PASSIVE HEATING AND COOLING *Checklist*

Achieving resilient design involves creating spaces that can remain habitable even in the absence of conventional utilities.

In today's world, with **rising climate concerns, having a passive system in place is paramount.** New technologies, often costly and tied to unreliable grids, foster dependence on unsustainable networks. The goal of this checklist is to help us remember and implement the profound wisdom found in vernacular systems.

“It’s the only path that makes sense... while there is still enough of the past to teach the present how to have a future.”

- Philip Kennicott and Sima Diab

IT'S TIME FOR US TO REVISIT AND LEARN FROM OUR PREDECESSORS

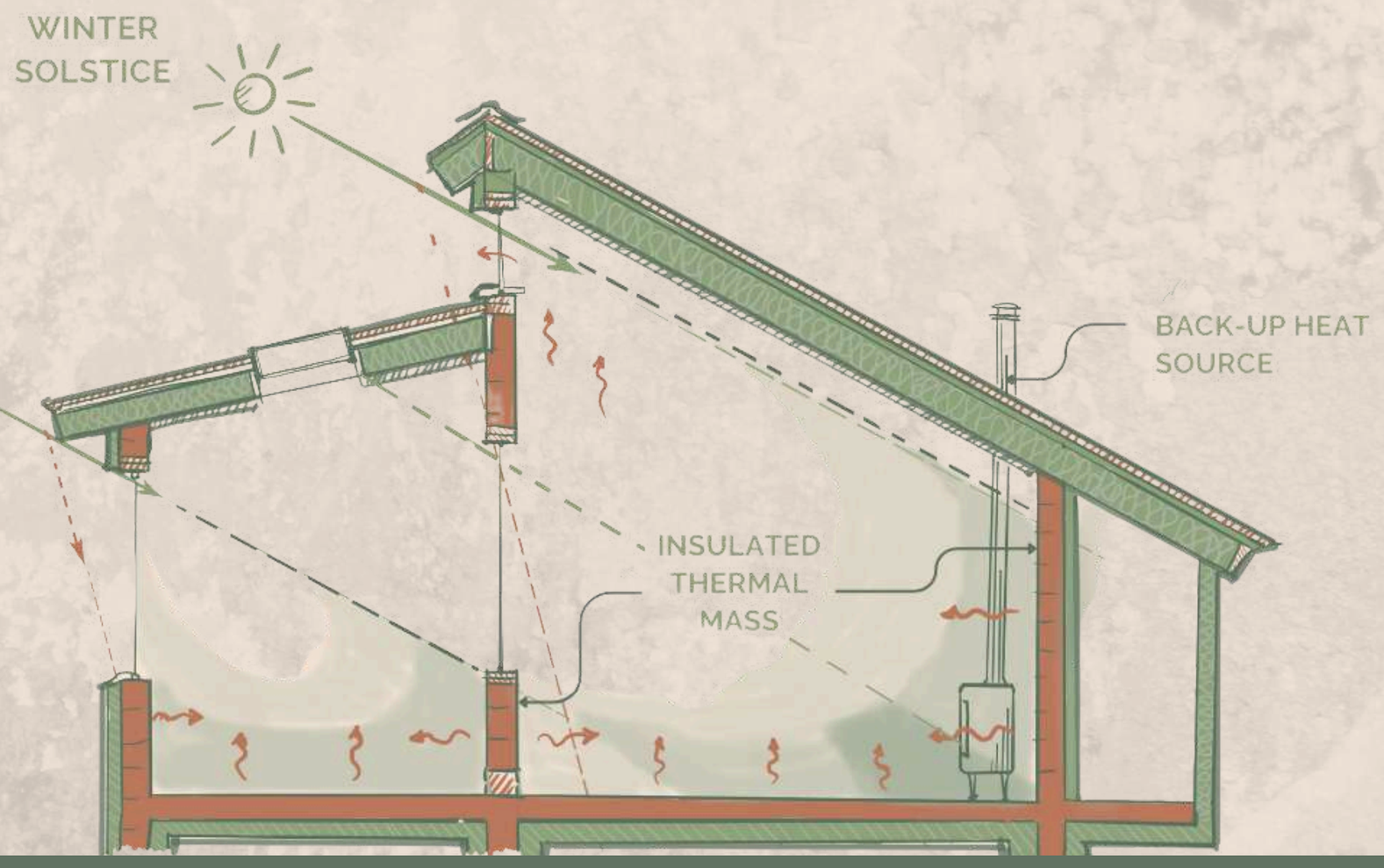
The wisdom of **passive heating and cooling has been ingrained throughout history.** Passive solar techniques are evident in the architecture of Pueblos, the Anasazi, ancient Greek structures like Priene, and the innovative works of architects like George Keck and Frank Lloyd Wright. Passive cooling elements are seen even today in Cairo, New Gourna, and Yazd.

These strategies of minimal mechanical and electrical intervention showcase enduring effectiveness even to this day. Skeptics must keep an open mind and recognize our dependence on modern systems, and re-calibrate our 'comfort' levels.

As we delve into the checklist, we will explore key elements to consider during the design phase of a project. Many of these designs do not cost any extra to implement, as we are simply harnessing existing elements in nature. By putting these simple principles to work, we can create a **harmonious balance between comfort and environmental reverence.**

PASSIVE HEATING

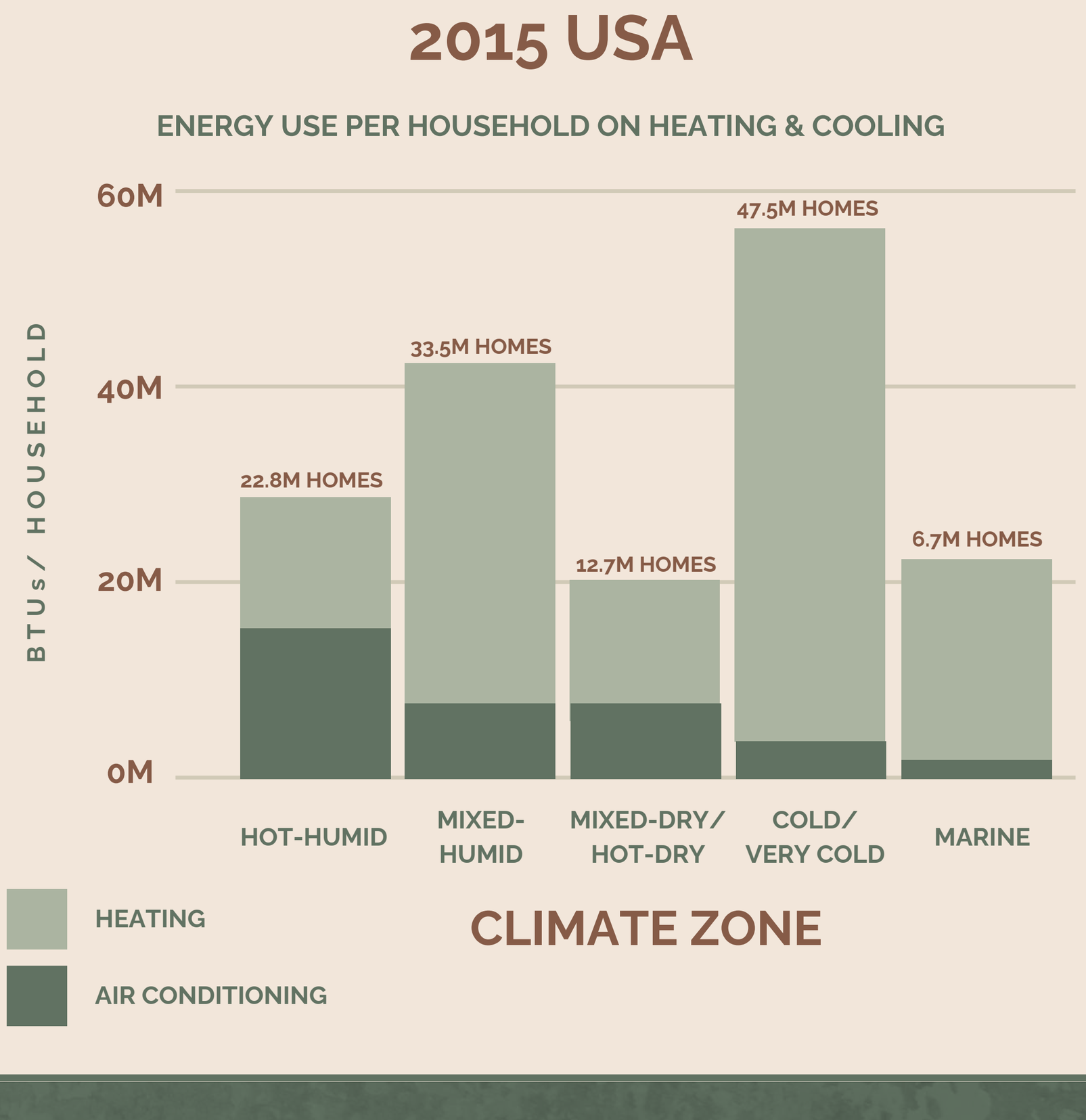
For those enduring cold winters or consistently chilly climates, harnessing the power of the sun can significantly heat our homes. Sometimes passive solar can produce **20% to 90%**, (occasionally even 100%) of the required warmth.



The foundation of passive heating lies in combining passive heating strategies with **increased insulation and enhanced airtightness.** The goal is to minimize reliance on mechanical and electrical systems, fostering a sustainable and self-reliant building.

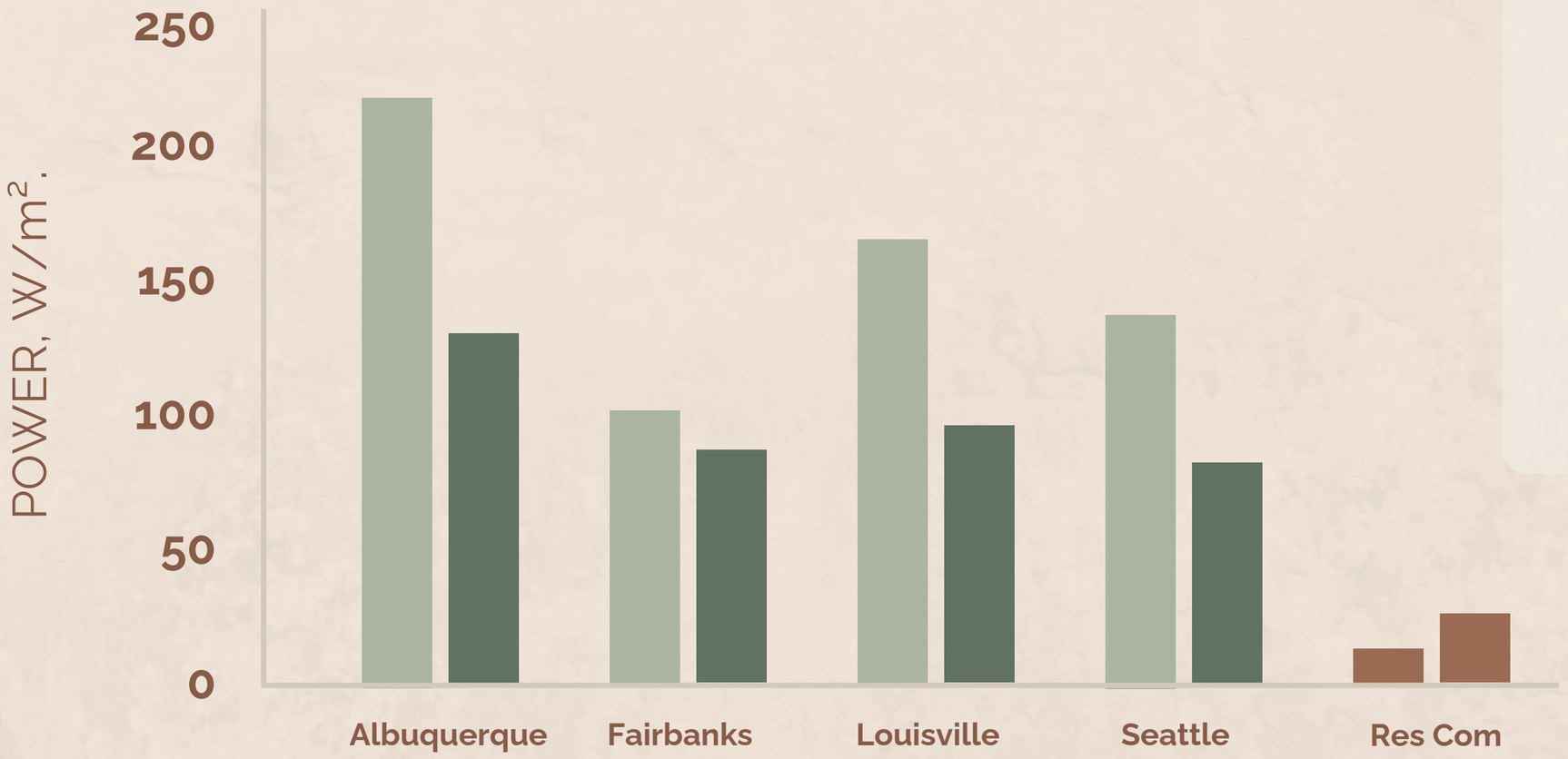
Did you know that up to **30% of the energy** used to heat buildings is wasted due to inefficiencies? Poor insulation, air leaks, and outdated heating systems all contribute to this loss.

Heating our homes and buildings eats up the lion's share of our energy use—it's actually one of the biggest energy guzzlers out there.



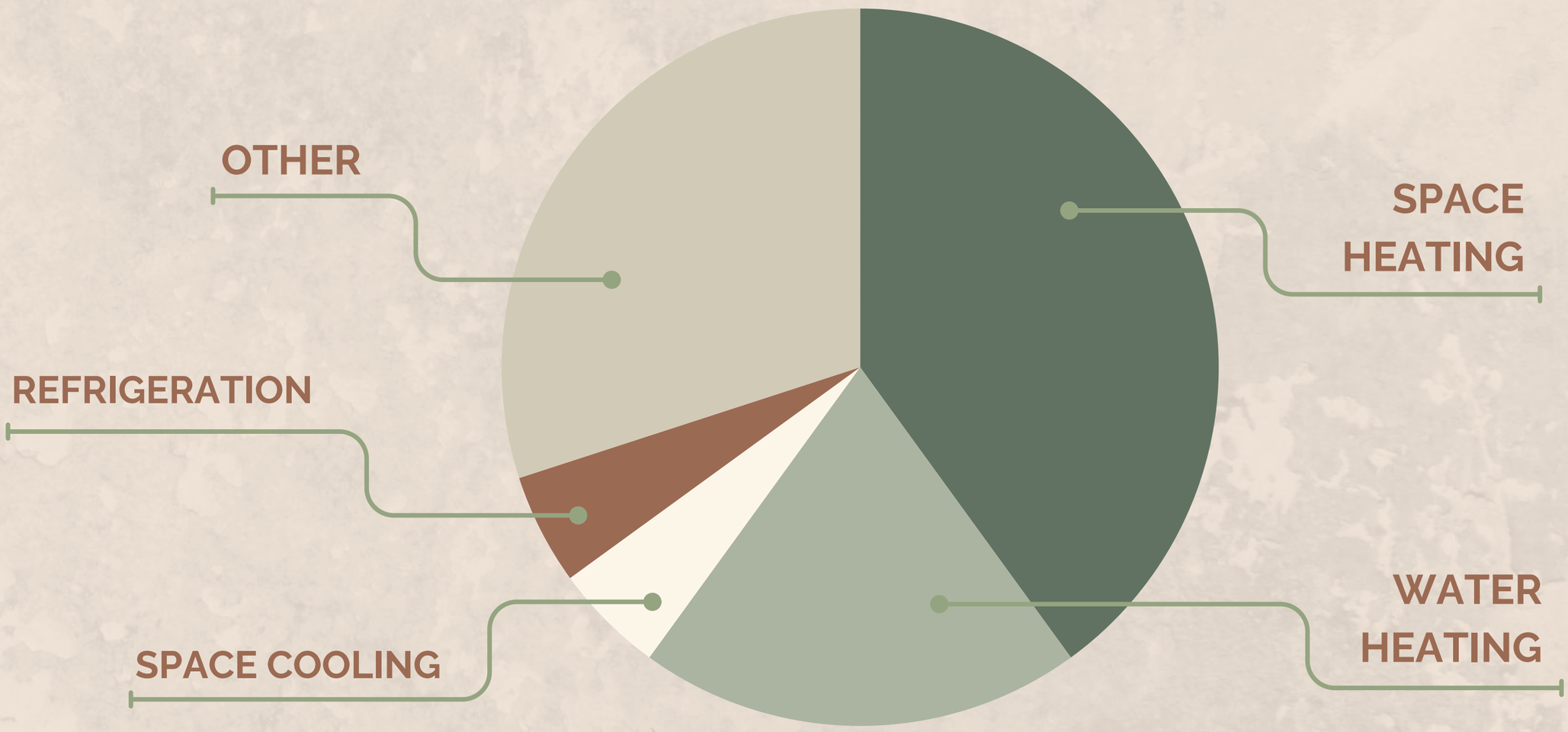
Not all of this heat needs to be by mechanical means though, we can utilize **free, ambient heat**!

SOLAR POTENTIAL



Annual average insolation on horizontal and south-facing vertical surfaces compared to mean residential and commercial building energy use rates.

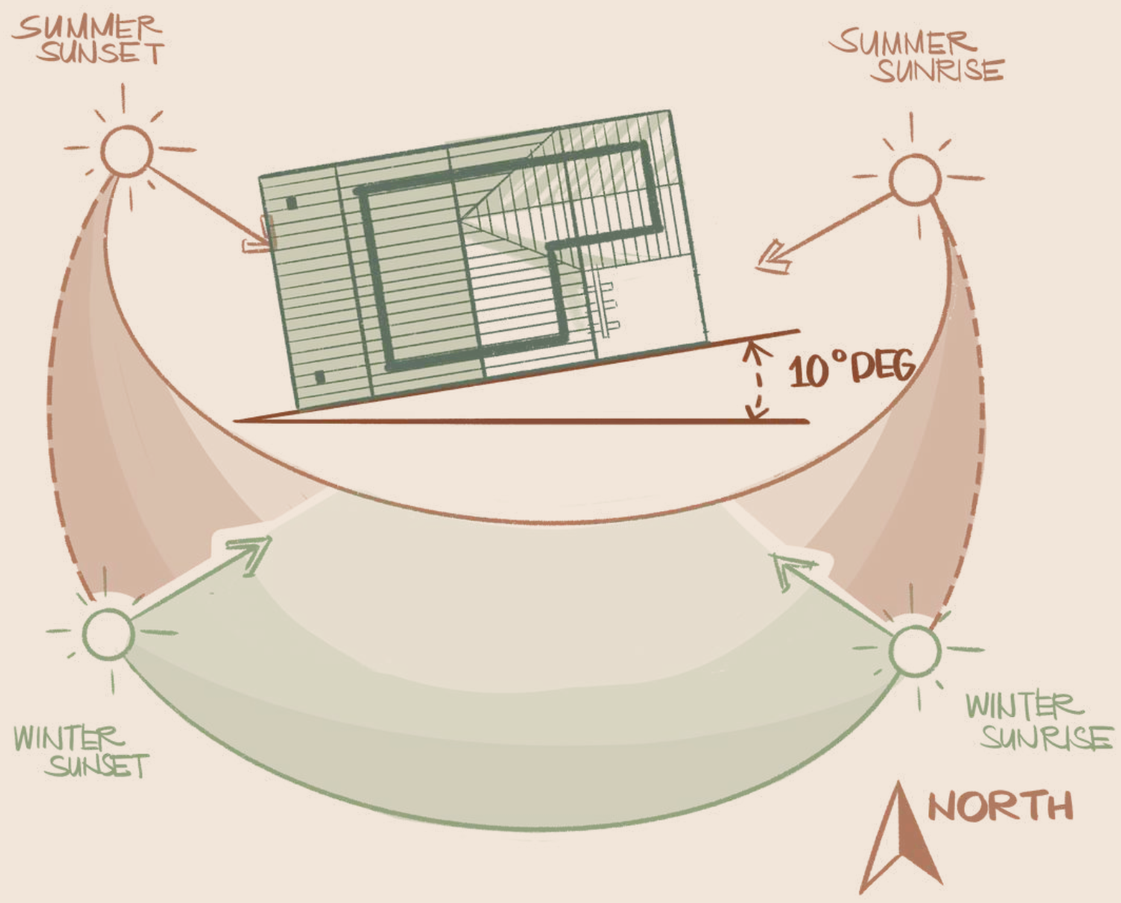
RESIDENTIAL ENERGY CONSUMPTION BY END USE, 2009



BUILDING DESIGN & LAYOUT

- [ ] **Equator Facing Orientation:** Align the longest wall to face the equator with a slight deviation of **10 degrees towards the east.**

- [ ] **Equator-Facing Windows:** Increase the number of windows on the equator-facing side (see chart below for amount)



PRO TIP: Magnetic north differs from true north, which can vary up to 18 degrees east or west. Verify your reference point using online maps or Google Earth.

- [ ] **Optimal Wall Space:** Increase wall space on the equator-facing side of the building. Rectangular shapes are preferable, but square designs can be adapted with features such as clerestories or courtyards.

BUILDING DESIGN & LAYOUT

- [ ] **Low Ceilings:** Promote efficient heat distribution where you need it most. Make sure to add doors to stairwells so you have the option to keep heat within the needed living spaces.

- [ ] **Room Placement:** Position frequently used spaces on the equator-facing sides, while keeping utility rooms and less used spaces on the wall opposite to the equator.

- [ ] **Shade Western Side:** Employ covered porches or tall trees to shade the western side to not overheat the space by the afternoon.

- [ ] **Exterior Color:** Opt for darker-colored exteriors to enhance heat absorption.

THERMAL MASS

- [ ] **Utilize Thermal Mass*:** Employ materials like concrete, brick, stone, tile, or plaster to store excess heat if equator-facing glass exceeds 5% of the floor area.

- [ ] **Insulate Thermal Mass:** Ensure proper insulation for thermal mass to make sure stored heat is released back into the building instead of escaping to the exterior.

- [ ] **Optimal Thickness:** Limit thermal mass thickness to 4 inches for efficient temperature absorption and release.

THERMAL CAPACITANCE
OF DIFFERENT MATERIALS

MATERIAL	kJ/m^3 K	Btu/ft^3 F
Concrete	1800	26.4
Water	4186	62.42
Adobe	1700	25.35
Gypsum	667	9.95
Paraffin	180,000	2,683.9
Glauber's salt	254,000	3,787.28

HEATING BACKUP

- [ ] **Explore Backup Heating Options:** Consider alternatives like masonry heaters, geothermal, radiant floors, or solar hot water. You may need these if you have many consecutive cloudy days.
- [ ] **HERs Rating*:** Target a Home Energy Rating System (HERs) rating between 40-50 for optimal energy efficiency with minimal external inputs.

WINDOW SPECIFICATIONS

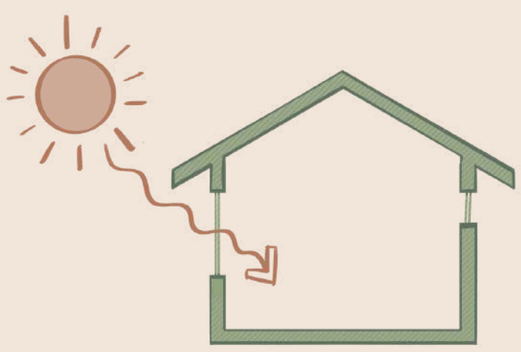
- [ ] **Maximum U-Value*:** Ensure a maximum U value of 0.23 - 0.30 (R4.3 minimum) for Windows. Ideally, you should go beyond these if your budget allows.

READING A WINDOW LABEL

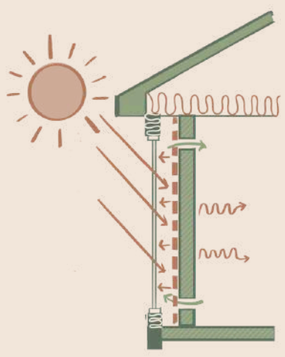
** The items in this checklist above with an asterisk above may incur additional costs outside the design and planning phase. Please be more thoughtful about implementing these if you have tighter budget concerns.

- [ ] **Solar Heat Gain Coefficient (SHGC)*:** This measures how much sunlight actually comes through a window into your home. This is climate dependent, but aim for a SHGC range of 0.2 - 0.5 for effective solar heat utilization.

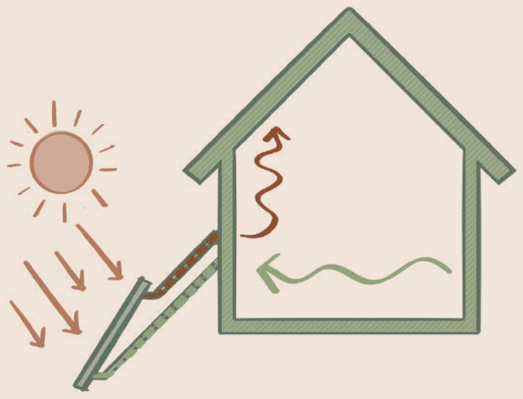
SOLAR GAIN METHODS



DIRECT GAIN



INDIRECT GAIN



ISOLATED GAIN

For east- and south-facing windows, an SHGC of around 0.50 is a good target. However, balancing SHGC with insulation (measured by the **U-value**) of the window can be tricky because they tend to work against each other. A lower U-value means better insulation, which helps retain indoor heat in winter and keep out external heat in summer. But here's the challenge: windows with a high SHGC (which is good for solar gain) often have higher U-values (meaning they're not as insulating). And the inverse is also true.

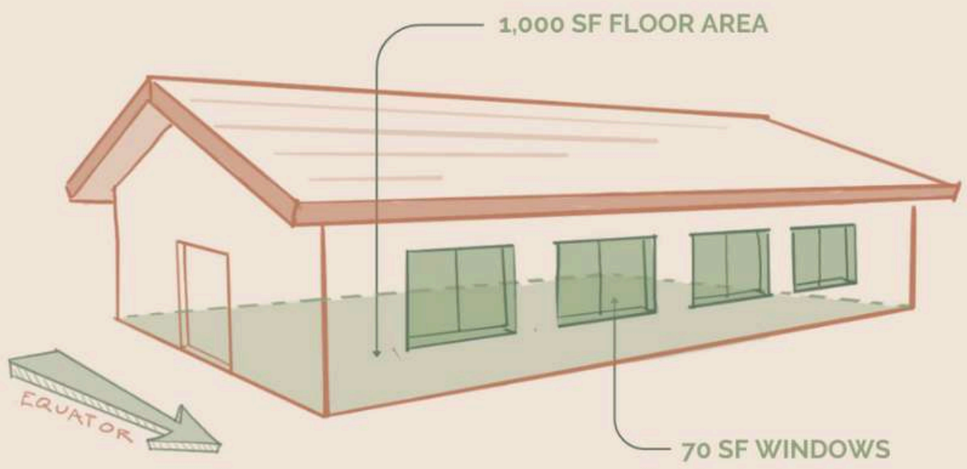
Here is a handy tool to use when specifying windows:

	For Windows Facing	% glass area to floor area	Solar Heat Gain Coefficient (SHGC)*	U-Factor*
☐	Equator Facing	7% min, 11% max (with thermal mass)	Highest	Lowest you can afford
☐	Opposite Equator	0%- 3%	N/A	Lowest you can afford
☐	West	2% max	Low (or shaded)	Standard
☐	East	2% max	Moderate	Standard

*__SHGC__ and __U-Factor__ values depend on the specific region you are building in. For warm climates (which probably won't require passive solar) standards for SHGC and U-factor should be low across the board.

SOLAR APERATURE RATIO

THE EQUATOR FACING GLAZING SHOULD BE 7% OF YOUR FLOOR AREA. FOR EXAMPLE:



PROTIP: Use a 'Solar Path Finder' to see what the annual shade patterns are on your site.

IF YOU HAVE MORE INTERIOR THERMAL MASS (CONCRETE FLOOR, PLASTER, BRICK), YOU CAN RAISE THE GLAZING UP TO:

11%

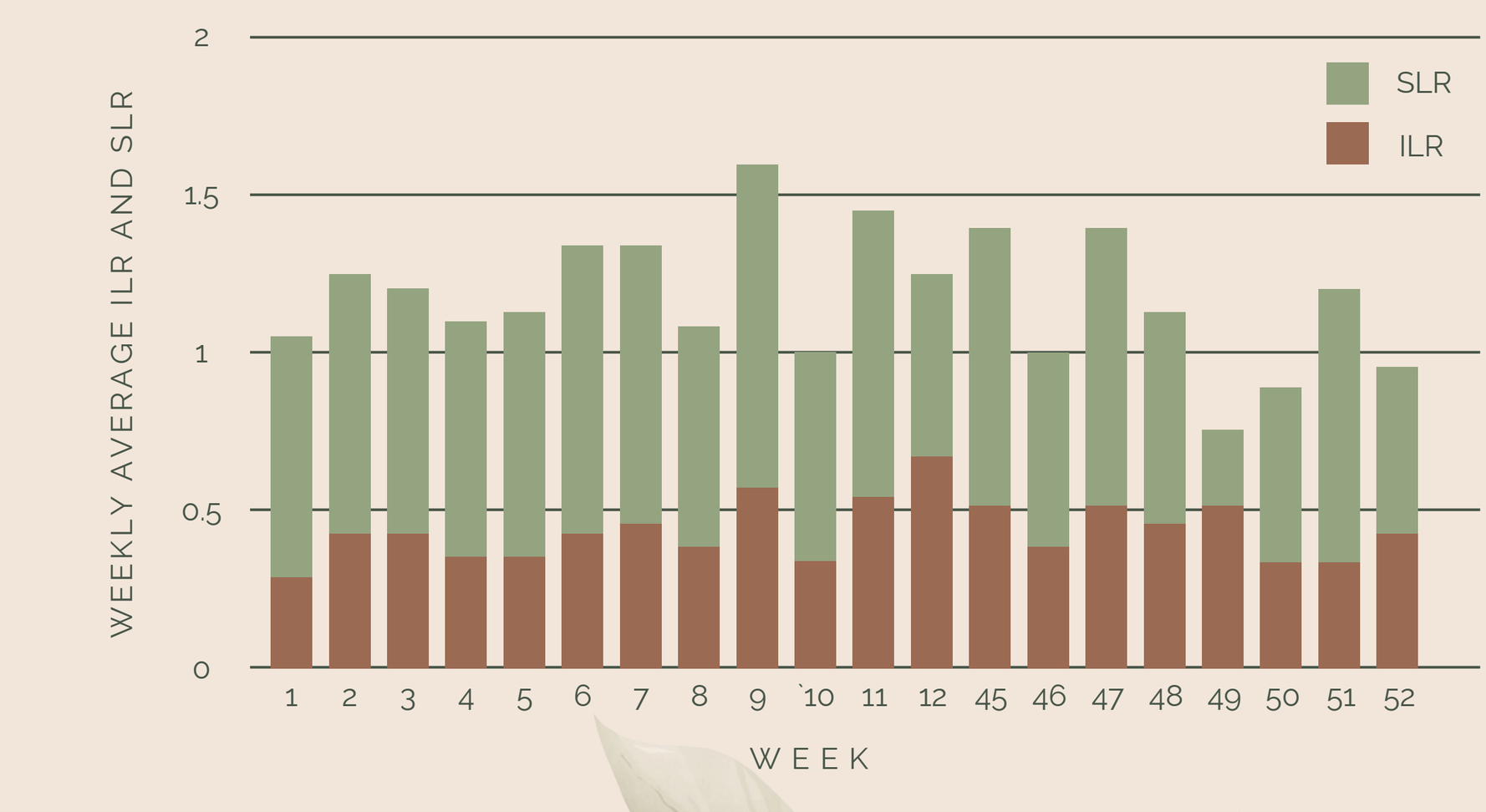
THERMAL MASS ↑ = ↑ GLAZING TO EQUATOR

INTERNAL GAINS

People and Pets: Humans generate about 100 watts of body heat continuously, and that adds up! Especially in a home with an efficient thermal envelope.

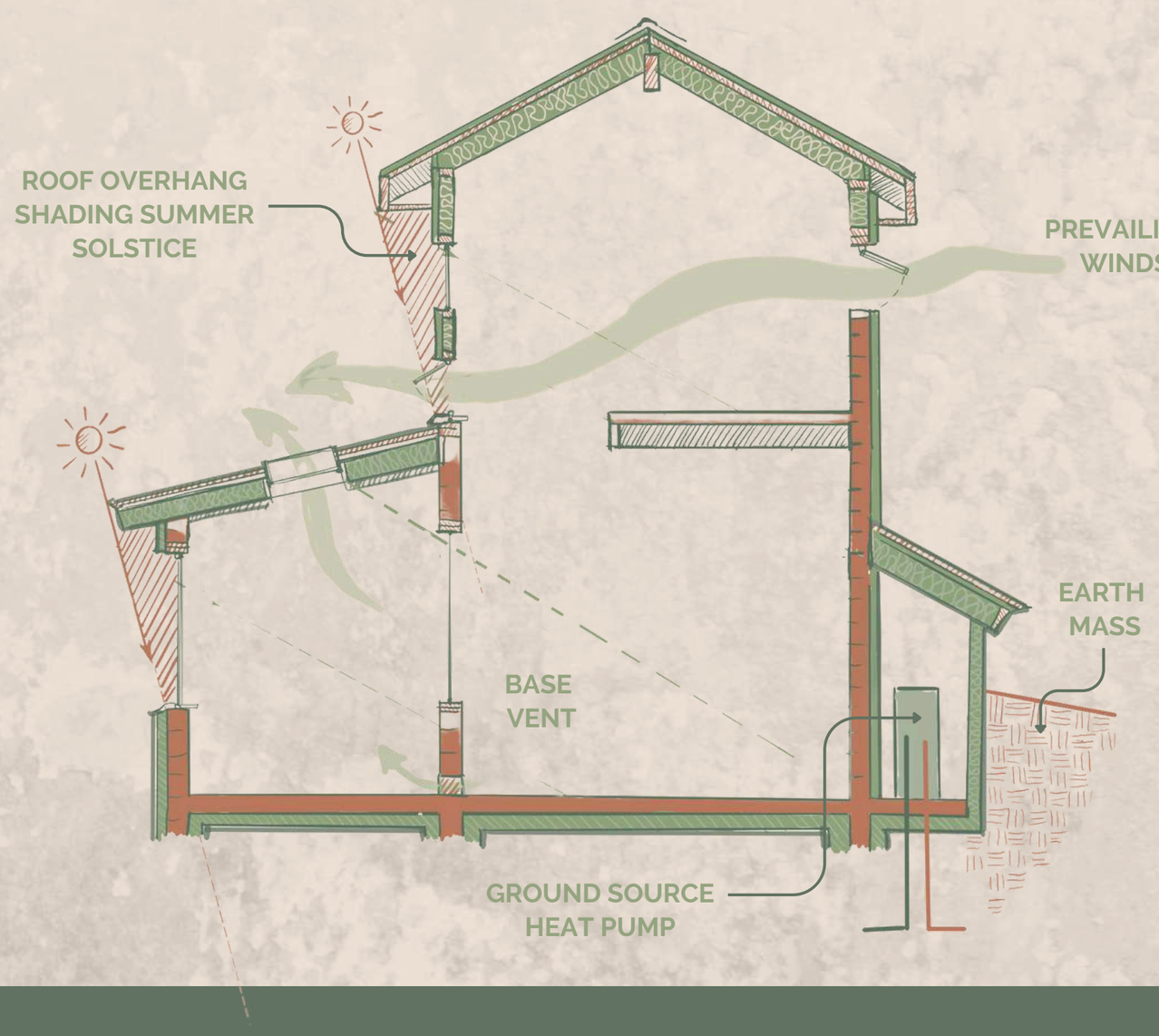
Cooking and Appliances: Using an oven, running electronics, and even lighting, all contribute to internal warmth.

My friend Keith is an amazing mechanical engineer who built a home with 100% natural heating and cooling. He created this chart to show just how powerful internal gains can be. Look at the red lines, which represent internal gains. The green lines represent solar gains. You can see the red lines are substantial, and pretty stable over the course of a year!



PASSIVE COOLING

For those navigating scorching summers or consistently warm climates, tapping into the principles of passive cooling can remarkably cool our living spaces. At times, passive cooling strategies can achieve impressive temperature reductions, alleviating the need for excessive reliance on air conditioning systems.



According to the **U.S. Department of Energy**, effective passive cooling strategies can result in energy savings of 20-50% in buildings compared to traditional cooling methods.

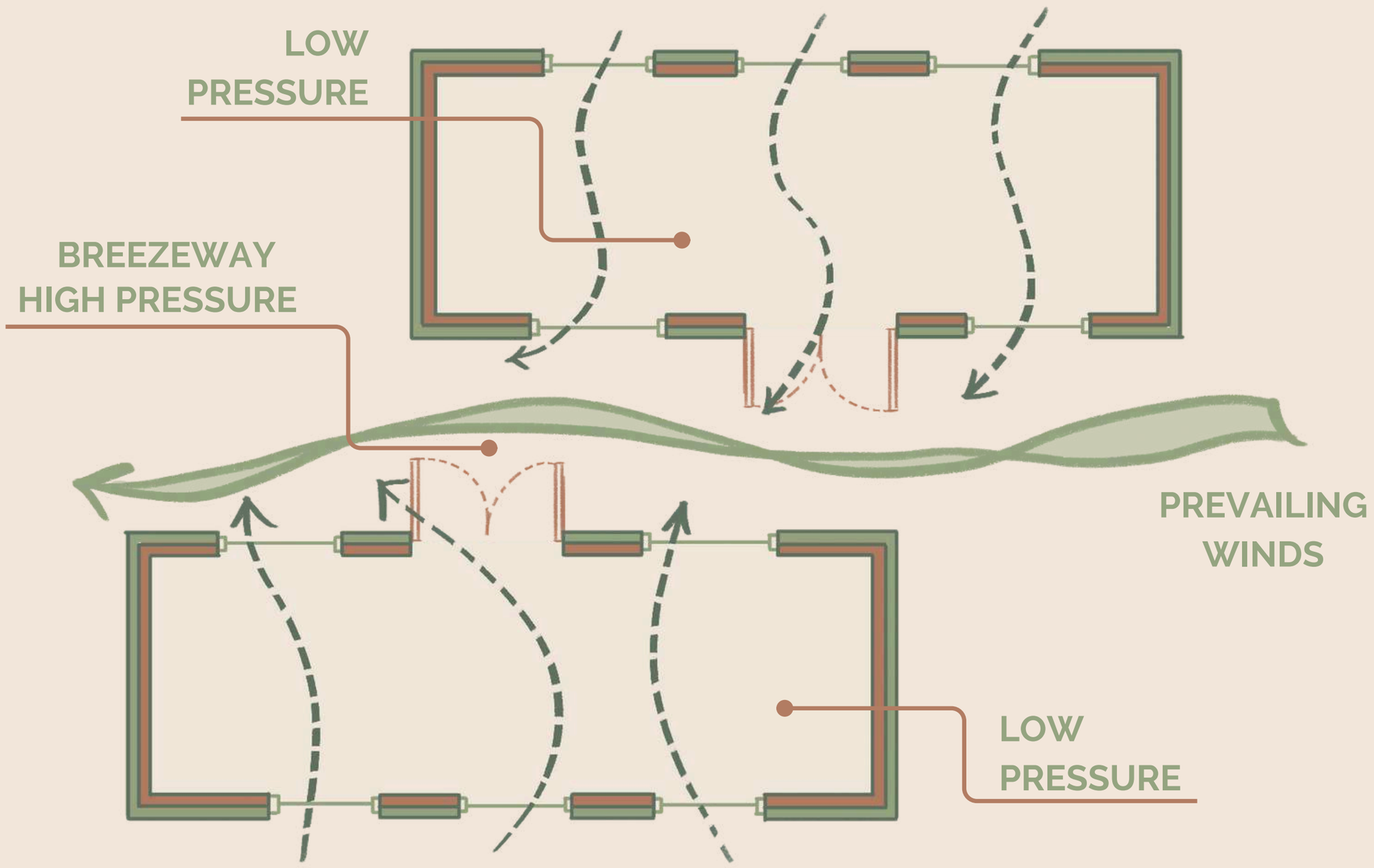
The essence of passive cooling lies in integrating smart design strategies with natural ventilation and shading solutions. The objective is to minimize dependence on energy-intensive cooling systems, fostering a sustainable and self-sufficient approach to maintaining a comfortably cool indoor environment.

PRESSURE DIFFERENCE

Pressure zones are massively important in how air moves within and around a building.

Low-pressure zones are areas where the air is less dense—it's lighter, the molecules spread far apart. This happens when air is heated. We all know that heat rises, right? Well, it rises into a low-pressure zone.

High-pressure zones are areas where the air is denser and more compressed. This can happen due to cooler temperatures. If hot air rises, cooler air is going to stay lower, in a high pressure zone.



High-pressure zones can also occur because of forces like the wind. If the wind blows on one side of a building, it creates a high pressure zone on that side. And on the other side, a low pressure zone is automatically formed.

MOVING AIR

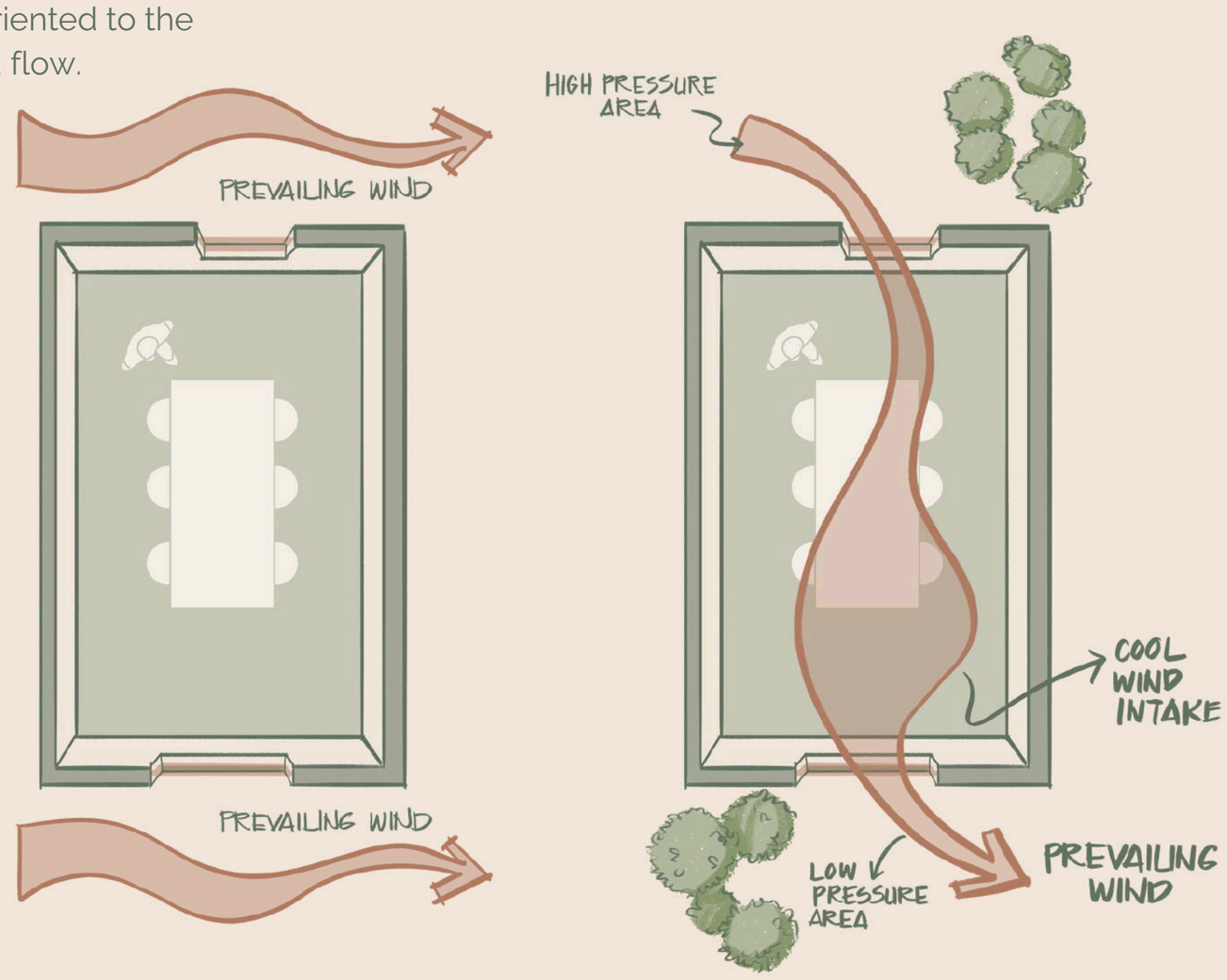
"When you can't change the direction of the wind — adjust your sails"

-H. Jackson Brown, Jr.

Wind Speed and Direction

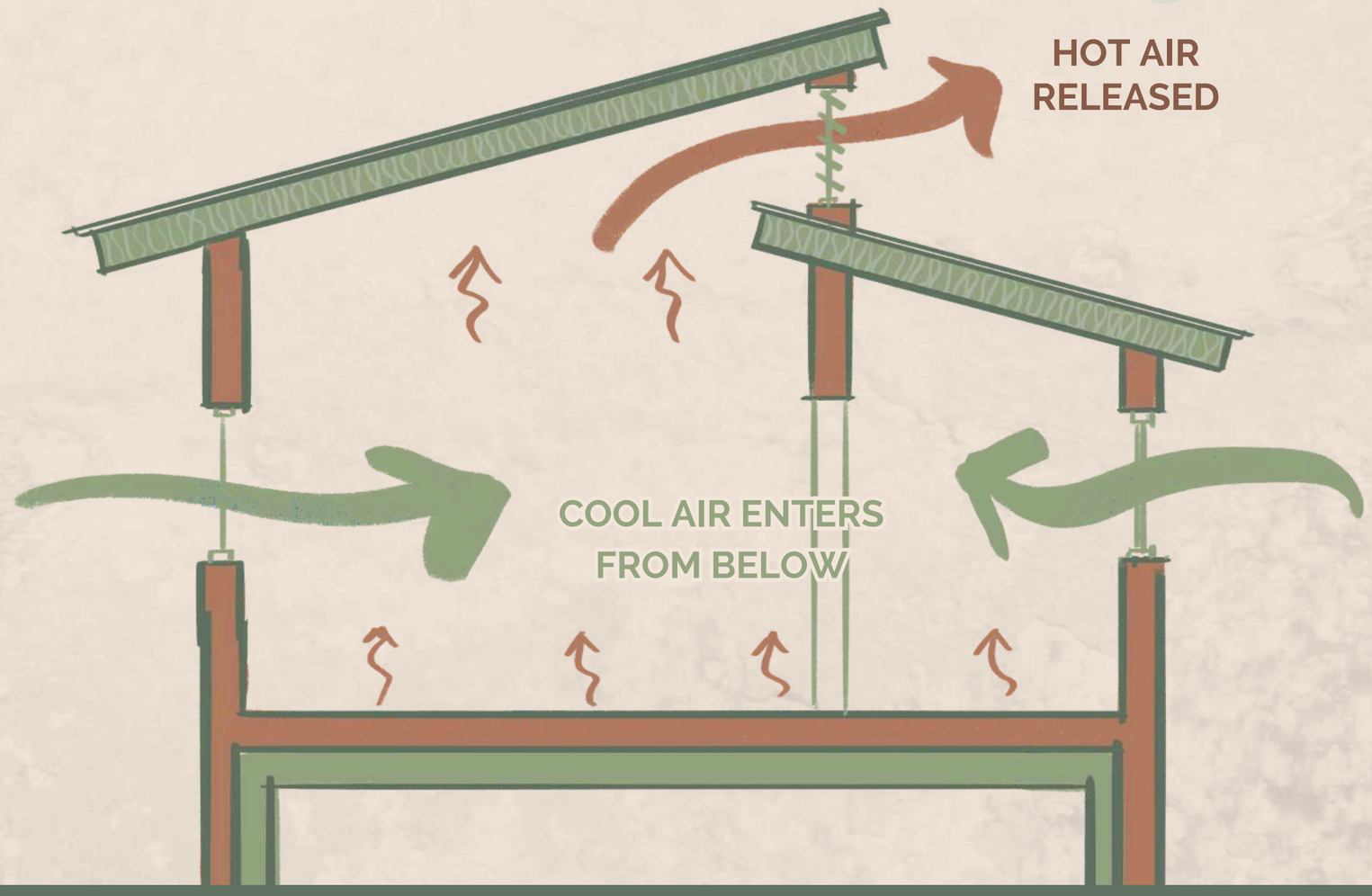
Instead of an electric fan, consider harnessing prevailing wind patterns for effective natural cooling. Align high windows or couplas, to capture this free energy resource and bring it down into the building. Even mild breezes can create pressure differentials on each side of a building allowing us to utilize the air flow created.

Note: This is if a building cannot be oriented to the current wind flow.



BEFORE **AFTER**

THE STACK EFFECT



The Stack Effect

Benefit from the stack effect by incorporating high ceilings with vents or windows to encourage the escape of rising warm air. Strategically bring cool air in from above to force the warm air from below out. Bedrooms toward the upper levels (even the roof) of the building allow for adequate airflow at night, while the thermal mass of walls below cool down.

Common Examples

Solar Chimney

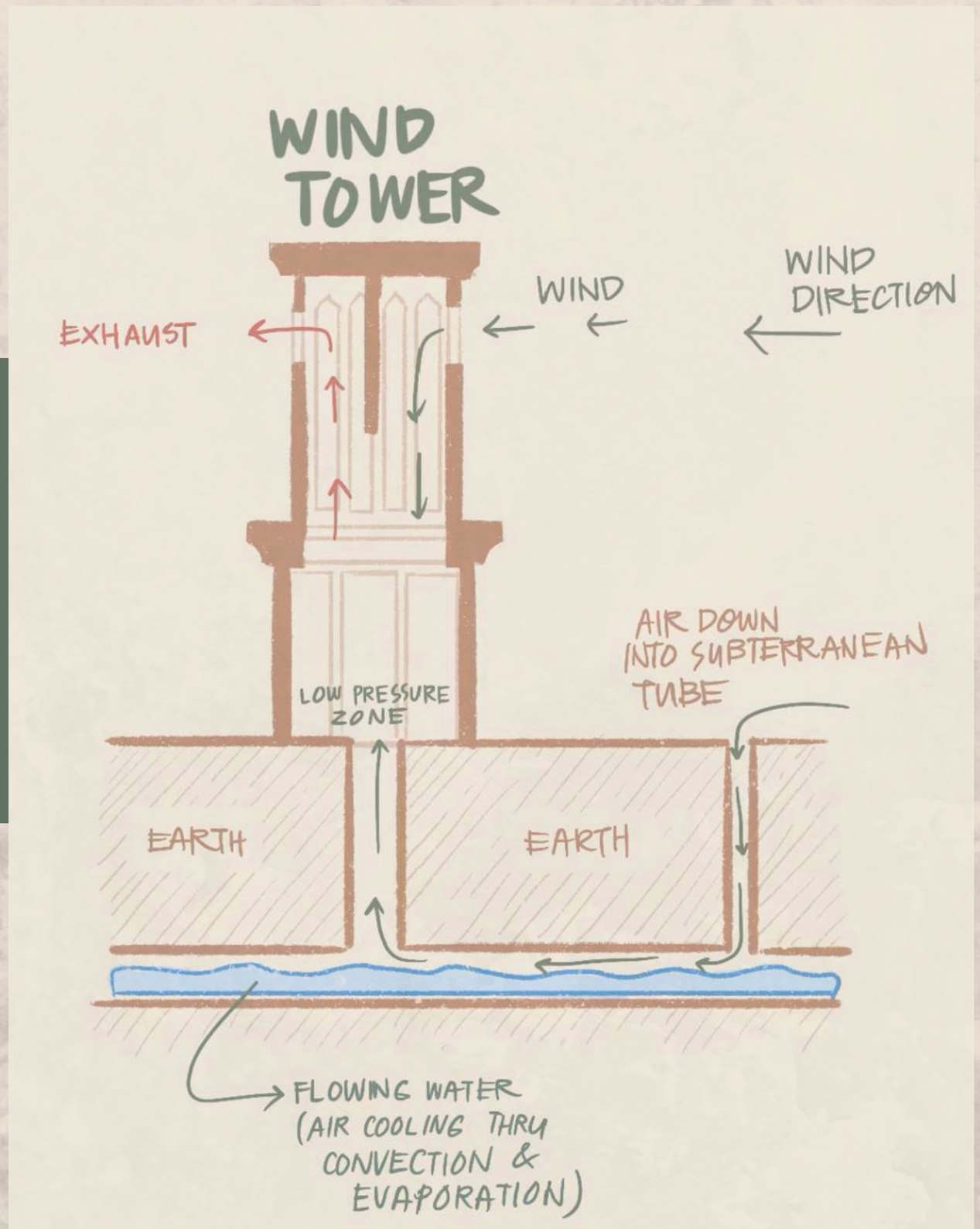
Atrium/ Vent Shaft

Breezeway

THE STACK EFFECT

Windcatchers (or wind scoops)*: An even more pronounced version of the stack effect. Also known as wind scoops, these vertical, vented-looking cupolas, capture wind while simultaneously allowing heat to rise and escape. The effect of this is historically enhanced with water channels below contributing to an evaporative cooling effect.

PROTIP: This is the essence of passive cooling. Utilizing temperature differences between hot and cold spaces that creates a pressure change that can increase air circulation.



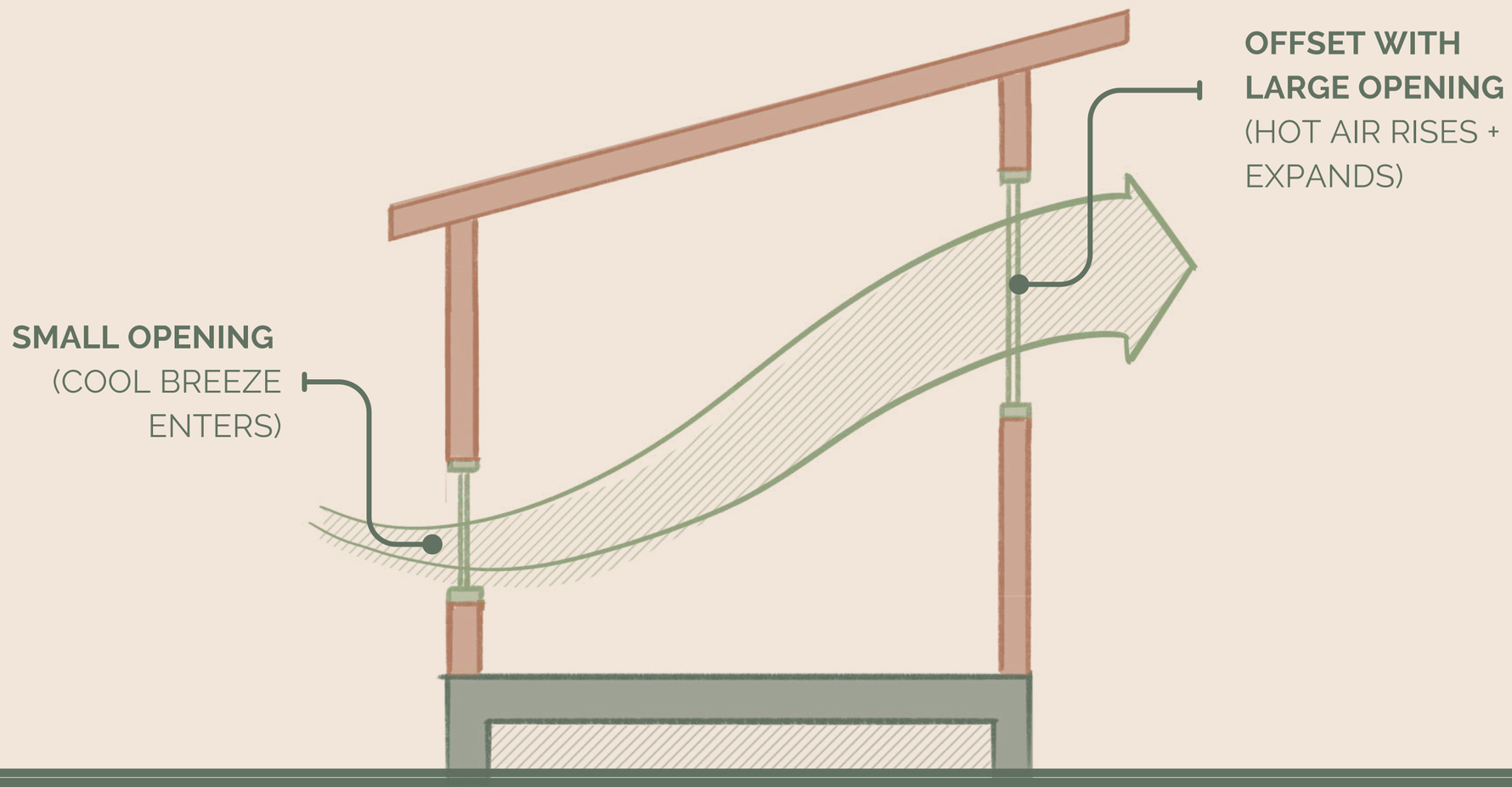
MOVING AIR

- [ ] **Breezeways**

  Design breezeways to facilitate the flow of prevailing winds, promoting natural ventilation. Wind blowing directly through a breezeway creates a negative pressure chamber forcing stale air in the surrounding buildings to move out through screens, or open windows and doors.

- [ ] **Cross Ventilation**

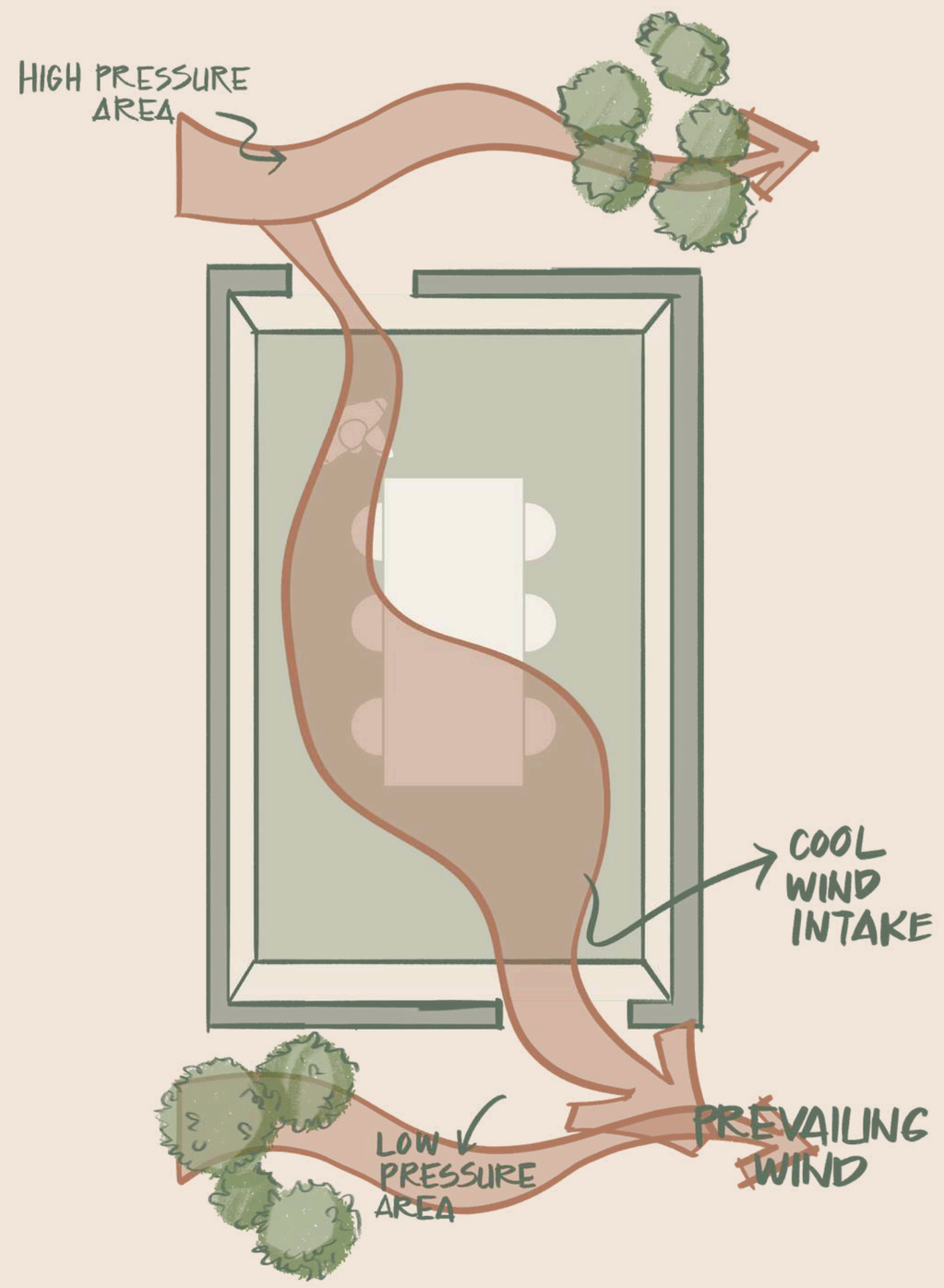
  Place operable windows on opposite sides of a room to enhance cross ventilation. Position them low on the windward side and high on the leeward side to leverage the stack effect.



CROSS VENTILATION DONE RIGHT

With cross ventilation, our goal is to invite the air to move **throughout** the interior space. Design plays a role here. If the windows are directly across from each other, the wind will just blow in a straight line from one side of the room to the other. It doesn't necessarily cool the whole room.

Instead, try to **stagger the location and size of your windows on opposite or adjacent walls.**

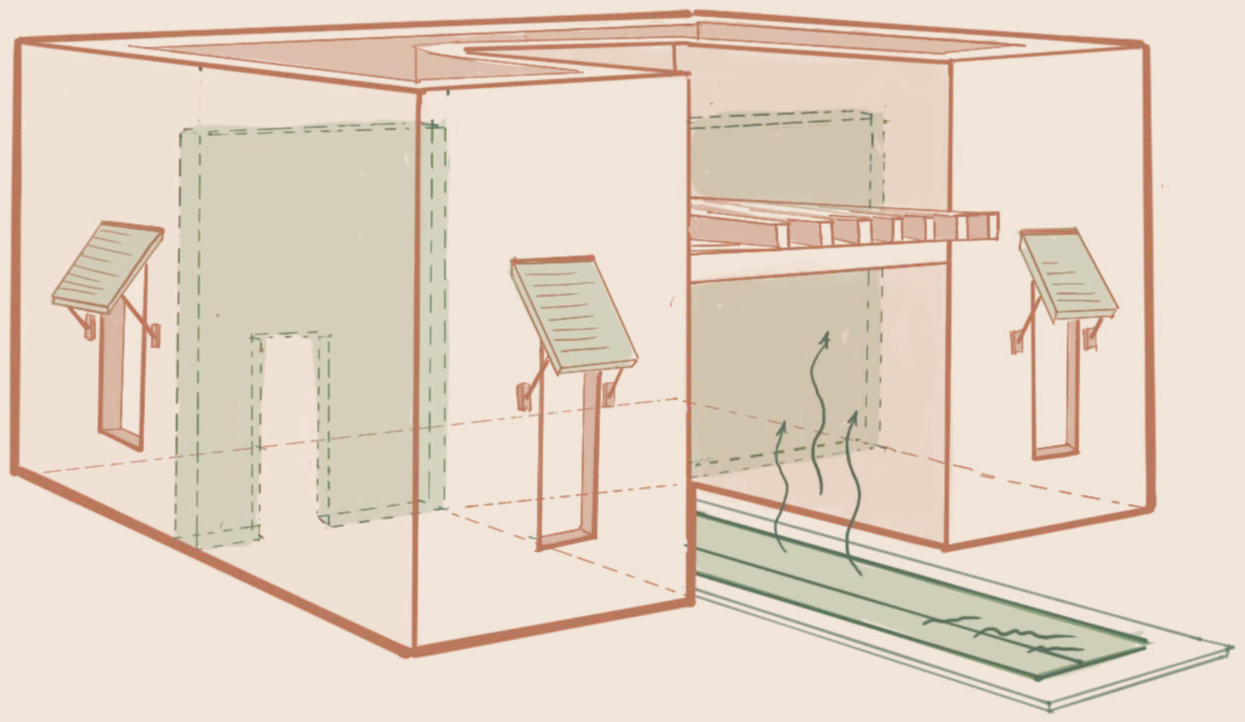


So for example, you could open windows that are diagonal from one another. This encourages the air to move **around** the room.

WATER & PLANTS

"From an environmental perspective, plants are always preferable to air conditioners for temperature control."

- Anne Simon Moffat and Marc Schiler

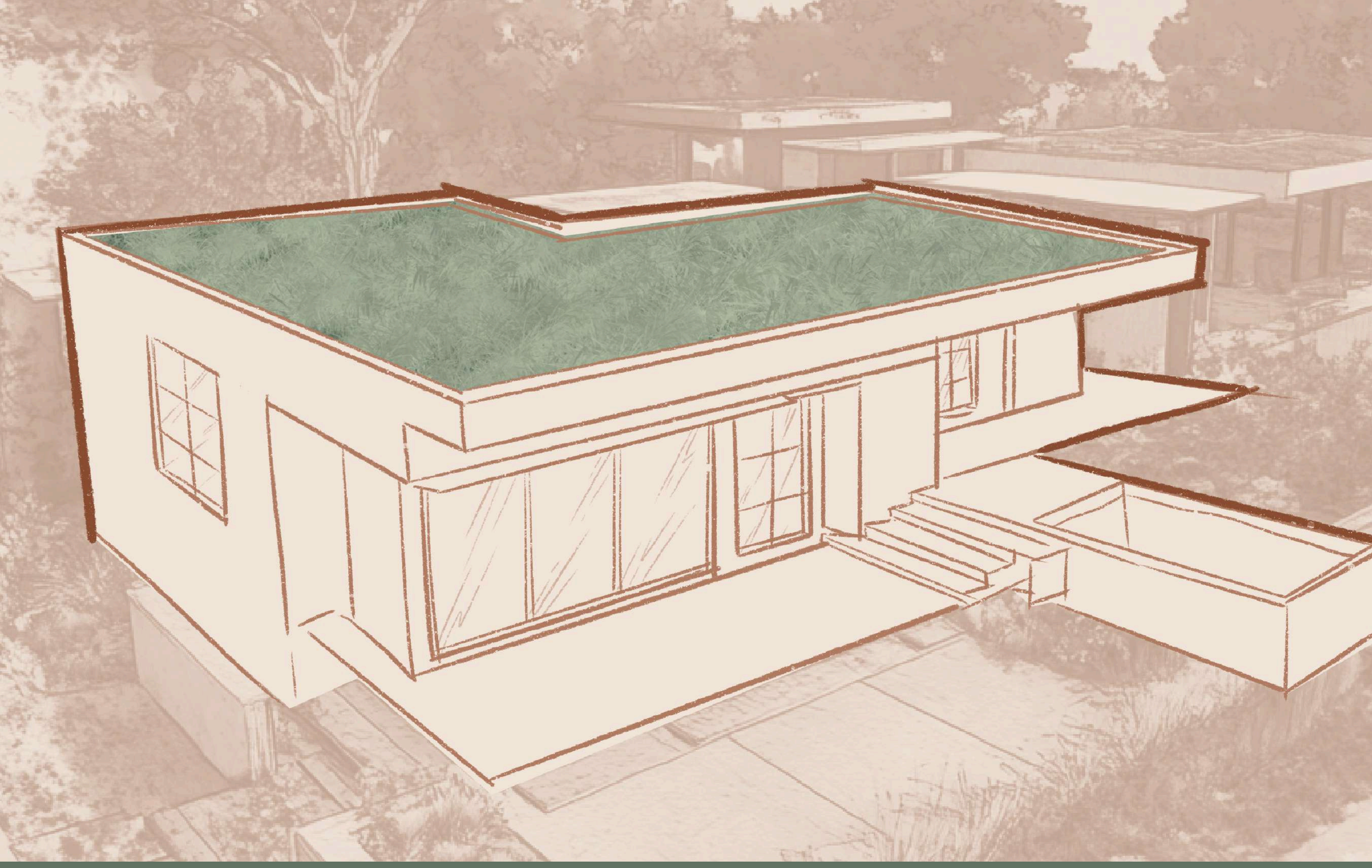


☐ **Evaporative Cooling***

Enhance cooling by incorporating pools, ponds, or fountains in spaces where there is already air movement. Here, cooling is dependent on water, vapor, and evaporation. Especially in dry climates, the evaporating water can cool the air significantly. When air moves over water, it is essentially acting as its modern equivalent, a swamp cooler.

☐ **Plants & Trees**

Plants not only provide shading but can cool air through **'evapotranspiration'**, wicking moisture into the air. Trees can also be planted in such a way as to funnel winds into particular areas that need more airflow.



- [ ] **Living Roofs for Heat Absorption***

  Roofs can get very hot especially if metal or asphalt. Opt for living roofs, acting as sponges for heat absorption and promoting natural cooling.

- [ ] **Courtyards**

  Courtyards become a great habitat for pools and plants in hot climates. Tall 4-sided courtyards provide the most shading. They also store cool air gathered at night and vent heat during the day. Rooms opening to the north side (south side in the southern hemisphere) of the courtyard stay the coolest.

SHADING AND EARTH

"Outside, the sun is withering; inside, the light is low and it feels a bit cavelike, but the bed is cool and inviting."

- Philip Kennicott and Sima Diab

☐ **Maximize Overhangs for Shading**

Calculate overhang dimensions based on the latitude of the site, particularly useful for locations with only summer cooling needs.

LATITUDE
CALCULATIONS

SUMMER SOLSTICE

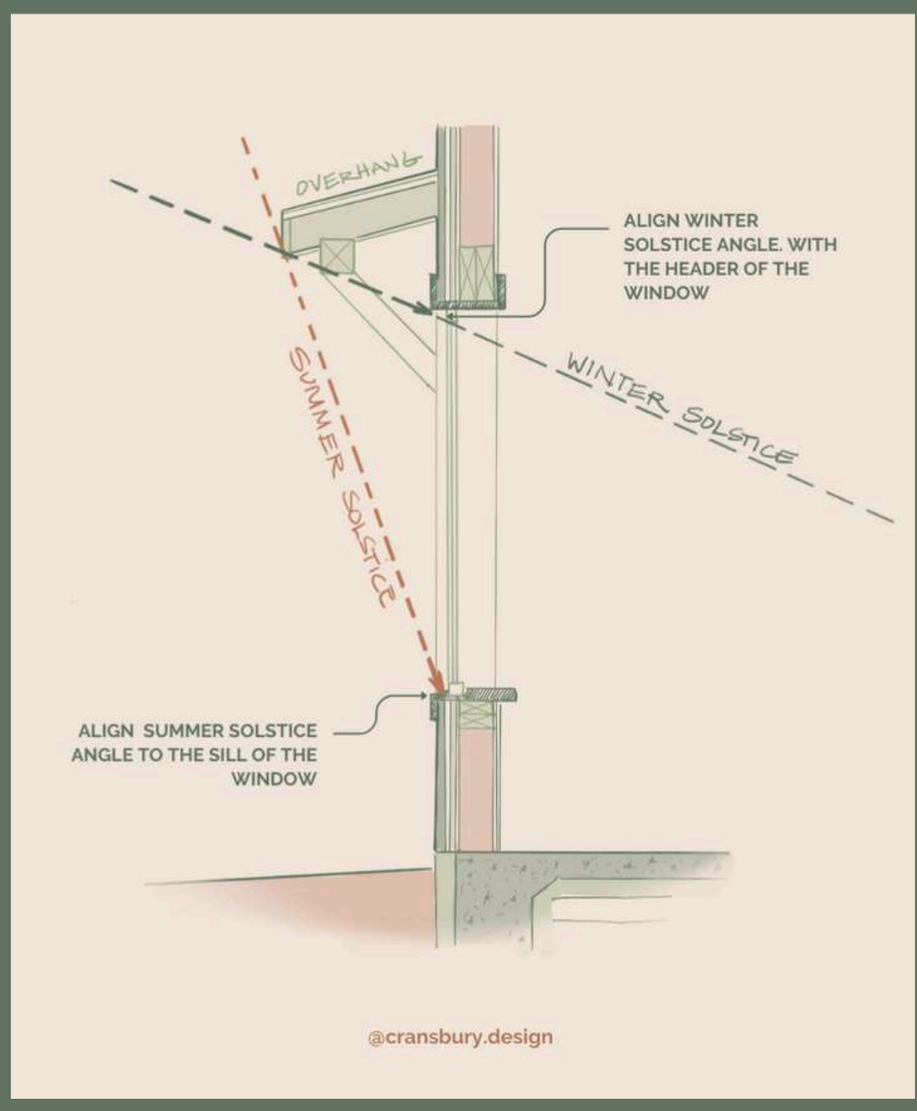
Angle = 90 degrees - (latitude + axial tilt)
Angle = 90 degrees - (43 degrees + 23.5 degrees)
Angle ≈ 23.5 degrees

+

WINTER SOLSTICE

Angle = 90 degrees - (latitude - axial tilt)
Angle = 90 degrees - (43 degrees - 23.5 degrees)
Angle ≈ 70.5 degrees

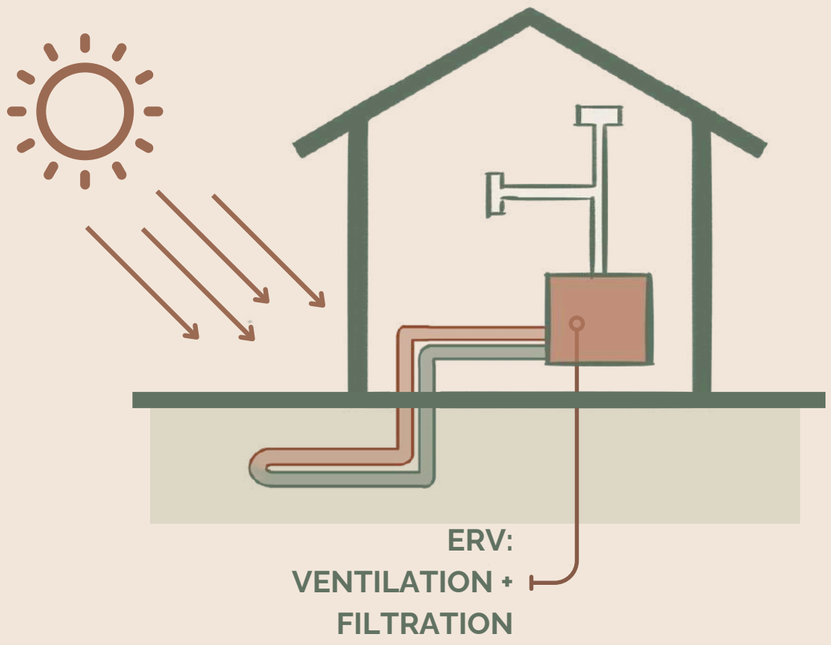
−



SHADING AND EARTH

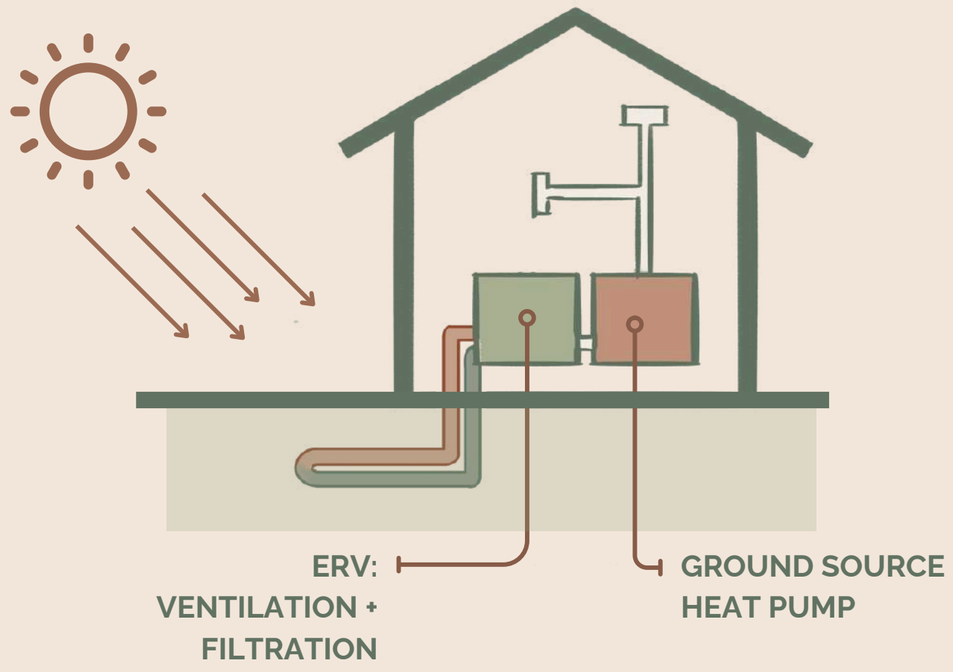
DIRECT

Earth Tubing or Ground Loops



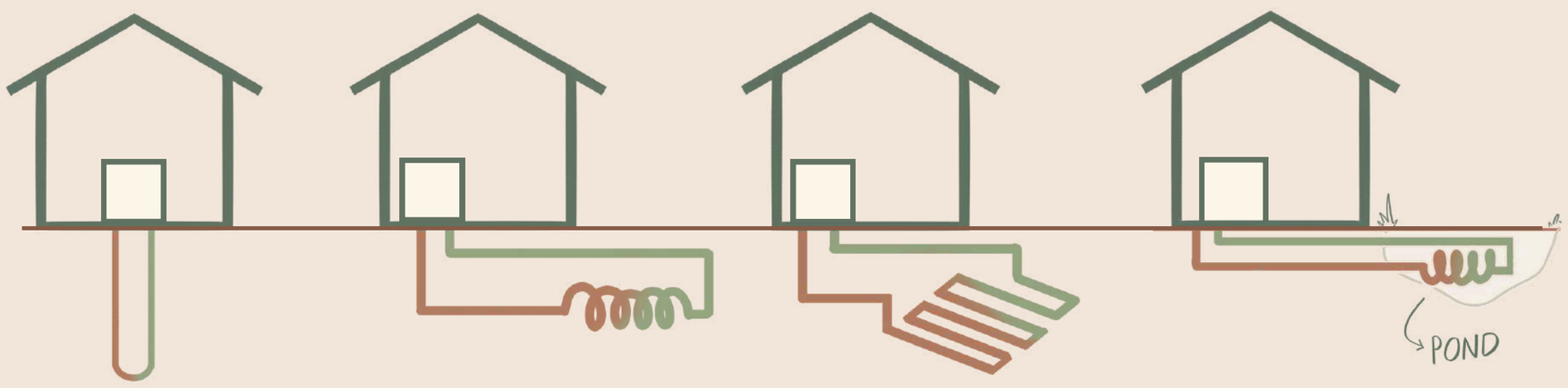
INDIRECT

Geothermal Heating



Ground Cooling & Earth Mass*

Leverage the cooling properties of the earth's mass to regulate indoor temperatures by building into earth berms. Explore alternatives like ground source heat pumps or earth cooling tubes for efficient backup cooling.



VERTICAL LOOPED HORIZONTAL POND

SHADING AND EARTH

Light-Colored Exteriors

Choose light-colored exteriors to reflect rather than absorb the sun's heat. Many natural lime plasters do this without any extra ingredients.

Incorporation of ‘Screens’

Screens provide both shade and airflow. When built with brick or earth, they can also store cool air passing through.

Interior Thermal Mass Walls*

Integrate thermal mass walls in the interiors to store and release cool temperatures. Make sure that these do not get direct sunlight unless you are trying to warm the house through the night. If this is the case, place thermal mass walls to receive solar heat from the west.

MODERN LUXURIES

☐ Humidity Control*

Managing humidity levels can be done by using **clay, which absorbs and stores moisture in the air**. However, by including a vapor barrier in the building envelope you can keep the humidity outside and inside separate (making sure the wall is permeable on both sides). If you do this, you will need to use a mechanical air-to-air heat exchanger to control indoor humidity build-up from human activities (showers, cooking, and breathing)

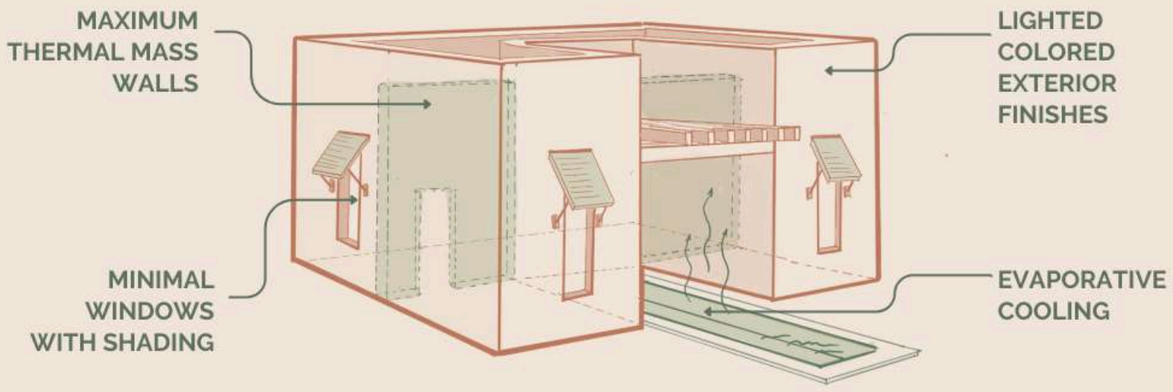
PRO TIP: When windows and doors remain closed, air distribution is essential for both heating and cooling. Consider HRVs/ERVs with a recirculation mode to redistribute heat efficiently. These systems can also bring in outside air, crucial for maintaining indoor air quality and preventing CO_2 buildup.

☐ Low-E Glazing on Windows*

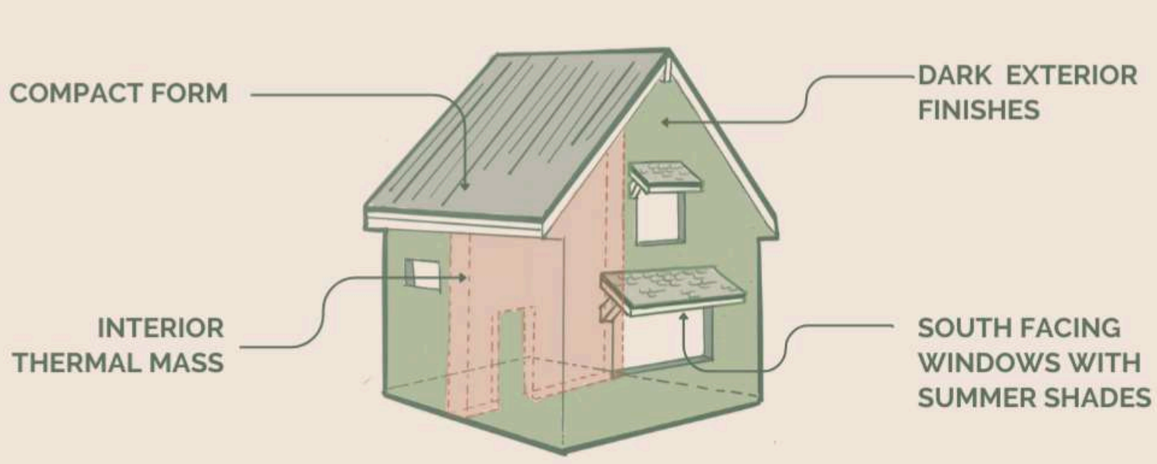
Install **Low-E glazing on all windows** to minimize heat gain while still allowing for natural light. This is usually code in most jurisdictions now, however, if you are using recycled windows make sure you get ones with low-e coatings.

CLIMATE SPECIFIC DESIGN

HOT-ARID

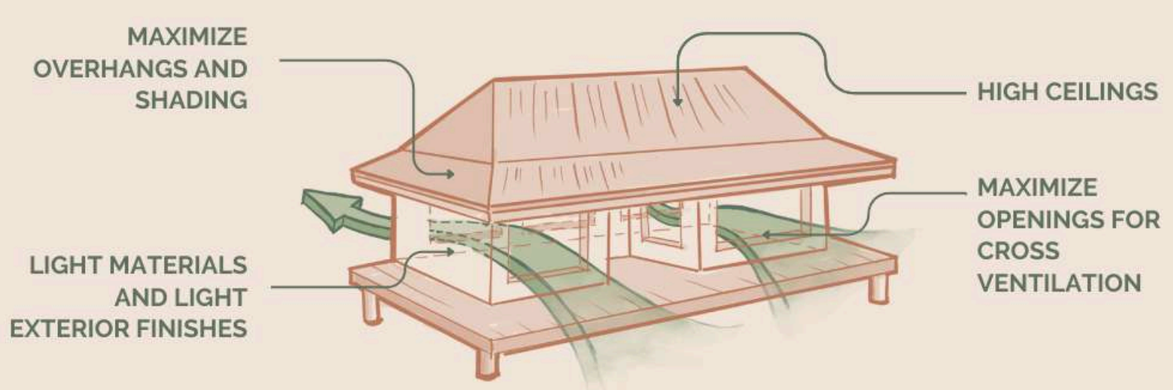


COLD

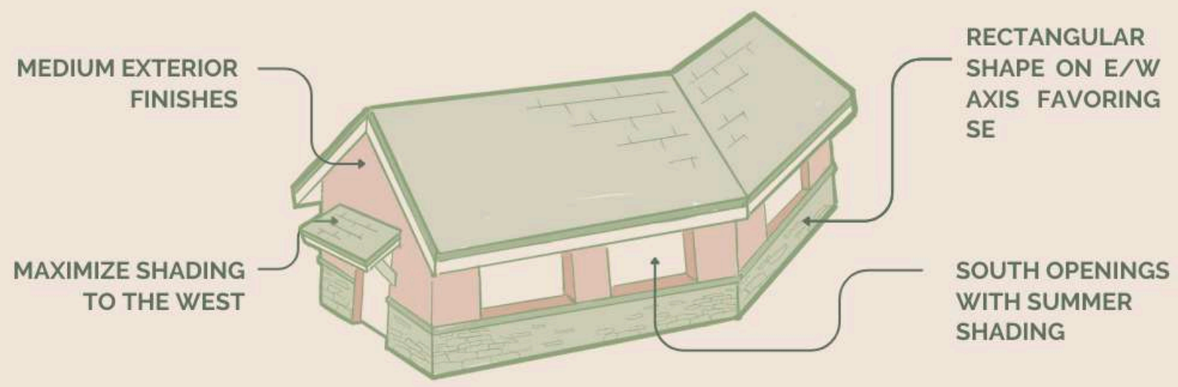


Passive Heating and Cooling techniques can be seen in climate-specific design approaches. Can you recognize which design attributes contribute to heating and cooling in each of these climates?

HOT-HUMID



TEMPERATE



Design with Nature

You've reached the end of this **Passive Heating and Cooling Checklist,** and it's time to pause and reflect -- Do you feel empowered knowing you're on the path to creating a more resilient home?

This checklist is more than a series of tasks; **it's a framework for designing a home that not only respects the principles of traditional architecture but also harmonizes with our natural world.** Every item you've checked off is a step closer to transforming your home into not just a place of shelter, but a thoughtfully designed, ecological sanctuary.

Remember, the journey toward sustainability is a continuous one, and the strides you make through these strategies are impactful.

If the process ever seems daunting, remind yourself that each small step is significant. Together, let's envision and build a future where our homes contribute to a healthier planet.

P.S. If you're ever uncertain about anything on this checklist, feel free to consult a designer or gather insights from local professionals. It's so important to get this right so we are building a more self-sufficient and healthy future for the planet and our own livelihood.

MEET THE *Designer*

& SUSTAINABILITY CONSULTANT

Hey! I'm Christina, and I am the heart behind C. Ransbury Design, Our approach extends beyond sustainable design to consider the interconnected relationship between built environment, land, and community.

I believe that the future of architecture is, in part, a returning to the ancient wisdom of the past. By blending these historical examples with contemporary technologies, we can create resilient buildings that last generations.

Navigating this process is not something I recommend doing alone. Crafting a home should be a rewarding journey, not an overwhelming one. This checklist is the first step to understanding the basics and forming an aligned team. With experts by your side, you can make sure you are heading in the right direction!

May your future space be beautiful, resilient, and connected to nature!

@cransburydesign @cransbury.design