PASSIVE DESIGN GUIDE

FOR TROPICAL , ARID & CONTINENTAL CLIMATES

NEW & ADAPTING EXISTING STRUCTURES

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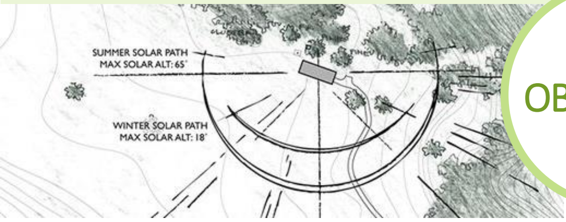
MEDECINS SANS FRONTIERES

HOW TO USE THIS GUIDELINE

This design Guideline is aimed at helping the user apply passive cooling design concepts to new or existing buildings in Tropical, Desert and Continental Climates. It focusses on African and Middle Easter countries in the northern hemisphere as a response to the ever-increasing challenges caused by climate change and the urgent need for sustainable and low-cost solutions.

In harsh climates, extreme weather patterns create challenging living conditions. Passive Design offers effective tools to address comfort and sustainability while minimizing energy consumption and greenhouse gas emissions, making it crucial for both new and existing structures.



OBJECTIVES

1. **Comfort**
2. **Sustainability**
3. **Adaptation**
4. **Low cost**

INSTRUCTIONS

This document is a comprehensive manual for applying passive design principles to the design of new structures or when renovating an existing structures. As shown in the Table of Contents, the document is divided into four parts:

01 **THE INTRODUCTION** section explains the different climatic conditions considered and introduces the main concepts for understanding how passive measures that can be applied. This way the user can better understand which concepts to apply for each climate considered.

02 In **BUILDING CONDITIONS**, the concept of the passive controls and methods are explained. Also, **Climate Based Specifications** are provided for existing buildings and new constructions for each climate throughout this chapter.

How to implement Passive Design concepts to an existing structure?

03 **ADAPTING EXISTING STRUCTURES**, will give you more specific solutions for modifying an **existing structure,** such as insulating and shading to reduce energy consumption.

04 Finally, in the **ANNEX**, in this part you will find important technical information and other techniques for Passive cooling.
This includes a ***decision-making flow chart*** to evaluate the existing buildings and identify areas for improvement based on passive design principles.

CONTENTS

01 INTRODUCTION TO **PASSIVE DESIGN**

WHAT IS **PASSIVE DESIGN?**

Passive design is a **building design approach** that aims to avoid the use of mechanical equipment for heating, cooling, and lighting. Instead, it **maximizes natural resources** taking advantage of sunlight, wind, and thermal mass to create **comfortable and energy-efficient** livable and working environments.

BENEFITS

A — **Maximizes** the efficiency of the building envelope without using mechanical devices.

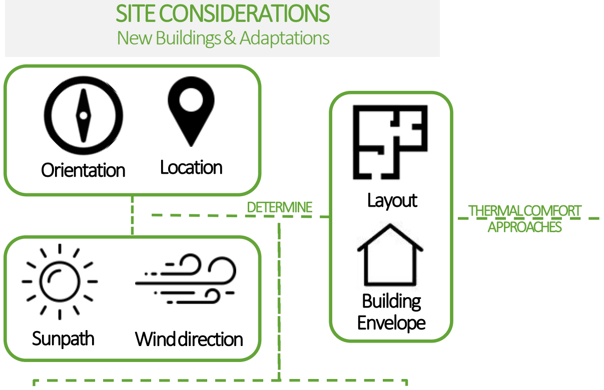
B — **Derives** cooling from evaporation, convection or radiation without using immediate electric devices.

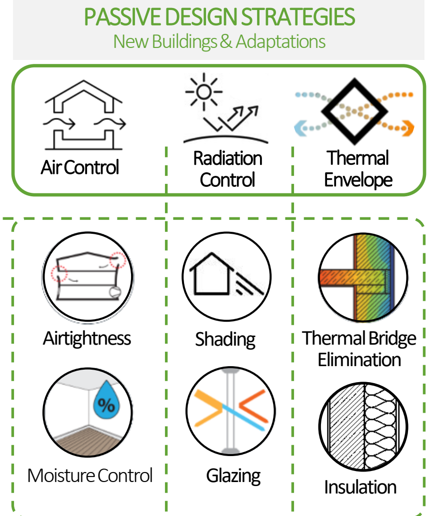
D — **Relies** on daily changes in temperature and relative humidity.

C — More **economic** than other forms of cooling, requires less maintenance.

DESIGN PROCESS

To successfully achieve a passive design building, important elements need to be considered to enhance the potential of the ***natural resources available like*** *<u>natural light, air, sun warmth and cooling.</u>*





PASSIVE COOLING

It aims to **control the heat gain and heat dissipation inside the building** in order to improve thermal comfort. Maintaining a comfortable environment within a building in a **hot climate** depends on **preventing heat from entering or by removing it from the building.**

PASSIVE HEAT GAIN

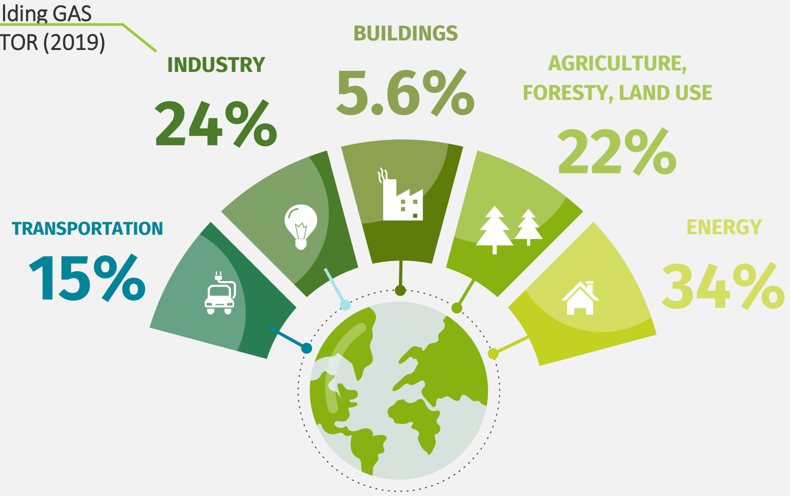
Collects the warming effect from the absorption of solar radiation wherein solar energy is exploited to induce heat from the affected surface to indoor, as well as promote **heat storage** within the building **using thermal mass, heat flow and insulation** effectively to **store, distribute, and retain the heat.**

01 INTRODUCTION TO PASSIVE DESIGN

CLIMATE CHALLENGES

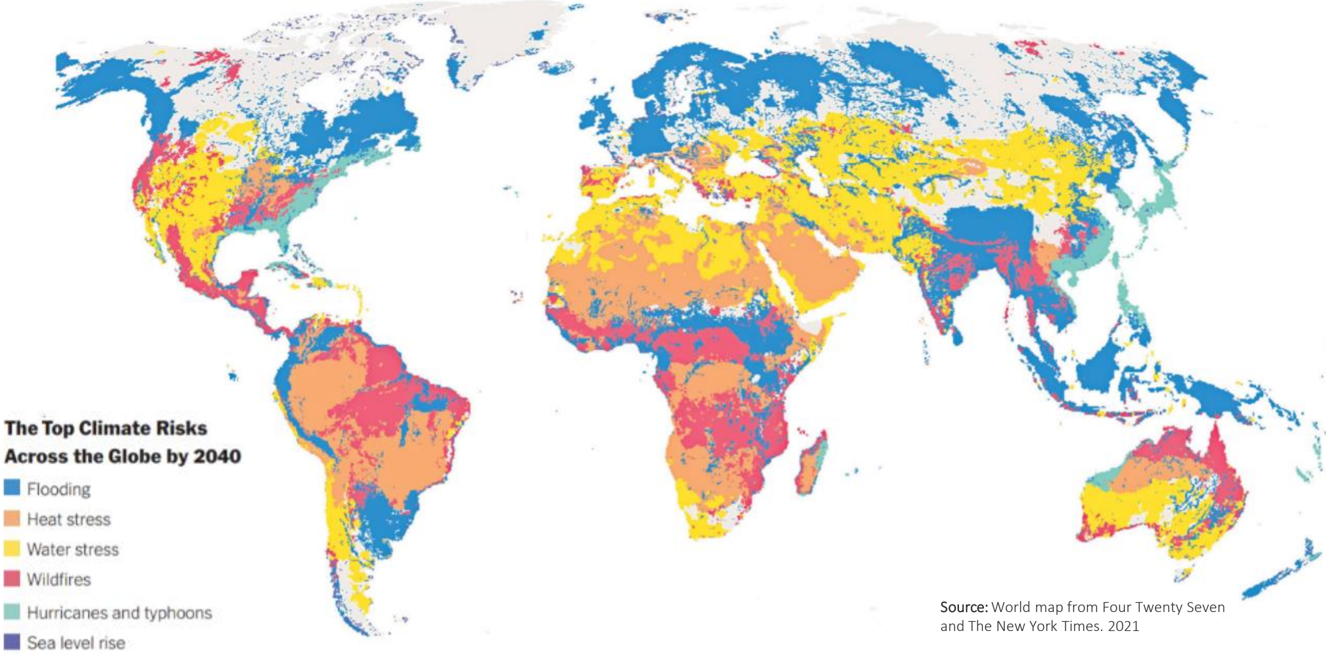
The acceleration and magnitude of climate change is the result of human activities that release **Greenhouse Gas Emissions (GHG)** into the atmosphere. Studies have shown that the most effective and least expensive way of **reducing the effects of climate change** is by **using less energy.**

GLOBAL GREENbuilding GAS EMISSIONS BY SECTOR (2019)



Source: IPCC

TOP CLIMATE RISKS BY 2040 DUE TO CLIMATE CHANGE

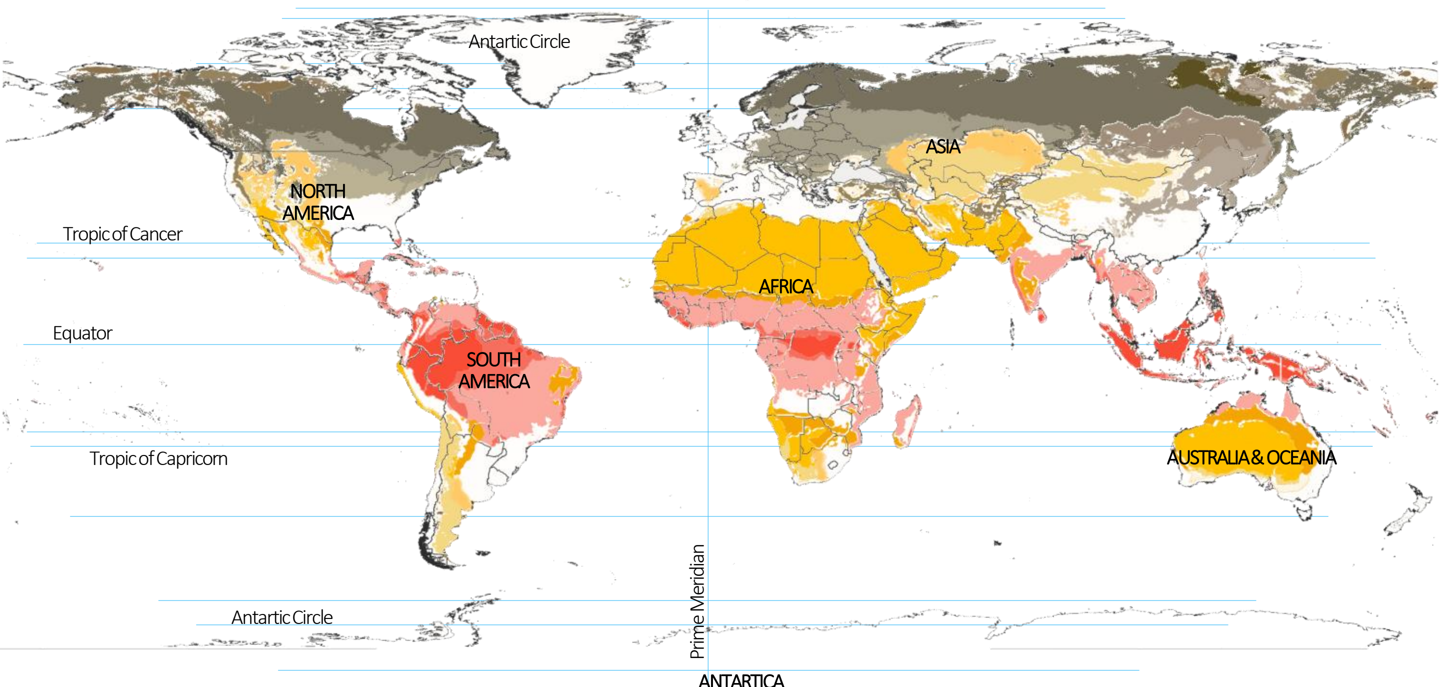


Source: World map from Four Twenty Seven and The New York Times. 2021

01 INTRODUCTION TO **PASSIVE DESIGN**

CLIMATE ASPECTS

With the variation of the climates in the world, **Passive Design** aims to improve building thermal performance for each different climate using specific local resources adapted to each environment.



TROPICAL CLIMATES
- Topical, rainforest (Af)
- Tropical, monsoon (Am)
- Tropical, Savannah (Aw)

ARID CLIMATES
- Arid steppe, hot (BSh)
- Arid, desert, hot (BW)
- Arid, steppe, cold (BSk)
- Arid, desert, cold (BWk)

CONTINENTAL CLIMATES
- Cold, dry summer, hot summer (Dsa)
- Cold, dry Winter, hot summer (Dwa)
- Cold, dry Winter, cold summer (Dwc)
- Cold, no dry season, hot summer (Dfa)
- Cold, no dry season, warm summer (Dfb)
- Cold, no dry season, cold summer (Dfc)
- Cold, no dry season, very cold Winter (Dfd)

Tropical Climates | Hot humid

Near the equator *(Af,* *tropical rainforest climate or equatorial climate)* year-round temperatures are consistently hot, as many of the equatorial climate, these regions have no dry season but have a well-developed monsoon period. There are high average temperatures and humidity throughout the year.

Arid Climates | Hot dry

Away from the equator the temperature in these locations can change drastically from day to night because the air is so dry that heat escapes rapidly at night.

Continental Climates

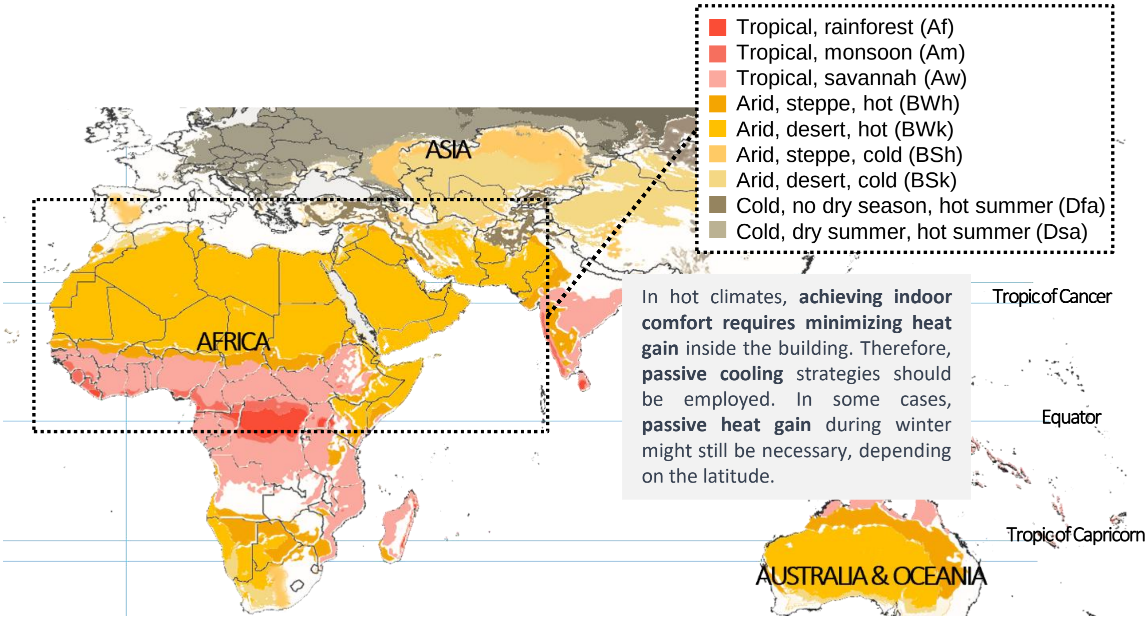
In these regions at mid-latitudes, it is common to experience seasonal variations. Spring and autumn serve as transitional seasons with mild temperatures.

Due to the absence of nearby oceans or large bodies of water, the temperature variations between day and night, as well as between seasons, are more pronounced. Consequently, humidity levels are lower as there is a lack of nearby water bodies, resulting in drier conditions, particularly during the winter months.

- *The specific temperatures and weather conditions can vary depending on factors such as altitude, proximity to bodies of water, and local geographic features.*
- *This map has used the Koppen-Gieger climatic classification and lists out the main climates of the world with the variations in temperature and precipitation. According to this classification, there are five climates; Equatorial, Arid, Warm, Snow, and Polar.*

01 INTRODUCTION TO PASSIVE DESIGN

DESIGNING FOR SPECIFIC LOCATIONS



In hot climates, **achieving indoor comfort requires minimizing heat gain** inside the building. Therefore, **passive cooling** strategies should be employed. In some cases, **passive heat gain** during winter might still be necessary, depending on the latitude.

This document focuses on **tropical climate (hot humid), arid climate (hot dry) and continental climate (cold winters) from the Northern Tropic region;** specifically, from the areas shown in the map above.

Tropical Climates

Tropical climates are warm all year with temperatures above 18°C, averaging 25-35°C during the day and 20-25°C at night. Because the tropics get more exposure to the sun, they don't experience the kind of seasons the rest of Earth does. These countries experience relatively consistent day lengths throughout the year.

There are three fundamental variations of tropical climates: **the tropical rainforest climate (Af, no dry season), the tropical monsoon climate (Am, wet and dry season), and the tropical savannah (Aw, dry winters/summers).** These distinctions are made based on the amount of precipitation and the levels of precipitation during the least rainy month in these areas.

Arid Climates

Arid climates are found in the subtropical latitudes, approximately between 15-30° North and South of the Equator, these regions are characterized mainly by their **aridity, high summer daytime temperatures, large daily temperature range, cool winters and high solar radiation.**

The daytime temperature averages **38°C while in some deserts it can get down to below 0°C at night.** The temperature also varies greatly depending on the location of the desert.

Continental Climates

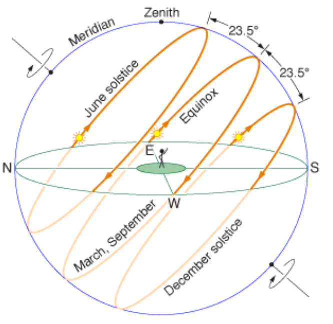
Continental climates are characterized by distinct seasons and a large temperature range between summer and winter. It typically occurs in the interior regions of large land masses, far away from the moderating influence of oceans or large bodies of water.

Summers can be relatively warm or hot, with temperatures frequently exceeding 30°C. Winters are typically cold (15°C to -7°C), with temperatures dropping below freezing, and heavy snowfall is common.

REFERENCE:
NASA. (n.d.). *Desert: Mission: Biomes*. NASA. https://earthobservatory.nasa.gov/biome/biodesert.php

02 GENERALITIES

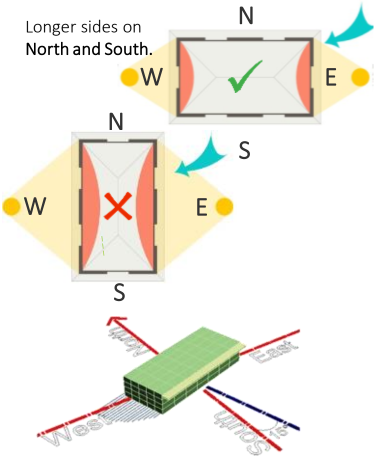
BUILDING CONDITIONS



ORIENTATION & LAYOUT

The Latitude, orientation and interior layout of a building are crucial to effective passive cooling design because they define how the building is positioned in relation to the sun's path in different seasons. Proper orientation and layout can be optimized to minimize or eliminate solar exposure through openings (windows) and thermal absorption through thermal masses (walls).

For existing buildings, it is recommended to consider repurposing certain areas of the building based on their solar exposure. Additionally, shading exposed walls and openings with shading devices or painting of exterior exposed walls white will increase thermal comfort. **E.g. use south-facing rooms for daytime activities and north-facing rooms for bedrooms where cooler conditions are preferred.**



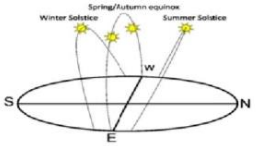
Slight orientation of **15° east of south**

North-South Orientation

As the sun rises in the East and sets in the West, the orientation of a building becomes crucial in managing solar exposure and heat gain. **The amount of sunlight a building receives varies depending on its latitude,** particularly with regards to the South and North inclination. To achieve optimal results, new buildings should have longer walls facing North and South.

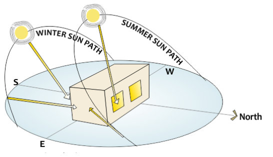
Facing the South allows a larger portion of the building to effectively absorb the sun's heat energy. On the other hand, **West-facing walls receive intense radiation during the hottest part of the day,** leading to excessive heat inside the building during the summer months. To mitigate this, it is recommended to limit the number of windows on the western side. Additionally, a slight deviation of around 15° east of South can reduce solar heat gain, which allows the western side of the building to absorb less radiation.

Near the **equator,** the sun's position remains relatively consistent throughout the year. It is **almost directly overhead during the equinoxes,** resulting in near-perpendicular angles of the sun's rays (around **90 degrees**) during midday.

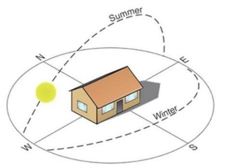


Tropical zone

Along the **Tropic of Cancer,** the sun's position changes more noticeably throughout the year. During the **summer solstice,** the sun is at its **highest point,** with angles of the sun's rays approaching perpendicular (around **90 degrees**) or slightly tilted towards the north. During the **winter solstice,** the sun appears **lower in the southern part of the sky**, resulting in shallower angles of the sun's rays (**around 30 to 45 degrees** or even lower) depending on the latitude.



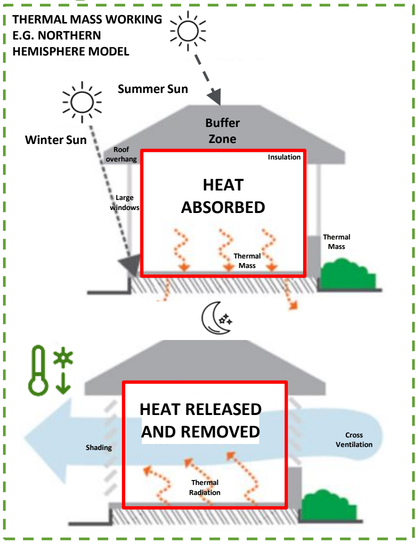
Along the **mid-latitudes** , the sun's position changes throughout the year. During the summer solstice, the sun is at its highest point in the sky, resulting in longer daylight hours and a more direct angle of sunlight. During the winter solstice, the sun is at its lowest point, leading to shorter daylight hours and a shallower angle of sunlight. During the equinoxes, the sun is positioned directly over the equator, resulting in roughly equal day and night lengths.



02 GENERALITIES

CLIMATE BASED SPECIFICATIONS

PASSIVE HEAT GAIN



THERMAL CONTROL

Thermal mass **is the ability of a building material to store and release energy,** it is crucial for achieving passive heat gain (passive solar design) in climate conditions where warmth is needed; for new buildings or adaptations it is important to strategically consider the materials, location and thickness.

It is a **quick absorber of solar heat,** preventing overheating at the most intense sun hours, effectively storing this solar heat for later use. During the cooler hours after sunset, **it gradually releases the stored heat,** providing a comforting warmth inside the building.

Depending on the latitude, ***during winter,*** *thermal mass stores solar energy collected during the day. This stored energy provides a warming effect inside the building. Conversely,* ***in summer,*** *proper ventilation allows the heat energy to be driven out of the building, offering a* *<u>cooling effect.</u>*

Lightweight building, encouraging constant air circulation.

Tropical Climates | Hot humid

The use of thermal mass is the most challenging in this environment, as it is not needed because **night temperatures remain elevated.** Considering lightweight materials and permeable surfaces that still contemplate sanitary standards will help regulate humidity levels. However, if existent, it needs to be strategically located to prevent overheating. **It should be placed in an area that is not directly exposed to solar gain and also allows adequate ventilation at night.**

When adapting a building, it is crucial to identify the existent thermal mass and consider modifications such as **openings,** when possible, to let the air flow and create permeable spaces.

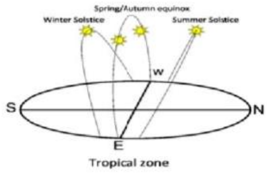
Massive building, blocking heat and encouraging air circulation.

Arid Climates | Hot dry

Continental Climates | Cold Winters

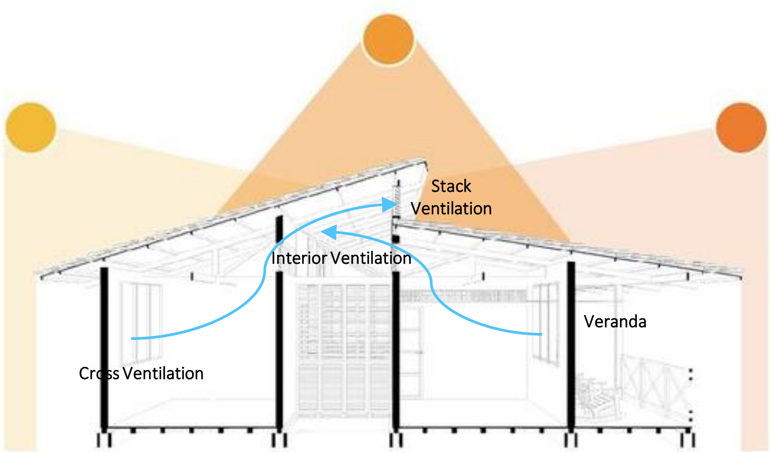
These environments require the strategical use of thermal mass to exploit the thermal qualities of materials. **High volumetric capacity and wall thickness should be considered.** To prevent heat from reaching the interior during hot periods, openings and shading are recommended, as thermal mass shaded from the sun, absorbs energy from the air cools down as it moves over it, cooling the space. So smart positioning of openings can thereby act like a natural cooling system, regulating temperature highs and lows to achieve thermal comfort. On the other hand, during cold periods, thermal mass exposed to the sun during the day will store the heat collected from the sun and release it inside over night while glazing also plays an important role to store this heat.

02 GENERALITIES

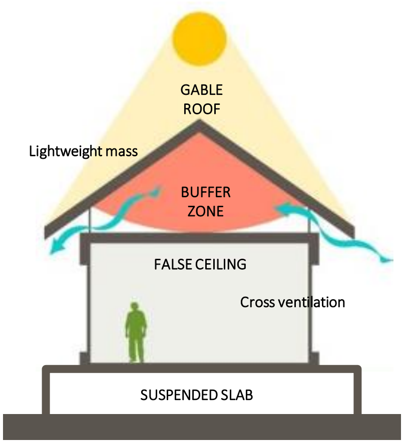


THERMAL CONTROL:

TROPICAL CLIMATES | HOT HUMID, EXAMPLES



Cantor, T. & Vanegas, D. / Yopal, 2016

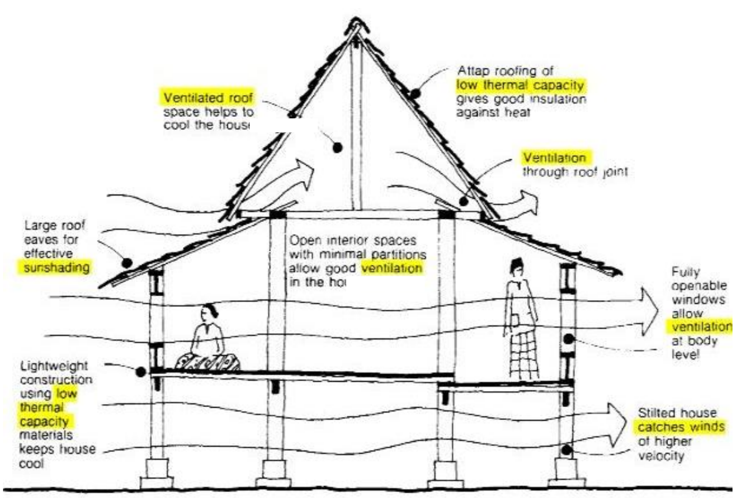


Passive cooling for tropial climates, basic principles.

The design for **tropical climates** requires to optimize the ventilation and reduce direct heat gain, by building with lightweight materials and shading with **large eaves** to protect it from the direct incidence of sunlight on the **eastern-western facades.**

Cross ventilation or Stack ventilation is required to maintain a comfortable internal space through natural ventilation, raise the building, locate openings in the facades and in the central corridors to force the hot air out due to pressure difference on the roof.

PASSIVE COOLING

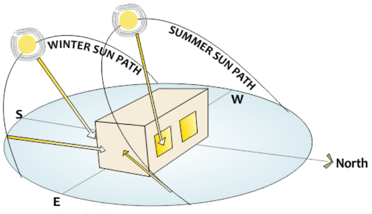


Malay building Prototype

Reflective Roofing: Choose light-colored or reflective roofing materials to reduce heat absorption and minimize heat gain.

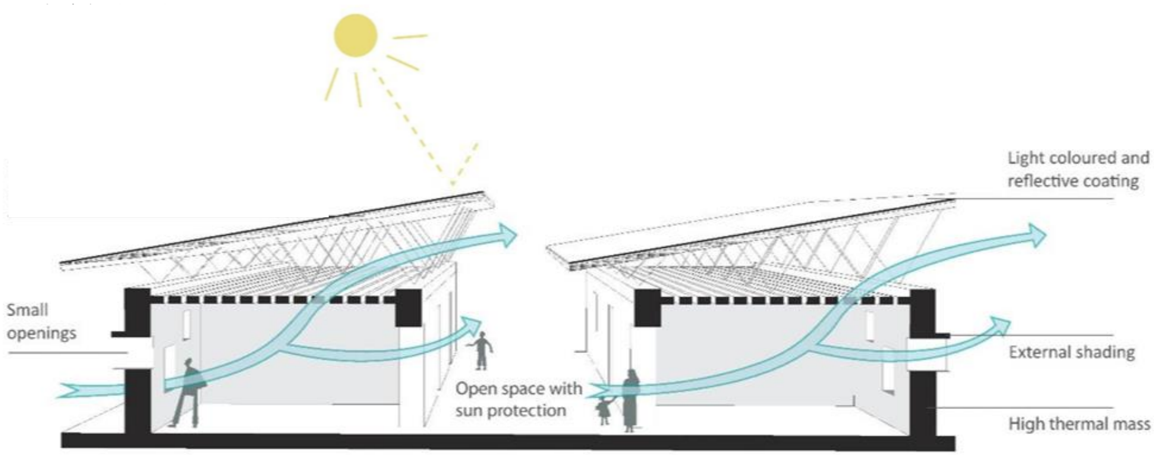
Lightweight structures with low thermal capacity are needed to maintain spaces cool and ventilated, enhancing **natural ventilation** and shading facades.

02 GENERALITIES



THERMAL CONTROL:

ARID CLIMATES| HOT DRY, EXAMPLES

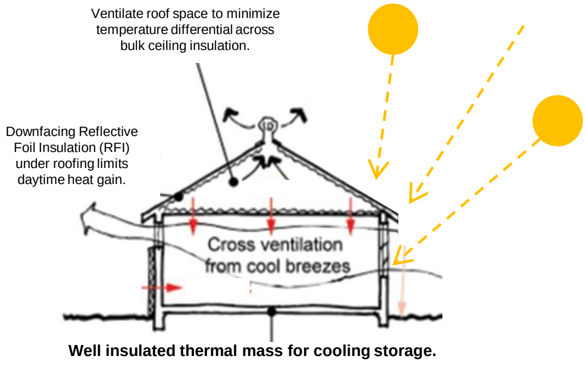


Open building type in hot-dry climates (Source: PEEB. 2019)

In this design approach, the buildings are **compactly arranged, emitting shadows on each other's facades,** with **thick walls** that serve as **effective heat barriers during peak daytime.** The roofs include **thermal insulation, reflecting solar heat with light-colored coatings** and incorporating **natural ventilation underneath,** while ample shading, including **generous awnings and roof overhangs,** as well as external shading elements, minimizes solar radiation on facades and windows. To enhance air circulation, small louvre or shutter windows are utilized, while optimizing window-to-wall ratios to **prevent excessive solar gains.**

PASSIVE COOLING

Minimize solar gain by using reflective insulation for roofs



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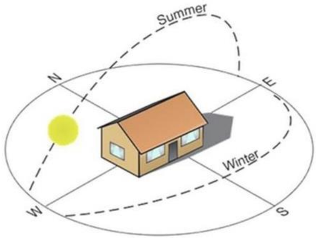
GENERALITIES



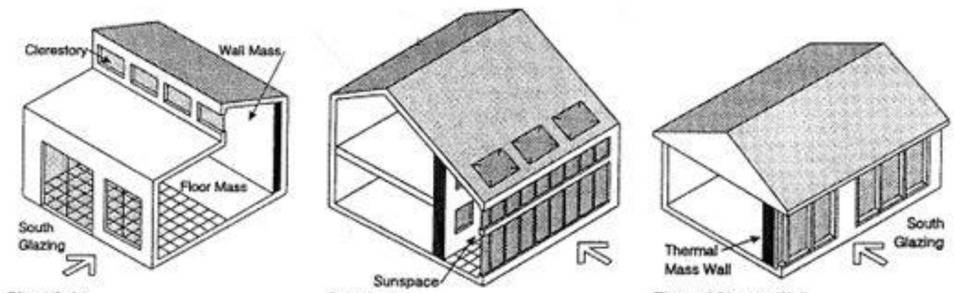
PASSIVE COOLING

PASSIVE HEAT GAIN

THERMAL CONTROL:

CONTINENTAL CLIMATES| COLD WINTERS, EXAMPLES

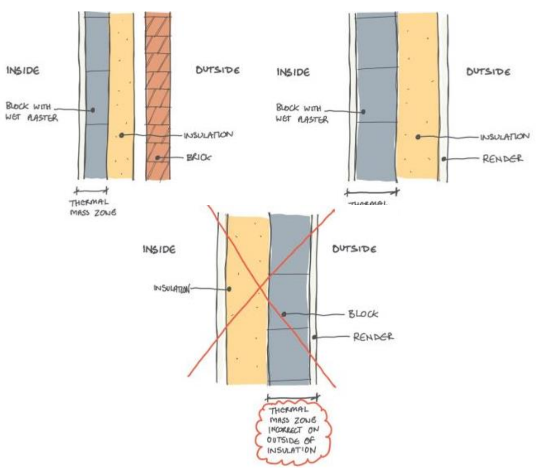
Distribute the thermal mass throughout the room. In direct gain systems, the primary collection mass is placed in direct sunlight. In addition to this mass, comfort is improved if mass is distributed evenly around the room because localized hot or cold spots are less likely to develop. Performance is relatively the same whether the mass is located on the east, west or north walls, or in the floor. The mass should be distributed over an interior surface area approximately equal to six times the solar glass area.



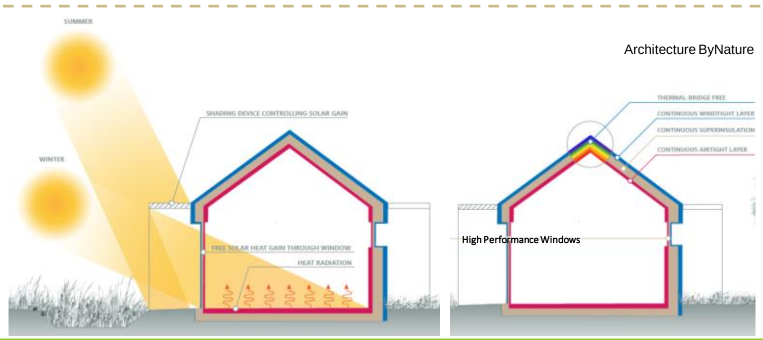
Direct Gain
Direct gain is the most common passive solar system in residential applications

Sunspaces
Sunspaces provide useful passive solar heating and also provide a valuable amenity to homes.

Thermal Storage Wall
A thermal storage wall is an effective passive solar system, especially to provide nighttime heating.



Effective construction is essential for achieving optimal thermal mass performance. Thermal mass works in cycle with insulation, with the thermal mass typically positioned on the interior side. For instance, in a cavity wall, insulation fills the cavity while the inner blockwork acts as thermal mass. The same principle applies to floors, where insulation is placed beneath the floor slab for best results.



20, E. on A., & Name. (2020, July 30). *Building fabric 06 – thermal mass*. First In Architecture. https://www.firstinarchitecture.co.uk/building-fabric-06-thermal-mass/

02 GENERALITIES

BUILDING CONDITIONS

RADIATION CONTROL

Building materials can **reflect, transmit, or absorb the solar radiation.** In addition, the heat produced by the sun causes **air movement** that can be optimized when designing spaces. These basic responses to solar heat should be addressed into design elements, material choices and placements that can provide heating and cooling effects in a space.

Insufficient consideration of solar control within a building can result in **overheating** due to **inadequate thermal mass,** leading to **rapid heat loss,** causing the space to become excessively hot when exposed to sunlight and excessively cold in its absence.

*Building materials can reflect, transmit, or absorb the solar radiation. In addition, the heat produced by the sun causes **air movement** that can be predictable in designed spaces. These basic responses to solar heat lead to design elements, material choices and placements that can provide heating and cooling effects in a building.*

WALLS

In continental climates, generally, shading for **South** openings must allow penetration of the **low angle sun for heat gain during winter** but must **prevent penetration of the high sun angle during summer**. Solar radiation on **East and West** facing openings does not vary much by the seasonal variations in the sun path. **They can be a significant source of heat gain and glare year-round,** because of low morning and evening sun angles as they receive uniform solar radiation, while compared to north and south facing openings.

There are several strategies to address these issues:

1. Limit the area of east- and west-facing glass.
2. Use wide overhangs.
3. Use glass that blocks solar heat.

ROOFS

The **large eaves** of the building protect it from the direct incidence of sunlight on the **eastern-western facades.**

- Windows facing within about 30° of true south can be shaded with properly sized overhangs.
- Off-south wall orientations reduce overhang effectiveness.

Stack ventilation effect: To maintain a comfortable internal space through natural ventilation, raise the building, locate openings in the facades and in the central corridors to force the hot air out due to pressure difference on the roof.

Roof turbines in hot climates offer benefits like cooling through heat ventilation, moisture control to prevent mold, improved air quality, extended roof lifespan, reduced heat transfer, natural cooling using wind, low maintenance, environmental friendliness, and cost-effectiveness.

02

GENERALITIES

BUILDING CONDITIONS

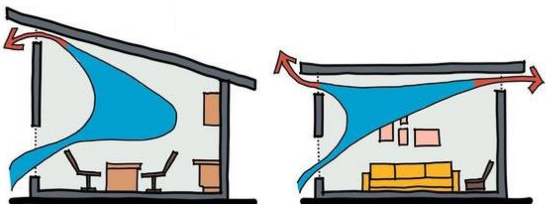
AIR CONTROL

Well-positioned Openings, Stack Ventilation and Cross Ventilation

In a hot climates, **wind direction is the most critical factor** that will provide thermal comfort. Even though the temperature is high, the wind movement and breeze collection can make you feel comfortable. So, **passive cooling strategies** are very important criteria for designing buildings in these contexts. Based on the latitude and weather conditions, study the possibility to incorporate openings to the building's roof or walls, as **hot air rises up.**

WALLS

Cross Ventilation



To enhance **cross-ventilation,** it is beneficial to incorporate **larger openings.** However, it is crucial to **ensure proper shading** for these openings to prevent direct solar radiation from penetrating the interior of the structure. When windows lack shading, it is recommended **to limit the glass area to 15% of the facade's total area and incorporate shading devices, as necessary**. These shading devices play a vital role in ensuring visual and thermal comfort while minimizing the need for mechanical cooling.

When designing, it is important to consider the orientation of the facade. **Minimal or no shading is required for the north orientation,** while **shading horizontal** devices for the **southern orientation** should be carefully designed based on an analysis of the sun's path.

Block excessive ventilation during the hottest parts of the day. This helps prevent the entry of hot outdoor air and dust into the building.

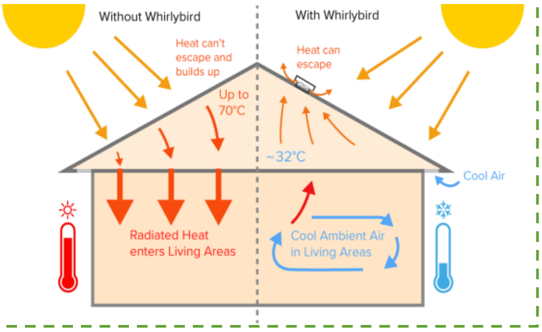
During cooler evenings and nights, when temperatures drop, **enabling natural ventilation is essential** to flushing out accumulated heat and promoting cooling.

ROOFS

Stack Ventilation

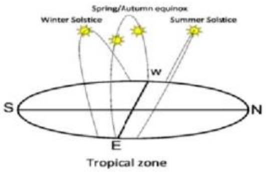
Hot air escapes through ceiling
Maximum use of Stack-Ventilation to make hot air rise up and resist the cool air from escaping.

This method takes advantage of temperature differences and relies on **warm air rising and being replaced by cooler ambient air.** It is useful for passive cooling in areas with large temperature variations. **Whirlybirds Turbines** help exchange warm indoor air with cooler outside air during the night, providing an effective cooling solution.



For cool air entrance: Windows, louvers, open facades.
For warm air exit: Roof vent, higher window openings, facade offset from the ceiling.

02 GENERALITIES



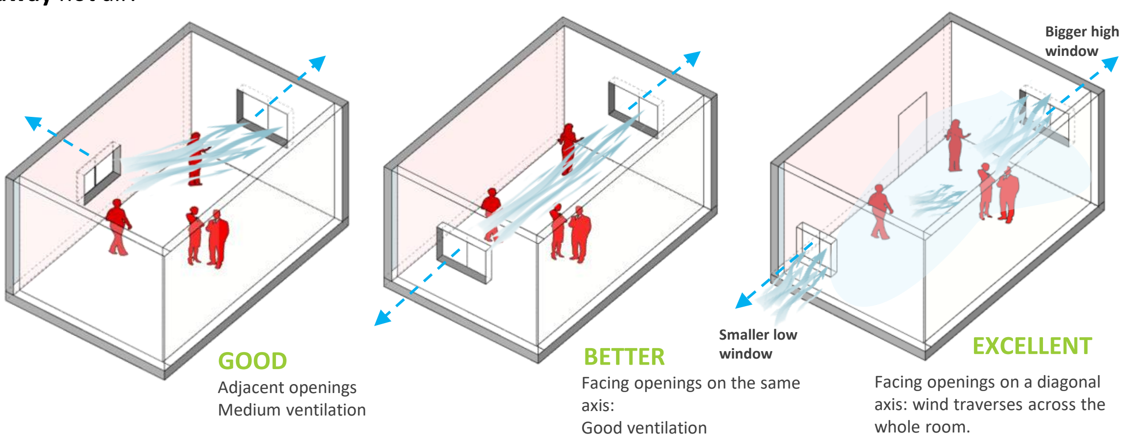
AIR & RADIATION CONTROL:

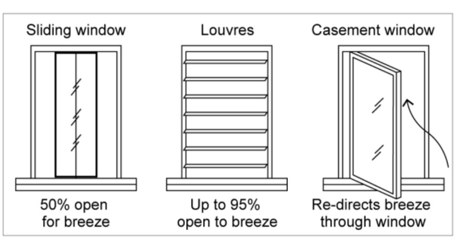
TROPICAL CLIMATES | HOT HUMID, EXAMPLES

CROSS VENTILATION

Window size and position are major factors for Passive Cooling.

When air moves across the spaces it will also begin to **pull hotter air out of it.** If windows on **the lower level** are opened and allow the **hot air to rise,** when it moves out of the space, the flow will also take the hot air radiating down from the attic with it. Natural ventilation actually **cools the space down as it pulls away** hot air.





Source: Dept of Environment and Resource Management, Qld

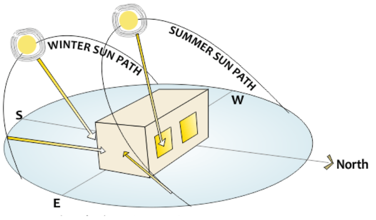
For breeze collection, **window design is more important than orientation.** Aim for long, narrow structures with opposite and large openings on the longest sides of the building so the cross-breeze has minimal obstructions.

Create inlet and outlet openings at different heights in stack ventilation shafts to remove warm air from inside and draw cool air inside.

NATURAL VENTILATION RECOMMENDATIONS

- Open windows during the cooler parts of the day and night, such as early morning and late evening, to allow fresh, cooler air to enter the building.
- **Cross-Ventilation:** Position windows on opposite sides of a room or building to create a pathway for air to flow through, promoting better ventilation.
- **Stack Effect:** Design the building with high openings or vents near the roof and lower openings at ground level to encourage the movement of warm air upwards and its replacement with cooler air from below.
- **Suspended slab** for air movement.

02 GENERALITIES

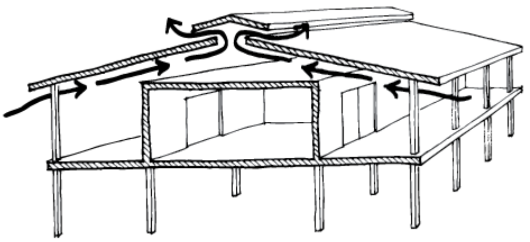


AIR CONTROL & RADIATION CONTROL:

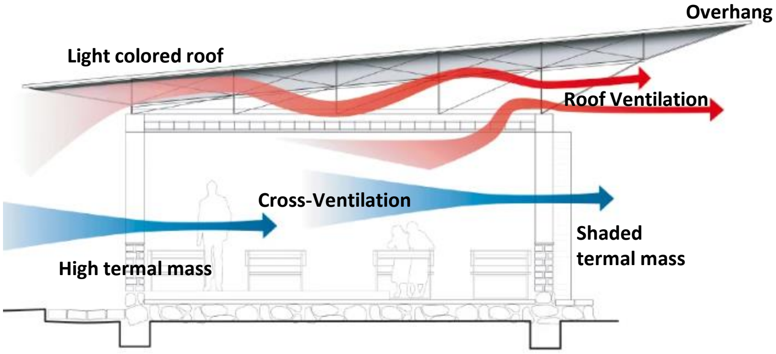
ARID CLIMATES | HOT DRY, EXAMPLES

*Depending on the season, it may be necessary to **block natural ventilation during daytime** (when the outdoor temperature is very high) and to **enable natural ventilation only during the night.***

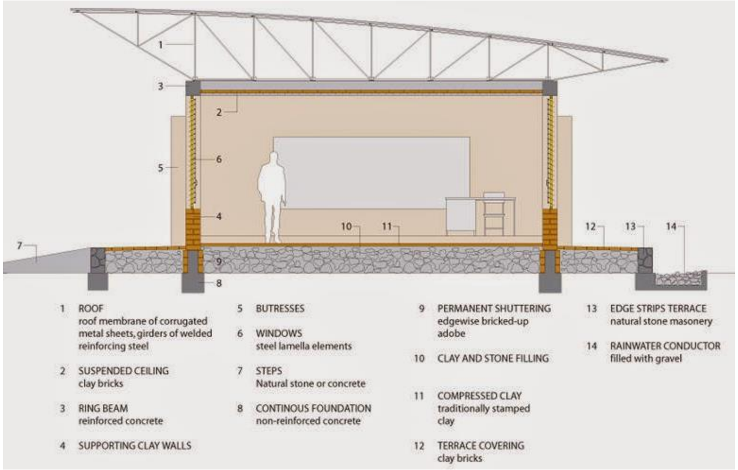
USE OF VERANDA



In these climates, the best weather conditions for veranda use are during the early mornings, late afternoons, and evenings when temperatures are relatively cooler, and the sun's intensity is reduced. They offer protection from harsh sun, high temperatures, and occasional sandstorms or dust. They serve as a barrier, enhancing the durability of building materials and reducing maintenance needs.



Dano High School, Kéré Architecture, 2006-2007.



OPERABLE WINDOWS

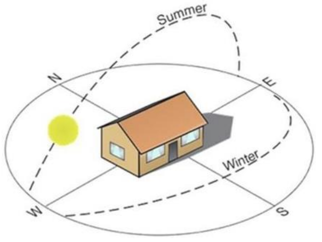
Use operable windows and openings that can be easily adjusted to control the amount of airflow. Louvers, vents, and adjustable openings are valuable for directing and controlling air movement.

SHADING

Provide shading devices such as overhangs, pergolas, and shade structures on the south and west facades. These can block direct sunlight during the hottest parts of the day while allowing for passive cooling.

- ***Take advantage of cooler nighttime temperatures by allowing for natural ventilation. Design windows that can be safely left open during the night to cool down the indoor spaces.***

02 GENERALITIES

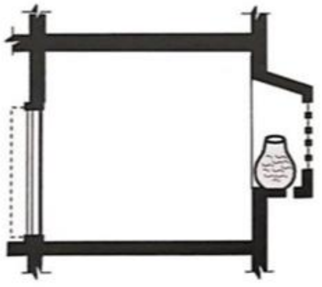


AIR & RADIATION CONTROL:

CONTINENTAL CLIMATES | COLD WINTERS: EXAMPLES

During **summer,** it's generally better to **block excessive ventilation** during the hottest parts of the day to prevent the entry of hot outdoor air with shading strategies.

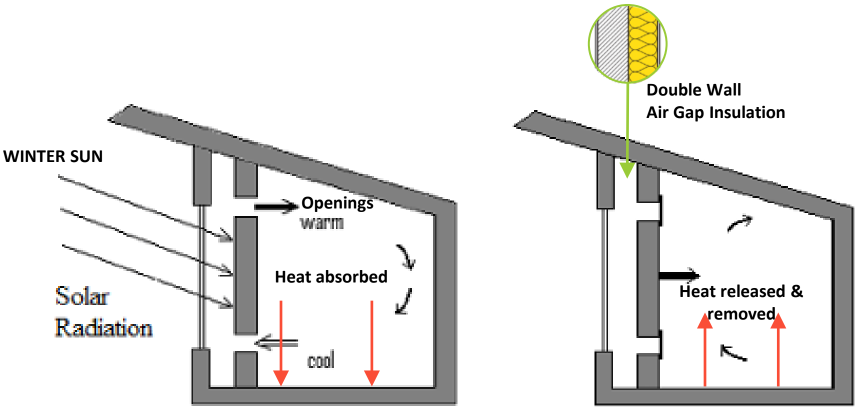
During **winter,** enabling natural ventilation during the warmer parts of the day. So solar gain will warm the building during the day. However, during **extremely cold periods, ventilation should be minimized** to prevent heat loss.



EVAPORATIVE COOLERS

Using evaporative coolers in hot dry climates is effective because it's energy-efficient, cost-effective, environmentally friendly, ***adds moisture to dry air, mimics natural cooling, improves air quality, promotes ventilation, and is a sustainable cooling option.*** It's important to note that its effectiveness diminishes in humid areas, and **regular maintenance is needed.**

Use wood as thermal breakers *for the windows, to prevent cold air at night, and reduce thermal gain in summer.*



Daytime - vents are open, wall stores heat and heats room

Nighttime - vents are closed, wall heats room

02 GENERALITIES

BUILDING CONDITIONS: **INSULATION**

Insulation highly **depends on the context**, climate, function and availability to **achieve effectiveness**. In hot climates, insulation is sometimes necessary to achieve interior thermal comfort. The table below shows the different types of insulation materials that should be taken into consideration before deciding which material to use for insulation, along with the context-based conditions. These insulation materials can be used to insulate walls, floors, roofs and other structures.

Check out MSF OCB "Thermal Insulation: Quick reference catalogue"

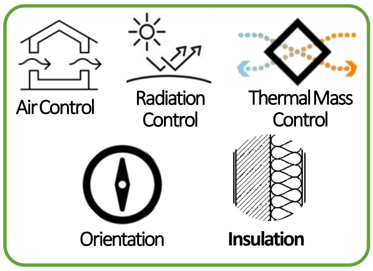
MATERIAL	FORM	INSTALLATION	ADVANTAGES
Fiberglass; Mineral wool Plastic fibers; Natural fibers	Batts and rolls	Unfinished walls; Foundation walls; Floors; Ceilings	Suited for standard stud and joist spacing that is relatively free from obstructions. Relatively inexpensive
Cellulose; Fiberglass; Mineral wool	Loose fill and blown-in	Enclosed existing wall or open new wall cavities; Unfinished attic floors; Other hard-to-reach places	Good for adding insulation to existing finished areas, and irregularly shaped areas
Polystyrene; Polyisocyanurate; Polyurethane; Phenolic	Foam boards	Unfinished walls; Foundation walls; Floors; Ceilings; Unvented low-slope roofs	High insulating value for relatively little thickness. Can block thermal short circuits when installed continuously over frames or joists.
Cementitious; Phenolic Polyisocyanurate; Polyurethane	Sprayed foam	Enclosed existing wall; Open new wall cavities; Unfinished attic floors	Serving as **thermal bridges*** reducer, Good for adding insulation to existing finished areas, and irregularly shaped areas
Fiberglass; Mineral wool	Fiber insulation	Ducts in unconditioned spaces; Other places requiring insulation that withstand high temperatures	Can withstand high temperatures

* **Thermal bridges**, also known as cold bridges, are weak points (or areas) in the building envelope which allow heat to pass through more easily. They occur where materials which are better conductors of heat are allowed to form a 'bridge' between the inner and outer face of a construction

02 GENERALITIES

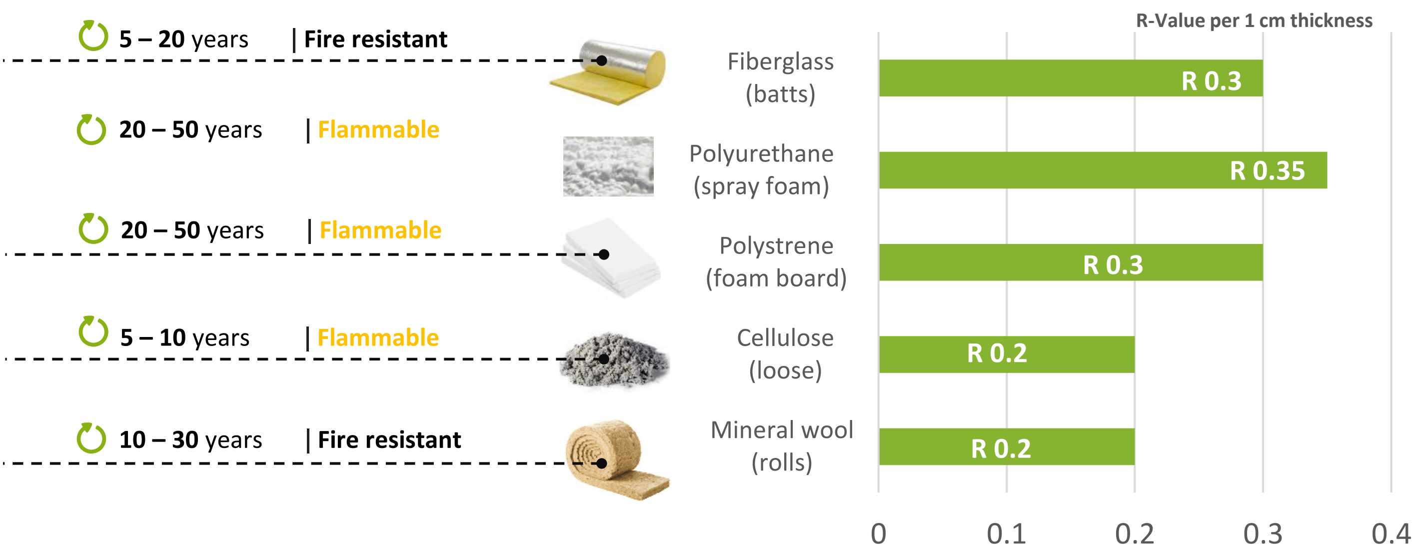
BUILDING CONDITIONS: INSULATION

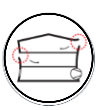
PASSIVE DESIGN STRATEGIES
New Buildings & Adaptations



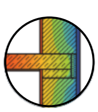
These concepts are most useful when the outside temperature is both above and below the desired indoor temperature during a normal 24-hour cycle. **If the outside temperature stays warmer or stays colder than the indoor temperature, insulation would be most ideal to focus on.** This is because the basic function of an insulation material is to **obstruct or delay heat transfer** which can happen via any combination of the three basic modes of heat transfer: conduction, convection, and radiation. A **properly insulated building** stops heat flowing into or out of the building.

R-Value: the measurement of an insulation material's thermal resistance. **Properties of the different insulation materials . Lifespan, fire resistance, and their R-value.**

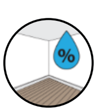




AIRTIGHTNESS
Continuous insulation throughout the entire building enclosure helps to reduce a buildings heating and cooling needs and improves comfort.



THERMAL BRIDGE ELIMINATION
Eliminates "cold corners," minimizes risk of mold growth on the interior, and improves comfort.



MOISTURE CONTROL
Manages indoor humidity through ventilation, insulation, and material choices. It prevents issues like mold and condensation, ensuring a comfortable and durable indoor environment.

Insulation Material	Price Sq./Ft.	Eco friendly	Notes
Fiberglass	$	+/-	Does not absorb water
Polyurethane Foam	$$$	-	Makes a great sound insulator
Polystyrene (EPS)	$	-	Difficult to use around imperfections
Cellulose	$$	+	Contains the highest amount of recycled content
Mineral Wool	$$	+/-	Does not melt or support combustion

02 GENERALITIES

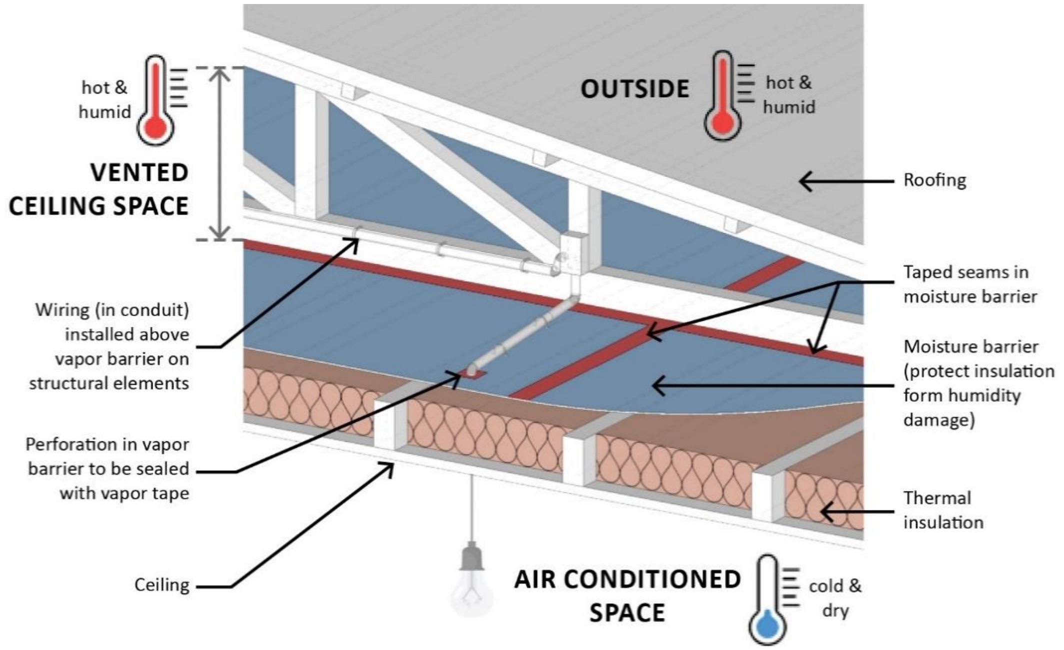
BUILDING CONDITIONS: **INSULATION AND MOISTURE BARRIER**

PREVENTING CONDENSATION
Condensation occurs when warm moist air gets in contact with a colder surface. It can easily occur inside a wall and quickly deteriorate the insulation, building materials and promote mold and bacteria growth if the wall has not been properly designed or built. In air-conditioned (cooled) spaces or climates with cold winters, careful attention must be paid to the choice of wall layering and to the quality of the works. Generally, in such situations, insulation should be placed on the cold side of the wall, and an air or vapor barrier should be placed on the warm humid side of the insultation, but exceptions often do apply. It is highly recommended to consult your construction or HVAC referent for further support in such cases.

MOISTURE BARRIERS

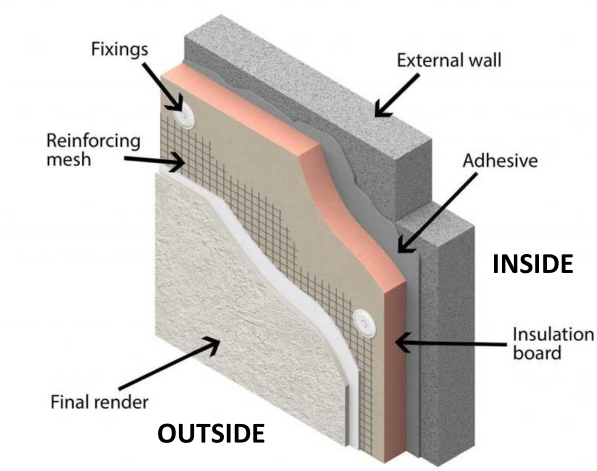
- Plastic sheeting can be used as an air/moisture barrier. It should be placed on the humid side of the insulation and should be continuous. It is critical that holes and seams are sealed. Such a barrier should never be placed on both sides of a wall or ceiling as this can trap moisture inside.
- PU or PIR panels can be used as both thermal insulation and moisture barrier, provided that the joints are sealed on the proper side (warm and humid side).
- In both cases, sealing of the joints can achieved effectively with good quality aluminum tape.

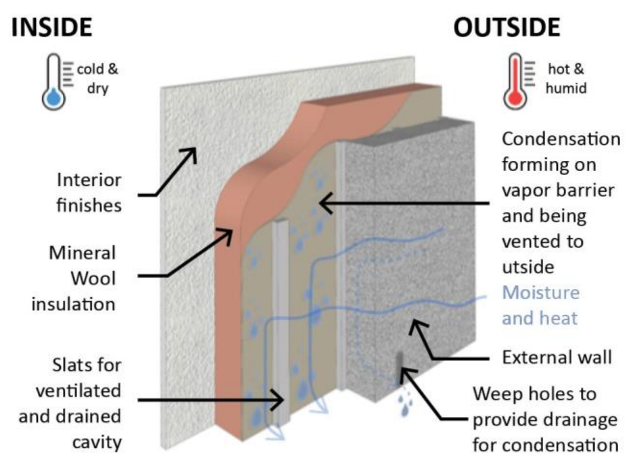
CEILING INSULATION



02 GENERALITIES

BUILDING CONDITIONS: INSULATION





EXTERNAL WALL INSULATION

<u>ADVANTAGES</u>

- Easier installation and more effective when insulating an entire building. (new or old)
- Typically results in less thermal bridging (for entire building)
- Increases your airtightness and reduces draughts.
- Insulation can be applied up to 300mm thick.
- Reduces the levels of street noise.

<u>DISSADVANTAGES</u>

- Requires a façade to protect the insulation from the elements
- Requires an external support structure
- Better suited for rigid insulation

INTERIOR WALL INSULATION

<u>ADVANTAGES</u>

- More cost efficient and effective when insulating one room in a building.
- Easier to install in existing suspended ceilings which is often the most cost beneficial insulating.
- Easy to install in wall cavities of existing wood structures
- More suitable to cost-effective fire-retardant insulations. (fiberglass)

<u>DISSADVANTAGES</u>

- hard to effectively insulate entire buildings for multi room buildings (thermal bridges)
- For existent buildings, it is difficult to install around existing electrical and plumbing components, skirting boards, door frames, paneling and other internal structures resulting in thermal bridges.

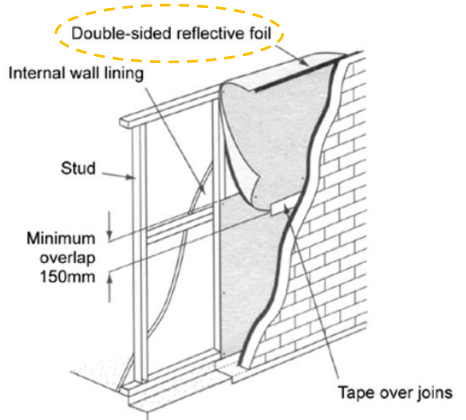
For best results, contact your construction referent to discuss the best approach for your situation

02 GENERALITIES

BUILDING CONDITIONS: INSULATION | *Climate specific*

TROPICAL CLIMATES | HOT HUMID

Lightweight structures and light colored surfaces are commonly used in these contexts, insulation is usually not needed. For specific cases, radiation or vapor barriers could be considered to control moisture.



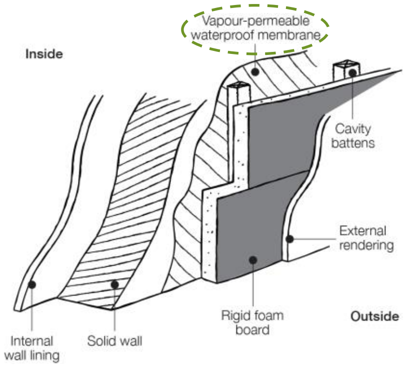
ARID CLIMATES | HOT DRY

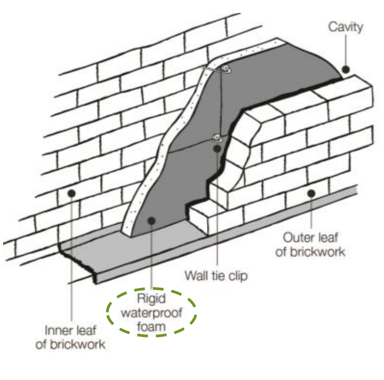
A radiant barrier (reflecting sheeting) is an effective solution in hot climates. It features a reflective surface that reflects radiant heat away from the walls, reducing heat gain.

It's important to note that the effectiveness of reflective foil insulation depends on the specific configuration and its ability to reflect radiant heat. Proper installation with an air gap on one side of the reflective foil is crucial to allow for effective heat reflection.

CONTINENTAL CLIMATES | COLD WINTERS

In regions with cold winters, the temperature difference between the warm indoor air and the cold outdoor air can lead to condensation forming within wall and roof assemblies. This can potentially lead to moisture-related problems, including mold growth and structural damage.





A **vapor barrier** is typically a plastic or foil sheet used for damp proofing to prevent interstitial condensation from forming in various building assemblies such as walls, roofs, foundations and floors. In a typical commercial building or home, vapor barriers or vapor diffusion retarders can improve energy efficiency and comfort, while also preventing problems from moisture and dampness.
(Source: U.S. Department of Energy.)

In cold climates, a vapor barrier is installed on the warm side of the insulation (usually the interior) to block the diffusion of moisture from entering the insulated assembly. This helps to maintain the integrity of the building envelope and prevents condensation from occurring within the walls or roof.

02 SUSTAINABILITY

SUSTAINABLE CONSTRUCTION

Sustainable construction comprehends a range of methodologies that involve factors such as material transportation, selection of locally sourced materials, engagement of local workforce, energy efficient processes and designs, and the incorporation of context-sensitive designs that consider orientation. These are integrated throughout every phase of both design and construction projects.

Promoting sustainable construction entails prioritizing **affordability and energy efficiency, while preserving the environment.** This involves using *locally available natural resources* to promote a construction process that minimizes environmental impact and amplifies material and product reusability, controlling waste. This sustainable approach not only resonates with ecological concerns but also supports the construction industry's resilience by obtaining materials from the local market.

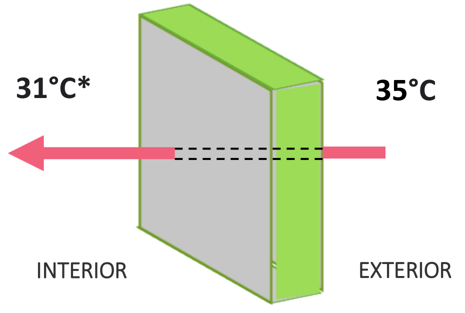
CONCRETE

While cement remains widely favored in the construction industry, it may not always represent the optimal or most environmentally sustainable choice due to its production process. The manufacturing of cement leads to the emission of CO_2 as a result of the thermal decomposition of limestone ($CaCO_3$) and the energy-intensive heating of the kiln. Although the heating energy could potentially be substituted with renewable sources, the emissions resulting from decomposition are inevitable.

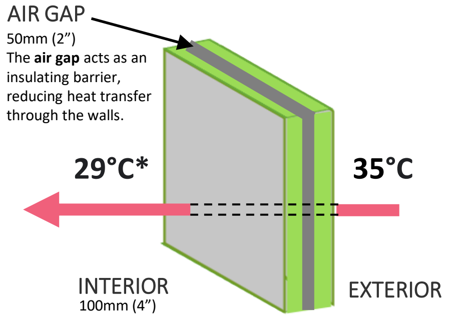
Relying on non-renewable resources is intrinsically unsustainable. Concrete production, requiring fossil fuels and finite sand and gravel, **emits CO_2 and decreases finite resources.** Hence, the prolonged use of concrete is not viable in terms of sustainability. Therefore, it is essential for the construction industry to minimize their use and optimize the effectiveness of the quantities used.

BCA Singapore. (Year). Sustainable Construction Materials. https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/sc_materials_book.pdf

02 MATERIALS



SINGLE WALL



DOUBLE WALL

WALLS

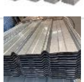
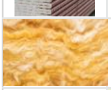
Depending on the latitude, the **thickness and materials for the walls must be considered for a better performance.** Generally, for **hot climates, the use of light colors on exterior surfaces will reflect the heat,** therefore, they are also chosen in interiors for their adaptability to temperatures.

The shown diagrams, expose how two types of walls work with temperature. The process of **heat transfer** through the building materials described as thermal **conduction,** and the value of heat transfer through a material is the **thermal transmission.**

The orientation of the building in relation to the sun's path will influence the wall's dimensions. **For buildings with more significant east-west orientation, a double wall with an air gap** can be particularly effective in reducing heat gain during peak sun exposure periods.

- **Thermal conductivity** is a property that describes a material's ability to conduct heat. It is often denoted as *k* and has the SI units of W/m·K (Watts per meter Kelvin). Thermal conductivity is a key parameter in measuring conductive heat transfer.
- Considering thermal mass on a daily cycle basis, the most effective depth of the material is the first 50 mm. Between 50 and 100 mm, efficiency further diminishes and beyond 100 mm the mass effect is largely inconsequential.

02 MATERIALS

	MATERIALS THERMAL PROPERTIES CHART					
	The higher the specific heat capacity and density are, the better the thermal mass performance will be.					
	The lower the thermal conductivity, the more effective the thermal insulation will be.					
	Thermal mass material	Specific heat capacity (J/Kg·K)	Thermal conductivity (W/m·K)	Density (kg/m^3)	Region of Production (MSF context)	Method of Production
	Sun dried clay bricks	1000	0.21	700	Worldwide	Manual
	Compress earth block	650-850	0.8-0.95	1700-2000	Africa, Asia	manual, mechanic
	Burnt clay brick ("cooked" brick)	800-900	0.73	1700	Worldwide	Manual, mechanic and industrial
	Engineered brick (extruded or perfurated)	400-800 (depends on design)	0.12-0.18 (can reach 0.07 if hollow parts are filled with rock wool)	1400-1600	EU, Balkans, NA, ME, in africa via importation	Industrial
	Adobe or rammed earth	800	0.57-0.59 (depends on the mixed materials)	1800-2200	Worldwide	Manual
	Hollow cement block	900	0.9-1	1800-1900	Widely used in Africa and ME, but also in EU, Balkans, SA, and Asia	Manual , mechanic and industrial
	Hollow cement block filled in with mortar	1000	163	2000	Widely used in Africa and ME, but also in EU, Balkans, SA, and Asia	Manual , mechanic and industrial
	Solid cement block (dense cement block)	1000	163	2300	Widely used in Africa and ME, but also in EU, Balkans, SA, and Asia	Manual , mechanic and industrial
	Cement plaster	800-1800	15-2.7	1400	Worldwide	Manual (mix and application)
	Reinforced Concrete	1000	113	2000	Worldwide	Manual (mix and application)
	Stone work	1000	18	2300	North Africa, ME, Asia	Manual
	Sandcrete block	800-1200	0.8-14	1800-2100	Widely used in Africa and ME, but also in EU, Balkans, SA, and Asia	Manual, mechanic and industrial
	Aircrete block	1000	0.15	600	EU, Balkans, ME	Industrial
	Galvanized steel/iron	480	45	7800	Worldwide	Industrial
	Timber (raw wood)	1200	0.14	650	Worldwide	Manual, mechanic industrial
	Plywood	1200	0.12	400-700	Worldwide	Industrial
	Gypsum plaster/board	1000	0.5	1300	EU, Balkans, ME, Asia, in africa via importation	Industrial
	Mineral fiber insulation	1000	0.035	25	EU, Balkans, ME, Asia, in africa via importation	Industrial
	•The numbers shown are symbolic and aim to compare the difference between the two wall types, as real values depend on wall thickness, material properties, and real climate context					
	•* **Thickness of walls** of different materials that give coefficients of **thermal transmittance** of approximately **1.163 W/m·K °)**					

02 MATERIALS

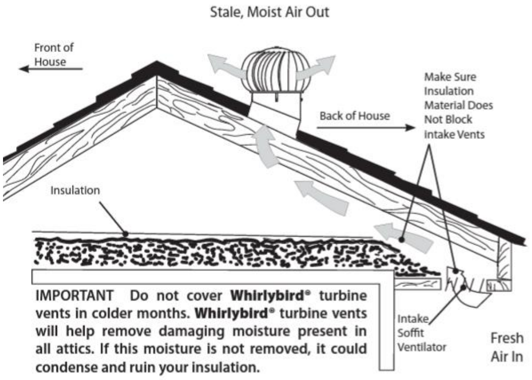
ROOFS

WHIRLYBIRD TURBINES

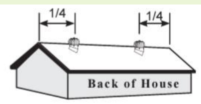
Wind turbines can be installed on various roofing materials and styles, including **metal, tile, asphalt, mansard, gable, and flat roofs.** However, it's important to note that whirlybird turbines may not be as effective in climates with extremely low wind speeds or highly variable wind directions. *(In such cases, other passive ventilation strategies, like natural ventilation through carefully positioned windows, may be more suitable.)* **If the vents don't spin, the ventilation system doesn't work.** Therefore, on summer days without wind, a whirlybird may not offer the relief a space requires.

When setting up whirlybird turbines for passive ventilation, **ensure specialized flashing on metal roofs to prevent leaks and curbs on flat roofs to divert water.** Incorporate proper **drainage** to avoid pooling, maintaining turbine function and roof integrity. Follow the guideline of **one turbine per 50 square meters for optimal ventilation coverage** (for standard 12" size turbines), enhancing airflow efficiency and overall comfort.

AIR CONTROL



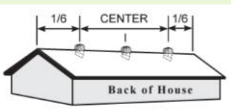
The ideal climate type for adding whirlybird turbines is generally characterized by consistent and moderate to strong wind patterns.



Proper Spacing With Two **Whirlybird®** Turbine Vents Installed

Whirlybird® turbine vents should be located near the peak of the roof on the rear slope, exposed to the wind from all directions. When installing two, place each one ¼ of the total length of the roof peak from each end of the house.

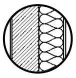
Example: On a 40' roof, each **Whirlybird®** turbine vent should be 10' from each end of the house.



Proper Spacing With Three **Whirlybird®** Turbine Vents Installed

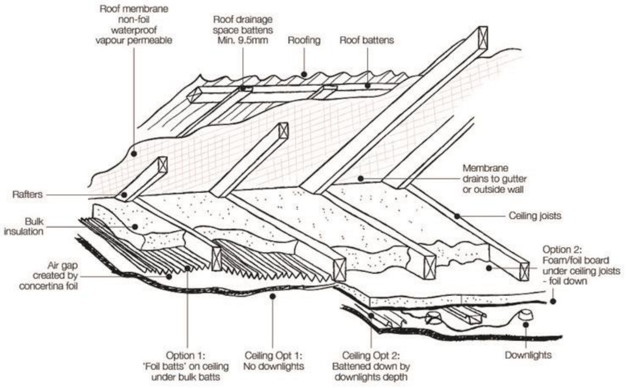
Whirlybird® turbine vents should be located near the peak of the roof on the rear slope, exposed to the wind from all directions. When installing three, one should be installed 1/6 of the total length of the roof peak from each end of the house and one should be installed in the center.

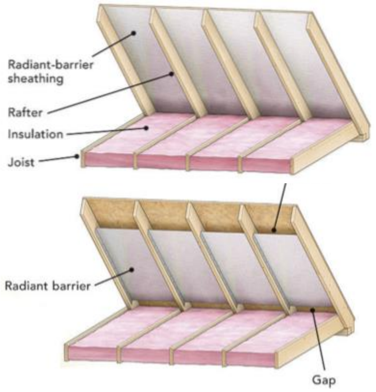
Example: On a 60' roof, the two outside **Whirlybird®** turbine vents should be 10' from each end of the house – and the center one should be 30' from either end of the house.



ROOF INSULATION — ARID CLIMATES | HOT DRY

Prioritize roof insulation as it is more effective in mitigating the impact of solar radiation during summer. Affordable options include **reflective roof coatings, shingles, and radiant barrier insulation.** Reflective coatings and shingles deflect solar heat, keeping the interior cool, while radiant barrier insulation beneath the roof prevents heat transfer. By focusing on cost-effective roof insulation, you can achieve efficient temperature control while considering budget constraints.





Reflective foil insulation can also be applied on the underside of the roof decking or on the rafters. This application prevents heat from penetrating the roof assembly and entering the living space.

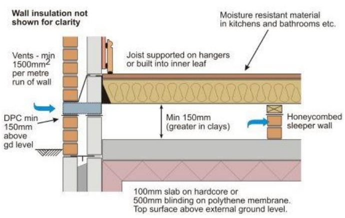
Avoid skylights unless openable and tinted.

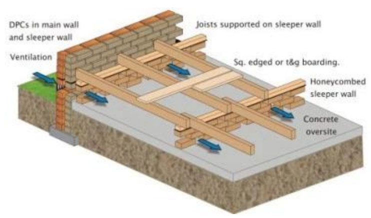
02 MATERIALS

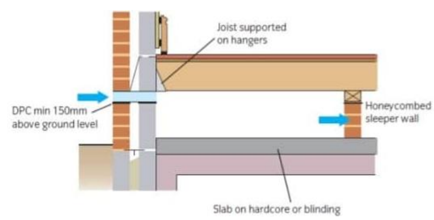
SLABS & FLOORING

In **hot climates,** prioritize slabs and floors that maintain comfortable temperatures and are durable and affordable. Options include **suspended slabs for ventilation specially in humid conditions,** insulated slabs and terrazzo flooring for thermal mass heat gain, ceramic tiles or polished concrete for durability and cooling, and natural stone floors. *Consider local availability, cost-effectiveness, and thermal properties. Incorporate insulation and ventilation strategies for energy efficiency. Consult with local experts for suitability in the specific context.*

TROPICAL CLIMATES | HOT CLIMATES



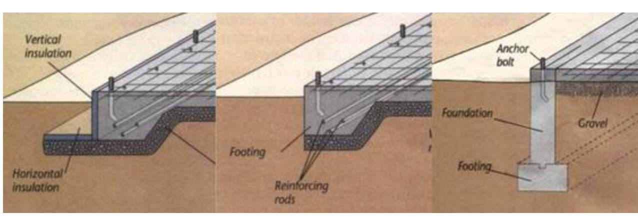




Source: https://thermohouse.co.uk/blog/suspended-floors/

Suspended Slab
A suspended slab, also known as a raised floor or elevated floor, can be an effective solution. By elevating the floor above the ground, it helps create a ventilated space beneath, allowing for natural air circulation and cooling. This can help mitigate the heat and humidity in the building.

ARID CLIMATES | HOT DRY



CONTINENTAL CLIMATES | COLD WINTERS

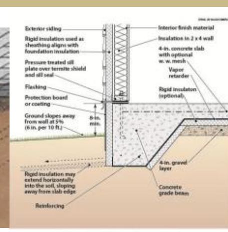


Figure 4-9: Slab-on-Grade with Integral Grade Beam (Exterior Insulation)

Slab on ground
Slab with thermal mass capacity that allows the absorption of heat during the day and lets it out during temperature changes in winter. During summer, insulation, shading techniques and natural ventilation should allow the building to stay cool.

FLOORING


STONE
(Terrazzo)


VINYL
(PVC LAMINATE WOOD, PANEL, TILE)


POLISHED CONCRETE


BAMBOO
(CARBONIZED/NON, STRAND WOVEN, CLICKLOCK SYSTEM)


WOOD
(NATURAL WOOD/ENGINEERED)

Tiled floors are ideal for hot climates for their durability and ability to withstand heat for a long time:

- For **hot and dry climates,** the dry heat air can damage certain flooring types, so you need to look for a material that can withstand warping and discoloration in the dry heat, like tiling.
- For **hot and humid climates**, porcelain tiles can withstand humidity much better than ceramic.
- Ensure the flooring professional installs expansion joints between each tile to accommodate humidity changes in the air especially with ceramic pieces.

02 MATERIALS

BUILDING CONSIDERATIONS

The use of materials directly affect indoor temperature and energy consumption, it is recommended to utilize **locally available, natural resources** as building materials and choosing materials with cooling properties. Materials that are lighter in color and thickness and consider insulation for colder temperatures.

BEST PERFORMANCE MATERIALS FOR SPECIFIC CLIMATES

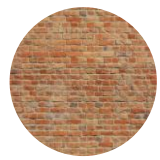
WALLS

*Walls of a building in an **arid environment** are more important than the ceiling (consider thickness for absorption and insulation for **cold winters).***

TROPICAL

Earth/clay, using local construction techniques such as rammed earth or adobe could be cost-effective

Sandcrete, locally available. manufacture could be for Solid blocks, hollow blocks. It could also be called cement block manufacture.



Clay bricks, easy to build in the field

DESERT / CONTINENTAL

Earth/clay

Compressed Earth Block (CEB) dry inorganic subsoil, non-expansive clay, sand, and aggregate.

Superadobe Block Polypropylene bags filled with a mixture of earth and lime are stacked on top of each other. The walls should be covered with three layers of dirt, lime, grass and manure.

ROOFS

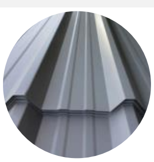
Choosing the material for the roof in hot climates is essential as the roof is the most exposed to the sun. Clay tiles have been known to stand up to the heat for centuries, regularly lasting as long as 50 years or more like Terra-cotta. Choosing light colored roofs will optimize their performance with radiation.

TROPICAL

*Lighter volumes and longer **roof overhangs.***

Grass/Thatch can provide insulation and protection from solar radiation, giving thermal comfort inside the building.
Consider fire prevention.

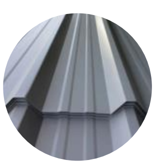
Terra-Cotta Tiles and Ceramic Roofs



Aluminum or galvanized Steel

DESERT / CONTINENTAL

Terra-Cotta Tiles and Ceramic Roofs are Ideal for hot climates. The curved shape allows air to circulate below the surface keeping roof and interior cooler.



Aluminum or steel are strong, lightweight materials with a long lifespan. It's resistant to snow, rain, and strong winds. To increase solar reflectivity and decrease heat absorption, light colors (white, silver) should be chosen when available, or reflective coatings can be applied existing roofs.

SLABS & FLOORS

Suspended slabs for tropical climates are recommended as it lets air flow.

TROPICAL

Timber is a locally sourced material, which makes it cost-effective. They are a sustainable and lightweight option.

Mud, made with clay, Grass/Thatch, sand, water and earth give the slab a structural condition and thermal qualities for hot climates.

DESERT / CONT

Terra-Cotta Tiles and Ceramic pavements are Ideal for hot climates.

CLIMATE BASED

CHAPTER SUMMARY

02 CLIMATE BASED SUMMARY

TROPICAL CLIMATE | HOT & HUMID

- **Air temperature:** Dry-bulb daytime average maximum between 27-35°C, occasionally higher. Diurnal range is generally narrow.
- **Humidity:** RH (Relative Humidity) remains high, at about 75% for most of the time, but may vary from 55 to 100%.
- **Precipitation:** Annual rainfall generally varies from 2000 to 5000 mm.
- **Sky conditions:** Cloudy throughout the year.

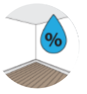
GENERAL STRATEGY

Air Control

- Increase air movement.
- Prevent moisture buildup indoors and improve thermal comfort.
- Increase night ventilation, using stack ventilation where hot air escapes and is replaced by cooler air, big windows for cross ventilation.
- Ceiling fans can be used to enhance the air movement.

Radiation Control

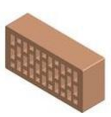
- Limit heat gain using **light-weight material structures.**
- Provide as much shading as possible to walls, roofs (highly ventilated plenum).
- Decrease the use of electric devices indoors and use recessed lightning if possible.



Moisture Control

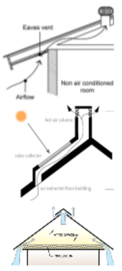
- Air conditioning in humid climates could enhance *condensation and moisture build-up in walls and ceilings.* Therefore, it is only recommended when temperature control is absolutely necessary; in such locations, **thermal insulation must be used on the interior side of the wall and an air or vapor barrier should be applied on the outside of the wall**

BUILDING ENVELOPE



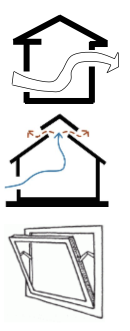
WALLS & SLABS

Porous walls are recommended to allow air to flow through the entire building. If **walls with high thermal mass** are used, include **shading from direct sunlight.**
Design suspended slabs for air flow.



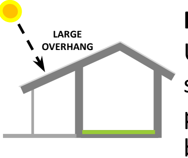
VENTILATION

Whirlybirds use thermal buoyance but mainly wind to discharge hot air and works with any wind direction.
Solar chimneys can be used to enhance stack effect.
Vented roofs are recommended to reduce moisture buildup and prevent overheating.



OPENINGS

Cross ventilation can be achieved by openings on opposite sides of the building.
Stack ventilation, vertical air movement is required to draw hot air out and replace it with cool air.
Operable windows can be used. Use windows with low U value and low solar heat gain coefficient.



ROOF/SHADING

Use **light colored roofing.** Extend shading areas as much as possible to provide shaded walkways around the buildings, and to limit direct sunlight on the building walls. All windows should be shaded.

02 CLIMATE BASED SUMMARY

ARID CLIMATE| HOT & DRY

- **Air temperature:** Dry-bulb day-time average maximum between 40 and 50°C, or between 25 and 35°C in the cool season. Diurnal range is very large between 15 and 25°C
- **Humidity:** RH varies from 10 to 55%
- **Precipitation:** is slight and variable throughout the year, from 50 to 150mm per year
- **Sky conditions:** Normally clear. Frequent dust storms may create a haze

GENERAL STRATEGY

Thermal Mass Control

- Consider the use of materials that will provide good thermal mass **inside** in order to absorb heat during the day, and to provide lower radiant temperatures, improving significantly the felt temperature and thermal comfort.

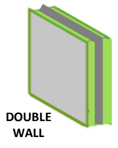
Radiation Control

- Limit heat gain by providing as much shading as possible to walls and roofs (highly ventilated plenum).
- Avoid electrical equipment in the used spaces as possible.
- Try to have as little air exchange as possible during the day since the outside air can be very hot.

Air Control

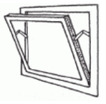
- For the thermal mass to be effective it's critical that the surfaces are **cooled during the night, when outside air temperature is colder.** As much natural ventilation as possible will have to be used during the night. Plan for rooms with opposite openings for **cross flow ventilation.**

BUILDING ENVELOPE



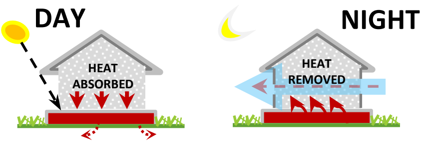
WALLS & FLOORS

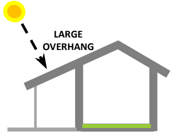
Heavy walls (brick, high density materials).
Double walls with an air gap.
Insulation is not needed, unless the space is air-conditioned (cooled). The space should also be **airtight and well sealed.**
Ceramic floor tiles are a good option for this climate.



OPENINGS

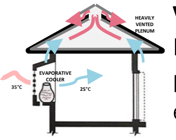
Minimize outside air circulation during the day, while ensuring **abundant nighttime natural ventilation.** Operable windows and/or scheduled mechanical ventilation can be used. **THIS IS ABSOLUTELY NECESSARY.**





ROOF/SHADING

Use **light colored roofing.** Extend shading areas as much as possible to provide shaded walkways around the buildings, and limit direct sunlight on the building walls. **All windows should be shaded.**



VENTILATION

In order to ensure air renewal while preventing hot outside air from entering in the building, natural coolers can be used to pre-cool (and filter) the air supply in the room. They work particularly well in this type of climate.

02 CLIMATE BASED SUMMARY

CONTINENTAL CLIMATE | HOT SUMMERS & COLD WINTERS

- **Air temperature:** Hot summers with dry-bulb temperatures above 35°C, and cold winters with occasional temperatures below 0°C. The temperatures vary a lot depending on the altitude.
- **Humidity:** RH varies from 10 to 55%.
- **Precipitation**: Differs a lot according to the topography but generally between 50 to 1000 mm per year.
- **Sky conditions:** Generally clear most of the year with isolated precipitations.

GENERAL STRATEGY

Thermal Mass Control

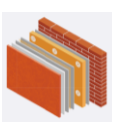
- Well insulated and well sealed thermal envelope to minimize heat transfer during both seasons.

Radiation Control

- **Heat gains:** Maximize heat gains during winter while minimizing them in the summer.

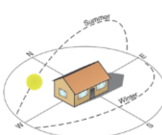
- *Specific design parameters must be carefully planned as they can either significantly improve the building performance, or they can largely deteriorate it, if poorly adjusted.*

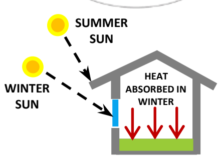
BUILDING ENVELOPE



WALLS

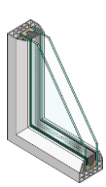
Heavy walls (brick, high density concrete, …) should be used combined with **external** insulation.





ROOF/SHADING

Use light colored roofing. Roof overhangs should be sized precisely to expose the windows to the sun rays during the winter while blocking them off in the summer. Operable blinds can be used but should be avoided if possible.



OPENINGS

Minimize outside air circulation during the day, while ensuring **abundant nighttime natural ventilation** during summer season.

Operable windows and/or scheduled mechanical ventilation can be used.

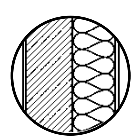
Use medium size windows with double glazing

VENTILATION

Heat recovery ventilation could be considered during winter season with airtight construction, to enhance indoor air quality while maintaining desired temperature.

FLOOR

High thermal mass floors are essential in this climate (thick concrete).



INSULATION

The walls and ceiling should be insulated.

Minimize thermal bridging in the choice of framing for the ceiling, as well as with the light fixtures. Insulation thickness should be at least **10 cm.** and the type should be rotproof, and durable.

Recommended insulation:

Hemp, Rockwool, Woodfiber

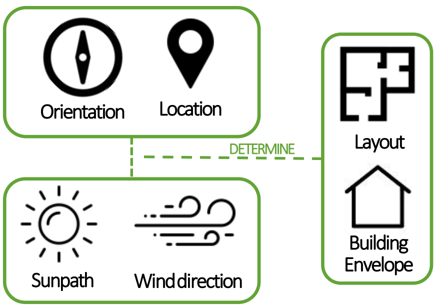
Avoid: Fiberglass insulation.

03 EXISTING STRUCTURES ADAPTABILITY

ALTERNATIVE WAYS

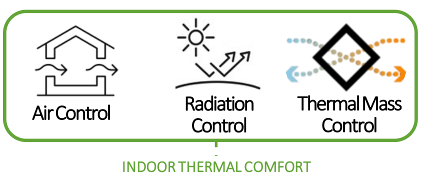
Passive design can be achieved through various simple measures, such **as shading, promoting natural ventilation, and maximizing natural light.** These measures primarily involve using shading elements, as well as **strategically arranging openings** and **optimizing the existent building orientation.**

1 SITE ANALYSIS



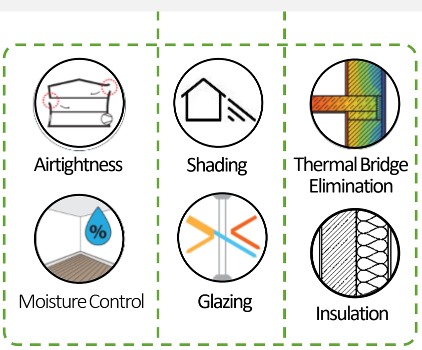
1. Gather all the **environmental information.**
2. **Study the building envelope and the interiors** by optimizing existing tools such as available data, drawings, materials used, and construction techniques.
3. **Identify the new project objectives** in terms of possible adaptations to improve energy efficiency, optimizing indoor comfort, and minimizing construction costs.
4. Analyze the **building envelope and orientation** to arrange the new layout based on the building's orientation. For the building's envelope, look for **air leaks, insulation gaps, and potential areas for improvement like openings and shading that are needed.**

2 PASSIVE STRATEGIES



By focusing on **low-cost passive design adaptations** and including **locally available materials and expertise,** sustainable and energy-efficient building projects could be created, considering the recommendations and strategies described in this Guideline.

3 APPROACHES



1. Retrofit external shading devices that best fit the environment, like awnings, pergolas, verandas, etc. to block direct solar gain during hot periods.
2. Use reflective coatings or films to the windows; on the building envelope adapt light colored walls and roofs.
3. Optimize cross ventilation by creating new openings or enhancing the existent ones, installing operable louvres, vents or whirlybirds for the roofs to promote air circulation.
4. Install insulation where needed.

Evaluate water usage and efficiency by identifying low-cost water-saving measures. Continuously monitor intervention performance to achieve intended objectives.

03 EXISTING STRUCTURES ADAPTABILITY

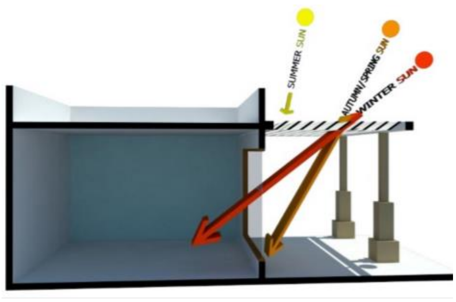
ALTERNATIVE WAYS | INTEGRATION OF SHADING

Shading of **south openings** is needed to prevent penetration of the high sun angle during summer (for upper hemisphere locations). Solar radiation on **east and west facing openings** does not vary much by the seasonal variations but is generally the most intense at lower latitudes due to its low angle. Shading of East and West openings is therefore important and effective in many cases.

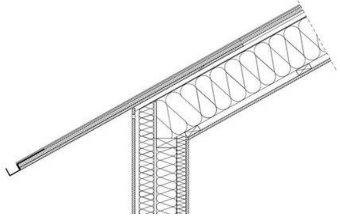
ROOF | WALLS

Elements	Variables	How to maximize their performance
Shading Devices	Horizontal louvers	Southern windows block high solar angles.
	Vertical louvers	East and west windows block low solar angles.
	Diagonal or eggcrate	Block low and high angles on east, south, and west directions.
	Overhangs, canopy	The depth and height, considering solar noon in summer and winter.
Device's variables	Space to depth	Depth-to-spacing ratio to balance between sunrays block and view out.
	Material	To reflect or to absorb sunrays.

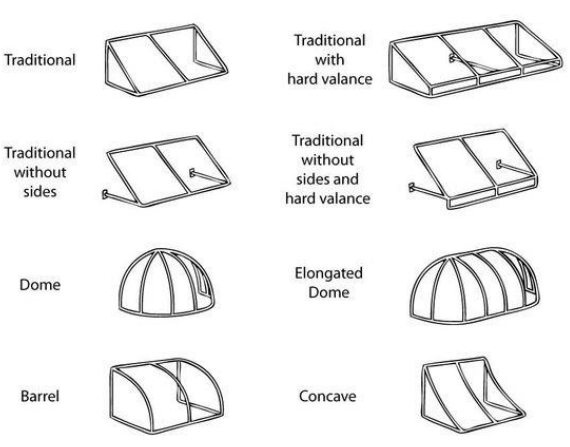
IMPLEMENTATION OF A VERANDA



OVERHANGS



AWNINGS



03 EXISTING STRUCTURES ADAPTABILITY

ALTERNATIVE WAYS | REINSTALLING INSULATION

1 Orientation · Location

The orientation of the building in relation to the sun's path will influence the wall's dimensions. For buildings with more significant east-west orientation, a cavity wall can be particularly effective in reducing heat gain during peak sun exposure periods.

2 Layout · Building Envelope

Once the building has been analyzed, rearrangement of the layout is the next step. Orientation will help to decide the location of the spaces in the building, some areas.

WEST

Rooms on the western side are cooler in the morning and tend to heat up in the afternoon hours.

Rooms that will be mostly used during the morning and afternoon, should be placed on the west side.

EAST

Rooms on the east side tend to be warm during the morning hours and cool down in the afternoon if it does not have much thermal mass.

Rooms that will be mostly used in evening hours can be designed on the east side of the building as this side remains cool in then, whereas storage areas can be placed on the west side.

NORTH-SOUTH

If provided with proper shading devices, rooms located in these locations remain cool.

Rooms that require lower exposure to direct sunlight, which helps to reduce cooling loads and improve overall comfort in hot climates.

3 INSULATION

Depending on the use of the space and location, the spaces will be optimized using insulation.

ROOF

- False ceiling
- Buffer zone
- Reflective insulation

WALLS

Interior

- Double wall with insulation.
- Internal insulation may reduce the wall's thermal mass, which can help regulate indoor temperatures.

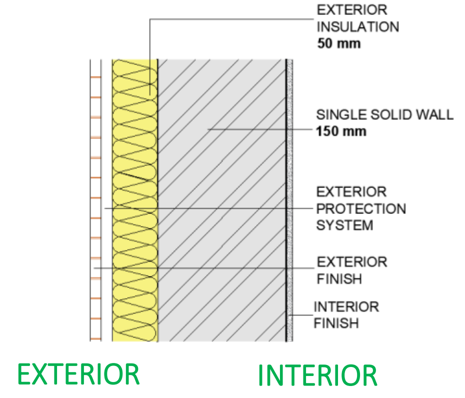
Exterior

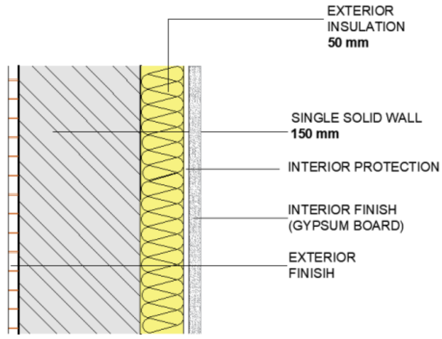
- External insulation creates a continuous thermal barrier, reducing thermal bridging and improving energy efficiency.
- The wall's thermal mass can be maintained since the insulation is applied on the outside.
- Retrofitting with external insulation is generally easier and less disruptive than internal insulation for existing buildings.

With increased levels of insulation, there are new warnings and stipulations that impact the project, such as moisture control, drying potential, and increased construction costs.

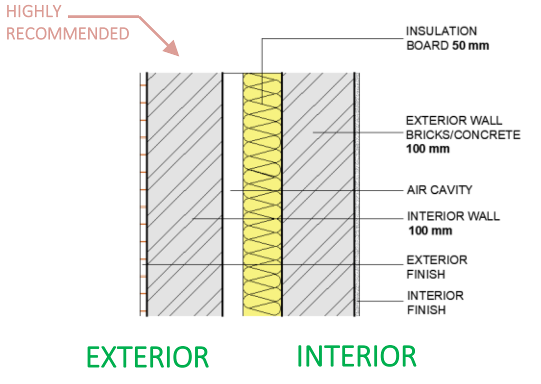
04 ANNEX

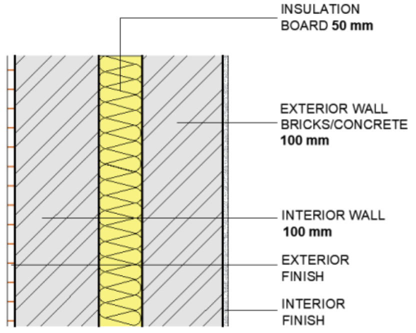
DRAWINGS AND TECHNICAL SPECIFICTIONS



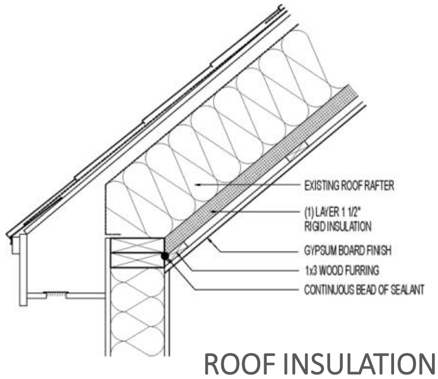


SINGLE WALL INSULATION

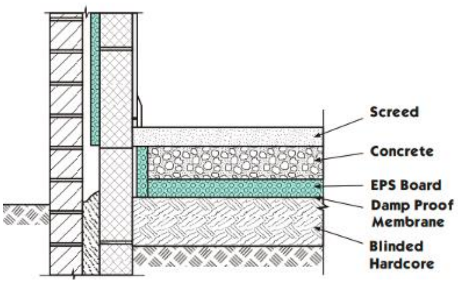




DOUBLE WALL WITH INSULATION AND AIR CAVITY



ROOF INSULATION



SLAB INSULATION

Source: Paton Construction, 2010

04 ANNEX

ALTERNATIVE TECHNIQUES FOR HOT DRY CLIMATES

Wind towers or wind catchers

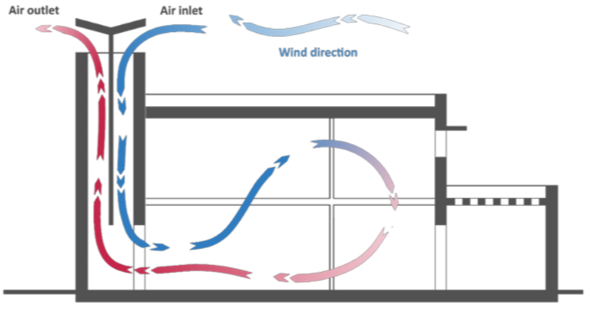


Figure 10: Scheme of wind tower (Source: PEEB. 2019)

Solar chimneys

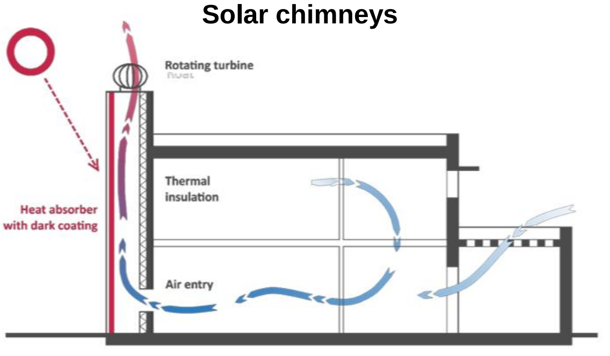


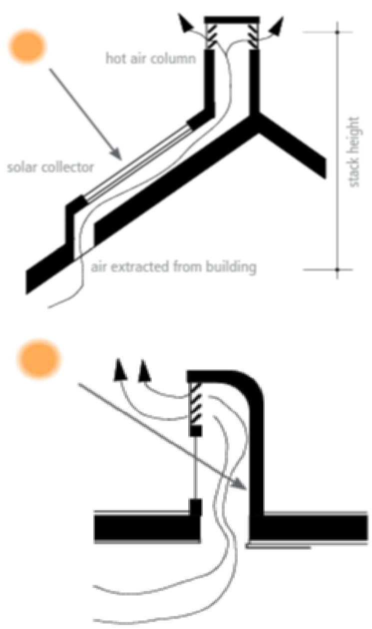
Figure 9: Scheme of solar chimney (Source: PEEB. 2019)

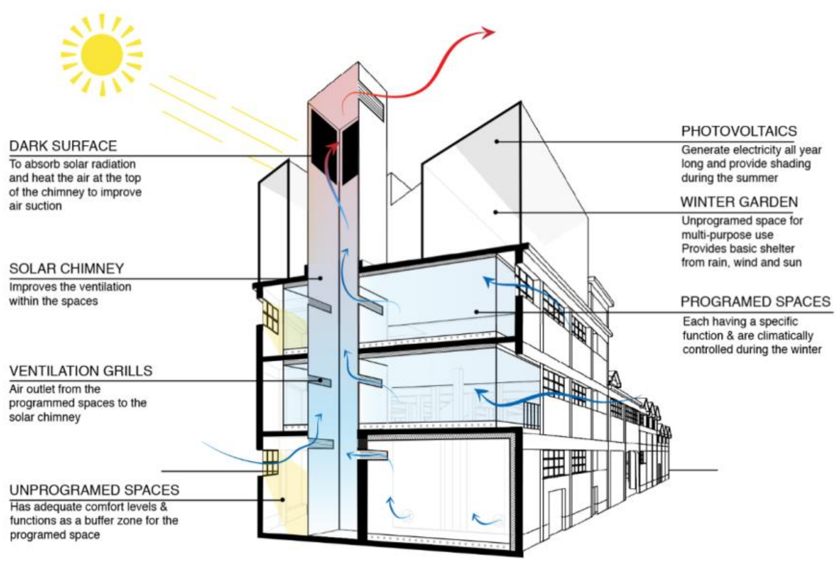
PASSIVE COOLING

Wind towers/ wind catchers work by providing building ventilation by being chimney-like structures built on top of buildings, which **harness air currents and provide a channel into the interior living spaces below to enable cooling.**

Solar chimneys can enhance the ventilation of rooms by creating an **air pressure differential.** Warmed by solar radiation, chimneys **heat the rising air and increase the difference in temperature between incoming and outflowing air.**

The heated air rises and escapes to the outside. This causes internal air to be pulled into the heated space and expelled thus enhancing airflow.





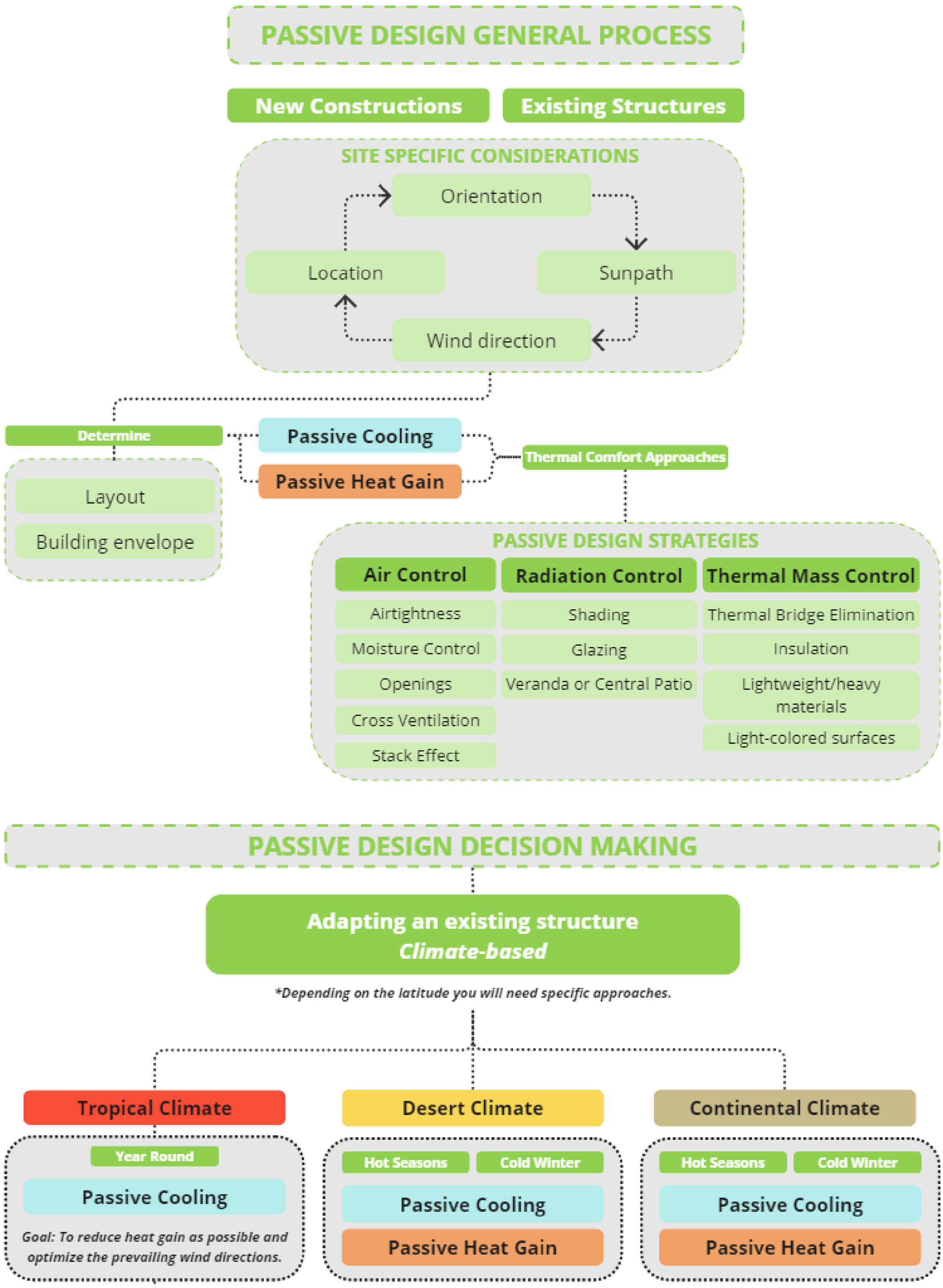
https://www.behance.net/gallery/47925383/3rd-Prize-Young-Architects-Competition

Please get in touch with your LogCo for precise information regarding the implementation of this construction type for your project.

04 EVALUATION OF AN EXISTING BUILDING

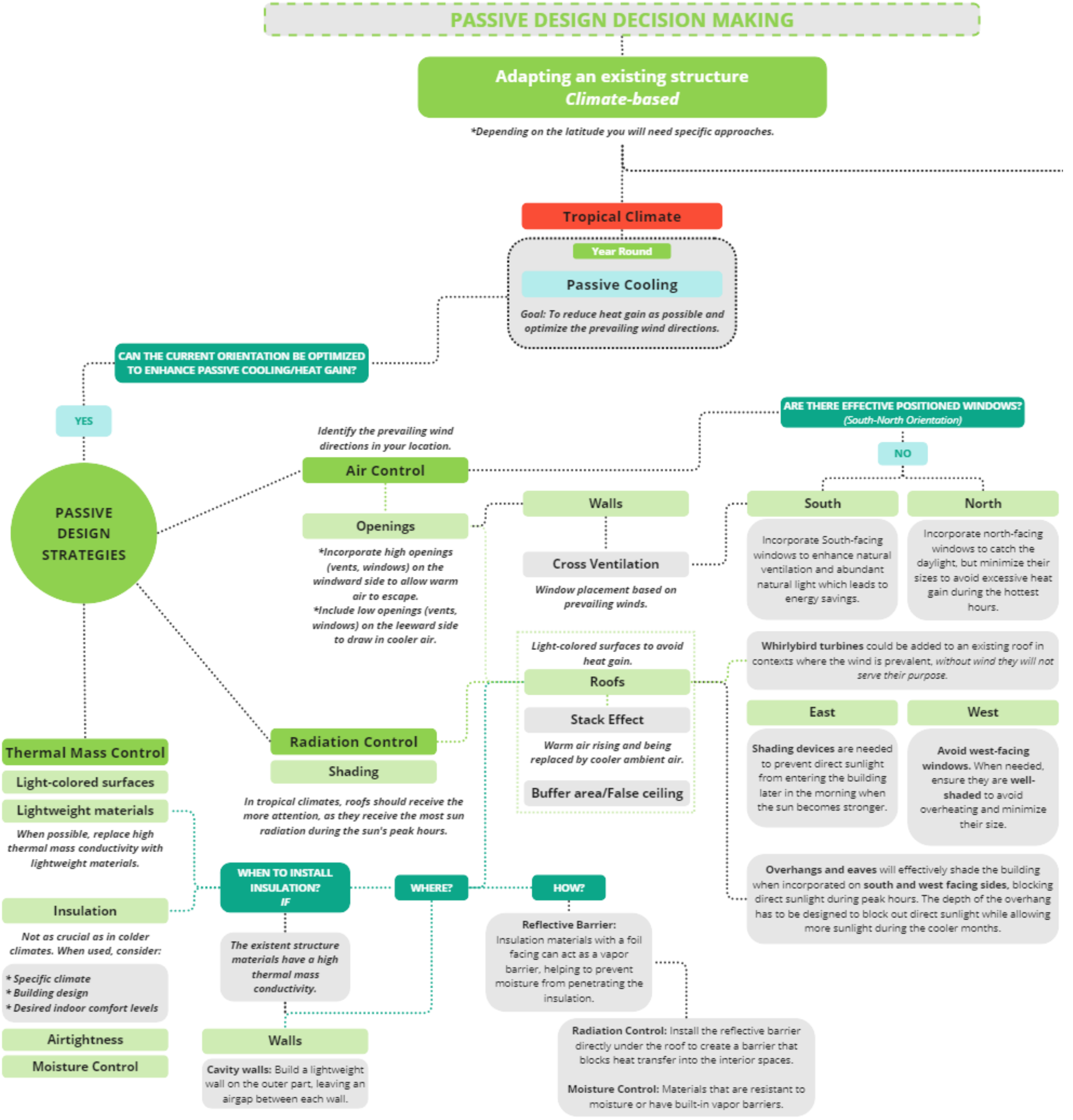
ASSESSMENT SHEET

Use the Excel document for "Existing Buildings Passive Design Evaluation" to assess the building you want to adapt.



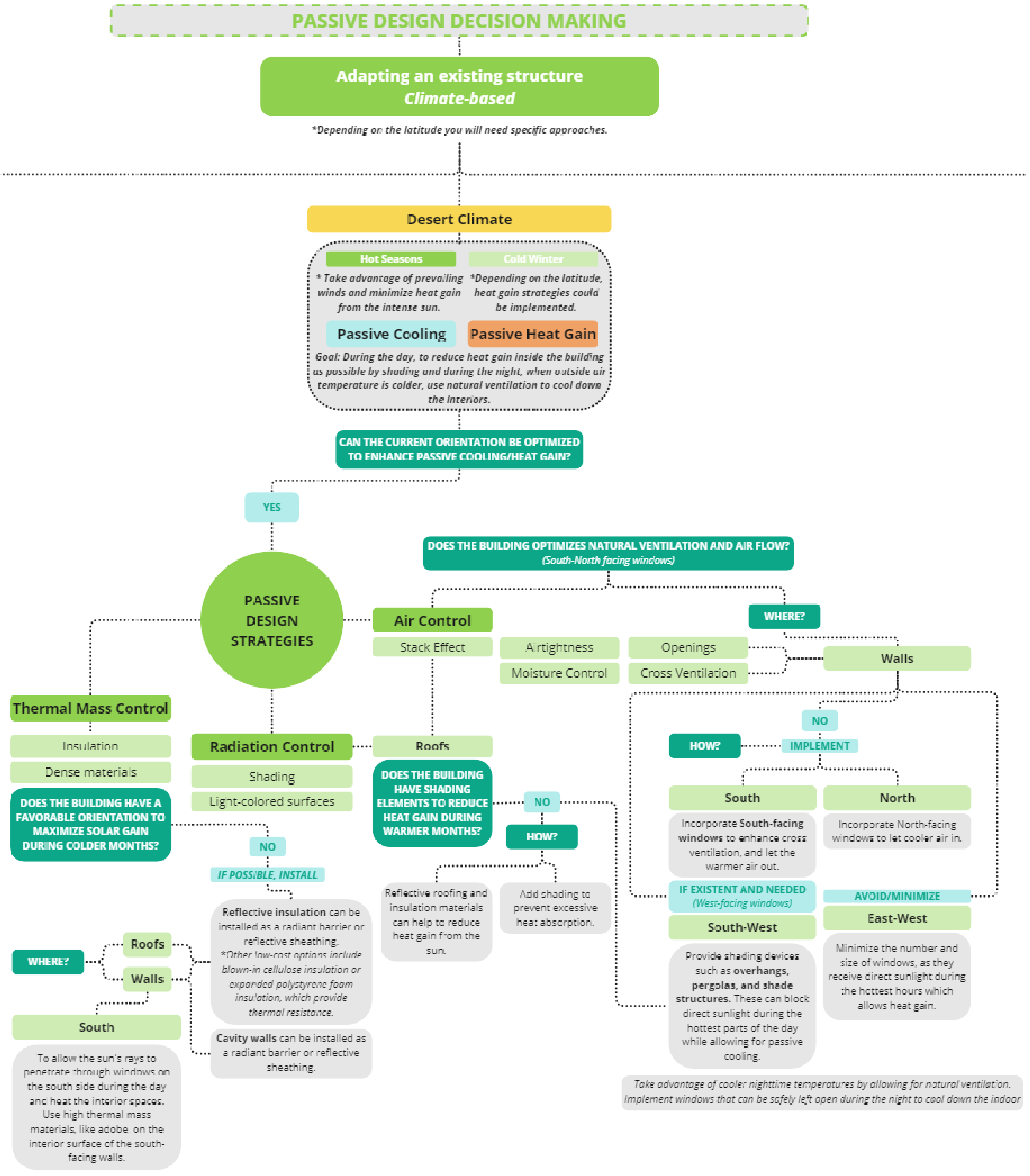
04 EVALUATION OF AN EXISTING BUILDING

DECISION MAKING FLOWCHART



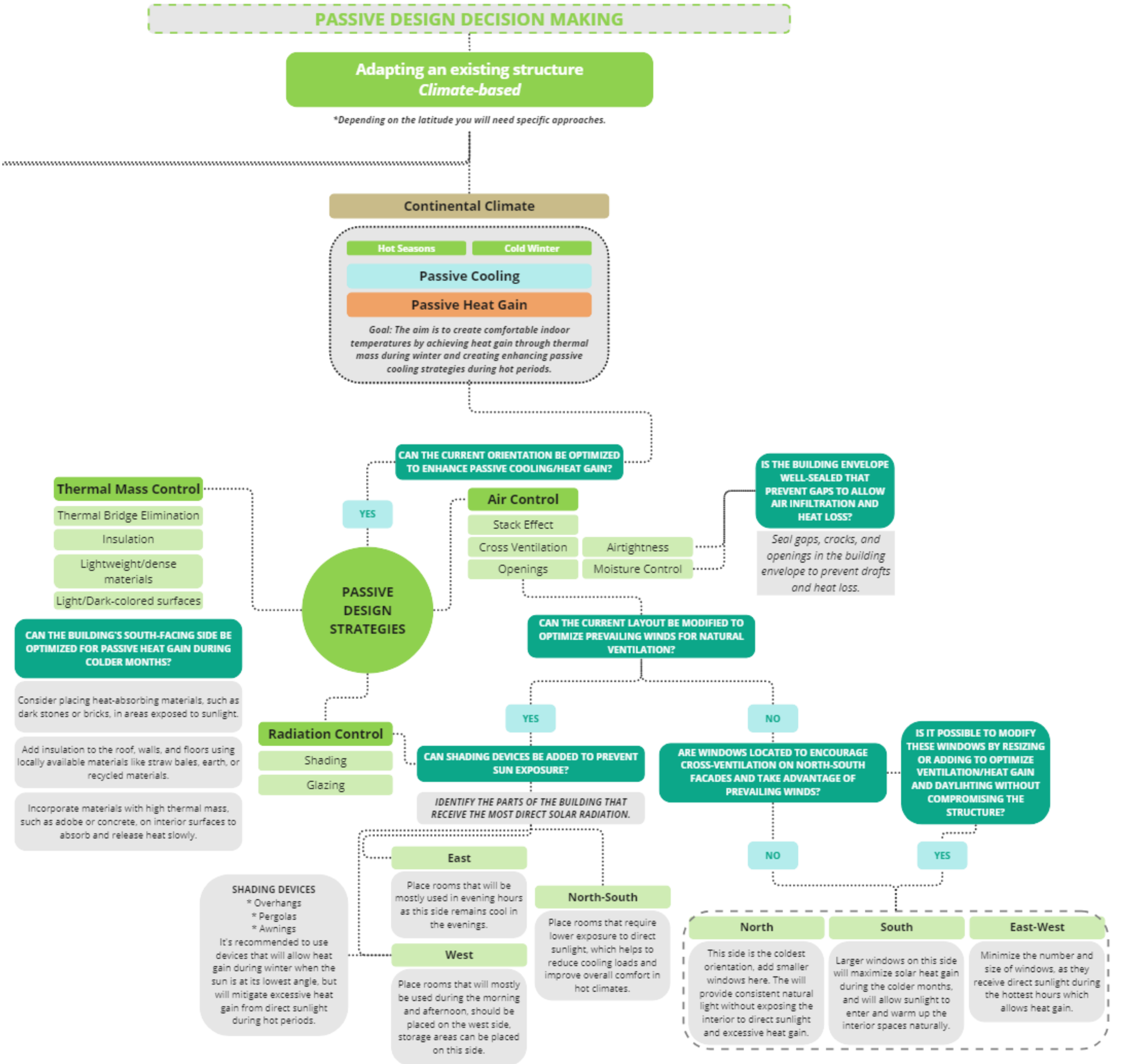
04 EVALUATION OF AN EXISTING BUILDING

DECISION MAKING FLOWCHART



04 EVALUATION OF AN EXISTING BUILDING

DECISION MAKING FLOWCHART



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