Principles of Building Physics for Sustainable Design

Vernacular Design Report

Mari Taylor

CLIMATE CHANGE

The period between 1983-2012 has been recorded as having the highest temperature in the Northern Hemisphere in the last 1400 years. In the IPCC's 5th Assessment Report (Pachauri, Mayer, & Intergovernmental Panel on Climate Change, 2015), it was outlined that "human influence on the climate system is clear" and that greenhouses gases in the atmosphere are the "highest in history". The report specifies that climate change is having an enormous impact on human life as well as the ecological system and, due to the global increase in temperature, snow and ice amounts have "diminished", causing a large rise in sea level. Evidence suggests a significant rise in global temperature is inevitable, "increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems" (Pachauri, Mayer, & Intergovernmental Panel on Climate Change, 2015). Buildings have a huge impact in the emissions of greenhouse gases, making up 18.4% of the total direct and indirect transmissions globally (fig. 1). Therefore, it is imperative that a change is made to a more sustainable future in this sector.

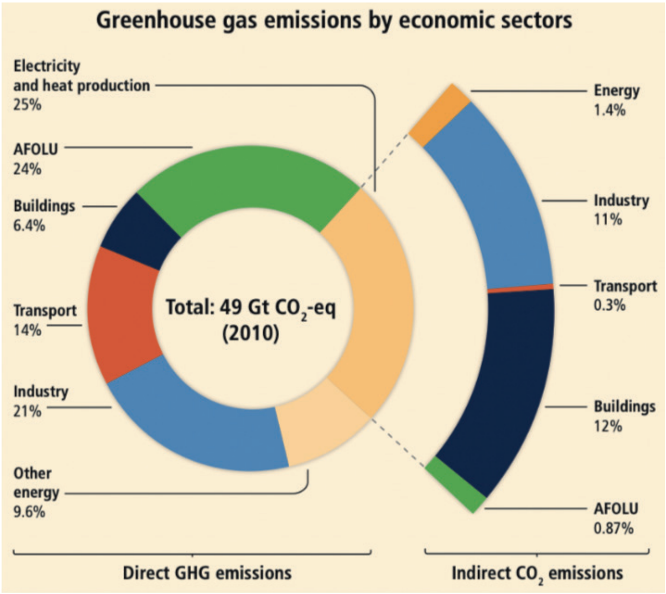


Figure 1: Global greenhouse gas emissions by economic sectors

Figure 2: Example of sumbanese vernacular architecture in Indonesia

VERNACULAR ARCHITECTURE

Vernacular" derives from the Etruscan language, meaning "domestic, native, indigenous" (The Oxford english dictionary., 2001). Vernacular architecture spans a vast array of preindustrial style architecture, distinguished by its simplicity and practicality (fig. 2). It makes use of traditional building methods, knowledge and local materials, and is largely influenced by culture, climate and the local environment (Caves, 2013). Vernacular style is raw, solving geographical and environmental difficulties expressed through primal human creativity without the use of contemporary, advanced technologies, and is typically constructed by non-professionals (Sayigh & Al-Sallal, 2014). It is important that we look back to the key principles of vernacular architecture as a sustainable guide for the future. Professor Manuel Guedes states that "the knowledge derived from vernacular architecture is at the core of true sustainable design" (Guedes & Cantuaria, 2019) and studies have shown that the use of this knowledge in contemporary design leads to more efficient, low carbon and better-performing buildings with optimised thermal comfort for occupants (Sayigh, 2019). Effectively, by utilising and understanding these principles, GHG emissions driven by the building sector in contemporary design can be reduced. Pelsmakers expresses that, due to buildings typically having a lifespan of 60 years, "we should design for the climate change predicted in that period" (Pelsmakers, 2019). Understanding how vernacular architecture stands up against a changing climate, could reveal potential mitigation and adaptation strategies, new ideas and progress in the field of sustainable design.

INTRODUCTION

In this report, the potential that the vernacular approach has for being successful in the contemporary environment of the climatic region of New Orleans, Louisiana, will be strategised. The aim and objective of this study will be to understand the principles of the vernacular architecture of New Orleans and analyse the success of these principles in a contemporary environment. These key principles will be used to conceptualise and analyse a contemporary residential dwelling within its climatic context. It will aim to draw conclusions from the findings that critically evaluate the use of climate-specific vernacular principles to create contemporary sustainable design.

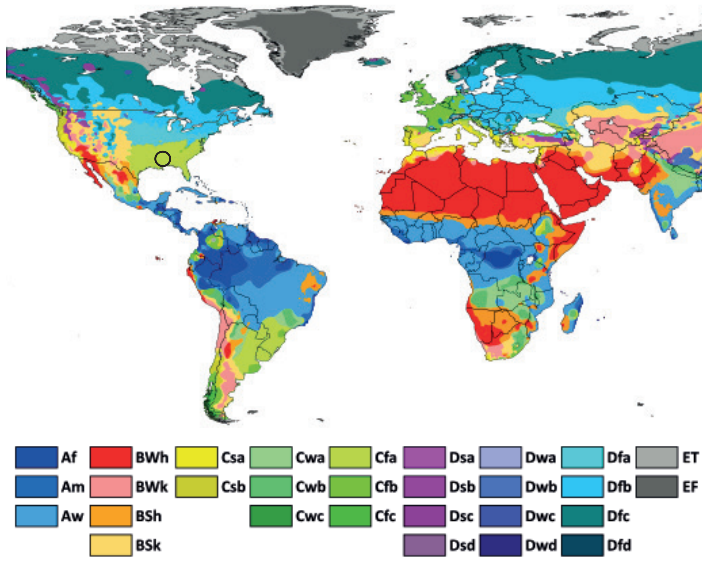

Figure 3: Map of New Orleans

NEW ORLEANS

The selected case study region I have chosen to synthesise in my vernacular design report is the region of New Orleans, Louisiana. This region sits in a humid subtropical climate and is classified as **Cfa** using the Köppen-Geiger climate classification system and it has distinct climatic seasons (Kottek et al., 2006).

The city is positioned in the Mississippi River Delta, south of Lake Pontchartrain and around 105 miles upriver from the Gulf of Mexico. The city's area is 350 square miles, of which 48% is land and 52% is water (City Population, 2020).

Figure 4: Map of the Köppen-Geiger climate classification system



ELEVATION & TOPOGRAPHY

Average city elevation (fig. 5): 0.30-0.61m below sea level (Campanella, 2007).

The city was originally built on the river's natural levees or high ground. 50% of the city is at or below local mean sea level and 50% is slightly above sea level. Evidence indicates that areas of New Orleans' elevation may be sinking lower due to subsidence (Greicius, 2016).

In figure 6, it is clear that with the combination of subsidence sinking the elevation of the city and the current low elevation, that the city is in great danger and at high risk of flooding, in the present and future. This meaning that even with the man-made flood walls and levees built to protect the city, flooding should be a high priority in the design of buildings.

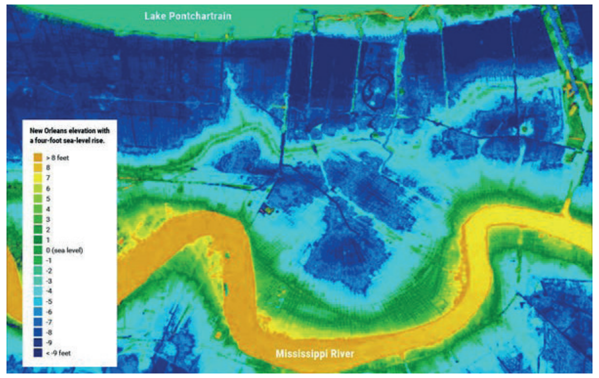


Figure 5: New Orleans elevation with a 4 foot sea level rise (elevation of Mississippi River and Lake Pontchartrain).

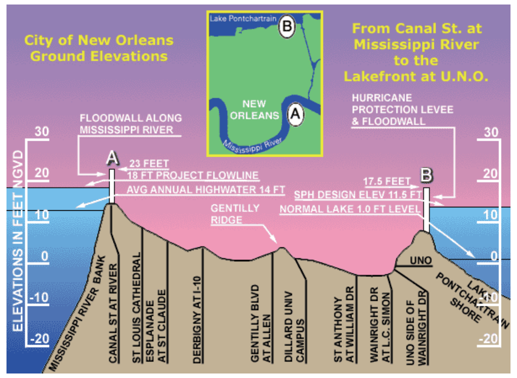


Figure 6: City of New Orleans ground elevation and from floodwall to floodwall.

TROPICAL STORMS

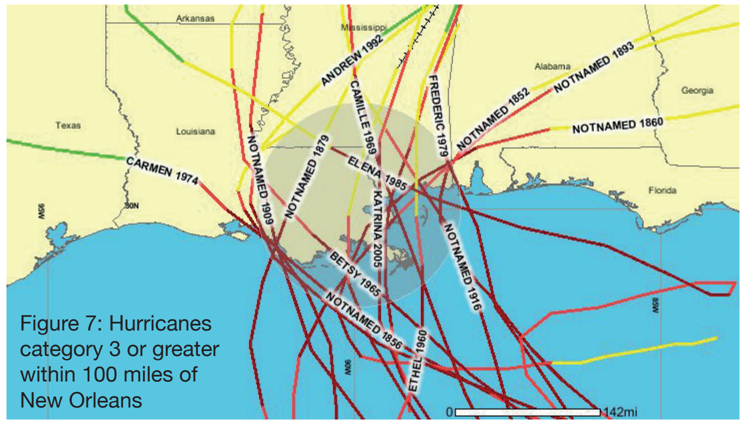


Figure 7: Hurricanes category 3 or greater within 100 miles of New Orleans

New Orleans is surrounded by water from the north, south and east (Tidwell, 2006), making it North America's most vulnerable city to hurricanes according to the Federal Emergency Management Agency (Federal Emergency Management Agency, 2020) and also at risk to severe flooding. The risks of hurricanes are dramatically greater at present due to coastal erosion from human interference (Barry, 2013). Figure 7 shows the hurricanes of Category 3 or greater passing within 100 miles between 1852–2005. In 2020, there were 30 tropical storms that hit Louisiana (breaking records of previous years), 4 of which were hurricanes of category 3 and above (NOLA, 2020).

TEMPERATURE

Figure 10

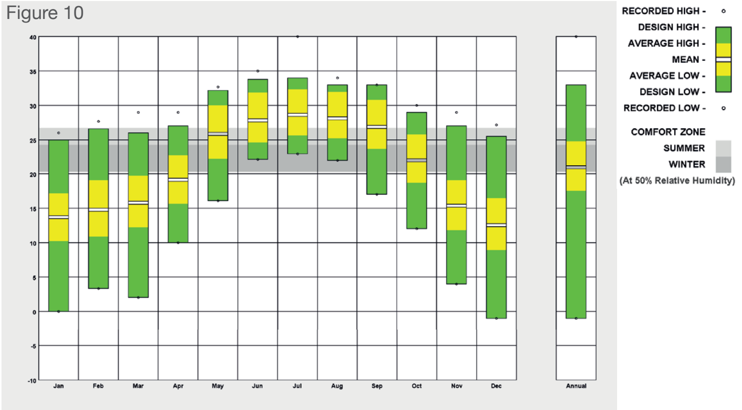


Figure 10: The mean dry bulb temperature of New Orleans is roughly 21°C. The average temperature in this climate zone annually will reach highs of 34°C in July and and lows of -1°C in December. It is clear that the temperatures in the summer are extreme, even reaching as high 40°C some days and will not drop much below 25°C. In the months of winter, temperatures can still reach 25°C, but are also likely to drop to -1°C some days. The chart also tells us that the comfort zone at 50% relative humidity is between 20-25°C in winter and 24-26°C in summer.

Figure 11

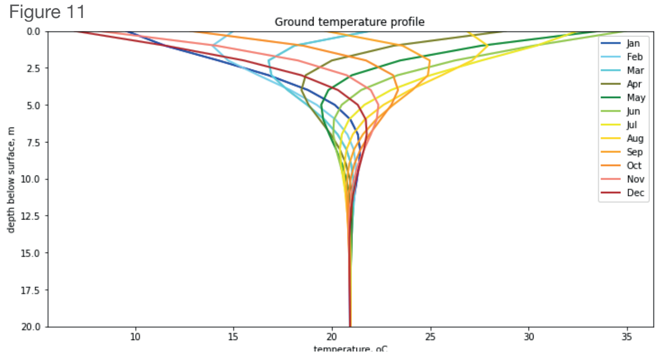


Figure 11 shows that the ground temperature all year round below 12.5m sustains about 21°C. Surface ground temperature ranges from 35°C in June down to 5°C in December.

Figure 8: Hurricane season 2020

Each year, hurricane season lasts from June 1st to November 30th. Dangers from these storms include high winds, heavy rain, tornadoes, flooding, and power outages. Depending on a storm's severity, the City of New Orleans might issue a mandatory evacuation order (Wells, 2020).

RAINFALL

Precipitation in this climate zone is high at an average of 150mm annually as seen below in figure 9. The wettest months are June, July and August. The high precipitation along with frequent tropical storms and a significantly low elevation make the city extremely vulnerable to flooding and major damage as a result of this.

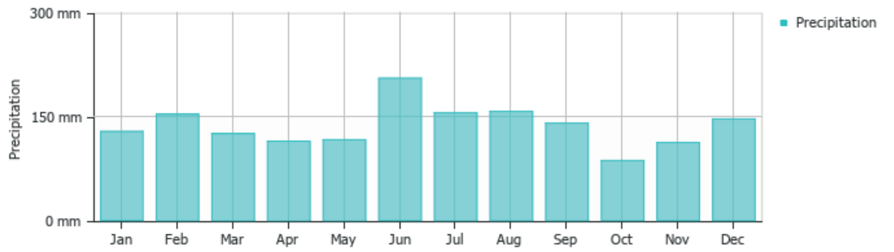


Figure 9: Average precipitation (rain/snow) in New Orleans

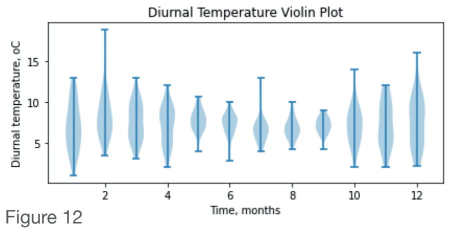


Figure 12

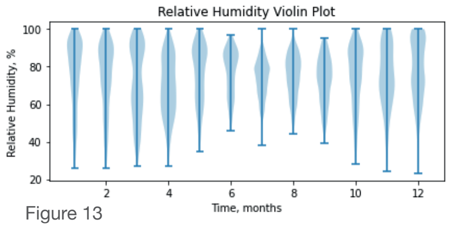


Figure 13

Figure 13: Relative humidity can be recorded at 25% at its lowest value in December, but also reaches highs of 100% most months. Figure 12: The diurnal temperature can give us an indication of the potential for using night-time ventilation to cool internal temperatures. The most extreme temperature differences are in the winter months of December, January and February. However, the data shows that the potential for night-time cooling is very high in the summer months.

RELATIVE HUMIDITY

Relative humidity is very high in this climate zone. It remains between 60-90% all year round, reaching highest in May and June as seen in figure 15.

Figure 14

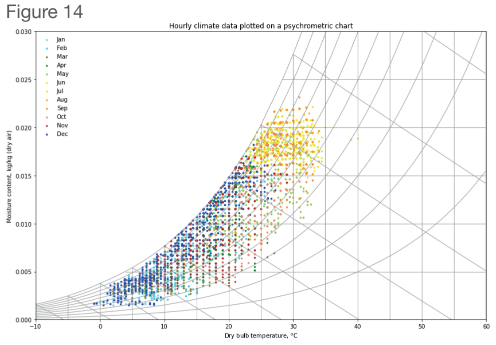
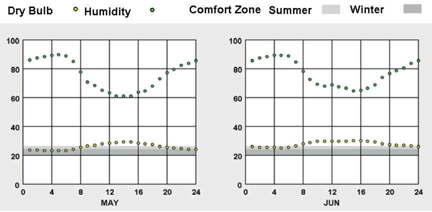


Figure 14: The psychometric chart shows that the relative humidity stays fairly constant all year round, between 60-90%. Relative humidity tends to accumulate higher between dry bulb temperatures of 10-25°C. The temperature differences between seasons and months are also clear.

Figure 15



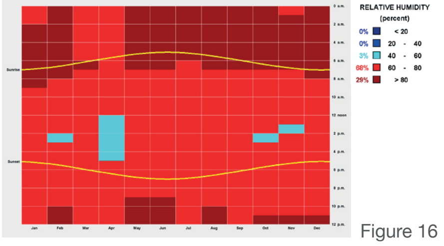
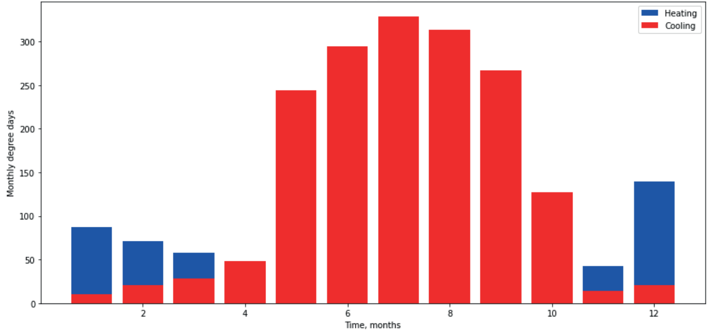


Figure 16

Figure 16: This chart indicates that for 68% of the time the relative humidity level is between 60-80% (mostly during the daytime) and that for 29% of the time, relative humidity level is above 80% (mostly during the night-time).

Figure 17



COOLING DEGREE DAYS

Figure 17: It can be concluded from this diagram that there is a huge demand for cooling for the majority of the year as if the balance point temperature was 15.5°C to achieve thermal comfort indoors. There are much fewer periods of the year in which require demand for heating. Peak demand for cooling is in July at about 325 monthly degree days and peak demand for heating in December with 140 monthly degree days.

SUN PATH

Figure 18

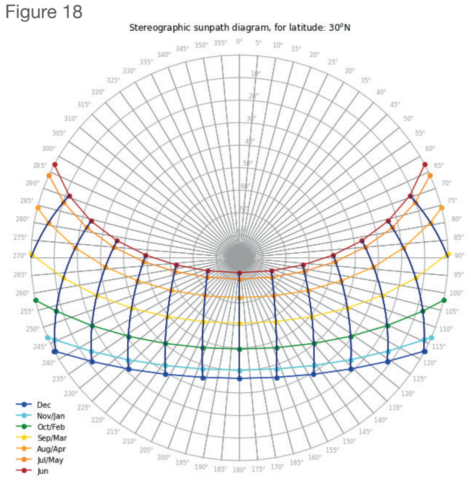
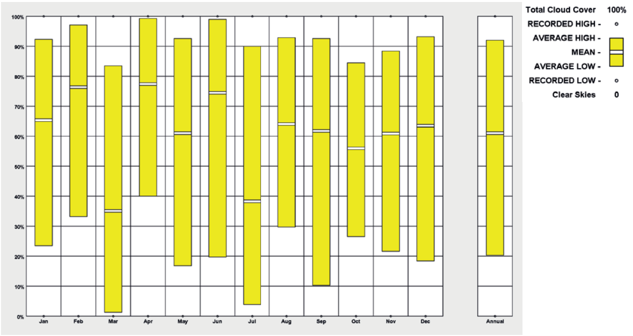


Figure 18: The sun path diagram shows that at the horizon, sunrise occurs in the east at around 7am in December and around 5am in July. Sunset occurs close to 5pm in the winter and and at 7pm in the summer. Solar altitude at noon all year round is not so extreme, exists around 145° in December and 95° in July. This being because the region is situated close to the equator at a latitude of 30° North.

SKY COVER

Figure 19



New Orleans is, for the most part, cloudy with an average of 60% sky cover. Therefore, simulations of daylight factor will be undertaken to achieve 'worst case scenario' results.

ILLUMINATION

Figure 20

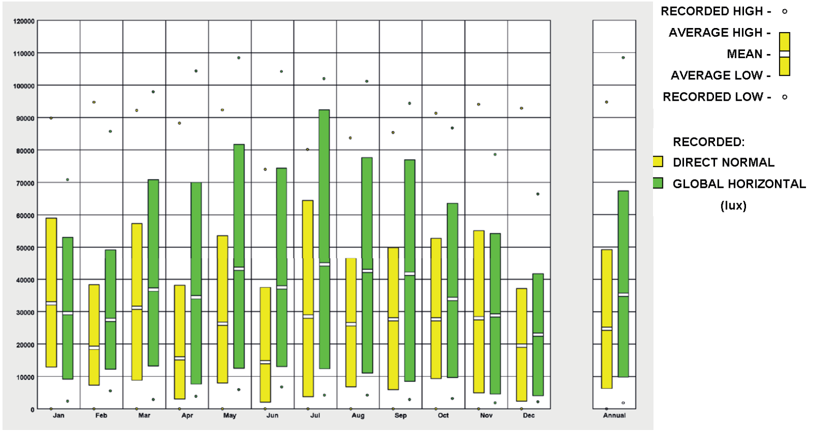


Figure 20: Illumination range is relatively high all year round, with direct normal averaging 2500 lux and the global horizontal averaging 3500 lux. In summer, illumination is higher than winter.

SOLAR RADIATION

Figure 23

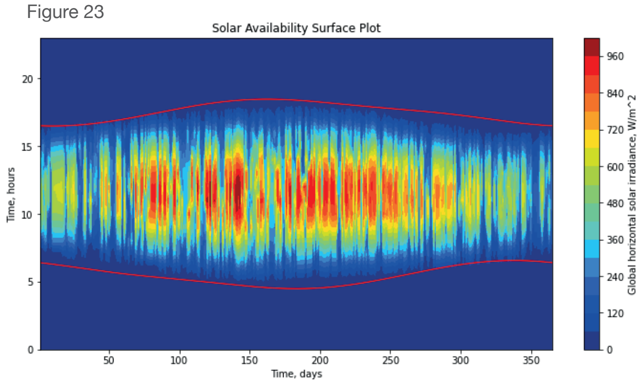


Figure 23 shows that the availability of a global horizontal solar irradiance between 840-960W/m² from 10am to 3pm, does not change drastically between seasons and only decreases to between 600-720W/m² in the winter months. Therefore, the availability of global horizontal solar irradiance

Figure 24

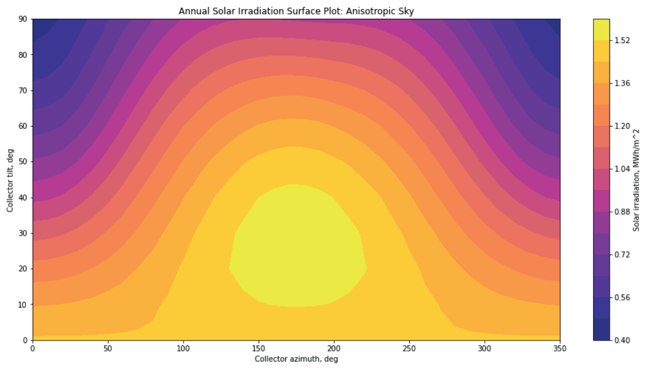


Figure 24 shows the amount of solar irradiation on a surface of a solar collector. It tells us the most appropriate angle for this. The graph shows that a south facing solar collector with a tilt of 25° would optimise the solar irradiation to the surface. This is particularly important with regards to orientation and placement of solar PV panels.

SUN SHADING

Figure 21

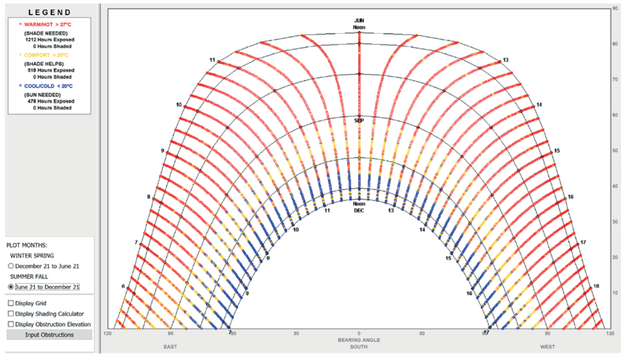


Figure 22

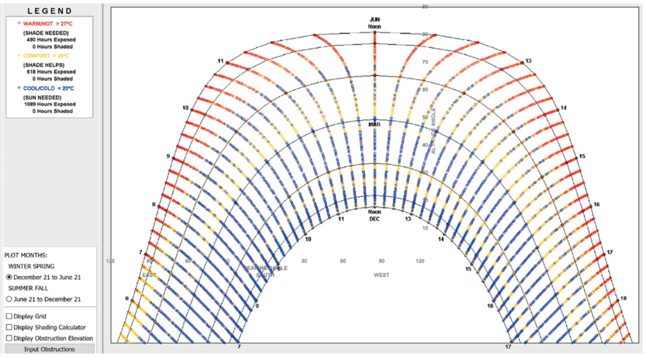


Figure 21 shows that, in the months of June to December, shading is needed and that there is 1212 hours of exposure to temperatures above 27°C and 518 hours of shade would be useful due to temperatures at 20-27°C. Similarly, figure 22 shows that in the months of December to June, shading is needed and that there is 490 hours of exposure to temperatures above 27°C and 618 hours of shade would be useful due to temperatures at 20-27°C.

WIND ANALYSIS

Wind velocity stays fairly constant all year round averaging 4.5m/s as shown in fig 25 (right). However, it is important to note that highs of 26m/s are reached in some cases due to a high frequency of tropical storms and hurricanes hitting the region. For example, there were 4 different occasions in 2020 (Wells, 2020).

Figure 25

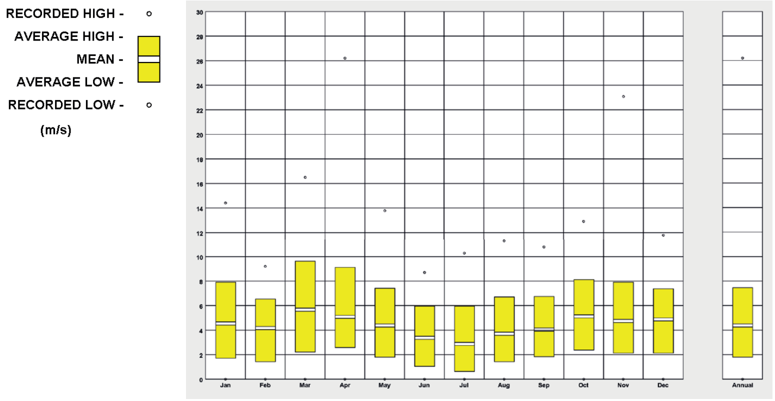


Figure 26

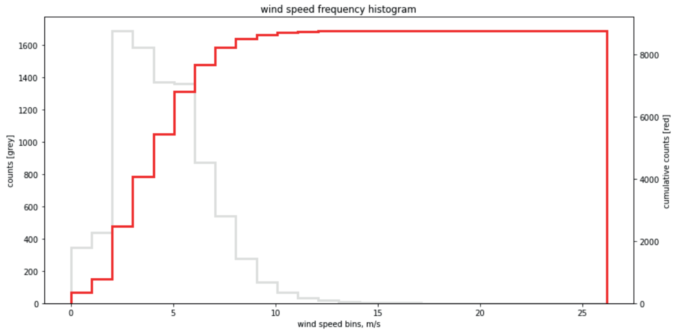


Figure 26: The histogram shows the annual wind speed frequency of the region. The wind is most commonly at speeds of 3m/s for 1700 hours. Cumulatively the wind speed of 3m/s is around 2000 hours, so fairly low.

Figure 27

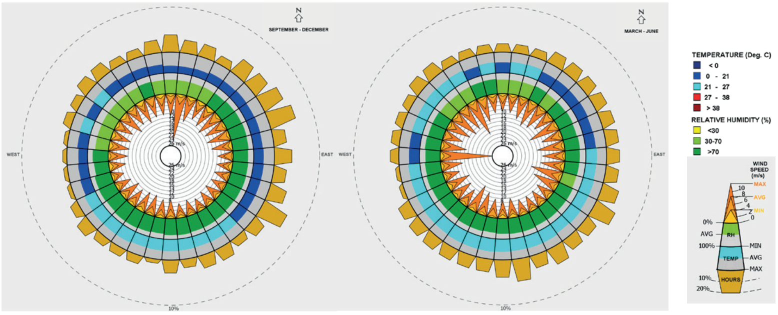


Figure 27: From the wind wheel diagrams show that the wind direction in New Orleans is, predominantly, from the south and east due its vicinity with the ocean. Wind stays fairly low all year round, however may sometimes spike to between 20-26m/s in the spring and autumn. The wind roses are also a clear depiction of high, stable humidity levels and temperature changes between the seasons.

CLIMATE ANALYSIS SUMMARY

To summarise the analysis, it is clear that the main issues regarding climate and weather are as follows:

- The **elevation** sitting at an average of 0.30-0.61m below sea level meaning high risk of severe flooding at present and in the future.
- **Subsidence** will cause the ground level to drop in the future, meaning flooding and irreversible affects on the city as a result of this.
- **High winds** from the south and east are not extremely frequent but will occur during **hurricane season** (June-November), this will cause damage to infrastructure.
- **Rainfall** and **relative humidity** is very high meaning that attention to moisture control is needed and ensuring protection of the building envelope is necessary through design.
- There are distinct seasons in regards to temperature. The summers are **extremely hot** and there is a high demand for shading, cooling and night-time cooling in these months in particular. **Solar irradiation** is also extreme in these months. Ensuring that thermal comfort is reached indoors will be necessary through design, all year round.
- New Orleans is not short of daylight and this remains fairly constant, receiving a large amount of illuminance annually. Therefore, glare control will need to be addressed through design.

The sunset and sunrise do not differ hugely between seasons due to its close latitudinal vicinity with the equator. However, it is clear that this is **a climate of extremes**, and it is very important to explore the strategies and principles used in the vernacular architecture, here, to depict the design principles that can efficiently manage these extremes.

PRINCIPLES OF CREOLE VERNACULAR ARCHITECTURE: THE SHOTGUN HOUSE

Time	1830s-1950s
Storeys	1
Massing	long, narrow and low structure
Layout	**single** shotgun = 1 room wide and 3 to 5 rooms deep, **double** shotgun = 2 rooms wide and 3 to 5 rooms deep, both with each room opening onto the next, no interior hallway and high ceilings
Roof	front gabled or hipped with a deep overhang or porch
Windows and doors	large and tall, double hung, usually shuttered
Facade	symmetrical, consists of a door and window, a porch or deep overhang is featured, the house is usually raised two to three feet (60 to 90 cm) off the ground
Construction materials	wood exterior, built on brick piers, single, uninsulated walls
Other elements	extremely popular among both the middle and working classes, inexpensive, other variations include - shotgun doubles, camelback shotguns, side-hall shotguns and side-gallery shotguns
History	the term “shotgun” originates from the idea that when standing in the front of the house, you can shoot a bullet clear through every room in the house

CAMELBACK SHOTGUN

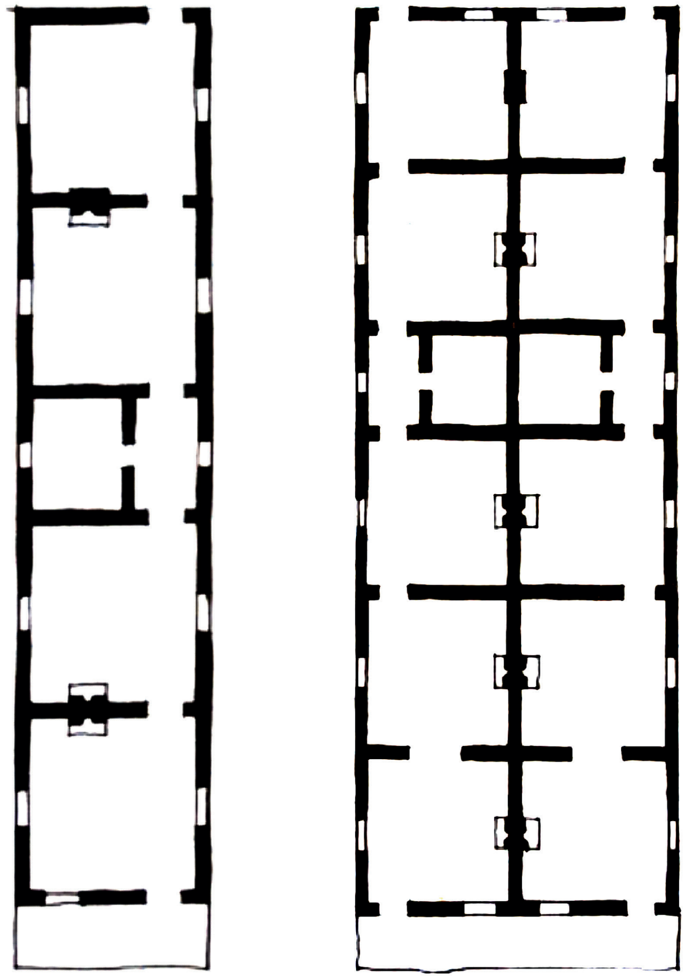
Essentially a shotgun single or a shotgun double, with a second story rising at the rear portion of the building

SIDE GALLERY SHOTGUN

Facade	usually are 3 bays wide with two windows and a front door
Layout	1 room wide and 3 to 6 rooms deep, include a passageway that runs most of the length of the house, there is a narrow covered side porch

Information from Hawkins & Barrier (2011); Architectural Patterns (nd). See reference list.

Figure 28: basic floor plan of a single (left) and double (right) shotgun house



LACK OF HALLWAYS, PLACEMENT OF WINDOWS AND LAYOUT

Aiding air circulation with cross ventilation in every room.

INTERNAL CENTRAL LOCATION OF CHIMNEYS

Allows the front and middle rooms to share a chimney with a fireplace opening in each room. The kitchen usually has its own chimney. Allows for even heat to distribute to the whole house.

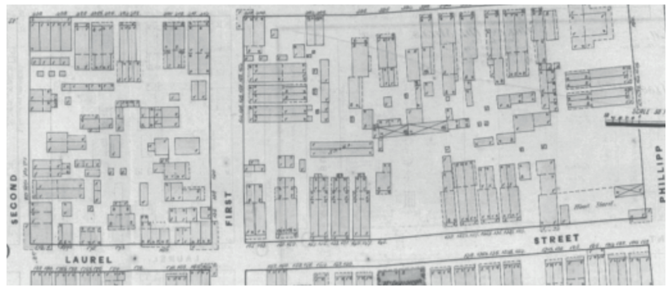
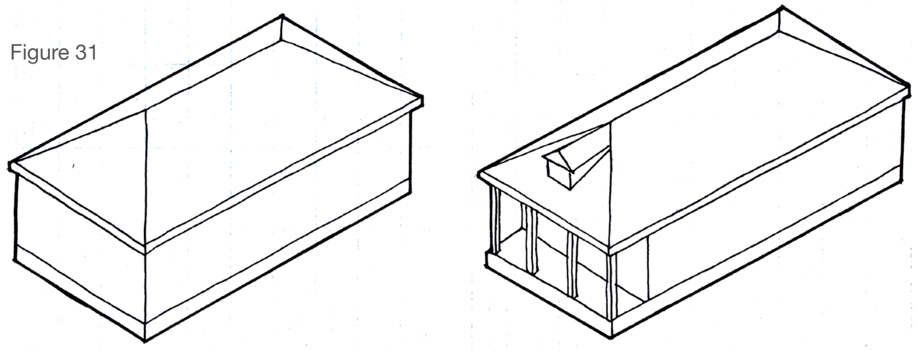


Figure 30: shotguns and camelbacks crowding the squares of the Irish Channel. 1876 Sanborn map

Figure 31



MASSING

Designed to fit to the small spaces available for residential housing, allows for multiple to be built side-by-side in a formulaic/modular way, dictated by the long, thin plots laid out by the city’s French (and later Spanish) surveyors

A form that could be more easily expanded to any desired length within the confines of the restrcitive geometric units of the french urban lots.

Allowed them to be built without the use of heavy framing, specially fitted roof trusses and ceiling joists didn’t have to support a second storey.

BOX-LIKE SHAPE

This places equal stress on the four corners and prevents leaning or sagging.

LOW PROFILE

This prevents destruction from the high winds and tornadoes common in New Orleans

Figure 32

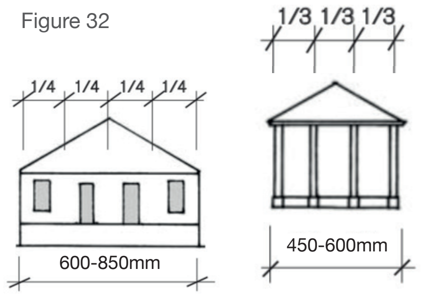
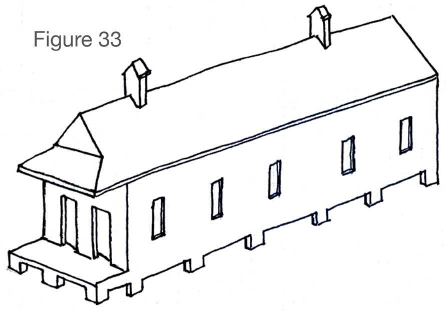


Figure 33



HIGH CEILINGS

Circulating air wards off mold, humidity and heat

Figure 34: shutter over door and window in a shotgun

LARGE AND TALL WINDOWS

They are often built to the floor - which makes use of the availability to natural daylight and aid air circulation.

SHUTTERS

Appear on windows and french doors - for shading during the day and also protection from weather.

Figure 35: wide dormer windows in a shotgun

GABLE DORMERS

added to introduce light into half-story and attic spaces

Information on pages 4-5 retrieved from archi-dinamica architects llc (2011); Caemmerer (2008); New Orleans 24/7 since 1718 (nd); Starr (2005); Toledano (2010); Vogt (1985); Wilson et al. (1971). See reference list.

Figure 29: gallery of shotgun homes, with some contemporary examples

Figure 36: shotgun with overhang and porch

LARGE OVERHANGS AND PORCHES

These protect the building from precipitation and wind, also to provide an area of shade for cooling, also an outdoor living space They also provide semi-public social gathering spaces for community interactions and safety with more “eyes on the street”.

Figure 37: shotgun with ground raised on stone piers

GROUND LEVEL RAISED

This provides protection from flooding and allows humid air flow to pass through, this air circulation also discourages termites and rodents, allowed houses to stand securely on the city’s alluvial soil, and to survive in the region’s notoriously humid climate, with its insects, termites and mold.

CONSTRUCTION OF RAISED FLOOR

Water-absorbing brick-between-post construction/brick masonry is sometimes used that could be raised above ground on brick or stone piers - allowed houses to stand securely on the city’s alluvial soil, and to survive in the region’s notoriously humid climate, with its insects, termites and mold.

SINGLE, UNINSULATED WALLS

Providing no dead air space for trapped moisture that would deteriorate the wood.

LOCAL CYPRESS AND CEDAR WOOD

Local source meaning a lower embodied carbon and these woods are extremely water proof materials.

NO FRAMING WALLS

One layer of bead board supports another. The boards run horizontal on exterior walls and vertical on interior ones

LIGHT COLOURED PAINT FINISH

horizontal bead boards were typically painted light colours to reflect sunlight

Figure 29

Figure 38 & 39: wooden exterior and construction

STEEP PITCH GABLE/HIPPED ROOF

Allows for higher ceilings, aids in air circulation and also in rain-water management

Figure 40: a single shotgun with symmetrical facade, porch and gable roof

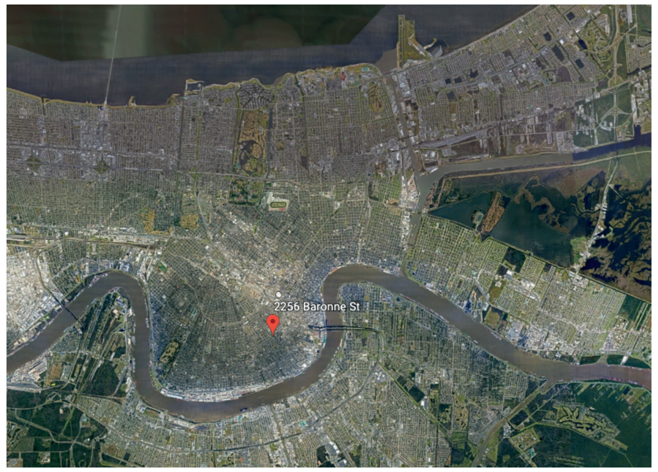


Figure 41: Google maps view of 2256 Baronne Street

SITE

The site that will be used for conceptual simulation of a contemporary dwelling in New Orleans is located on 2256 Baronne St New Orleans, LA 70113 USA.
Latitude: 29.935456741737045, Longitude: -90.08346890244735
The area is situated between the Garden District, Central City and Faubourg Lafayette, just north of the Mississippi River. Surrounding the site are a high frequency of shotgun and creole vernacular style housing. The majority are long, narrow and low in massing. The lot is empty, and sits at the corner where Baronne Street meets Phillip Street.
This area has been chosen due to its low elevation at 1 metre above sea level and is surrounded by similar residential dwellings.

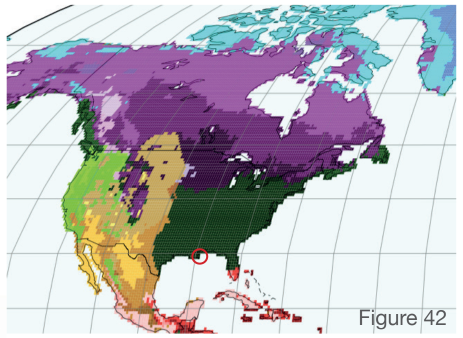


Figure 42

Figure 42: According to the World Map of Köppen-Geiger climate classification projected with Tyndall temperature and precipitation data for the period 2076-2100, New Orleans will remain in the same humid subtropical climate classification of **Cfa** (Rubel & Kottek, 2010).

NEW ORLEANS: FUTURE CLIMATE PREDICTIONS

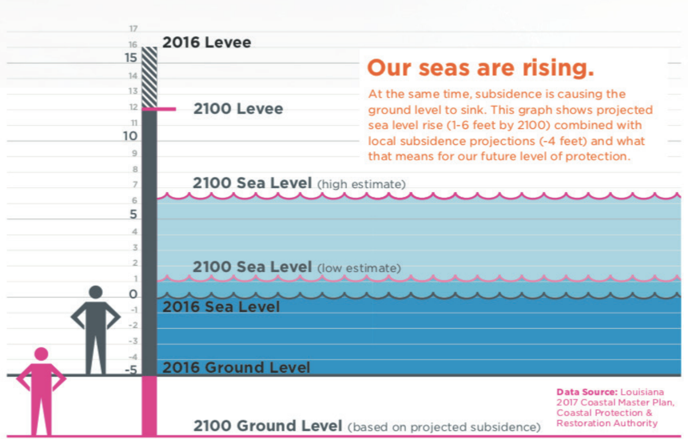


Figure 43: **Sea level rise** - The graph shows the ground level, sea level and levee level in 2016. By 2100 the projected sea level rise will be between 1-6 feet (30-180cm), taking into account subsidence (Hebert & Landrieu, 2017).

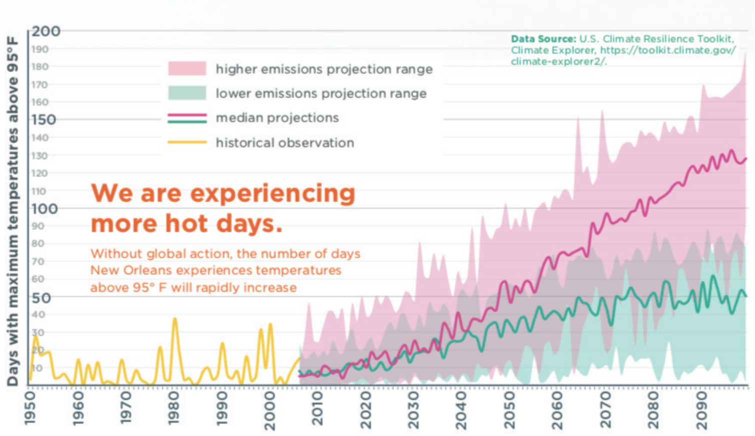


Figure 44: **Heat stress** - This is the expected temperature rise in New Orleans to 2100. It is predicted that the number of days temperatures exceed 35°C (95°F) could quintuple to more than 80 days per year (Hebert & Landrieu, 2017).

OTHER CLIMATE PREDICTIONS INCLUDE:

- **Coastal land loss:** More than 1,800 additional square miles (4,600 sq km) could disappear by 2060 if the Louisiana Coastal Master Plan is not implemented in full.
- **Land subsidence:** a result of low groundwater levels maintained during dry times. As the ground sinks, pipes are breaking, utility poles are becoming less stable, streets and sidewalks are buckling, and the foundations of homes and businesses are becoming structurally compromised, all while increasing regular flood risk in low-lying neighborhoods.
- **Intense weather:** Greater intensity in storm events, including hurricanes and severe storms, that can cause flood and wind damage. Flooding due to intense rainfall. Waterlogged soils due to etreme flooding (Hebert & Landrieu, 2017).

CONTEMPORARY DESIGN: TROPICAL STORM RESILIENCE

Figure 45

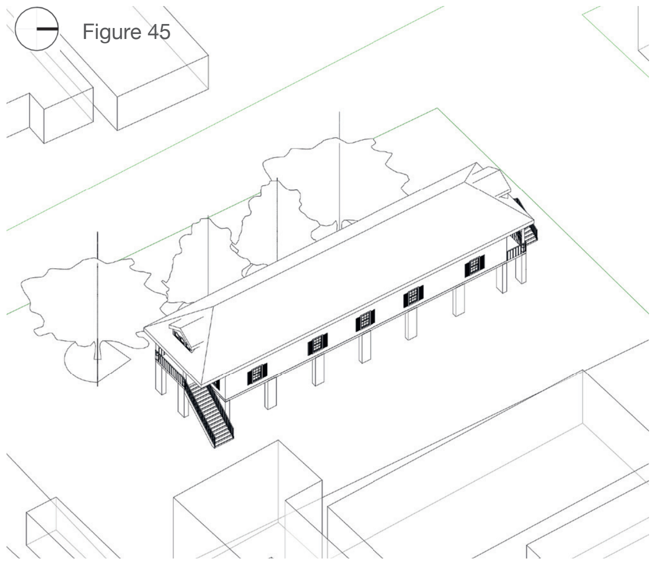


Figure 46

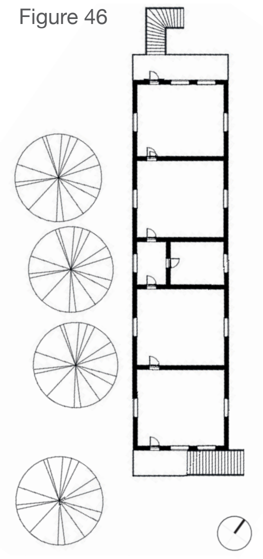


Figure 46 shows the layout in plan view of the 1 storey, narrow and long massed residential dwelling. The isometric view in figure 45 shows a 3D projection of the dwelling in which has been design according to the bioclimatic response and principles of the vernacular architecture of a shotgun house.

Figure 47

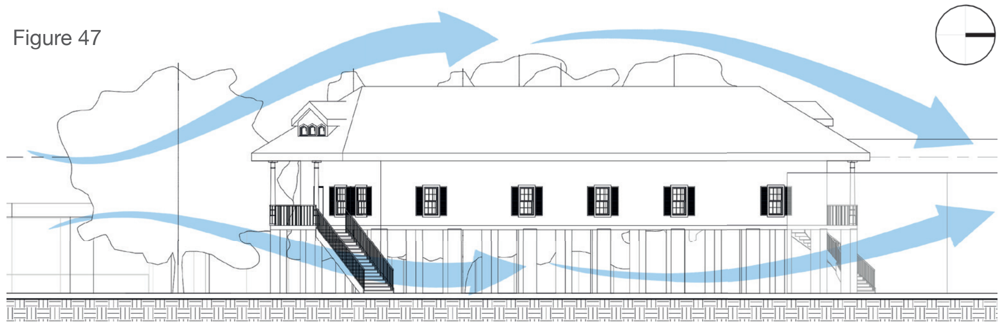
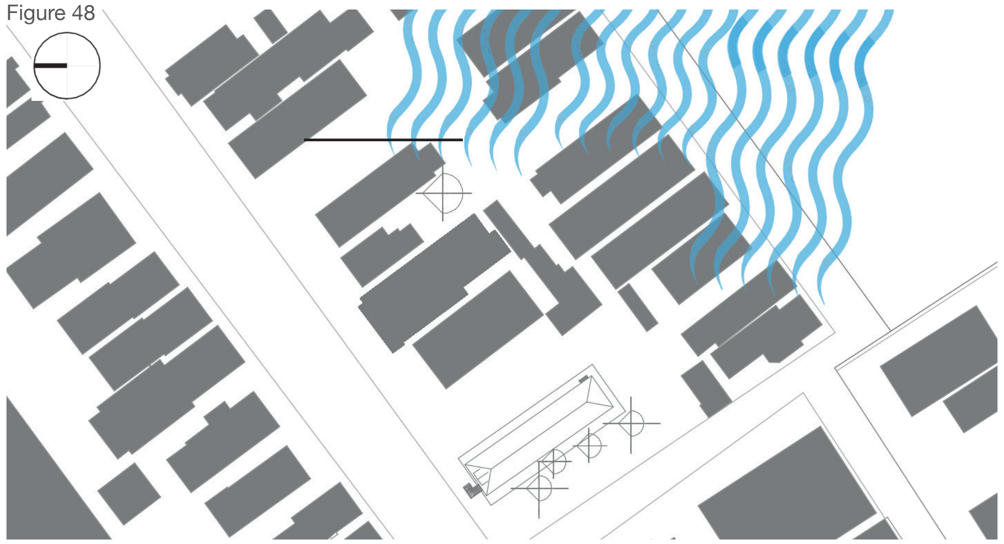


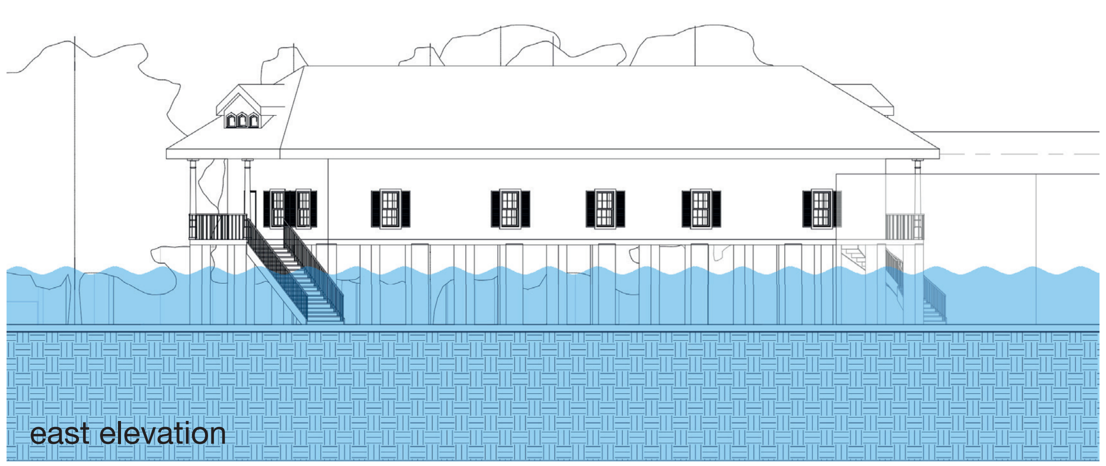
Figure 47 shows the way in which the dwelling allows free movement of wind to pass over and under the dwelling when they occur during hurrican season (Daemei, Eghbali, & Khotbehsara, 2019).

Figure 48



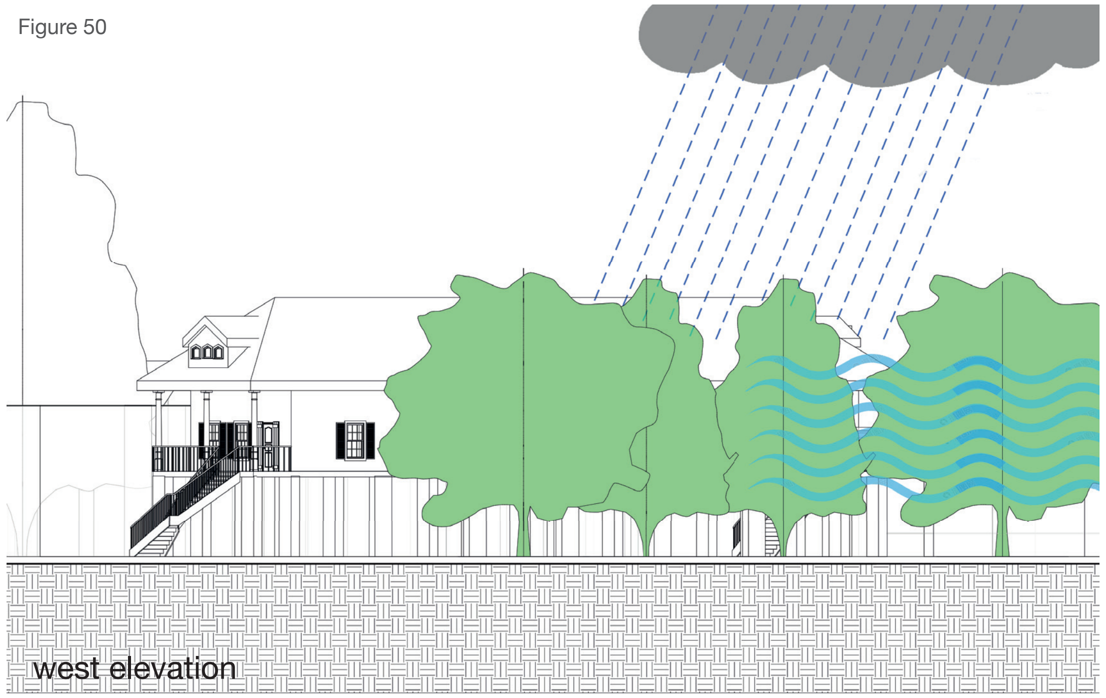
The hurricanes and winds will typically occur from the south-east direction, the surrounding masses provide a small amount of protection from the direction of storms in this particular site and the rectangular form of the building means that equal stress is placed on all corners of the building's mass.

Figure 49



The ground floor has been raised in this design to the height of 3 metres off the ground. This may seem excessive, however, due to frequent flooding, tropical storms, sea level expected to rise 180cm and subsidence causing the grounds elevation to drop, it is a necessary height to ensure a sustainable and long lasting building (Hebert & Landrieu, 2017). It is also raised to obtain better exposure to breeze which will cool the building and provide protection from insects and small animals. The raised floor also allows for pemeability, and therefore allows more efficient ventilation through the whole building envelope (Coch, 1998). The construction of these piers should be concrete or masonry to ensure structure integrity and supported via pile foundations (Federal Emergency Management Agency, 2012).

Figure 50



Specific plantation and tree placement is key not just for shading purposes. It also provides protection to the building from southern winds (from the direction of the ocean), and also protection from heavy rainfall (Daemei, Eghbali, & Khotbehsara, 2019). Due to the hurricane season being June to November, when trees have not yet shedded their leaves, they can provide much needed protection during these months.

Figure 51

Shutters have been placed on the exterior of windows and doors to allow users to shut when there are heavy winds which may cause disturbance or damage to these elements.

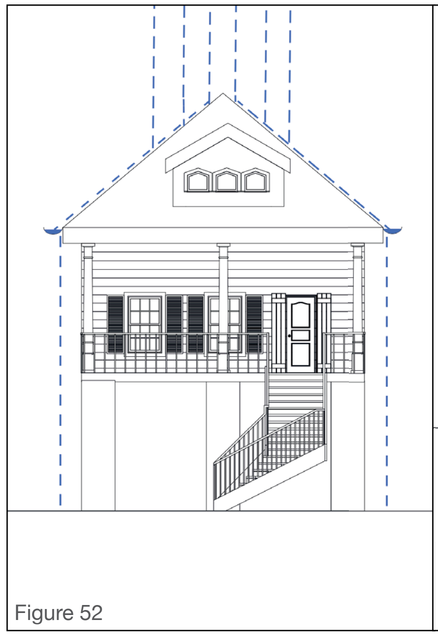


Figure 52

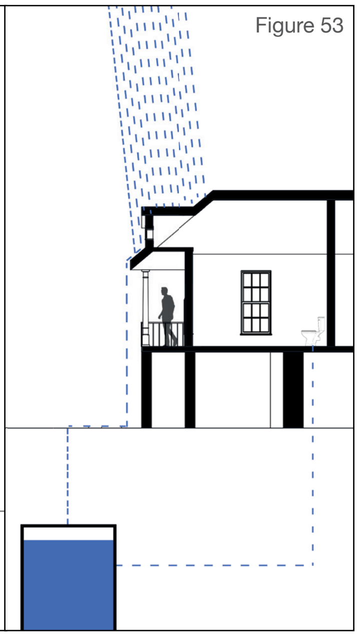


Figure 53

The roof has been designed to be sloped steeply in order to allow rain to be directed and not form puddles on a flat roof. Large eaves and overhangs help to protect the building facade and guttering can funnel the water (Coch, 1998).

In this particular climate, due to the frequent annual precipitation, a rainwater harvesting system could be introduced in order to supply plumbing to the building (for example, flushing of a WC, however not as drinking water). This would help to minimise the effect of flooding and help to desaturate the soil through recharge pits on the ground where the surface water is directed into a tank underground (Tamagnone, Comino, & Rosso, 2020).

CONTEMPORARY DESIGN: BUILDING ENVELOPE

Local cypress wood will be used for the wall and roof construction this is due to local sourcing, meaning a lower embodied carbon and the good thermal and permeable properties of this type of timber (Vogt, 1985).

It is a characteristic of the shotgun vernacular to make use of thin, vapour permeable walls due to the heavy rainfall and hot, humid climate.

The hot climate requires wall and roof construction with a good U value in order for the indoor temperature to remain consistent and reduce thermal loss. Therefore, insulation should be used for a contemporary wall construction (Beccali et al., 2018; Robinson & Claudette Hanks, 2016).

It is important for the wall and roof construction to be vapour permeable due to the high relative humidity and heavy rainfall. Therefore, natural, breathable, lightweight materials should be used for the contemporary wall construction (Daemei, Eghbali, & Khotbehsara, 2019) (fig. 54).

Bio-climatic response: cold and hot climate = house with thick skin

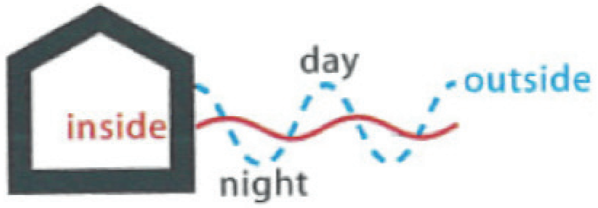


Figure 55: Thermal inertia

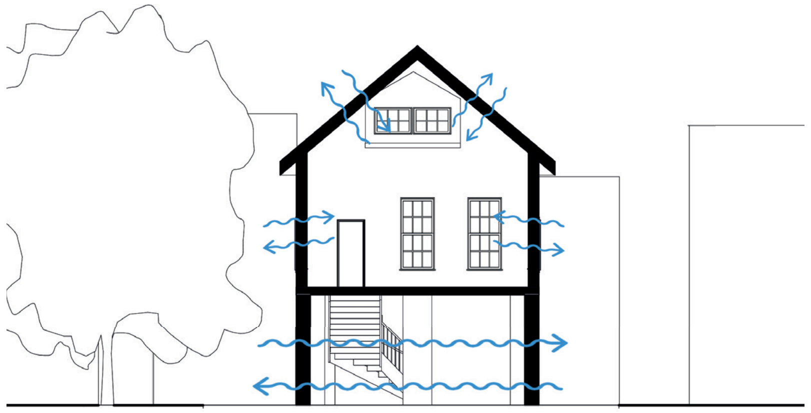


Figure 56: vapour permeable walls

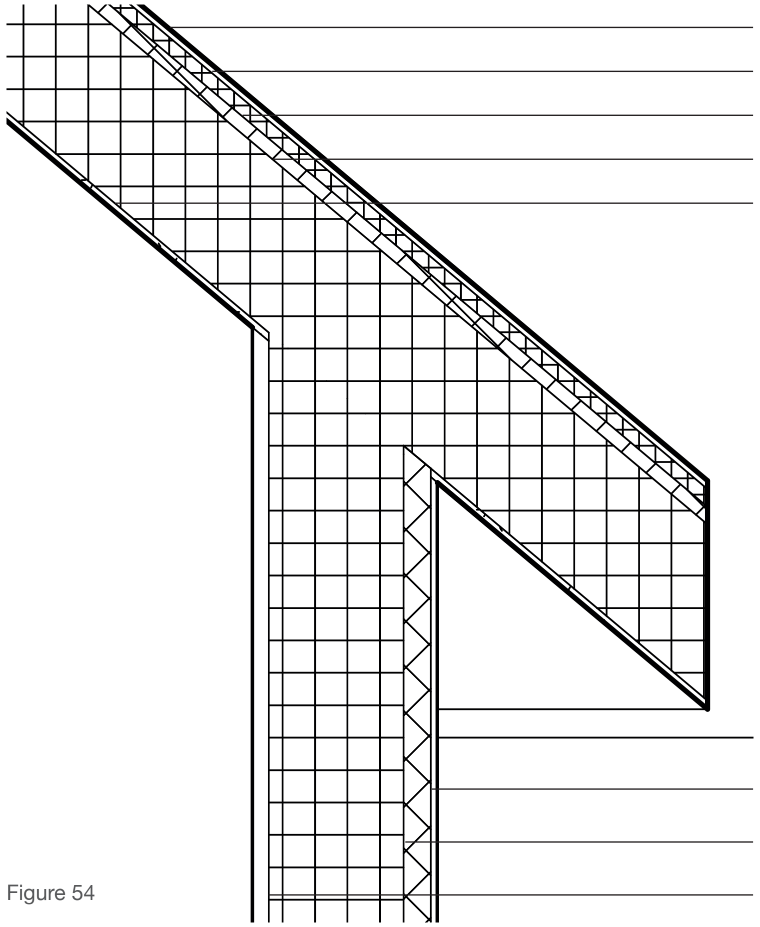


Figure 54

Wall and roof thickness: 332mm

local cypress wood finish 20mm
OSB board 50mm and breathable membrane
air infiltration barrier
timber rafters (infilled with wood fibre insulation) 250mm
interior finish 12mm

U-value = $\frac{1}{(\text{thickness} / \lambda)}$

λ = thermal conductivity

ROOF:
U-value = 0.135 W(m3K)

WALL:
U-value = 0.128 W(m3K)

loal cypress wood finish 20mm
OSB board 50mm and breathable membrane
timber I beams (infilled with wood fibre insulation) 250mm
air infiltration barrier and interior finish 12mm

Total room heat loss:

$$\dot{q} = \left(\dot{m}C_p + \sum_{i=1}^{n} UA \right) \cdot \Delta T \quad \approx \quad \left(nV/3 + \sum_{i=1}^{n} UA \right) \cdot \Delta T$$

$$\dot{m}C_p = \rho \dot{v} C_p = \rho n V \frac{1}{3600} C_p = 1.2 \cdot nV \cdot 1000 \frac{1}{3600} = nV \frac{1}{3}$$

Where n is the infiltration rate [1/h] and V is the room volume [m3]

8% glazing ratio (glazing u value is double glazed = 1.2 w/m2K)
3.5m height of walls
7.4m width
29.5m depth
assuming infiltration rate is low 0.25l/s

Assuming that the change in temperature is 1 degree (outdoor mean is 22 degrees and comfort zone indoors is 21 degrees) in summer, then the total room heat loss would be 182.32w/K

Assuming that the change in temperature is -6 degree (outdoor mean is 14 degrees and comfort zone indoors is 21 degrees) in winter, then the total room heat loss would be 1093.92w/K

ENERGY ANALYSIS

The Autodesk Insight total energy usage of the contemporary dwelling calculates as 110 kWh/m2/yr. This is very low and within Passivhaus standards (Pelsmakers, 2019). It also does not take into account the use of renewable energy systems, which means that this value could drop significantly if these systems were to be introduced.

Figure 57: Autodesk Insight results

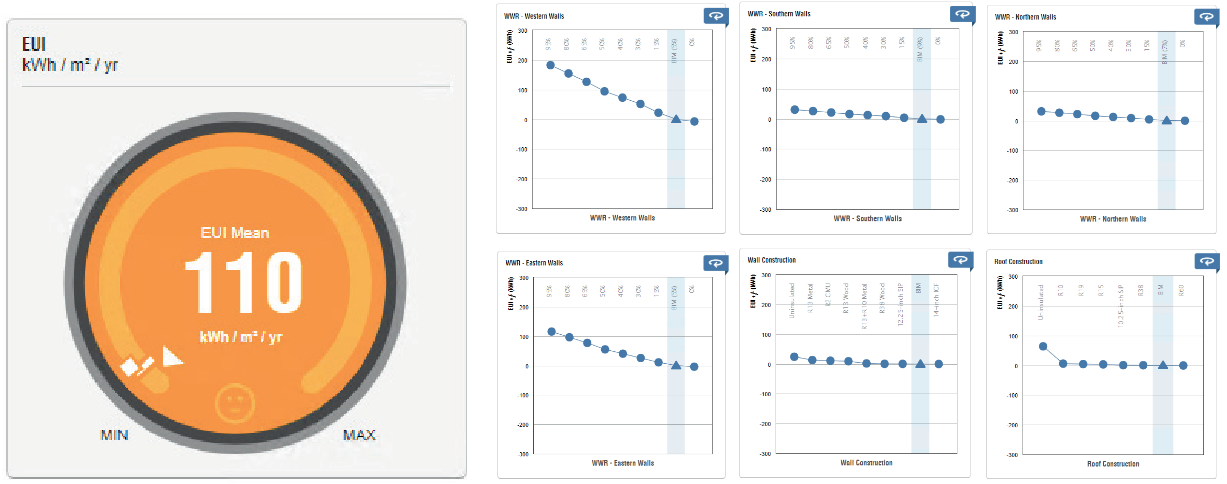


Figure 60 and 61 shows the cumulative insolation of radiation on the roof and facades of the conceptualised building. It indicates that the use of solar panels would be appropriate on the east and west roof as there is also a large surface area. Covering 90% of the roof would result in the energy usage annually to be -137kWh/m2/yr and therefore producing more energy than would need to power the building and also be carbon positive. Figure 58 shows the solar irradiation surface plot has the potential to collect 152MWh/m2 at an azimuth of 175° at a tilt of 25°.

Figure 58

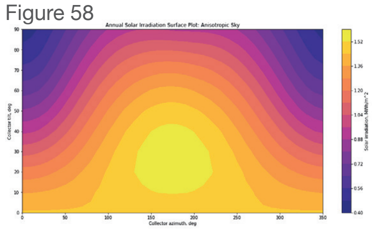


Figure 59

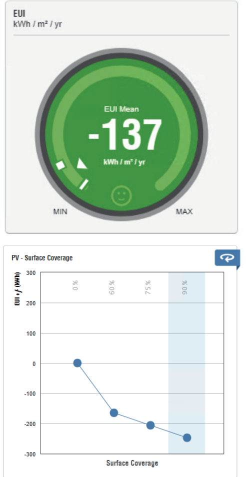


Figure 60

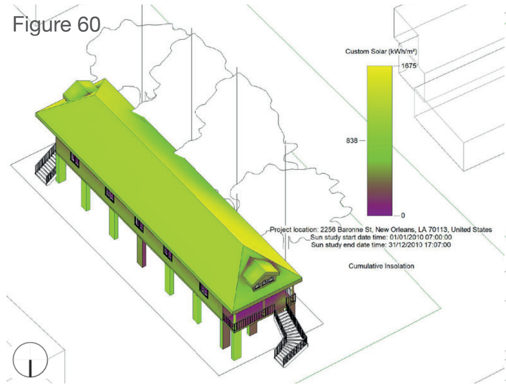
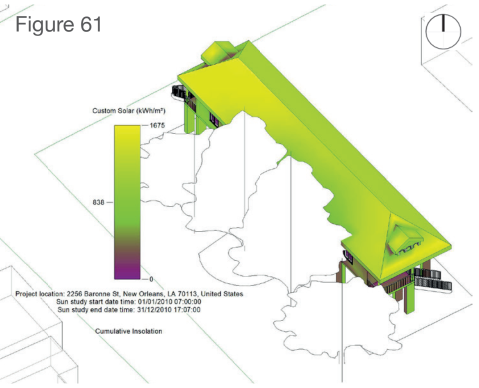


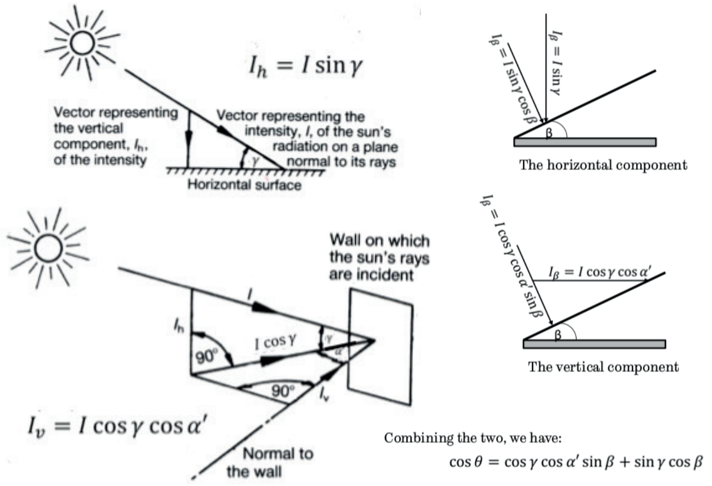
Figure 61



CONTEMPORARY DESIGN: SHADING DEVICES

Due to the extreme heat in the summer (highs of 34°C in July) and cooler winters (lows of -1°C in December), it is common of the creole vernacular to make use of shading devices to provide much needed shelter from the sun in the summer and access to radiation in the winter. Fig. 62 shows the use of a large overhang and porch design provide protection from the sun and rain.

It is important to obtain the maximum possible protection against the sun, to stop not only direct but also diffuse radiation, which is of importance in these climates (Coch, 1998).



Combining the two, we have:

$$\cos\theta = \cos\gamma \cos\alpha' \sin\beta + \sin\gamma \cos\beta$$

Figure 62

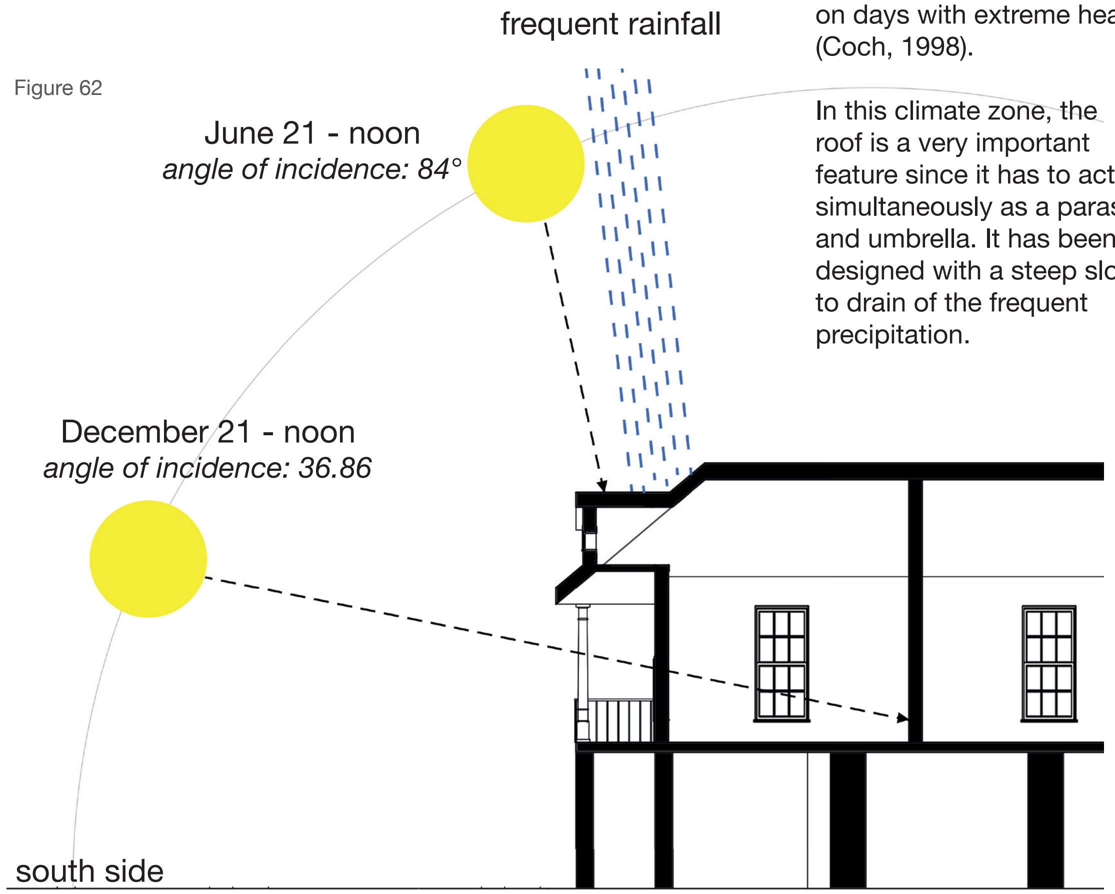


Figure 63: summer radiation on the north west facades

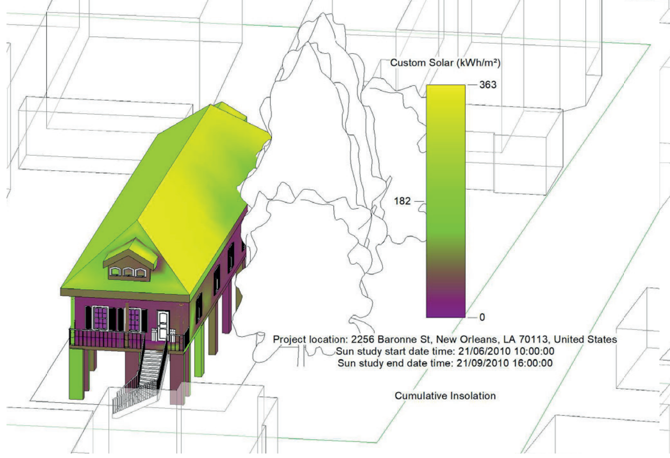
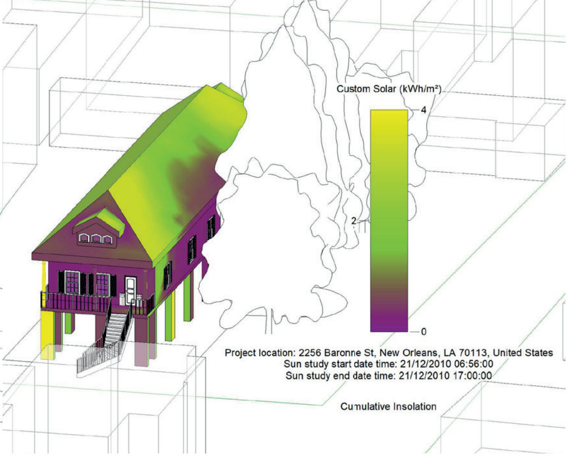


Figure 64: winter radiation on the north west facades



The roof is light-weight in order to avoid heat storage from radiation. It is also painted a light colour in order to reflect sunlight and avoid absorption of radiation. In this design, strategic placement of trees is evident on the west facade to shade the building from radiation in the summer and protect from wind and rain (Daemei, Eghbali, & Khotbehsara, 2019). During the winter months, trees may shed leaves and allow more sunlight to enter through the glazing on the west.

The porch generates shady intermediate spaces during the day-time and spaces protected from the cool damp air at night. Thus it is then possible to rest or sleep on days with extreme heat (Coch, 1998).

In this climate zone, the roof is a very important feature since it has to act simultaneously as a parasol and umbrella. It has been designed with a steep slope to drain of the frequent precipitation.

Figure 65

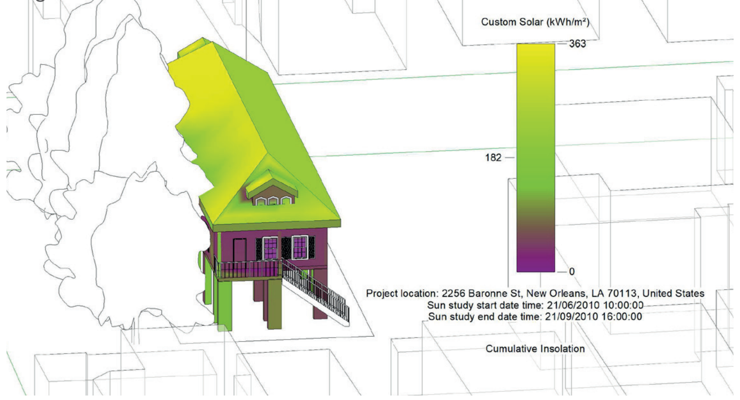


Fig. 65 shows the shading provided by the overhang and porch design on the south facade in the summer months.

Figure 66

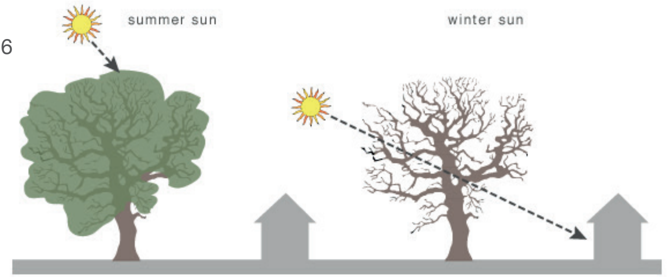


Fig. 66 shows the access to sunlight during the winter and shading from trees in the summer. Strategy from greenspec.

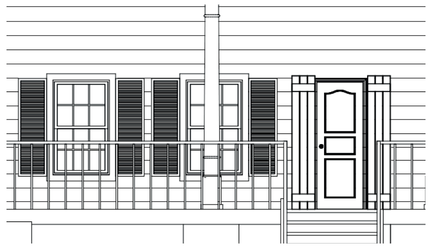
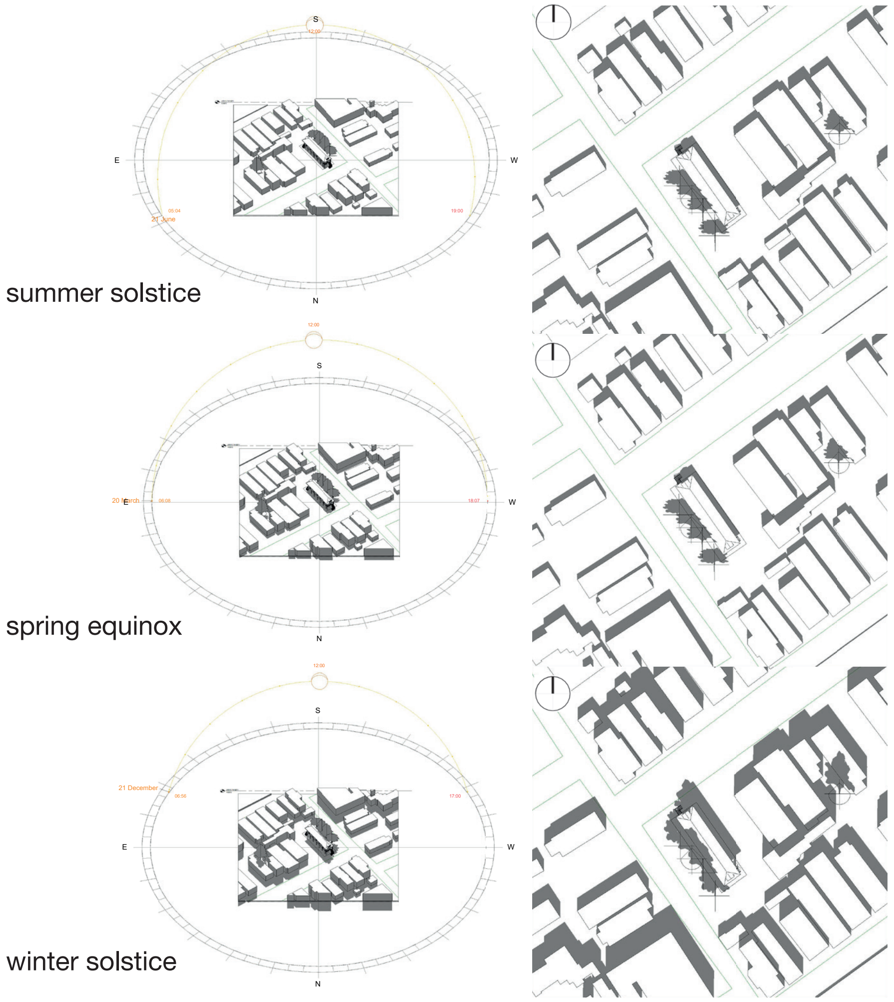


Fig. 67 shows shutter design which has been used for occupants to close when there is unwanted sunlight entering the space.

In figure 68, it is clear that there is no overshadowing of the building from the surrounding site, therefore surrounding massing provides no necessary shade to the building. However, this is not completely necessary due to the placement of trees and employing of large overhangs and porches.

Figure 68



The use of trees placed on the south west facade of the building provides a value of 257 hours of shade altogether. The use of a horizontal projection at 135° from north will provide vital shading in the summer months at an angle of 20° or more. A horizontal projection at 315° from north will provide a useful amount of shading year round at angle at 30°.

Figure 70

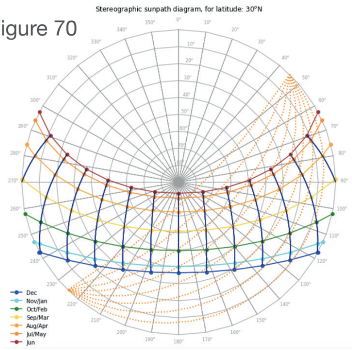


Figure 69

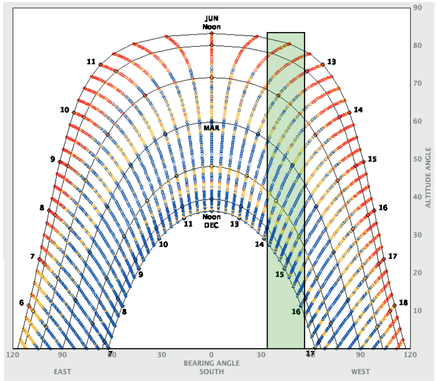
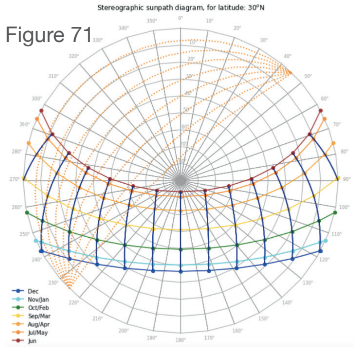


Figure 71



CONTEMPORARY DESIGN: DAYLIGHT AND ILLUMINANCE

New Orleans is not short of daylight, and the sky produces a very intense amount of illuminance in all directions annually, at an average of 3500 lux. It is important to allow lots of daylight for indoor spaces, however, too much can create unwanted heat gain and too much direct sunlight could cause an uncomfortable environments for occupants, especially in summer (Coch, 1998).

Windows are large for ventilation purposes and also too keep indoor illuminance high and provide occupants a connection to the outdoors with beautiful views (Daemei, Eghbali, & Khotbehsara, 2019). However, placement of trees and shading devices have also been used here to control any excessive indoor illuminance. See figure 72, 73 and 74 to understand the indoor illuminance and daylight factor of these internal spaces.

Figure 73: summer solstice illuminance

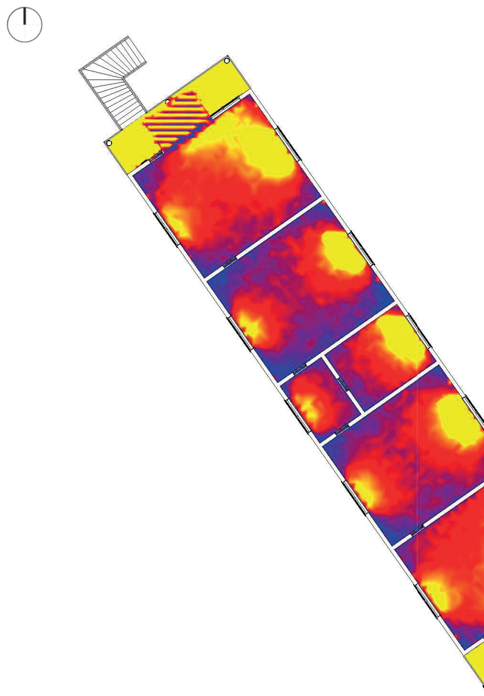
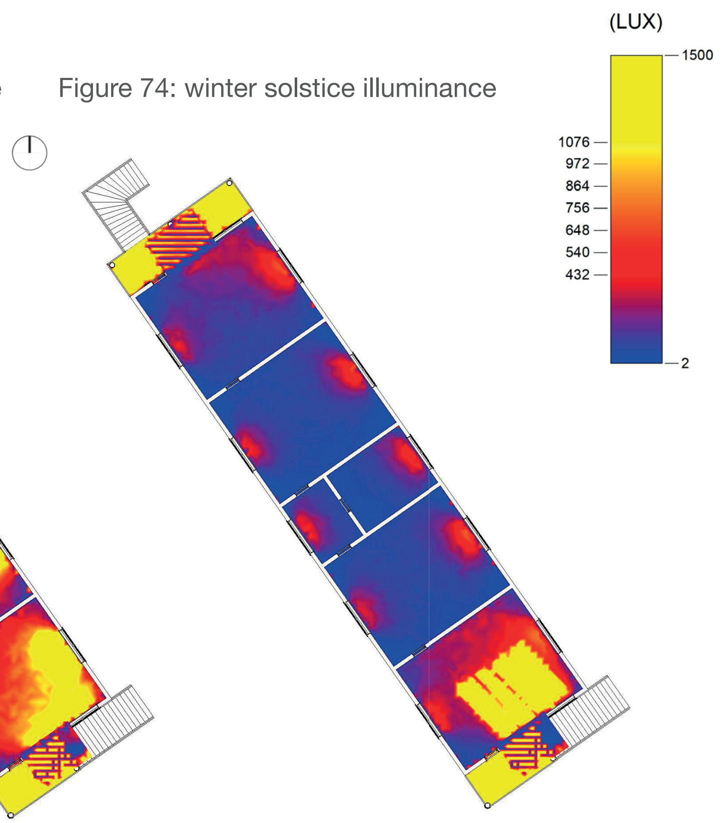


Figure 74: winter solstice illuminance



Standard Day - 37% Passing

Daylight Factor Sky

Building ADF: 2.2%

63% below threshold

0% above threshold w/o shades

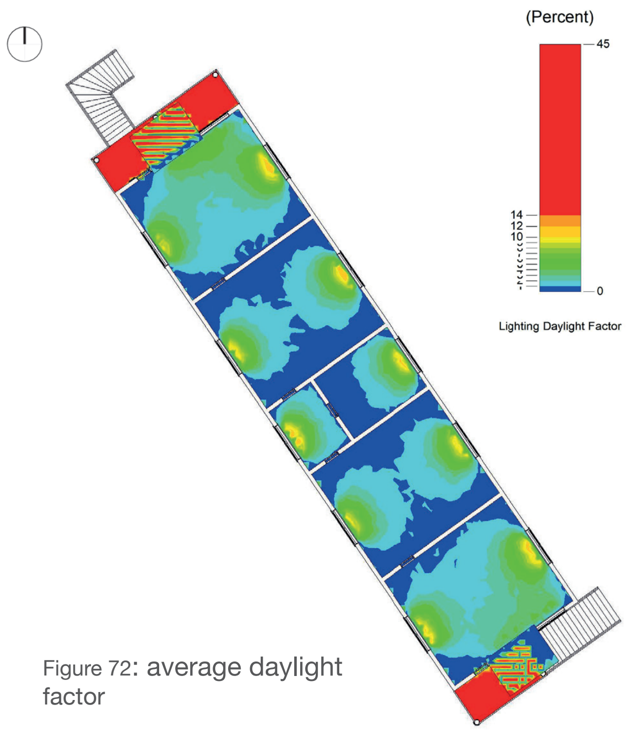


Figure 72: average daylight factor

The daylight factor provides us an idea of the worst case scenario. The average daylight factor is 2.2% internal to the building, this figure within a good range where the BREEAM standard requirement is 1.5-2% (BREEAM, 2016). Using this figure, we can use the CIBSE guidance chart in figure x to work out the percentage of time in which lights can be switched off in order to achieve a desired indoor illuminance. Figure 75 shows that in order to achieve an indoor illuminance level of 500 lux, the lights can be switched off for 55% of the time.

Figure 75: photoelectric switching CIBSE

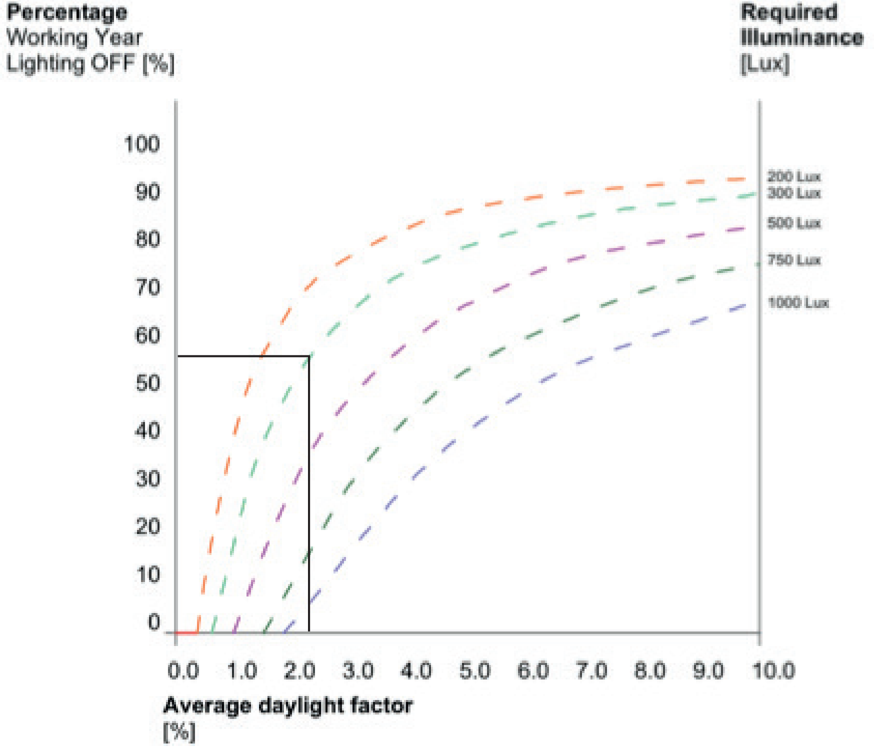


Figure 74: It is clear that there is a large drop in illuminance during the winter, this is a worst case scenario and is averaging in each room around 200 lux which meets the BREEAM standard of indoor illuminance which is an average of 100 lux (BREEAM, 2016). However on the southern side of the building illuminance is still reaching 1500 lux round the window.

Figure 73 tells us the indoor illuminance in summer with a clear sky. This would be the best case scenario. It shows that there is an excessive amount of illuminance inside the building even reaching values of 1500 lux at the windows. Therefore, design devices have been introduced in order to minimise the effects of glare and overheating, which are especially important on the south and the east facades of the building as evident in the figure.

GLARE CONTROL AND SHADING DEVICES ON WINDOWS

Glare control must provide shading from both high level summer and low level winter sun (BREEAM, 2016). The methods employed in this design are occupant controlled devices (Meek & Brennan, 2011) and external shading.

Figure 76 & 77

Figure 76 & 77 show the use of manually operated glare control blinds which can be fixed internally and controlled by the occupants. This will allow adaptive visual comfort for the user, diffused light which will then avoid ultraviolet degradation of interior materials and furnishings, and ensure that glare into the building is not excessive (Hyde, 2000). This is particularly important in summer due to the large amount of external illuminance available.

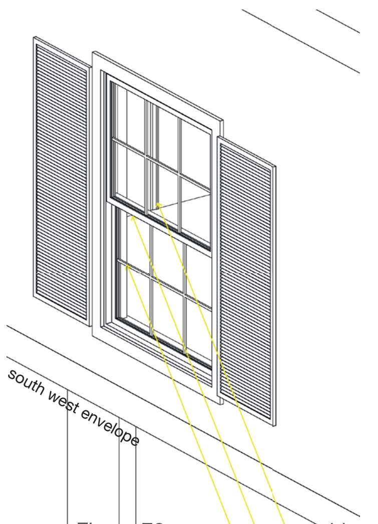


Figure 78: summer sun at 11am

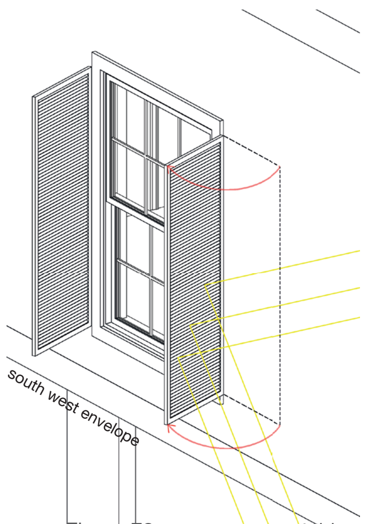


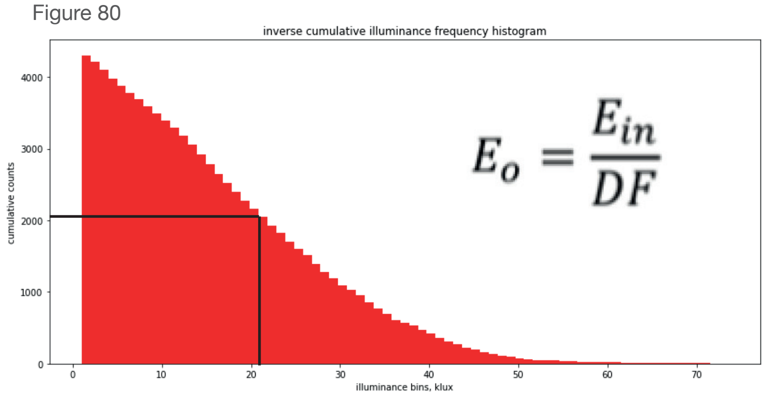
Figure 79: summer sun at 11am

Wings or shutters are to sit externally to each window. This will provide protection from unwanted glare for occupants, whereby they can adjust shades to the desired angle which can provide optimal and adaptive visual comfort and relief from excessive illuminance. This is also particularly important for summer. In figure 79, you can see the direct southern sun can be blocked on the west facade using the shutters as a shading device, whilst still allowing windows to remain open for ventilation and letting indirect external illuminance to still enter the room.

Using the equation and inverse cumulative illuminance frequency histogram (fig. 80), we can detect the the number of hours in which lights need to be turned off in order to achieve a desired internal illuminance level.

Therefore, in order to achieve an internal illuminance level of 500 lux, which is a good level for residential dwellings (BREEAM, 2016), then lights can be switched off for around 2000 cumulative hours annually.

Figure 80



$$E_o = \frac{E_{in}}{DF}$$

CONTEMPORARY DESIGN: VENTILATION STRATEGIES AND THERMAL COMFORT

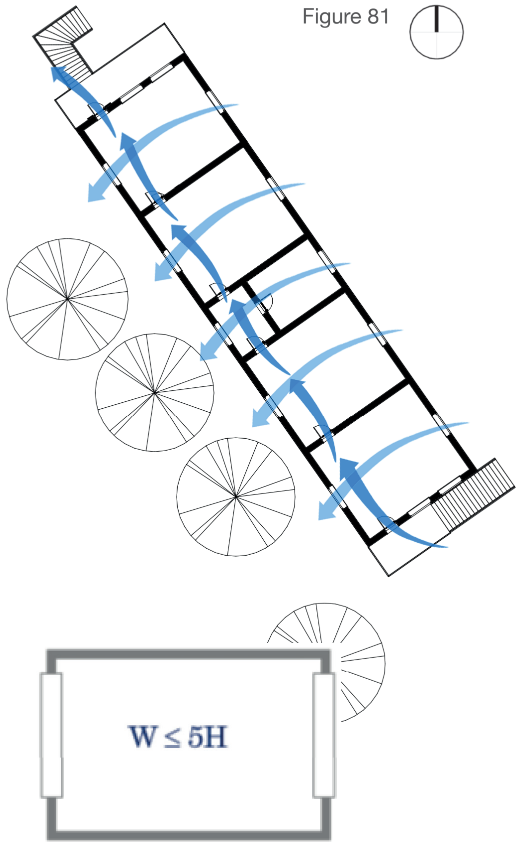


Figure 81

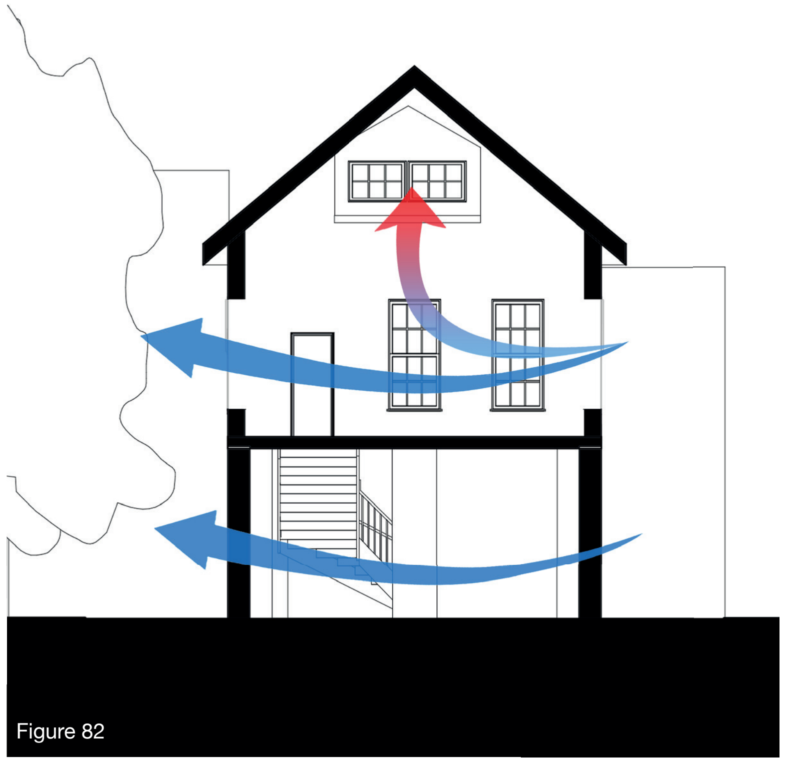


Figure 82

Ventilation is the main form of cooling in this building. It is used to replenish the air quality and quantity for the lives of the occupants, and to also cool the people inside the building to achieve thermal comfort (Hyde, 2000). The prevailing winds in this climate occur from the south and east direction predominantly as evaluated in the climate analysis. Therefore the ventilation is seen in figure 81 to flow from this direction.

Cross and wind-driven ventilation is the most common form of ventilation design used in hot climates due to wind pressure difference usually being higher than temperature pressure difference. Temperature-driven ventilation makes use of a passive stack system which has been employed in the design. Here, the buoyancy in hot air will cause it to rise and displace the cooler air. Due to temperature differences between the internal and external air being very minimal, the effect of passive stack ventilation will be very small (Hyde, 2000). Therefore, the main form of ventilation in the building relies on cross ventilation (a wind-driven system) (fig. 82 and 83).

The rule of thumb for cross ventilation is that the width of the space must be less than 5 times the height of the building (Chartered Institution of Building Services Engineers, 2016). Therefore, due to the height of the rooms being 7.4m including the roof space, the width and length of the building were designed to be no more than 37m (7.3m width x 29.4m length).

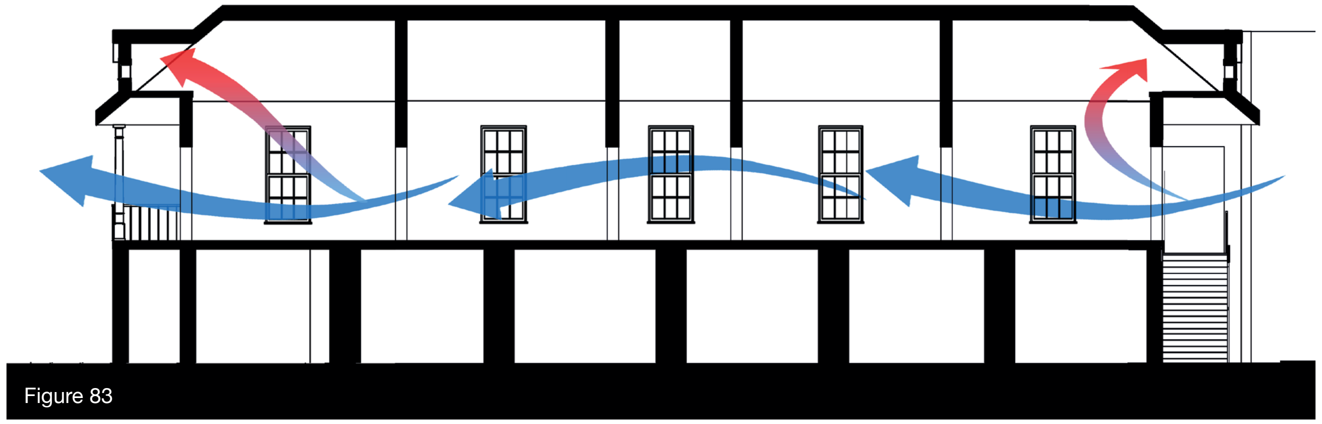


Figure 83

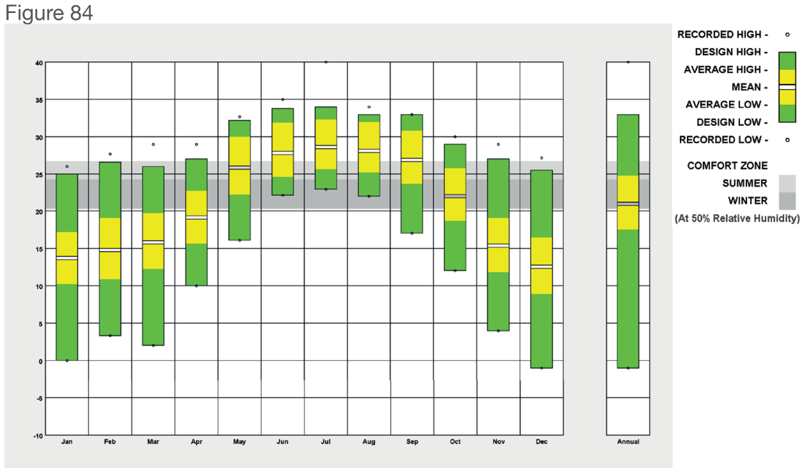
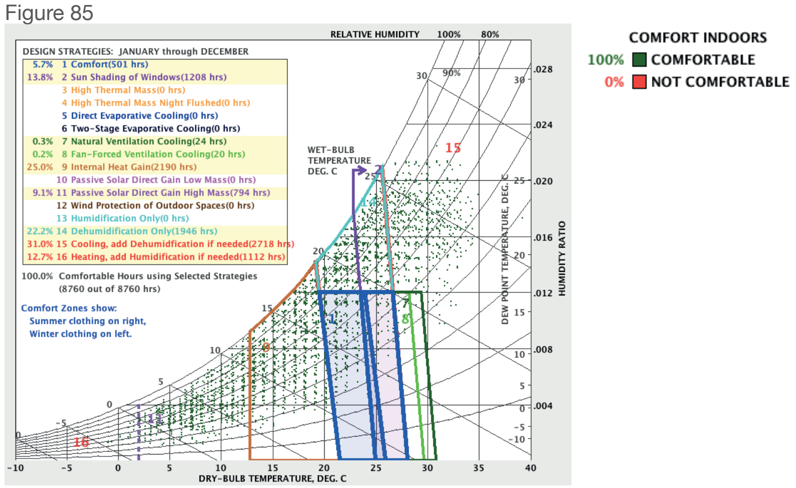
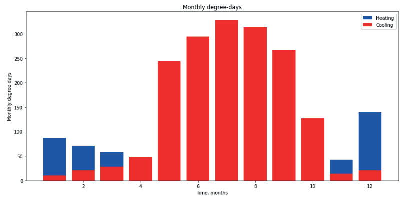
Figure 84


Figure 85
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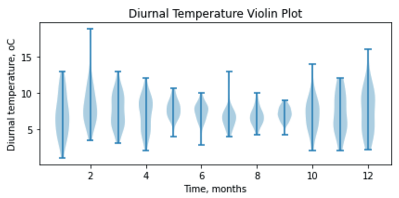
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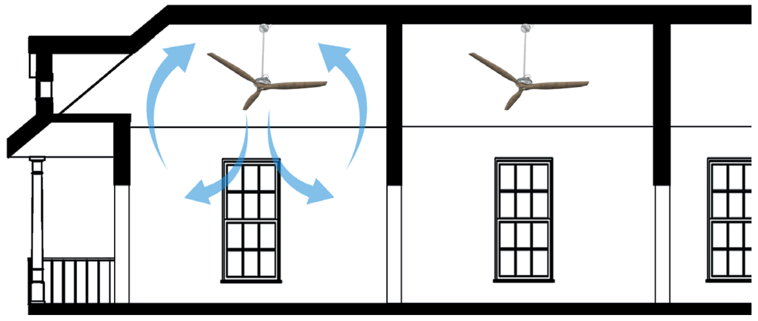


Figure 88: ceiling fans circulate the air, the balance of these is important to avoid noise and reduced efficiency. Also depending on the number and pitch of the blades, they can cause noise, so 4 blades can be used for noise-sensitive areas such as bedrooms. Reversible motors are also advised for winter use to avoid stratification of hot air at the ceiling (Hyde, 2000).

COOLING

Sun shading on windows has been applied using shutters which allow occupants to block the direct sunlight and simultaneously make use of cross-ventilation. Natural ventilation takes form through cross and stack ventilation with mechanical ventilation of ceiling mounted fans to help cool the air by 3°C to a thermally comfortable level and also allows for adaptive thermal comfort.

The average temperature in the peak of summer is around 28°C. For this temperature the cooling needs to decrease to a temperature of 25°C indoors in order to achieve a thermally comfortable level. In the winter, the temperature indoors should be 20-23°C to achieve a thermally comfortable level.

The strategies suggested via climate consultant in which will achieve 100% comfortable hours are as follows:

- Sun shading on windows
- Natural ventilation cooling
- Internal heat gain
- Passive solar direct gain high mass
- Dehumidification only
- Cooling
- Heating

It is not advised to make use of fan-forced ventilation by climate consultant, however, Hyde (2000) states that the use of ceiling mounted fans which recycle the air in the space and give it movement, can reduce the air temperature by 3°C. This is a good amount needed for optimal thermal comfort within the New Orleans climate condition during the summer, and therefore is a cooling strategy in which will be employed in the building.

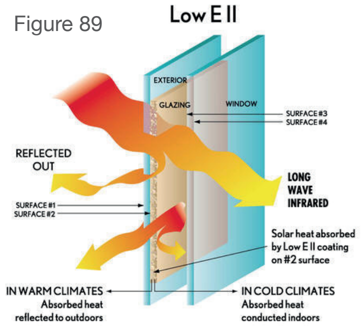
THERMAL MASS ASSISTED NIGHT-TIME COOLING (NIGHT PURGE)

A high thermal mass absorbs the internal heat during the day-time and will release it during the night so that it can be cleared by natural ventilation. Also known as a night purge, it can be controlled by automatic windows or louvers programmed to remain open during the night to let the air flow naturally through the building (Shaviv, Yezioro, & Capeluto, 2001). A thermal mass floor will be used for the raised floor construction of the building. This system can be used to passively enhance the ventilation in the building and simultaneously reduce the demand for cooling during the summer Tuohy, McElroy, & Johnstone, 2005).

Stone is a thermal mass material with a high specific heat capacity of 1000J/kg.K (GreenSpec, nd) and is typically used in shotgun construction for pier design (Federal Emergency Management Agency, 2012), therefore it has been selected as a contemporary material to use for the floor as it is also structurally good for load bearing.

HEATING

Heating degree days occur in the months of November, December, January, February and March. The heating strategies used in the building include the use of Low-E glass (fig. 89) in order to create a greenhouse effect on glazing, internal heat gains (sourced from bodies: humans and animals, lighting, computers and office equipment, electric motors, cooking appliances and other domestic equipment) and the use of a stone floor which acts as a thermal mass store to release heat when the temperature falls below a certain point (Daemei, Eghbali, & Khotbehsara, 2019). Passive solar heating systems can minimise the need for a mechanical air conditioning system, this takes place in the form of solar gain from Low-E glazing on the windows (Hyde, 2000).

Figure 89


CONCLUSION

It can be concluded that, the potential of the Creole Vernacular style shotgun house has, to be translated into a contemporary environment, is high. The most predominant climatic challenges that the building faces are those of tropical storms, extreme heat and humidity in the summer, heavy rainfall and a high amount of radiation. The creole vernacular has adapted to the these challenges and has provided a good thermal comfort level for occupants in the past, especially due to the fact that the majority of housing in New Orleans remains of this style (Vogt, 1985). However, with temperature rise and global warming, it is clear that some contemporary approaches could be introduced in order to achieve optimal thermal comfort. For example, the introduction of ceiling mounted fans for cooling, glare control blinds, solar panels for a carbon negative energy usage, a new building envelope construction with modern insulation materials which will also achieve the high permeability of the classic shotgun construction, Low E glazing and a stone floor construction for thermal mass assisted night-time cooling. Throughout the report, the principles of this vernacular style residential dwelling have performed extremely well in a contemporary environment as a result of simulation outputs and this can provide an indication as to the success of a vernacular approach to design. It is clear that New Orleans, has and will, be facing extreme geographical difficulties with regards to tropical storm frequency, flooding and subsidence. Consequently, these have been considered in the contemporary design due to huge damage to infrastructure that could occur as a result of this. It is evident that raising the elevation of buildings could be a successful vernacular approach to these issues. Overall, it is understood in this report that many principles of the vernacular architecture in this hot and humid climate, stand up against a changing one, and should be considered as innovative ideas to more sustainable design going forward.

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FIGURES

Cover: Dundon, R. (2017). A Visual Chronicle of the Shotgun Shack, a Truly American Architectural Icon | by Rian Dundon | Timeline. Retrieved February 26, 2021, from https://timeline.com/visual-shotgun-shack-american-d507d33d83c2

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