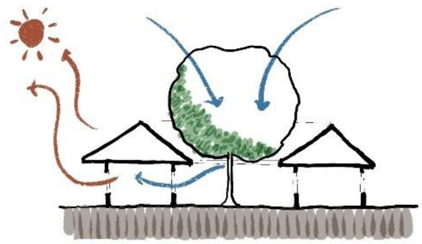
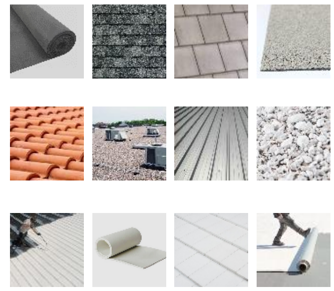
Passive Design Techniques for the Built Environment

Technical guidelines to optimise energy and water consumption





1) Background

Climate change and economic crisis are cutting children off from their chance to thrive. To address this challenge, UNICEF is committed to contribute to the Sustainable Development Goals (SDGs), in particular, to Goal 12 – “Ensure Sustainable Consumption and Production Patterns” and its target 12.7 – “promote public procurement practices that are sustainable, in accordance with national policies and priorities”. UNICEF features the three pillars of sustainability, in particular environmental concerns, highly in the UNICEF Strategic Plan 2022–2025. Alongside, UNICEF Supply Division has identified sustainability in supply as a top-line priority in SD's 2022-2025 OMP cycle.

As world’s leading voice for children, UNICEF works in the world’s toughest places to reach the most disadvantaged children. As part of our work, UNICEF supports programmes with tailored construction solutions to meet the needs of children, including for example the construction and rehabilitation of schools to improve access and quality of education, or building health posts and water and sanitation facilities to improve children’s health.

Yet, construction has a significant adverse impact on the environment, starting from the irresponsible use of raw materials, long journeys to transport materials to the site, insensate disposal of waste throughout the lifespan of the building. Particularly in 2020, the construction sector accounted for 36% of global final energy consumption and 37% of energy related CO_2 emissions.

Understanding the large impact that the built environment has on children’s wellbeing, growth, development and health, UNICEF is promoting the use of sustainable construction techniques, including the application of Passive Design Techniques in all construction and rehabilitation works we do. Maintaining proper indoor air quality, temperature control, and access to natural daylight is paramount in supporting children's wellbeing, growth, development and health. Passive Design Techniques offer sustainable solutions to achieve these objectives.

Passive Design comprises a set of architectural and building design techniques aimed to optimise energy and water consumption, while ensuring a healthy and comfortable indoor environment. It achieves this by harnessing natural energy sources like sunlight and wind, decreasing water consumption, and relying on the physical conditions of construction materials to reduce the building’s dependency on mechanical heating, cooling and artificial lighting. It entails a focused approach in comprehending the local year-round climate variables, such as temperature, precipitation, humidity and prevailing winds, as well as the site-specific features like the sun's trajectory, existing vegetation and proximity to natural water bodies.

Passive Design Techniques are to be applied during the initial stages of planning and designing a building.

2) Objective

This guideline presents a set of Passive Design Techniques that allows optimizing energy and water consumption, while ensuring a healthy and comfortable indoor environment. This is achieved by reducing reliance on artificial heating, cooling and lighting, as well as minimizing mainland water usage through adequate technical specifications that leverage natural resources and consider climatic conditions.

The guideline emphasizes those Passive Design Techniques that are most relevant to UNICEF's standard construction projects and highlights their applicability to the specific regions and climates where UNICEF carries out most of its construction work.

3) Guidelines

The table below presents Passive Design techniques categorized into four aspects commonly found in the design process of our typical construction projects:

A. Outdoor
B. Building layout and orientation
C. Building envelope
D. Indoor

These guidelines include technical cards for each Passive Design technique listed here below:

CATEGORY	DESIGN TECHNIQUES
A. Outdoor	A1 Vegetation
	A2 Evaporative cooling
	A3 Rainwater harvesting
B. Building layout and orientation	B1 Solar orientation
	B2 Building massing
	B3 Cross and stack ventilation
C. Building envelope	C1 Window-to-wall ratio
	C2 External shading devices
	C3 Insulation and sealing
	C4 Thermal mass
	C5 Double envelope
	C6 Colour and reflection
D. Indoor	D1 Efficient lighting
	D2 Water efficient fixtures
	D3 Greywater recycling

4) Technical cards

Each technical card comprises the following three sections:

- A section describing the Passive Design Technique, including its impact on achieving indoor comfort.
- Practical design applications and considerations and customisation for specific climates and building types.
- A quick reference section that outlines Do's and Don'ts for the technique in question.

5) Practical use of the technical cards

These cards are meant to be used from the early stages of the architectural design process and through the development of detailed drawings, technical specifications, in addition they need to be available during construction, operation, and maintenance. This ensures that the techniques are fully able to complete their purposes.

The techniques are meant to be combined (e.g., Solar Orientation with Building Massing and Shading Devices to improve daylight without additional solar heat gain in warm climates) to maximise the desired effect and the final goal of reducing energy consumption and water use while creating a comfortable indoor and outdoor environment.

These cards are part of the resources available for Country Offices' in-house Construction Engineers, provided on the Construction Unit Website to support the enhancement of the quality and sustainability of construction.

To effectively use these cards, they should be:

- Owned and well-known by the in-house Construction Engineer.
- Communicated and socialized with different Program sections.
- Informed and discussed with the Government counterpart.
- Shared and mandated for use by the external Engineering Firm providing engineering services on behalf of our counterpart.
- Well-known by Field Offices and Site Construction Engineers responsible for site identification and assessment, to check compliance and identify challenges and opportunities related to passive design techniques on-site. as support to improve the quality of construction and its sustainability.

A1	Technique: Vegetation	Category: Outdoor

Description and impact:

The use of vegetation plays a crucial role in maintaining comfortable outdoor and indoor environments. When placed correctly, vegetation can act as natural insulation, thus helping to **regulate building temperatures**, reducing the need for cooling in summer and contributing to maintain accumulated heat inside the building in winter or cold climates.

Trees and plants can be used to **create shade** in the surrounding areas and in the building façade, which in turn **lower the temperature** of the air through the process of evapotranspiration and by cooling the soil. In colder climates, trees and plants can be positioned **to block cold air breezes** from entering buildings, helping to maintain warmer indoor temperatures.

Additionally, vegetation can serve as noise buffer or protection from sand or dust carried by the wind.

Design applications:

a) **Green courtyards** that include trees, vegetated pergolas and groundcovers and shrubs, generate shade and evaporative cooling that can improve natural ventilation, consequently cooling the interior of the building.

- **Vegetated pergolas** can be created by installing columns, beams, or wires to support climbing plants on a building's exterior.
- **Groundcover and shrubs** around buildings lower air temperatures and reduce reflected sunlight.
- **Trees** with a high canopy provide shade and allow in beneficial cooling winds during summer.

In climates with cold winters, trees should be located away from the walls facing the equator a minimum distance of twice the height of tree to ensure solar heat gain during the colder months.

- **Trees and bushes** can also be positioned to prevent undesired cold breezes to go inside the building

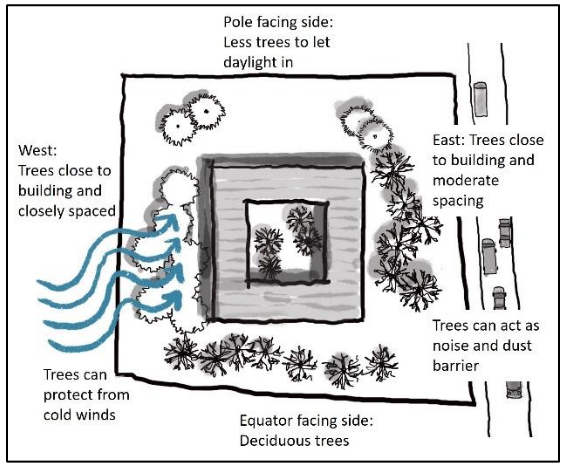


Fig. 1: Orientation of trees in a building (Source: Author)

b) **Green screens, green walls or vertical greenery systems** are vertical structures on a building's exterior that use living vegetation to cool the interior through shading and evapotranspiration while enhancing indoor air quality and deflecting noise. A green wall is also effective in lowering the thermal losses through the walls by insulating them.

To build a green screen or green wall:

- Identify windows, glazing facades or walls that can benefit from it
- Protect the wall from moisture
- For screens: Create a robust frame, usually can be trellises or wires. For walls: Select a suitable structure, panels directly attached to the wall or a freestanding wall
  - Choose the type of planting medium, planters, trays with soil, textile, or fibre mats for hydroponic growing
  - Incorporate an efficient irrigation system for water management
- Select and plant appropriate species. Climbing or trailing plants that thrive vertically for screens, and plants with shallow root systems, such as succulents, moss, or herbs for walls.

Fig. 2: Vegetated Pergola (Source: www.architectureartdesigns.com)

Fig. 3: Green wall and green screen (Source: www.jakobusa.com)

c) **A Green roof** involves the installation of living vegetation on the roof of a building. This technique enhances energy efficiency, mitigates the urban heat island effect, improves stormwater management, and promotes biodiversity.

To design and build these roofs:

- Evaluate structural resistance and feasibility.
- Choose between:
  - A simple green roof, with less maintenance, a shallow growing medium and vegetation like groundcovers, grass, or moss
  - A roof garden, that requires higher maintenance, a much deeper substrate and complex irrigation systems, but can include bushes and small trees
- Check for water leakages or consider a waterproofing layer. Include a root barrier and a drainage system
- Identify the most suitable growing medium according to the type of green roof and the slope
- Consider including a water efficient irrigation system
- Select and plant vegetation according to the slope and type of green roof

Fig. 4: Sunoo Temple House, Saket Sethi Design
(Photo: Fabien Charuau)

For all these design applications, it is essential to conduct preventive maintenance and regularly monitor both plants and trees and supporting structures. This is necessary to sustain the positive impact of vegetation on the building's energy-saving performance and comfort.

Considerations for different climates and types of building:

In **dry climates** to optimize water usage while preserving vegetation benefits, use xeriscaping by:

- including native plants and drought-tolerant varieties with reduced water needs once established
- employing groundcovers or mulch for moisture retention, soil temperature regulation, and erosion prevention
- strategic planting and efficient irrigation systems.

For **climates with hot summers and cold winters**, choosing deciduous plants or trees that lose their leaves in winter allows for harnessing solar heat during colder months while providing shade during summer.

Fig. 5: Xeriscaped landscape
(Photo: David Madison / Getty Images)

In **tropical climates or regions with heavy rainfall**:

- Incorporate soft surfaces like ground covers or rain gardens to improve soil infiltration rates.
- Combine with trees for rain interception and plants like Vetiver grass for erosion protection, enhancing flood resilience.

Incorporating vegetation for cooling in **educational infrastructure** offers multiple additional benefits:

- Green courtyards can serve as playgrounds for children.
- Vegetated pergolas provide outdoor spaces suitable for diverse learning activities.
- Inclusion of species that attract insects or birds can enhance early-child development.

In **health facilities**, the integration of green pathways or vegetated pergolas creates comfortable waiting areas, minimizing the built surface of the buildings.

Dos	Don'ts
• Choose native trees and plants • Built structures to guide climbing plants or vines • Use groundcovers and mulch as natural surfaces • Incorporate deciduous trees in the facades facing the equator, for mild climates • Guide rainwater to landscaped areas or rain gardens • Use water efficient irrigation systems	• Avoid using introduced or exotic species • Avoid trees with invasive roots that may affect foundations or building piping systems and keep deciduous trees away from roofs to prevent leaf blockage in drainage systems • Do not utilize water-intensive grass lawns or other high-water-consuming plants. • Control the use of impermeable surfaces • Do not undervalue or relegate landscaping in budgets

A2	Technique: Evaporating cooling	Category: Outdoor

Description and impact:

Evaporative cooling is a passive design technique employed to naturally cool buildings by capitalizing on the heat-absorbing and cooling properties of water's evaporation process.

The process involves introducing water into the environment through various means, such as ponds, fountains, or wetted surfaces

As the water evaporates, it **absorbs heat energy** from the air, causing **the temperature of the surrounding air to decrease**. This cooled air can then be directed into the building's interior spaces, offering a refreshing and energy-efficient cooling effect.

Design applications:

a) **Ponds, water fountains, or wetted surfaces** are an easier way to include the evaporative cooling capacity of a mass of water into a building, with low water consumption

- Consider locating them in the cooler side of a building (usually the side not facing the solar path) where the inlet of air for indoor natural ventilation is located.
- Courtyards or building entrances can be a good location to ensure that the air entering a building is properly cooled.
- Consider using recycled or treated water sources to minimize water waste
- Include solar or energy efficient pumps to recirculate the water and minimize the need for refilling. Keeping the water moving also prevents mosquitoes from laying their eggs on the surface.
- Implement water treatments or filtration systems to maintain the water quality and reduce the risk of mosquito breeding. Consider including water-filtering plants such as water lilies, water irises, cattails, or other locally grown submerged and floating plants.
- Incorporating water jets increases the cooling effect of these water features
- A splash pad or a spray pool can be used as a recreational area with cooling effects both through the direct contact of water with the body and the evaporative cooling effect

b) **Natural bodies of water:**

- Consider natural bodies of water as a free source of evaporative cooling
- Orient the building to receive the cool breezes coming from the natural body of water

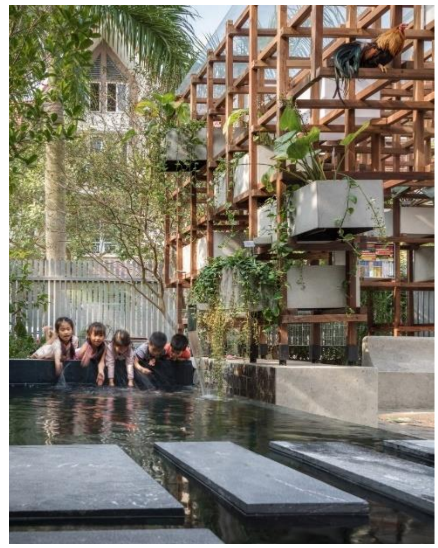


Fig. 6: VAC Library, Vietnam. Farming Architects (Photo: Thai Thach and Viet Dung An)

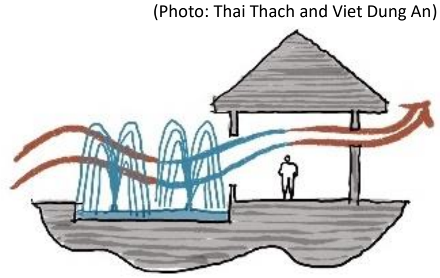


Fig. 7: Evaporative cooling of air before entering a building (Source: Author)

Considerations for different climates and types of building:

In **dry climates**, evaporative cooling is a good way to lower several degrees the air temperature due to its higher capacity to absorb moisture.

In **schools or educational premises**, the use of wet surfaces or fountains can have cooling purposes as well as recreational benefits when included in playground areas.

Special attention should be given to safety measures in early childhood development facilities to prevent drowning.


Fig. 8: Bicentennial Children's Park, Chile. ELEMENTAL Architects (Photo: Cristobal Palma)

Dos	**Don'ts**
• Use water features in areas with hot dry seasons to cool the air • Use water features for recreational and educational purposes as well as its cooling effects • Consider using recycled water or rainwater as a water supply source for these features to prevent water wastage • Position these water features close to the inlet of fresh air of surrounding buildings to benefit from its cooling effect • Prioritize solar energy as power source for water pumps and use natural or biodegradable water treatment	• Avoid using water features for cooling purposes in highly humid climates • Avoid water fountains or ponds in areas with children under the age of 4. Instead, opt for wet surfaces with a depth of less than 2 centimetres • Prevent water stagnation to avoid mosquito breeding • Don't neglect maintenance and treatment of water

A3	Technique: Rainwater harvesting	Category: Outdoor

Description and impact:

Rainwater harvesting is the practice of collecting and using rainwater from roofs, surfaces, and open areas to reduce the need for treated freshwater in non-potable applications.

Typically, water used for drinking, cooking and sanitation accounts for approximately 10% to 20% of the total water consumption, from which around 80% is allocated for non-potable uses. Even considering that these percentages can vary depending on factors like geographic location and local water availability, rainwater harvesting can significantly reduce the need for fresh water.

Design applications:

a) **A rooftop harvesting system** involves collecting rainwater from the roof of a building for various non-potable uses. To implement it:

- install rooftop gutters and downspouts to collect and channel rainwater from the roof
- use a rainwater collection system like a gutter mesh or leaf diverter to filter out debris
- connect a downspout diverter to guide rainwater into storage tanks or barrels. Calculate the storage volume based on used roof surface and average rainfall pattern
- use a first flush diverter to divert initial runoff, which may contain contaminants, away from storage containers
- ensure the storage system has proper overflow and drainage to prevent flooding during heavy rainfall and mosquito breeding due to water stagnation
- add a tap or spigot near the bottom of the storage container for easy access to collected rainwater. A clear sign that water is not fit for drinking must be included.

Fig. 9: Rooftop rainwater harvesting system (Source: Author)

b) **Rain Gardens** are landscaped areas designed to capture and manage rainwater runoff. They help prevent soil erosion, promote groundwater recharge, reduce stormwater pollution, and provide the benefits of vegetation. To include a rain garden:

- select an appropriate location where rainwater runoff naturally collects
- create a shallow, saucer-shaped depression
- amend the soil with organic matter to improve drainage and plant native, water-loving vegetation
- mulch the area with natural materials to reduce erosion and conserve moisture
- install a berm or edge to contain water within the rain garden during heavy rainfall
- direct downspouts or runoff channels towards the rain garden to capture rainwater
- regularly maintain the garden by weeding and ensuring proper drainage

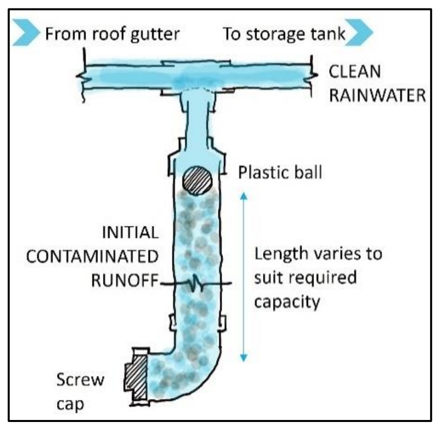


Fig. 10: First flush diverter (Source: Author)

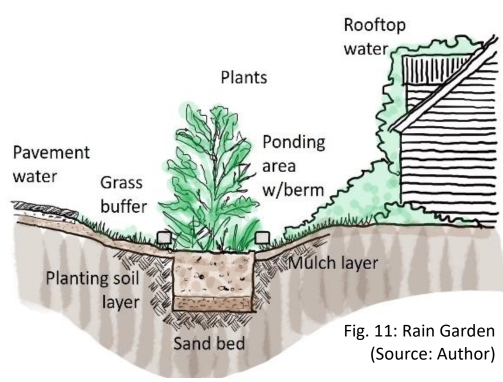


Fig. 11: Rain Garden (Source: Author)

Considerations for different climates and types of building:

Rainwater collected from a rooftop harvesting system **can provide schools or health centres with water for toilet flushing or floor cleaning**. When collected, treated, and stored properly, it can also be used for handwashing.

Rain gardens offer an effective solution for school playgrounds to harness the cooling benefits of vegetation without excessive water usage. This is especially relevant in tropical climates or regions with heavy rainy seasons.

Dos	Don’ts
• Install rooftop rainwater systems at schools and health facilities • Perform routine maintenance • Filter and treat water to allow multiple purposes • Engage and educate students in rainwater use • Implement rain gardens to prevent erosion and flooding in playgrounds	• Don't waste fresh water when rainwater is available for suitable purposes • Don't use untreated rainwater for drinking • Avoid using the initial contaminated runoff; install a first flush diverter • Don't divert rainwater to the sewage system • Never neglect rainwater system maintenance • Prevent rainwater stagnation to deter mosquitoes

B1	Technique: Solar orientation	Category: Building layout and orientation

Description and impact:

Solar orientation alongside building massing plays a vital role in a building's ability to manage solar heat gain and maximize natural daylight. Evaluating the sun's path throughout the day and seasons is crucial for optimizing the building's placement, interior layout, and fenestration design. This technique shall be applied early in the design process.

It is important to differentiate between direct sunlight and daylight or skylight, when considering the building's orientation in relation to daylighting. Direct sunlight can cause glare, excessive contrast, and unwanted heat gain, while daylight or skylight offers even, glare-free illumination, enhancing visual comfort, natural perception and colour rendition. Even areas of the building not facing the solar path can benefit from relatively uniform illumination, though it may not be as intense.

Design applications:

a) Sun path and building's facades considerations:

- **East facing facades:** Morning sun with low altitude, sun rays directly enter the building.
    - In hot climates, reduce window areas or use breeze block walls to minimise solar heat gain and to store cold air and allow natural ventilation
    - In cold climates, increase window area to allow solar heat gains and break the cold air accumulated during the night
    - In mild climates, place rooms that can benefit from morning sun (i.e., bedrooms or kitchens)
- **Equator facing facades:** Midday sun with high altitude during summer days and lower during winter days.
    - Consider large windows and high thermal mass materials to store heat to release at night, for cold climate
    - Use external shading devices to reduce heat gain while maintaining natural daylight indoors in warm climates
    - Horizontal shading devices on the upper part of the windows allows solar heat gain in winter but not in summer, without affecting natural daylight year around
- **West facing facades:** Late afternoon and evening sun from the west has a lower altitude. Sun rays enter the already heated building directly.
    - Include smaller windows with vertical shading protection and wall material with high thermal mass to store heat for night release, for cold climates
    - If solar heat gain is not desired, consider living spaces that are used in the mornings or use buffer spaces, like storage or pathways

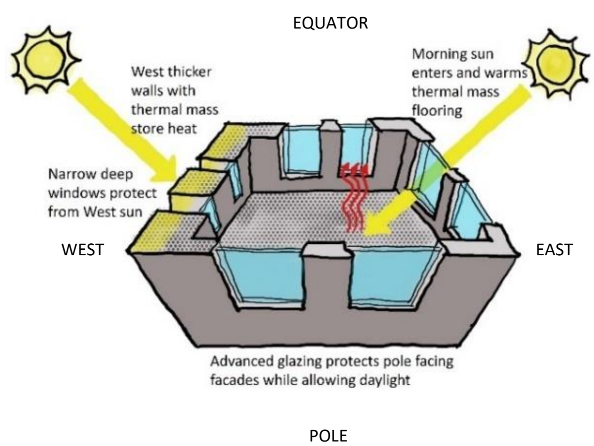


Fig. 12: Facades consideration regarding sun path
(Source: Adapted from Building Orientation | Sustainability Workshop (venturewell.org))

- **Facades facing away from the sun's path** get no solar heat gain but can still get large amounts of diffuse light and can store cold air to cool the spaces where desired
    - Advance glazing allows daylight while minimising heat loss for colder climates

b) Orientation of the building for daylighting: In terms of natural lighting, the best orientation of the building is east – west, meaning the longest side of the building faces the equator. This orientation consistently harnesses daylight and control glare along the long faces of the building. It also allows minimizing glare from the rising or setting sun.

- **Light coming from side windows** can only penetrate so far into a building. Consider this when dimensioning rooms and distributing windows to allow indoor spaces with maximum daylight.
    - A general rule of thumb for most latitudes is that daylight can penetrate into a room to a depth roughly 2.5 times the height of the top of the window. For example, if the window height is 2 meters, daylight can reach approximately 5 meters into the room. If larger room dimensions are desired, consider adding additional windows on the opposite wall or incorporating top apertures.

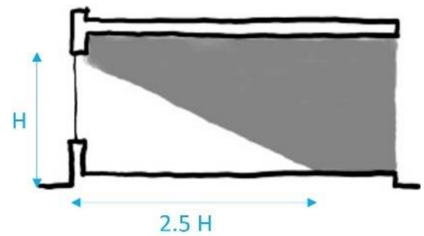


Fig. 13: Daylight penetration from side aperture (Source: Author)

- **Top daylighting** utilizes roof apertures to admit ambient daylight from above onto a horizontal task plane.
    - This design technique encompasses various methods, such as skylights, sawtooth roof glazing, or high clerestories with reflecting ceilings.
    - It provides consistent daylighting but requires effective control of direct solar radiation, which can cause glare and unnecessary heat gain.

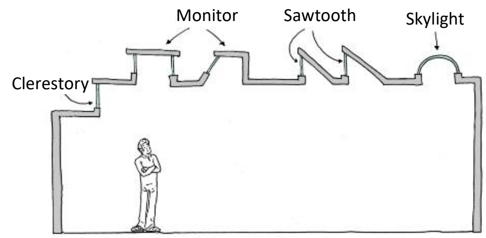


Fig. 14: Different types of top apertures (Source: [Apertures for Daylighting | Sustainability Workshop (venturewell.org)])

- **Light shelves** are designed to reduce glare and enhance daylighting by shading windows and redirecting light upwards. These are extremely useful in classrooms to maximise daylighting while reducing glare.
    - They are horizontal structures, that can be part of the window frame, positioned above eye level, dividing a window into a lower view area and an upper daylighting area
    - To enhance its effectiveness, the surface of a light shelf should be reflective or coated with white paint. A similar finish should also be applied to the ceiling to maximize the light-reflecting effect
    - A general guideline is to make the internal light shelf's depth roughly equal to the height of the clerestory window above it

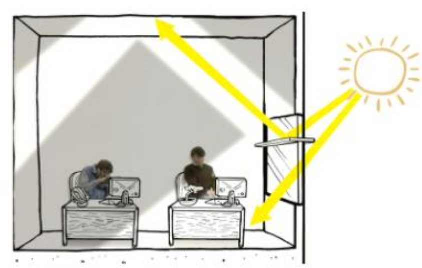


Fig. 15: Light shelf (Source: [Redirecting Light | Sustainability Workshop (venturewell.org)])

Considerations for different climates and types of building:

For any climate and for both hemispheres, **classrooms with double orientation facing both north and south** gives the most natural light for daylighting with low glare, especially when using light shelves. If heat gain is not desired, the side facing the sun path must include shading devices.

In hot climates**, roofed pathways to access the classrooms** can act as buffer spaces for equator facing facades, minimising solar gain by providing shade.

Storage rooms and bathrooms can also be used as **buffer spaces** to protect living spaces from undesired external conditions like heat gain in extreme warm climates, heat loss from pole-facing sides in cold climates or direct glaring from the west.

Dos	Don'ts
• Consider orientation of the building as the most important passive design technique • As a rule of thumb, the best orientation of a building is east west, meaning the longer façade faces the equator • Place classrooms with its longer sides facing north and south • Consider shading devices in sides facing the equator to benefit from the daylight while avoiding extreme heat gain	• Don't neglect site analysis as some general considerations might be affected by site conditions • Don't ignore pole-facing facades for daylighting, particularly in hot climates where minimizing equator-facing heat gain is crucial • Avoid prioritizing aesthetics in window design over essential factors like daylighting and heat management • Don't forget that walls with thermal mass can also contribute to heat gain, not just windows.

B2	Technique: Building massing	Category: Building layout and orientation

Description and impact:

Building massing is a critical early design decision that involves determining the overall shape, size and arrangement of a building. This decision may include creating separate buildings and strategically positioning them.

An effective massing strategy employs these characteristics to mitigate external impacts such as excessive sunlight while maximizing solar and wind energy utilization for lower energy loads. Massing and orientation are interdependent and must be optimized together.

Design applications:

a) **Thinner buildings** facilitate the use of natural ventilation for passive cooling (fig. 16)

- Every room gets natural ventilation
- Effective cooling of the entire building

b) **Compact or cube shaped massing**, on the other hand minimise the surfaces exposed to heat loss, making it better for colder climates

- Increasing the surface area facing the sun's path, for solar heat gain while reducing exposure on the shaded sides and placing buffer rooms can effectively heat the building (fig.17).

c) **Tall buildings** benefit from increased natural ventilation

- At greater heights there are higher wind speeds and reduced obstructions
- Shaping a building including taller sections enhance both cross ventilation and stack effect ventilation (Fig. 18).

Although thin and tall buildings enhance natural ventilation for cooling, they also increase heat transfer through the building envelope. However, shading devices can mitigate heat transfer while maintaining natural ventilation.

d) **Buildings with courtyards** can store cold air or cool the air before entering the interior spaces (Fig. 19)

- If the height of the building is equal to the length of the courtyard, the building shades the courtyard, consequently cooling it
- This effect can be amplified with complementary passive design techniques like the use of vegetation, shading, water fountains, etc.
- This massing technique is particularly useful for schools allowing the use of the courtyard as playground

e) **Utilizing building mass to create shade** through the incorporation of overhangs, openings, recesses, or setbacks is a straightforward method to cool specific areas of the building that require lower temperatures and to avoid direct sunlight (Fig. 20).

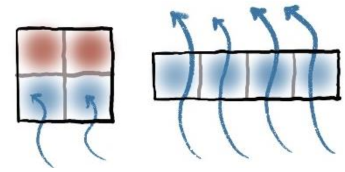


Fig. 16: Comparison between a thin building and a compact one for natural ventilation (Source: Author)

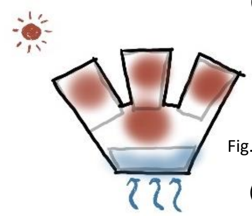


Fig. 17: Massing for solar heat gain (Source: Author)

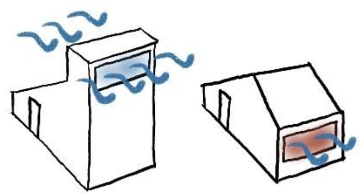


Fig. 18: Taller buildings can benefit from unobstructed higher wind speeds at greater heights (Source: Author)

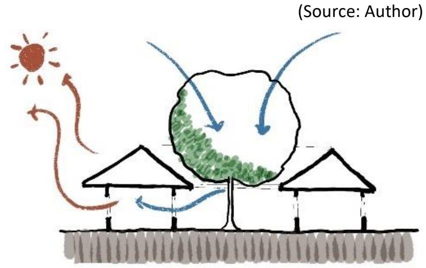


Fig. 19: Building with a courtyard helps cooling (Source: Author)

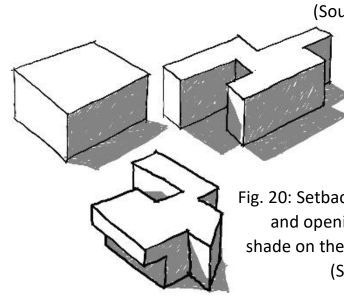


Fig. 20: Setbacks, overhangs, and openings can create shade on the building itself. (Source: Author)

Considerations for different climates and types of building:

Separating different program units of a building (e.g., individual classrooms) and creating intermediate shaded spaces, can have a similar effect to a courtyard and can increase the speed of wind to improve natural ventilation through the venturi effect (Fig. 21)

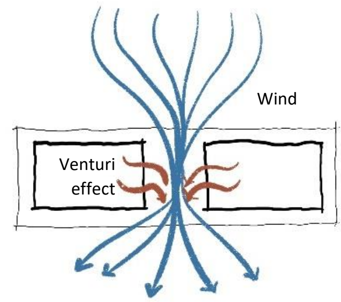


Fig. 21: Two classrooms connected to an open covered space can create a Venturi effect (Source: Author)

In dry or tropical climates, organizing a **health centre** with a covered central hall with openings to allow natural ventilation, can create a fresh waiting area and help cooling the consultation boxes (Fig.22).

Classrooms are densely populated structures that even in colder climates can benefit from a thinner floor plan to get more cooling from natural ventilation.

Spaces with **low population and minimal activity** (e.g., medical examination room) produce limited internal heat. In cold climates, they benefit from compact floor plans to reduce heat loss to the outside.

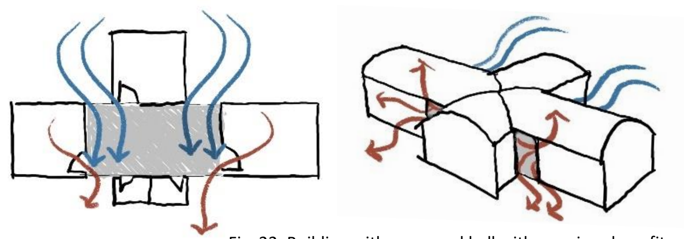


Fig. 22: Building with a covered hall with openings benefits from natural ventilation and Venturi effect (Source: Author)

Dos	Don'ts
• As a rule of thumb, design thinner and taller buildings plus natural ventilation for cooling, and compact buildings with areas exposed to the sun path for heating • Consider openings and overhangs to create shade and improve natural ventilation within the building • In courtyards, to cool the air through shading, consider a ratio between height and width nearing 1:1	• Don't ignore solar path when deciding the building's shape • In hot climates, to achieve the courtyard effect and create shade, do not exceed the width of the courtyard more than three times the height of the surrounding building • Do not forget the impact of grouping or separating buildings on their performance regarding temperature and daylight

B3	Technique: Cross and stack ventilation	Category: Building layout and orientation

Description and impact:

Natural ventilation, also known as passive ventilation, harnesses the principles of natural air movement and pressure differences to efficiently cool and ventilate a building. Additionally, even a mild breeze can make people feel 5°C cooler than in still air.

Cross ventilation is a cost-effective form of natural ventilation that is easy to achieve in traditional buildings. It relies on the flow of air through openings on opposite sides of a space to promote airflow and maintain comfortable indoor conditions.

Stack ventilation uses the stack effect, driven by air thermal buoyancy through unsealed openings, chimneys, or roof apertures. It operates on the physics of warm air rising and cool air sinking, ensuring a constant airflow in buildings, particularly beneficial for tall or multi-story structures. Unlike traditional ventilation, it is less influenced by external factors such as wind direction and speed.

The use of natural ventilation can save up to 20% ~40% of energy consumption according to the local climate.

Design applications:

Buildings should be oriented to maximize benefits from cooling breezes in hot weather and shelter from undesirable winds in cold weather.

a) Use of prevailing winds

The prevailing winds can be identified using a "wind rose" diagram, but usually local community has more knowledge of specific wind directions

- Generally, orientating the building to have the longest side facing the direction of the prevailing winds will provide the most wind ventilation
- Site obstructions such as trees or other buildings should be considered as they might block, reduce, or increase wind speed

b) Cross ventilation is more effective if considering:

- Placing openings across from each other in a space but not directly opposite, each other causes the room's air to mix, better distributing the cooling and fresh air (Fig. 23)
- Having larger openings on the sides of the building where the wind is not as strong compared to the sides where the wind hits directly
- Positioning inlets in areas where the air pressure is higher and outlets in areas where the air pressure is lower
- Placing inlets low in the room and outlets high in the room (Fig. 24)

Floor plan widths larger than 15 m reduce the efficiency of natural ventilation in warm and humid climate and reduce the degree of thermal comfort

c) To implement stack ventilation, (Fig. 25) consider:

- Low inlet openings that draw cool outside air in and high outlet openings that allow hotter exhaust air escapes
- Openings at the top and bottom roughly the same size to encourage even air flow through the vertical space
- A large difference in height between air inlets and outlets. The bigger the difference, the better
- Integrating a solar chimney to improve stack ventilation. Using solar heat gain to warm a column of air which then rises, pulling new cool outside air through the building

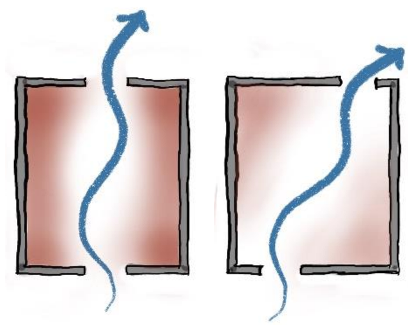


Fig. 23: Placing openings across from each other but not directly to better distribution of cool air (Source: author)

Fig. 24: Low inlet openings in the cold facade and high outlet openings in the façade facing equator (Source: author)

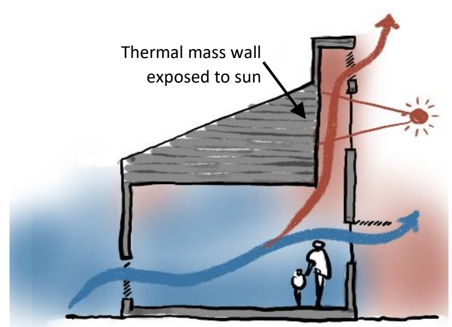


Fig. 25: Integrating a solar chimney to improve stack ventilation (Source: author)

d) **Skylights or clerestory windows** (Fig. 26) can be used to increase ventilation through the air buoyancy effect.

- Positioning these windows in the upper portion of a room serves to exhaust hot air while allowing natural sunlight to enter. When thoughtfully designed with consideration for the sun's path, they can also facilitate desired solar heat gain
- Skylights and clerestory windows can be made operable with the use of mechanical systems or extendable poles for easy control

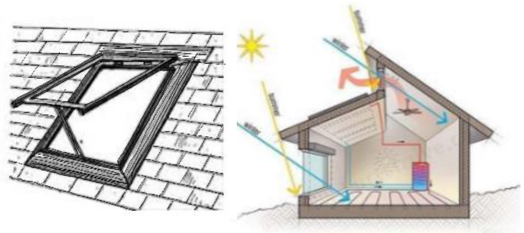


Fig. 26: Skylights and clerestory windows (Source: Author & Passive Solar Design Retrofits, Princeton University)

e) **"Breeze steerers"** (Fig. 27) since not all parts of a building can be oriented for cross-ventilation, architectural elements can steer air into a room:

- When such structures are positioned on opposite walls facing different directions, they can enhance this airflow
- These elements can vary in size and type, from casement windows or baffles to larger structures like fences, walls, or hedgerows

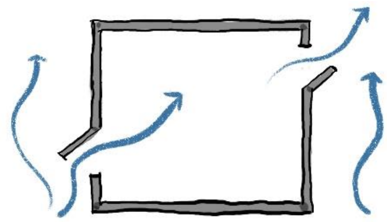


Fig. 27: Breeze steerers (Source: author)

f) **Wing walls** (Fig. 28) project outward next to a window, so that even a slight breeze against the wall creates a high-pressure zone on one side and low on the other. The pressure differential draws outdoor air in through one open window and out the adjacent one. Wing walls are especially effective on sites with low outdoor air velocity and variable wind directions.

- Design the depth of wing wall projections to be at least 0.5 to 1 time the width of the window
- Ensure the spacing between wing walls at least 2 times the window width

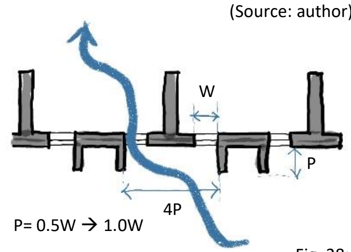


Fig. 28: Wing walls (Source: Author, adapted from Chandra et al. 1983 at Florida Solar Energy Center)

Considerations for different climates and types of building:

Night- purge ventilation:

In climates with significant day-to-night temperature variations, a strategy called night-purge ventilation or night flushing (Fig.29) can be employed. This involves the following:

- During the day:
  - Closing windows to prevent warm air inside
  - Thermal mass surfaces (such as walls or floor surfaces) remain shaded to let them absorb indoor heat
- At night:
  - Thermal mass releases accumulated heat and cools itself for the next day
  - Windows are opened to remove warm air from the building

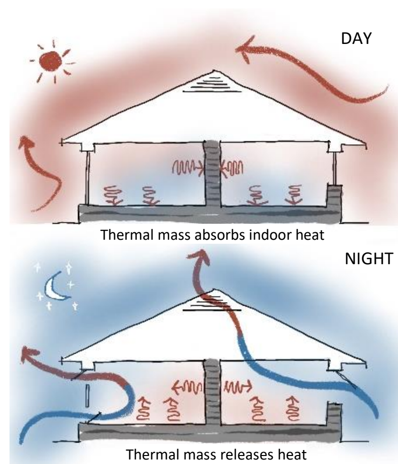


Fig. 29: Night-purge ventilation (Source: Author)

Dos	Don'ts
• Orient the building to capture prevailing winds, identifying potential obstacles in the site • Strategically place openings • Utilize building elements to boost ventilation • Incorporate thermal mass to enhance stack ventilation • Opt for narrower buildings to maximize ventilation	• Don't compromise security; consider shading devices that can also serve as protections or consider inner courtyard orientation of operable windows to deter intrusion • Do not obstruct ventilation paths • Don't overlook outdoor elements that could block or redirect breezes • Don't place air inlets near sources of pollution or noise

C1	Technique: Window-to-wall ratio	Category: Building envelope

Description and impact:

The window-to-wall ratio (WWR) is an indicator used to determine the proportion of a building's facade that is occupied by windows.

This ratio plays a crucial role in optimizing natural lighting, thermal comfort, and energy efficiency within a building's interior spaces. By carefully considering and adjusting the window-to-wall ratio, the design can enhance the building's overall performance and occupants' wellbeing while minimizing the need for artificial lighting and excessive heating or cooling.

Design applications:

The window to wall ratio (WWR) is defined as the ratio of the total area of the window or other glazing area (including mullions and frames) divided by the gross exterior wall area.

$$\mathrm{WWR}\ (\%) = \frac{\sum \text{Glazing area } (\mathrm{m}^2)}{\sum \text{Gross exterior wall area } (\mathrm{m}^2)}$$

A building with higher WWR transfers more heat and daylight from the sun inside the space compared to one with a lesser WWR. At the same time in colder climates, higher WWR with regular glazing can generate heat losses. To find a balance use the following strategies:

a) **Strategies for lighting while minimizing heat gain include:**

- Using a small window opening (15% WWR) to illuminate a surface that spreads light across a large area (see light shelves)
- Using a moderately sized window (30% WWR) with exterior reflective surfaces and shading devices to prevent direct sunlight

b) **Strategies for lighting and heat gain while minimizing heat loss include:**

- Using a moderate WWR (30-40%) and consider double glazing.
- Alternatively using a higher WWR (40-50%) but including advance glazing with very low thermal conductance

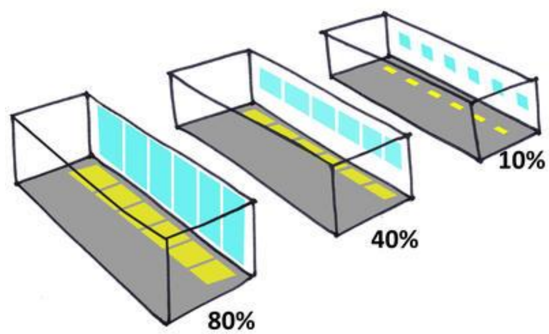


Fig. 30: Different window-to-wall ratios and the resulting illumination
(Source: sustainabilityworkshop.venturewell.org)

Considerations for different climates and types of building:

In dry climates, keep WWR below 20-30% to reduce excessive heat gain. Use shading devices to minimize direct sunlight.

In continental climates aim for WWR of 20-40%. This moderate WWR helps maximize daylighting while minimizing heat loss.

In mild climates, consider WWR between 30-50%, to achieve a balance between natural light and energy efficiency.

In tropical climates, consider WWR of 40-60% allowing to maximize natural cross ventilation and daylighting.

When designing **educational buildings**, it's crucial to balance external views, visual control, and a conducive environment for student concentration. This balance guides decisions on the window-to-wall ratio (WWR) and window placement.

Dos	Don'ts
• Adjust WWR based on the building's location and orientation to harness or mitigate solar gain and heat loss • Consider occupant comfort with operable windows for natural ventilation • Strategically place windows for external views and a connection to nature • When a low WWR is required, ensure daylighting using light colours in the interiors or devices like light shelves	• Do not overglaze in hot climates without proper shading or in colder climates without appropriate glazing efficiency • Avoid single glazing for higher WWR in cold climates • When lower WWR is required do not dismiss the importance of daylight and external views • Do not ignore building function and privacy

C2	Technique: External shading devices	Category: Building envelope

Description and impact:

External shading devices are a passive design technique used to control and optimize the amount of sunlight entering a building's interior spaces.

These devices must be strategically placed on the building's exterior to block or diffuse direct sunlight, reducing solar heat gain, glare, and the need for excessive cooling during hot periods.

Glazed areas that are fully shaded from the outside can reduce the solar heat gain by up to 80% compared to those located behind the glazing surface.

Design applications:

The below considerations are useful to decide which type of external shading device to use:

- Analyse the building orientation and specifically the windows' area and shape and its relation to the sun's path. Different orientations require different types of shading devices.
- Identify the interior requirements in terms of heat gain and daylight needs year-round
- Use solar analysis software or tools to simulate the building's performance with different shading configurations and evaluate the effectiveness

To prevent warm air from getting trapped between the device and the facade and entering the building, consider options like detaching the device from facades/windows, using perforated devices, or avoiding bulky structures.

a) Horizontal devices

- They can control summer sunlight and allow winter sunrays in to benefit from solar heat gain, if required
- Should be installed in windows facing the equator, considering the sun has a higher angle during summer and lower angle during winter
- Horizontal devices can also serve as light shelves
- Awnings act like horizontal shading devices that can benefit from its adjustability, since they can be extended or retracted. They are also easily applicable for renovation of existing buildings

b) Vertical devices, fixed/movable

- Vertical devices are useful to minimize the sunlight coming from the west, considering the sun's lower angle in the evenings
- The angle, length and position should be calculated understanding the window's orientation and the changes of the sun's path throughout the year
- Movable vertical shades can adapt to the different requirements throughout the year, but require proper maintenance and operation

c) Recessed window

- Recessed windows can benefit from having both vertical and horizontal shading
- Attention needs to be paid to impact negatively with prevailing winds for natural ventilation and views from the inside

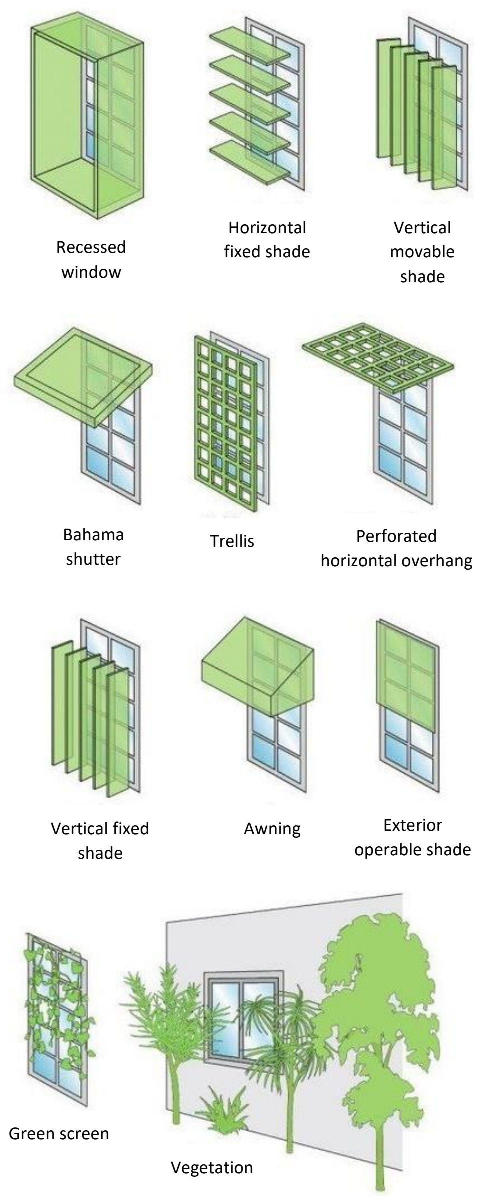


Fig. 31: Different types of external shading devices (Source: Al-Yasiri & Szabo 2021)

d) Double skin façade, trellis

- Creating a second skin (Fig. 32), which can include vegetation, can add esthetical value while being extremely effective to reduce heat gain through shading and evapotranspiration
- Obstructed views and accumulation of warm air should be evaluated prior using these solutions

Fig. 32: Min Tu Won School, Thailand, Estudio Cavernas et al, Architects (Photo: Juan Cuevas)

e) Exterior shades

- Installing exterior operable shades can reduce heat gain and diffuse direct sunlight
- This application can be easily introduced as a passive design measure in renovation of existing buildings
- The distance between the shade and the window should be enough to allow ventilation and minimize accumulation of heat that can enter when opening the windows or through conduction

f) Louvered windows or shutters (Fig. 33)

- These type of shading devices are common in many cultures and allow sunlight protection and security
- They can be an external device outside of the glazed window or they can replace the window in tropical climates, considering protection from insects

Fig. 33: Louvered shutters, Turkey (Source: iStockphoto.com)

Considerations for different climates and types of building:

In **desert climates** with cold nights and hot days, external shading devices might be needed for the sides of the building facing the equator and west facades. East facades might benefit from morning sun to break the cold air accumulated at night.

In **mild climates** with warm to hot summers and mild to cool winters, external shading devices must be designed to protect from undesired heat gain from summer sun and allow desired winter sun (Fig. 34).

In locations within the **tropical** belt, shading is necessary in all orientations given the intensity of solar radiation and the lower temperature variation between day and night.

The side of the building facing away from the equator needs no shading, except **near the equator** where the sun may be on the north or south side depending on the season.

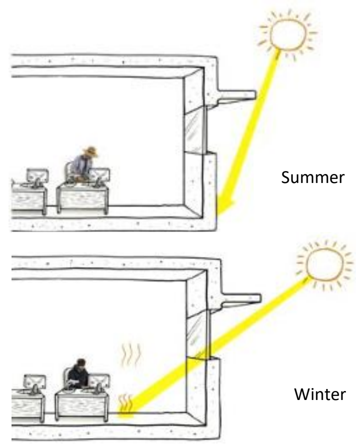


Fig. 34: Horizontal shading device facing the equator (Source: sustainabilityworkshop.venturewell.org)

Dos	Don'ts
• Use horizontal shading devices for facades facing the equator and vertical shading devices for those facing west • Use available tools (such as [InSight plug-in for Revit]) to calculate dimension, position, and angles of shading devices or manually using [sun-path diagrams]. • Explore vernacular solutions with proven results like mashrabiya (a traditional Islamic window element) or jaali (Indo-Islamic lattice screens) and adapt them to the contemporary designs • When designing consider the balance between daylight diffusion and sunlight reduction	• Avoid overcomplicated shading devices without proper operation and maintenance budget • Avoid devices that can accumulate dust or sand • Do not block with the shading devices the operation of windows for natural ventilation • In climates with cold winters do not block the desired heat gain from the sunlight • Don't forget vegetation as a natural shading "device". Deciduous trees are particularly useful in mild climates with hot summers and cold winters

C3	Technique: Insulation and sealing	Category: Building envelope

Description and impact:

Insulation involves incorporating thermal barriers within a building's envelope to reduce heat transfer between the interior and exterior spaces. It allows spaces to retain what heat they have, while avoid gaining excess heat from outside. These additional thermal barriers help improve the thermal resistance of other components of the building's structure. See Thermal resistance of typical construction materials

Sealing, also known as air sealing, airtightness, or weatherization, involves identifying and sealing gaps, cracks, and leaks in the building envelope. These gaps can allow the uncontrolled exchange of indoor and outdoor air, resulting in heat loss during cold periods and heat gain during warm periods.

Both techniques have great impact in energy consumption savings, and when combined, they can result in savings often exceeding 30% or more compared to a poorly insulated building with significant air leakage issues.

Design applications:

INSULATION: primarily is designed to prevent heat transfer from conduction and radiation.

Insulation usually comes in five physical forms:

a) Batting/ Blankets (Fig. 35)

- Batts or continuous rolls that are hand-cut or trimmed to fit. Stuffed into spaces between studs or joists
- Can be made from fiberglass, mineral fibre such as 'rock wool', recycled or cotton fibres such as Denim insulation, an eco-friendly and sustainable alternative
- Available with or without vapor and flame retarding facings

Pros: ease of installation, cost-effectiveness, and good conduction thermal performance

Cons: challenges with proper installation, potential health irritants from fiberglass, and sensitivity to moisture

Fig. 35: Insulation through blankets

b) Blown-in/ Loose-Fill (Fig. 36)

- Loose fibres or fibre pellets are blown into building cavities using special pneumatic equipment
- Some include adhesives that are co-sprayed with the fibres to avoid settling
- Composition can vary from fiberglass, rock wool, foam particles or cellulose
- Cellulose is made from recycled plant material (such as newspaper) treated with fire retardant chemicals

Pros: An insulating material for conduction that can offer added resistance to air infiltration, effective coverage prevents thermal bridging, can be applied in hard-to-reach spaces, quick installation

Cons: higher costs, requires professional installation and more complex equipment, potential health hazards due to microfibre inhalation

Fig. 36: Blown-in insulation

c) Foamed in Place (Fig. 37)

- Polyurethane or polyisocyanurate sprayed directly into cavities within the building, where it expands as it sets to fully seal the cavity, filling all nooks and crannies

Pros: superior performance both for air sealing and conduction insulating, can even provide structural shear strength

Cons: higher costs, expert installation, potential environmental concerns

Fig. 37: Foamed in place insulation

d) Rigid board (Fig. 38)

- Plastic foams extruded into boards, or fibrous materials pressed into boards
- Can also be moulded into pipe-coverings or other three-dimensional shapes
- Common materials are Polyisocyanurate, polyurethane, extruded polystyrene (“XPS”), expanded polystyrene (“EPS” or “beadboard”)
- May also be faced with a low-E reflective foil

Pros: strength with low weight, high R-values, can be used in confined spaces

Cons: higher costs, expert installation, if badly installed can cause thermal bridging

Fig. 38: Insulation using rigid boards

e) Reflective barriers (Fig. 39)

- Fabricated from aluminium foil with backings such as craft paper, plastic film, polyethylene bubbles or cardboard
- It can come as a roll of foil, integrated into house wrap, or integrated into rigid insulation board
- Typically located between roof rafters, floor joists or wall studs
- They always require at least a 20mm air gap adjacent to the reflective side to be effective

Pros: Resists radiative heat transfer, most effective in hot climates, can reflect heat back reducing heat loss in winter

Cons: For cold climates, it requires to be combined with a high R-value material

Fig. 39: Reflective barriers to resist radiative heat transfer

f) Combined systems (Insulation & Structure)

- **Structural Insulated Panels (SIPs)** (Fig. 40) consist of a layer of foam insulation sandwiched between two layers of oriented strand board (OSB) or other structural facing materials. These panels are used for walls, roofs, and floors, providing both insulation and structural support.
- **Insulated Metal Panels (IMPs)** (Fig. 41) are sandwich panels specifically made with metal facings (typically steel or aluminum) and an insulating core (such as polyurethane or mineral wool). They offer both insulation and structural capabilities and are commonly used in commercial and industrial buildings.
- **Insulating Concrete Forms (ICFs)** are forms or molds made of foam insulation that are filled with concrete to create a structurally sound wall system. The foam provides thermal insulation, while the concrete core offers strength and durability.

Pros: High insulation efficiency with structural strength, quick construction, factory-controlled quality

Cons: Higher costs, limited on-site adjustability, transportation issues, specialized installation

Fig. 40: Structural insulated panel (SIP)

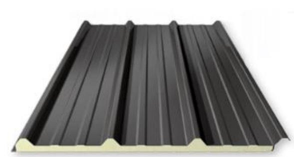


Fig. 41: Insulated metal panels (IMP) or Sandwich Panel

SEALING: Some considerations and applications to improve sealing proof of a building are:

- Include architectural elements like vestibules or airlocks
- Limiting envelope penetrations (e.g., for electricity supply)
- Identify most common leakages sites (Fig. 42)
- Treat opaque walls
- Treat joints between building components and walls

g) Opaque walls treatment: Walls can develop air leaks due to either their inherent porosity or the presence of numerous discontinuities. The primary methods for enhancing the airtightness of these extensive surfaces include:

- Plasters, they are employed to seal structures constructed from masonry materials

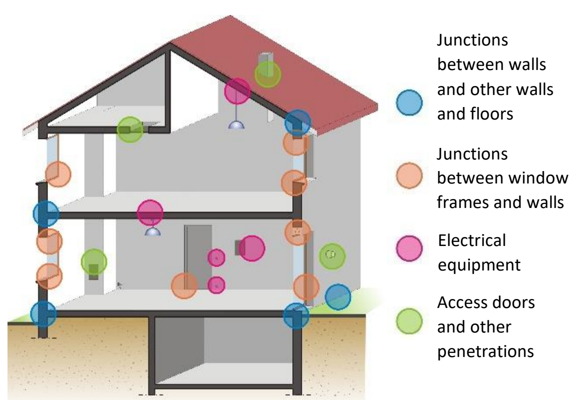


Fig. 42: Common leakage sites (Source: CEREMA – Pôle QERA)

- Vapor Barriers or Retarders, they are used in dry constructions, such as timber frame constructions. It's essential to understand the correct usage and placement of vapor barriers or retarders to prevent adverse effects, such as obstructing the escape of vapor from interiors or causing moisture issues within walls

h) <u>**Joint sealing:**</u> (Fig. 43 and 44) To seal joints between opaque walls and other building components (e.g., windows or door frames) consider using:

- Pre-compressed impregnated foams
- Adhesive membranes and tapes
- Extruded mastics
- Closed cell expanding foams
- Sealing products for pipes, electrical boxes, and other envelope penetrations

Fig. 43: Sealing foundation and framing

Fig. 44: Sealing wall and window gap

Considerations for different climates and types of building:

Insulation and airtightness play a crucial role, especially in **cold climates** and regions with significant temperature variations between night and day or across seasons.

Reflective barriers are particularly effective insulation systems in climates characterized by **high solar radiation levels**.

In extremely hot climates, it's important to assess the airtightness of a building, taking into consideration that a cost-effective approach to achieving comfort may involve prioritizing ventilation. This consideration becomes particularly critical in extremely hot and humid climates, where both ventilation and indoor humidity control are fundamental.

Dos	Don'ts
• Choose the right insulation for the climate and specifics application • Do proper installation • Use vapor barriers and retarders strategically and carefully • Evaluate if airtightness is required particularly in tropical climates	• Don't ignore gaps, cracks, and joints • Do not overlook moisture management • Don't compromise indoor air quality with extreme airtightness without appropriate ventilation systems • Don't ignore the required air space to allow reflective barriers work • Don't ignore health and safety measure including Personal Protective Equipment (PPE) particularly Respiratory Protective Equipment (RPE) when installing these materials

C4	Technique: Thermal mass	Category: Building envelope

Description and impact:

Thermal mass, as a passive design technique, involves the use of materials with high capacity to store and release heat slowly over time. This technique optimizes the building's ability to regulate temperature by absorbing excess heat during warm periods and releasing stored heat during cooler periods. Conversely, a construction material with high thermal mass can resist heating up too fast from solar radiation slowing the rate at which the sun heats a space and the rate at which a space loses heat when the sun is gone.

Design applications:

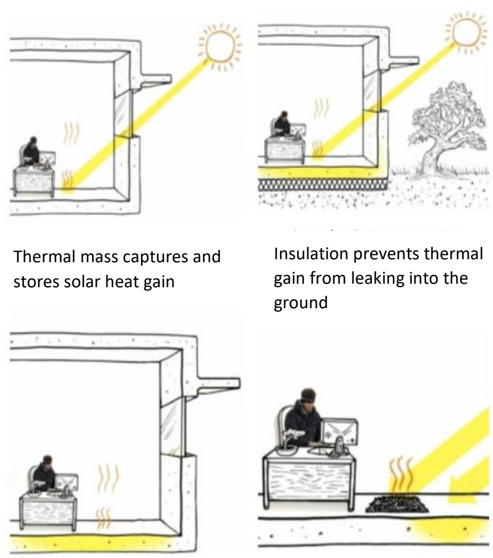
Improve heating efficiency with thermal mass:

- Choose materials with high thermal mass, such as concrete, stone, or masonry, for interior surfaces like floors and walls
- Position these surfaces with high thermal mass where it can absorb heat during the day, preferably on the side exposed to direct sunlight
- Locating thermal mass in interior partitions is more effective than external walls
    - Assuming they both have equal solar access; the internal wall heat will transfer heat out of both surfaces whereas the external wall will often lose half to the outside
- As a rule of thumb, the exposed area of thermal mass should be about six times the area of glass that receives direct sunlight
    - For example, an equator-facing room with a 1m2 window should have about 6m2 of exposed thermal mass, located where it will be exposed to direct winter sun
- Insulation prevents accumulated heat from being conducted to the ground or the outside air, where it is lost

a) **Trombe wall:** (Fig. 46) it consists of a dark-coloured wall of high thermal mass facing the sun, with glazing spaced in front to leave a small air space

- The glazing traps solar radiation like a small greenhouse, also heating the air
- The heat passes through the wall in several hours and release heat when the outside temperature drops in the evening and night

b) **Attached Sunspace** (Fig. 46) is essentially a Trombe wall where the air space is so big it is habitable.



Thermal mass captures and stores solar heat gain

Insulation prevents thermal gain from leaking into the ground

Thermal mass re-radiates heat after the sun is gone

Insulative coverings (like carpets) can interfere with thermal mass

Fig. 45: Use of thermal mass to improve heating efficiency (Source: sustainabilityworkshop.venturewell.org)

Improving cooling efficiency through Thermal Mass design:

c) **Night-purge ventilation or night flushing:**

- Incorporate indoor materials with high thermal mass located in the path of cross ventilation
- These materials absorb the indoor heat accumulated during the day
- The heat is released at night and expelled from the building through cross-ventilation

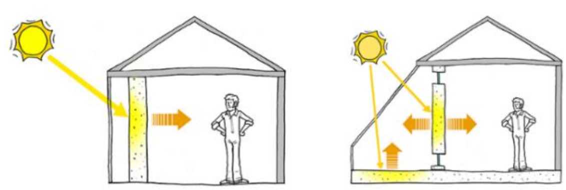


Fig. 46: A Trombe wall (left) and an Attached Sunspace (right) (Source: sustainabilityworkshop.venturewell.org)

d) **<u>High thermal mass external walls</u>** can also function as a buffer to prevent heat gain in warm climates with cool nights (Fig. 47).

- These walls are usually constructed with significant thickness, often around sixty centimetres if made of adobe
- In thick walls like these, the heat is absorbed but it does not penetrate to the interior before the day ends
- As outdoor temperatures drop below indoor ones, the heat stored in these walls reverses direction, moving outward
- This cycle continues day and night, preventing the heat from entering the home

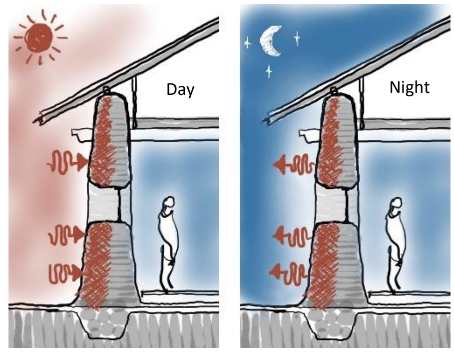


Fig. 47: Adobe built constructions can be effective for cooling efficiency (Source: Author)

Considerations for different climates and types of building:

Thermal mass is most effective in regions with **significant day-to-night temperature fluctuations**. While it does not completely block heat transfer in or out of occupied spaces as insulation does, it can significantly slow this heat flow.

In extreme climates, the thermal mass effect can be counterproductive, as all mass surfaces align with the daily temperature. In warm tropical areas, lightweight and open designs are favoured, while extremely cold areas prioritize heavy insulation with minimal exposed thermal mass.

Dos	Don'ts
• Use thermal mass when significant day-to-night temperature fluctuations exists • Combine thermal mass with other passive design techniques like solar heat gain and ventilation • When used for heating, prefer indoor elements with high thermal mass • When used for cooling, use exterior thick walls with thermal mass • Include proper ventilation when used for night flushing	• Don't neglect insulation; it prevents the loss of accumulated heat or excessive gain • Don't rely solely on thermal mass • Don't use thermal mass in tropical climates or near the poles • Don't oversimplify the design; using thermal mass requires a carefully considered design approach • Don't forget to shade thermal mass when used for night flushing • Do not overlook seismic structural requirements when using adobe in earthquake-prone areas

C5	Technique: Double envelope and double roof	Category: Building envelope

Description and impact:

The building's envelope and roof play a crucial role in managing external factors and maintaining indoor comfort like sunlight, weather and noise. To achieve energy savings, a double-envelope approach can be employed. This involves adding an intermediate buffer space and a second outer skin to the inner facade, creating an additional protective layer against external conditions.

These double envelopes can take various forms, from a simple ventilated facade that creates an air cavity or gap between the building's exterior cladding and the structural wall to a liveable buffer zone or transitional area within or around the building.

Similarly, double roofs offer energy efficiency benefits. They range from a more basic ventilated attic to a second roof structure positioned above the primary roof. This secondary roof provides shading and allows for the release of warm air, reducing the need for indoor cooling and heating.

Design applications:

ENVELOPE:

a) **A ventilated facade**, (Fig. 48) also called a ventilated cladding or rainscreen facade, consists of three layers:

- Outer Cladding: The visible layer facing the external environment, made of materials like metal, ceramic, stone, glass, or composites.
- Air Cavity: An open space behind the outer cladding that aids ventilation, enhances thermal insulation, and prevents moisture damage.
- Inner Wall/Insulation Layer: The innermost layer providing thermal insulation and weather protection for the building's interior.

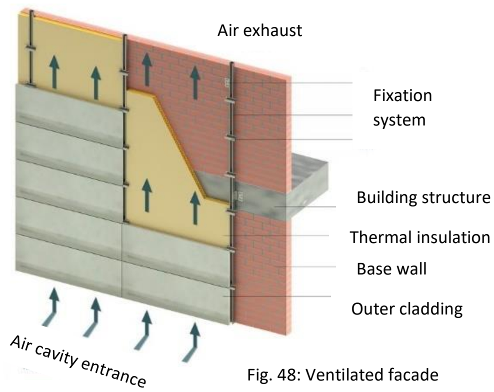


Fig. 48: Ventilated facade (Source: baffsystem.com)

b) **A Double-skin façade** consists of two distinct layers – an outer layer and an inner layer – separated by an intermediate space.

- Both layers can be made of various materials, including glass, metal, or other cladding options.
- The intermediate space can be a liveable space while also helps natural ventilation, solar shading, and thermal insulation.

While double-skin facades are commonly incorporated into high-rise buildings, a similar effect can be achieved in smaller projects by adding an outer lighter skin to the building.

- This outer skin provides shading
- Allows cool air to enter
- Protects the core façade from rain and humidity.
- It can also incorporate local materials or building techniques and create transitional liveable areas (see figures 49 and 50).

Fig.49: Lycée Schorge, Burkina Faso
Kéré Architecture, Photo: Iwan Baan

Fig.50: High School Thazin, Myanmar
a+r ARCHITEKTEN, Photo: Julia Raff

c) **<u>Traditional architectural elements like verandas</u>** can achieve a similar effect in a building by including shading devices like shutters or even climbing plants, providing cool transitional or intermediate spaces. (Fig. 51)

Fig. 51: Verandas and vegetated pergolas as intermediate cooling spaces (Source: Pinterest.com)

<u>ROOF:</u>

d) **<u>A ventilated attic</u>** (Fig. 53) helps maintain attic temperature and prevents moisture build-up, preventing excess heat build-up in summer and minimizing heat loss in winter. To build a ventilated attic is required to:

- start by ensuring proper insulation between the attic floor joists to prevent heat transfer
- install soffit vents along the eaves
- incorporate ridge vents along the roof peak to create a continuous airflow path
- install a gable vent on the end walls of the attic to enhance cross ventilation
- use baffles to keep insulation away from the eaves, allowing air to flow from the soffit vents to the ridge vents

Fig. 52: UNICEF Bangladesh office featuring a verandah all around to minimize direct exposure to solar heat gains (Source: Construction at UNICEF)

e) **<u>A double roof</u>** positioned above a building's primary roof effectively reduces direct exposure to the intense heat of the sun, significantly lowering indoor temperatures (Fig. 54 and 55).

- Extend the double-roof structure to cover outdoor areas, creating livable spaces that naturally cool the surroundings.
- The double roof can also be just a shading element, as seen in figure 53.

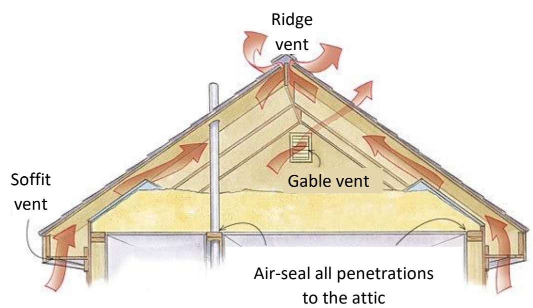


Fig. 53: Ventilated roof (Source: FineHomeBuilding.com)

Fig. 54: Casa Entreluz, Chile
Pablo Padilla Carvacho + Jesús del Río. Photo: Marcela Melej

Fig. 55: Gando Primary School Extension, Burkina Faso
Kéré Architecture. Photo: Erik Jan Ouwerkerk

Considerations for different climates and types of building:

- **Ventilated facades** help reducing energy costs in all different climates but are **particularly useful in colder and humid ones.**
- **An outer skin** can be very beneficial to improve indoor comfort in **hot and humid climates**.
- **Double roofs** can keep cooler indoor spaces particularly in **hot and dry climates.**
- **Ventilated attics** are also beneficial **for every climate**, levering temperature and regulating moisture.

Dos	Don'ts
• Consider utilizing ventilated facades when feasible	• Don't ignore the extra costs of these features
• Always ensure proper attic ventilation	• Don't allow hot air to accumulate in attics
• Implement double roofs in hot climates	• Avoid direct sun exposure in hot climates
• Integrate verandas and use double-skins to maximize their benefits	• Don't neglect exteriors, letting them overheat

C6	Technique: Colour and reflection	Category: Building envelope

Description and impact:

Colour and reflection are essential passive design techniques that harness the characteristics of building materials to reflect or absorb solar radiation and daylight.

Light-coloured, cool-coloured, or reflective materials used for exterior surfaces can help minimize solar heat absorption, keeping building envelopes cooler and reducing the need for excessive cooling. Similarly, reflective glazing and finishes can control solar heat gain and glare while allowing ample natural light indoors. Darker and matte colours, on the other hand, can assist in passive solar heating in colder climates by absorbing and retaining solar energy.

Design applications:

Colour and reflection can be used with the purpose of cooling or heating when applied to the main envelope components that receive the most sun, such as the roof and external walls.

Opting for a roof or wall finish with higher solar reflectivity (Albedo) can decrease the cooling load in air-conditioned spaces and enhance thermal comfort in non-air-conditioned spaces. This choice additionally extends the lifespan of the finish due to reduced surface temperature and contributes to mitigating the impact on the urban heat island effect.

On the other hand, choosing a material with lower Albedo will absorb and retain heat, contributing to the warmth of buildings in colder climates.

a) <u>Colour and reflection on roof materials:</u>

For climates with higher cooling requirements:

- Prefer neutral, light colours like white, beige, or light grey.
- Choose a glossy finish paint or material for increased light reflection.

For climates with higher heating requirements:

- Prefer darker colours, like dark grey or black
- Choose a matte-finished material

When other finishes or colours are necessary, always check the solar reflectivity (SR value) of the roofing material.

- Some manufacturers may provide the Solar Reflectance Index (SRI value), which considers both reflectivity and emittance. Note that certifications like EDGE focus on solar reflectivity alone.
- Explore advanced options like heat-reflective coatings, commonly used in cool-roofs or cool-walls. These coatings, often available in various colours, incorporate microelements, such as glass microfibers, for effective solar energy reflection.


Grey Asphalt Shingle: **22%**

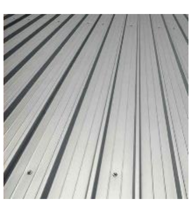

Grey EPDM: **23%**

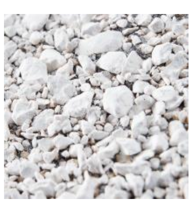

Unpainted Cement Tile: **25%**


White Granular Surface Bitumen: **26%**


Red Clay Tile: **33%**


Light gravel on Built-Up Roof: **34%**


Aluminium: **61%**


White Gravel on Built-Up Roof: **65%**


White EPDM: **69%**


White Cement Tile: **73%**


PVC White: **83%**

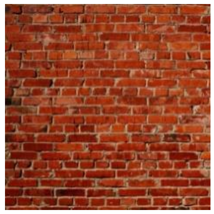

White coating on metal roof: **67%**
1 coat, 8 mils: **80%**
2 coats, 20 mils: **85%**

Fig. 56: Solar reflectivity values for typical roofing materials - 0% least reflective, 100% most reflective. These values are for reference only and are not for use as substitutes for actual manufacturer data. (Data source: EDGE / Table source: Author)

b) Colour and reflection on wall materials:

Exterior building walls are exposed to only about half the amount of sun as roofs, but they can also absorb heat. The same principles as roofs apply for walls.

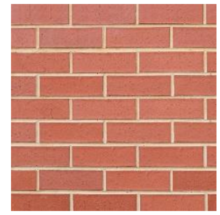
Dark Acrylic Paint: **15%**



Fired clay bricks: **17% - 56%**

Medium Dark-coloured paint: **25%**

New concrete: **35-45%**



Red brick: **40%**

Concrete block: **40%**

Medium-coloured paint: **45%**

Shades of white paint: **65%**

White Portland cement concrete: **70-80%**

White Acrylic Paint: **70%**

White Plaster: **90%**

Fig. 57: Solar reflectivity values for typical wall materials - 0% least reflective, 100% most reflective (Data source: EDGE / Table source: Author)

c) Indoor Colour for Daylight Enhancement:

Lighter-coloured interiors can effectively reflect daylight, thereby reducing the need for artificial lighting and minimizing energy consumption.

d) Hue-heat effect:

Warm colours create a perception of warmth, while cool colours have the opposite effect.

- Using blue and green evokes a cooler feeling
- Using yellow and red hues feel warmer

While this influences temperature perception, thermal comfort is a subjective state of mind reflecting satisfaction with the thermal environment. For considerations of colour temperature in artificial lighting see Efficient Lighting.

e) Water heating: Dark colours are used in solar water heaters, either commercial ones or simpler dark coloured water tanks

Considerations for different climates and types of building:
For dry, mild, and tropical climates, use light colours or for the building's envelope can effectively help maintaining buildings cooler during hot seasons.
For continental, cold climates, darker colours and materials with low albedo can improve the solar heat gain capacity of the building.

Dos	Don'ts
• Use light colours to reduce heat gain in the building's envelope and darker colours if heat gain is desired • Look for materials with higher Albedo to minimize heat gain and lower Albedo whenever solar heat gain is desired • Utilize light-coloured painting in interior surfaces to maximize daylighting • Consider the psychological effect of colours to improve comfort considering the function of the built spaces	• Avoid roofing materials with low Solar Reflectivity in hot climates or regions with mild to warm summers • Avoid excessive use of bright, white-coloured surfaces in places that may cause glare • Do not neglect the psychological effects of colour on thermal comfort • Refrain from using dark colours in spaces with limited daylight

D1	Technique: Efficient lighting	Category: Indoor

Description and impact:

Efficient lighting involves the utilization of lighting systems and technologies designed to minimize energy consumption while still delivering sufficient illumination for their intended purposes.

This goal of energy efficiency can be realized through a combination of strategies, including selecting energy-efficient light sources like LEDs, optimizing lighting designs tailored to specific tasks, integrating natural light through strategic window placement, implementing motion sensors and timers for precise lighting control, utilizing dimming and advanced controls to adjust light intensity as needed, selecting energy-efficient fixtures, conducting regular equipment maintenance, and adhering to energy codes. These practices collectively could contribute to achieving energy savings of over 80%.

Design applications:

To design an **energy-efficient lighting system** the following steps should be consider:

a) <u>Assess Lighting Needs:</u>

- Begin by understanding the specific requirements of the space. Consider factors like the purpose of the area, the tasks performed, and the desired ambiance

b) <u>Calculate Lighting Requirements:</u>

- Determine the amount of light (measured in lumens) needed for the space based on industry standards, local regulations and the activities taking place. Lighting calculations should account for factors like room size, colour, and reflectance

c) <u>Select Energy-Efficient Light Sources and fixtures:</u>

- Choose energy-efficient light sources, such as LED bulbs, based on the calculated lighting requirements. LEDs are highly efficient and have a long lifespan, reducing energy consumption and maintenance costs
- Select lighting fixtures that are designed for energy efficiency. Look for fixtures with reflectors or lenses that direct light effectively and minimize light loss

d) <u>Optimize Lighting Layout and consider task lighting:</u>

- Design the placement of lighting fixtures to provide uniform and adequate illumination
- Avoid over-lighting or creating glare
- Ensure that lighting is focused on task areas and avoids unnecessary spillage (Fig. 58)

Fig. 58: Engelbach Kindergarten, Austria
Innauer-Matt Architekten. Photo: Adolf Bereuter
(What is Human Centric Lighting? ArchDaily.com)

e) <u>Incorporate Natural Lighting:</u>

- If possible, design the space to maximize the use of natural daylight.
  Consider the orientation of windows, skylights, and light wells to reduce the reliance on electric lighting during daylight hours

f) <u>Implement Lighting Controls:</u>

- Integrate lighting controls, such as occupancy sensors, timers, and dimming systems, to manage the use of artificial lighting
- Consider independent lighting controls for task lighting fixtures

g) <u>Consider Colour Temperature and Colour Rendering:</u>

- Pay attention to the colour temperature (warmer or cooler) of the lighting, as well as the colour rendering index (CRI) to ensure that the lighting meets aesthetic and functional requirements

Considerations for different climates and types of building:

For school projects:

Consider different lighting settings in the classrooms, allowing for reduced artificial lighting when less illumination is needed and full lighting when required.

If the different rooms or outdoor spaces incorporate areas for other activities such as reading, hands-on work, or laboratory work, contemplate specific lighting for these tasks, with independent controls.

To determine the appropriate colour temperature for lighting in classrooms, consider the age group of students and the types of activities. Here are some examples:

- **Cool White (4000K to 4500K)**: This temperature is energizing and well-suited for tasks that require focus, such as reading and math classes
- **Neutral White (3500K to 4000K):** This temperature provides a balanced lighting environment and is suitable for various classroom activities, including general instruction and computer work
- **Warm White (2700K to 3500K):** This temperature creates a soft and inviting atmosphere, making it ideal for areas in a school like preschool classrooms or relaxation zones

Kelvin Color Temperature	2700K	3000K	3500K	4100K	5000K	6500K
Associated Effects and Moods	Ambiant Intimate Personal	Calm Warm	Friendly Inviting	Precise Clean Efficient	Daylight Vibrant	Daylight Alert
Appropriate Applications	Living/Family Rooms Commercial/ Hospitality	Living/Family Rooms Commercial/ Hospitality	Kitchen/Bath Light Commercial	Garage Commercial	Commercial Industrial Institutional	Commercial Industrial Institutional

Fig. 59: Kelvin Color Temperature of Lighting: associated effects and moods with appropriate applications

For Health facilities:

Install occupancy sensors in areas like restrooms and storage rooms to ensure lights are only on when needed. Use timers and scheduling systems to automatically turn off or dim lights during non-peak hours or when areas are unoccupied, such as in corridors, waiting rooms, and exam rooms. Design the lighting layout to include zoning and task-specific lighting

To determine the appropriate colour temperature for lighting in health facilities, consider the activity and tasks for each zone, such as:

- **Patient rooms**: Opt for warmer tones (2700K to 3500K) for patient rooms, creating a comforting atmosphere that aids in relaxation and recovery
- **Operating or procedure rooms**: Use cooler temperatures (4000K to 5000K) in surgical areas to ensure bright and focused lighting for medical procedures
- **Waiting areas**: Employ neutral white lighting (3500K to 4000K) in waiting rooms for a welcoming and functional environment
- **Nurse stations**: Utilize cooler lighting (4000K to 5000K) at nurse stations to enhance visibility and alertness.
- **Corridors**: Maintain neutral white lighting (3500K to 4000K) in hallways to facilitate movement and wayfinding

For UNICEF offices:

Use the Checklist to identify Eco-Efficiency and Inclusive Access Features from the Division of Financial and Administrative Management (DFAM) and IDEAs evaluation tool (Important and Desirable Environmental Actions) a tool used to guide the establishment or selection of Resilient and Efficient UN offices.

Dos	Don'ts
• Incorporate LED technology • Consider task lighting with individualized controls • Separate the lighting layout with different light controls to allow different amounts of artificial light depending on the hour of the day and the tasks • Use occupancy sensors, motion sensors, and dimmers • Include emergency lighting	• Don't overlight spaces • Don't rely solely on one single manual switch • Don't mix colour temperatures haphazardly • In schools, avoid extremely blueish colour temperatures • Avoid incandescent or older fluorescent fixtures

D2	Technique: Water efficient fixtures	Category: Indoor

Description and impact:

Water-efficient fixtures are plumbing devices designed to minimize water usage without compromising functionality.

Incorporating fixtures with reduced flow rates and educating users about their effective usage can save from 30% to 50% of indoor water use and yield substantial savings on water, sewer, and energy consumption. With less water usage, energy consumption relative to the use of water heaters and other household appliances that use water and energy is reduce on average by 25%. Water-saving plumbing can also reduce moisture, improve indoor air quality, and reduce risk of mould growth within the building.

Design applications:

a) **Dual-flush toilets:** (Fig. 60) These toilets have two buttons or levers that allow users to choose between a full flush (for solid waste) or a partial flush (for liquid waste).

- A dual-flush toilet can save up to 67% of water compared to a standard toilet.

Fig. 60: Dual Flush Toilets

b) **Dry or compost toilets** (Fig. 61) are eco-friendly alternatives to traditional flush toilets that use little to no water and instead convert human waste into compost.

- Organic materials like sawdust or peat moss must be added to aid in decomposition and control odour
- Compared to pit latrines, compost toilets have better odour control, reduced pollution of groundwater and consequently less risk of waterborne diseases.
- Compost toilets, while needing less frequent emptying than pit latrines, may require vigilant management to ensure efficient operation and prevent composting issues.

Fig. 61: Dry Toilets

c) **Aerators** (Fig. 62) are small parts placed on the end of faucets. Typically, they are small mesh screens that break up the flow of water into multiple small streams, adding air in between. By diluting the water stream with air, aerators significantly reduce the volume of water flowing from a faucet.

- Using a low-flow aerator (< 2 litres per minute or LPM) instead of a standard aerator (>9 LPM) result in approximately a 78% reduction in water usage.

Fig. 62: Aerators

d) **Self-closing metering faucets**, (Fig. 63) also known as metering faucets or push-button faucets, are a type of faucet that is designed to automatically shut off the flow of water after a predetermined amount of time.

- Savings of up to 50% in water usage can be achieved by using these types of faucets in public restrooms.
- Some of these faucets also prevent cross-contamination and are accessible for people with reduced mobility or limb difference because they allow operation with the elbow or forearm. See UNICEF's Handwashing Stations Fact Sheet for more details.

Fig. 63: Self-closing metering faucets

e) **A sensor-activated faucet**, also known as a touchless or automatic faucet, is a type of faucet equipped with sensors that detect the presence of a user's hands or objects near the faucet, activating the flow of water for a fixed period or until the hands are removed.

- While it offers hygienic and water-saving benefits, its higher cost, dependency on a power source, and the complexity of repairs may limit its suitability for all contexts.

f) **Waterless urinals** (Fig. 64) are restroom fixtures that conserve water by eliminating the need for flushing. Instead of using water, they utilize a liquid barrier or sealant in the urinal bowl to trap odours and direct urine into the plumbing system.

- Using a waterless urinal can save approximately 7,300 litres of water per year compared to a regular urinal
- Some models require the regular replacement of cartridges or sealant liquid, involving extra operational procedures and maintenance costs

Fig. 64: Waterless Urinals

Considerations for different climates and types of building:

Water-saving fixtures such as low-flow toilets and urinals, self-closing metering faucets, and faucet aerators can be used in schools to conserve water and promote sustainability.

In health facilities, sensor-activated faucets can offer hygiene advantages while reducing water consumption.

Dos	Don'ts
• Install low-flow toilets and faucets • Consider replacing some toilets with urinals when possible and in accordance with local building codes • Install metering faucets to control water flow • Implement regular maintenance checks to detect and address water leaks promptly • Educate users on water-saving habits and use of fixtures • Always specify locally available products for easy repair and replacement, if needed.	• Don't underestimate the higher initial cost of water-efficient fixtures • Don't forget to evaluate the availability of spare parts and trained maintenance personnel • Don't neglect scheduled preventive maintenance • Don't compromise on low-cost or low-quality water fixtures

D3	Technique: Greywater recycling	Category: Indoor

Description:

Greywater recycling is a process that involves treating and reusing wastewater generated in buildings. This wastewater comes from sources other than toilets and is free from faecal contamination. It is used for specific non-drinking purposes, such as flushing toilets and watering plants, helping to lessen the demand on fresh water sources.

While percentages can vary considerably worldwide, water used for toilets and irrigation can account for nearly 50-60% of total household water consumption. Therefore, the impact of reutilizing greywater for these purposes can significantly help in reducing overall water consumption.

Greywater recycling, based on life-cycle costs, has been evaluated as the most effective water efficiency measure.

Design applications:

Greywater Recycling System Components:

a) **Collection System:**

- Greywater is gathered from drains, such as those in sinks, showers, bathtubs, and the washing machine
- It is collected through a separate piping system from toilets, which may contain faecal material, and kitchen sinks, where food remnants or grease may be present, requiring a different treatment

b) **Treatment System:**

- Greywater is treated to eliminate impurities and ensure its safety for reuse
- Some of the most common treatment processes might include:
  - Aerobic Screening: insoluble material is removed from the wastewater. The process efficiently reduces the material into almost negligible residue, which is discharged into the public sewerage system, the remaining greywater flows to the second stage
  - Biological Treatment Plant: In this process, air is flown into the water so that bacteria can consume impurities up to a large extent. To achieve the maximum metabolizing levels, a sustainable concentration of biomass is maintained in the chamber. As a result, almost all of the incoming waste gets cleaned, and the amount of residue is the minimum. Typically, 99.9% of the water can be reused.
  - Ultrafiltration: Special membranes with microscopic pores filter bacteria, virus, and other toxic particles. Membranes should be cleaned regularly by air scouring so that maximum cleaning is assured.
  - Disinfection via UV: Ultraviolet lamps are used for additional protection against pathogens.

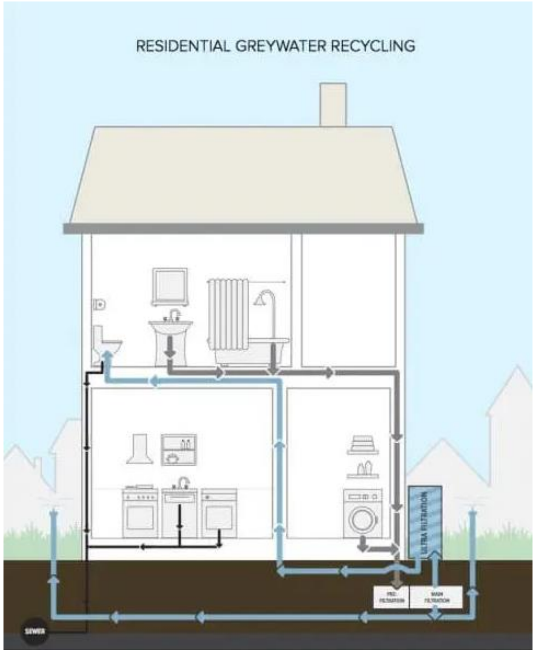


Fig. 65: Example of a greywater recycling system (Source: elemental.green)

c) **Storage Tank:**

- Once treated, the cleaned greywater is stored in a designated tank
- The tank's location can vary, either inside or outside the building, based on available space and local regulations
- Chlorination: Chlorine is added to the water in reticulation and storage system. It removes impurities by ionizing water molecules.

d) **Distribution System:**

- The treated greywater can be distributed for use, such as flushing toilets or outdoor irrigation
- To prevent any mixing with clean, potable water, a separate distribution system is crucial
- This system often includes pipes, pumps, and valves to ensure the safe and efficient use of recycled greywater

Considerations for different climates and types of building:

A basic greywater recycling system can be designed and implemented in schools, utilizing handwashing wastewater to flush toilets and irrigate plants in the playground.

Dos	Don'ts
• Install separate piping for sink, shower, bathtub, and washing machine wastewater • Treat, store and reuse this greywater for toilet flushing and irrigation • Opt for biodegradable soaps and detergents • Educate students and staff on system usage • Continuously monitor water quality • Label pipes and use signs to prevent confusion and misuse • Perform routine maintenance • Maintain records of investment costs and monitor payback over a period of 3 to 5 years as evidence of a cost-friendly choice	• Don't solely depend on fresh water for flushing toilets and irrigation • Ensure proper treatment of greywater • Avoid the use of harmful chemicals or toxic cleaners • Be mindful not to overload the system; make sure the water storage can handle the incoming greywater • Never use greywater for drinking or food preparation • Exclude outdoor faucets that could be mistaken for potable (drinkable) water sources • While greywater recycling is considered a safe practice, it is not recommended for use in health facilities.

6) 40 sustainable actions to achieve indoor comfort - by climate type and energy source

ALL CLIMATES			Why?	Card
Wind	1	Control infiltration.	HL	C3
	2	Admit controlled fresh air ventilation.	AQ	B3 / C1
Sun	3	Collect sun for service hot water	ES	C6
	4	Collect sun for producing electricity	ES	*
Humid.	5	Allow vapor to dry inward/outward	AQ / OM	C3 / C5
	6	Remove excess moisture by ventilation	AQ / OM	B3
Daylight	7	Preserve daylight access on the site	VC / ES	B1
	8	Capture daylight architecturally	VC / ES	B1 / C1
	9	Reflect daylight deep into interiors	VC/ES	B1 / C2
	10	Admit reflected or diffuse light to reduce heat gains	VC / -HG	B1
	11	Provide a range of lighting conditions.	VC / ES	D1
	12	Control glare	VC	C2
	13	Integrate daylight and electric light	ES	D1
Multi	14	Use efficient fixtures	WS	D1 / D2
COLD CLIMATES				
Wind	15	Block cold wind.	HL	A1 / C3
	16	Decrease interior air velocity	HL	B3
Sun	17	Preserve site solar access	+HG	A1 / B1
	18	Admit sun when there's a heating load at night	+HG	C1 / C4
Temp.	19	Shift schedules to avoid peak cold	ES	**
	20	Increase/concentrate internal heat generation	ES	B1 / B2
	21	Block heat loss through the envelope	HL	C3 / C5
	22	Store daytime heat for use at night.	+HG	C4
Multi	23	Create a warmer outdoor microclimate	+HG	A1

ALL HOT CLIMATES			Why?	Card
Temp.	24	Shift schedules to avoid peak heat	ES	**
	25	Decrease, isolate and/or disperse internal heat generation	ES	B1 / B2
	26	Block heat gain and allow heat loss through the envelope when indoors is hotter that outdoors	-HG / +HL	B3 / C2
	27	Store heat in thermal mass when it is too hot to ventilate	+HL	C4
	28	Move cool air to where is needed	+HL	B3
Wind	29	Preserve wind access to the site	+HL	A1 / B1
	30	Admit outside air when it is not too hot for cooling	+HL	B3 / C1
	31	Increase interior air velocity	+HL	B3
Multi	32	Create a cooler outdoor microclimate	+HL	A1
Sun	33	Block sun when outside temperature is above recommended temperature range	-HG	C2
	34	Use sun to enhance stack-ventilation	+HG	B3 / C4
HOT-ARID CLIMATES				
Humid.	35	Use evaporative cooling when it's too hot for other cooling strategies	+HL	A1 / A2
	36	Add moisture to indoor air (humidify)	AQ	A2
	37	Add moisture to ventilation air	+HL	A2
HOT-HUMID CLIMATES				
Humid.	38	Remove moisture from indoor air	AQ / OM	B3 / C3
	39	Remove moisture from ventilation air	+HL / OM	C2 / C5
	40	Avoid creating additional humidity	AQ / OM	D2

LEGEND:

- **-HL:** To avoid heat loss and maintain indoor temperature
- **+HL:** To increase interior heat loss, cooling indoor spaces
- **-HG:** To avoid Heat Gain hence energy savings in cooling
- **+HG:** To increase Heat Gain hence energy savings in heating
- **VC:** To improve Visual Comfort
- **AQ:** To improve Air Quality
- **ES:** For Energy Saving purposes
- **WS:** For Water Saving purposes
- **OM:** To reduce operation and maintenance and protect the building

*For solar electrification of programme facilities visit: 8 Steps for Solar Electrification of Programme Facilities

** Building operation and maintenance manual should include recommendations on schedule to minimize energy consumption

7) Glossary

Sun path, azimuth angle, zenith angle, solar elevation, solar altitude: Sun path refers to the seasonal arc-like path that the sun appears to follow across the sky during the day. It is measured using the solar azimuth angle, the horizontal angle with respect to north, and the solar zenith angle (or its complimentary angle, solar elevation, or solar altitude) that defines the apparent solar altitude.

Thermal mass: refers to the ability of a material or an object to absorb, store, and release heat over time

Thermal comfort: refers to an individual's satisfaction with the temperature and environmental conditions of a space. It is subjective and influenced by factors such as air temperature, humidity, air movement, and personal preferences. In general, a comfortable indoor temperature range for most people falls between 18°C and 26°C. Relative humidity levels are typically comfortable between 30% and 60%. However, individual preferences can vary, and factors like clothing and activity level also influence perceived comfort.

Visual comfort: refers to the quality of lighting in an environment and how it affects a person's visual well-being, ease of seeing, and overall comfort while performing tasks or simply occupying a space. It involves achieving appropriate illumination levels, minimizing glare and shadows, ensuring accurate colour representation, selecting suitable colour temperatures, preventing flicker, providing task-specific lighting, adjusting artificial lighting to complement natural light, and allowing user control.

Acoustic comfort: refers to the level of satisfaction or comfort an individual experiences with the acoustic environment they are in. It involves the perception of sound quality, including noise levels, sound clarity, and the absence of disruptive or annoying sounds.

Indoor air quality refers to the state of the air within indoor spaces, which includes factors like pollutant levels, humidity, temperature, and ventilation.

Urban Heat Island Effect: A city's core temperature is often significantly higher than its surrounding area due to the retention of heat from the built environment.

Conduction: refers to the molecular transfer of heat, such as the flow of heat through a solid.

Convection: The transfer of heat by circulation or movement of a fluid (liquid or gas).

R-Value**:** Thermal Resistance of a construction material. In construction, a material's capacity to resist heat flow from one side to the other is measured by the R-value (high thermal resistance = high R-value). In simple terms, R-values measure the effectiveness of insulation, and a higher number represents more effective insulation. R-values are additive. For instance, if you have a material with an R-value of 12 attached to another material with an R-value of 3, then both materials combined have an R-value of 15. Conduction is the dominant factor for heat transfer when materials are touching each other.

Solar Radiation: the energy emitted by the sun in the form of electromagnetic waves. It becomes important when there is an air gap between materials. Resistance to radiative heat transfer is measured by emissivity (high resistance = low emissivity and high reflectance)

Sun path diagram: It is a diagram that can tell how the sun will impact a site and building throughout the year. Stereographic sun path diagrams can be used to read the solar azimuth and altitude for a given location. More information in the Sustainability Workshop by VentureWell.org. To find a sun path diagram for a specific site consult these available online tools: Sunpath2d or SunEarthTools

Albedo or Solar Reflectance (SR): The measure of how much light or radiation is reflected by a surface, rated on a scale of 0 to 1 or 0-100%, where higher numbers indicate greater reflectance.

Continental climate: climate that experiences extreme seasonal change with cold winters and warm, wet summers. Continental climates are only found in the Northern Hemisphere.

Evapotranspiration: is a natural process in plants that helps regulate temperature by releasing water vapor through leaves and stems, thereby cooling the surrounding environment, and contributing to temperature control within ecosystems.

Glazing Efficiency: For assessing the effectiveness of windows, skylights, translucent panels, or similar products in allowing sunlight into a building, three key properties come into play:

1. Thermal Conductance (U-Factor): Measures glazing insulation; lower values signify better insulation properties.
2. Solar Heat Gain Coefficient (SHGC): Gauges how much incoming sunlight heat is transmitted into the building; values range from 0 to 1, with lower values indicating more effective resistance.

3. Visible Light Transmittance (VT): Assesses the amount of visible light passing through; higher values mean more visible light transmission.

As a general guideline:
Efficient windows for warm climates: Low SHGC, high VT, and possibly low U-factor.
Efficient windows for extreme cold climates: Low U-factor, higher SHGC, and high VT.

Rain gardens: a designed and landscaped area that collects and filters rainwater runoff from roofs, driveways, and other surfaces to prevent pollution and promote groundwater recharge. It typically features native plants and a shallow basin to manage stormwater sustainably.

Xeriscaping: is a water-efficient landscaping and gardening approach, featuring drought-tolerant plants, efficient irrigation like drip systems, and elements like mulching and rock gardens. It's designed to conserve water, making it well-suited for arid climates or water-scarce regions.

Thermal emittance – Thermal emissivity: often denoted by the symbol ε (epsilon), is a property of a material that describes its ability to emit thermal radiation. It is a measure of how efficiently a material emits heat energy in the form of infrared radiation when it is heated. Thermal emittance is expressed as a dimensionless number between 0 and 1, where 0 indicates a material that is a perfect thermal reflector (emits no radiation), and 1 indicates a perfect thermal emitter (emits radiation as efficiently as a blackbody)

Thermal radiation: Electromagnetic radiation emitted from a surface. The spectrum of this radiation depends on the temperature of the surface. "Thermal" radiation typically refers to that emitted by a surface whose temperature is near 300K (~25°C).

Thermal conductivity: Thermal conductivity (sometimes referred to as k-value or lambda value (λ)) is a measure of the rate at which temperature differences transmit through a material. The lower the thermal conductivity of a material, the slower the rate at which temperature differences transmit through it, and so the more effective it is as an insulator. Very broadly, the lower the thermal conductivity of a building's envelope, the less energy is required to maintain comfortable conditions inside.

8) Online resources

- Passive Design Strategies | Sustainability Workshop (venturewell.org)
- 2030 Palette – A database of sustainable design strategies and resources
- Cerema, climat et territoires de demain. Aménagement et résilience (Ressources en Français)
- CLEAR (new-learn.info)
- ShadeMap - Simulate sun shadows for any time and place on Earth
- Key features of designing a home with passive design (level.org.nz)
- Cómo implementar el diseño solar pasivo en tus proyectos de arquitectura | ArchDaily en Español (Información en español)
- Architecture Projects | ArchDaily
- An Architect's Guide To: Green Walls - Architizer Journal
- Green Walls: How to Create a Living Landscape (or Wallscape) (lawnstarter.com)
- Green Roofs and Living Walls: The Future of Urban Spaces (ugreen.io)
- What are Passive Design Strategies? - RTF (re-thinkingthefuture.com)
- Energy Education
- BSD-106: Understanding Vapor Barriers | buildingscience.com

- How to make a first-flush diverter for rainwater harvesting (arkitrek.com)
- Passive Design Strategies For Hot and Dry Climate | PDF | Building Insulation | Window (scribd.com)
- How to Implement Passive Solar Design in Your Architecture Projects | ArchDaily
- A Guide To Starting a Bamboo Building Project | ArchDaily
- Efficient Water Management and Collection as Seen in 3 Indian Residential Projects | ArchDaily
- Semillas | ArchDaily
- Kéré Architecture | ArchDaily

9) Thermal resistance of typical construction materials

Every material has a specific thermal resistance. A thoughtful selection of a building's materials can contribute to reduce the requirements of additional insulation components.

CONSTRUCTION COMPONENT	R-VALUE	CONSTRUCTION COMPONENT	R-VALUE
BUILDING BOARD		**ROOFING**	
Gypsum Wall Board 1/2" thickness	0.45	Asphalt Shingles	0.44
Medium Density Particle Board 1/2" thickness	0.53	Wood Shingles	0.97
Gypsum Wall Board 5/8" thickness	0.5625	**GLAZING**	
Plywood 1/2" thickness	0.62	Single Pane 1/4" thickness	0.91
Plywood 1" thickness	1.25	Double Pane with 1/4" air space	1.69
Fibre board sheathing 1/2" thickness	1.32	Double Pane with 1/2" air space	2.04
MASONRY AND CONCRETE		Double Pane with 3/4" air space	2.38
Granite 1" thickness	0.05	Triple Pane with 1/4" air spaces	2.56
Concrete high-density 1" thickness	0.07	Triple Pane with 1/2" air spaces	3.23
Sandstone / Limestone 1" thickness	0.08	**INSULATING MATERIALS**	
Concrete regular density 1" thickness	0.21	Expanded Polystyrene (Extruded) 1" thickness	5
Face Brick 4" thickness	0.44	R-11 Mineral fibre with 2x4 metal studs @ 16" OC	5.5
Concrete low-density 1" thickness	0.52	Polyurethane Foam (Foamed on site) 1" thickness	6.25
Common Brick 4" thickness	0.8	R-11 Mineral fibre with 2x4 metal studs @ 24" OC	6.6
Concrete Blocks 4" thickness	0.8	R-19 Mineral fibre with 2x6 metal studs @ 16" OC	7.1
Concrete Blocks 8" thickness	1.11	Polyisocyanurate (Foil Faced) 1" thickness	7.2
SIDING		R-19 Mineral fibre with 2x6 metal studs @ 24" OC	8.55
Aluminium / Vinyl Siding (not insulated)	0.61	R-11 Mineral fibre with 2x4 wood studs @ 16" OC	12.44
Aluminium / Vinyl Siding (1/2" insulation)	1.8	R-19 Mineral fibre with 2x6 wood studs @ 24" OC	19.11

These values are for reference only and are not for use as substitutes for actual manufacturer data.