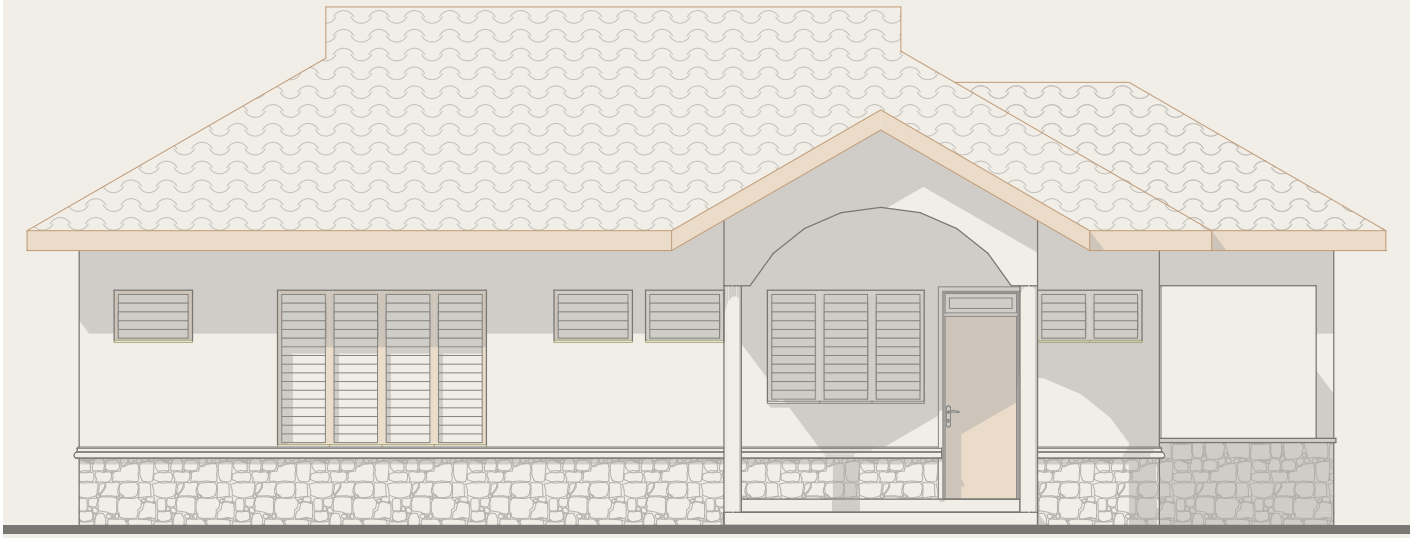
ISSUE NO. 2

The Journal of SUSTAINABLE BUILDING DESIGNS

Single dwelling housing



UN HABITAT
FOR A BETTER URBAN FUTURE

The Journal of Sustainable Building Designs

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The Journal of
SUSTAINABLE BUILDING DESIGNS

Single dwelling housing

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Contents

1 Introduction

Buildings have a strong potential to impact positively or negatively two important elements of everyday life: our environment and energy bills. Their contribution to climate change mitigation on greenhouse gas emission and higher or lower energy bills are directly related to the way buildings are designed in relation to the local climate and site-specific characteristics.

This journal calls for change in the way we build. It promotes creative ways to produce buildings which achieve optimum conditions for their inhabitants whilst making minimum demands on fossil-based energy. The first step in creating comfort and thermal delight in buildings is to understand the relationship between the local climate and our need for shelter. Buildings should vary with climate and thus with location.

Designing an energy efficient built environment involves minimising the wastage of energy resources while maximising the use of passive design options and renewable energy sources.

The design of energy efficient buildings and homes depends on, solar path and solar radiation, rainfall, humidity, prevailing wind, and ambient temperature of a particular place among others. Design parameters of buildings and homes, therefore, vary with different climatic zones. Therefore, to achieve sustainable housing, it is important to build conssidering the prevailing climatic conditions.

Poor climatic design of buildings, all too often seen in 'modern' architecture, causes many buildings to overheat, even in temperate or cold climates where such problems were never faced before the advent of modern architecture. The influence of the sun should be understood and respected by designers of passive solar buildings in which the sun's free energy is used for natural lighting, heating and drying out but will not interfere with the occupants' comfort. Well-designed buildings with environmentally friendly solutions use less energy. They require lower maintenance compared to ordinary buildings and are more comfortable spaces to live in.

Designing an energy efficient built environment involves minimising the wastage of energy resources while maximising the use of passive design options and renewable energy sources. The green building (or sustainable building) is a result of a holistic approach. It is designed, constructed, and operated in an environmentally responsible way; it is resource efficient (land, water, energy, material, waste) throughout the building's life-cycle.

This journal acts as a guideline in providing applicable passive design principles for different climatic conditions that should be taken into consideration when designing in the different climates. These include:

- Site analysis
- Building orientation
- Natural ventilation
- Day lighting
- Solar shading
- Building materials
- Window sizes
- Window location
- Location of building services

Whereas sustainable buildings are directly related to local climate and site conditions, this journal is not intended to provide generic templates replicable in any part of the East African region. It aims to discuss examples and guide the user on how best to explore local climatic conditions.

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Site Analysis

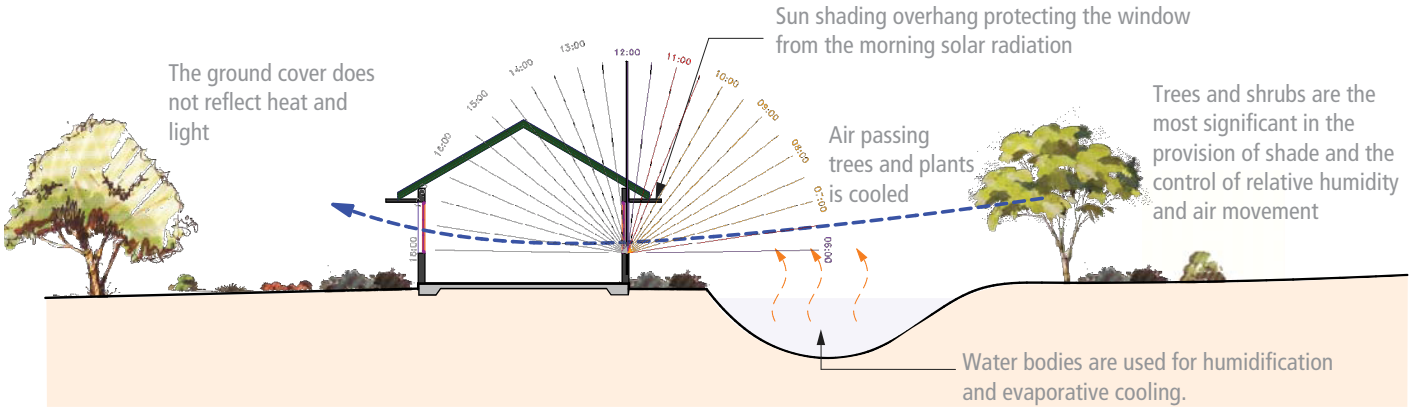
Site analysis helps to identify opportunities or constraints which will influence the outcome of the urban and building design. Careful site analysis and planning ensures that the proposed building placed on the site will have minimal negative effects on the environment while maximizing their efficiency. A proper site analysis should, therefore, be completed before design development can start.

Elements of site analysis include the following:

- **Sun Path:** Understanding the movement of the sun during the day and throughout the year allows for a qualitative analysis of the incident sunlight and heat. It is important to establish the sun shading needs and estimating the effects of the vegetation, relief and neighbouring buildings' shading. In the tropics, the optimal orientation of the main road path is along the East-West axis.
- **Prevailing Winds:** Knowledge of the speed, frequency and directions of the prevailing winds will facilitate natural ventilation. Ideally, the main road or open space orientation should follow the prevailing wind direction to assure natural ventilation and dust removal to all buildings along the road. A compromise, depending on the need for cooling or heating should be taken in case the prevailing winds direction are in conflict with the sun path.
- **Site Topography:** The existence of rivers, streams, valleys, hills, mountains and their position relative to prevailing winds may assist or obstruct natural cooling, wind and sun shading. Proper site analysis is required to maximize the use of the existing microclimate.
- **Vegetation:** The types, density and location of plants affect the site's microclimate (solar radiation, wind, humidity, amount of dust, air quality and temperature), the definition or visual screening of external spaces and the absorption or dispersion of sound. Trees act as windbreakers and produce oxygen through photosynthesis.
- **Neighbourhood:** An analysis of the neighbouring buildings is necessary to understand their effect on the site. For instance, neighbouring buildings with reflective surfaces can increase the proposed building's needs for sun shading if they reflect the sun onto the new buildings' facade. Even if the latter's orientation is optimal.

Urban layout orientation and density also influence ventilation of the urban space and may condition building design.

Figure 1: Passive design strategies



3

Case Studies

The way buildings are planned and designed today has a direct implication on their energy bills.

CASE STUDY 1

CLIMATIC ZONE 1:
Hot and Humid climate

Single dwelling housing

Climatic Zone 1: Hot and Humid climate

Location	Mombasa, Kenya
Latitude	4°03'S
Longitude	39°40'E
Altitude	55 m above sea level
Temperature	Min average temp 26.3°C; Max average temp 33°C
Annual Rainfall	Average 1083.2 mm
Humidity	Average relative humidity is 77.6%
Prevalent Wind Direction	South and East prevailing winds

Figure 2: MOMBASA (Hours of Sunshine / Temperature)

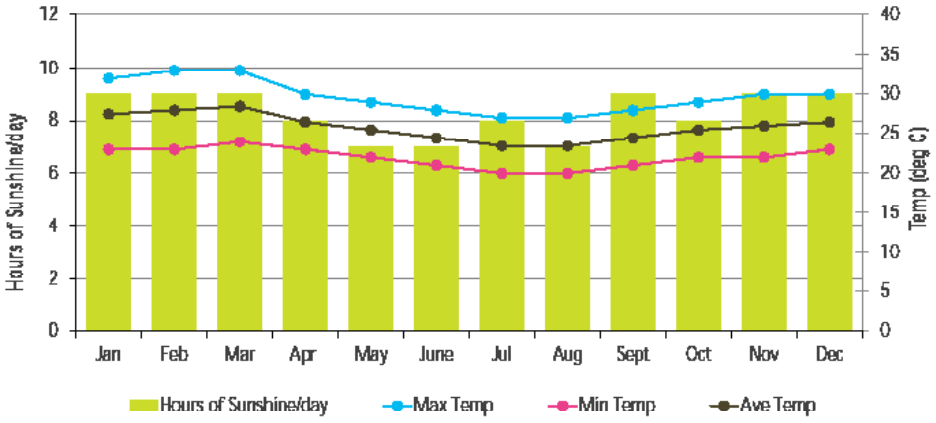


Figure 3: MOMBASA (Relative Humidity / Rainfall)

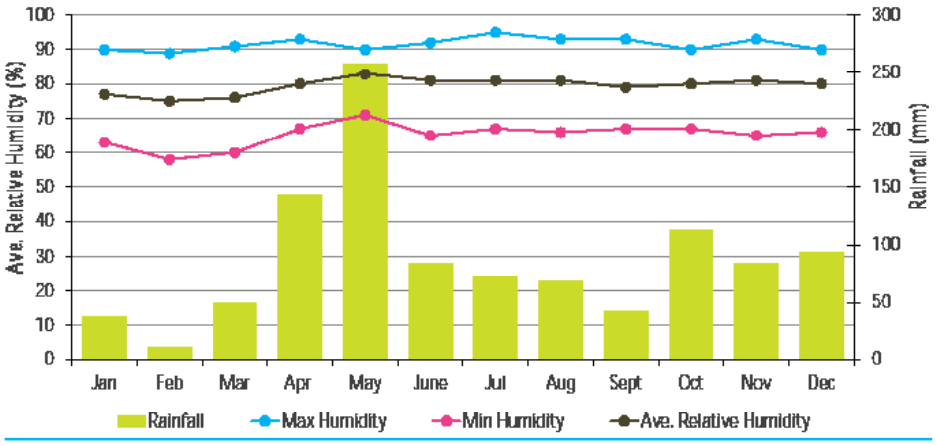


Figure 4: Prevailing wind direction

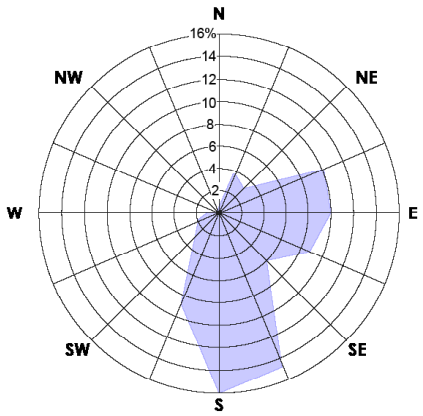


Figure 5: Sun path Diagram for Latitude 4° South

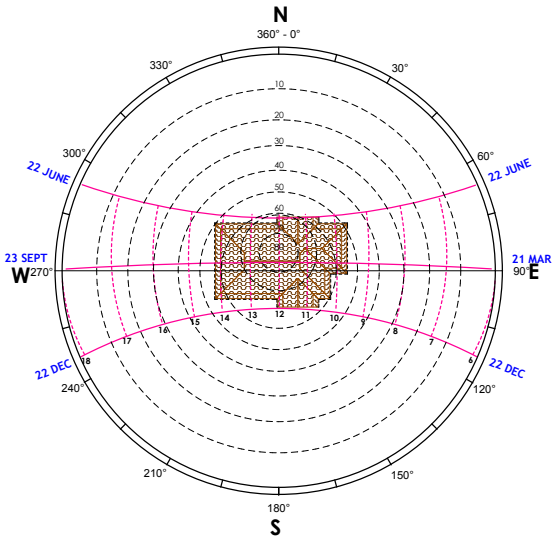
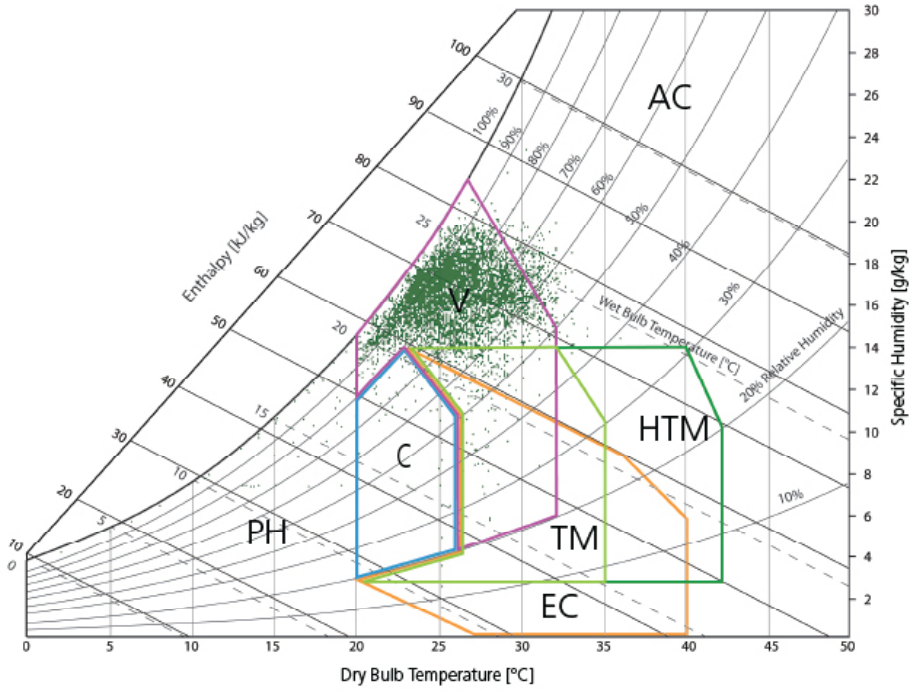
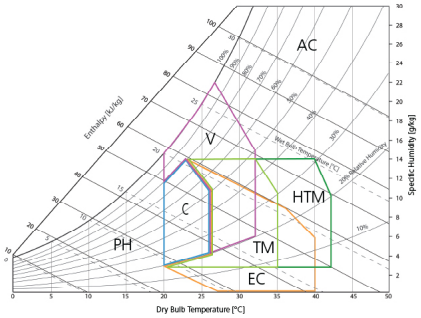


Figure 6: Bioclimatic Chart





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
AH	Artificial Heating
AC	Air Conditioning

INTERPRETATION

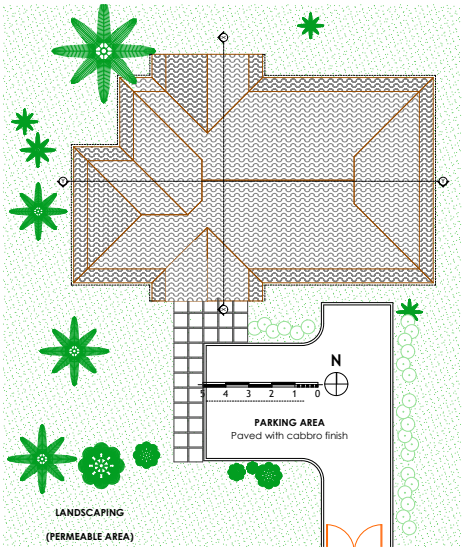
- Both day and night temperatures in this zone are high. The humidity levels are equally high throughout the year.
- The prime design objective for this zone is to provide free air movement through the house while preventing internal surface temperatures from rising above the outdoor shade temperature protecting all the facades from solar radiation.
- Natural ventilation and solar radiation are the most effective passive design strategies for improving thermal comfort.
- Cross ventilation strategies should be adopted to improve the indoor thermal comfort. Open buildings are preferable.
- Buildings should be lightweight with minimum possible thermal storage capabilities. They should be oriented with the long axis running east-west to provide effective shading.
- Air conditioning may be necessary to provide comfortable indoor conditions by cooling the air during high day temperatures and humidity levels during certain periods of the year.

CLIMATIC ZONE 1:
Hot and Humid climate

CASE STUDY 1

Single dwelling housing

Figure 7: Site Plan



Use of permeable boundary wall to avoid obstruction of prevailing winds to enhance ventilation.

Tall trees improve shading without obstructing natural ventilation.

Figure 8: Ground Floor Plan

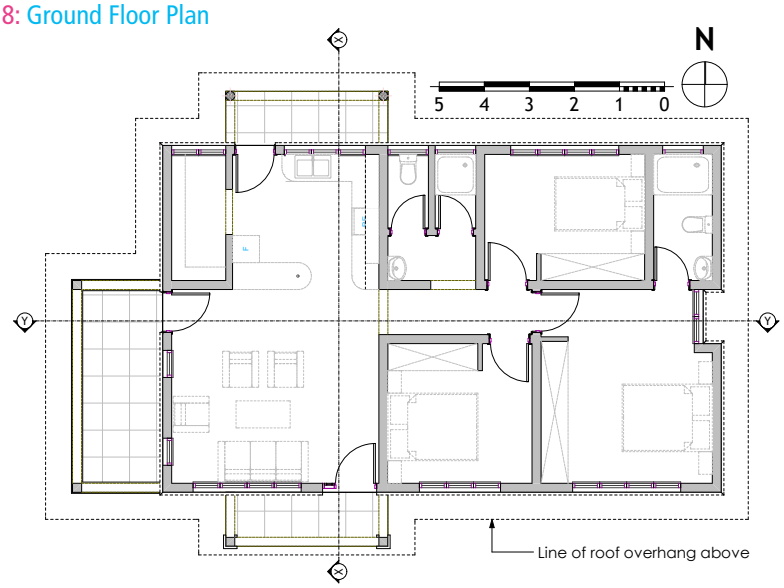
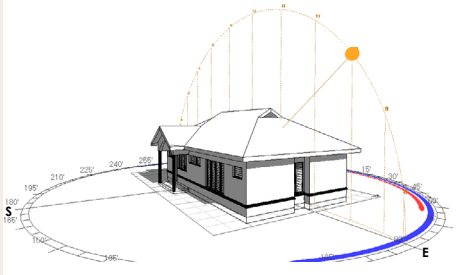


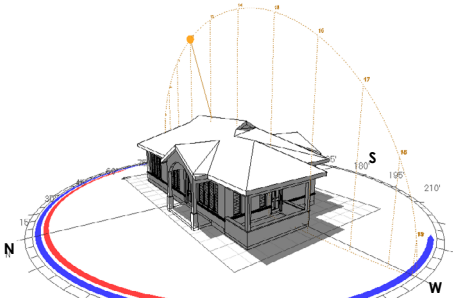
Figure 9: Position of the Sun at different times during the equinox

March 21st at 9.00 a.m.



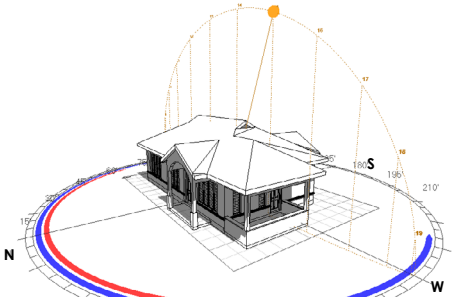
The window on this eastern facade is recessed to minimize exposure to the morning solar radiation.

March 21st at 12.00 p.m.



The roof overhang completely shades walls and openings from the overhead midday sun.

March 21st at 3.00 p.m.



The western walls and openings are completely shaded from the afternoon sun by the deep verandah.

Figure 10: North Elevation

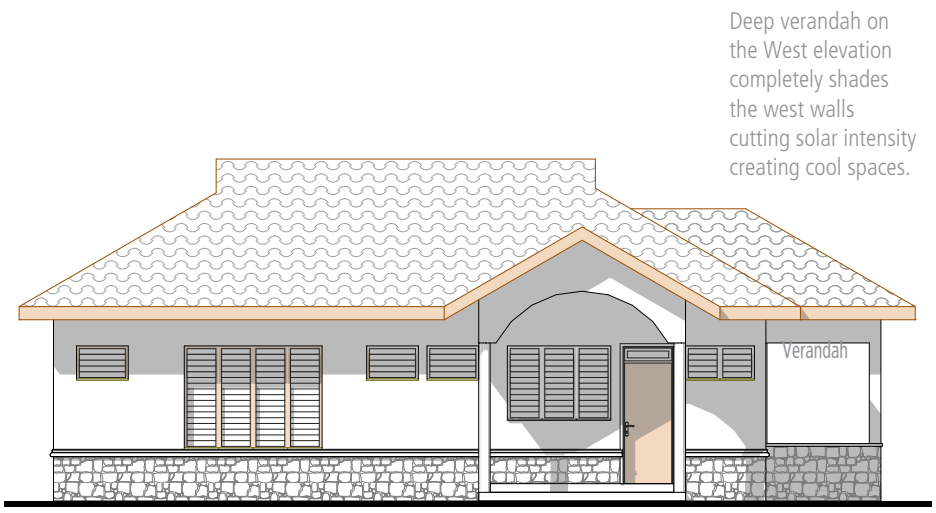


Figure 11: South Elevation

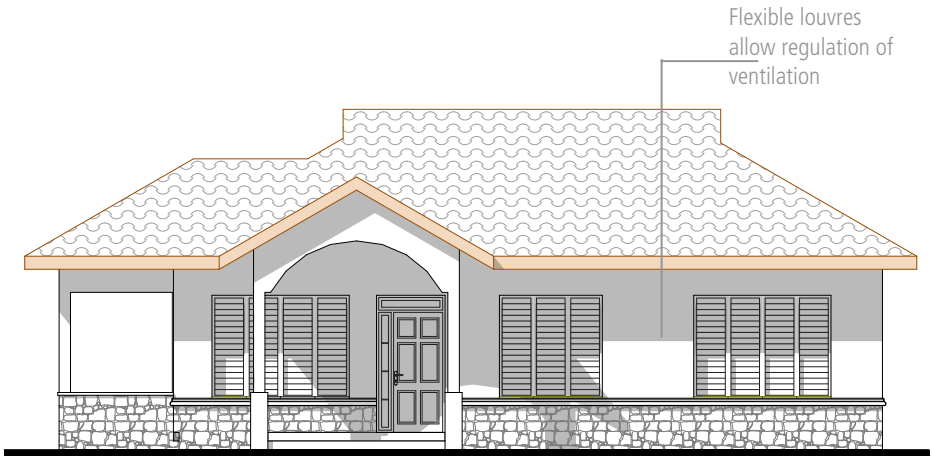
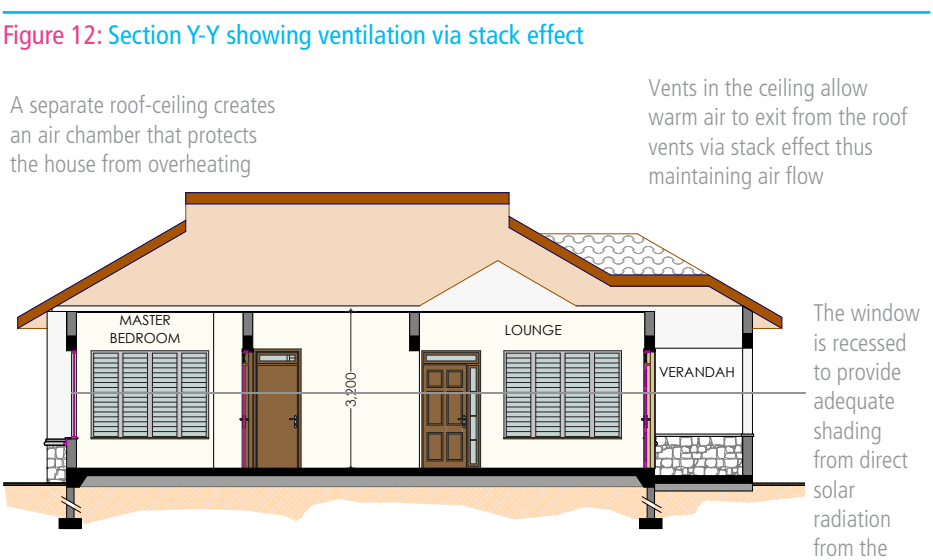


Figure 12: Section Y-Y showing ventilation via stack effect



DESIGN RESPONSES

1 **Orientation** - This house is optimally oriented along the East-West axis with the main openings facing the North-South direction for protection against solar radiation.

2 **Ventilation** - The house is oriented to take advantage of the South East and East prevailing winds. Large windows with glazed areas not exceeding 20 per cent of the elevation area, and permanently opened vents have been provided at the ceiling level to maximize on passive ventilation. The windows have been fitted with adjustable louvres allowing a regulation of ventilation and lighting. Windows to the living and sleeping places have been placed at 600 mm above the floor for comfort ventilation. The open plan of the lounge and kitchen area decreases resistance to air flow thus creating flow paths through the house.

3 **Daylighting** - The provision of large windows (20 per cent of respective elevation area) in all the rooms ensures that there is adequate natural lighting.

4 **Sun shading** - Large overhangs (600 mm) have been used to shade the walls and windows against unwanted solar radiation and driving rain. The opening along the eastern wall has been recessed to shade it from the morning sun radiation. Shade to the southwest and west is important for blocking peak solar gain in the late afternoon.

5 **Building materials** - Lightweight materials that do not store heat are desirable for construction. Recommended materials and finishes include hollow walls, insulated roofs (if possible), lightly coloured finishes to lightweight floors etc. Reflective roofs are preferred to reflect heat and therefore reduce the amount of heat absorbed into the building.

CASE STUDY 2

Single dwelling housing

CLIMATIC ZONE 2:
Hot semi-arid / Savannah climate

Climatic Zone 2: Hot semiarid / Savannah climate

Location	Makindu, Kenya
Latitude	2°28'S
Longitude	37°83'E
Altitude	1000 m above sea level
Temperature	Min average temp 16.1°C; Max average temp 28.3 °C
Annual Rainfall	Average 641 mm
Humidity	Average relative humidity is recorded at 68%
Prevalent Wind Direction	East Prevailing winds

Figure 13: MAKINDU (Hours of Sunshine / Temperature)

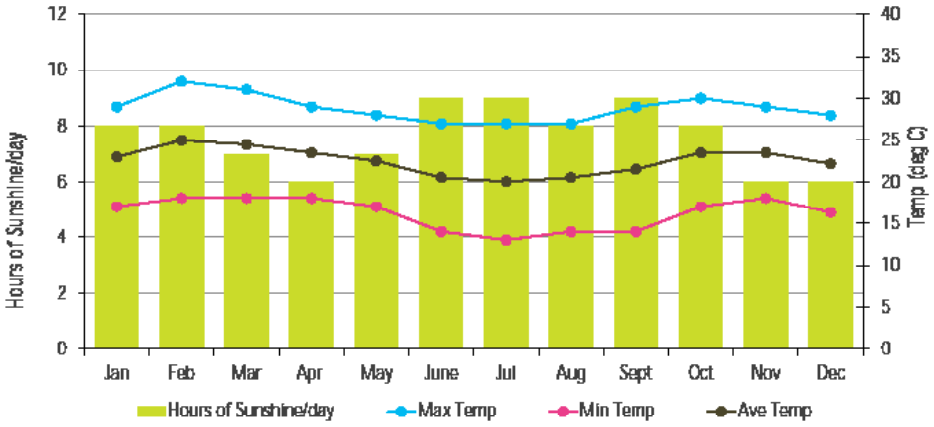


Figure 14: MAKINDU (Relative Humidity / Rainfall)

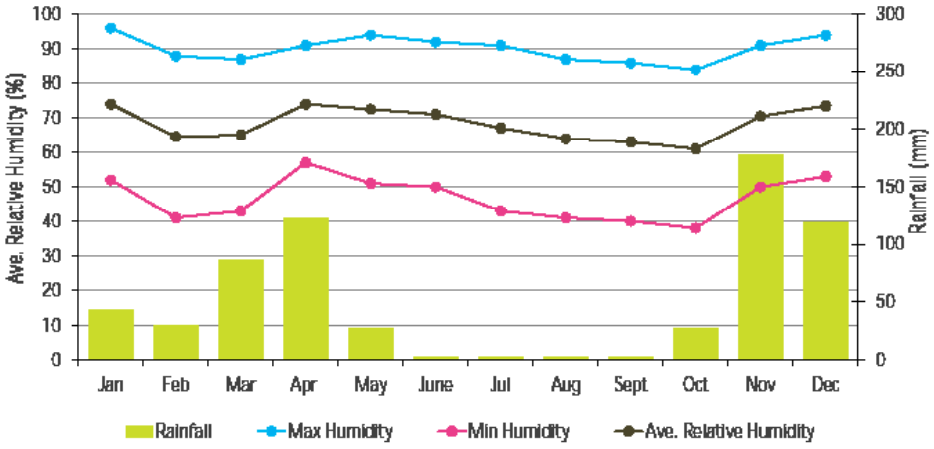


Figure 15: Prevailing wind direction

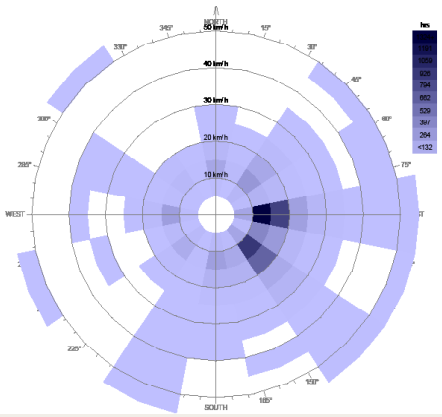


Figure 16: Sun path Diagram for Latitude 2° South

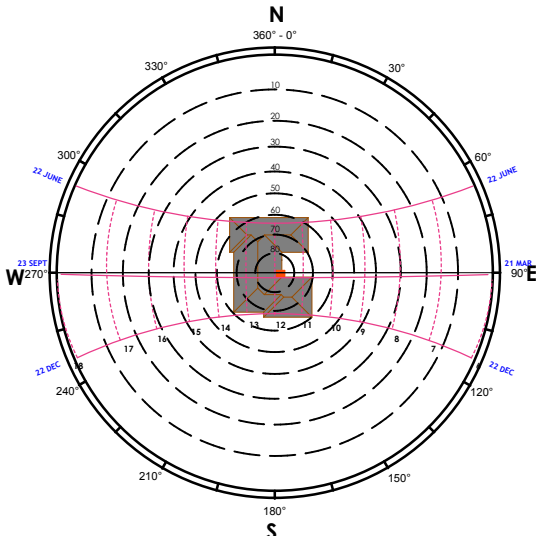
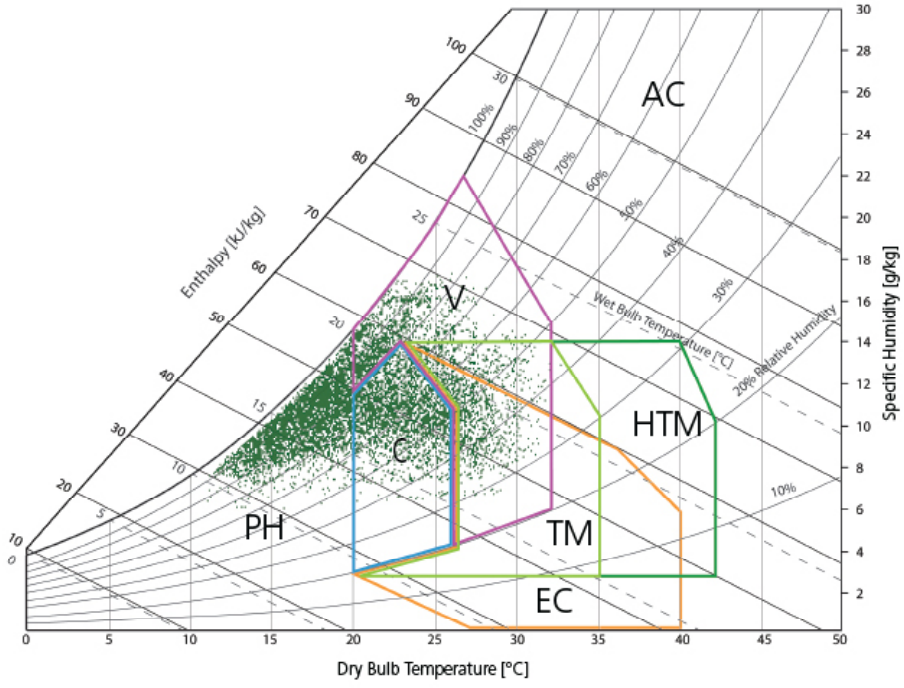
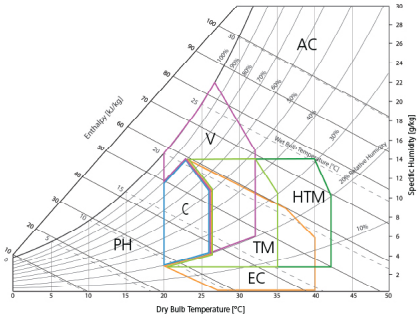


Figure 17: Bioclimatic Chart





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
AH	Artificial Heating
AC	Air Conditioning

INTERPRETATION

- Both temperature and humidity levels fall within the comfort zone for most periods of the year.
- Natural ventilation (night ventilation), high thermal mass and solar shading are the most effective passive design strategies for improving thermal comfort.
- Medium or heavy weight walls are preferable in this zone since they are subjected to greater heating by day and faster cooling at night.
- Passive heating through thermal mass assisted with ventilation is an appropriate way to maintain thermal comfort inside the building.
- Compact buildings are suitable for the type of climate to reduce the facade exposed to solar radiation, thus solar heat gains.
- Buildings should be oriented with the long axis running east-west to provide effective shading.

CLIMATIC ZONE 2:
Hot semi-arid / Savannah climate

CASE STUDY 2

Single dwelling housing

Figure 18: Site plan

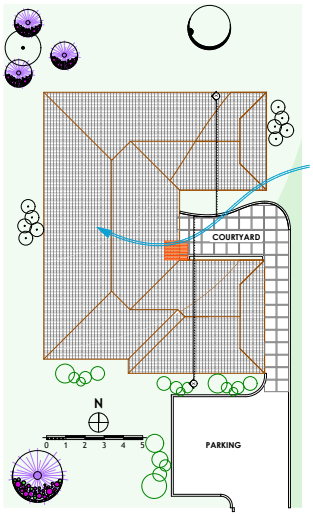


Figure 19: Ground floor plan

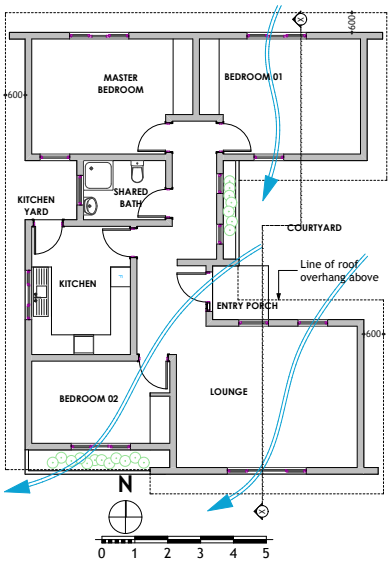
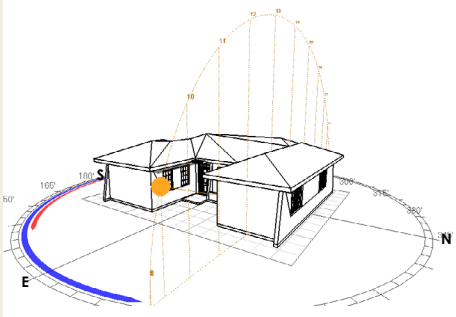


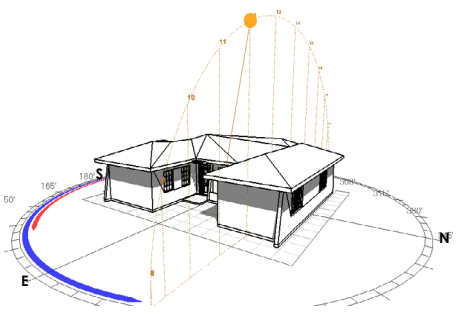
Figure 20: Position of the Sun at different times during the winter soltice

June 22nd at 9.00 am



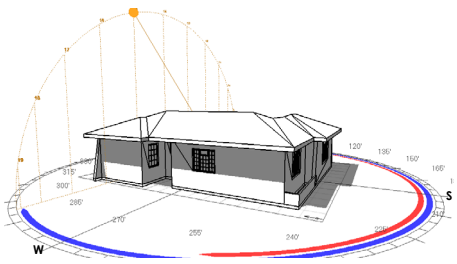
Few openings on the eastern side reduce the morning solar radiation into the house.

June 22nd at 12.00 pm



At noon, the roof overhang shades the walls and openings.

June 22nd at 3.00 pm

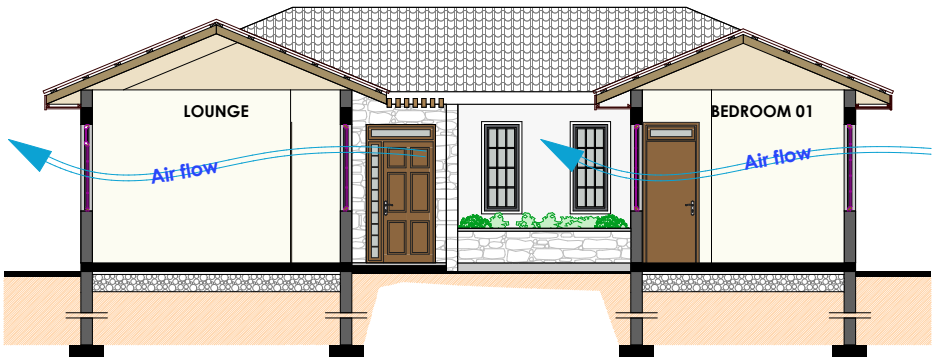


In the afternoon, the western walls are completely shaded from solar radiation by the roof overhang.

Figure 21: South Elevation

Figure 22: East Elevation

Figure 23: Section X-X showing cross ventilation



DESIGN RESPONSES

1 **Orientation** - Despite the long sides of the building facing the east-west direction, all the major windows have been oriented in the north-south direction minimizing exposure to direct solar radiation. The openings on the east facing walls have been shaded using roof overhang against the morning sun.

2 **Ventilation** - The building has also been oriented and designed to capture the prevailing winds (from the east) and exploit them for ventilative cooling at night. Each primary space (lounge and bedrooms) is also designed to have openings on two opposing or adjacent walls in different axes to encourage cross ventilation.

3 **Daylighting** - All the rooms are naturally lit during the day by the provision of windows. A glazed portion of the north and south walls should not exceed 15 per cent of the total wall area. This reduces the energy consumption required for artificial lighting. During the cold months, the openings on the east and west facing walls contribute to warm the building through heat gain from the morning and afternoon sun respectively.

4 **Sun shading** - Roof overhang is used to generate mid-day shade and to cut off unwanted solar radiation.

5 **Building materials** - A heavy house structure that will offset hot days and cold nights is appropriate in this zone. Heat accumulated during the daytime should be stored by an adequate thermal capacity of the walls, ceilings and floors to balance the temperature. Materials such as concrete floors, masonry walls (200 mm thick), brick pavers, and tiles are preferred as they store heat and regulate interior temperatures both in hot and cold seasons. Light coloured finishes are recommended to reflect solar radiation.

CASE STUDY 3

CLIMATIC ZONE 3:
Hot arid climate

Single dwelling housing

Climatic Zone 3: Hot arid climate

Location	Garissa, Kenya
Latitude	0°26'S
Longitude	39°38'E
Altitude	147 m above sea level
Temperature	Min av. temp 22.81°C; Max av. temp 35.84°C
Annual Rainfall	Average 415 mm
Humidity	Average relative humidity is 62%
Prevalent Wind Direction	South prevailing winds

Figure 24: GARISSA (Hours of Sunshine / Temperature)

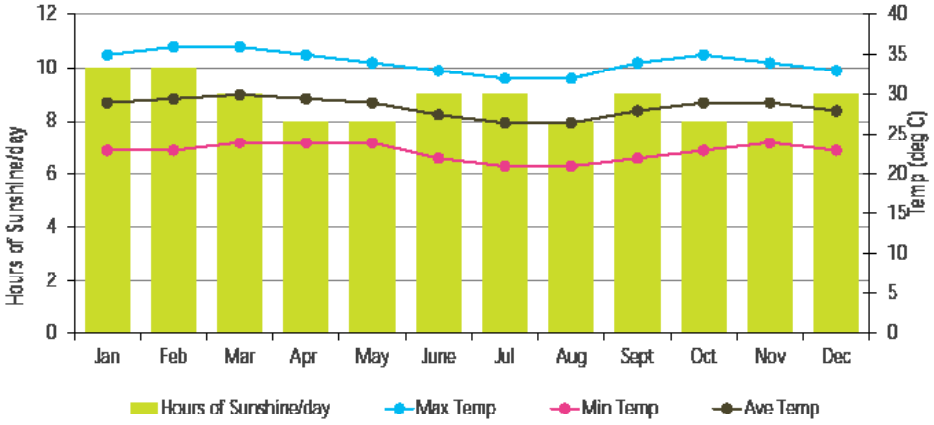


Figure 25: GARISSA (Relative Humidity / Rainfall)

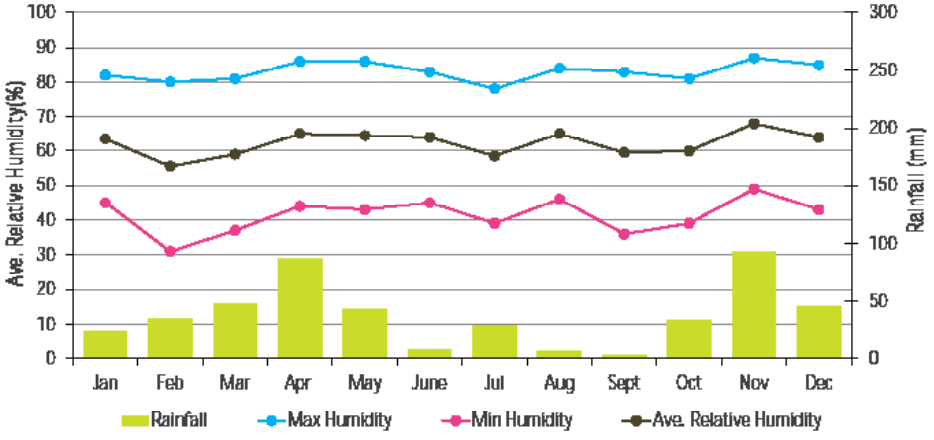


Figure 26: Prevailing wind direction

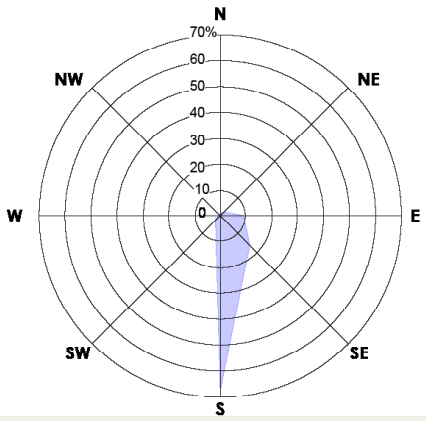


Figure 27: Sun path Diagram for Latitude 0° South

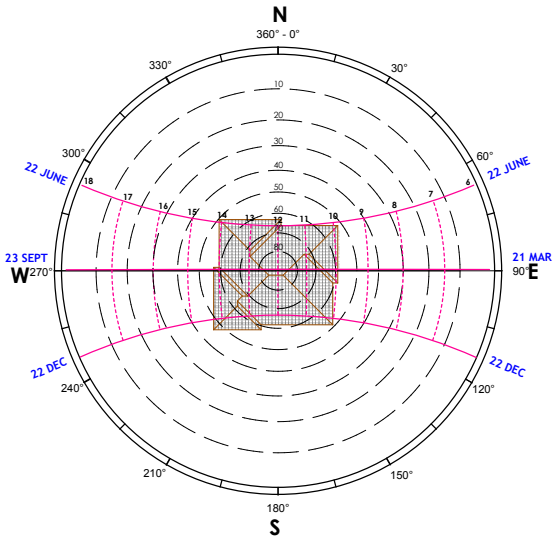
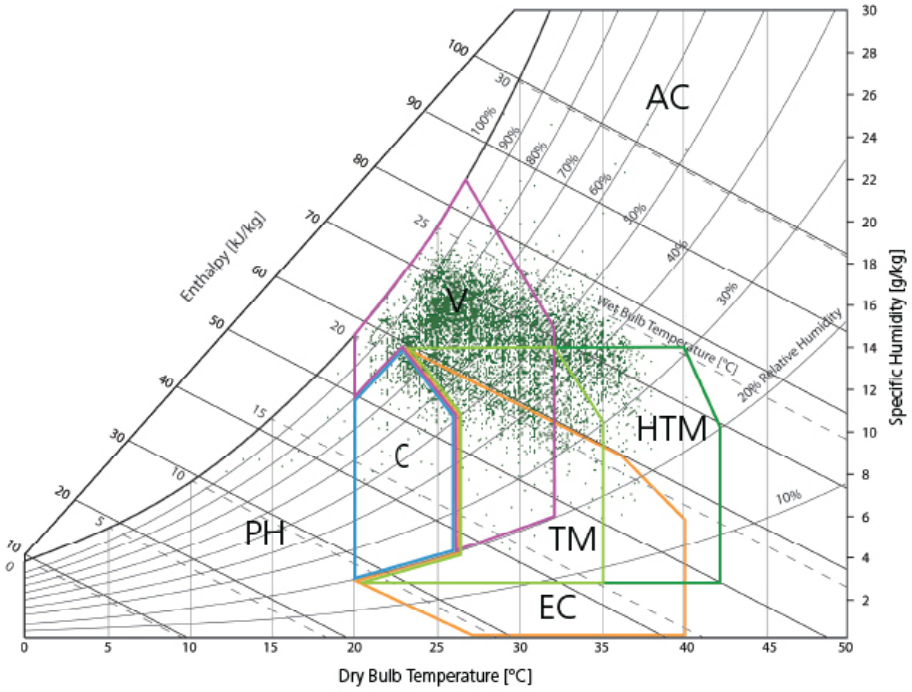
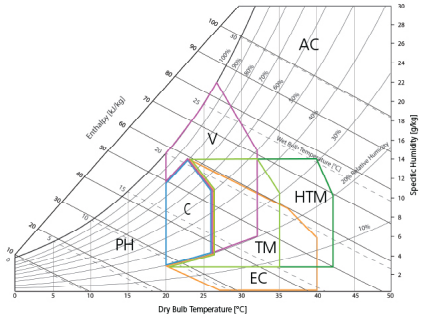


Figure 28: Bioclimatic Chart





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
AH	Artificial Heating
AC	Air Conditioning

INTERPRETATION

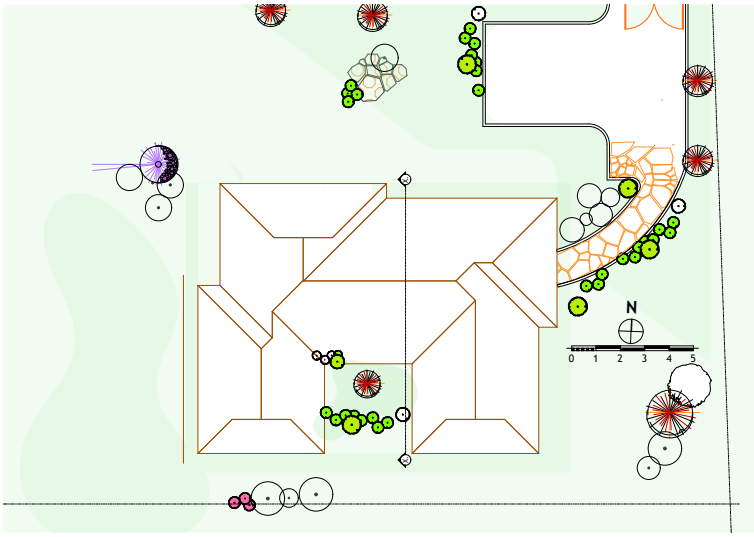
- Days in this zone are invariably hot. High daytime temperatures are accompanied by moderate to low humidity levels.
- Because of high daily temperature variation, it is best to keep heat out during the day and ventilate during the night.
- Natural ventilation (night ventilation), high thermal mass, solar shading and evaporative cooling are the most effective passive design strategies for improving thermal comfort.
- The maximum temperatures in some months are outside the high thermal mass area, thus additional air conditioning means may be required to provide adequate thermal comfort indoors during the day.
- High thermal mass for walls and roofs prevents overheating during daytime while natural ventilation combined with evaporative cooling relieves heat delivered by the heavy structures at night.
- Buildings should be compact and oriented with the long axis running east-west to provide effective shading.

CLIMATIC ZONE 3:
Hot arid climate

CASE STUDY 3

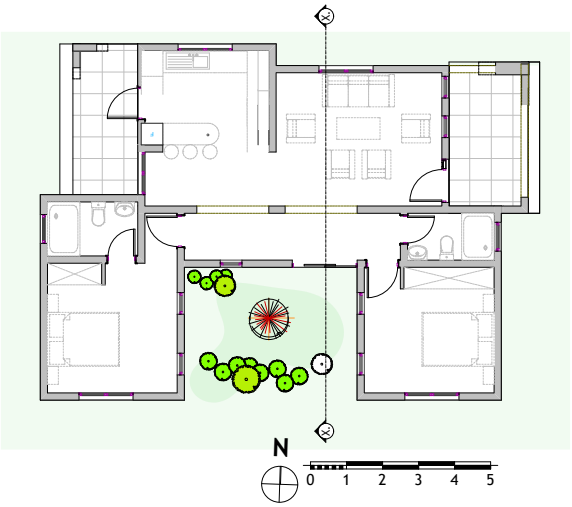
Single dwelling housing

Figure 29: Site plan



Appropriate location of trees and vegetation helps with evaporative cooling as well as sun protection.

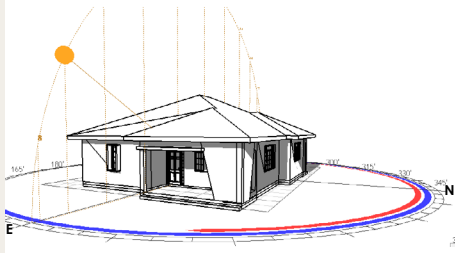
Figure 30: Ground floor plan



Courtyards are very useful for evaporative cooling in this climate.

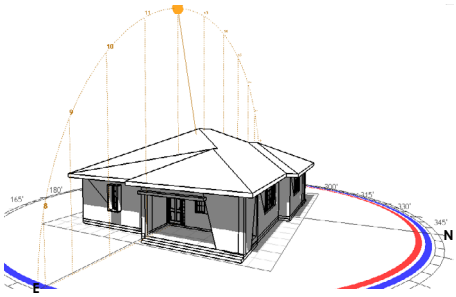
Figure 31: Position of the Sun at different times during the equinox

September 23rd at 9.00 a.m.



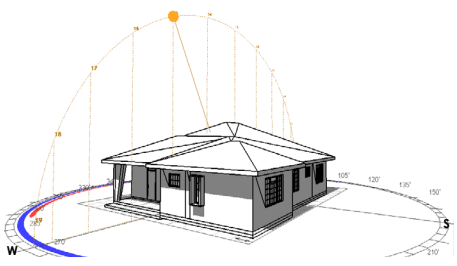
The entry porch minimizes exposure to the morning sun.

September 23rd at 12.00 p.m.



The roof overhang shades the walls and openings from the midday sun.

September 23rd at 3.00 p.m.



The roof overhang shades the walls and openings from the afternoon sun.

Figure 32: South Elevation

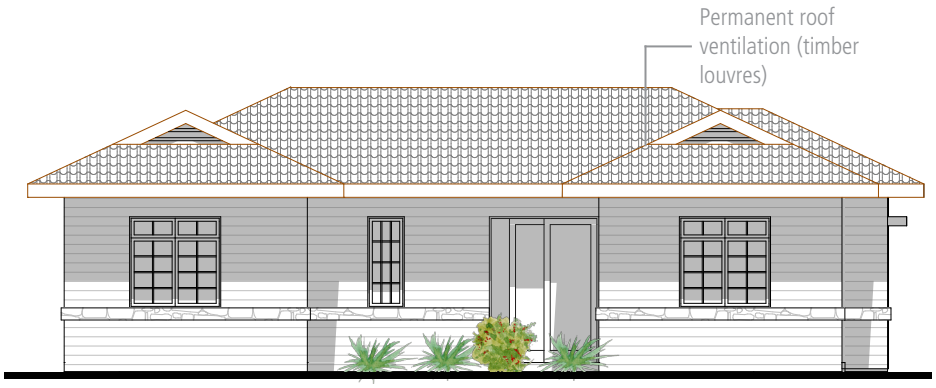


Figure 33: East Elevation

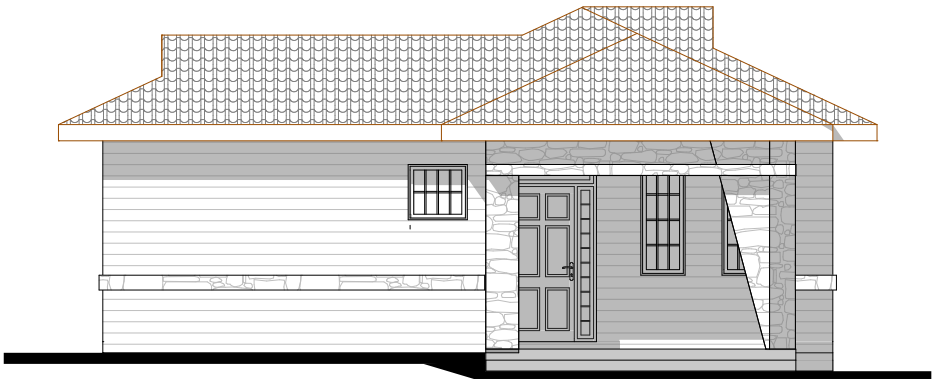
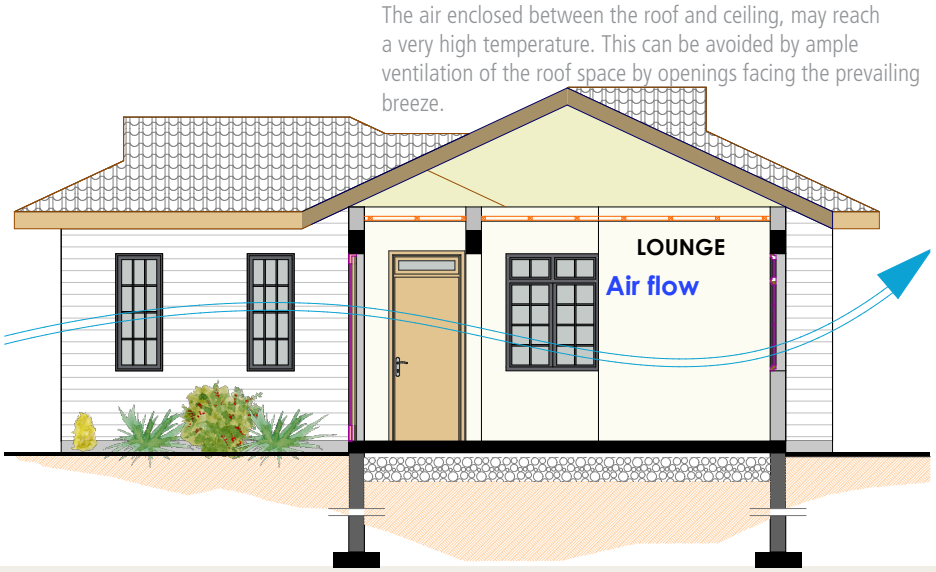


Figure 34: Section X-X showing cross ventilation



DESIGN RESPONSES

1 **Orientation** - The long axis of the building is optimally oriented in the east-west direction with the main openings facing the north-south direction to help control the effect of the sun on heating and cooling loads.

2 **Ventilation** - The main openings, placed along the north and south facing walls and in different axes, allow for maximum cross-ventilation of the rooms. All rooms have openings in two opposite directions and vents located above windows and doors. Vertical shading devices have been provided on the slit windows on the east and west facing walls. Vents at the roof prevent the build-up of hot air within the roof space and encourage thermal air movement. This is important especially at night.

3 **Daylighting** - For this type of climate, in hot-arid zones, openings should be of a minimum size or adjustable in size by shutters, and the view not directed towards the ground (glare) as far as considerations of natural lighting permits. 10 - 20 per cent of the area of north and south facing walls should be openable in order to provide good natural light to every room and to avoid power consumption for lighting during the day.

4 **Sun shading** - Large roof overhangs are provided on all elevations to effectively keep direct sunlight out of the windows. The roofed entry porch and kitchen yard minimize direct heat gain into the house from the morning and strong afternoon sun respectively.

5 **Building materials** - Materials with high thermal mass are recommended for construction because of the high diurnal temperature range. High reflective roofs and light-coloured walls are desirable to prevent overheating.

CASE STUDY 4

CLIMATIC ZONE 4:
Highland climate

Single dwelling housing

Climatic Zone 4: Highland climate

Location	Nairobi, Kenya
Latitude	1°17'S
Longitude	36°49'E
Altitude	1800 m above sea level
Temperature	Min average temp 17.7°C; Max average temp 26°C
Annual Rainfall	Average 790 mm - 925 mm
Humidity	Average relative humidity is 72.8%
Prevalent Wind Direction	North East and East prevailing winds

Figure 35: NAIROBI (Hours of Sunshine / Temperature)

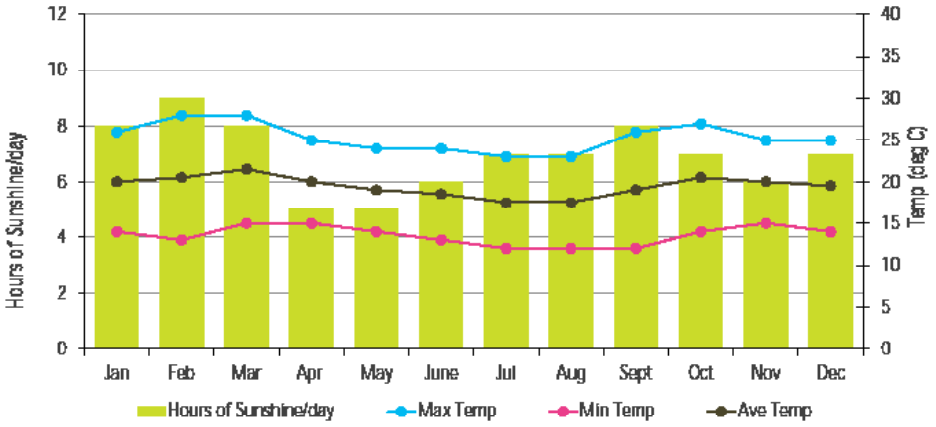


Figure 36: NAIROBI (Relative Humidity / Rainfall)

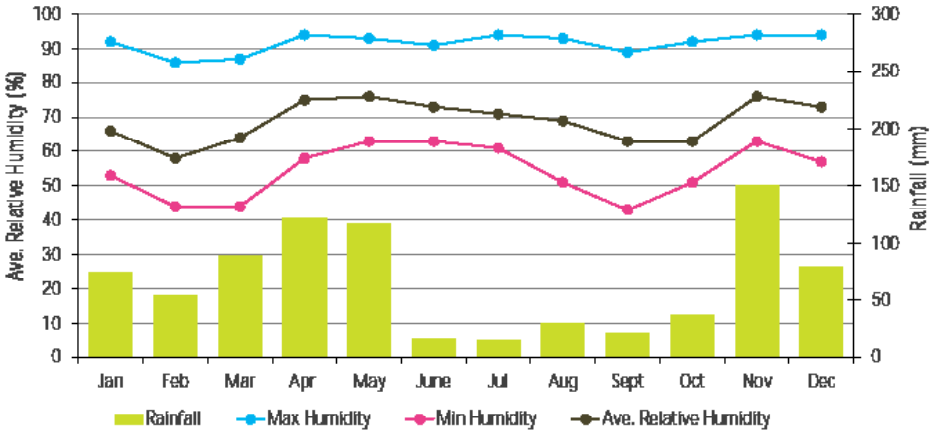


Figure 37: Prevailing Wind Analysis

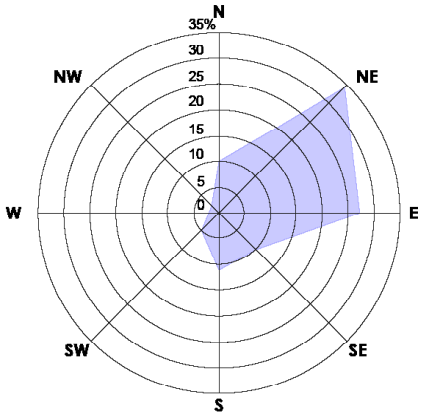


Figure 38: Sun path Diagram for Latitude 1° South

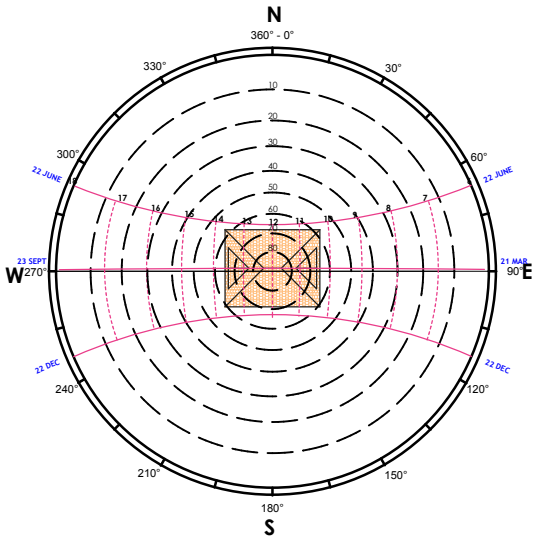
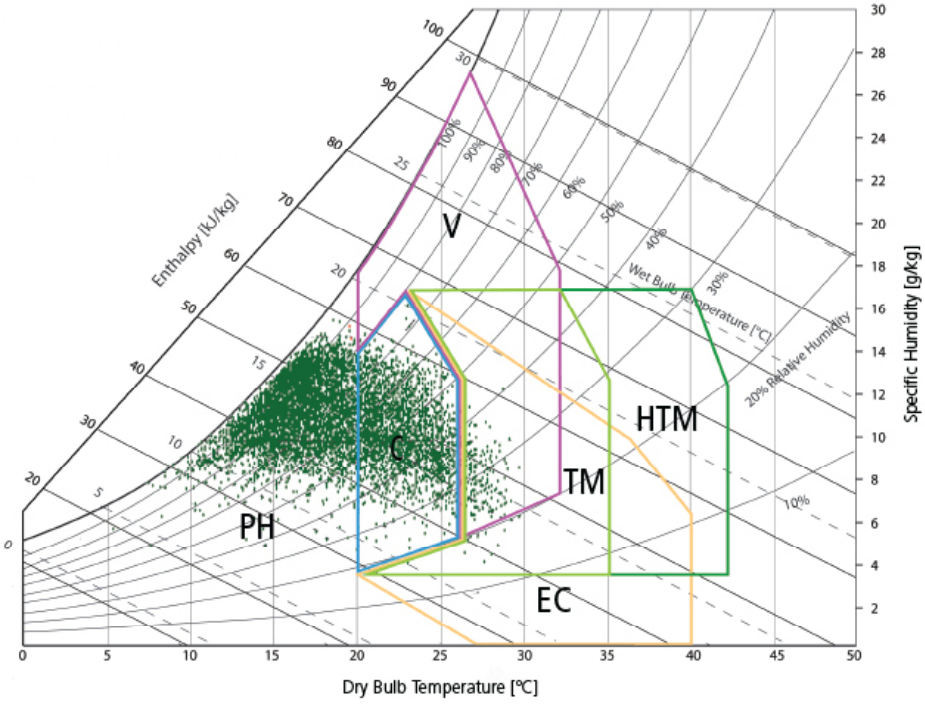
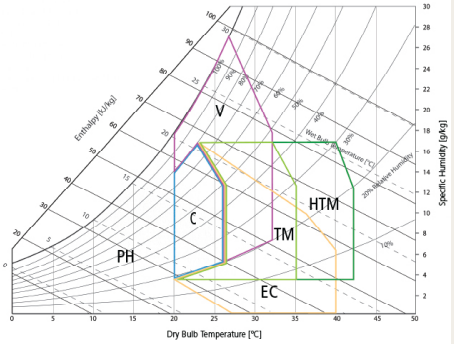


Figure 39: Bioclimatic chart





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
AH	Artificial Heating
AC	Air Conditioning

INTERPRETATION

- This zone's climate is exceptionally agreeable and with regard to comfort, the most favourable. Extremes of temperatures do not occur rarely rise above the upper limits of the comfort zone although they regularly drop below the lower limits.
- Passive heating and medium thermal mass are the most effective design strategies for improving thermal comfort.
- Because of the low temperatures, some passive heating (e.g. by sunshine) is welcome during the cool period of the year.
- Natural ventilation is important for indoor comfort although it not a requisite for human comfort for air temperatures only rarely exceed the upper limit of the comfort zone.
- Medium weight structures are preferred in order to limit the heat admitted to interiors during hours of strong sunshine and to store some of the day's heat so it may be re-emitted to interiors during the cool of the night.
- Buildings should be oriented with the long axis running east-west to provide effective shading.

CLIMATIC ZONE 4:
Highland climate

CASE STUDY 4

Single dwelling housing

Figure 40: Site Plan

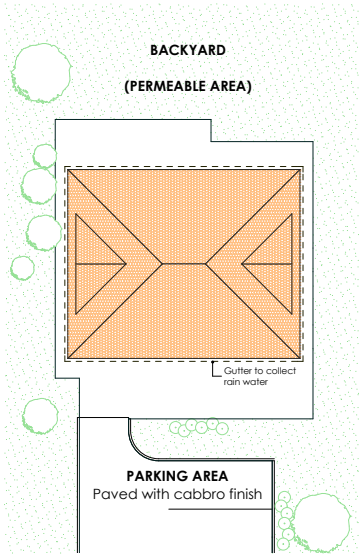


Figure 41: Ground Floor Plan

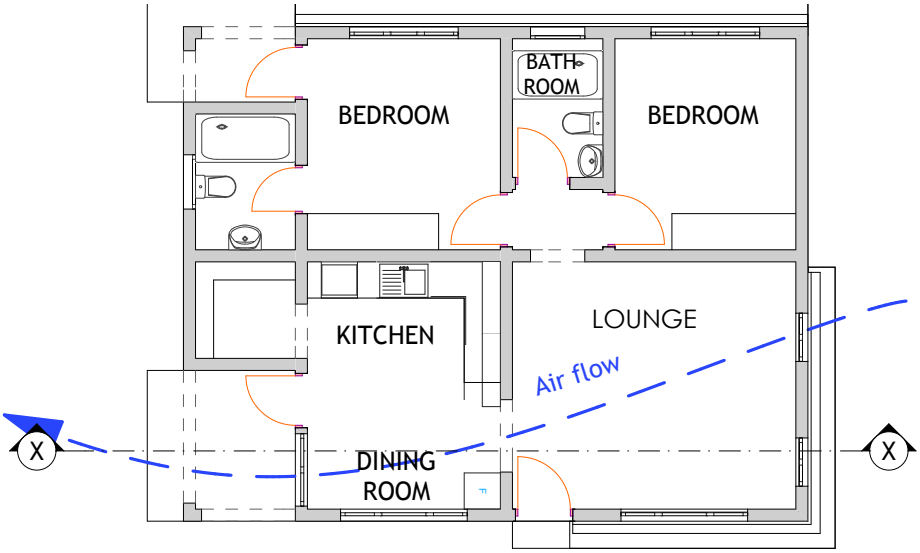
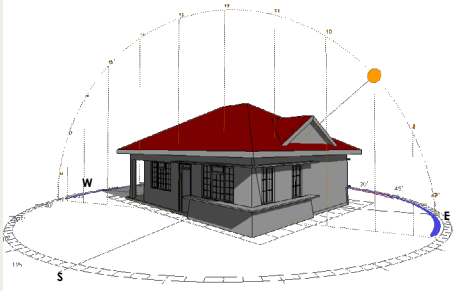


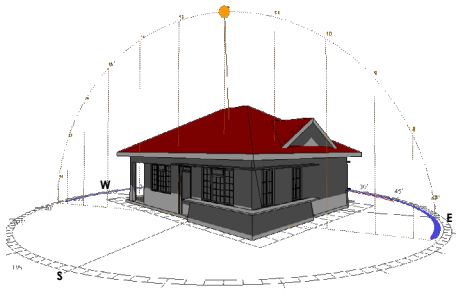
Figure 42: Position of the Sun at different times during the summer soltice

December 22nd at 9.00 am



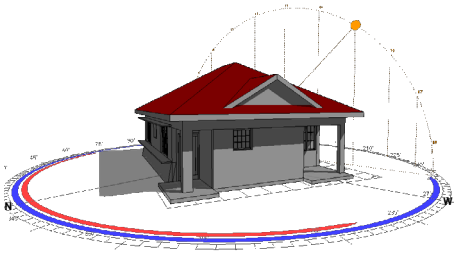
At this time the sun hits the eastern facade. The roof overhang provides shade to the windows.

December 22nd at 12.00 pm



The sun is overhead at noon. The roof overhang provides shade on all facades against the noon sun.

December 22nd at 3.00 pm



To minimize solar radiation into the house, there are few openings on the western walls. The roof overhang provides shade to the window.

Figure 43: South Elevation

Figure 44: East Elevation

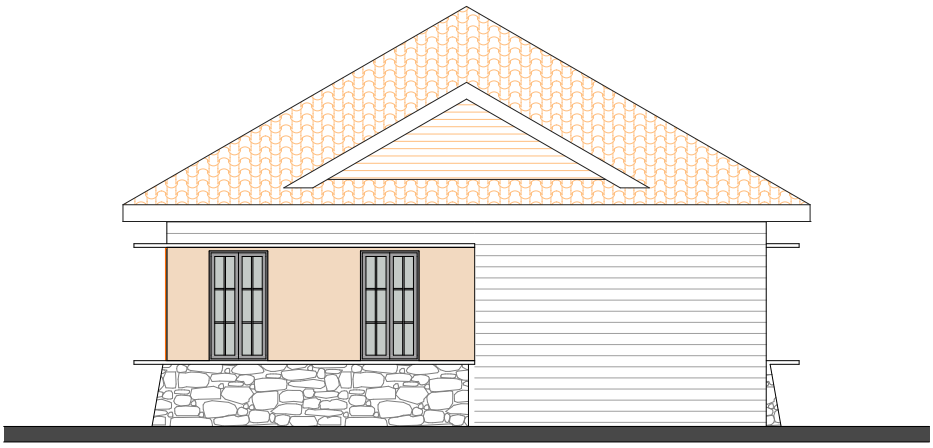
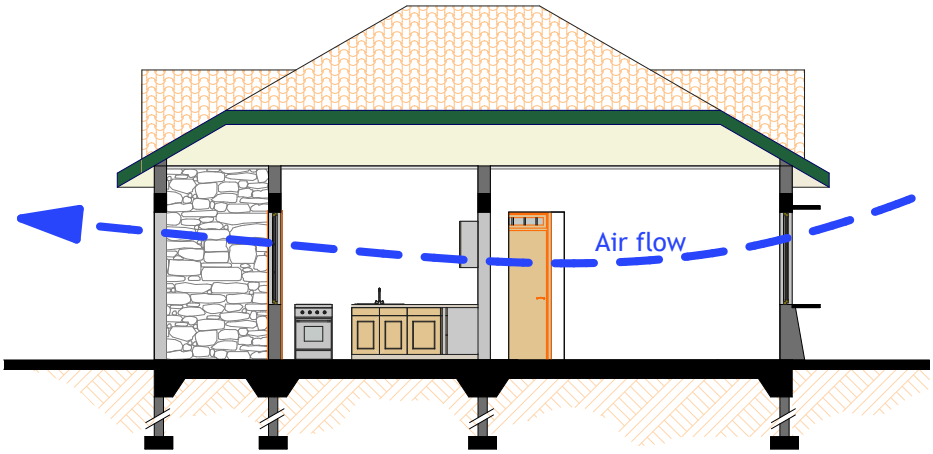


Figure 45: Section X-X



DESIGN RESPONSES

1 **Orientation** - This house is optimally oriented: the main openings are facing North-South direction, minimizing the exposure of the rooms to direct solar radiation. Ancillary spaces have been located on the west side of the house to act as a thermal barrier that protects the rest of the house.

2 **Ventilation** - Passive ventilation has been achieved through cross ventilation. All rooms have openings in two directions and vents located above windows and doors. Small top-hung openings have been used in habitable rooms for night ventilation. For main openings located on the north and south facing walls, a desirable area of between 15 and 25 per cent of the area of these walls should be openable for ventilation.

3 **Daylighting** - All windows in each room meet the minimum required area - 20 per cent of the elevation area - for good natural lighting.

4 **Sun shading** - Windows are minimized on the west elevation to avoid the strong afternoon sun. Roof overhang is used to shade the windows on the east elevation. Large roof (800 mm wide) overhangs are provided on all elevations to shade walls and openings from the strong midday sun.

5 **Building materials** - For the building envelope, natural stone is recommended for the walls, lightly coloured clay tiles for roofing while dark massive floors are preferred to retain heat during the day. These materials of high thermal mass are adequate for this type of climate where the difference of temperature between day and night is 14°C as they regulate the fluctuations in temperature.

CASE STUDY 5

CLIMATIC ZONE 5:
Lake region climate

Single dwelling housing

Climatic Zone 5: Lake region climate

Location	Kisumu, Kenya
Latitude	0°6'S
Longitude	34°45'E
Altitude	1149 m above sea level
Temperature	Min average temp 14°C; Max average temp 34°C
Annual Rainfall	Average 1740 - 1940 mm
Humidity	Average Humidity is 70%
Prevalent Wind Direction	South west and East prevailing winds

Figure 46: KISUMU (Hours of Sunshine / Temperature)

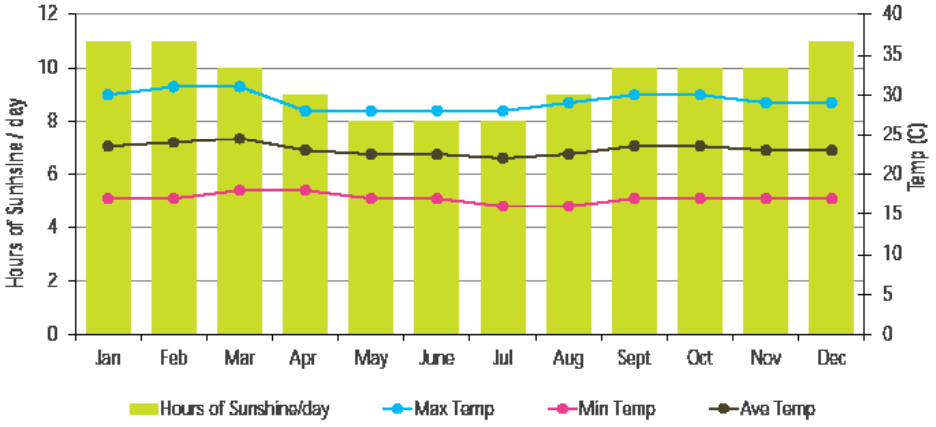


Figure 47: KISUMU (Relative Humidity / Rainfall)

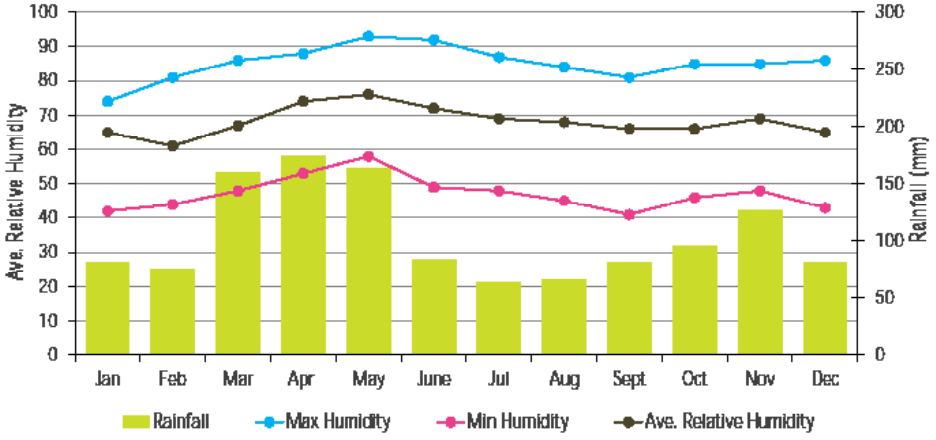


Figure 48: Prevailing wind direction

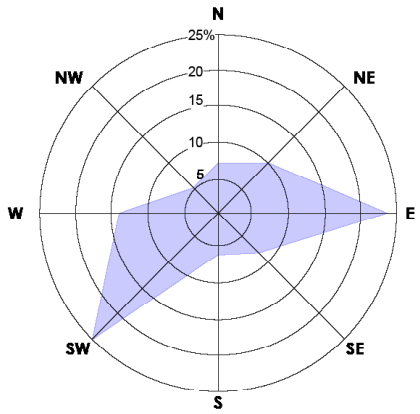


Figure 49: Sun path Diagram for Latitude 0° South

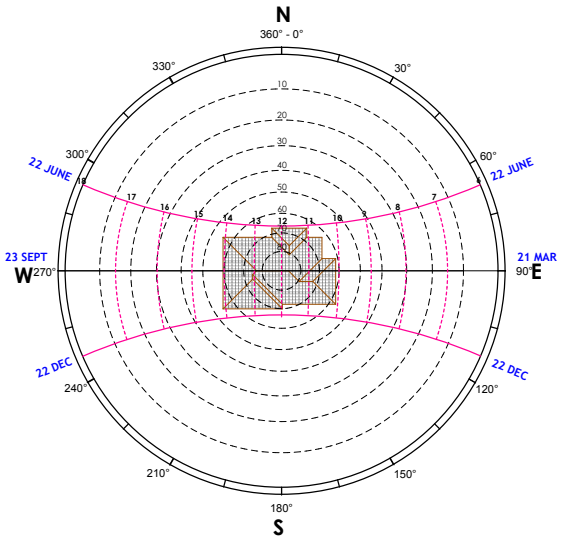
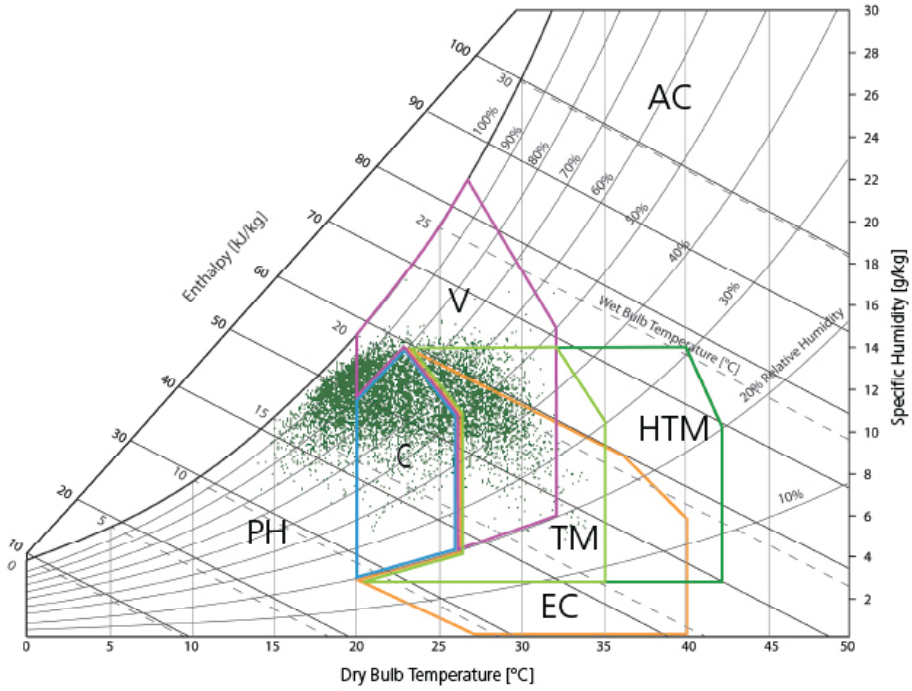
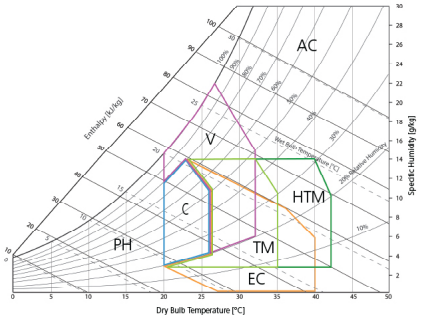


Figure 50: Bioclimatic Chart





LEGEND

C	Comfort Zone
V	Ventilation
TM	Thermal Mass
HTM	High Thermal Mass
EC	Evaporative Cooling
PH	Passive Heating
AH	Artificial Heating
AC	Air Conditioning

INTERPRETATION

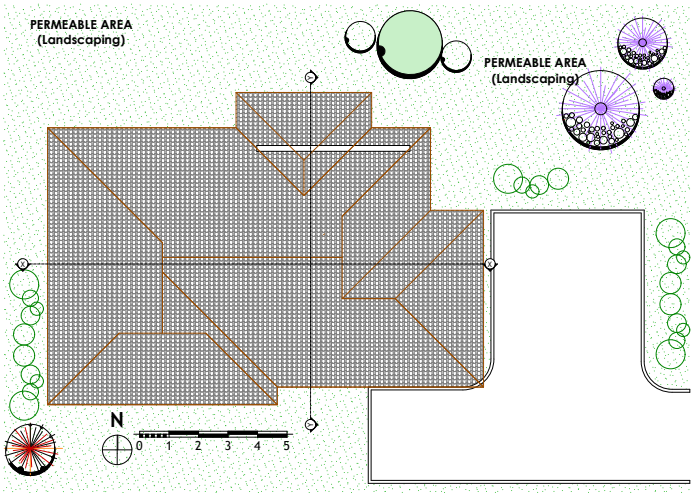
- This zone experiences high daytime temperatures and low nighttime temperatures for some periods of the year.
- Natural ventilation, passive heating and solar shading are the most effective strategies for improving thermal comfort.
- The most critical climatic requirements of buildings in this zone are the needs for cool indoor spaces during the high day temperatures and, warm interiors during the night. Mid-weight walls are therefore recommended to even out the indoor temperatures.
- Cross ventilation should be achieved in all habitable rooms by having well-placed openings in internal walls and by having permanent openings that admit air but not direct sunlight to interiors.
- Buildings should be oriented with the long axis running east-west to provide effective shading.

CLIMATIC ZONE 5:
Lake region climate

CASE STUDY 5

Single dwelling housing

Figure 51: Site plan



Use of permeable boundary wall to avoid obstruction of prevailing winds to enhance ventilation.

High trees provide shade and allow ventilation.

Figure 52: Ground floor plan

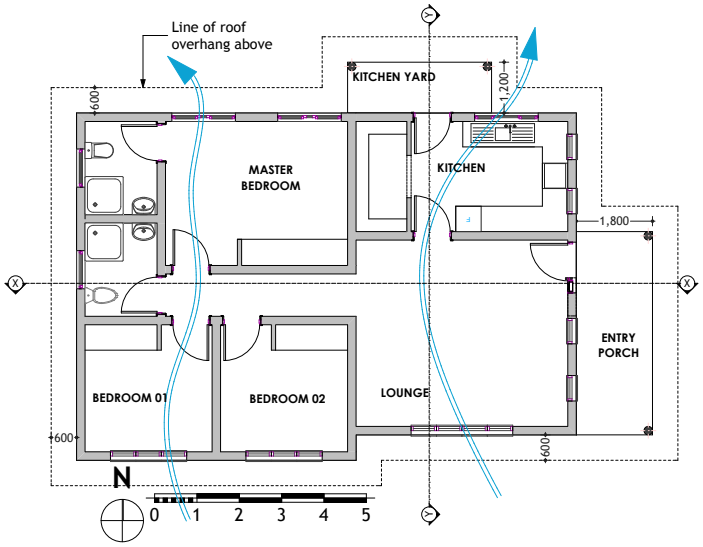
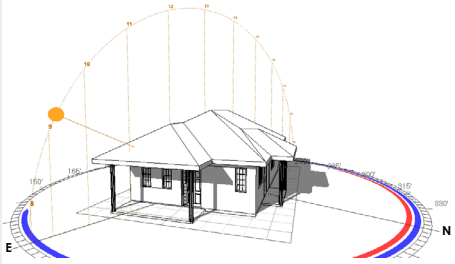


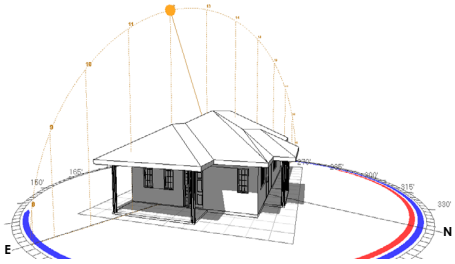
Figure 53: Position of the Sun at different times during the equinox

September 23rd at 9.00 a.m.



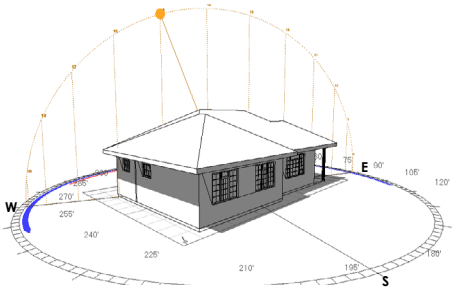
The verandah on this facade shades the openings minimizing exposure to the morning solar radiation.

September 23rd at 12.00 p.m.



The walls and openings are shades from the solar radiation at noon by the roof overhang.

September 23rd at 3.00 p.m.



Openings on the west and south facing facades have been shaded from the afternoon solar radiation by the roof overhang.

Figure 54: South Elevation

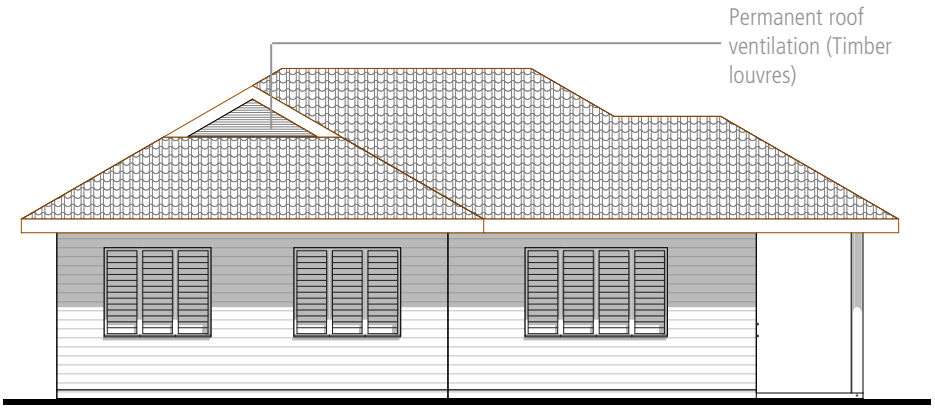


Figure 55: East Elevation

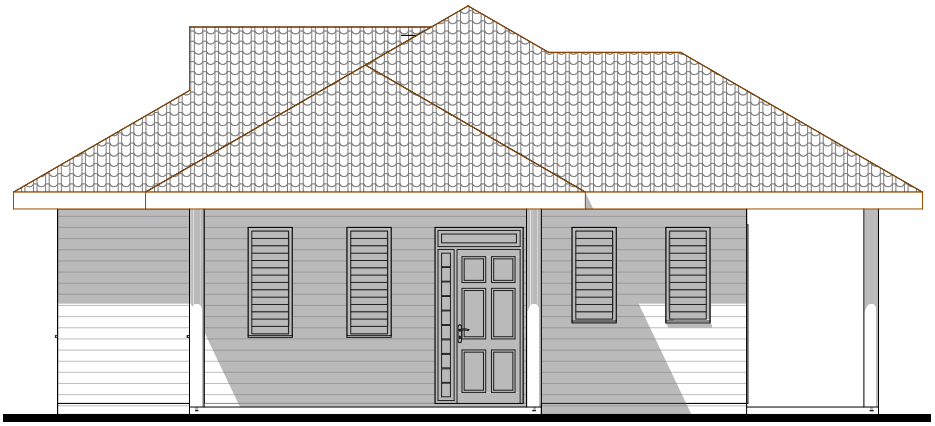
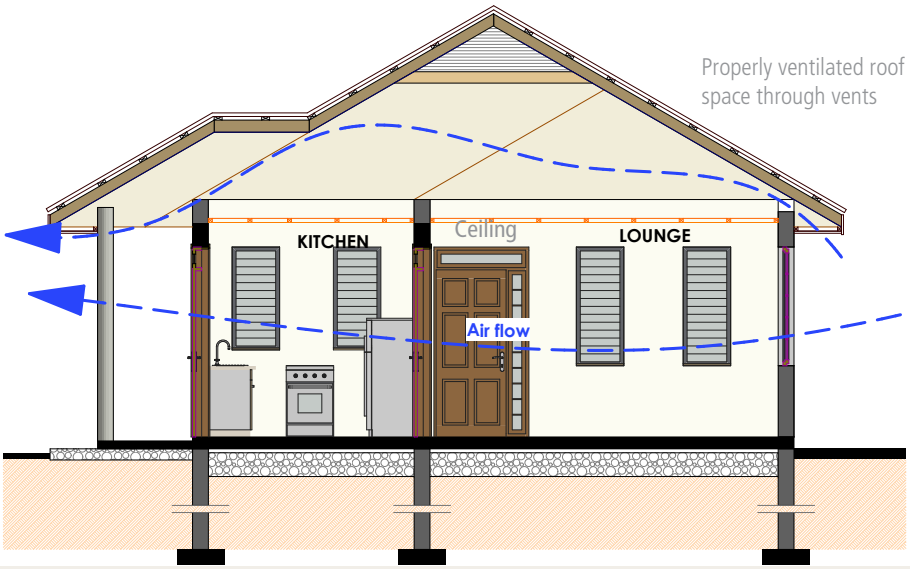


Figure 56: Section Y-Y showing cross ventilation



DESIGN RESPONSES

1 **Orientation** - The house is optimally oriented along the east-west axis in order to minimize the solar exposure of the structure and all major openings are located in north and south facing walls with rotation towards NE-SW to capture prevailing winds.

2 **Ventilation** - All rooms have been passively ventilated, taking advantage of the prevailing winds. A separate roof and ceiling is provided with the space in between ventilated to prevent the house interior from heating up. Openings at the roof have been put in place providing exits for the hot air as it rises as cool air enters through windows. The operable windows provide maximum ventilation and free air movement thus improving the indoor air quality. For this zone, adjustable louvres are appropriate as they regulate natural ventilation.

3 **Daylighting** - To enable natural daylight into the room, the glazed parts of the openings are not more than 20 per cent of the area of the elevation. This prevents unnecessary solar penetration to the interiors and subsequent overheating.

4 **Sun shading** - The roof overhang protects the walls and openings from unwanted solar radiation. The entry porch completely shades the openings on the eastern walls from the morning sun.

5 **Building materials** - For this type of climate, building materials with high thermal mass are recommended. Hollow blocks/cavity walls can be used for non-shaded elevations. Light coloured finishes are preferred to reflect solar radiation. Lightweight roofing materials with low thermal capacity and high reflectivity should be used for roofing.

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Simulation tool: SOLANGLES

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The project Promoting Energy Efficiency in Buildings in East Africa is an initiative of UN-Habitat in collaboration with the United Nations Environment Programme (UNEP), the Global Environment Facility (GEF) and the governments of Kenya, Tanzania, Uganda, Rwanda and Burundi.

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