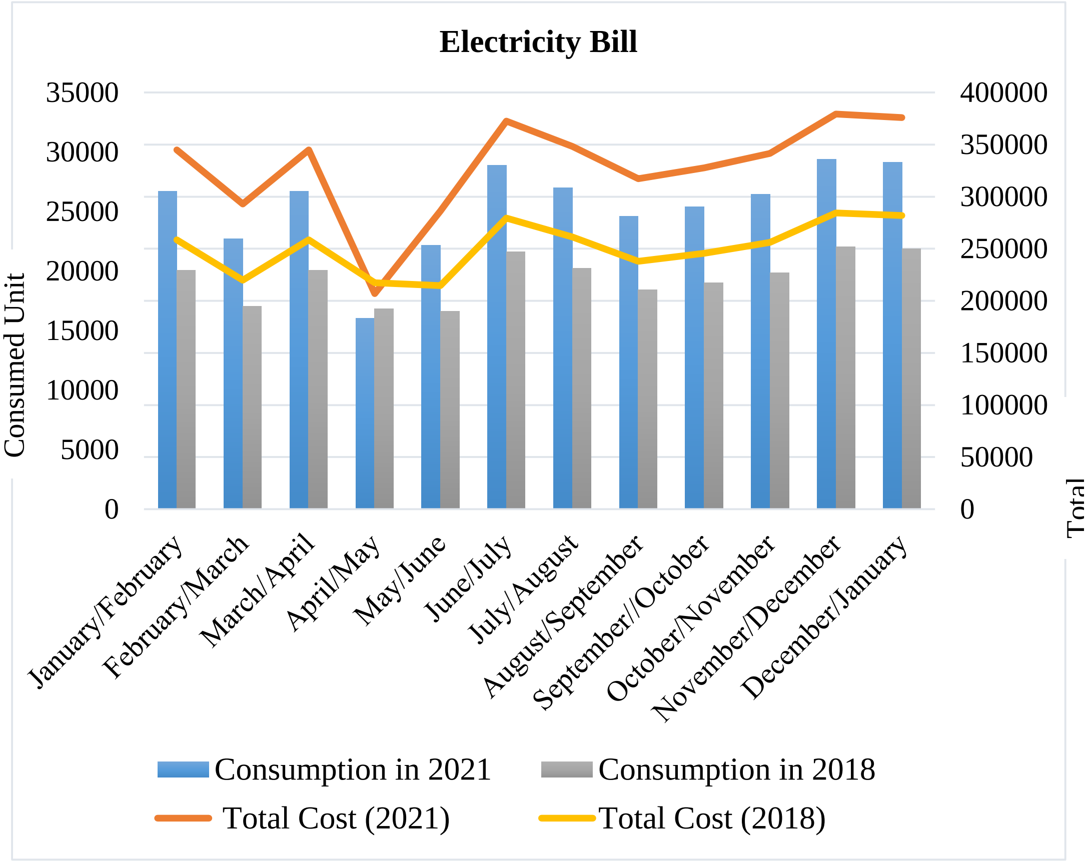


Figure 53: Electricity Bill of year 2021 and 2018 -Hama Complex

Approximately 66% of the interior have access to natural daylight and the remaining 34% of spaces need artificial lighting systems which were fulfilled by Solar Energy in past years. The 14kw of energy produced by Photovoltaic Solar Panels were used for internal lighting in previous years (till 2019) but presently there is no use of Solar

Energy for Electricity. When there was the use of 14kw Solar Energy (From January 2018- to December 2018)) it fulfilled 25% of the electricity requirement of the building as shown in Figure 53.

The figure shows the electricity consumption of two years (2018 (January-December) and 2021 (January-December)) which shows that there was minimal consumption during the year 2018. So, it is found that the 14KW Solar Energy fulfils the 25% of electricity requirement when it is in use. In near future, the system (Panels and Batteries) will be repaired as per the manager of Hama Complex.

5.9.2 Energy Efficiency- BPC

BPC also has maximum use of renewable sources of energy for space heating and cooling, hot water, lighting etc.

Energy-efficient VRF (Variable Frequency) type air-conditioning systems and air control units with ERV (Energy Recovery Ventilation) are another key energy-saving method used in HVAC (Heating Ventilating and Air-Conditioning) systems.

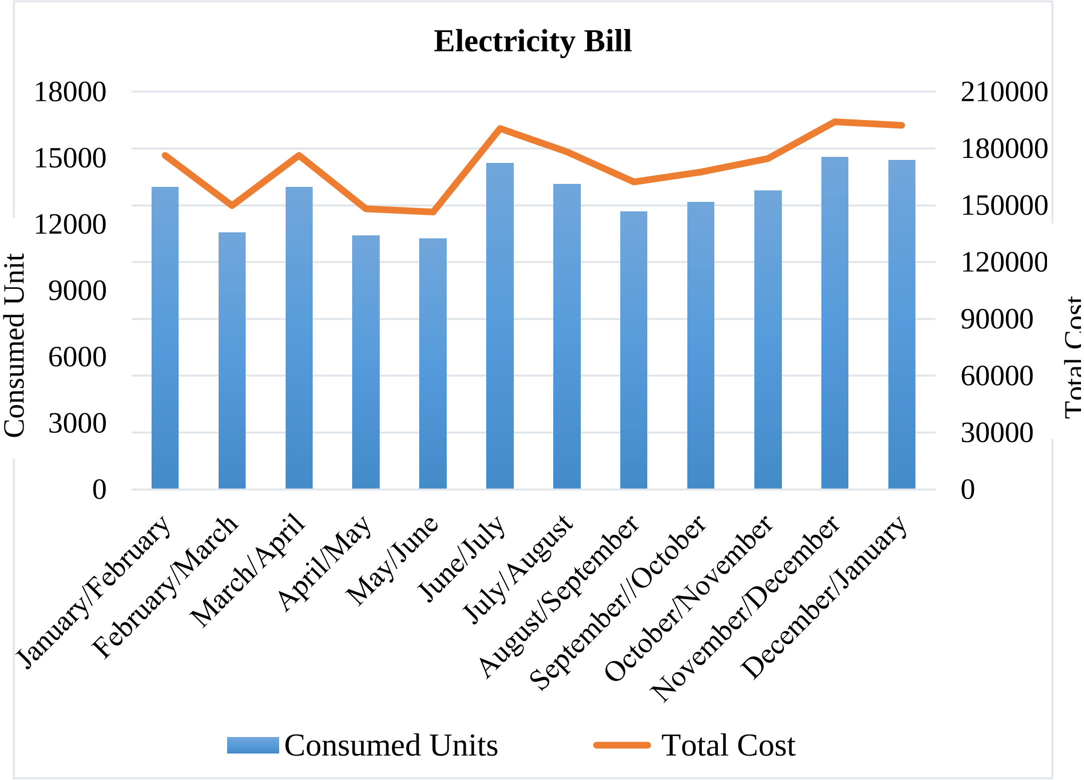


Figure 54: Electricity Bill of 2021 -BPC

The use of Light and Sensor devices has also reduced energy use. The building has saved 60% of the energy needed for Space heating and cooling in the working areas by use of the renewable source of energy (EAT).

Figure 54 shows the electricity consumed during the year 2021, the energy consumed is found to be less than of Hama Complex in Comparison as it has a provision of a Solar System for Space heating and cooling. As per standards also the maximum energy requirement in the corporate building is for a heating and cooling system.

5.9.3 Energy Efficiency- Stock House

There is no provision of renewable source of energy as it does not follow any kind of green design strategies so the building completely relies on the external sources of energy due to which the electricity consumed by this building is quite higher than those of passive buildings. Energy-efficient fixtures like CFL Lamps, LED and energy rated VRF AC systems are used in the building.

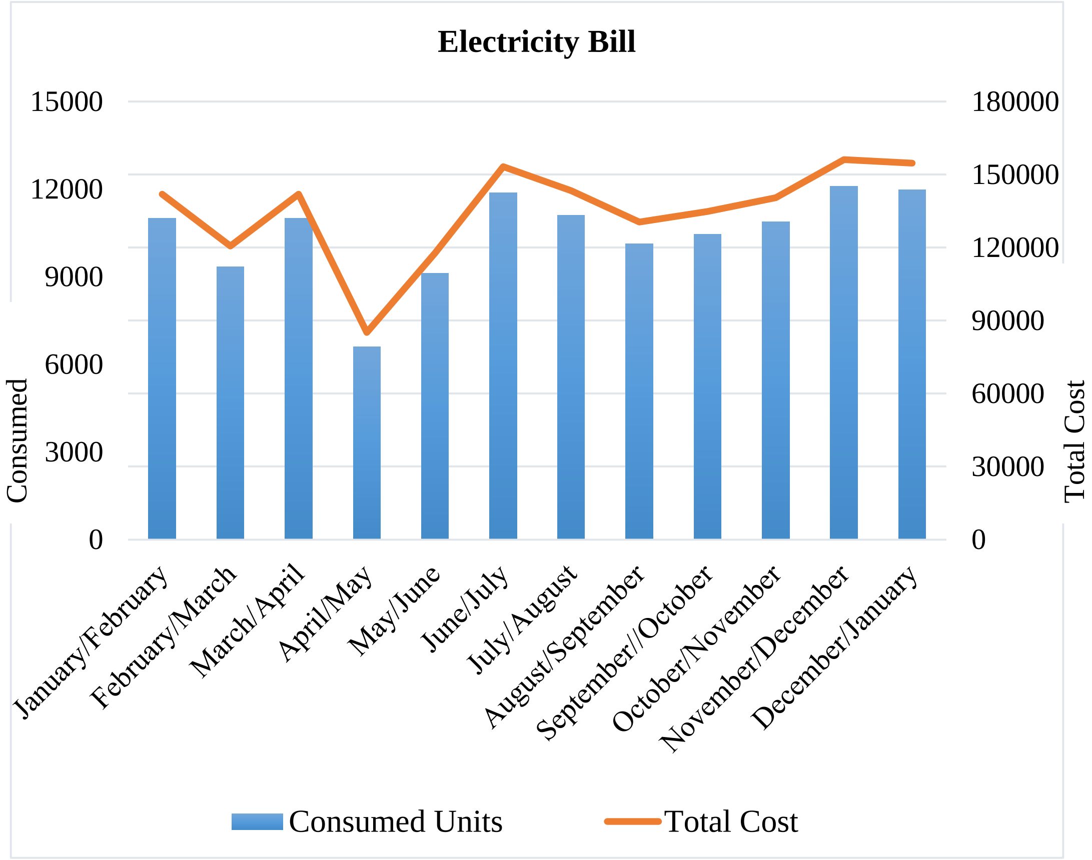


Figure 55: Electricity Bill of 2021 -Stock House

Figure 55 shows the electricity consumed during the year 2021, the energy consumed is found to be higher than that of passive buildings in Comparison as it has provision for renewable energy.

5.9.4 Comparison for Energy Efficiency

For a Comparative analysis of energy efficiency, the electricity bills of BPC (the Year 2021), Hama Complex (the Year 2018 and Year 2021) and Stock House (the Year 2021) were analyzed. The average units of one-year consumption were calculated of all the buildings then the comparison was plotted in the graph as shown in Figure 56 below.

The ratio of Total Floor Area to Electricity Consumed

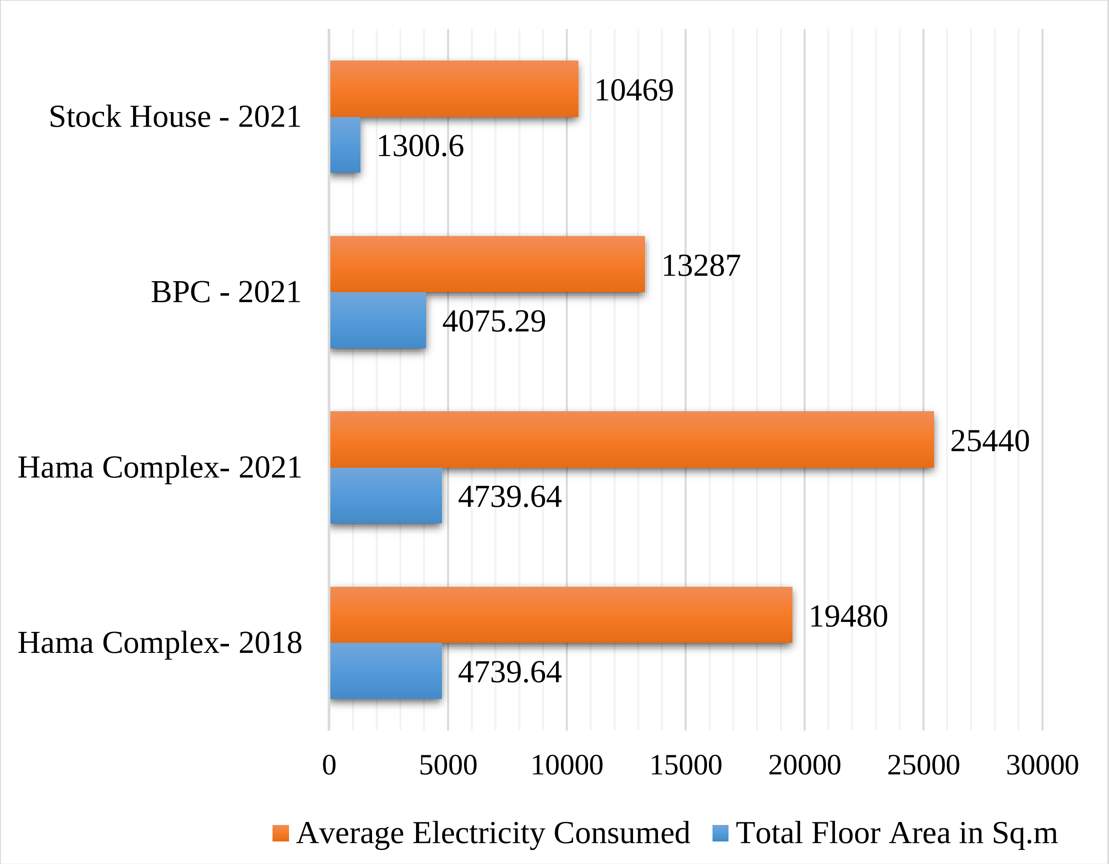


Figure 56: Comparison for Electricity Consumed

Figure 56 represents the ratio of total floor areas to the average electricity consumption of one year of each building. As shown in the figure it is found that the passive buildings have comparatively less energy consumption in comparison with conventional types of buildings. The average energy consumed by BPC is less than all it is due to the provision of EAT system for space heating and cooling which has saved so much energy.

The past scenario of Hama Complex where there was no use of renewable sources of energy for internal lighting also has very minimal consumption if compared with Conventional Building. So, it shows that the choices of proper building materials, insulating materials and technology used during construction have also a role in saving energy.

The data obtained from comparison were further calculated to find out the energy consumed per square meter of these buildings which is explained in Table 10 below.

Table 10: Calculation for Electricity Consumed per Sq.m in one month

Building	**Per Sq.m Electricity Consumed (kWh)**	**Remarks**
Hama Complex - 2018	4 kWh per Sq.m	2 times less than of Conventional Building
Hama Complex - 2021	5 kWh per Sq.m	1.6 times less than of Conventional Building
BPC - 2021	3 kWh per Sq.m	2.66 times less than of Conventional Building
Stock House -2021	8 kWh per Sq.m	Very high in comparison with Passive Buildings

Findings

The overall findings of the research are as follows:

- The building geometry of all three buildings studied were found to have rectangular which is the most preferable as per standard as well to have maximum openings. The orientation of Hama and BPC are focused on south orientation to gain heat whereas Stock house is oriented east, so Hama and BPC meet these standards as well.

- To achieve thermal comfort and energy efficiency in the building Hama and BPC are found to provide the building materials like wall insulations, double pane windows and passive technologies for solar gains whereas Stock House only rely on the mechanical system of Heating/ Cooling system. So, Hama and BPC are found to be more efficient than Stock House for thermal efficiency, indoor environment, building services etc.

- Maximum use of daylight through all orientations has led to having minimal energy consumption for lighting purposes in Hama and BPC. The internal layout of BPC with half partitions in interior working spaces increases the areas for capturing daylight. So, BPC is found to have maximum use of daylight.

- Passive and Active technologies are essential adaptive measures that provide clean energy as well as reduce the dependency on the external source of energy. Hama and BPC are found to be less dependent on external sources of energy as compared to Stock House due to the proper use of passive and active technologies like photo-voltaic cells, wind turbines, solar heating, EAT systems etc.

- Major services like rainwater harvesting, sewerage treatment plant, EAT, fire safety, emergency exits are observed in Hama and BPC which makes the building self-efficient and functional in use. As per standard also the building should be functional in use, self-efficient to be an adaptive building sot this passive building meets these standards as well whereas Stock House does not have any major building services which make it adaptable and efficient in use.

- Lastly, the comparison of electricity bills also shows that Stock House has higher consumption in comparison with Hama and BPC, this proves the efficiency of passive building. BPC is found to have less consumption i.e. 3 units per Sq.m. overall it is due to the use of the renewable source of energy for 60% of areas space heating/ cooling.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This research work demonstrates that the integration of green building strategies can support the process of reducing the energy consumption of the building as well as provide comfortable space. As per Standards, the physical and functional attributes of the buildings like building geometry, orientation, form, materials used, lighting, services, thermal performance, internal layouts, passive & active designs and energy efficiency in the building promotes productivity and adaptability of the buildings. The case studies on Hama Complex, Butwal Power Company and Stock House shows that the buildings (Hama Complex and BPC) which attempted LEED strategies (Green Design Strategies) are observed to meet the maximum of parameters such as building orientation, form, choice of materials, daylighting, building services, thermal performance, internal layouts, passive & active designs, energy efficiency as the standards. But the Stock House does not follow any guidelines of green buildings so there are also very minimal parameters (daylighting, orientation, form and internal layout) that meet as per standards of climate adaptive buildings. The comparative study of Hama Complex, BPC and Stock house also results that the passive buildings are being more energy-efficient, adaptable and functional in use. So, the improvement in conventional buildings can be achieved through improvement in attributes and integrating green design strategies within the building. There is a role of green buildings to make building climate adaptable which makes building more energy-efficient as well.

The project, construction of the Hama and BPC was done keeping in mind the LEED certification guidelines following the components of the LEED: sustainable site, materials and resources, water efficiency, energy and atmosphere, indoor environment quality, innovation in operation and regional priority. Though these buildings were designed in order to meet all the components of LEED the existing conditions of buildings shows that the building is not following the functions provided completely. In Hama Complex, there is no use of Solar Panels due to a lack of maintenance presently and this renewable energy was used for internal lighting previously which fulfilled 25% electricity requirements of the building. The comparison on electricity bill of the year 2021 of Stock House and Hama Complex results that when there is no use of renewable energy also Hama Complex have 1.6 times less consumption in comparison to Stock House which is due to proper use of insulating materials and the passive technologies used in the buildings. BPC has 2.66 times less energy consumption than Stock House. So, passive buildings have less energy consumption in comparison with conventional ones due to proper choices of building material, technologies used like the Earth Tunnel System, VRV for heating and cooling.

These passive buildings are found to be following the adaptive measures of the climate adaptable buildings as well more energy-efficient and sustainable. After doing case studies of the corporate buildings in Kathmandu it is found that the project which is following the green building movement could withstand as one of the best examples of energy-efficient or sustainable passive building and can also be a climate adaptive building. So, as per this research, it is concluded that green buildings can combat climate change and are good options for climate-adaptive buildings.

6.2 Recommendation

The following recommendations are suggested:

- Integrating the adaptive measures and green design strategies like active solar energies, passive techniques, building services in new development works which could increase the adaptability of the buildings.

- Incorporation of Eco- friendly features in Planning, Construction techniques and Building materials from the beginning of any project is suggested which can make it self-dependent, sustainable and energy-efficient.

- For better performance of the building's use of renewable sources of energy like photovoltaic solar panels, EAT (Earth Air Tunnel) system, wind turbine, rainwater harvesting, daylight etc. are suggested which also reduces the electricity bills comparatively.

- Energy efficiency in the building is a growing issue all over the world so it is suggested for the collaboration of stakeholders with governments at different levels and enhance sustainability, the efficiency of new development works through the integration of policies, building codes, bye-laws etc. following green design strategies.

- All the parameters of climate adaptive building correlate with one another, so it is suggested to integrate all the adaptive parameters so that the final building envelope would be climate-responsive.

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- <https://www.createers.com.np/bpc.html>

APPENDICES

Appendix I: Questionaries' for Interviews

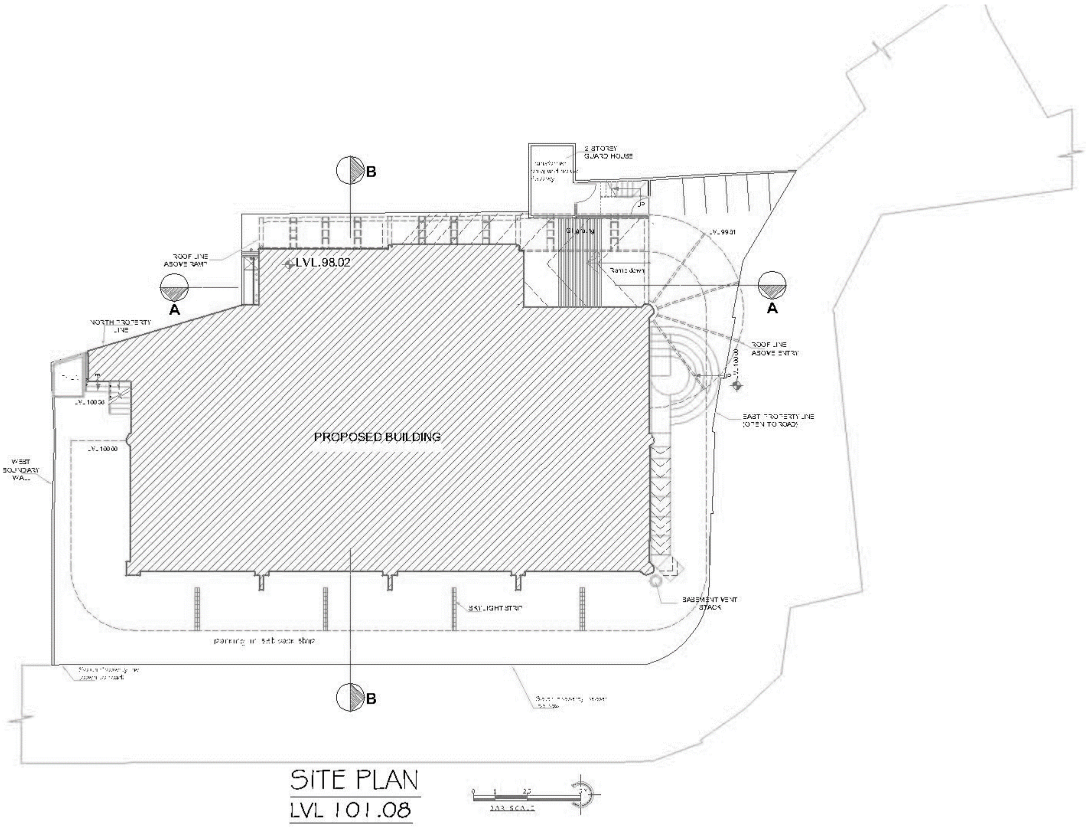
Building Data Collection	
Contact Person Details Name	
Designation	
Questions	
1. What are the Sources of energy used in your Building?	
2. Is the Renewable Sources of energy sufficient for electricity, heating and cooling inside the building?	
3. Do you have storage for the energy generated from solar panels?	
4. Is Stored Rainwater being sufficient during all seasons? For what purposes recycled water is being used?	
5. For what purposes you are dependent on external sources of energy?	
6. Is natural daylight sufficient for internal lighting?	
7. Do you feel Thermal comfort (at your workplace) during summer?	
8. Do you feel Thermal comfort (at your workplace) during winter?	
9. Do you feel Visual comfort (at your workplace)?	
10. How do you rank your indoor environmental quality?	

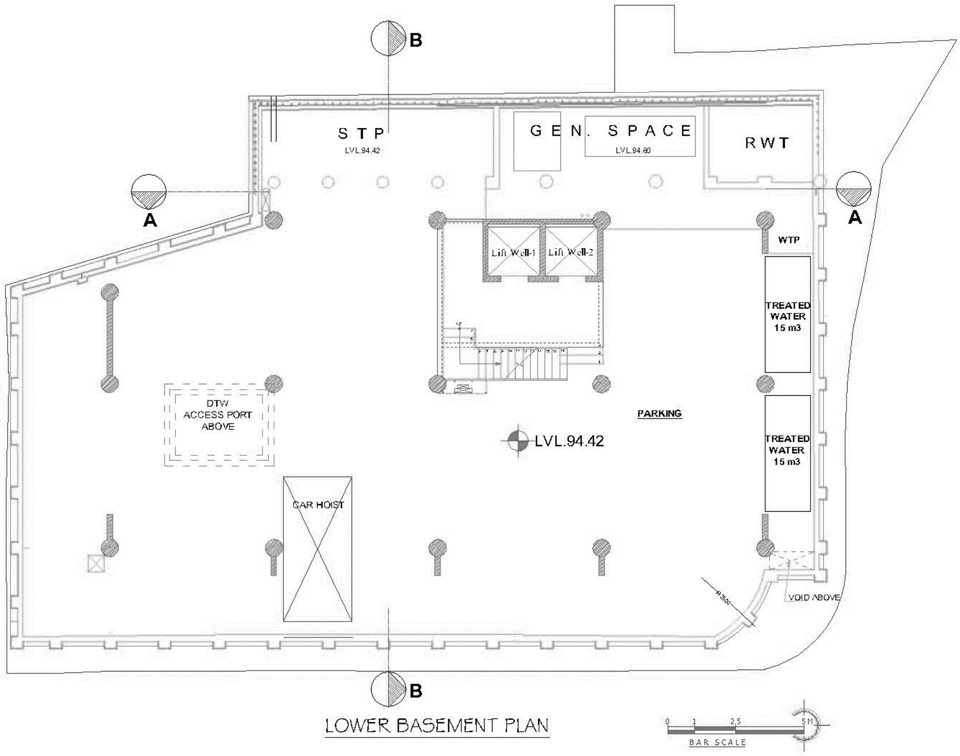
Appendix II: Building Data Collection

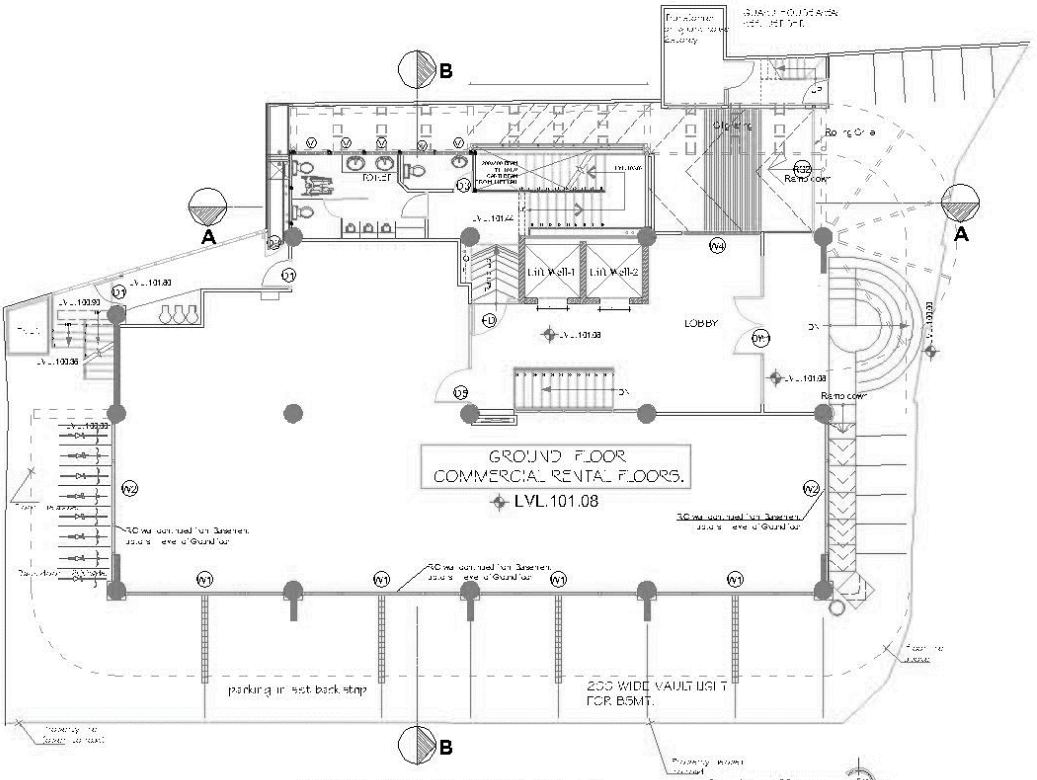
Building Data Collection
1. Buildings Architectural Drawings and Specifications
2. Electricity Bills of selected buildings
3. Data of Net Metering
4. Photographs of Interior and Exterior Spaces
5. Past Reports and Research Paper related to Selected Buildings

Appendix III: Drawings

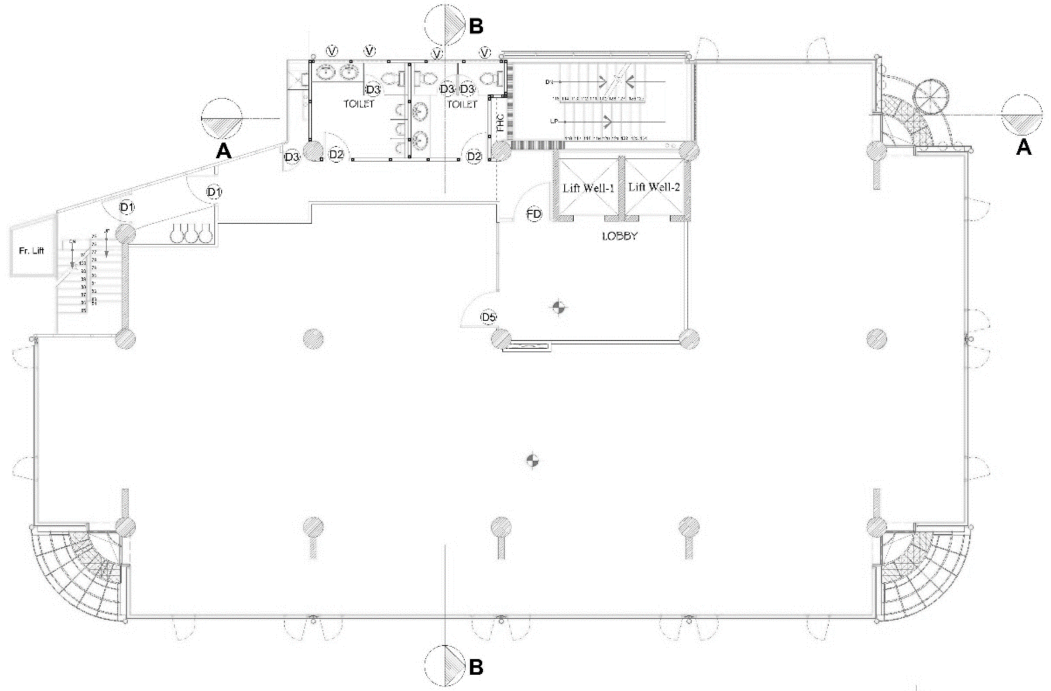
Floor Plans of Hama Iron Steel Building


SITE PLAN
LVL 101.08

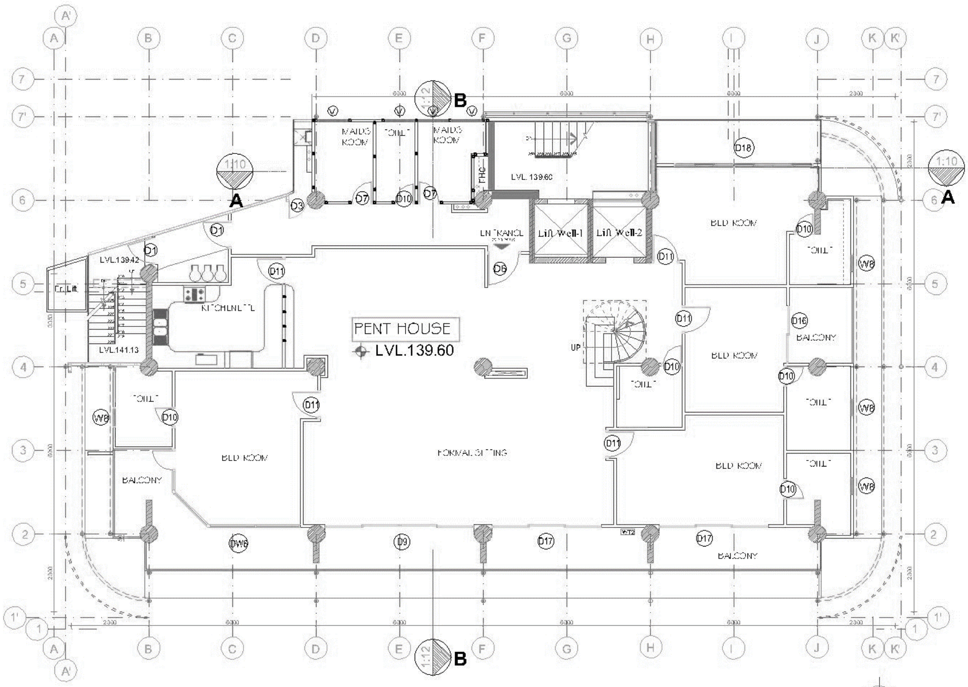

LOWER BASEMENT PLAN



GROUND FLOOR PLAN

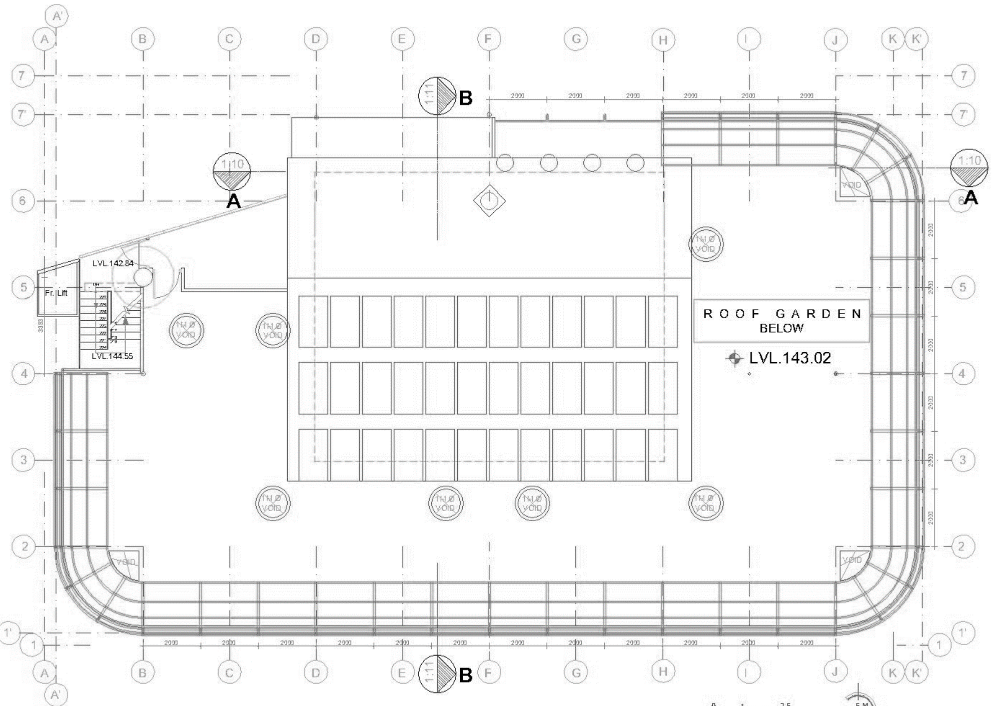


TYPICAL FLOOR PLAN
(FIRST-TENTH)



ELEVENTH FLOOR PLAN

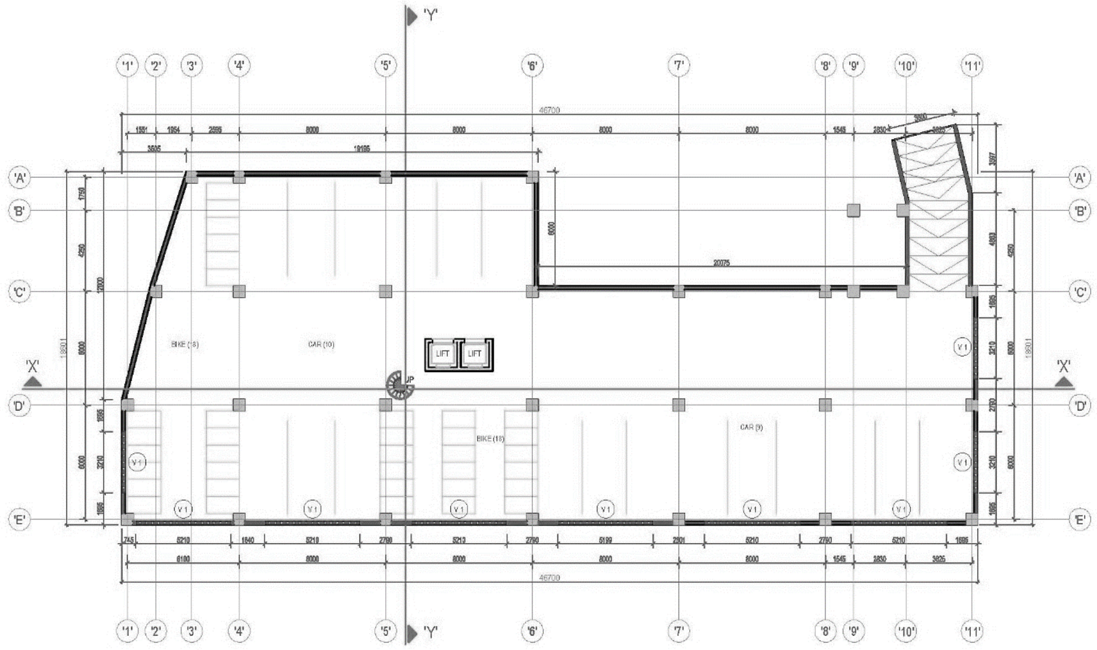
BAR SCALE



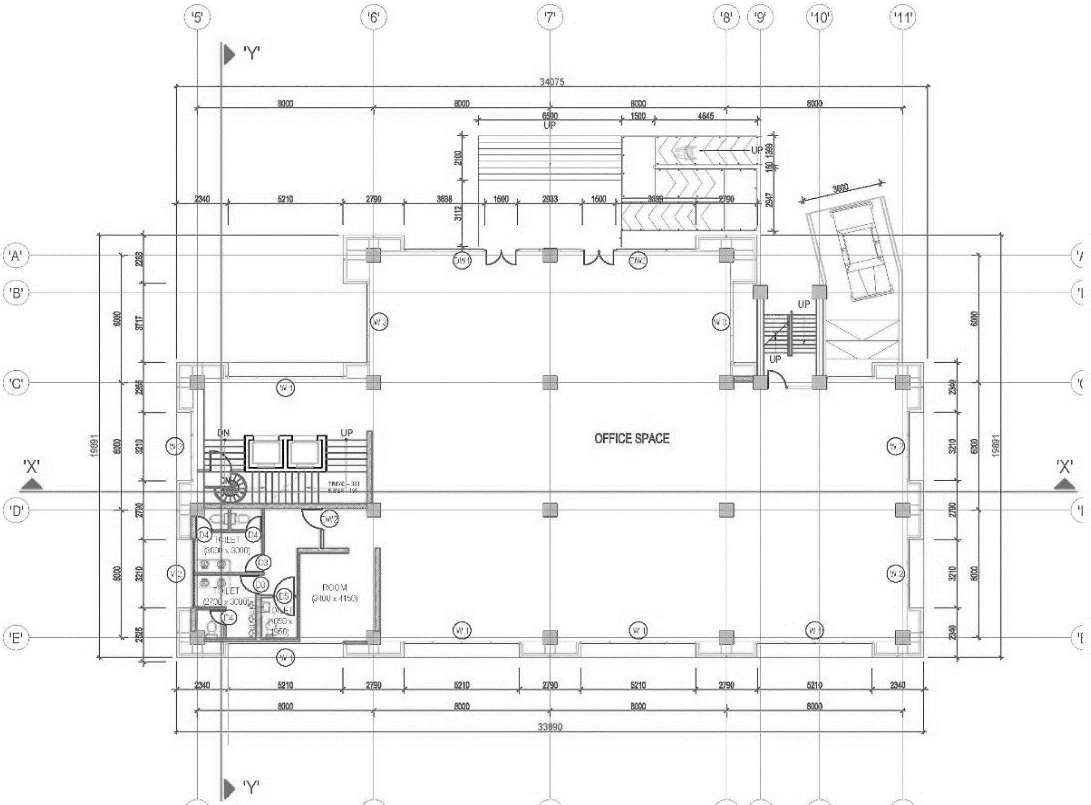
SOLAR ROOF PLAN

BAR SCALE

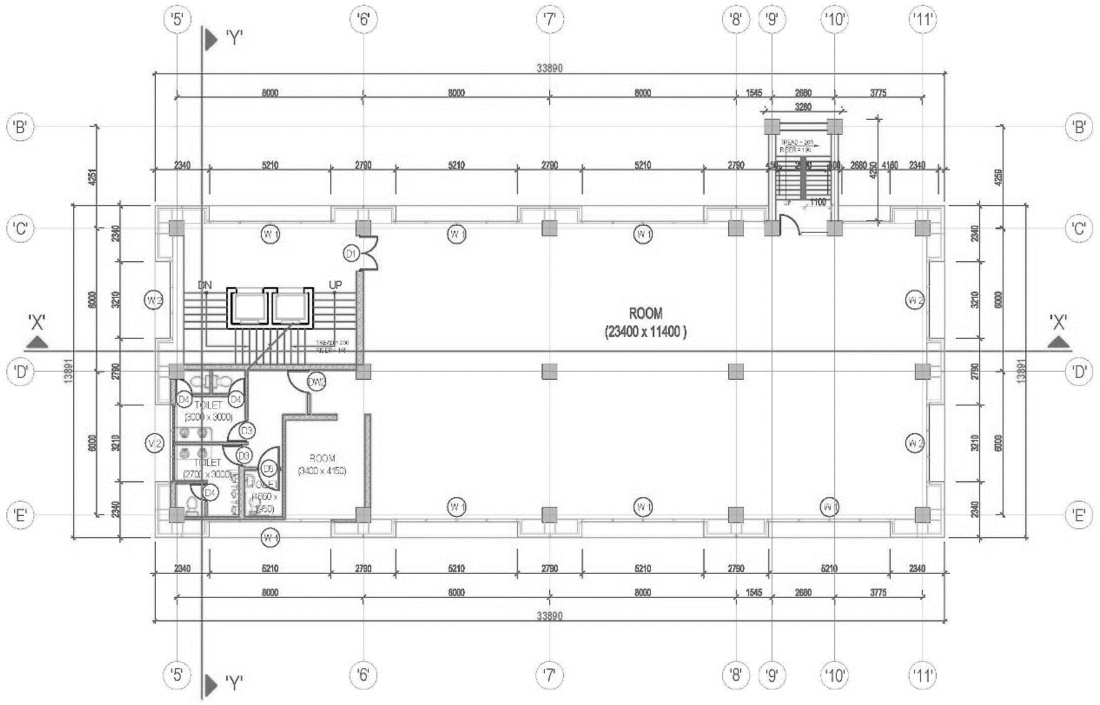
Floor Plans of Butwal Power Company



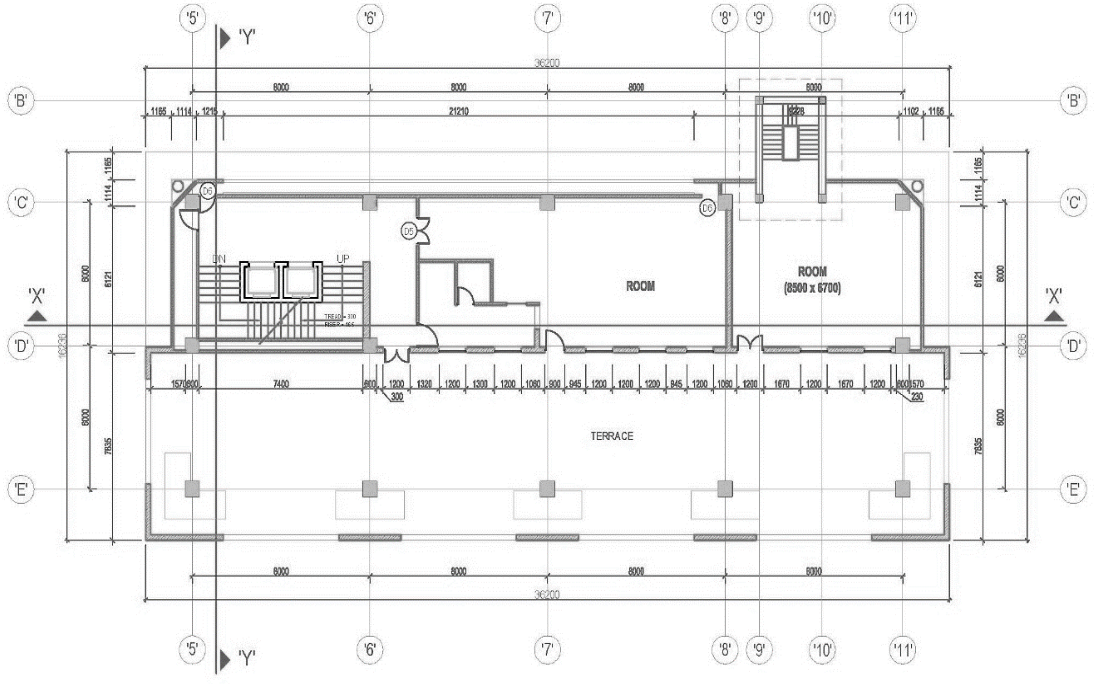
BASEMENT FLOOR PLAN
Area- 703.62 Sq. m.



GROUND FLOOR PLAN
Area- 539.3 Sq. m.

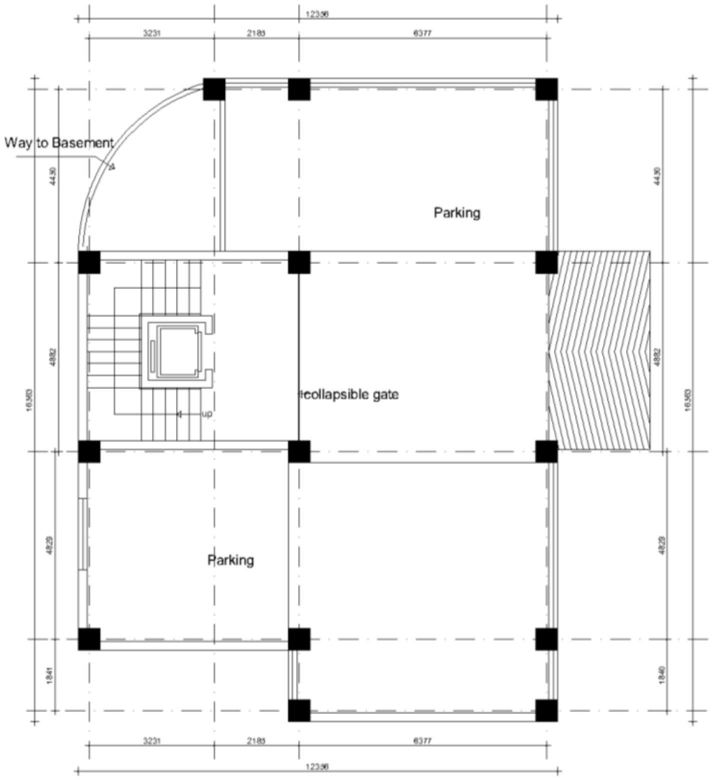


TYPICAL FLOOR PLAN
(THIRD - SIXTH)
Area- 450.8 Sq. m.

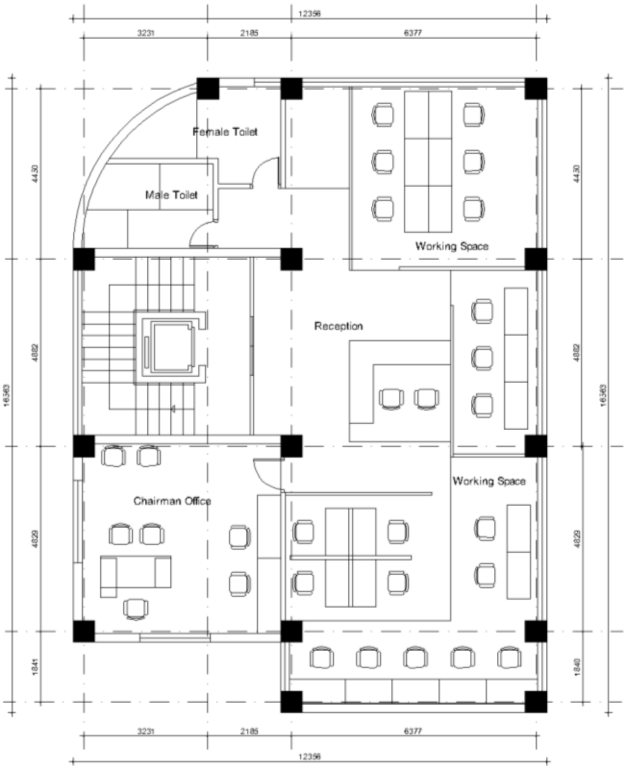


TOP FLOOR PLAN
Area- 241.2 Sq. m.

Floor Plans of Nepal Stock House



GROUND FLOOR PLAN
AREA: 187.52 SQ.M



TYPICAL FLOOR PLAN (FIRST-SIXTH)
AREA: 187.52 SQ.M

Appendix IV: Electricity Bills

Electricity Bill-Hama Complex- 2021

S.No.	**Month**	**Unit**	**Consumed Unit**	**Unit Cost**	**Total Cost**
1	January/February	kw per unit	26732	12.9	344842.8
			149	350	52150
					396992.8
2	February/March	kw per unit	22722	12.9	293113.8
			149	350	52150
					345263.8
3	March/April	kw per unit	26731	12.9	344829.9
			149	350	52150
					396979.9
4	April/May	kw per unit	16039	12.9	206903.1
			149	350	52150
					259053.1
5	May/June	kw per unit	22187	12.9	286212.3
			149	350	52150
					338362.3
6	June/July	kw per unit	28870	12.9	372423
			149	350	52150
					424573
7	July/August	kw per unit	26999	12.9	348287.1
			149	350	52150
					400437.1
8	August/September	kw per unit	24593	12.9	317249.7
			149	350	52150
					369399.7
9	September//October	kw per unit	25395	12.9	327595.5
			149	350	52150
					379745.5
10	October/November	kw per unit	26464	12.9	341385.6
			149	350	52150
					393535.6
11	November/December	kw per unit	29405	12.9	379324.5
			149	350	52150
					431474.5
12	December/January	kw per unit	29137	12.9	375867.3
			149	350	52150
					428017.3
	TOTAL				**4563834.6**

Electricity Bill-Hama Complex -2018					
S.No.	**Month**	**Unit**	**Consumed Unit**	**Unit Cost**	**Total Cost**
1	January/February	kw per unit	20049	12.9	258632.1
			149	350	52150
					310782.1
2	February/March	kw per unit	17041	12.9	219828.9
			149	350	52150
					271978.9
3	March/April	kw per unit	20048	12.9	258619.2
			149	350	52150
					310769.2
4	April/May	kw per unit	16841	12.9	217248.9
			149	350	52150
					269398.9
5	May/June	kw per unit	16640	12.9	214656
			149	350	52150
					266806
6	June/July	kw per unit	21652	12.9	279310.8
			149	350	52150
					331460.8
7	July/August	kw per unit	20249	12.9	261212.1
			149	350	52150
					313362.1
8	August/September	kw per unit	18445	12.9	237940.5
			149	350	52150
					290090.5
9	September//October	kw per unit	19046	12.9	245693.4
			149	350	52150
					297843.4
10	October/November	kw per unit	19848	12.9	256039.2
			149	350	52150
					308189.2
11	November/December	kw per unit	22053	12.9	284483.7
			149	350	52150
					336633.7
12	December/January	kw per unit	21853	12.9	281903.7
			149	350	52150
					334053.7
	TOTAL				**3641368.5**

Electricity Bill-BPC- 2021

S.No.	Month	Unit	Consumed Unit	Unit Cost	Total Cost
1	January/February	kw per unit	13675	12.9	176407.5
			149	350	52150
					228557.5
2	February/March	kw per unit	11623	12.9	149936.7
			149	350	52150
					202086.7
3	March/April	kw per unit	13674	12.9	176394.6
			149	350	52150
					228544.6
4	April/May	kw per unit	11487	12.9	148182.3
			149	350	52150
					200332.3
5	May/June	kw per unit	11350	12.9	146415
			149	350	52150
					198565
6	June/July	kw per unit	14769	12.9	190520.1
			149	350	52150
					242670.1
7	July/August	kw per unit	13811	12.9	178161.9
			149	350	52150
					230311.9
8	August/September	kw per unit	12581	12.9	162294.9
			149	350	52150
					214444.9
9	September//October	kw per unit	12991	12.9	167583.9
			149	350	52150
					219733.9
10	October/November	kw per unit	13538	12.9	174640.2
			149	350	52150
					226790.2
11	November/December	kw per unit	15042	12.9	194041.8
			149	350	52150
					246191.8
12	December/January	kw per unit	14905	12.9	192274.5
			149	350	52150
					244424.5
	TOTAL				**2682653.4**

Electricity Bill-Stock House - 2021					
S.No.	**Month**	**Unit**	**Consumed Unit**	**Unit Cost**	**Total Cost**
1	January/February	kw per unit	11000	12.9	141900
			149	350	52150
					194050
2	February/March	kw per unit	9350	12.9	120615
			149	350	52150
					172765
3	March/April	kw per unit	10999	12.9	141887.1
			149	350	52150
					194037.1
4	April/May	kw per unit	6600	12.9	85140
			149	350	52150
					137290
5	May/June	kw per unit	9130	12.9	117777
			149	350	52150
					169927
6	June/July	kw per unit	11880	12.9	153252
			149	350	52150
					205402
7	July/August	kw per unit	11110	12.9	143319
			149	350	52150
					195469
8	August/September	kw per unit	10120	12.9	130548
			149	350	52150
					182698
9	September//October	kw per unit	10450	12.9	134805
			149	350	52150
					186955
10	October/November	kw per unit	10890	12.9	140481
			149	350	52150
					192631
11	November/December	kw per unit	12100	12.9	156090
			149	350	52150
					208240
12	December/January	kw per unit	11990	12.9	154671
			149	350	52150
					206821
	TOTAL				**2246285.1**

Appendix V: Photographs

Photographs of Hama Complex

Figure 58: Ventilation at Basement- Hama Complex

Figure 57: Building Facades- Hama Complex

Photographs of BPC

Figure 59: Internal Lighting in Passage-BPC

Figure 60: Entrance- BPC

Figure 61: Roof Top Cafe and Photovoltaic Cells- BPC

Figure 62: Main Facade- BPC

Photographs of Stock House

Figure 63: Daylight at Lobby and Staircase Areas- Stock House

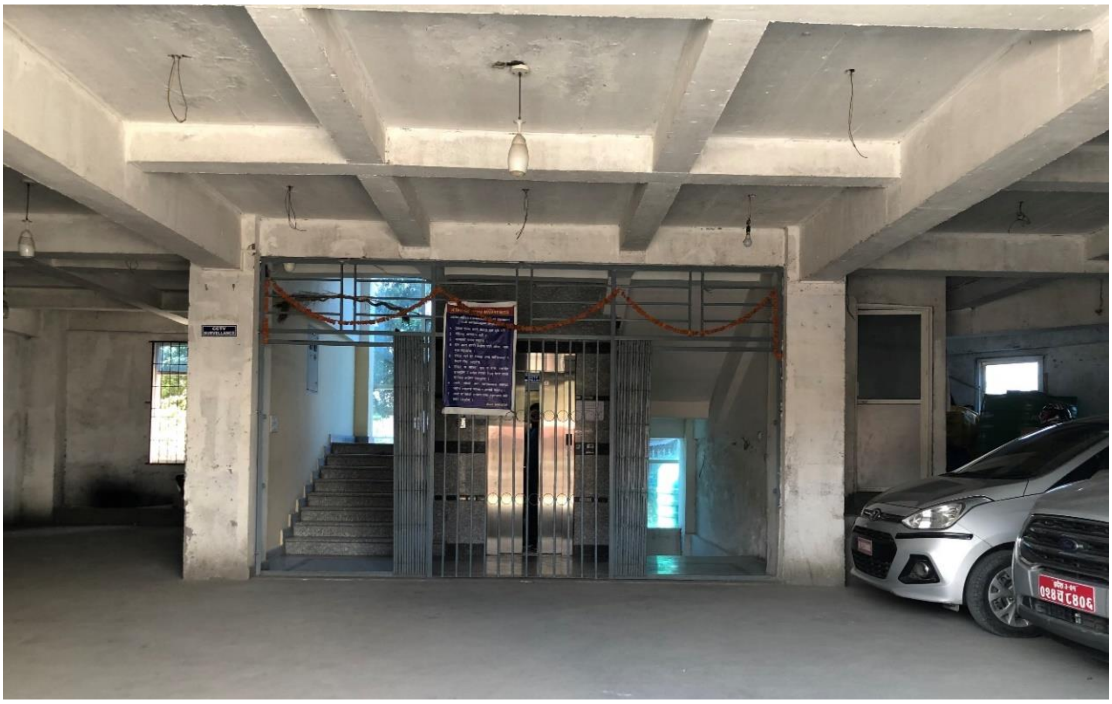


Figure 64: Ground Floor- Stock House

Figure 65: Building Facades- Stock House