DESIGN OF A GREEN BUILDING FOR HOT AND HUMID CLIMATE

FINAL YEAR PROJECT UG-2013

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Islamabad, Pakistan

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This is to certify that the

Final Year Project titled

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has been accepted towards the requirements

For the undergraduate degree

in

Civil Engineering

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O my soul, do not aspire to immortal life, but

exhaust the limits of the possible

— Pindar, Pythian III

ACKNOWLEDGEMENT

بسم الله الرحمن الرحيم

نحن ممتنون

الله سبحانه وتعالى
لبركاته لا تعد ولا تحصى،

إلى المدرسة الرئيسية للهندسة المدنية والبيئية،
الدكتور طارق محمود

إلى مشرفنا الدكتور محمد جمال الدين ثهيم
على دعمه ودوافعه وتوجيهاته

إلى والدينا وأفراد الأسرة
لتشجيعهم وتربيتهم

ولزملائنا، وخاصة دانيال عابد
على إسهامه وتوجيهاته

ABSTRACT

Global warming has many contributors, with majority of stakes coming from human activities. Almost 50% of the energy produced in US is consumed by construction industry and building operations. Colossal consumption of resources and lack of conservation is leading to a catastrophic future, calling a need for sustainability. Whereas, construction industry is facing tremendous challenges such as time and cost overruns, reluctance to change, lack of innovation is making this industry highly unsustainable. To familiarize sustainability in buildings and construction industry, this project points out innovative and green solutions and delivers a viable design that integrates active and passive systems. This thesis is aimed to cater construction of green buildings in hot and humid regions where main challenges are high temperatures, humidity, high wind pressure and low precipitation. Green technologies used in the design include Building Integrated Photovoltaic (BIPV), water conservation methods, waste water recycling, rainwater harvesting, steel structure and Internet-of-Things (IoT).

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1. CHAPTER 1

INTRODUCTION

1.1. General

The global temperature is rising due to the shortening of the oscillations of the madden Julian cycles that also contributes to the ongoing climatic changes. Climate changes have already caused numerous disasters on this planet. Global warming has many contributors, with majority of stakes coming from human activities; increased carbon footprint and pollutants. As shown in the pie chart, almost 50% of the energy produced in US is consumed by construction industry and building operations alone. With this chronic problem of colossal consumption of resources, and no or minimal conservation is leading to a catastrophic future, calling a need for sustainability. (Sustainability is explained in Section 2.1) Relocation into urban territories and developing populace prompt to a few issues like air, clamor, and water contamination, increment in solid structures and hard surfaces, lack of vegetation, expanding urban warmth island, an Earth-wide temperature boost and so forth. Expanded air temperature prompts to developing distress in indoor situations. Applying practical techniques as greenery frameworks and applying these frameworks to structures is a clever approach to relieve some of these downsides, and can moderate consumption of assets. (Safikhani 2014)

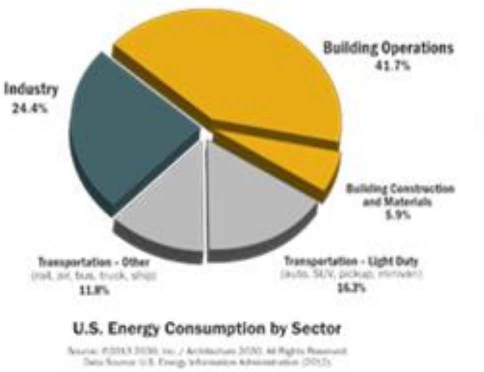


Figure 1.1. US energy consumption by sector

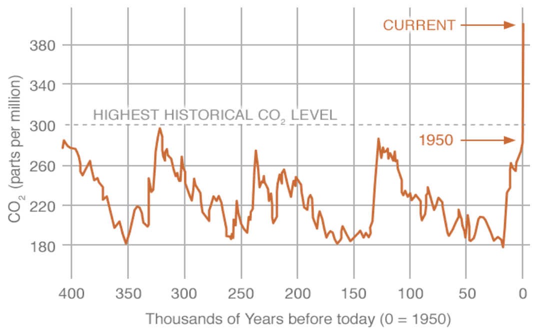


Figure 1.2. CO2 emissions (last 50 years)

1.2. Problem statement

As explained earlier, there is a need for sustainability, even in construction industry, i.e. a ‘reluctant to change’ industry that inhibits innovation and advancements. With global challenges such as rising urbanization and need for houses, it is necessary to tackle industry problems such as time and cost over runs due to conventional constructions methods. Solutions involving technology and innovation can be utilized to counter these challenges. Green Buildings are one of the solutions in response to these challenges. The problem is catered by design and simulation of a green buildings capable of water recycling, rain water harvesting, that are sustainable and energy efficient. We’ll design it and test it using simulation on Building Information Modeling (BIM).

1.3. Objectives

The objective of this project is to design a solar-powered house that utilizes the integration of active-passive systems. The house is aimed to follow the Modern Methods of Construction (MMC). The environment selected for this project is Hot and Humid climate. Conclusively, our design should meet the following attributes:

- Energy efficiency
- Sustainability
- Innovation
- Vegetation and landscaping
- Water conservation (Rain water harvesting & Wastewater treatment)
- Photovoltaic Design
- Mobility and Modularity
- Disaster Management

The basic goal of this project is to propose a design that would integrate technology with previous methods to demonstrate a seamless control over the house functionalities and simultaneously provide greater comfort and improved energy efficiency. In doing so, it identifies certain improvements to baseline technology in areas of building energy management, risk management and sustainable construction. It aims at obtaining a high-performance, energy efficient, sustainable, low GHG emitting, highly climate resilient and health and safety compliant building.

2. CHAPTER 2

LITERATURE REVIEW

2.1. What is Sustainability?

Sustainability is often defined using the “UN Brundtland Report” or commonly referred as “Our Common Future” published in 1987, explained as “… meeting the needs of the present without compromising the ability of future generations to meet their needs.”

Sustainability has three indicators;

1. Social
2. Environmental
3. Economical

This is also informally known as People, Planet and Public or 3Ps.

2.2. What is Sustainable Development?

Sustainable development can be defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations Development Agenda). UN has formed Sustainable development goals based on this definition which calls for efforts to make a future sustainable for people and planet. Sustainable Development requires the integration of 3Ps for the well-being of our society. UN has developed a Sustainable Development Goals (SDGs) so that “… there must be promotion of sustainable, inclusive and equitable economic growth, creating greater opportunities for all, reducing inequalities, raising basic standards of living, fostering equitable social development and inclusion, and promoting integrated and sustainable management of natural resources and ecosystems.”

2.3. What is a Green Building?

Green Building is a building that has positive effects on environment and people and eliminates negative effects. Green Buildings cater various factors such as energy, water, materials, site selection, wastage, indoor environmental quality and quality of life.

Green Buildings are designed to

- efficiency utilize resources, water and energy
- minimize toxic materials usage
- adapt to changing environment
- provide good indoor environment

A Green Buildings must portray above mentioned properties not only in design, but also in construction and operations. Green Buildings also cater for the local context such as local climatic conditions, building practices, traditions and cultural norms.

2.3.1. Green, energy efficient, sustainable and Solar Powered House

Utilizing renewable energy is an exercise to achieve sustainability and is appropriate for creating nations with clean energy although this is material for created countries too. A few essential renewable energy frameworks are ground source-based systems, day-lighting frameworks, and sun powered based energy frameworks. Even though the sun is the primary wellspring of characteristic energy on the planet, its radiation warms the situations and prompts to expanded temperatures. Consequently, sun based energy ought to be controlled, because on the off chance that it is not controlled effectively it has a negative warming impact. Utilizing plants and greenery is a natural answer for control sun based radiation and decrease temperature. Moreover, the utilization of plants offers regular points of interest as plants zone clean source. (Safikhani, 2014)

2.3.2. Vertical Greening Systems

Vegetation can be integrated with structures, such as through green roofs or vertical greening that permits getting a critical change of the building's productivity, biological and ecological advantages. Along these lines one or a few sorts of vegetation can develop vertically on a surface whether or made by people in or out of the building, joined to the mass of the building or standing freely before the divider. In short, vertical vegetation systems are depicted as becoming each sort of plants on every sort of vertical surface. (Perini, 2011; Safikhani, 2014)

2.3.3. Green Roofs

Green roof is thought to be a powerful commitment to the determination of a few ecological issues at the building and urban levels. Notwithstanding the production of a lovely situation, green roof offers a few advantages in contrast with routine roof. They enhance storm water administration and in addition decrease air contamination and clamor. Green roof increment vegetal and creature biodiversity in urban areas and they likewise lessen a city's carbon impression by changing over carbon dioxide to oxygen through photosynthesis. (Jaffal, 2012)

The application of green roof is turning out to be progressively well known for both new and retrofit structures. Green roof enhances building vitality effectiveness by upgrading the warm exchange through roof. The decrease of the mid-year temperature around green roof enhances the effectiveness of HVAC frameworks by giving a neighborhood free cooling impact to the liquid before it comes back to the chiller. This diminished temperature additionally enhances the productivity of encompassing photovoltaic boards. Green roof enhances the life span of material films by restricting the warm worry to which they are subjected. At long last, at the city level, green roof adds to the alleviation of the urban warmth island impact. (Chan, 2013; Jaffal, 2012)

2.3.4. Useful Daylight Illuminances

The misuse of sunlight is perceived as a powerful intends to decrease the counterfeit lighting prerequisites of nondomestic structures. Practically speaking be that as it may, sunshine is a significantly under-misused common asset. Critical among the different explanations behind this might be the absence of authenticity of the standard prescient strategy: the sunshine calculates approach.

Real daylight illuminances over the work plane display vast varieties both spatially and transiently. For instance, sunshine illuminances commonly decrease quickly with expanding separate from windows. Similarly, sunlight illuminances at a point can shift enormously starting with one minute then onto the next due to changing sun position or potentially sky conditions. As noted, originations of illuminance consistency that emerge from utilizing the standard cloudy sky approach are inapplicable for practical conditions where the commitment of direct daylight brings about substantial contrasts between the greatest and least sunshine levels.

2.4. Legislative/ Organizations

The organizations related to green building guidelines are divided into two categories:

2.4.1. Legislative Organizations

Green Building codes are being updated and refreshed to meet the new challenges of industry. These codes can be divided into two broad formats; prescriptive and performance, with outcome-based becoming a developing third option.

These formats are explained as:

Prescriptive: A fast and conservative approach to code compliance. Materials and equipment must meet a certain level.

Performance-based: A target is established for the energy usage and measurement and reporting techniques are developed.

The difference between codes and building rating systems is that codes are mandatory. If green codes become adopted on a wide spread basis, their impact can change the building environment rapidly and extensively.

For example, the International Green Construction Code (IgCC) that details requirements intended to reduce the negative impact of buildings on the natural environment.

The California Green Building Standards Code (CALGreen Code) is another example of legislative Green Building codes. The purpose of CALGreen is to improve public health, safety and general welfare by enhancing the design and construction of buildings through the use of building concepts having a reduced negative impact or positive environmental impact and encouraging sustainable construction practices.

2.4.2. Voluntary Organizations

The effort of sustainable construction and design boosted in the 1990s with Building Research Establishment's Environmental Assessment Method (BREEAM), the first Green Buildings rating system in the U.K.

Then, in 2000 the U.S. Green Building Council (USGBC) produced Leadership in Energy and Environmental Design (LEED) rating system that targeted improving performance for new construction. LEED was improved and further developed as the leading green building rating system in the world. Others prominent efforts include the Green Building Initiative (GBI) that was developed in Canada and produced Green Globes. Voluntary organizations include LEED, BREEM, Green Globes etc.

2.5. Market Trends

During the literature review, it is observed that green buildings are trending because there is lack of research papers for residential buildings for hot and humid climate.

Due to higher initial costs, Green Buildings are not popular and unattractive to local market base. However, there has been a shift of introducing green technologies (technologies that help in making house environmental friendly, economical and comfortable) in residential buildings as well as commercial buildings. There is a shift of trend towards commercial sectors that seek to conserve huge amount of energy by implementing green technologies.

The rising trends among green buildings include increase of research in Net Zero Energy (NZE) buildings, as it has become a hot topic for researchers, conferences and industry.

There has been a drastic increase in competition between available assessment systems, such as new entrants in specialized niches, such as shopping centers or office interiors.

The green building certifications growth has reduced dramatically, due to the same reason.

Globally, there have been efforts to reduce energy consumption and a lot of effort is put to achieve efficiency in systems.

2.6. Singapore Model

Singapore emerged as a beacon of hope for the green construction industry when much of Asia is dwelling in poor design and construction methods. There is little to no attraction towards green buildings and hence lack of government support and incentives. However, Singapore's Building and Construction Authority (BCA) initiated with a master plan to introduce and incentivize green buildings in Singapore. BCA has also introduced its rating tool, Green Mark that is considered as well as utilized as a brand in neighboring nations. BCA has introduced third green building master plan that is aimed to research, adoption of green principles and focus on occupant behavior. The plan also includes $S50 million incentive scheme for existing buildings to adopt sustainable elements and improve efficiency of buildings. This incentive scheme also offered co-funding the cost of retrofitting buildings for energy improvements.

The Singapore model attracts building owners to proactively participate in this green movement so to meet the government's goal to achieve a 35 percent reduction in the energy intensity of its economy by 2030.

"… by proactively changing their energy consumption behavior and practices, tenants and occupants can be part of the solution rather than the problem."

— John Keung, CEO, BCA

It is encouraging to state that the certified green buildings account for more than a fifth of the floor area in the island city-state and the city's Green Mark standards shaved 11.6 percent off total operating expenses of buildings in Singapore.

2.7. Research Gap

During the literature review, it is noticed that a lot of work has been done on the high rises structures in the hot and humid regions, but there is lack of study for residential structures in hot and humid regions.

Hence, it is recommended that an extensive study to be conducted for the design and feasibility of green buildings in hot and humid regions.

3. CHAPTER 3

RESEARCH METHODOLOGY

3.1. Design Approach

3.1.1. Feasibility

The user requirements are researched, performance requirements are established and corresponding regulations are studied.

3.1.2. Design

The feasibility details the requirements of user and design parameters; hence, a concept is established for design, and sub system design is made, that aids the construction of schematic design.

3.1.3. Verification

The schematic is detailed, and then verified against the user requirements, design parameters and code compliances. Bio Climatic Analysis is conducted for the orientation of building against solar path and wind conditions.

3.1.4. Validation

The validation of design is conducted with respect to professional reviews with industry experts; further environmental testing was conducted by simulating the site conditions.

3.1.5. Design Transfer

The design is then transferred to professional drawings, a study of cost was conducted, and a complete set of drawings was prepared.

3.1.6. Design Changes

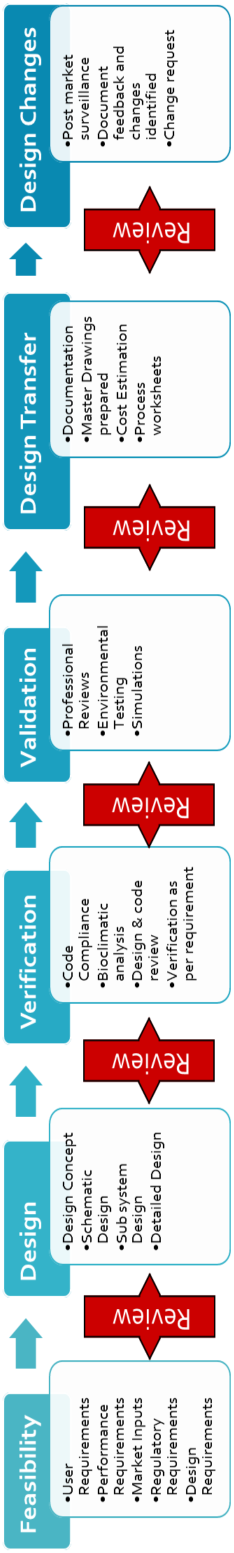


Figure 3.1. Design Approach

The design was catered for continuing industry trends and changing market and environmental conditions.

3.2. Design Methodology

3.2.1. Social Data

The social data of Dubai is obtained from Dubai Statistics Center (DSC). DSC publishes annual report by the name of 'Dubai in Figures' stating social and economic demographics. Apart from this, it also publishes data relating buildings and their divisions with respect to types.

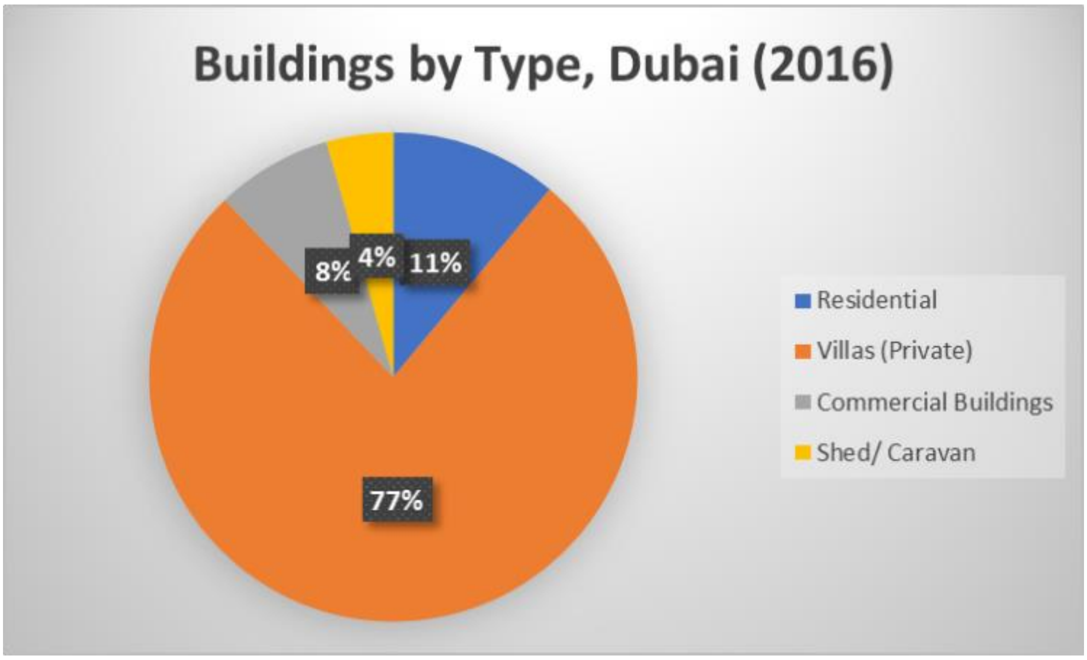


Figure 3.2. Building Types, Dubai (2016)

In the year 2016, 88 percent of buildings were used for residential purposes, including 77 percent of private villas. Commercial buildings account for 12 percent within Dubai, including 4 percent of large shed ad portable caravans.

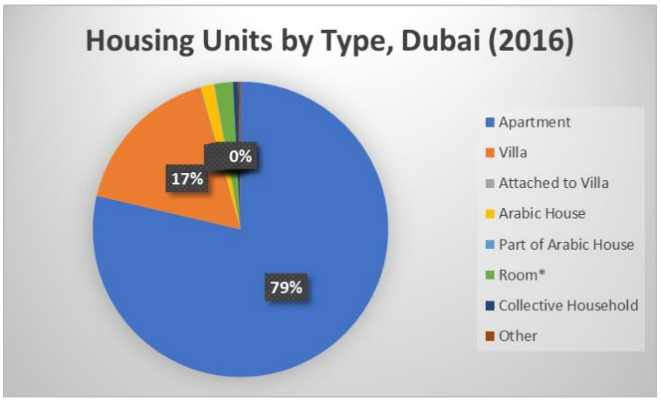


Figure 3.3. Housing Units type, Dubai (2016)

In the year 2016, the household population of Dubai was divided in mainly two building types; 79 percent of household dwelling in Apartments and 17 percent of household in Villas.

Conclusively, it can be understood that 79 percent of population in Dubai resides in 11 percent of residential apartment buildings; however, 17% percent of population resides in 77 percent of villas.

3.2.2. Environmental Data

Environmental data was extracted from National Center for Metrology Services (NCMS), United Arab Emirates. NCMS offered two types of data; 38 years trends as well as detailed daily data for the Year 2016. Hence, the data was imported to Microsoft Excel form, it was arranged and plotted to view trends in following graphs.

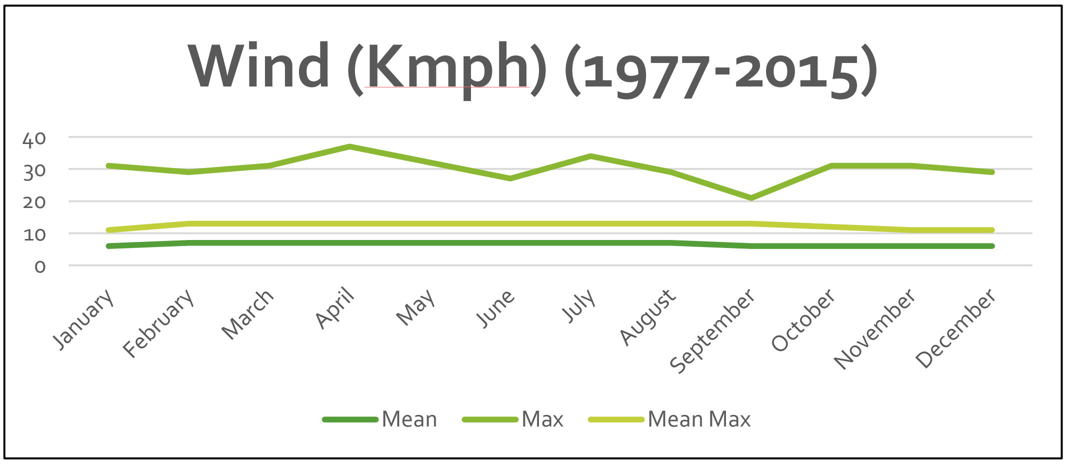


Figure 3.4. Wind Data (1977-2015)

Wind Data for the 38 Year time (1977 to 2015). It can be noted that 38 Kmph is the maximum wind speed recorded in the month of April.

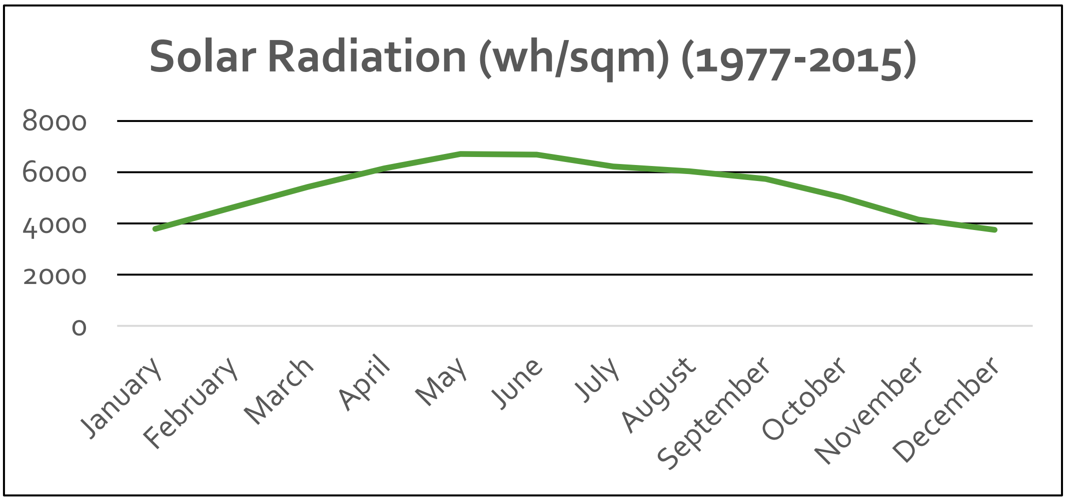


Figure 3.5. Solar Radiation Data (wh/sqm) (1977-2015)

United Arab Emirates is fortunate to receive abundant solar radiation throughout the year, making the place best fit for Photovoltaic technology, the maximum solar radiation recorded from the 38 Year time period (1977 – 2015) is 6300 wh/sqm in the month of May.

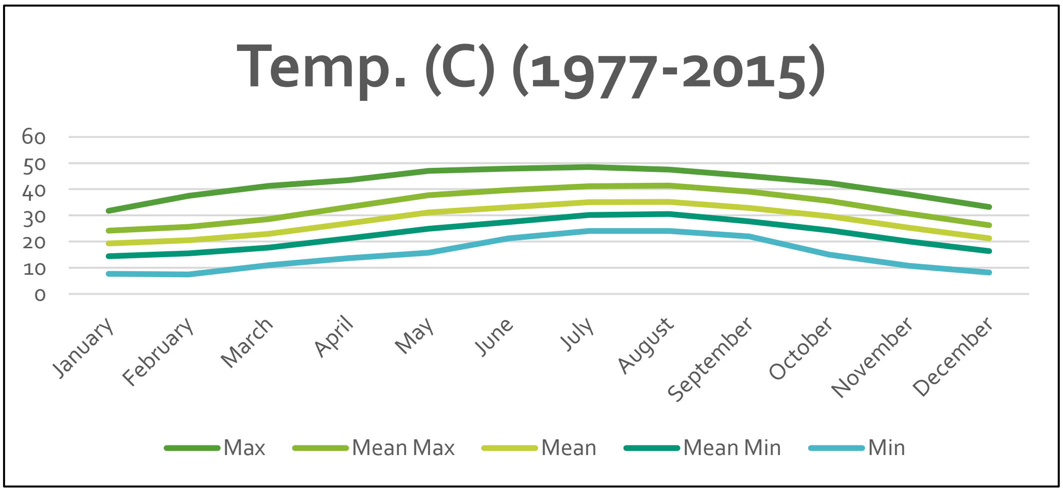


Figure 3.6. Temperature Data (Centigrade) (1977-2015)

The temperature recorded for the 38 Year time period (1977 – 2015) is recorded maximum at 48C in the month of July and minimum at 7C in the month of December.

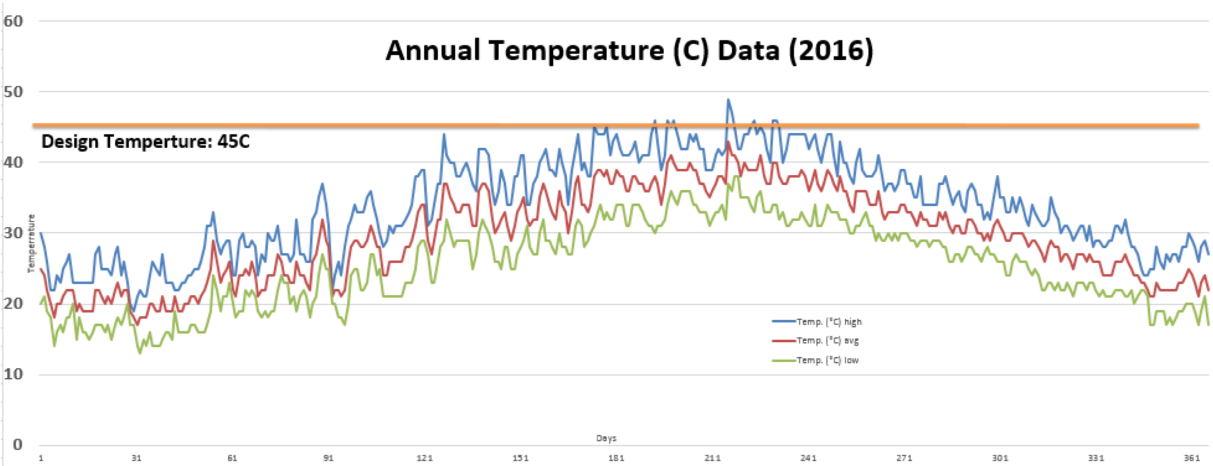


Figure 3.7. Annual Temperature data (Centigrade) (2016).Design temperature selected as 45°C

The annual temperature for the Year 2016 graph is represented with daily temperatures readings. The maximum temperature recorded is at 48.5C in the month of July. The minimum temperature recorded is 12C in February.

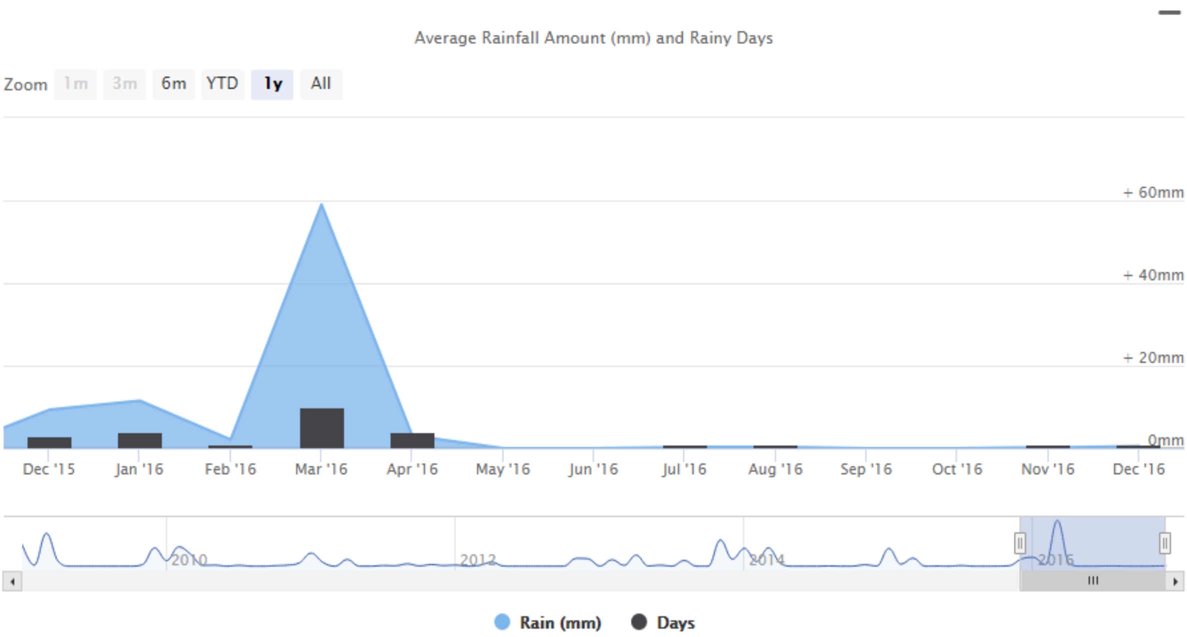


Figure 3.8. Average Rainfall Amount (mm) and rainy days

The average annual rainfall data of 2016 is displayed with respect to monthly readings. The maximum rainfall poured in the month of March for 60mm, whereas the annual average is 8mm.

3.3. Conceptual Model

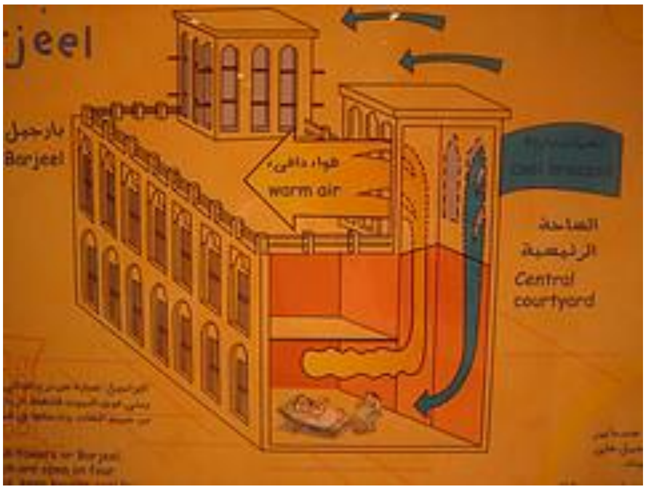


Figure 3.9. Burjeel (wind tower)

Burjeel is a concept known in West as ventilation towers. The basic function of these towers are to allow wind to pass through them into the house, and due to their geometry cools the air as it reaches the rooms, and these columns allow the warm air to escape. Burjeel have been used extensively in the Arab Architecture and are a perfect fit for the passive ventilation in hot and humid climatic regions.

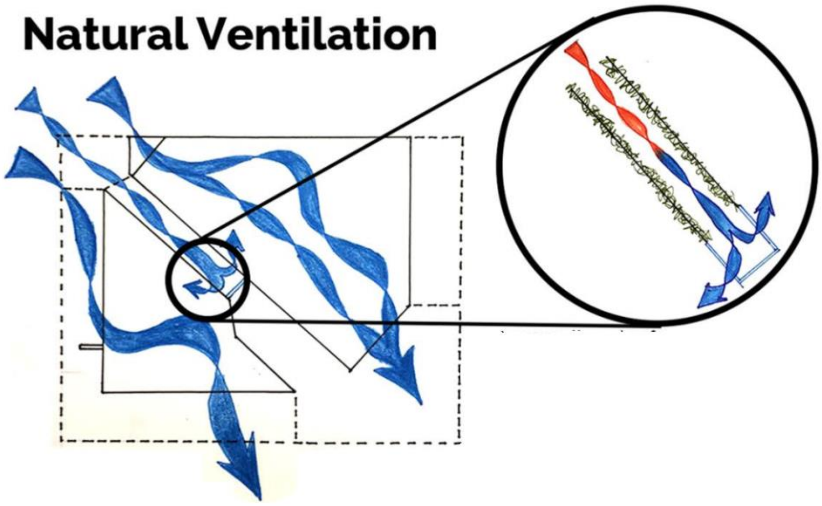


Figure 3.10. Ventilation patterns of our design in accordance with the keffiyeh

Based on Burjeel, the ventilation patterns are innovated, utilizing the wind in favor such that when warm air enters house, it passes through vertical vegetation that cools the warm air, providing stream of cool air passing through the house, and pushing warm air out. These are few of the passive strategies helping to keep interior temperatures down.

Figure 3.11.Ventilation patterns of our design in accordance with the Keffiyeh

The original idea of wind and its relation with local context is obtained from Keffiyah or Ghatra (the Arabic Cloth), which is a head cloth, popular among locals in Middle East. The Ghatra helps in covering the head and shoulders from the scorching sun and provides a path for the warm air to enter shoulder air, and raise to keep the back of head cool.

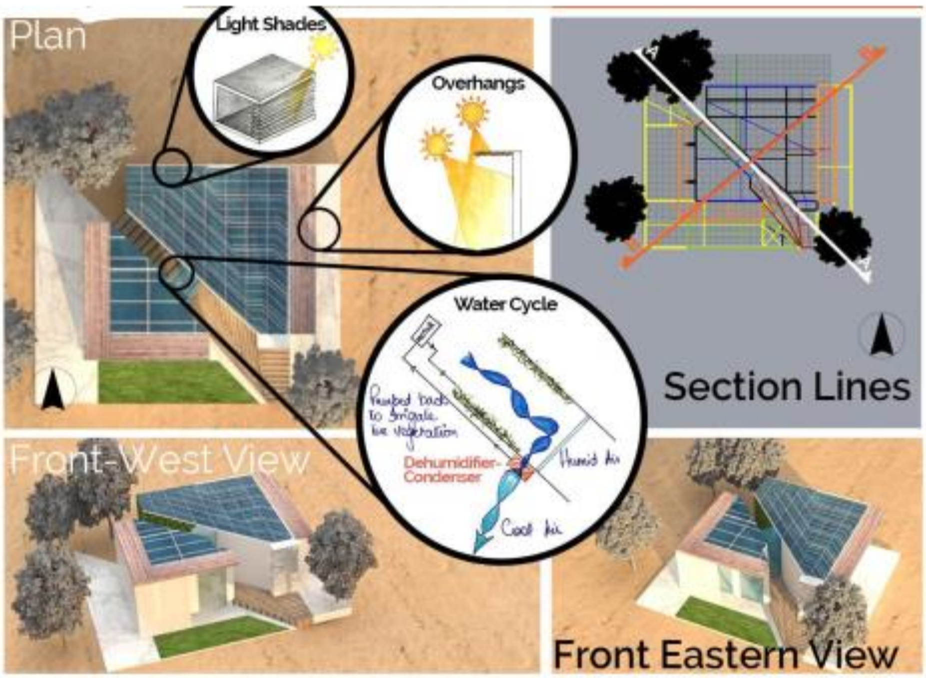


Figure 3.12. Conceptual model

These concepts were taken into context to initiate the design process. The design process is iterative in nature, and the initial design was developed to convey the concepts. Later, the design is modified to cater for reviews and critical elements.

3.4. Iterative Design

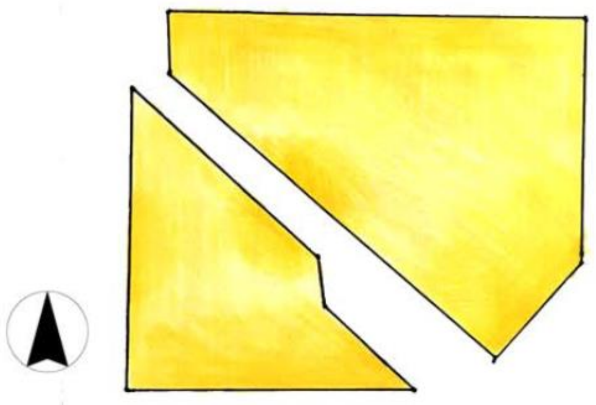


Figure 3.13. First Draft in accordance with the wind patterns of keffiyeh

The design process passed through various iterations before settling down to following design. The process initiated from developing a mass to utilize maximum area.

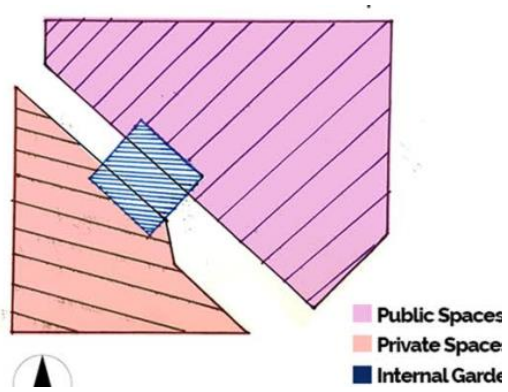


Figure 3.14. Spaces Defined for the initial draft

Then, the mass was divided to fulfill respective functions, and then according to conceptualized elements were added. This gave a holistic sense to model.

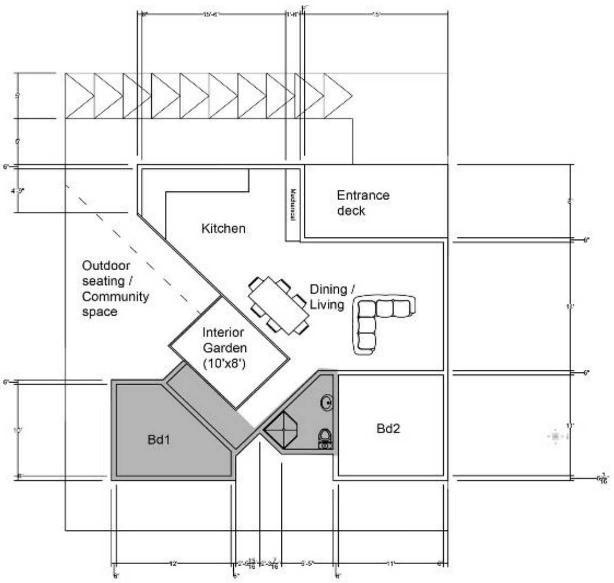


Figure 3.15. First AutoCAD Design with definite dimensions

Then, a detailed AutoCAD drawing was prepared based on previous reviews.

Figure 3.16. Final Architectural design following iterative process

Lastly, the final design was prepared, that was modified to consider ground condition and certain limitations. The final design was validated and verified by the Design Approach to fulfill objectives laid out by the project.

4. CHAPTER 4

DESIGN

4.1. Design Parameters

Keeping in view the demographics and environmental data, the parameters for design have been finalized such as;

4.1.1. Temperature

With the maximum temperatures, and the urban temperature is taken as 45C.

4.1.2. Humidity

The humidity is taken as 85%.

4.1.3. Rainfall

The average annual rainfall is 8mm.

4.1.4. Wind Speed

The house is designed for the maximum wind gust of 85 mph.

4.1.5. Solar Radiation

The solar radiation is designed as 3500 wh/sqm.

4.1.6. Seismic Zone

The Seismic zone is 2A*, in accordance to International Building Code (IBC).

4.2. Designed Model

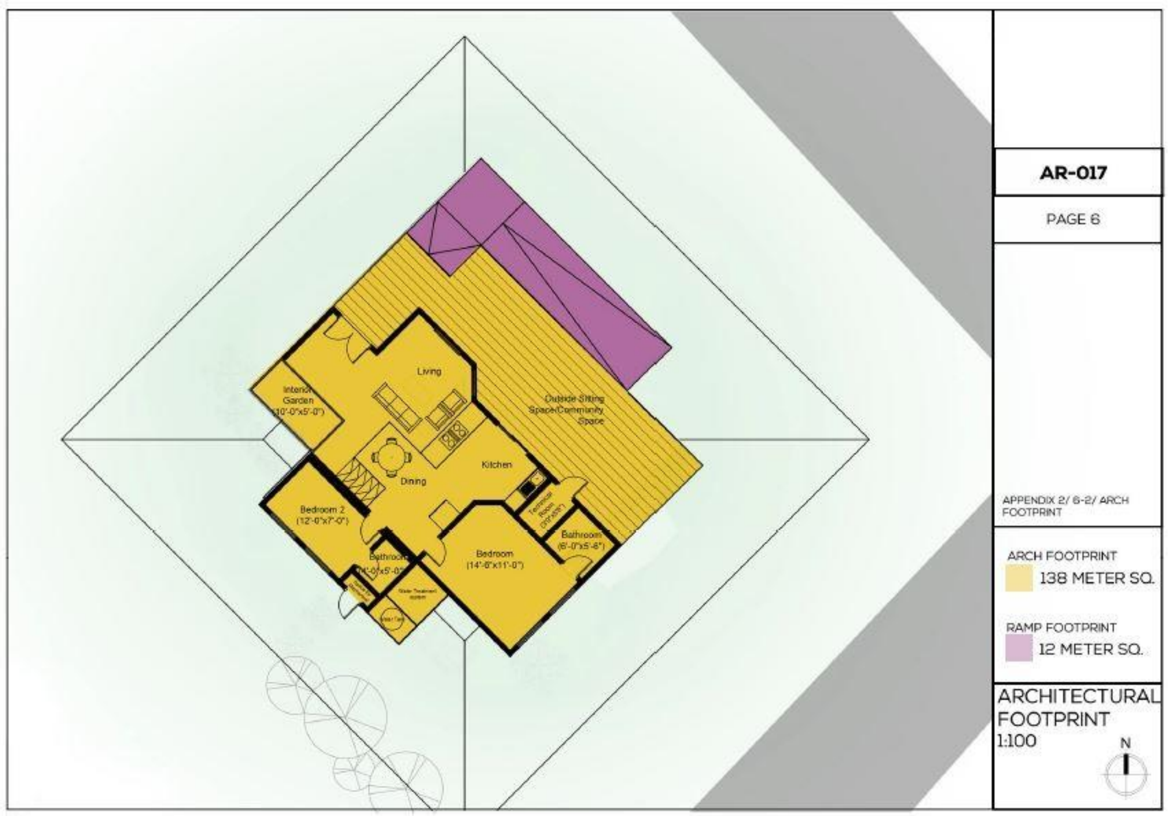


Figure 4.1. Architectural footprint of final design (Total area 150m2)

Architectural Footprint includes building area and additional areas included in the building.

Figure 4.2. Total covered area of House 63.8m^2 excluding ramp and deck

The total area is 150 sqm, where Architectural Footprint is 138 sqm and Ramp is 12 sqm.

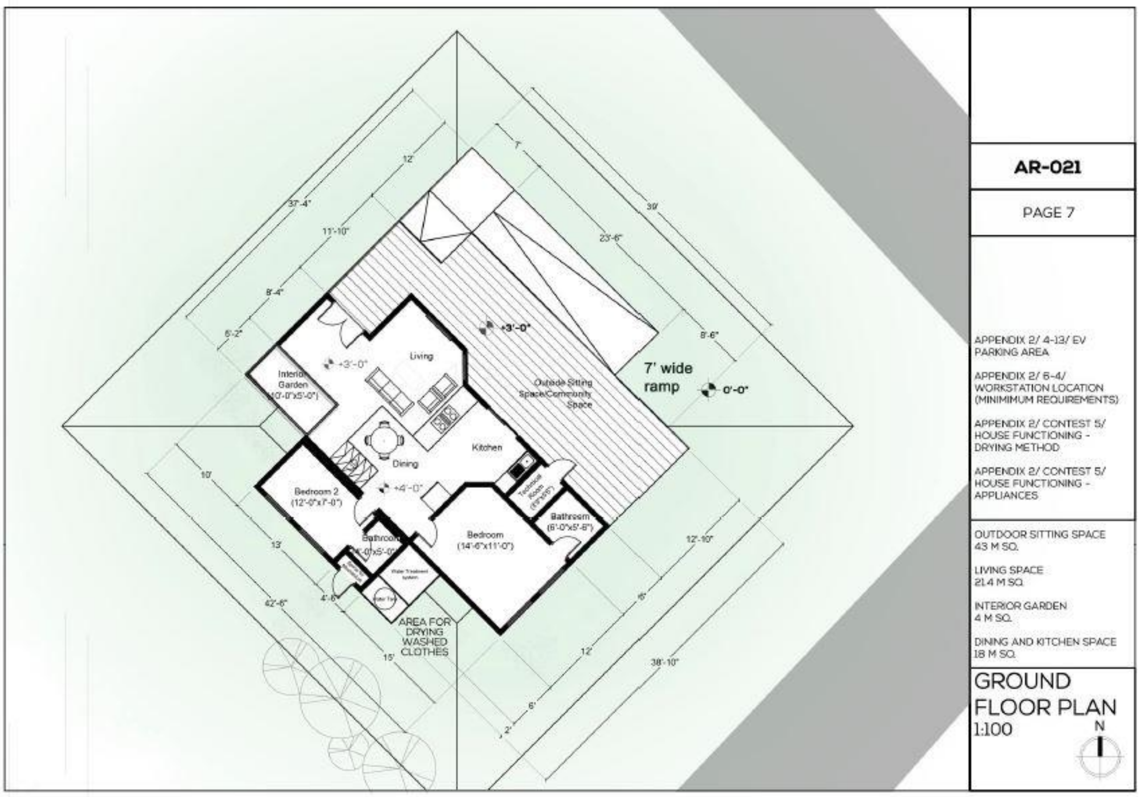


Figure 4.3. Detailed Description of Architectural Elements

This drawing details the Ground Floor Plan. The Living Area, Bedroom, Bedroom 2, Kitchen, Bathroom, Bathroom 2, Interior Garden, Technical Room and auxiliary components of house are seen with respect to their dimensions and areas.

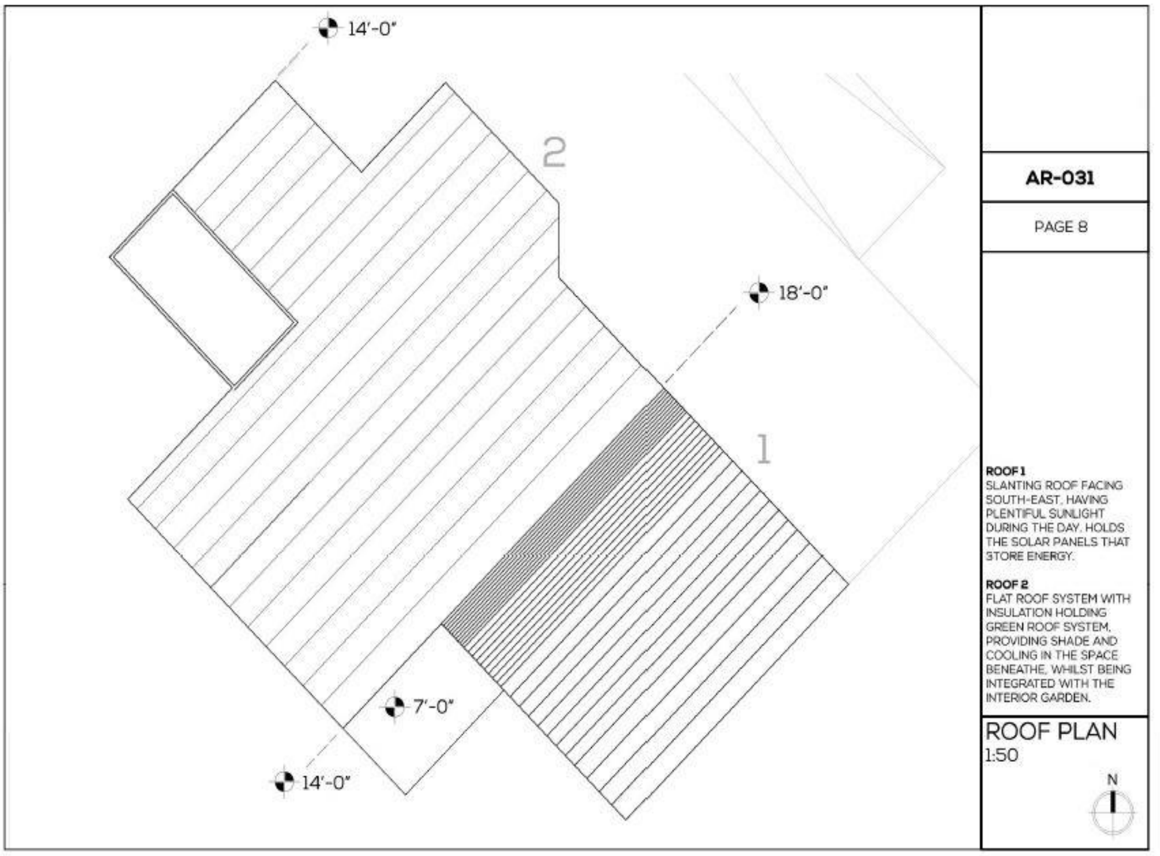
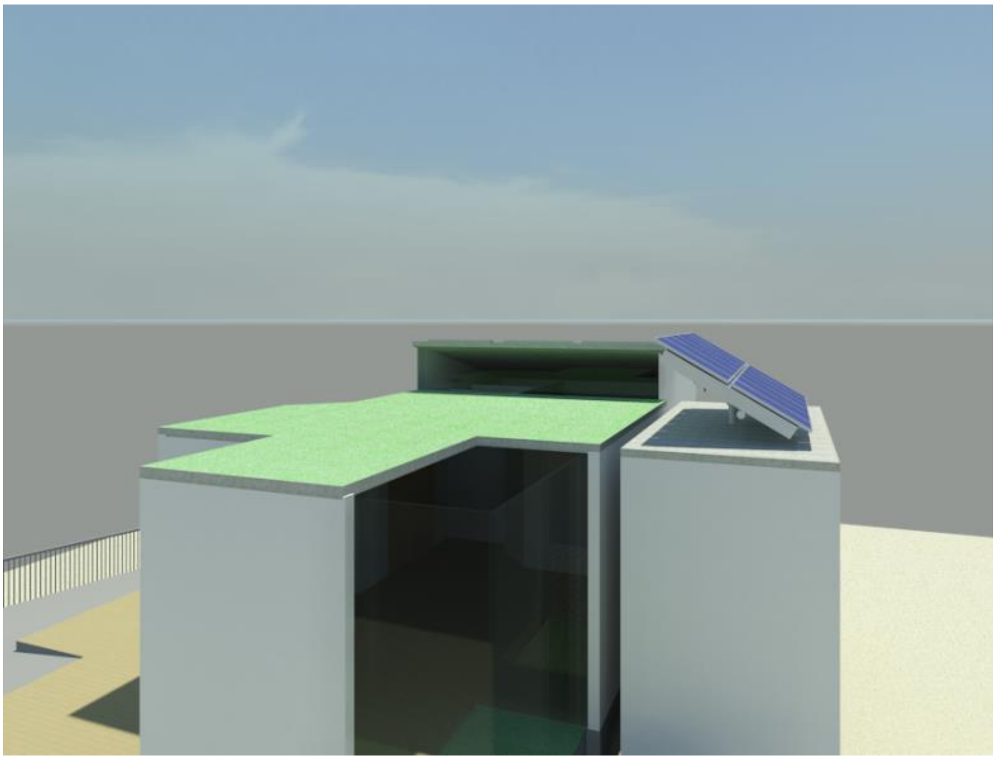
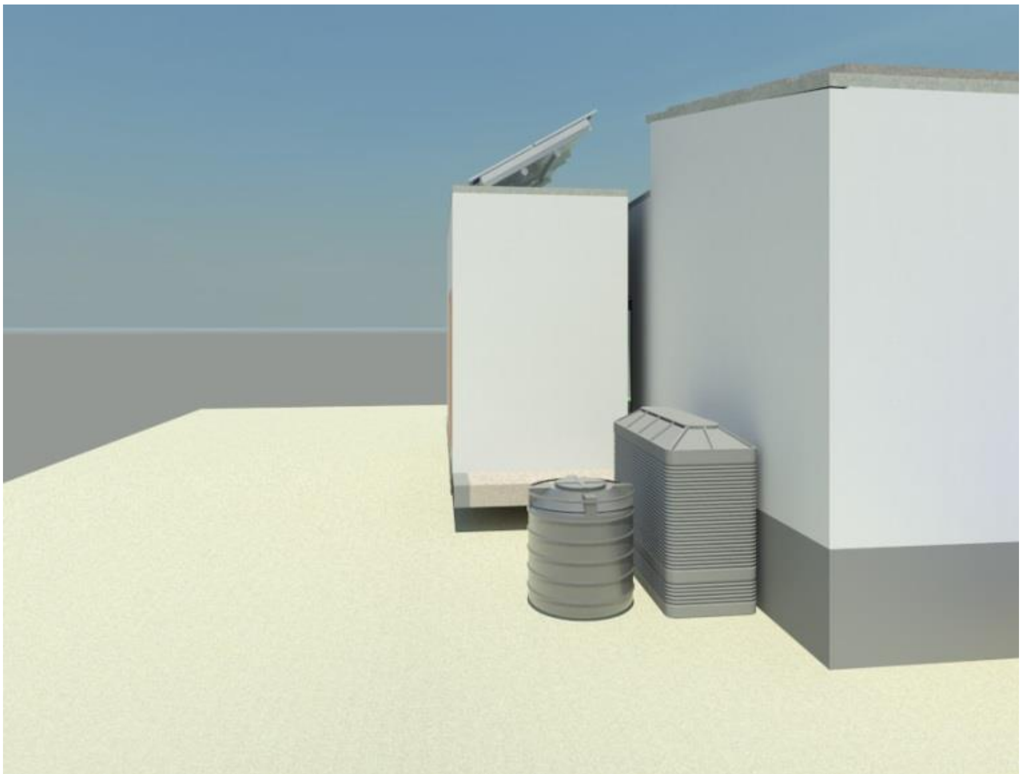


Figure 4.4. Roof Plan with maximum slope of 1:50

The Roof is divided into two portions; Roof 1 is a slanting roof, facing south-east, for maximum solar exposure, hence bears Photovoltaic panels and Roof 2 is flat roof with minimal allowed slope, this slope bears Roof Garden.

4.3. BIM Model Renderings





4.4. Bio-Climatic Analysis

A bioclimatic is a preliminary analysis for early planning of a building. A bioclimatic chart is used to design buildings efficient passive including cooling and heating strategies based on the environment and site of the building.

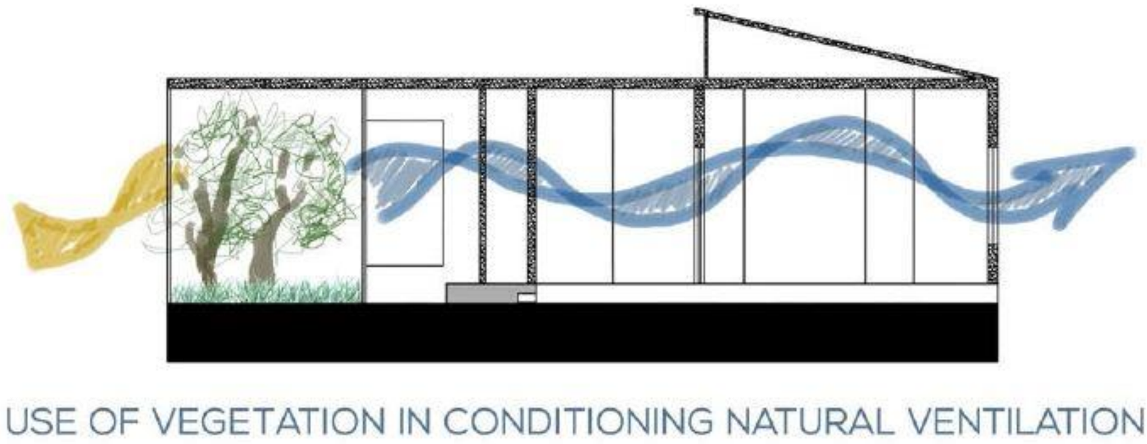


Figure 4.5. Using Vegetation to condition natural air

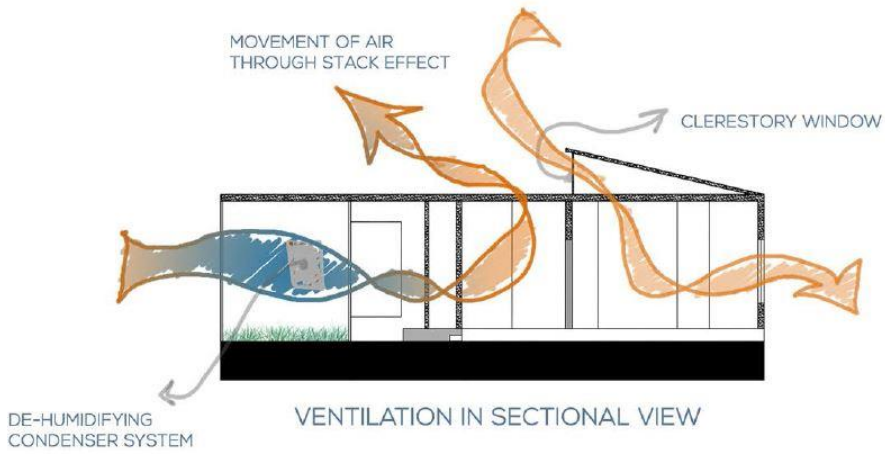


Figure 4.6. Sectional view of Ventilation

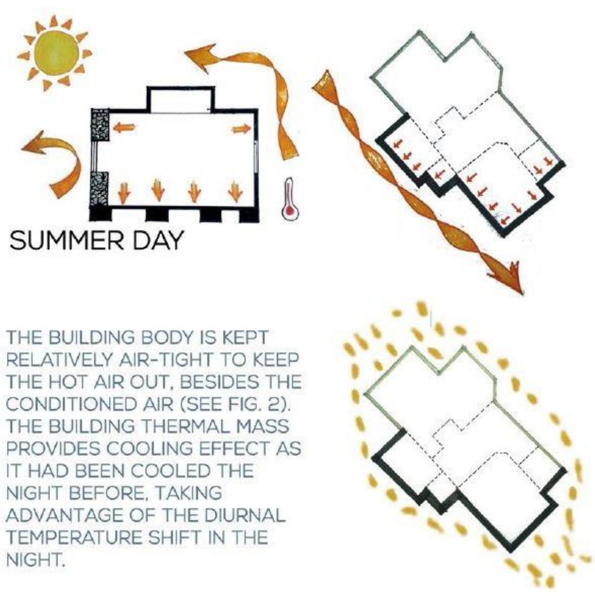


Figure 4.7. Behavior of wind in summer daytime for design

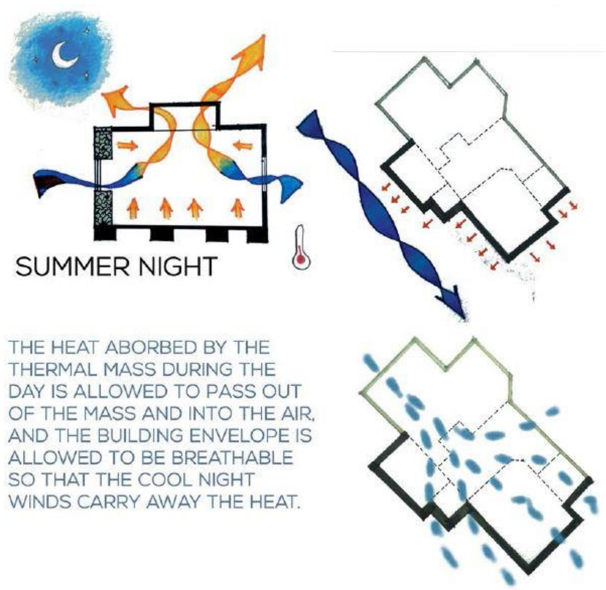


Figure 4.8. Behavior of wind in summer nights for design

4.5. Design Features

A concept design incorporates the brainstorming session most successfully and allows IPD team to review the opportunities and risks associated with the project, the most important aspects in concept design are**;**

- Status of site conditions including effects caused by surrounding buildings
- Availability of natural resources
- Local Material for reuse
- Status of surrounding buildings and planning codes that could be an obstruction to the present natural resources
- Potential of landscaping that may help to reduce heat island effects
- Security concerns
- Accessibility and transportation
- Opportunities for sustainability
- Environmental risks and challenges

A secondary analysis should be performed for green buildings

- Daylight potential
- Surfaces reflectivity
- Natural ventilation potential
- Shading devices
- Window sizes
- Daylight harvesting impact on energy saving

Schematic design gives us further time to develop the ideas that are still feasible. Normally at this phase the team usually begins to identify the various occupancies in the building this is a very useful process as it usually leads to better design and may show vacant places that can be used to better the indoor environment of the building and predict a better solar path and description of the cost analysis of the materials and services used.

A more detailed weather, climate and natural resource analysis usually quantifies true potential for the following:

- Natural ventilation
- Free cooling through HVAC systems
- Day lighting
- Nighttime heat purge of thermal mass
- Heat recovery
- Use of radiant surfaces

The final stage of designing process provides a more detailed cost conformation of the budget supplied by the schematic design. As control is essential to achieve energy efficiency at all the stages it is recommended that the design team produce a document that shows design control for all categories of HVAC, lighting and plumbing equipment

4.5.1. Color and exposure of the roof and walls

"Light colored roofs with 70– 100% exposure to direct radiation show significant reduction in the energy consumption. If the roof is partially or totally shaded, the influence of its color on the energy consumption is minimal" (Valerie et. al. 2008)

4.5.2. Window's size and position

The windows have a significant influence on the energy consumption (Valerie et. al. 2008). The most important aspects in hot and humid climates are conduction. Through fenestration, indoor moisture can be removed to generate cooling energy providing suitable ventilations.

4.5.3. Envelope

In hot and humid climates, the fenestration area, orientation, and shading are paramount. The goal is to reduce the heat gain through envelope as much as possible through strategic shading placement. Care must be taken to reduce infiltration through the upper levels of the building envelope; positive building pressure control can help reduce infiltration and the related moisture. Cool roofs, which reduce solar heat absorption into the building, are also useful. It should be noted that these areas can experience high winds and hurricane and storm impacts, which may direct the selection of wall, roof, and shading constructions as well as the selection of safety tempering of glazing products all of which can affect the energy performance.

4.5.4. HVAC

These climates experience average daily dew point temperatures higher than 50°F throughout much of the year consistent humidity control is essential. A necessary strategy to maintain humidity control is proper dehumidification of all outdoor air for ventilation. Energy recovery wheels and deep multi row cooling coils can provide sufficient dehumidification of ventilation air. (Book) It may also be achieved by mixed air both outdoor and indoor delivered with minimum flow set points and reheat. Air-side and water-side economizers may have seasonal efficacy during times of lower dry-bulb and wet-bulb temperatures.

4.5.5. Water Conservation

Water conservation systems will include usage of sensor taps, low flush toilets, dual flush toilets and flow restriction valves. Rainwater harvesting would be utilized to water the vegetation already present on roof and walls. Water retaining abilities of Mulch Basin would also help in utilization of rainwater. Waste water would be treated through an Aerated Wastewater Treatment System and Composting Toilets. Dehumidifiers are the basic atmospheric water generators utilized to gather water from moisture. Other than that, overnight water collecting fog fences are also used.

- Water Sense Showerheads (1.5-2 GPM as compared to 2.5 GPM of normal Showers.)
- Using Efficient Faucet aerators on taps (reduces water flow as much as 50% without decreasing pressure.
- Flow restriction valves. (Saves water by reducing the overall pressure of the piping system.) Sensor taps.
- Low flush toilets. (Use 6 LPM as compared to 13.5 LPM of normal toilets.) Dual flush toilets.

4.5.6. Rainwater Harvesting

4.5.6.1 Wet System

The storage tank will be located right next to the home but underground to give it better protection from sunlight to protect the water from heating. Surface runoff will also be collected from the garden but its total volume would be lesser due to size restriction of the garden and the absorption in the ground.

The rooftop has a grass covering. Initial rain water would be allowed to be used up by the grass at the rooftop. In case of an overflow, the excess water would be directed towards the gutter with the help of slight sloping of the roof. A wire mesh present at the mouth of the gutter would help in removing large sediments which may cause clogging. From the pipe, the water would be led towards the first flush diverter which would get rid of the initial more contaminated rain water. From here the water would be directed towards Filter. In this case, we use Sponge Filter since it’s cheaper and more suitable for residential use. From the filter, the water would be stored in a large underground tank for future use like kitchen or irrigation purposes. Pipes (UV resistant PVC pipes) and Tank (Normal water storage tanks) would suffice.

4.5.6.2 Mulch Basin System

In case of excessive rainfall or sudden storm, the sudden influx can be stored in a slightly dug trench filled with woodchips (Mulch). Such a basin is ideal for growing trees. The excessive water can be stored here for a while till the system is no longer overloaded and then routed towards the underground water storage tank.

- Waste Water Treatment
- Aerated Waste Water Treatment System
  (Treating black water for irrigation use)
- Composting Toilets
  (Used for human waste)

4.5.7. Design Modeling

Design will be simulated using BIM and Green Building Studio to check energy variations, cross ventilation, temperature variations, wind movements in summer as well as winter.

4.6. Drawings

4.6.1. Architectural Design

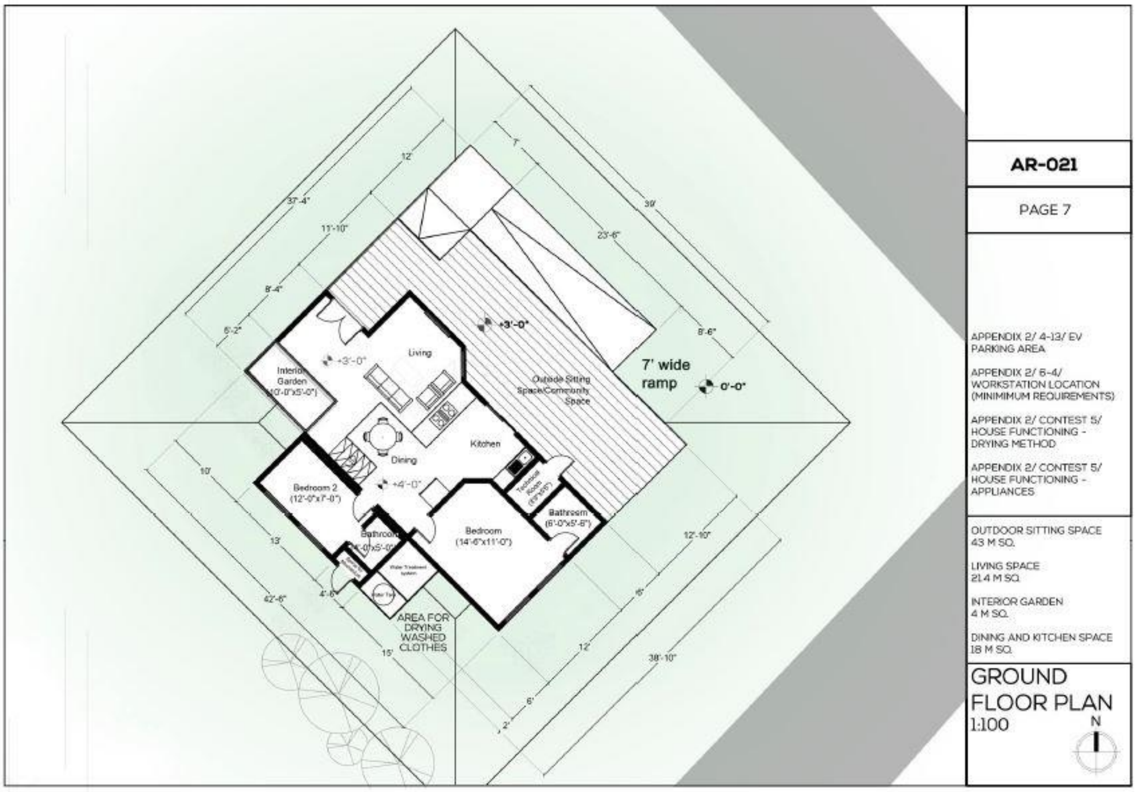


Figure 4.9. Final Architectural design along with dimensions

The Ground Floor Plan is displayed, detailing dimensions and areas.

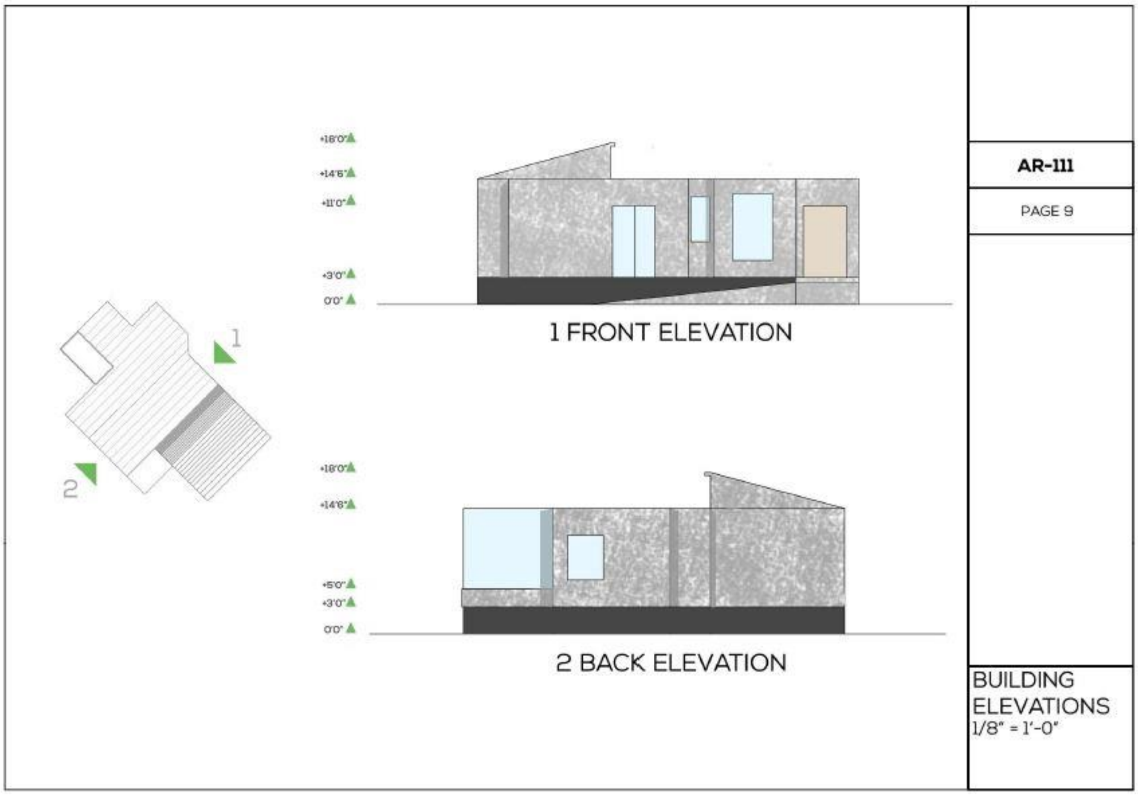


Figure 4.10. View of front and back elevations

The Building Elevations for front and back is displayed.

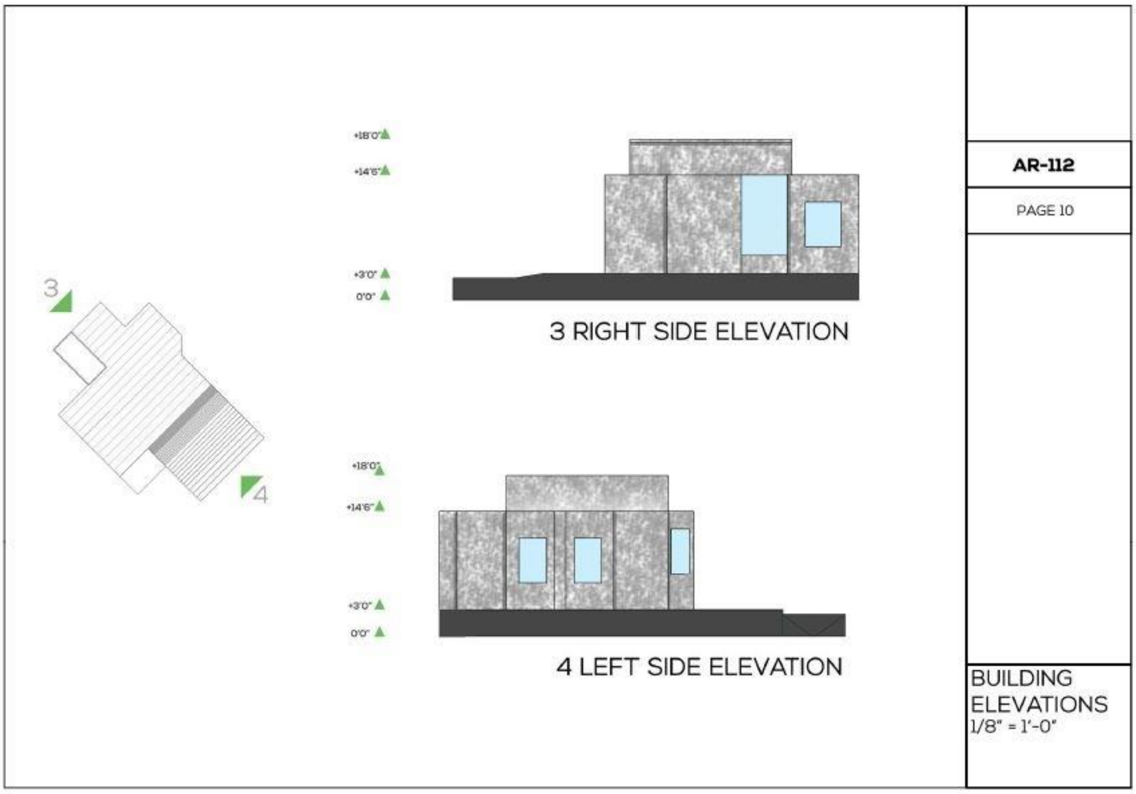


Figure 4.11. View of left and right side elevations

The Building Elevations for Right and Left side is displayed.

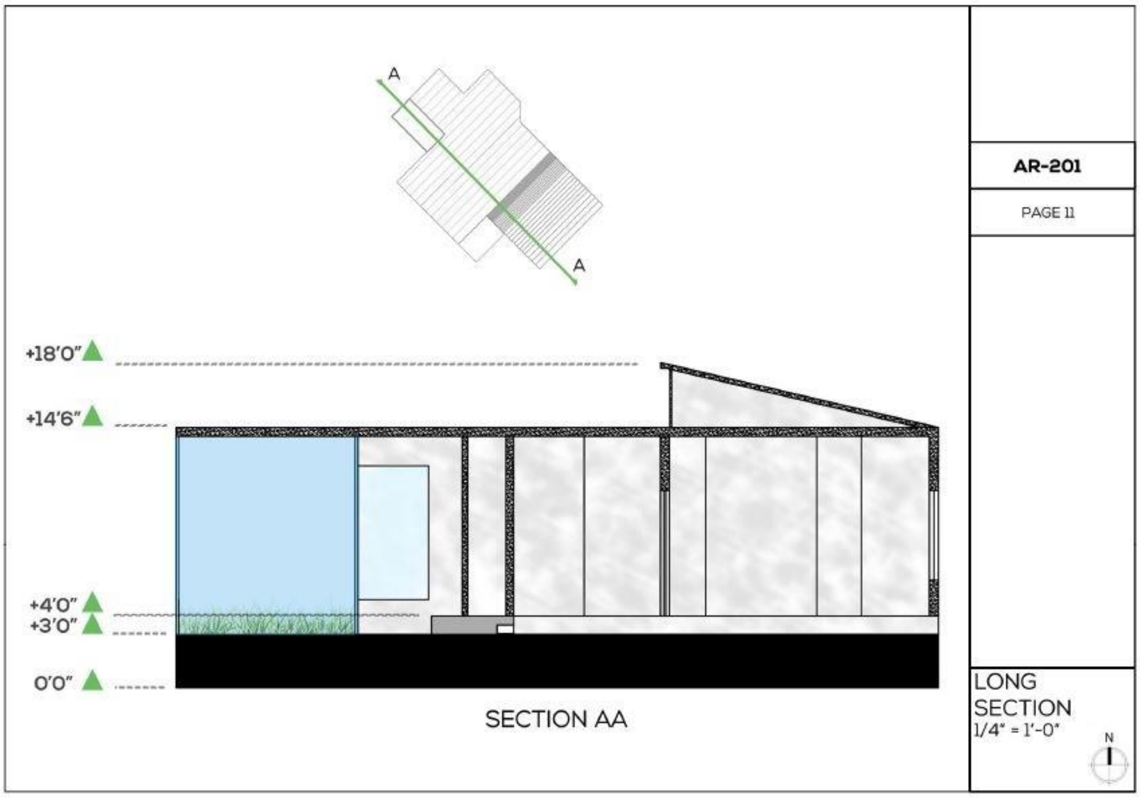


Figure 4.12. First section AA

Section AA for building (as shown in previous elevations) is displayed.

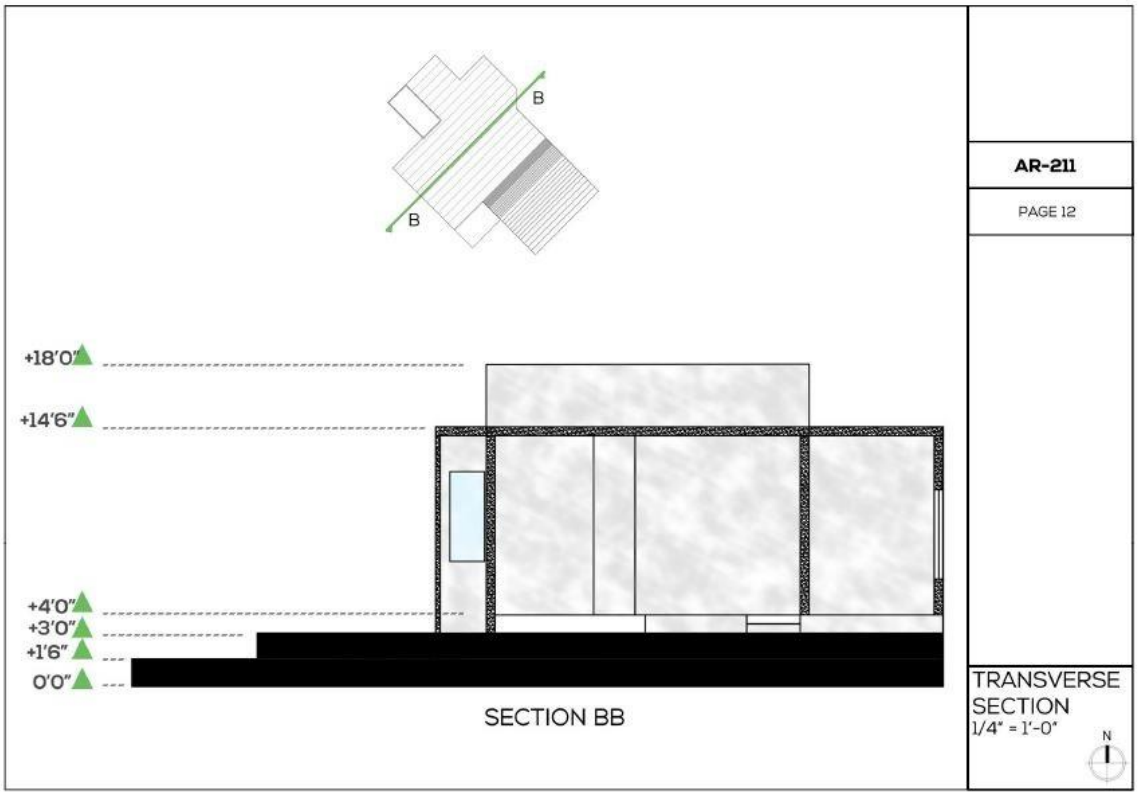


Figure 4.13. Second Section BB

The Section BB (as shown in previous elevations) is displayed.

4.6.2. Structural Design

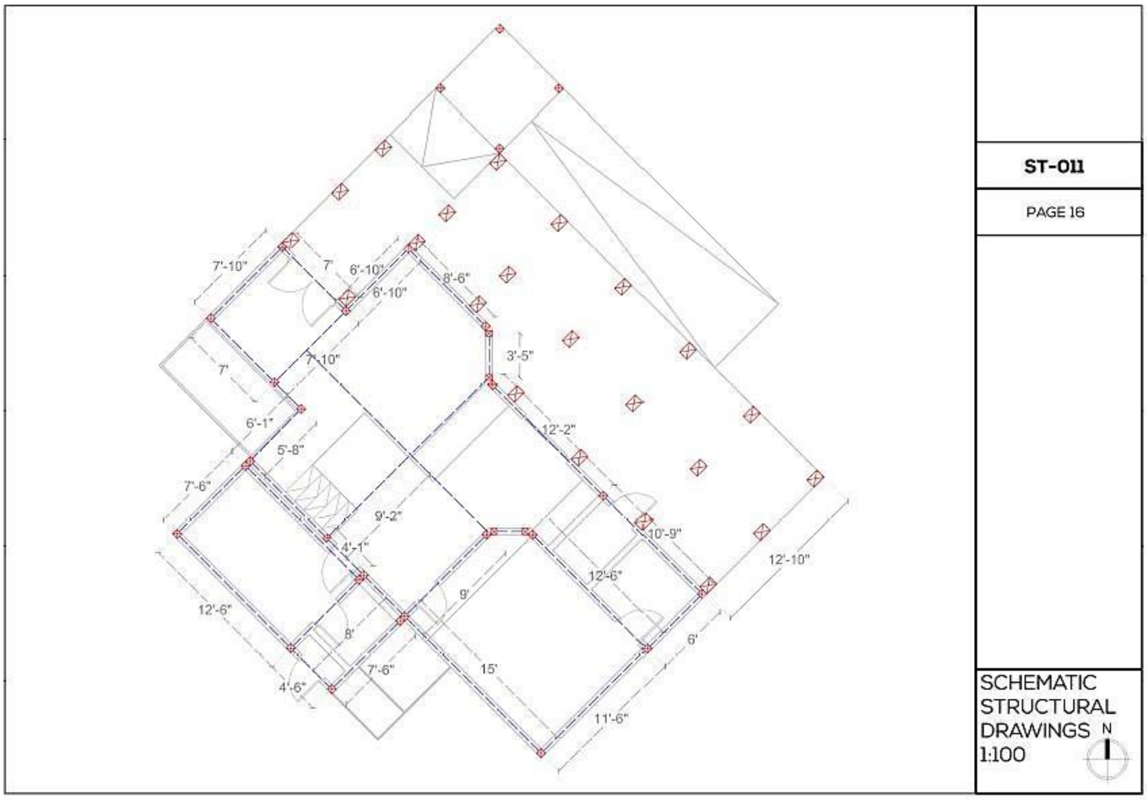


Figure 4.14. Structural Column placement design

The structural plan is displayed, with red boxes portraying columns and blue dotted lines locations for beams. The structural system used is a composite of hot-rolled steel and Light Gauge Steel (LGS).

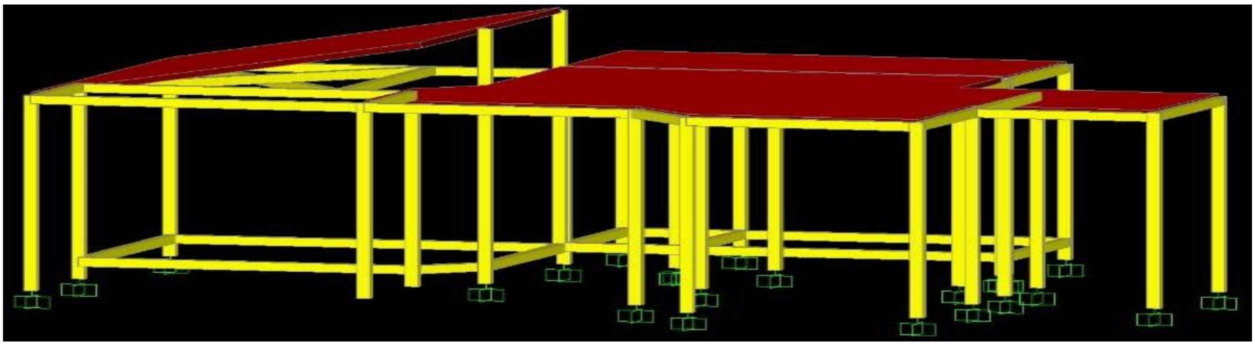


Figure 4.15. SAP 2000 Structural model

The SAP2000 model of the house is displayed.

4.6.3. Foundation System

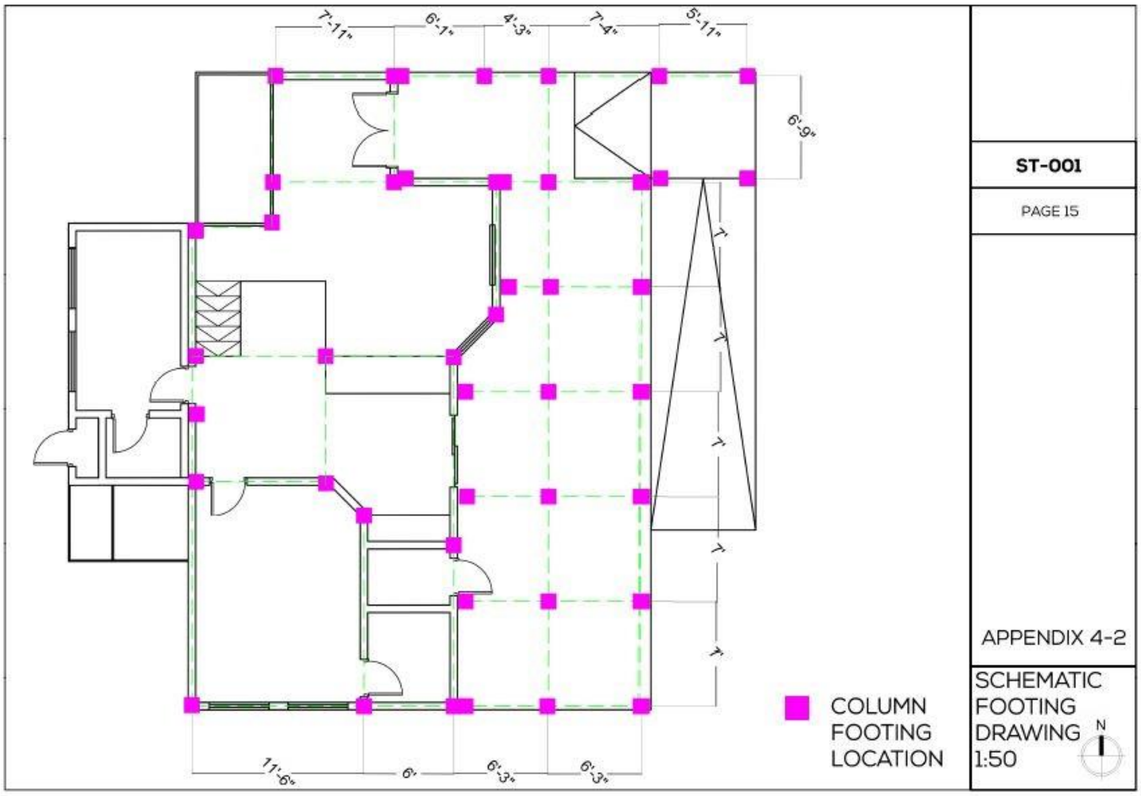


Figure 4.16. Design of footing placements

The foundation systems used is called pin foundations or low-impact foundations. This type of system is not common in Asia and Middle East

4.6.4. Mechanical Design

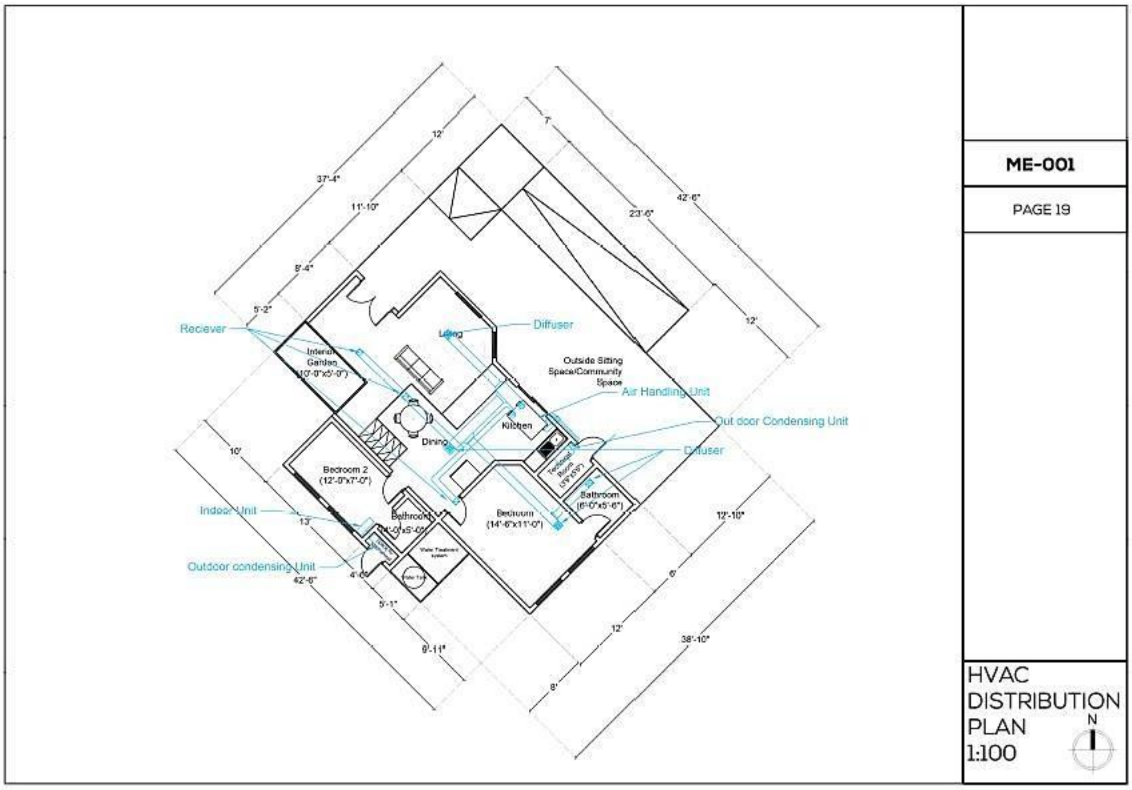


Figure 4.17. HVAC Design

The Heating Ventilation and Air Conditioning (HVAC) systems are installed for the ventilation and cooling of house. The system is composed of Central Cooling Unit, Diffusers, Receivers and Outdoor Units.

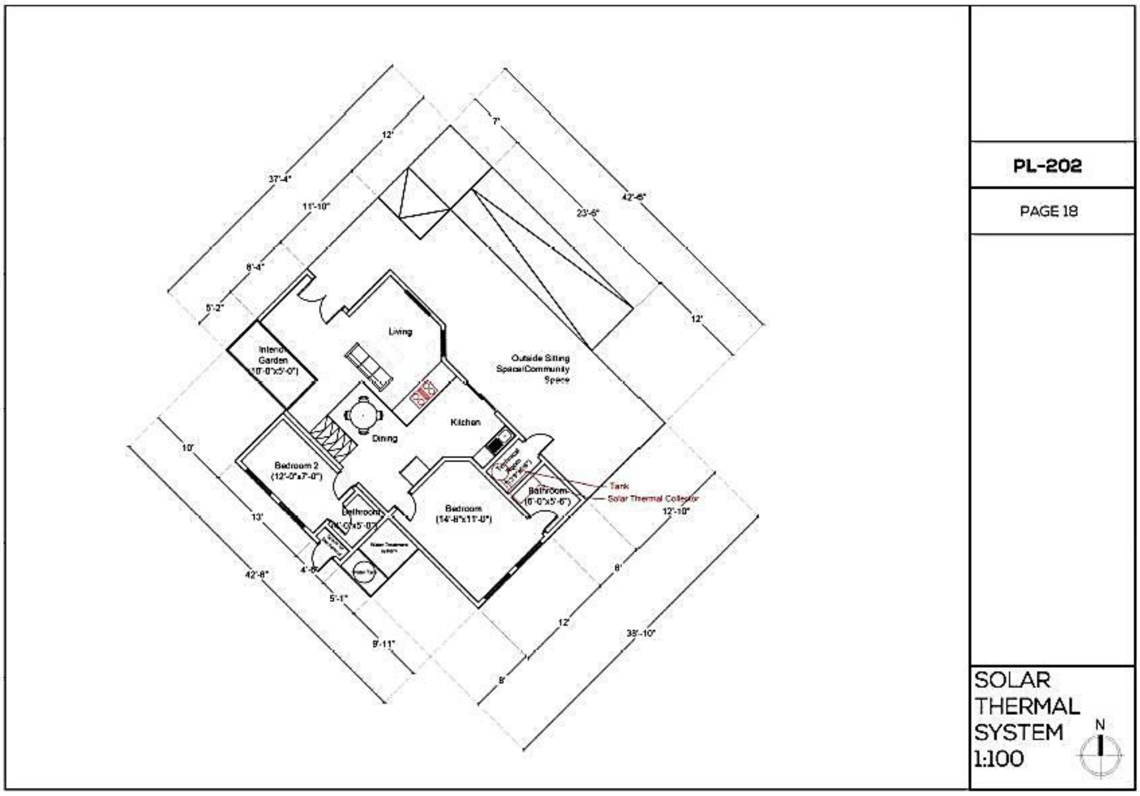


Figure 4.18. Solar Thermal Design

The Solar Thermal System is also installed that is composed of Solar Heater, for the usage of water in bathing, laundry, and dishwashing.

4.6.5. Plumbing Design

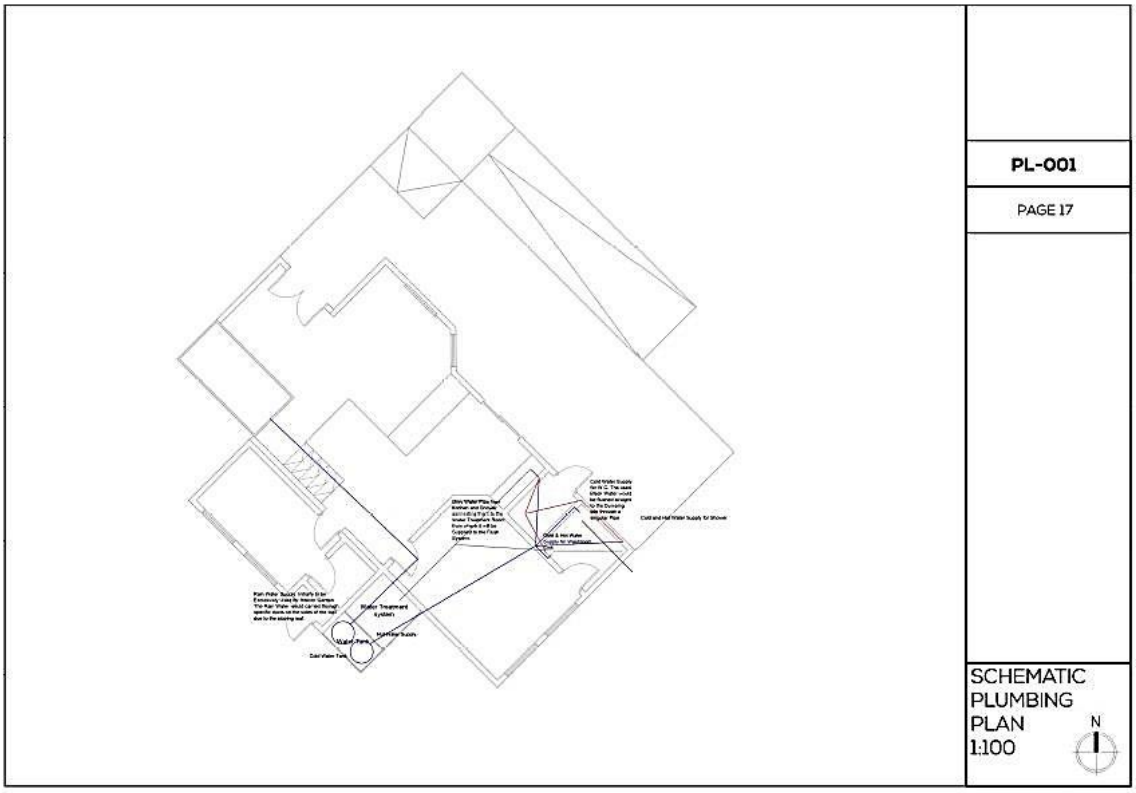


Figure 4.19. Wastewater treatment and plumbing design

The Plumbing system is displayed, portraying the connection between washroom and kitchen, the system of kitchen and bathroom are kept in proximate locations to reduce lengths of pipes required to enhance system efficiency and cost reductions. Further, these pipelines are connected to the water tanks and treatments tanks placed outside the house.

4.6.6. Electrical & PV Systems

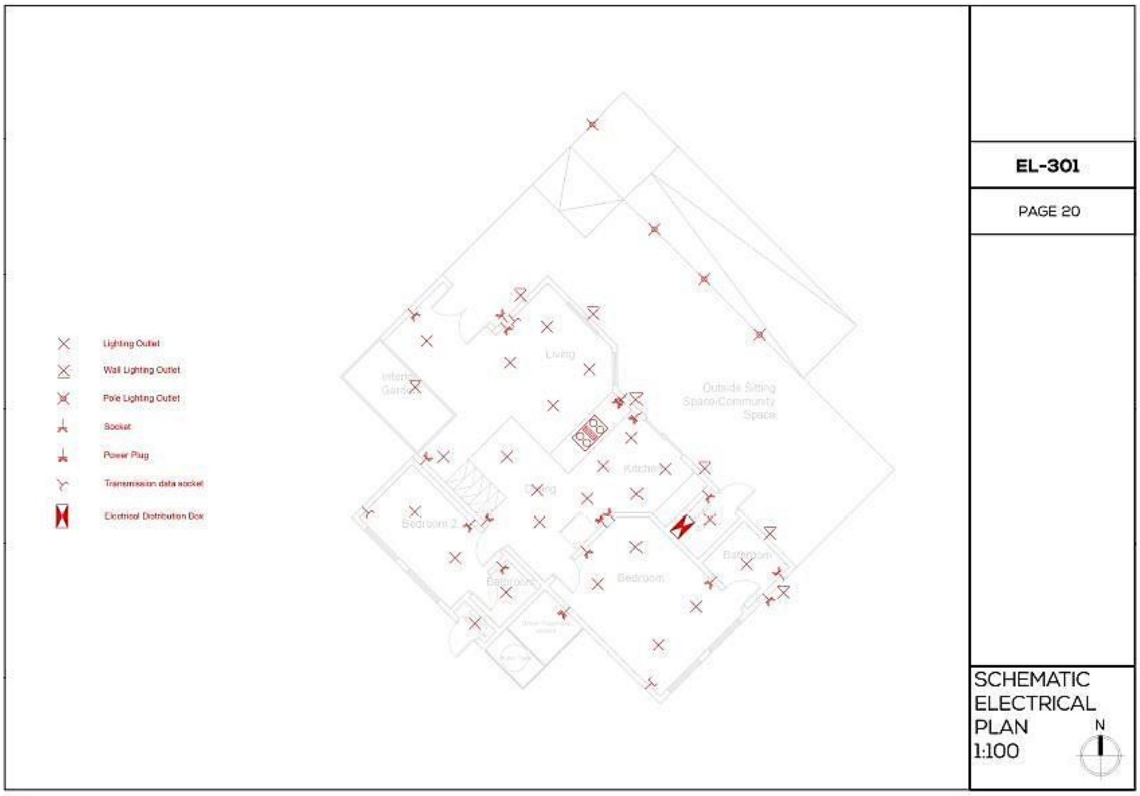


Figure 4.20. Electrical and Photo Voltaic plan

A generic lights layout has been displayed here, with locations of Distribution Boards (DBs). It is to be noted that all the main components, wiring and sensor systems are placed in Technical Room.

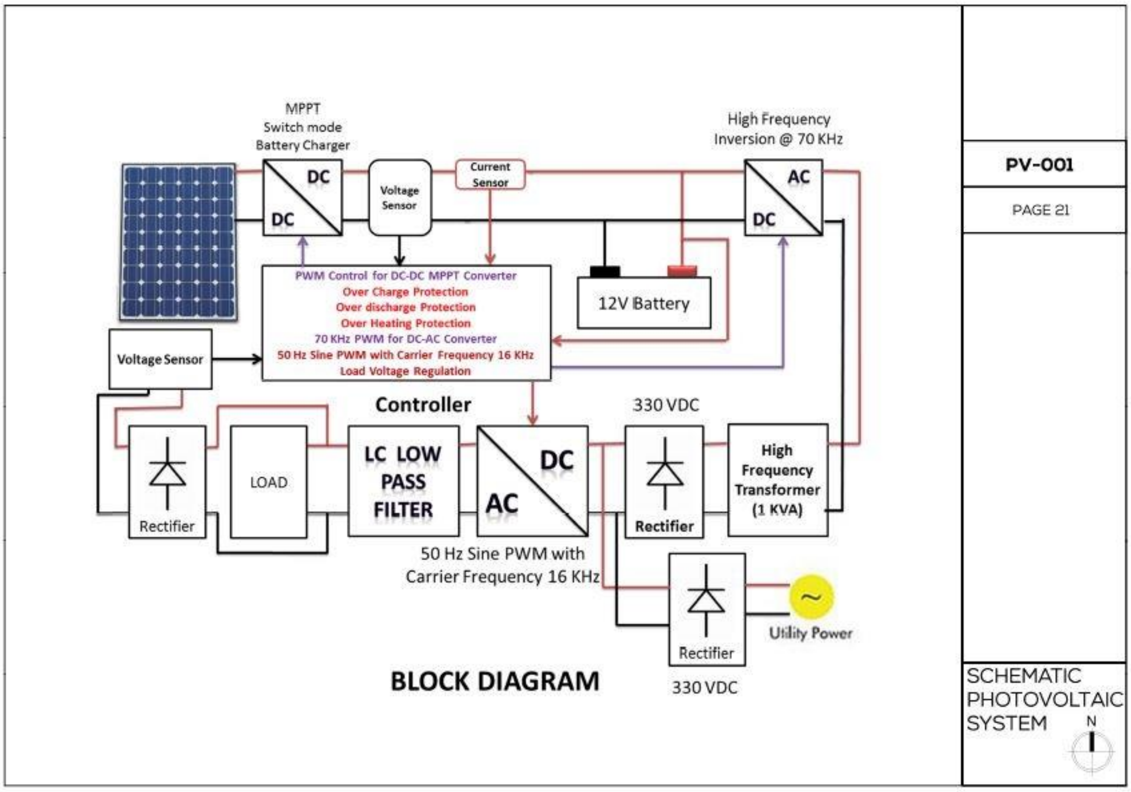


Figure 4.21. Photo Voltaic System design

- Rectifiers 330VDC
- 12 Volt Battery
- Voltage Sensors
- High Frequency Inversion @
- LC low pass filter
- High frequency transformer 1 KVA
- 50 Hz sine PWM with carrier frequency 16kHz
- MPPT Switch mode Battery Charger

4.6.7. Materials (Design)

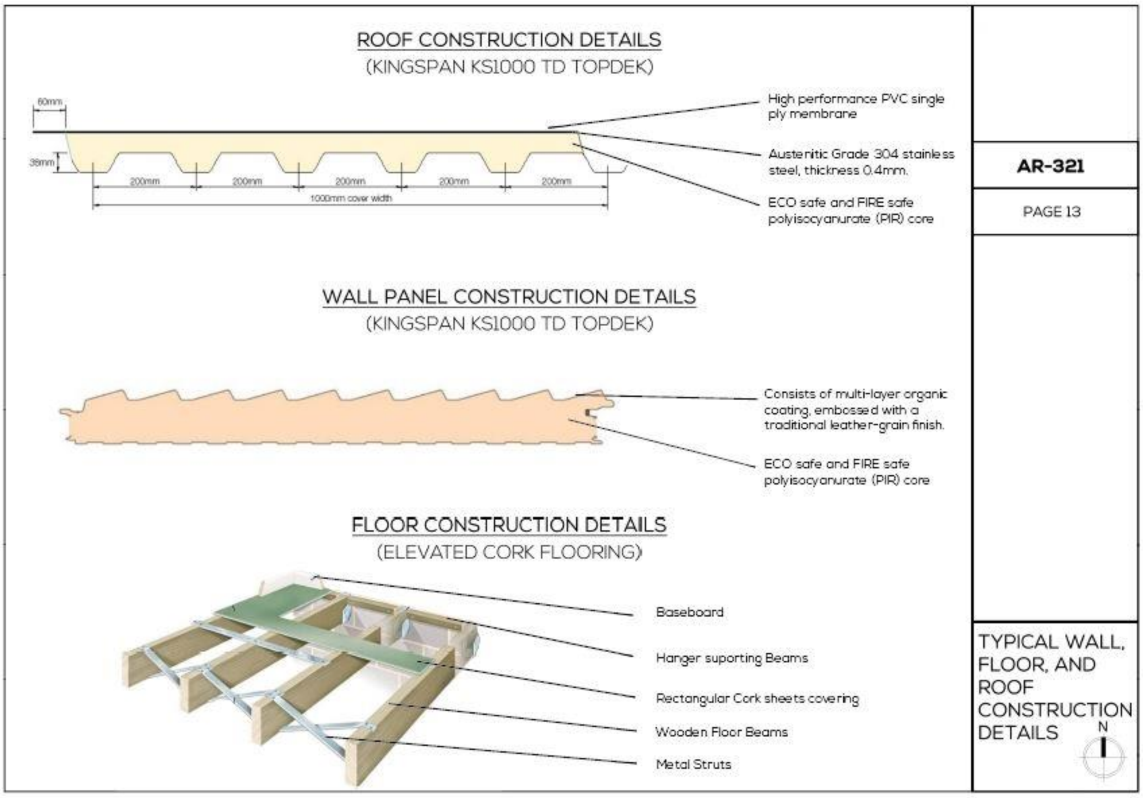


Figure 4.22. Detailed description of selected wall panels (Kingspan KS1000)

The materials used for the house includes;

Roof Panels – Kingspan KS1000 TD Topdek

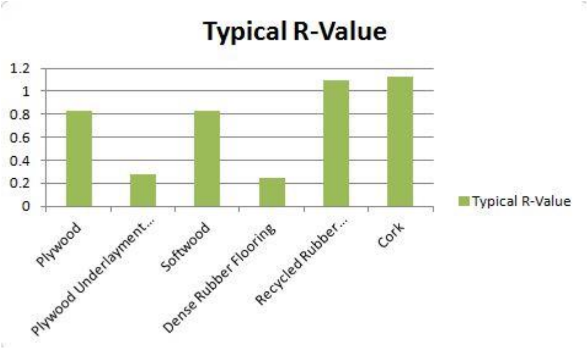
Wall Panels – Kingspan KS1000 TD Topdek

Floor Panels – Cork Flooring

These materials have been selected after a rigorous analysis between other alternatives, based on R-value, cost, span lengths and load-bearing.

4.6.8. Materials Analyses

Cork and Sandwich panels has been analyzed here with respect to their R-value and cost in US Dollars from international vendors.



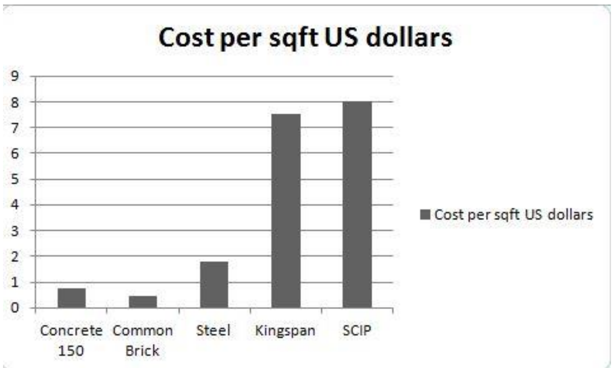


Figure 4.24. R- Value comparison of Different Materials

Figure 4.23. Cost Comparison of Different Materials (wall)

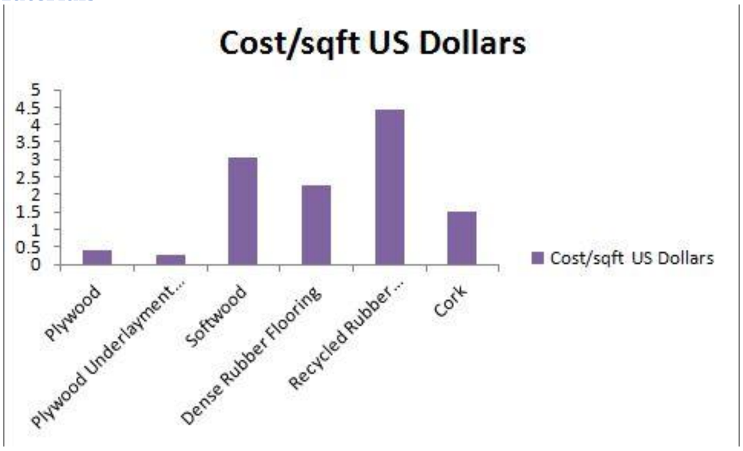


Figure 4.25. Cost Comparison of Different Materials (floor)

4.6.9. Active Systems

During study of American household water usage, it was found that 40 percent of water is used in Bath, Showers and Clothes washer, and the used water is called Gray water. Dishwashers and Toilets consume about 28 percent of water, whereas rest of the water is either run down the drain for poor water conservation habits and leakages. It has been estimated that a total of 9.5 gallons per capita per day water is leaked, which is an alarming figure.

Scarcity of water is a global phenomenon, and in particularly hot and humid regions have less ground water.

In order to tackle these issues, active systems are installed including smart devices, such as outdoor programmable water timers, multiple flush WC, water conserving faucets (that reduce the average water about half). Desiccant dehumidifiers are installed for the dehumidification of humid air. Heating, Ventilation and Air Conditioning (HVAC) Systems are installed for efficient ventilation and cooling of house.

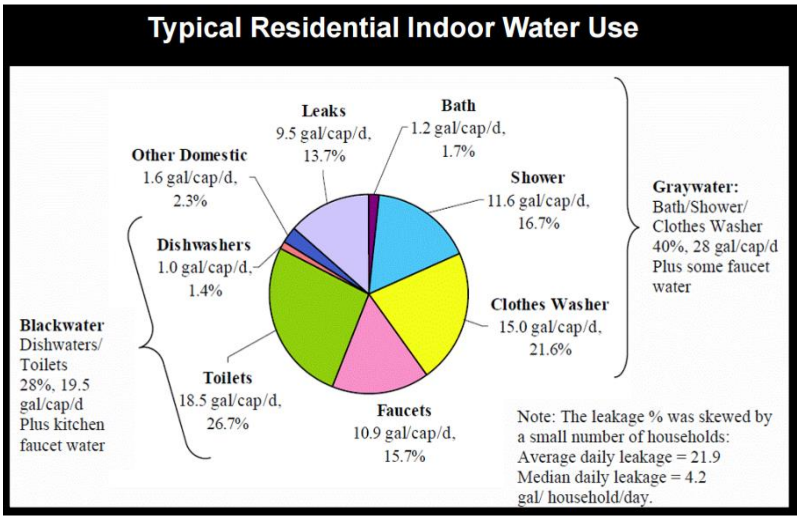


Figure 4.26. Typical residential indoor water use

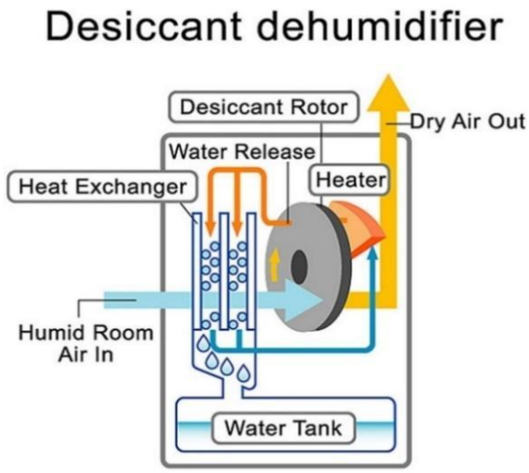


Figure 4.27. Water Efficient taps and showers

Figure 4.28. Desiccant Dehumidifiers

Figure 4.29. Programmable water timers

Figure 4.30. Dual flush toilets

4.6.10. Passive Systems

Passive strategies are an integral part of a green building, passive includes such systems which do not use any electricity or energy to operate, and provide a natural means of reaching comfort in the house. Systems used in this design include Burjeel concept that means that a portion of house is elevated to allow fresh air to enter the house, and provide warm air an escape route.

The concept of Burjeel is also integrated with vertical vegetation walls, that will cool the warm air from outside and dehumidify it as it enter the house, providing a stream of fresh and cool air.

Another system is a roof garden that is, providing a carpet of grass on the roof, for both insulation and aesthetic purposes.

Figure 4.32. Xeriscaping and roof gardens

Figure 4.31. Vertical Gardens

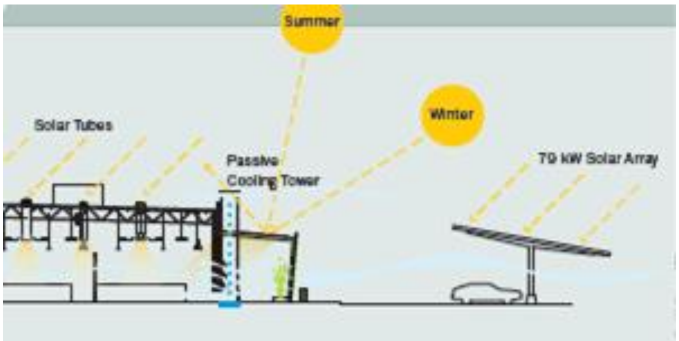


Figure 4.33. Barjeel for passive cooling

4.6.11. Constructability

The design is made on the line to be able to assemble and dissemble quickly, in a span of 20 days for each process. This has been made possible, due to the modular nature of house, as each part of house can be prefabricated and divided into various modules, ultimately, enhancing mobility as well.

The design was enhanced to be accessible to every person, without discriminating, as the house is to be used ultimately by all; children, adults, elderly and disabled persons. Hence, the disability code is applied from American Disability Association (ADA).

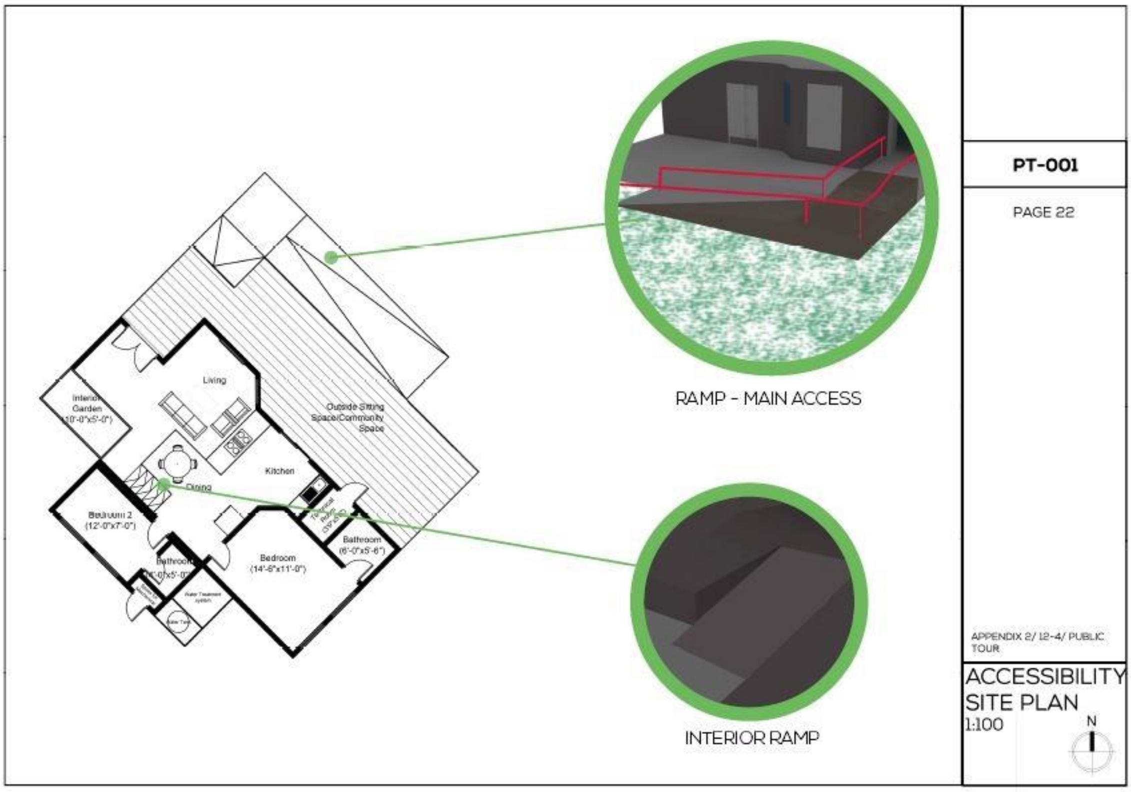


Figure 4.34. Ramp provided in accordance with ADA

4.6.12. Disaster Management

The house is also designed to cater for the natural disasters; therefore, firstly, the structure is designed to cater for mild sand storms, and high intensity earthquakes. Regarding the floods and tsunamis, the house can be disassembled, assembled and made mobile accordingly.

Figure 4.36. Earthquakes

Figure 4.37. Flooding

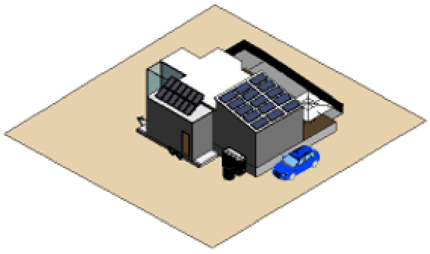
Figure 4.38. Sandstorms

4.7. Building Performance Analyses

Autodesk Revit was utilized to run Building Performance Analyses to validate the results.

4.7.1. Performance Analysis

Energy Analysis Result



Building Performance Factors

Location:	24.8757514953613,55.3804054260254
Weather Station:	1303853
Outdoor Temperature:	Max: 117°F/Min: 50°F
Floor Area:	682 sf
Exterior Wall Area:	1,350 sf
Average Lighting Power:	0.90 W / ft²
People:	4 people
Exterior Window Ratio:	0.00
Electrical Cost:	$0.09 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	17 kWh / sf / yr
Fuel EUI:	5 kBtu / sf / yr
Total EUI:	62 kBtu / sf / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	343,309 kWh
Life Cycle Fuel Use:	1,075 Therms
Life Cycle Energy Cost:	$15,018

*30-year life and 6.1% discount rate for costs

Figure 4.39. Revit Energy Analysis Results

Annual Carbon Emissions have shown our design produces more energy as compared to how much it consumes and can earn money by providing power to the grid. As it is renewable energy it has no negative effects on the environment.

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	5,878 kWh / yr
Roof Mounted PV System (Medium efficiency):	11,756 kWh / yr
Roof Mounted PV System (High efficiency):	17,633 kWh / yr
Single 15' Wind Turbine Potential:	1,117 kWh / yr

*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

Figure 4.40. Renewable Energy potential

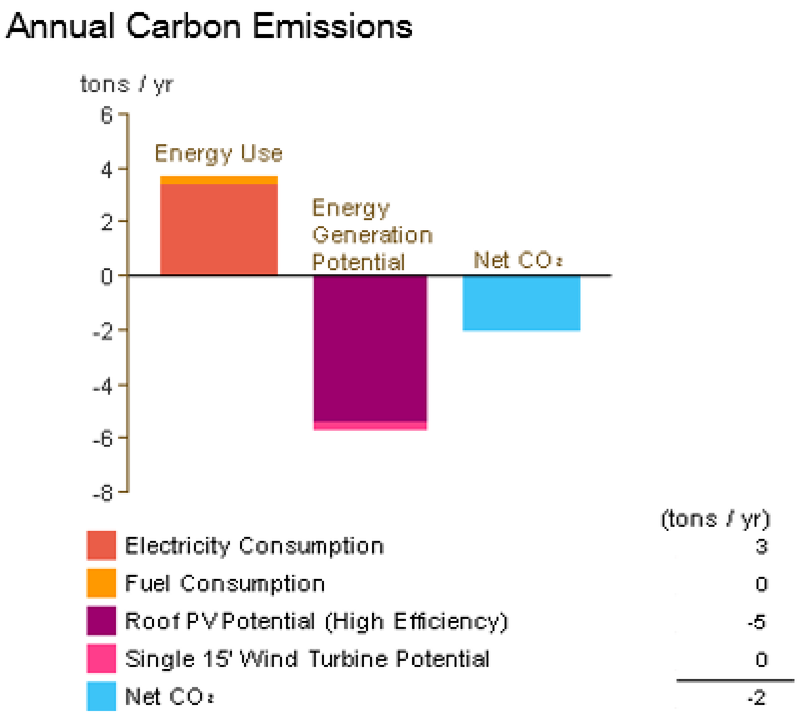


Figure 4.41. Annual Carbon Emissions

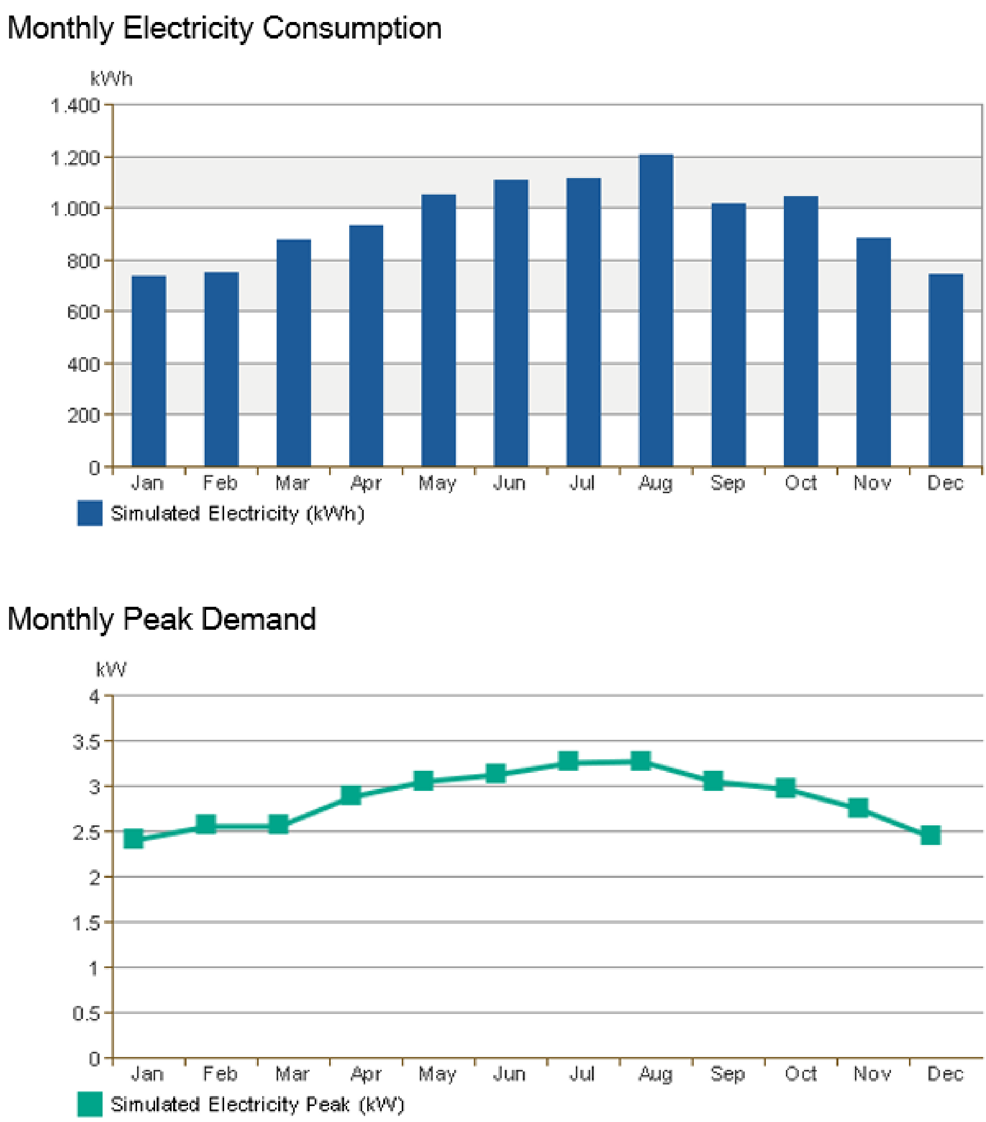


Figure 4.42. Monthly Electricity Demands and Peak Electricity Demand

Monthly Electricity demands of our design are as same as standard for a house of size $150m^2$ but is covered by the energy produced by solar panels

4.7.2. Energy & Fuel Analysis

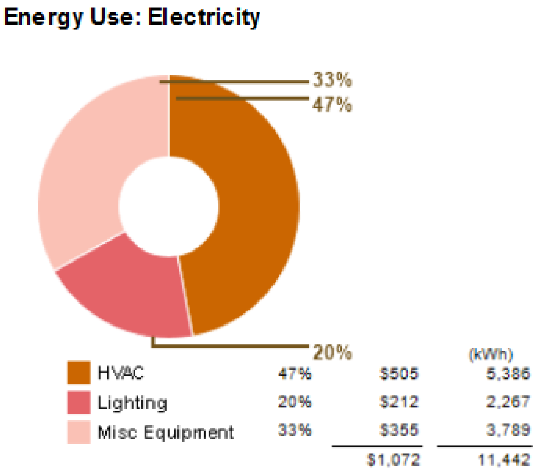
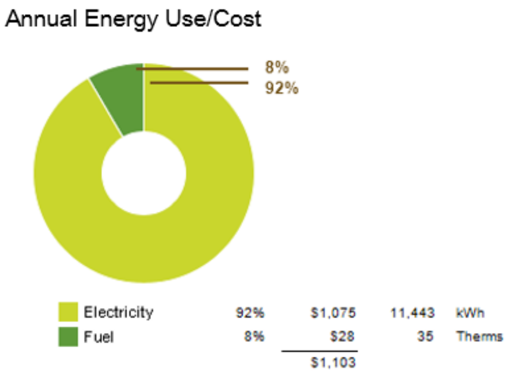
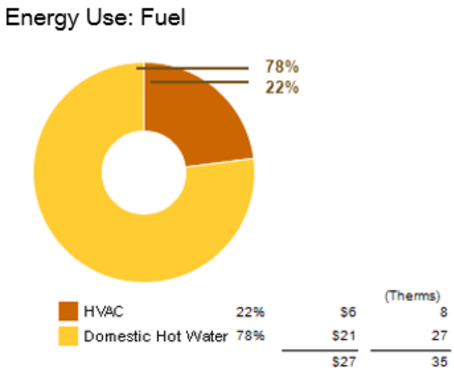


Figure 4.43. Electricity Usage and Cost





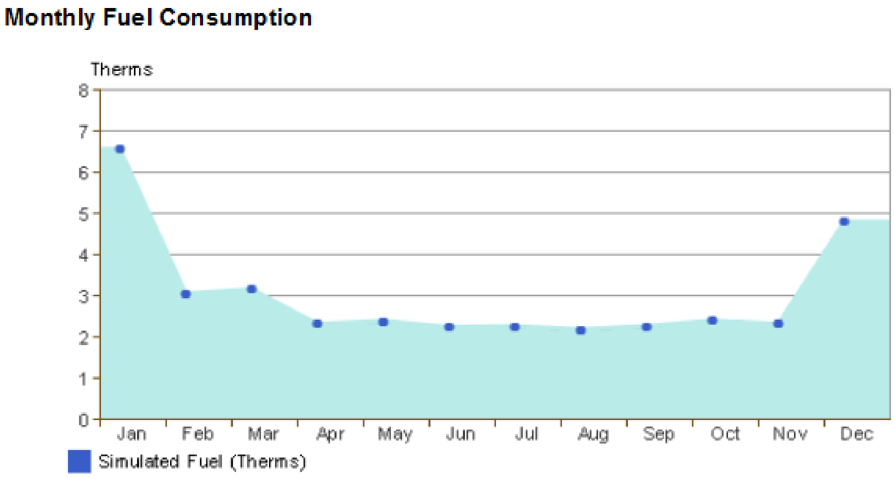


Figure 4.44. Energy and Fuel Usage and Cost

Fuel and Electricity consumption are per standard and can be easily fulfilled by the installed solar panels

4.7.3. Wind Rose Analysis

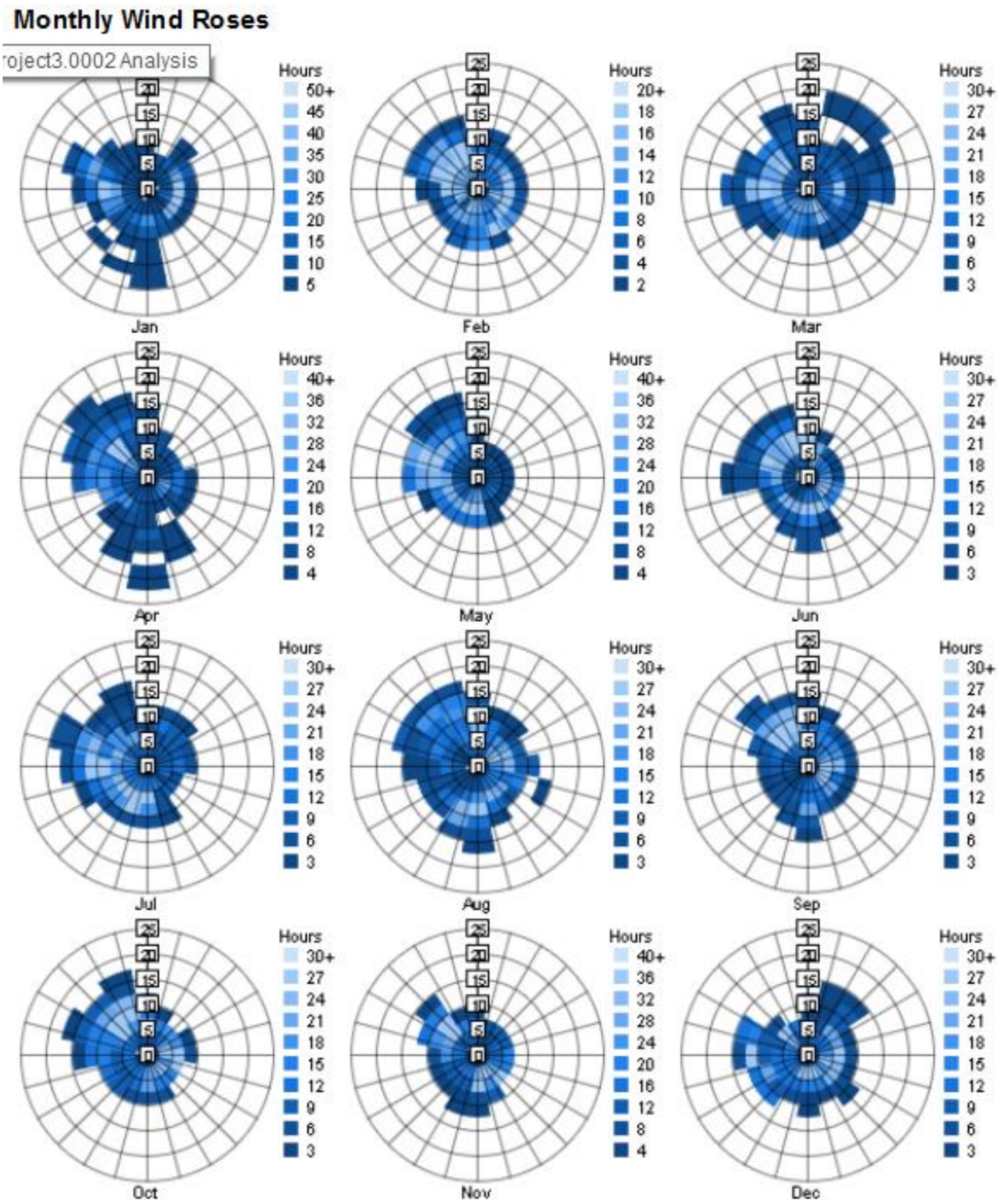


Figure 4.46. Monthly Wind Rose

Wind roses were formed by providing spatial data of a hot and humid region in a desert region

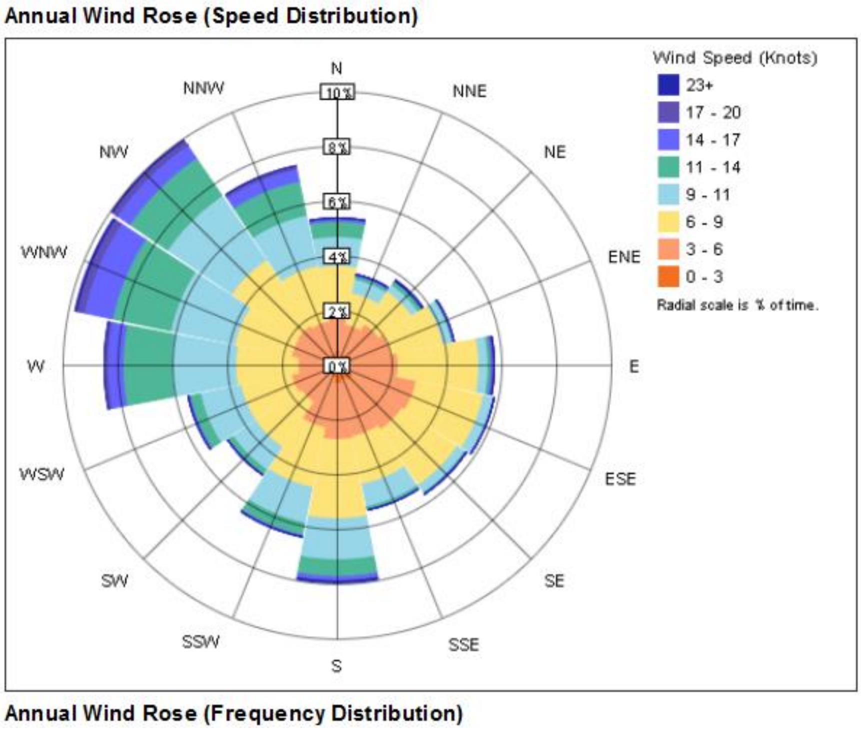


Figure 4.47. Annual Wind Rose (Speed)

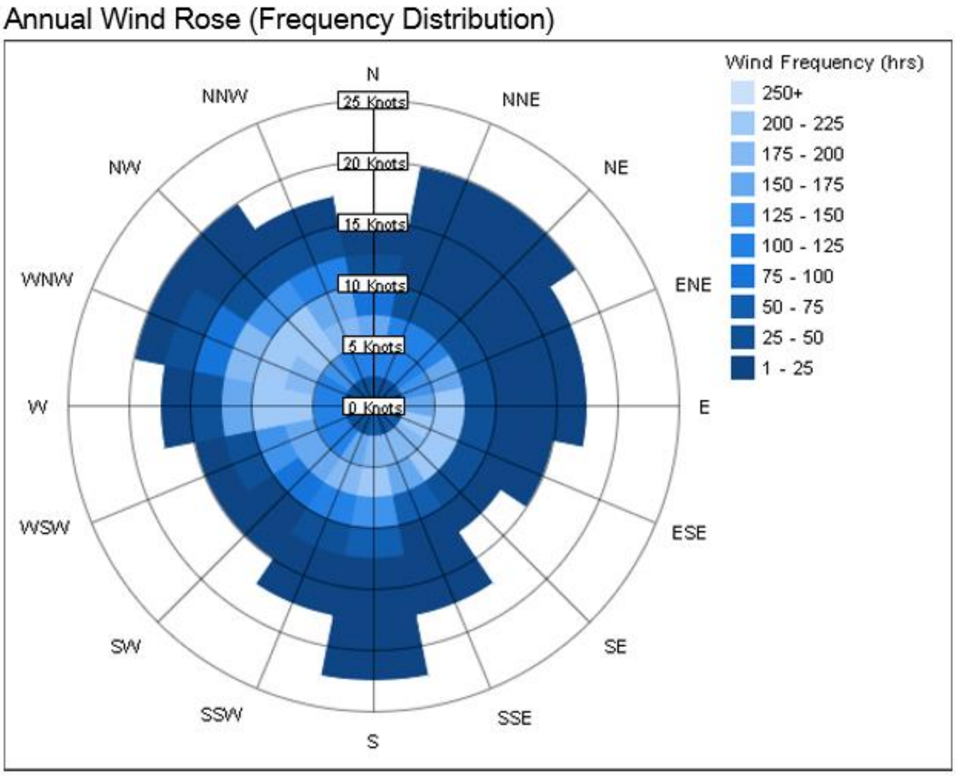


Figure 4.48.Annual Wind Rose (Frequency)

4.7.4. Environmental Analysis

Further Environmental data of the site on which Building performance analysis was

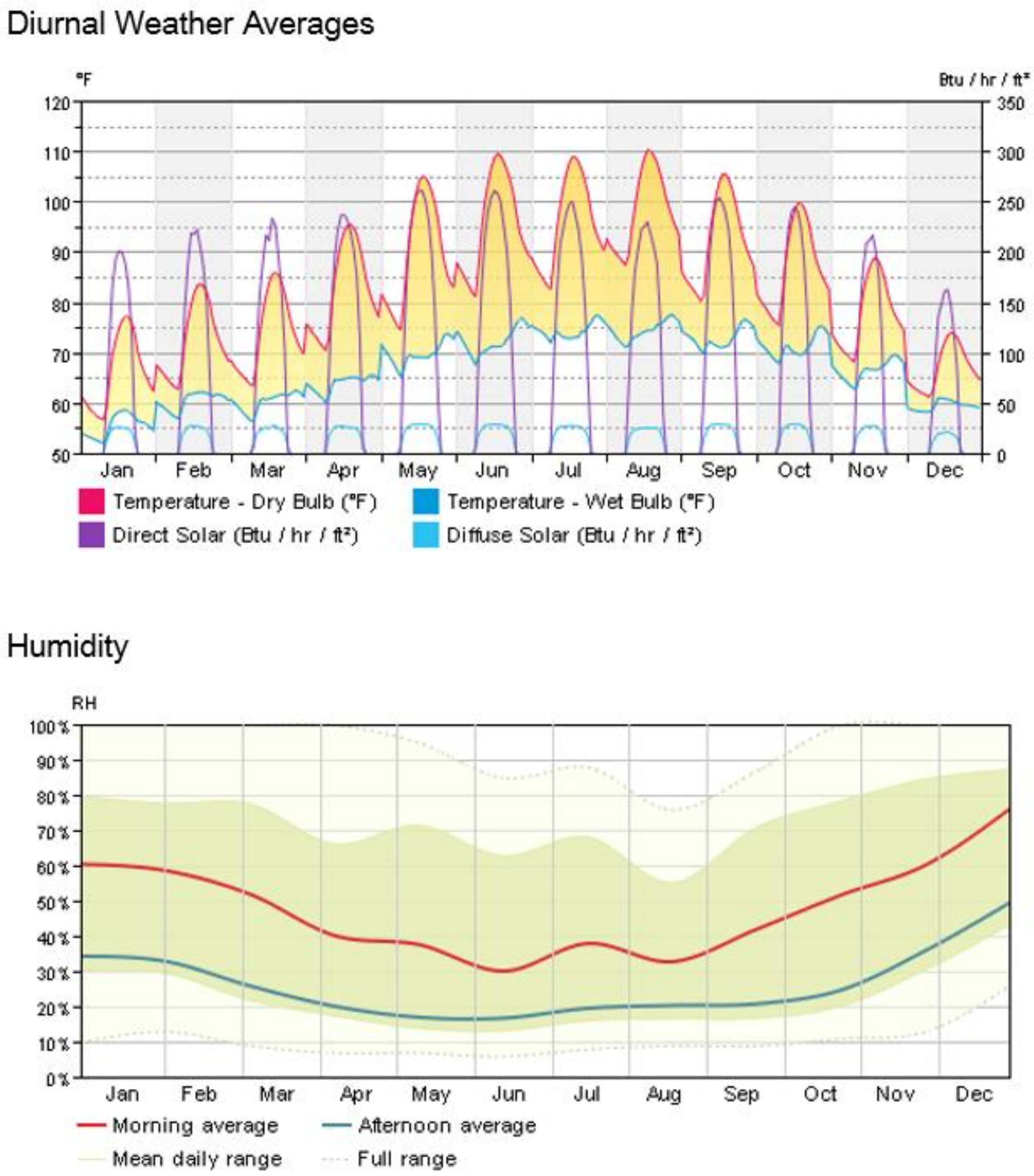


Figure 4.49. Diurnal Weather Averages and Relative Humidity

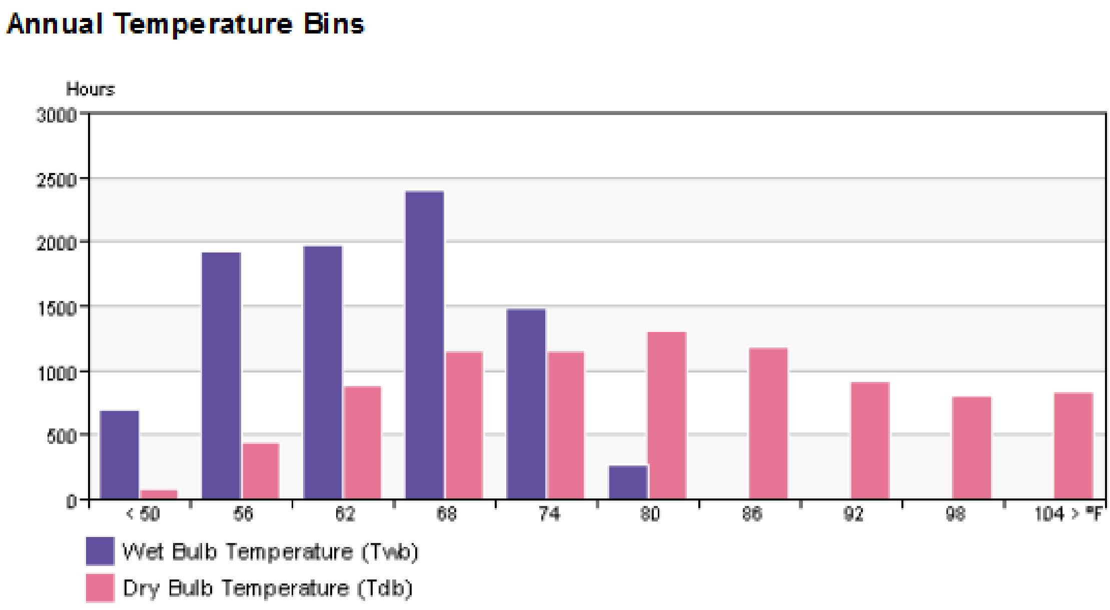


Figure 4.50. Annual Temperature Bins

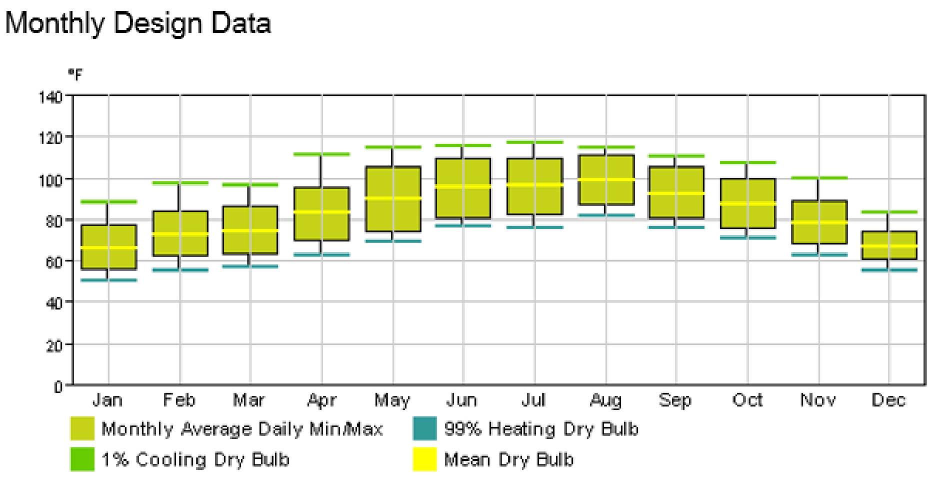


Figure 4.51. Monthly Design Data

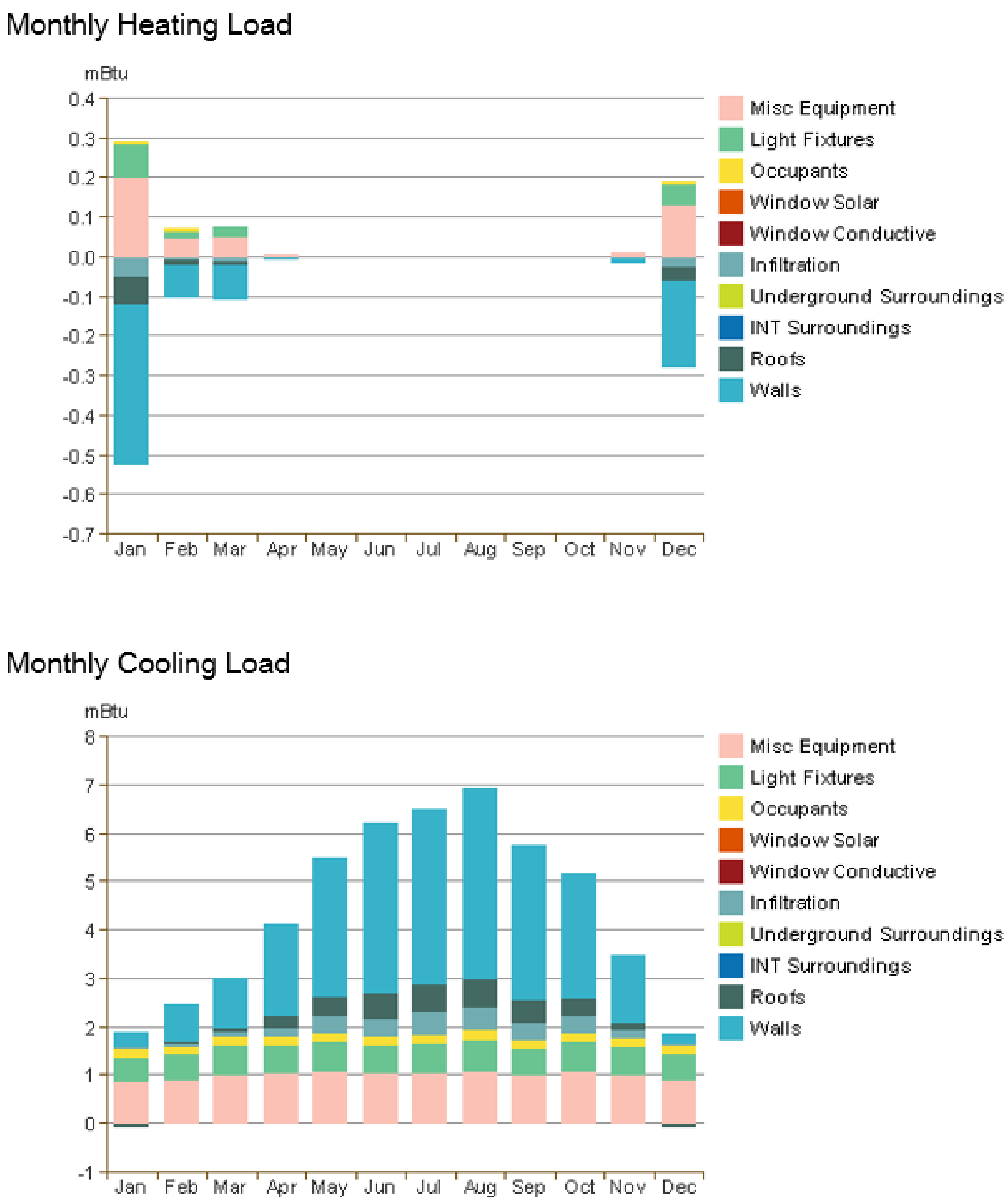


Figure 4.52. Monthly Heating and Cooling loads

Monthly cooling and heating loads of our design are shown indicating the need of cooling in the summers which is indeed very large but is catered for by our design as for the cooling load only in the months of December and January high amounts of fuel is required.

5. CHAPTER 5

CONCLUSIONS

All the objectives of our design have been achieved. It has been observed that by smartly applying active and passive design technologies, the house can perform better in Hot and Humid Regions. These details were validated as well as compared with other data. Green Buildings will enhance efficiency of systems, allowing major reductions in energy usage, hence, contributing a significant role in bringing down global warming effects from building operations and construction industry. Green Buildings not only provide comfort to the user but is also beneficial to the environment.

This rapidly constructible design can solve major global problems and industry challenges, such as rising urbanization and mass migrations. The design successfully incorporated the intensity of environmental challenges including high temperatures, humidity, high wind pressure and low precipitation. Green Buildings further pave way for smart buildings, utilizing technologies such as Building Integrated Photovoltaic (BIPV) and Internet-of-Things (IoT) technology.

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