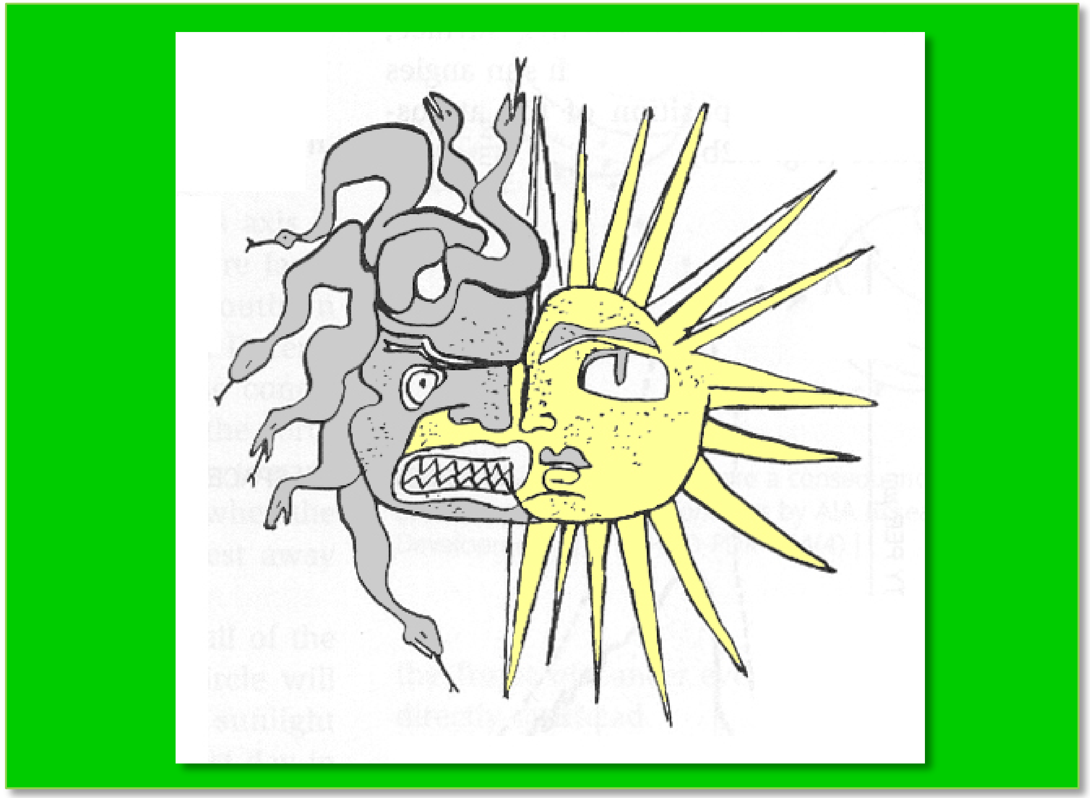
THE EVOLUTION TOWARDS CONTEMPORARY CLIMATE RESPONSIVE DESIGN: Part Two



Drawing by LeCorbusier

Applying Passive Strategies to Design

You might not remember August 14, 2003?

Radical Wake Up Call

The Northeast Blackout of 2003 was a massive widespread power outage that occurred throughout parts of the Northeastern and Midwestern United States, and Ontario, Canada on Thursday, August 14, 2003, at approximately 4:15 pm EDT (20:15 UTC). At the time, it was the most widespread electrical blackout in history. The blackout affected an estimated 10 million people in the Canadian province of Ontario and 45 million people in eight U.S. states.

Radical GREEN THINKING

- Radical problems need Radical solutions
- Radical solutions are seldom thought about until there are…
- Radical CATALYSTS!

You might remember December 21, 2013?

ICE STORM = NO POWER = NO HEAT

Radical PROBLEM!

- No power…
- Hot August weather… or
- Cold December temperatures…
- *Hooked* on electricity, heat and A/C
- What buildings/environment/systems “worked”?
- What buildings/environment/systems “didn’t” work?

SEALED BUILDINGS CANNOT BREATHE

ELEVATORS AND LIGHTS NEED POWER

Radical AWAKENING!

- Grid and energy dependent buildings/environment/systems DID NOT WORK!
- OPERABLE WINDOWS WORKED!
- NATURAL VENTILATION WORKED!
- SHADE WORKED!
- SUNLIGHT WORKED!
- DAYLIT SPACES WORKED!
- WALKABLE NEIGHBOURHOODS WORKED!
- BICYCLES WORKED!

Radical THOUGHT!??

MAYBE WE SHOULD BEGIN TO DESIGN OUR BUILDINGS/ENVIRONMENTS IN REVERSE!

Start with a basic UNPLUGGED building

Radical Steps!

#1 - ***start*** **by UNPLUGGING the building**

Then…

#2 – heat only with the sun

#3 – cool only with the wind and shade

#4 – light only with daylight

USE the ARCHITECTURE first, and mechanical systems only to supplement what you cannot otherwise provide.

#5 – USE RENEWABLE CLEAN ENERGY BEFORE HOOKING UP TO NATURAL GAS, OIL OR THE REGULAR ELECTRICAL GRID (with all of its nastiness – including CO_2)

Radical IS Passive…

PASSIVE DESIGN is where the building uses the SUN, WIND and LIGHT to heat, cool and light

ARCHITECTURALLY

Carbon Reduction: The Passive Approach

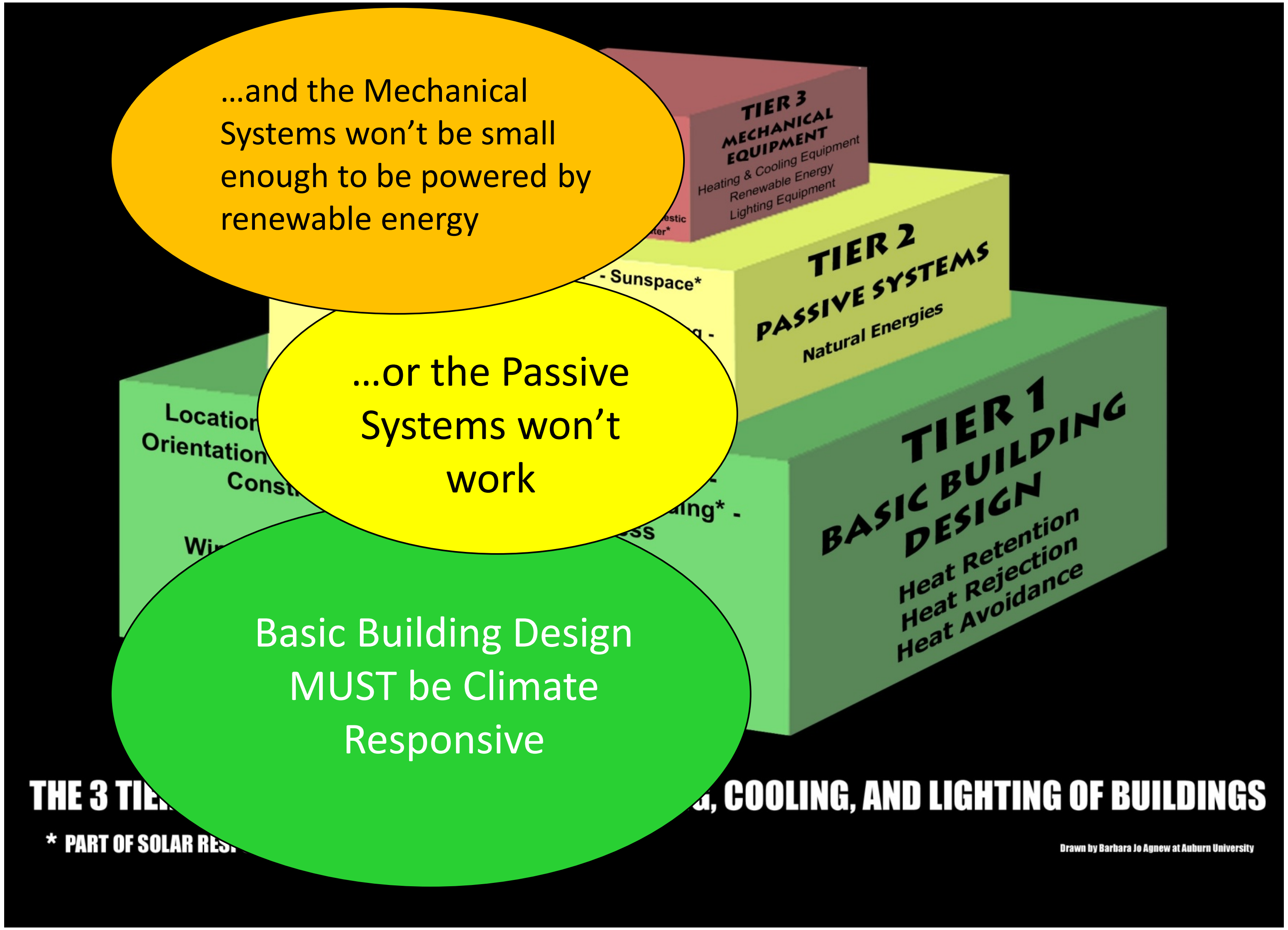


Image: Norbert Lechner, "Heating, Cooling, Lighting"

Operating Energy of Building

80% of the problem!

Landscape + Site

Disturbance vs. sequestration

Embodied Carbon in Building Materials

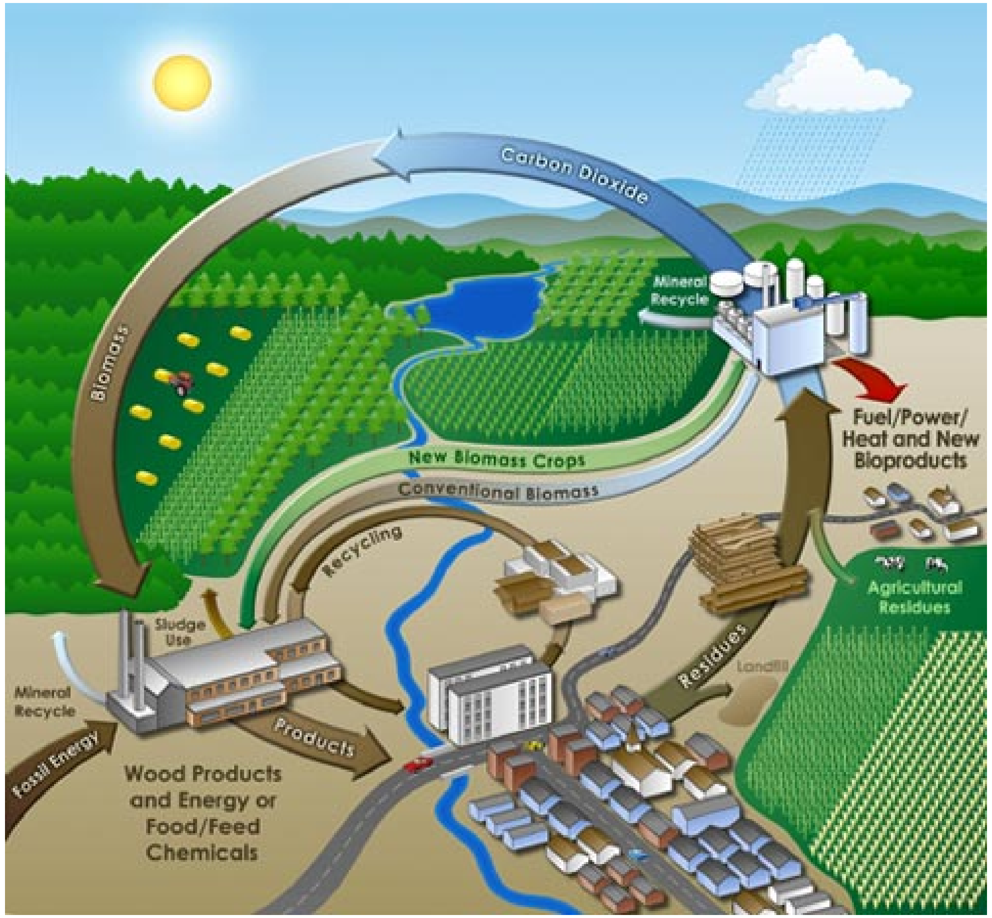
People, "Use" + Transportation

Renewables + Site Generation

Counting Carbon costs….

+ purchased offsets

Buildings / Processes and the Carbon Cycle:



http://www.repp.org/bioenergy/bioenergy-cycle-med2.jpg

As the way that buildings interact with carbon is highly complex, the first aim is to reduce operating energy as it is the most significant and easiest to control.

Energy vs Greenhouse Gas Emissions

In BUILDINGS, for the sake of argument

ENERGY CONSUMPTION = GHG EMISSIONS

BUILDING ENERGY IS COMPRISED OF

EMBODIED ENERGY

+

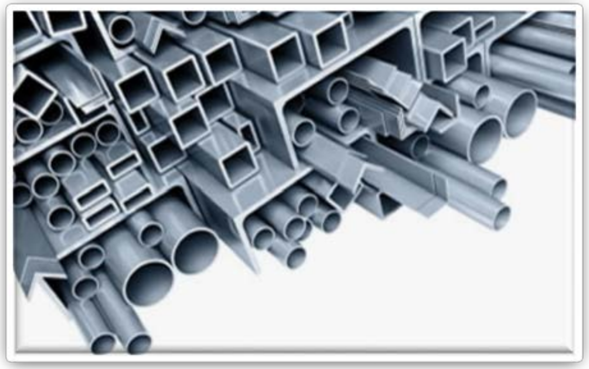
OPERATING ENERGY

Energy Use in Buildings

Embodied Energy

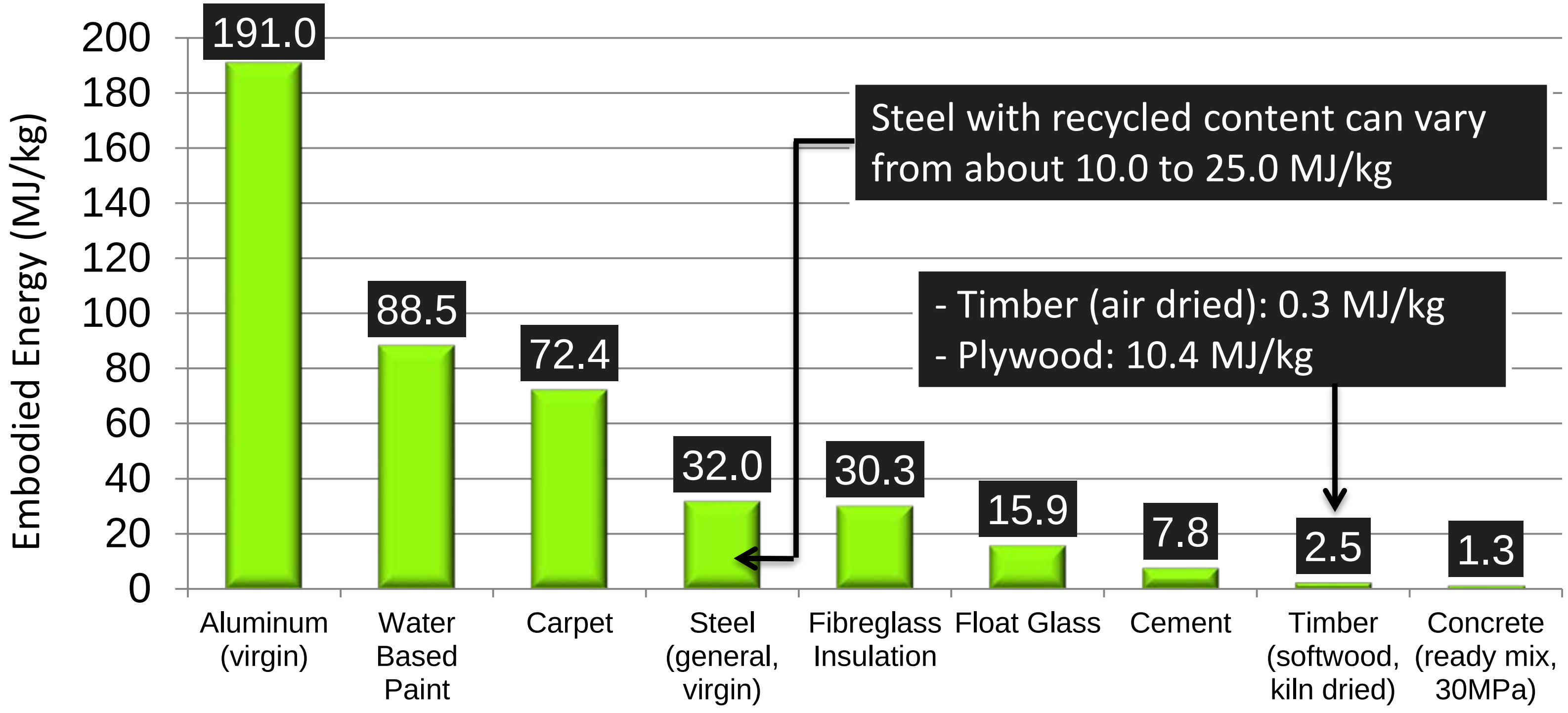
- Initial Embodied Energy: Non-renewable energy consumed in the acquisition of raw materials, their processing, manufacturing, transportation to site, and construction

- Recurring Embodied Energy: Non-renewable energy consumed to maintain, repair, restore, refurbish or replace materials, components, or systems during life of building



www.cn-sbs.cssbi.ca

Initial Embodied Energy of Building Materials Per Unit Mass

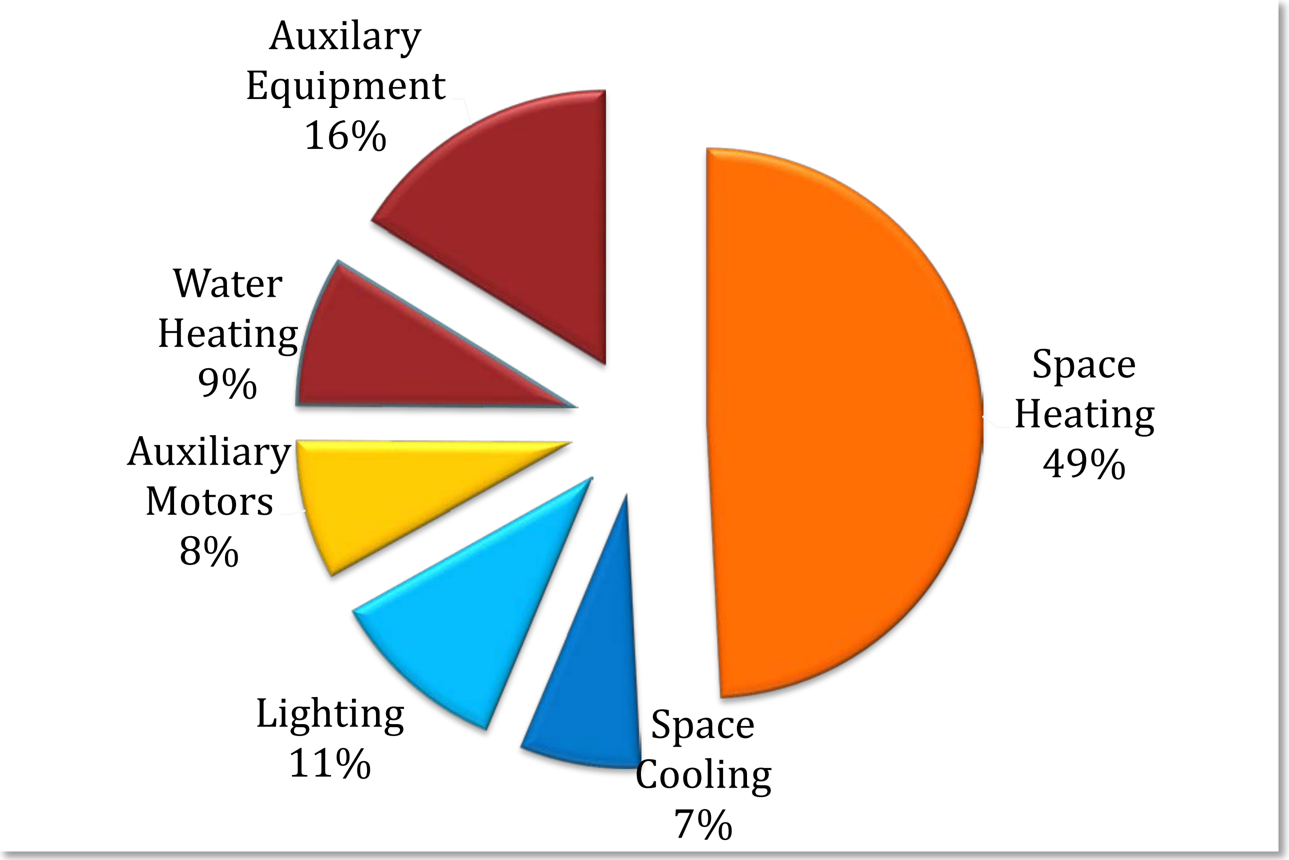


Source: University of Wellington, NZ, Center for Building Performance Research (2004)

www.cn-sbs.cssbi.ca

Energy Use in Buildings: Operating Energy

Total Commercial/Institutional Secondary Energy Use by End Use in Canada (2006)



Source: Natural Resources Canada, 2006

REDUCING OPERATING ENERGY

Three Key Steps – IN ORDER:

#1 - Reduce loads/demand first

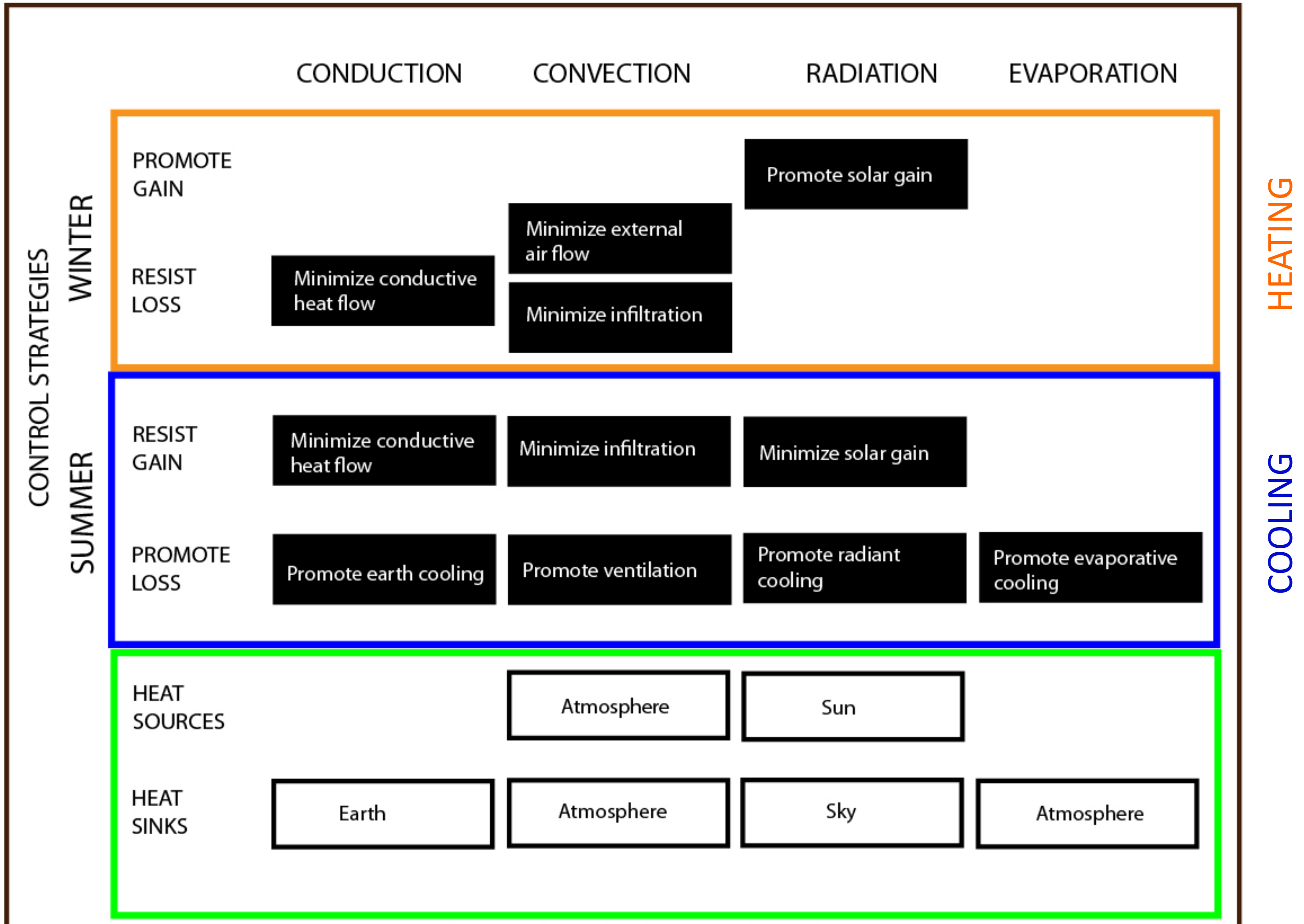
(conservation, passive design, daylighting, shading, orientation, etc.)

#2 - **Meet loads efficiently and *effectively*** (energy efficient lighting, high-efficiency Mechanical Electrical and Plumbing equipment, controls, etc.)

#3 - **Use renewables to meet energy needs** (doing the above steps *before* will result in the need for much smaller renewable energy systems, making carbon neutrality achievable.)

Use purchased Offsets as a *last resort* when all other means have been looked at on site, or where the scope of building exceeds the site available resources.

Begin with Passive Strategies for Climate Control to Reduce Energy Requirements



Strategies of Climate Control

(chart modeled after Watson "Climatic Building Design")

CLIMATE RESPONSIVE

HEATING ↔ SUN

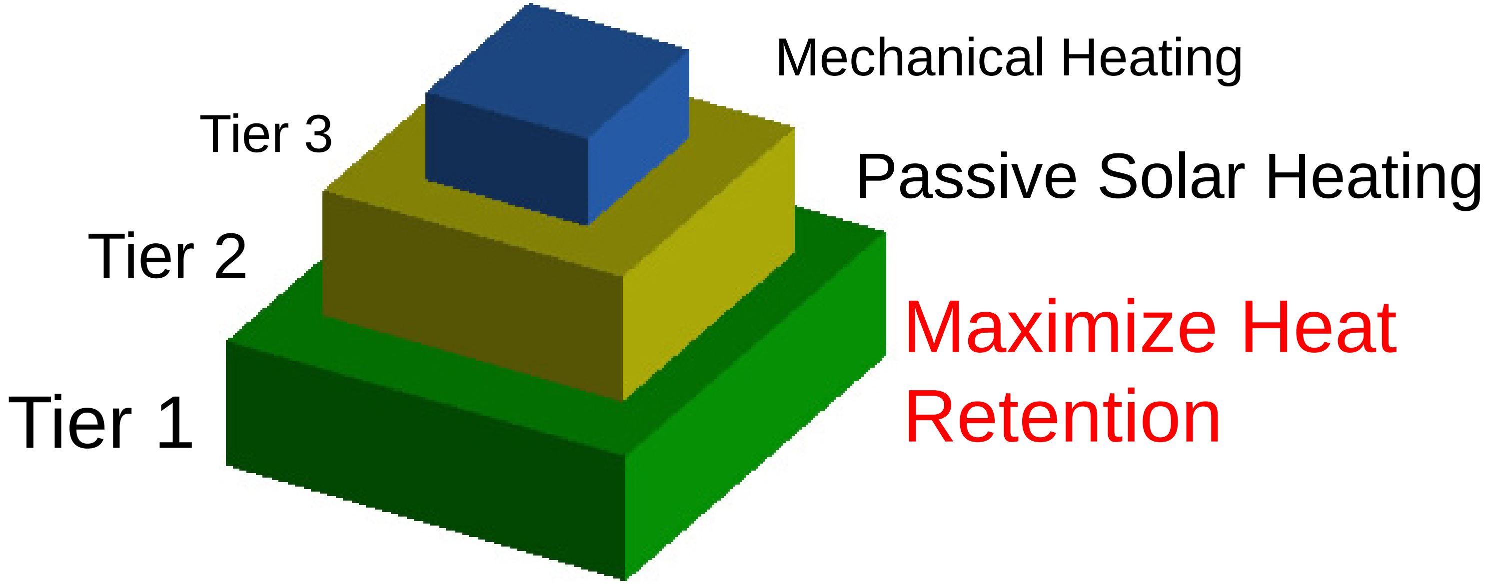
COOLING ↔ WIND

DAYLIGHTING ↔ LIGHT

PASSIVE STRATEGIES

Reduce loads: Passive Heating Strategies

The tiered approach to reducing carbon for **HEATING**:



First reduce the overall energy required, then maximize the amount of energy required for mechanical heating that comes from renewable sources.

Source: Lechner. Heating, Cooling, Lighting.

Passive Heating Strategies:
Maximize Heat Retention

1. Super insulated envelope (*as high as <u>double</u> current standards*)
2. Tight envelope / controlled air changes
3. Provide thermal mass **inside** of thermal insulation to store heat
4. Top quality windows with high R-values – up to triple glazed with argon fill and low-e coatings on two surfaces

Premise – what you don’t “lose” you don’t have to create or power…. So make sure that you keep it! *(…NEGAwatts)*

Passive Heating Strategies

1. primarily south facing windows
2. proportion windows to suit thermal mass and size of room(s)

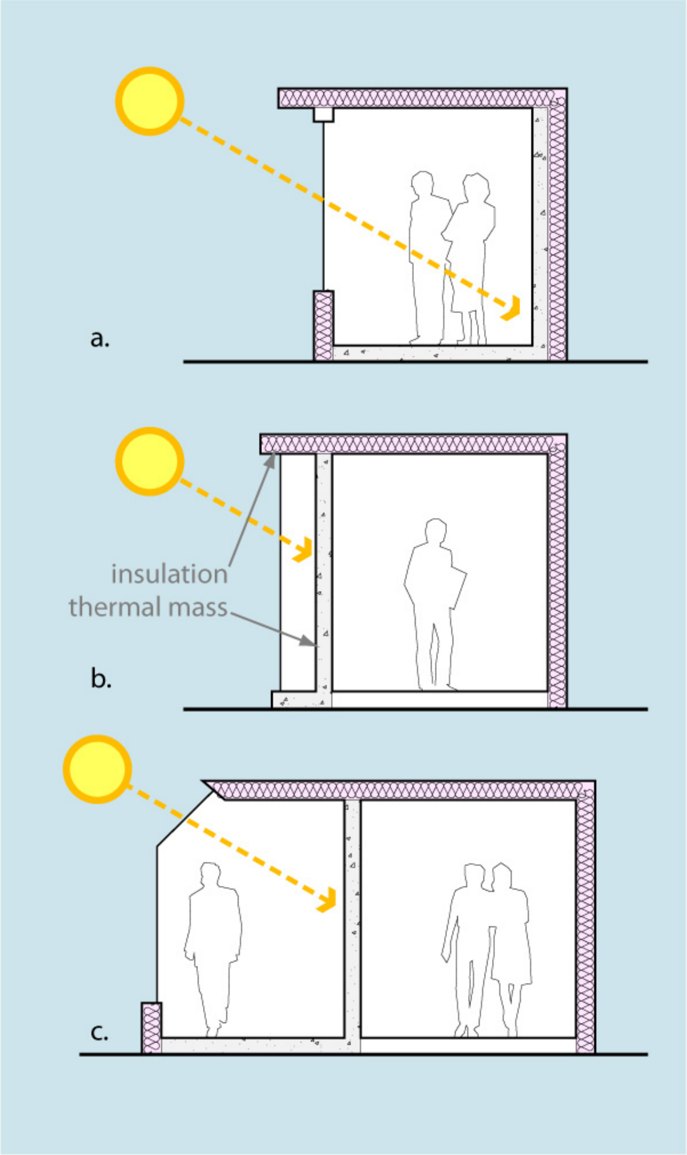
3 MAIN STRATEGIES:

a. **Direct Gain**

b. Indirect Gain

c. Isolated Gain

The dominant architectural choice is Direct Gain.



Thermal Mass is Critical!

To ensure comfort to the occupants….

People are 80% water so if they are the only thermal sink in the room, they will be the target.

And to store the FREE energy for slow release distribution….

Aldo Leopold Legacy Center:
Concrete floors complement the insulative wood walls and provide thermal storage

Thermal mass is the “container” for free heat…

If you “pour” the sun on wood, it is like having no container at all.

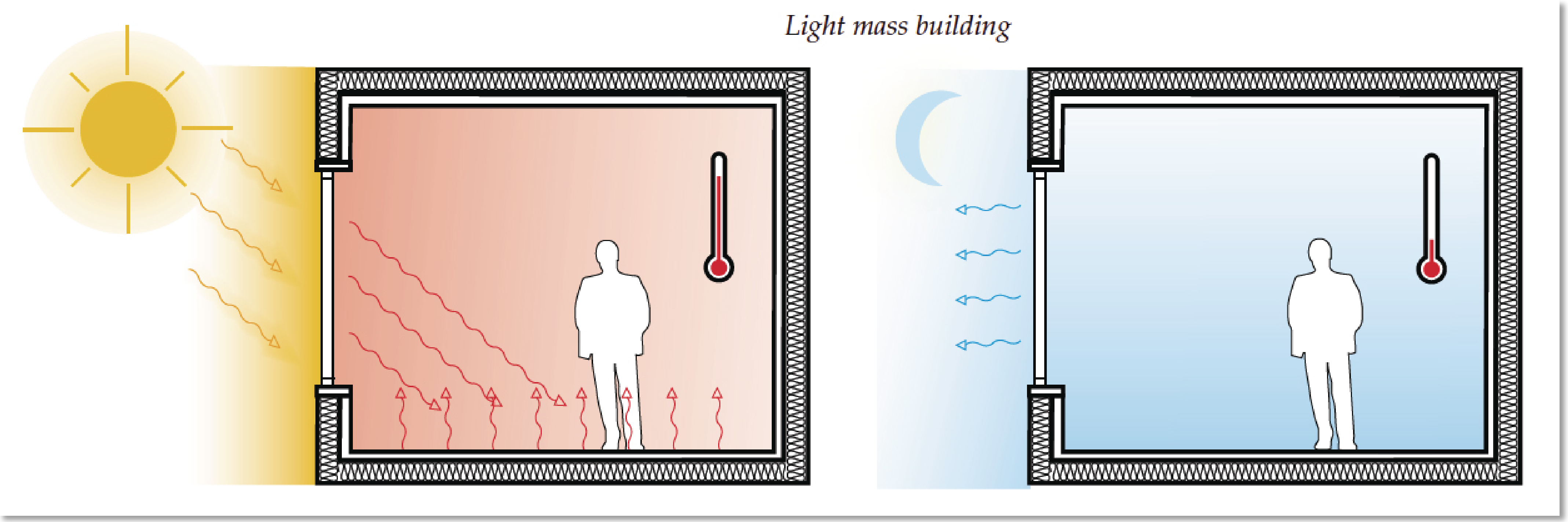
Just like water, free solar energy needs to be stored somewhere to be useful!

Problems with traditional placement of thermal mass

Proper thermal mass placement runs counter to the standard method of residential construction in Canada.

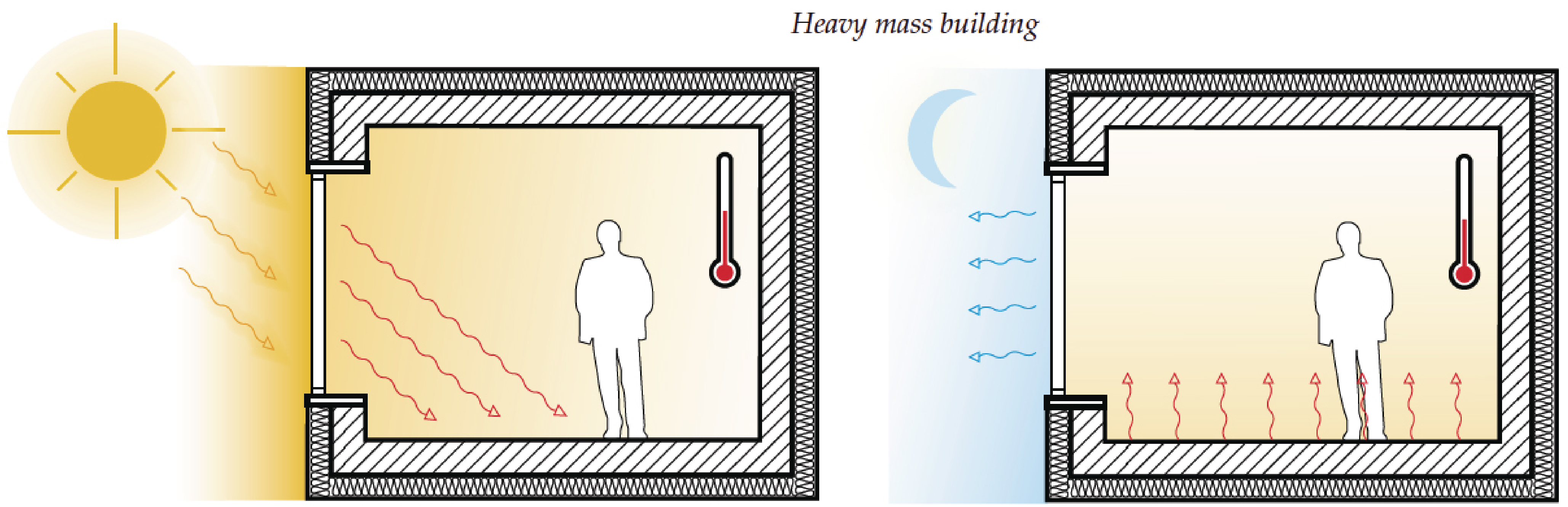
Thermal mass is needed on the INSIDE of the envelope – as floor and/or walls.

Light Mass Building Problems



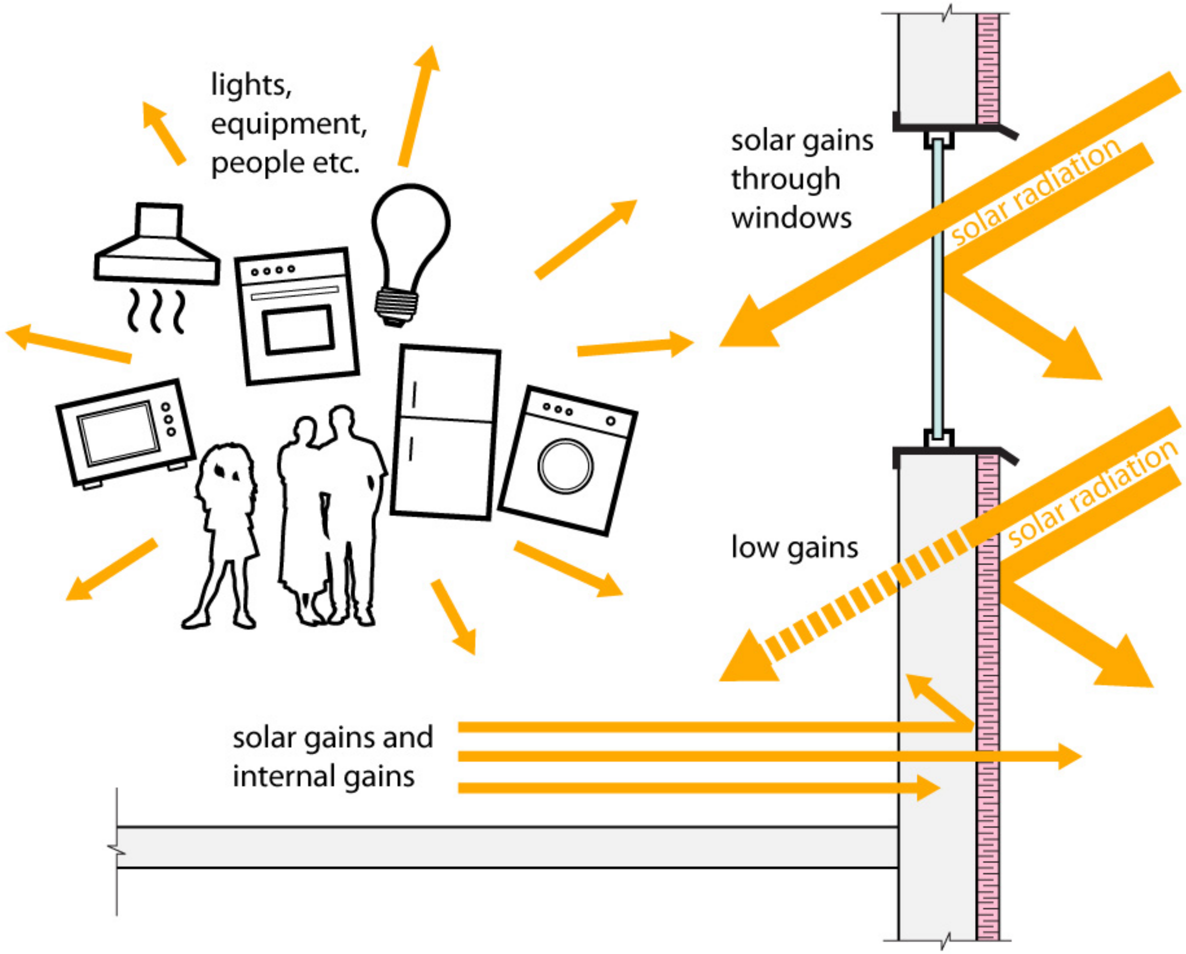
- Wide swings of temperature from day to night
- Excess heat absorbed by human occupants
- Uncomfortably cold at night

Heavy Mass Building Benefits



- Glass needs to permit entry of solar radiation
- Also need insulating blinds to prevent heat loss at night.

Thermal mass and exterior insulation

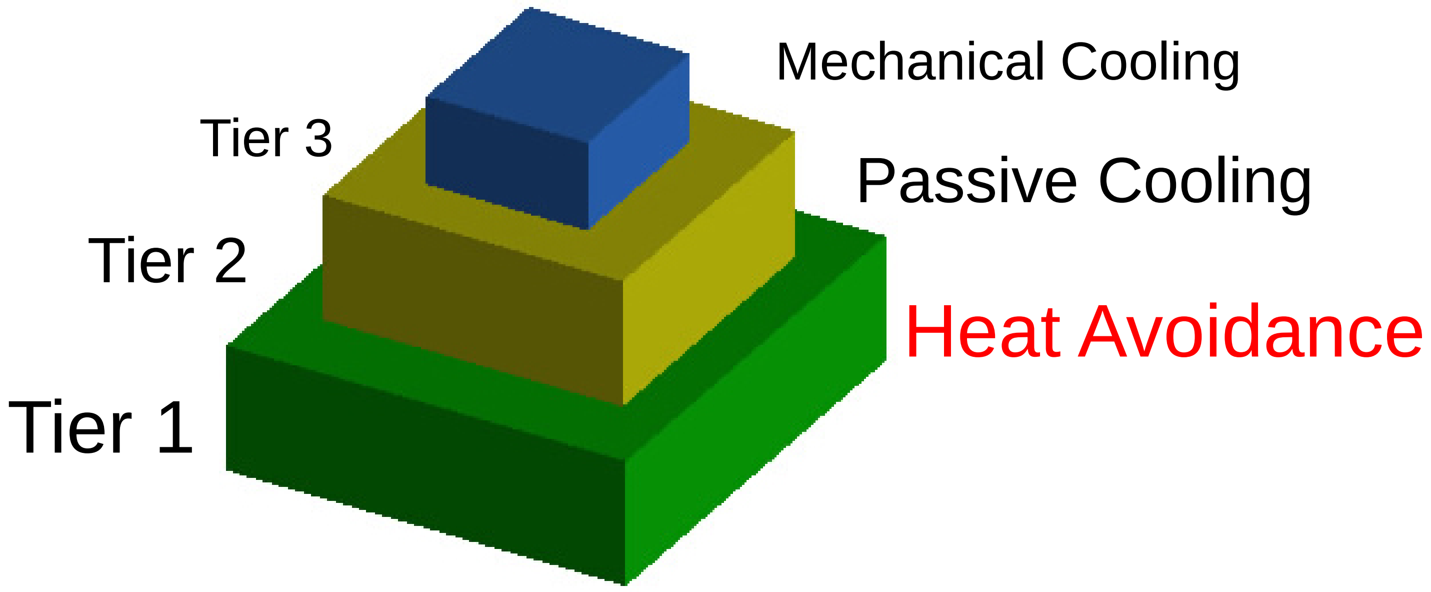


If the insulation is on the OUTSIDE of the building envelope (and thermal mass element), the heat that gets in STAYS in.

As windows/glass elements are good at allowing solar radiation to pass through, this configuration is the best solution.

Reduce loads: Passive Strategies

The tiered approach to reducing carbon for COOLING:

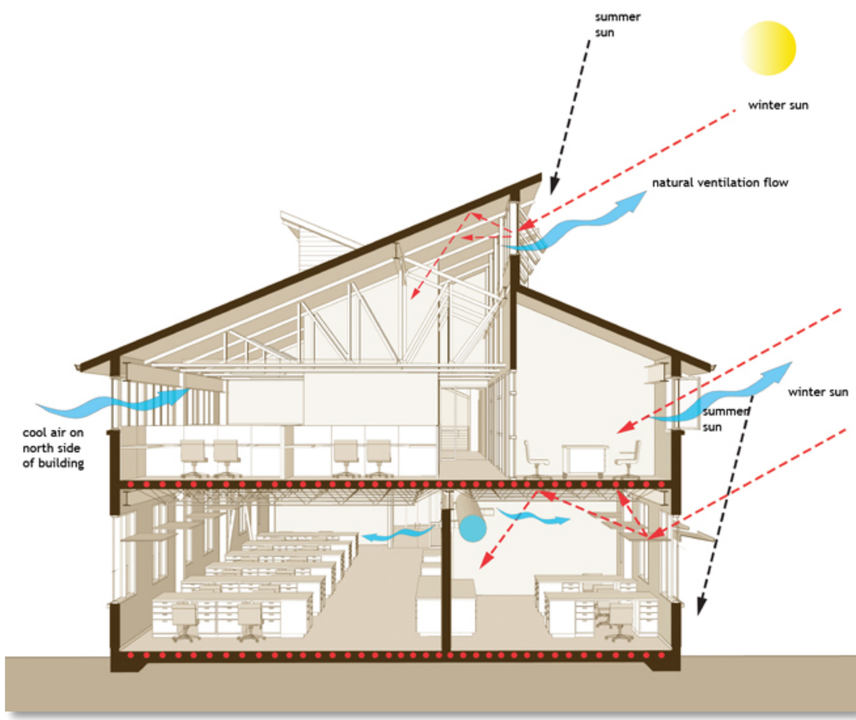


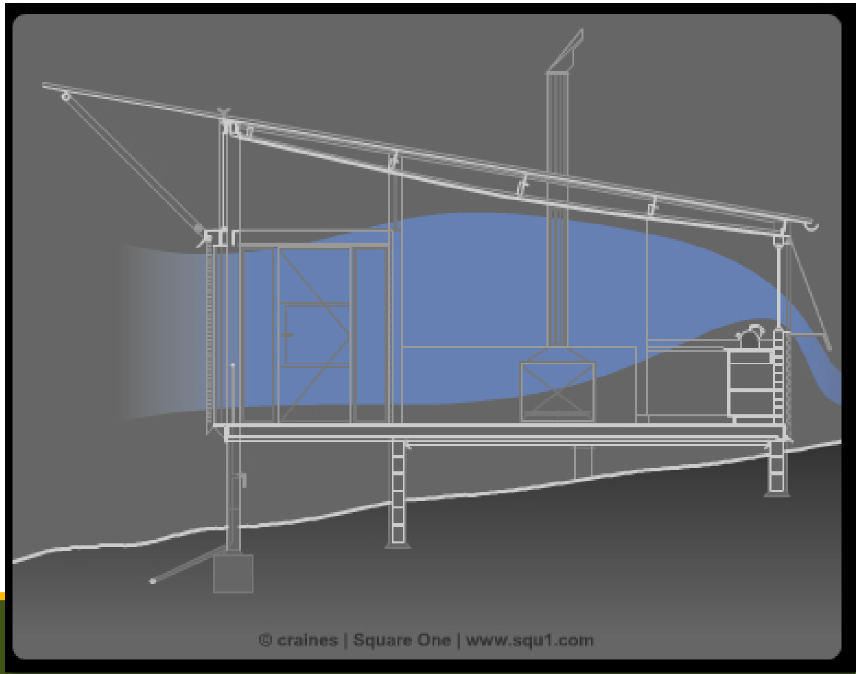
Maximize the amount of energy required for mechanical cooling that comes from renewable sources.

Source: Lechner. Heating, Cooling, Lighting.

Passive Cooling Strategies:
Passive Cooling

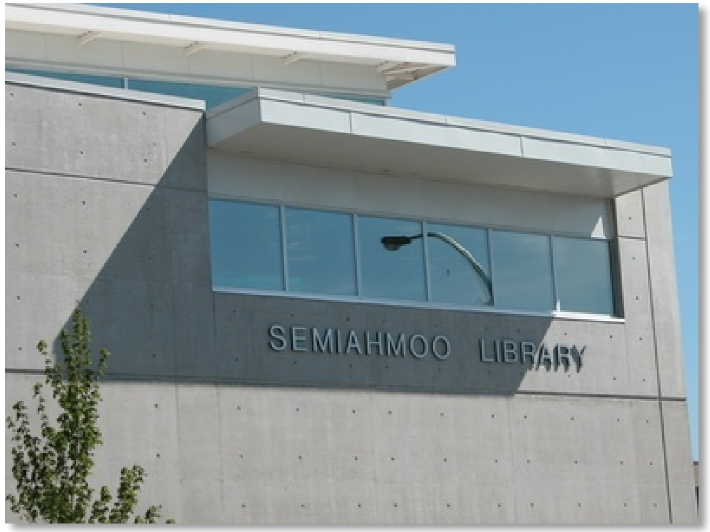
1. design for maximum ventilation
2. design plans as open as possible for unrestricted air flow
3. use easily operable windows at low levels with high level clerestory windows to induce stack effect cooling





Passive Cooling Strategies:
Heat Avoidance

1. shade windows from the sun during hot months
2. design materials and plantings to cool the local microclimate
3. locate trees and trellis’ to shade east and west façades during morning and afternoon low sun
4. If you don’t invite the heat in, you don’t have to get rid of it!



Think Heat AVOIDANCE!

If it does not get IN, you don't have to deal with it!

One way to avoid heat gain is by modifying the glazing.

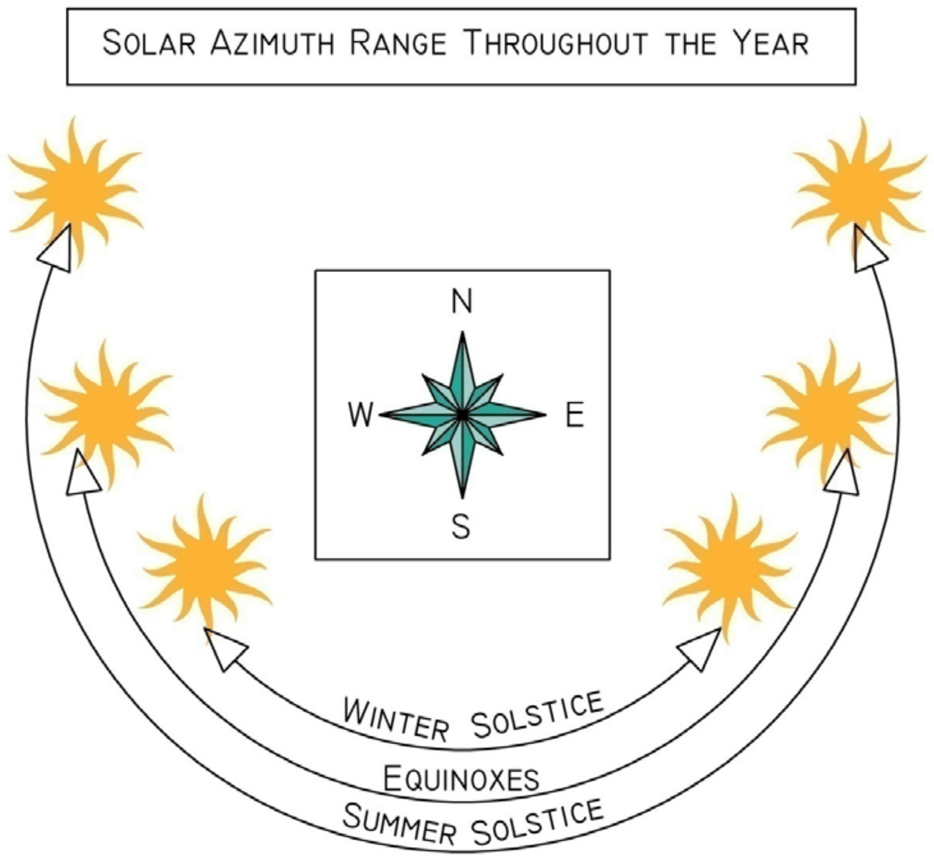
Atrium buildings have long had issues with solar gain, so some of the glass is opaque to give the appearance of "sky" without the solar gain.

Toronto, Eaton Centre – Zeidler Partnership

Salt Lake City Library, Moshe Safdie

Blinds must be manually drawn by the librarian every sunny day to avoid baking the children in the lower library area!

#1 Starting Point ORIENTATION – Locate the SUN



- use it to get FREE energy for heating
- avoid it to reduce cooling requirements

Solar geometry works for us because the sun is naturally HIGH in the summer, making it easy to block the sun with shading devices on SOUTH façades.

And it is naturally LOW in Winter, allowing the sun to penetrate below our shading devices and enter the building - with FREE heat.

The sun is always low on the EAST and WEST façades, so they need different strategies.

Solar transmission and glass type

Solar Transmission of Flat Glass

Type	Thickness, mm (in)	Solar transmittance, %
Clear	2.5-6 (0.1-0.25)	78-87
Heavy-duty clear	8-22 (0.3-0.87)	67-74
Tinted	6-12 (0.25-0.5)	47-68
Heavy-duty tinted	10-12 (0.39-0.5)	24-33
Reflective	6-12 (0.25-0.5)	3-29
Insulating	15-18 (0.59-0.7)*	†
Solar	6-30 (0.25-1.18)	90-93
Architectural laminated	6-30 (0.25-1.18)	†
Spandrel	6- (0.25)	
Figured	3-4 (0.12-0.15)	78-80
Wired	6 (0.25)	78-80
Heat-resisting	3-12 (0.12-0.5)	80-92

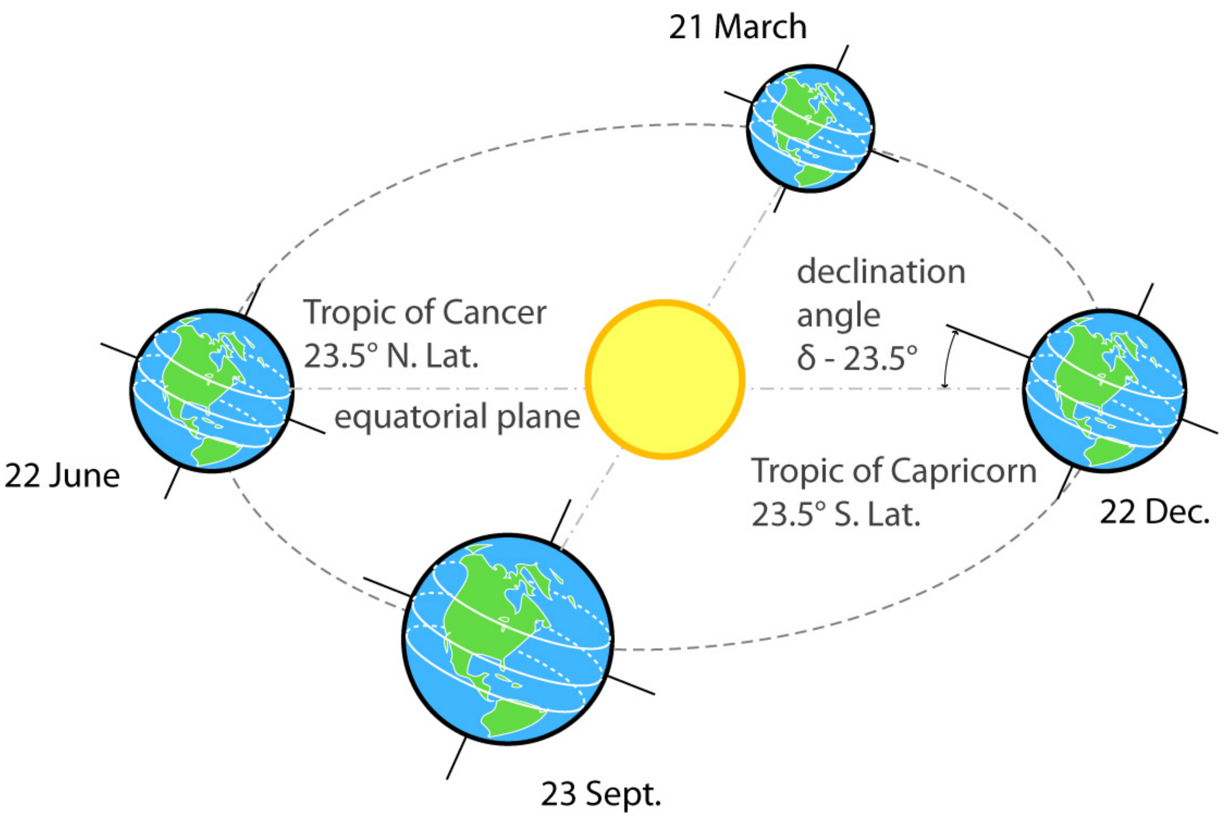
*Thickness listed is total thickness, made up of lights 3 to 6 mm (1/8 to 1/4 in) thick separated by a 12-mm (1/2-in) air space.

†Transmittance of insulating and laminated glass varies widely depending on whether or not one or more surfaces are treated with reflective films.

Solar Geometry

In studying Solar Geometry we are going to figure out how to use the sun's natural path in summer vs. winter to provide FREE heat in the Winter, and to reduce required COOLING in the summer.

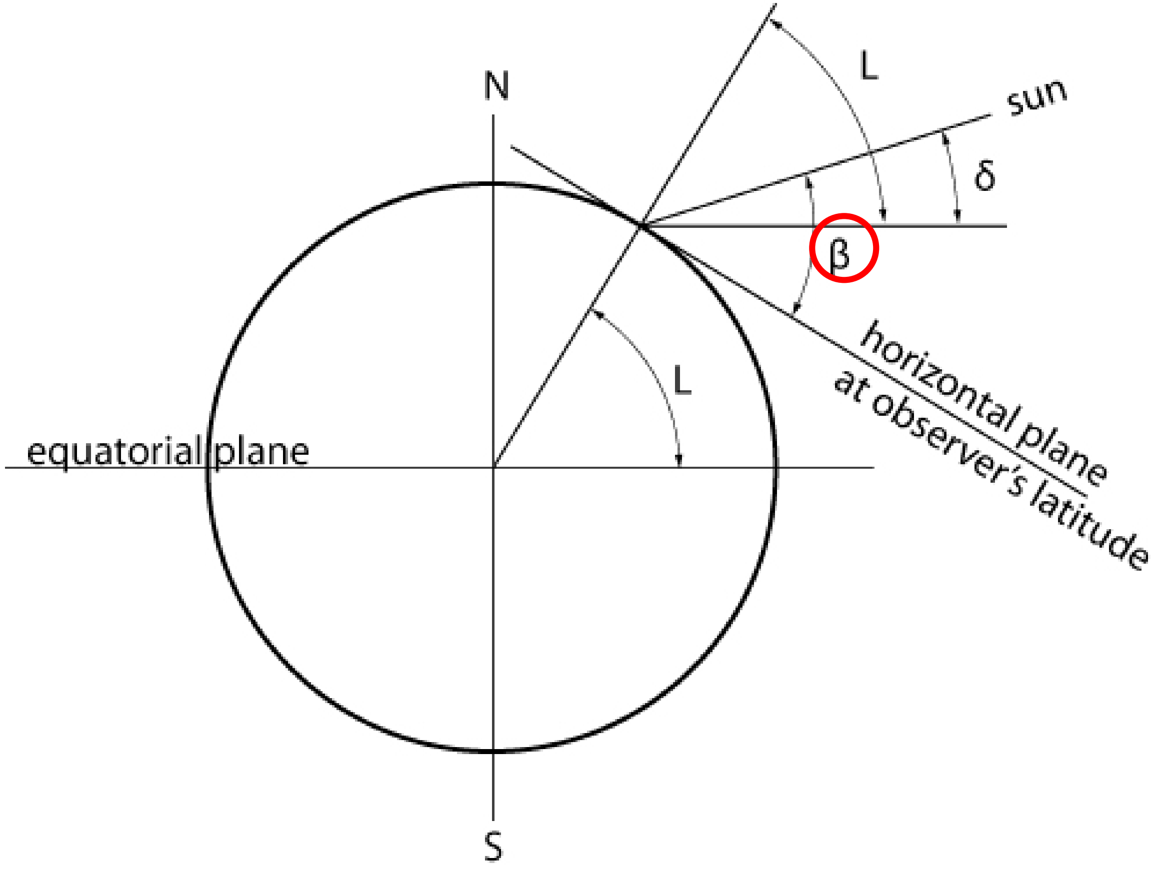
Solar Geometry



Earth's motion around the sun.

We need to look at this very particularly as a function of latitude and longitude in order to tailor our approaches quite specifically for each project.

Solar Geometry Terms



Relation between declination, altitude angle, and latitude.

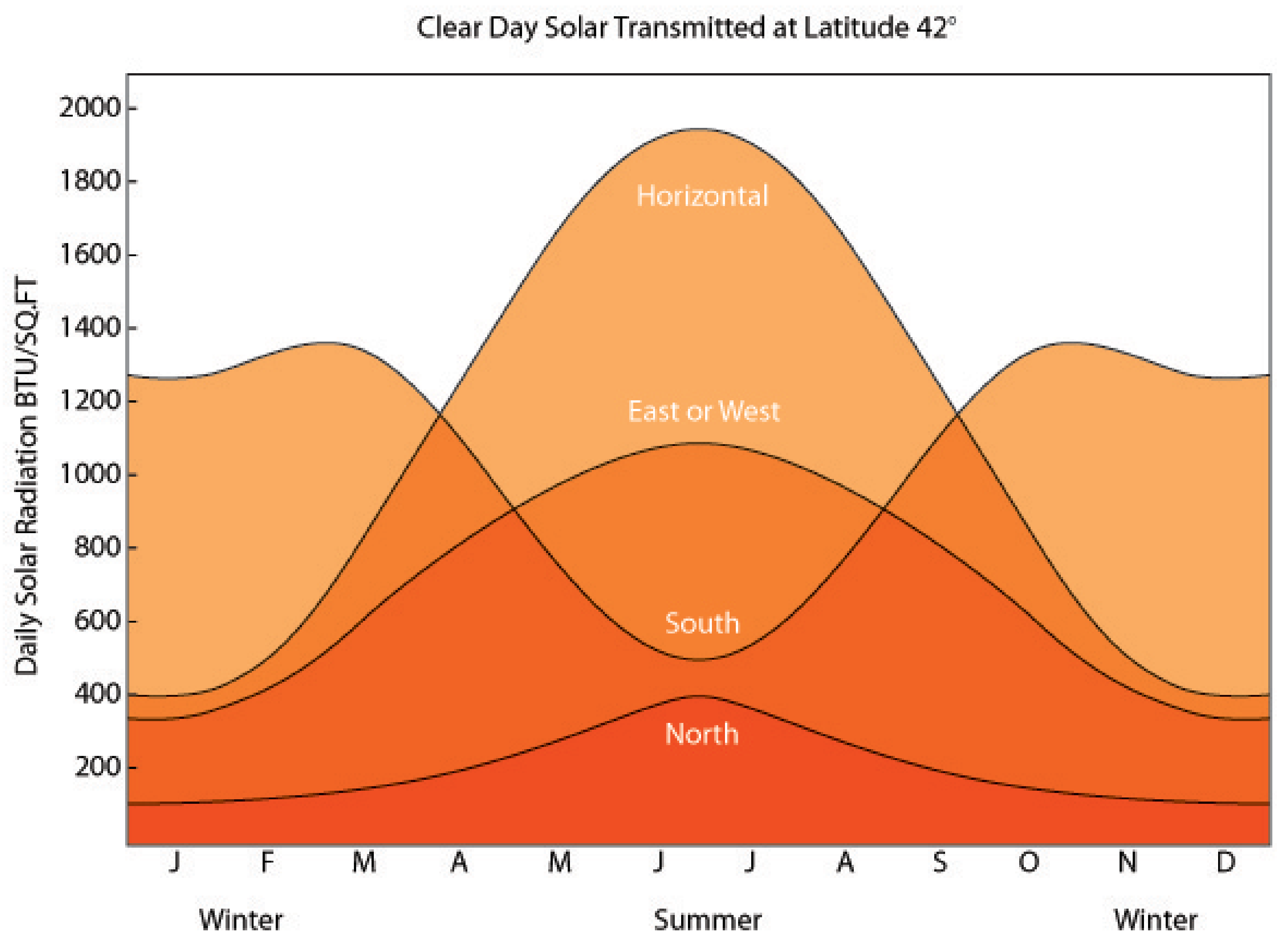
Beta is the most important to you as it is the angle of the sun above the horizon and will set the length of shading devices.

Solar Energy as a Function of Orientation

This chart demonstrates the variation in solar energy received on the different facades and roof of a building set at 42 degrees latitude.

A horizontal window (skylight) receives 4 to 5 times more solar radiation than south window on June 21.

East and West glazing collects almost 3 times the solar radiation of south window.



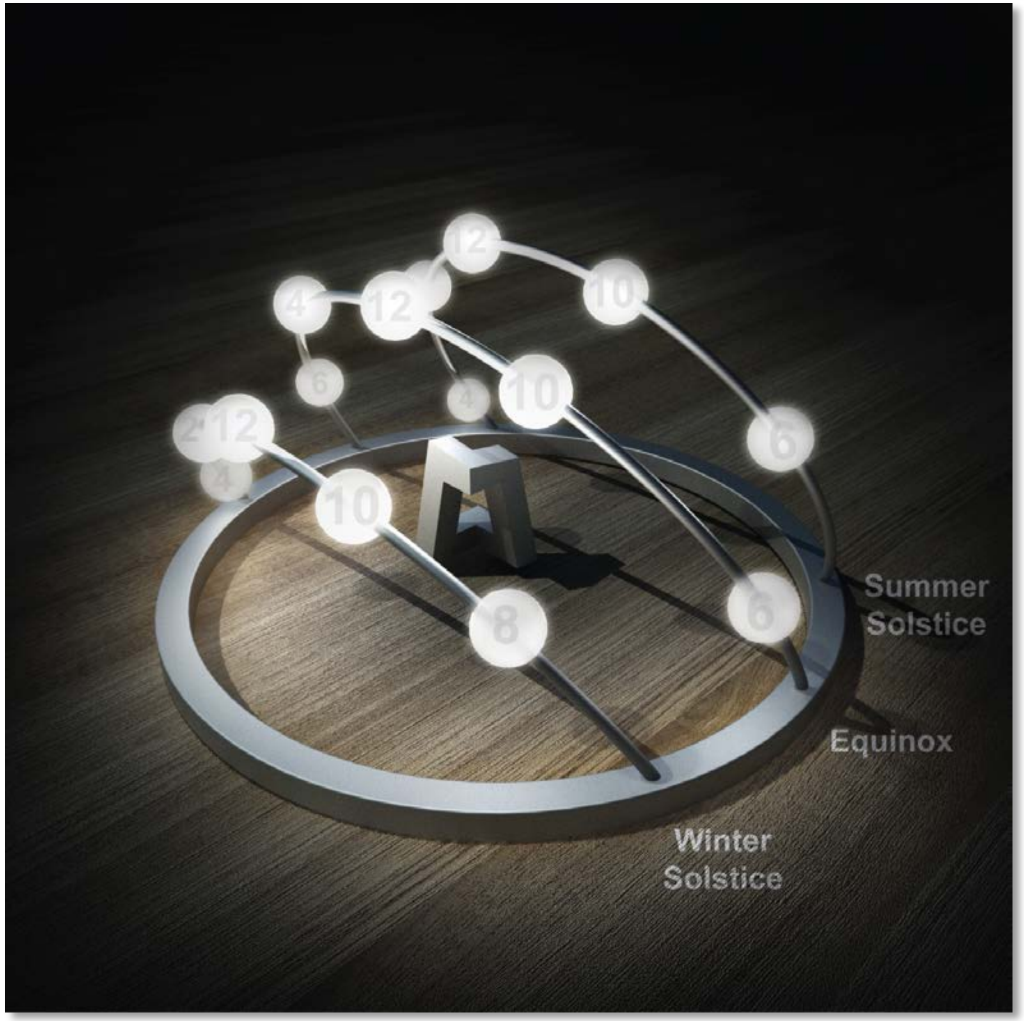
Tracking the solar path for times of the year

The local solar path affects:

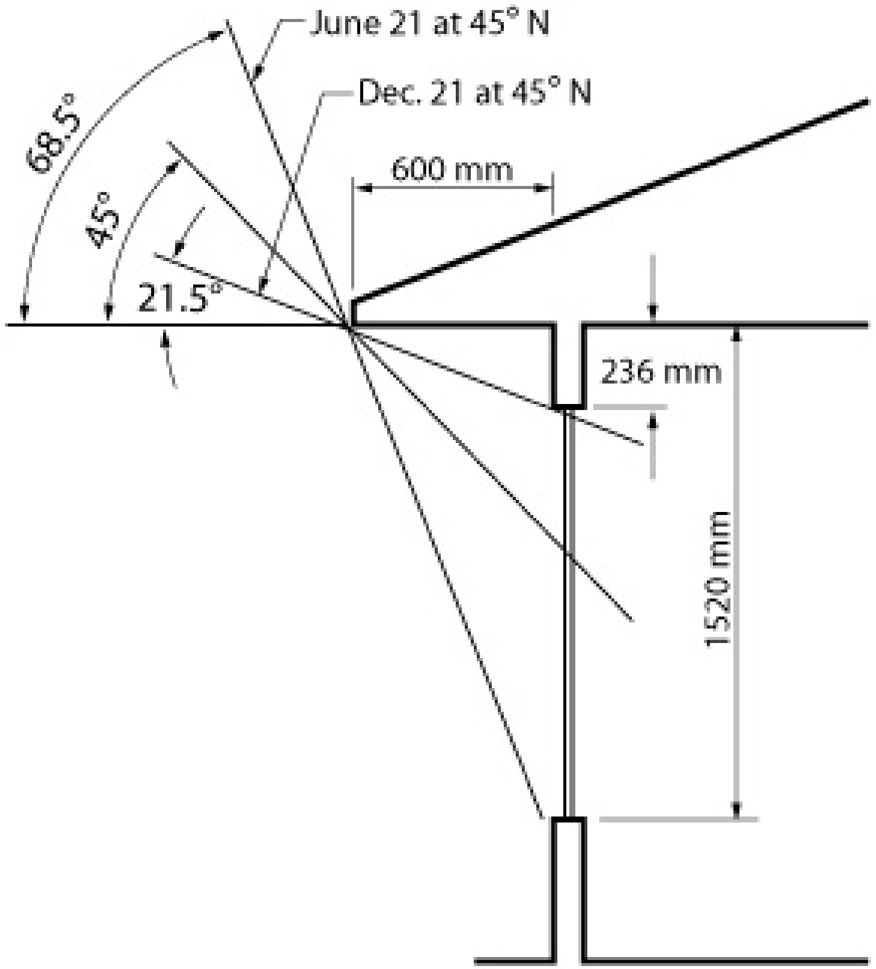
➢ Location of openings for passive solar heating

➢ Design of shading devices for cooling

➢ Means differentiated façade design



South Shading Device Basics



Shading angles for a south wall at 45°N

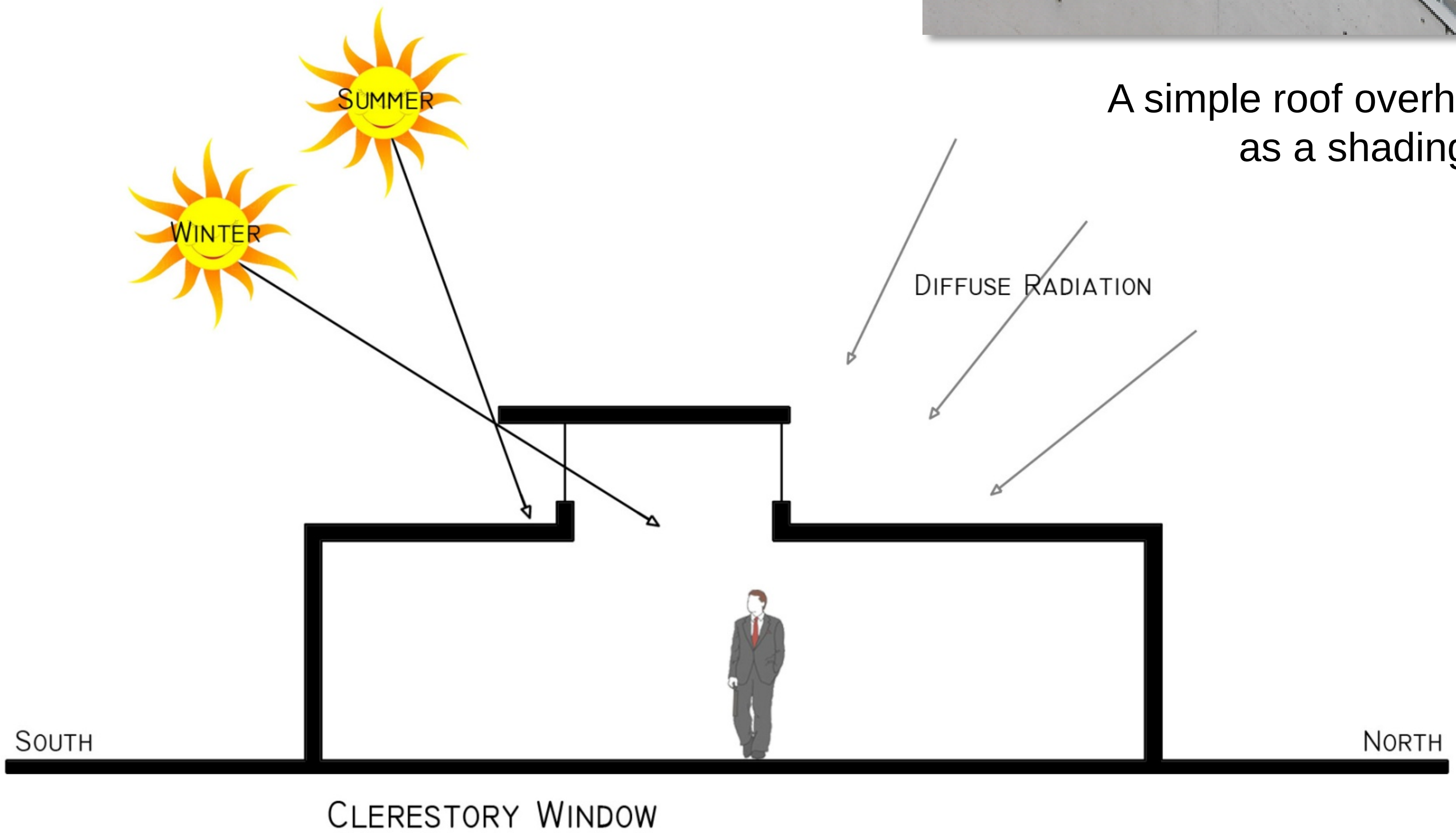
South facing windows are the EASIEST for control of sun penetration.

Many buildings will allow windows to dominate the south façade for this reason.

Shading devices can be simple horizontal projections.

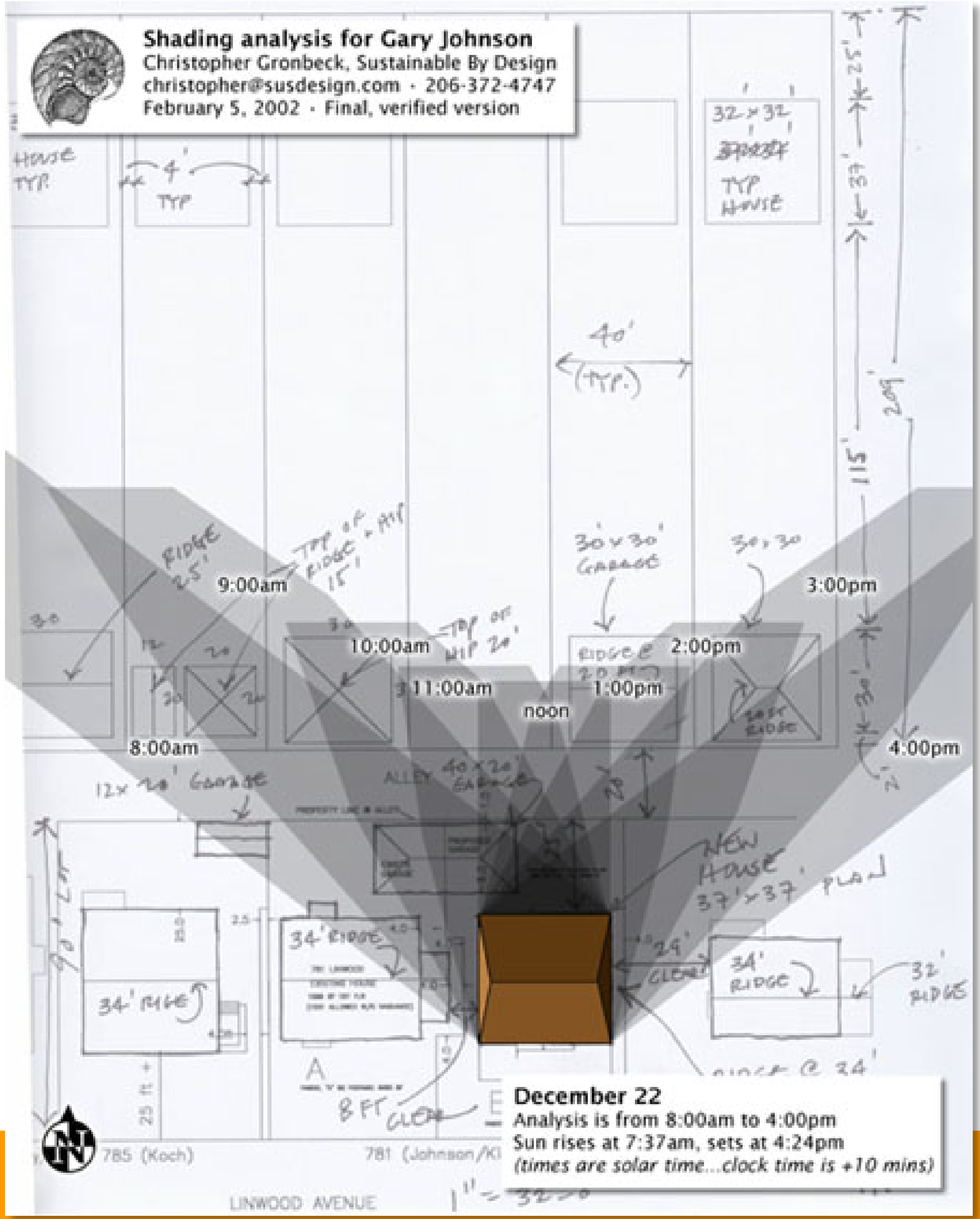
Calculation of size is pretty simple.

A simple roof overhang acts
as a shading device.



Here we can see how a simple roof overhang acts as a shading device on the south side of the building.
North facing glazing will only receive diffuse light for the majority of the year, and so no shading devices are required.

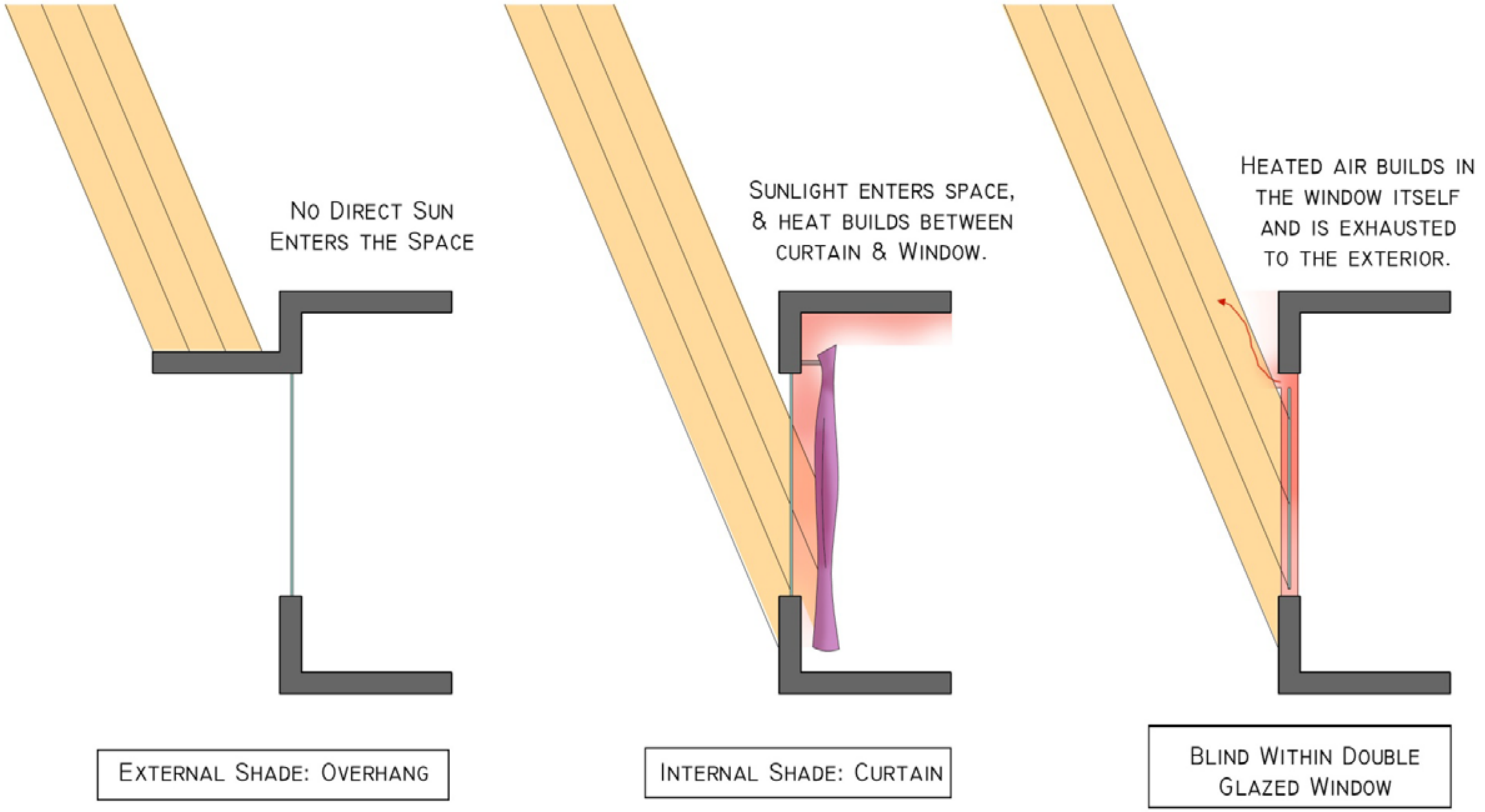
When we design our elevations to be solar responsive, this will mean having different facade treatments to respond to sun angles and the degree of exposure of the facade.



This type of analysis is a "must do" for every building that you design.

What is MISSING here, is the shading diagrams from the neighbouring properties (all sides). Their shadows will impact your building too.

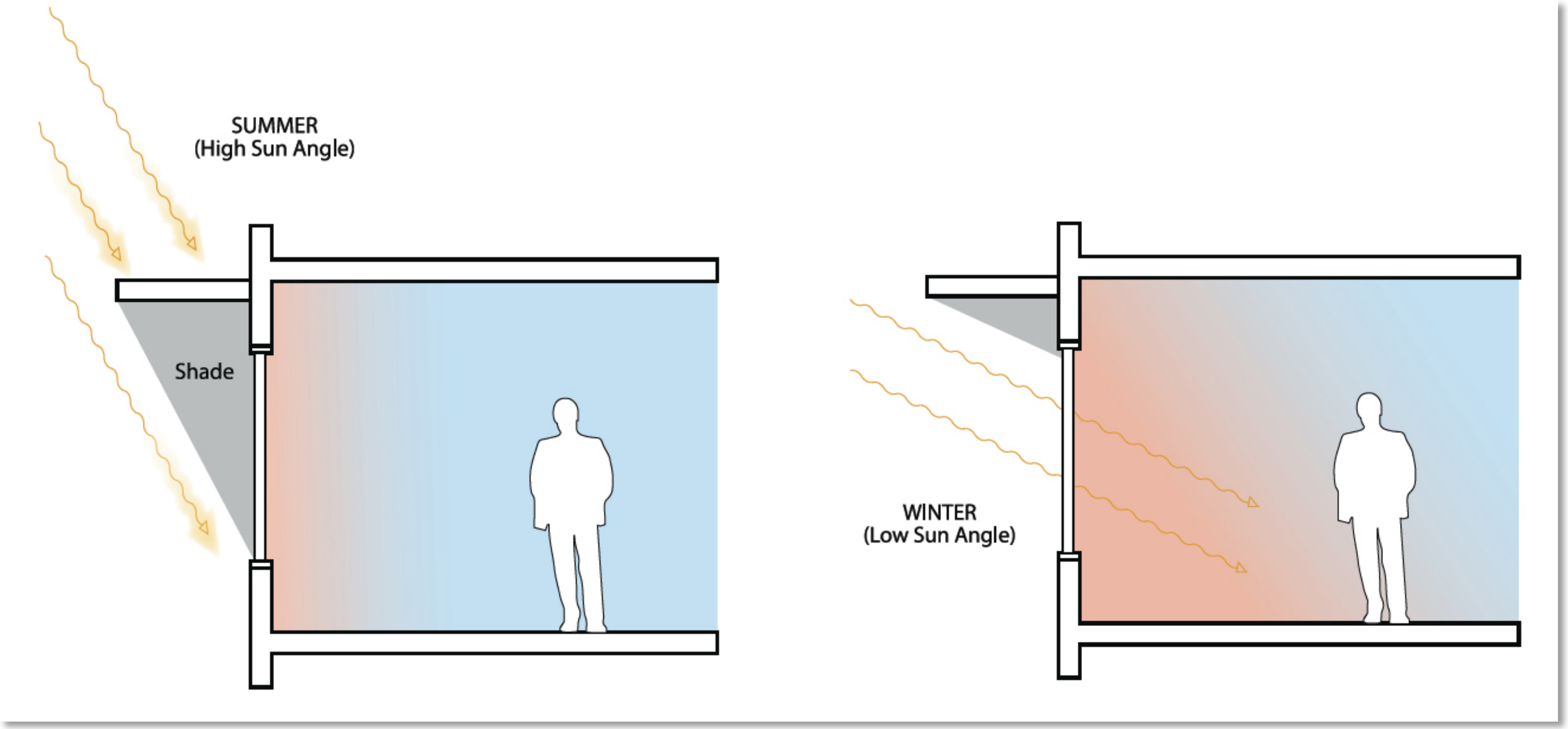
Interior vs Exterior Shades



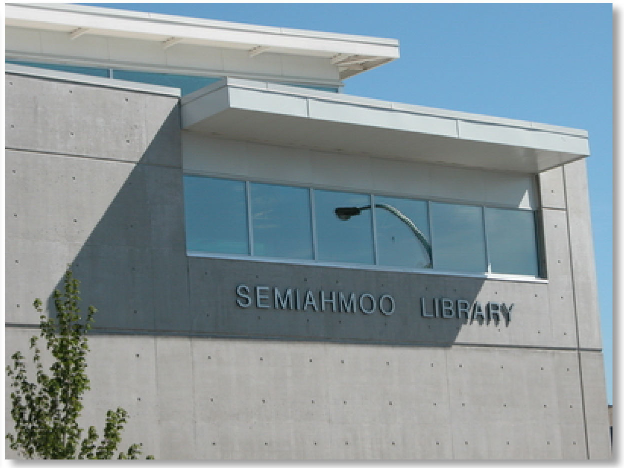
Once the heat is IN, it is IN!

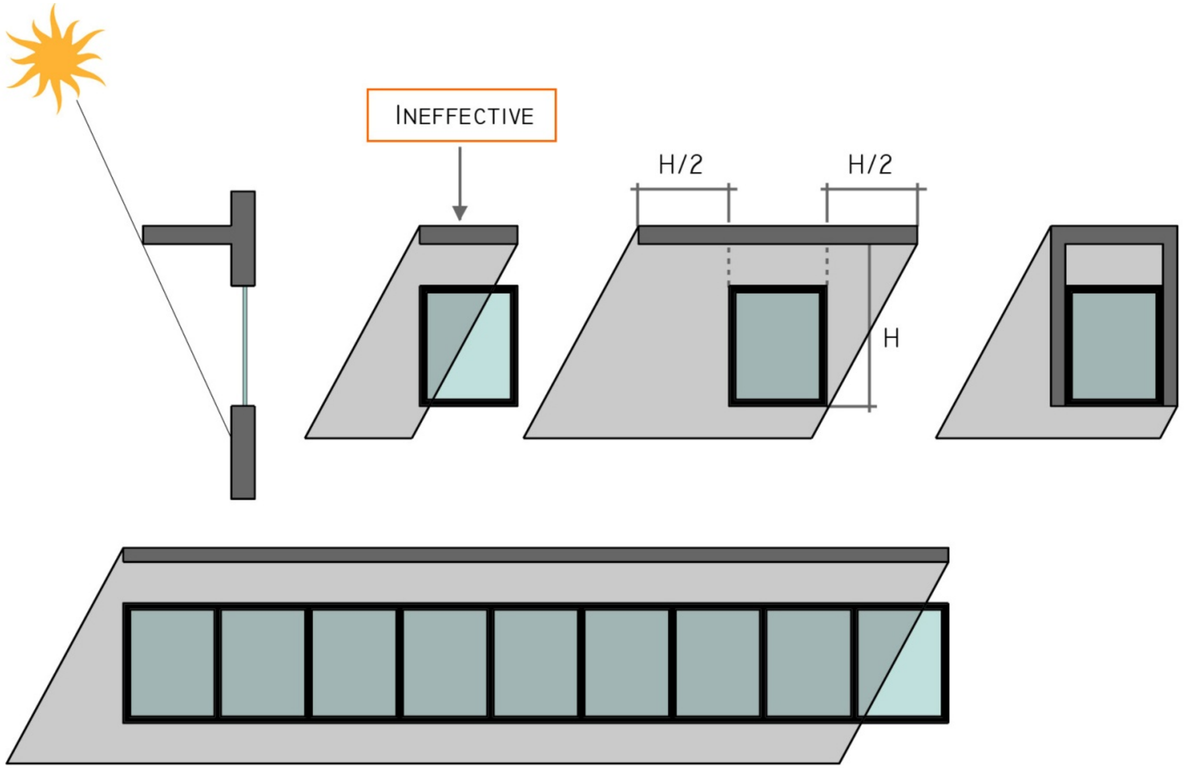
Internal blinds are good for glare, but not preventing solar gain.

South Façade Strategies



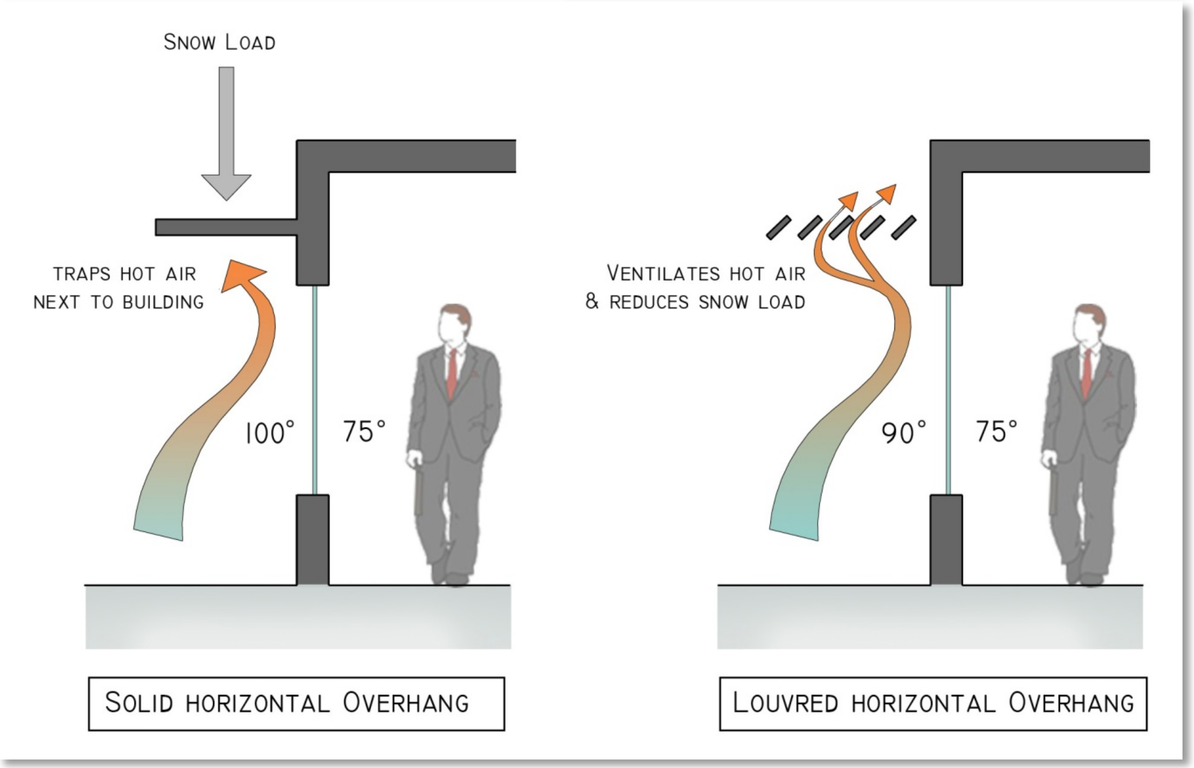
- South façade is the easiest to manage as simple overhangs can provide shade in the summer and permit entry in the winter.
- Need to design for August condition as June to August is normally a warm period.





…extend device for full shading

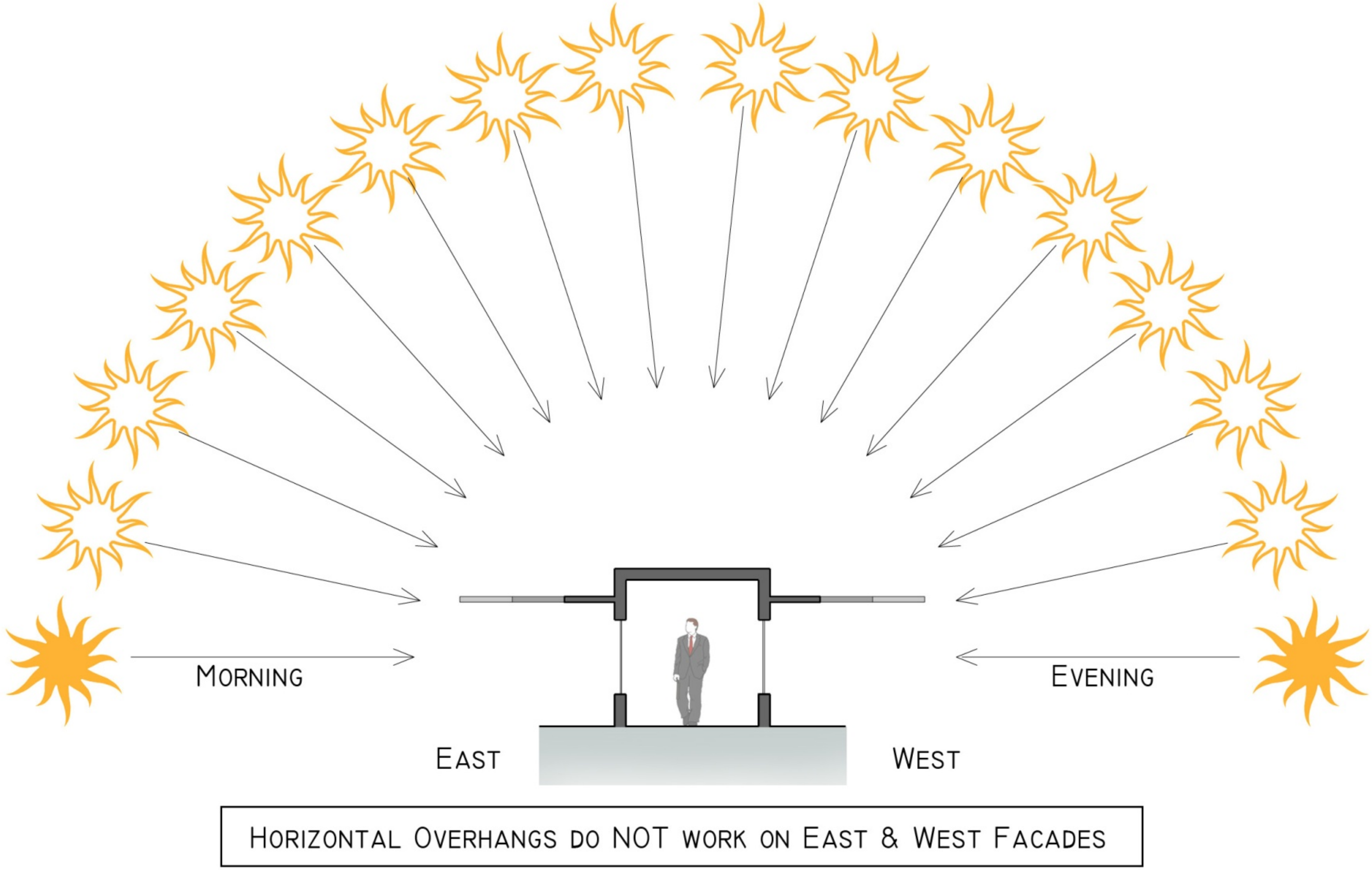
This one uses ceramic fritted glass that is sloped, to allow some light but shed rain and wet snow.



The above two use louvers or grates that will let snow, rain and wind through.

A simple tension supported shading device is able to block all of the direct sun from these very large glass doors.

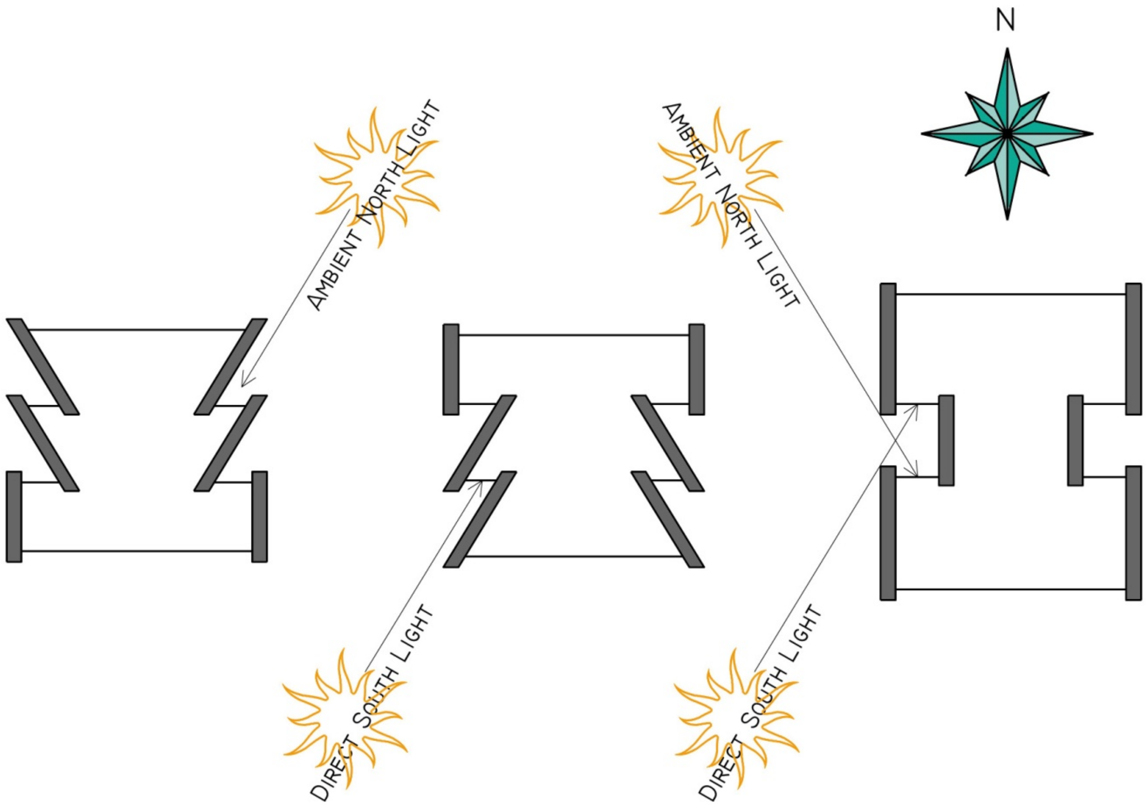
Shading Strategies for East and West Orientations



Shading Strategies for East and West Elevations

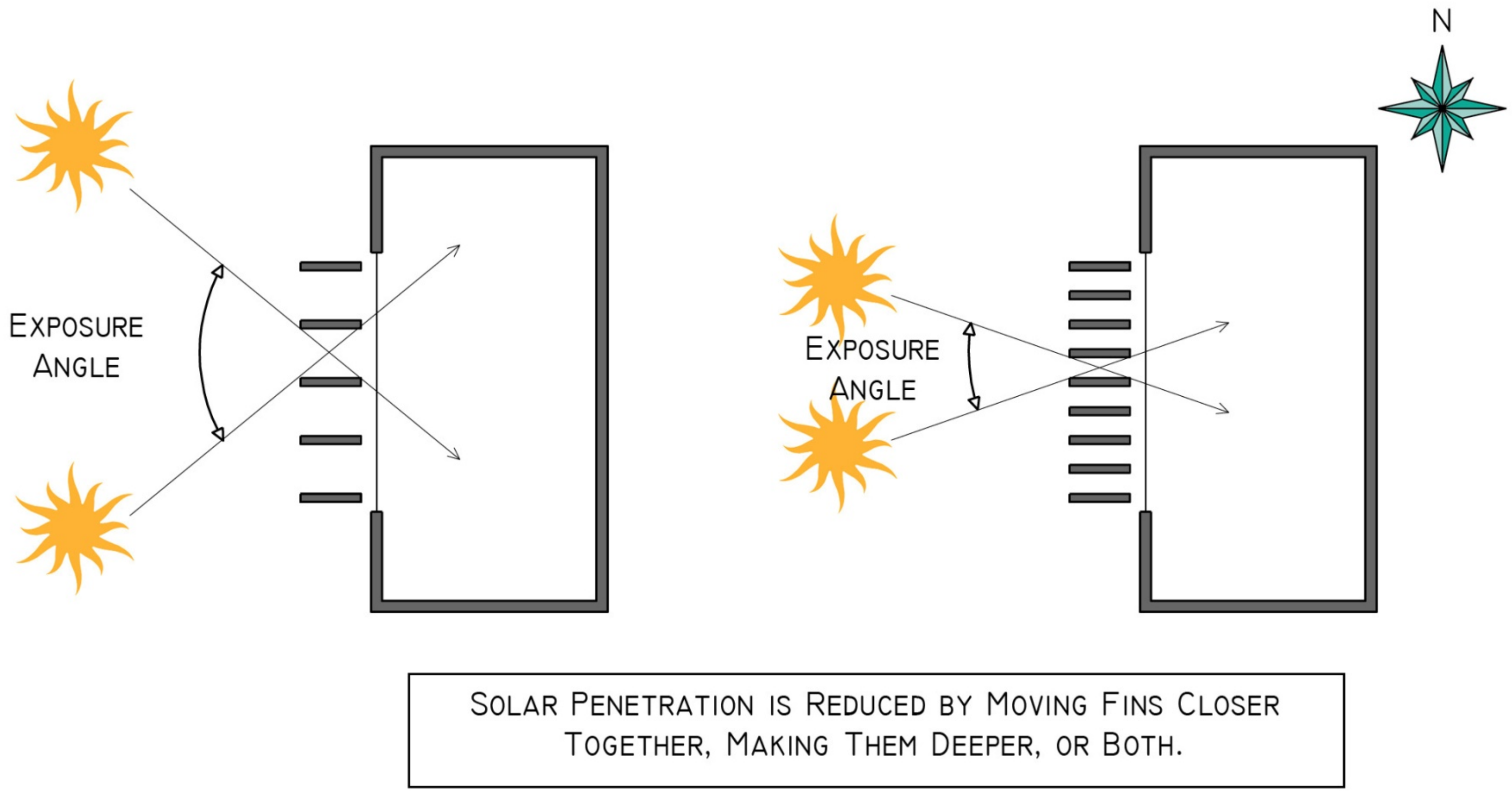
1. The best solution by far is to limit using east and especially west windows (as much as possible in hot climates)

AVOID WINDOWS ON THE EAST & WEST FACADE
BY SHIFTING THE WINDOWS TO FACE NORTH OR SOUTH:



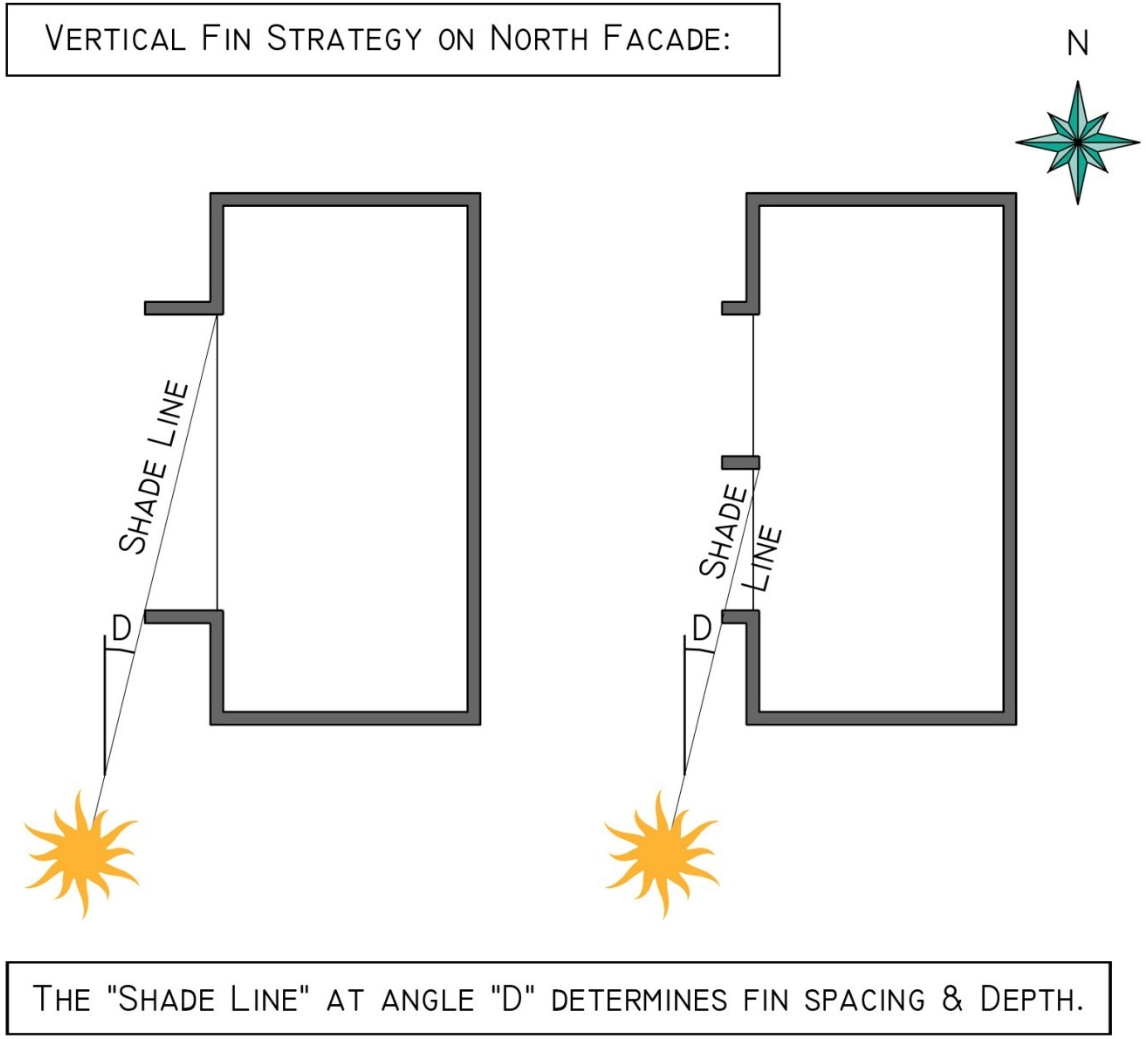
2. Next best solution is to have windows on the east and west façades face north or south

Shading Strategies for East and West Elevations



3. Use Vertical Fins. Spacing is an issue, as well as fin length. Must be understood that if to be effective, they will severely restrict the view.

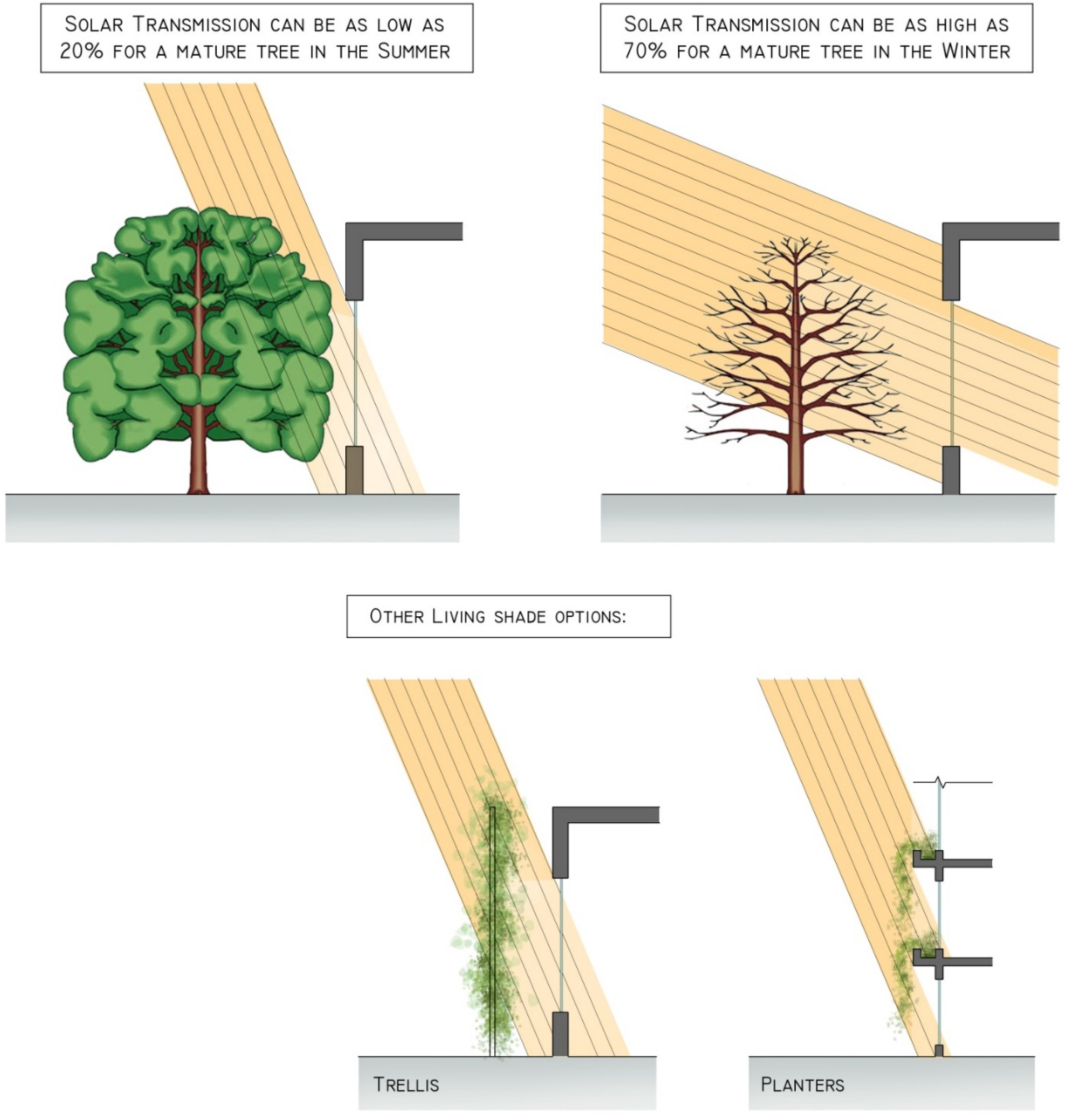
Shading Strategies for the North Elevation



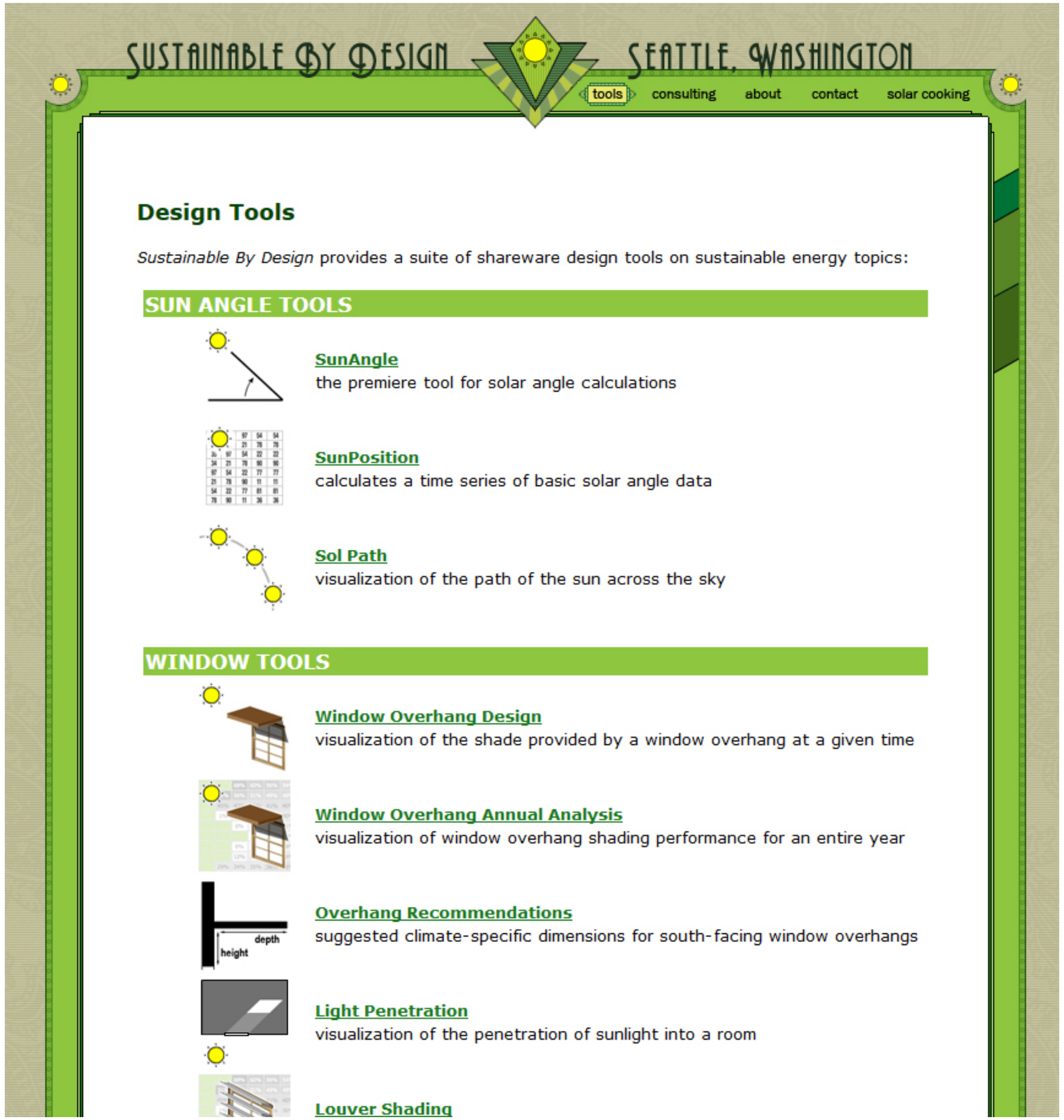
The sun also hits the façade from the north east and north west during the summer. Fins can be used to control this oblique light as well. It is a function of the latitude, window size and fin depth/frequency.

Living Awnings

Living Awnings such as deciduous trees and trellises with deciduous vines are very good shading devices. They are in phase with the thermal year – gain and lose leaves in response to temperature changes.

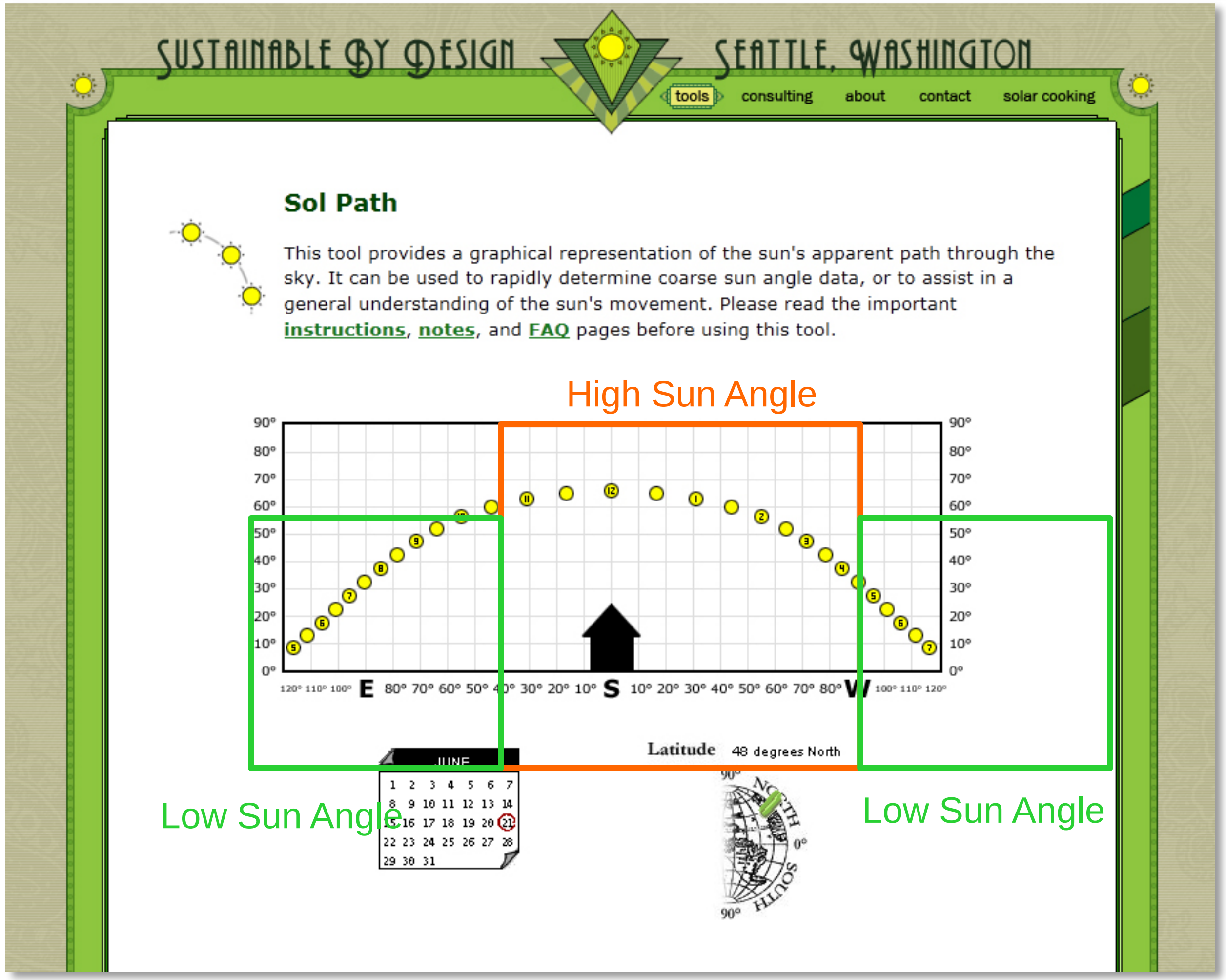


Helpful online tools



http://susdesign.com/tools.php

Differentiated Shading Strategies



http://susdesign.com/tools.php

Differentiated façade treatment

Different envelope construction on north, east/west and south

Terasan Gas, Surrey, BC

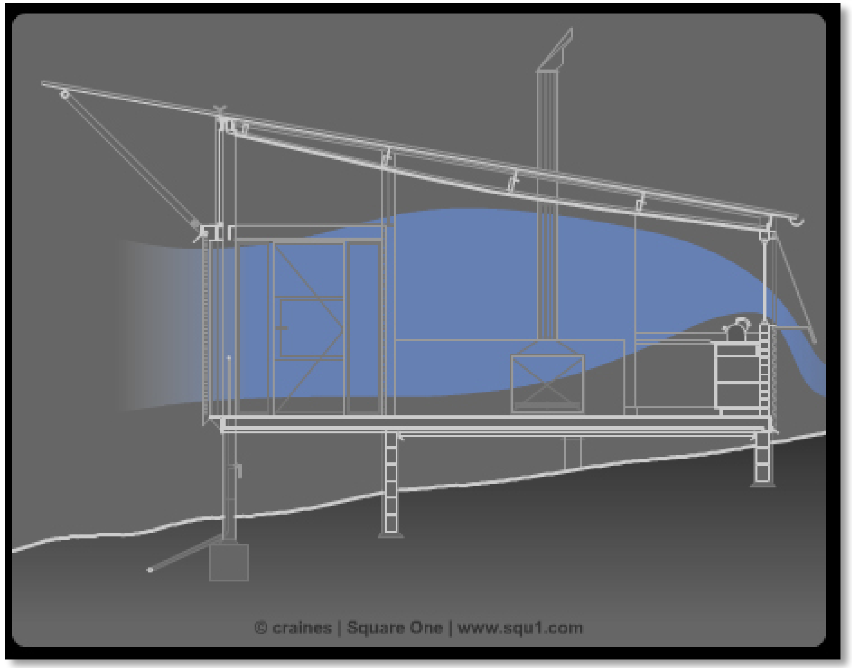
Passive Cooling Strategies:
Ventilation

- design for maximum ventilation
- Keep exterior building planning open to allow for breezes
- Examine site and surrounding microclimate to take advantage of natural cool areas and planting and shade

Passive Cooling Strategies:
Ventilation

- keep plans as open as possible for unrestricted air flow
- Obstructed plans limit natural air flow

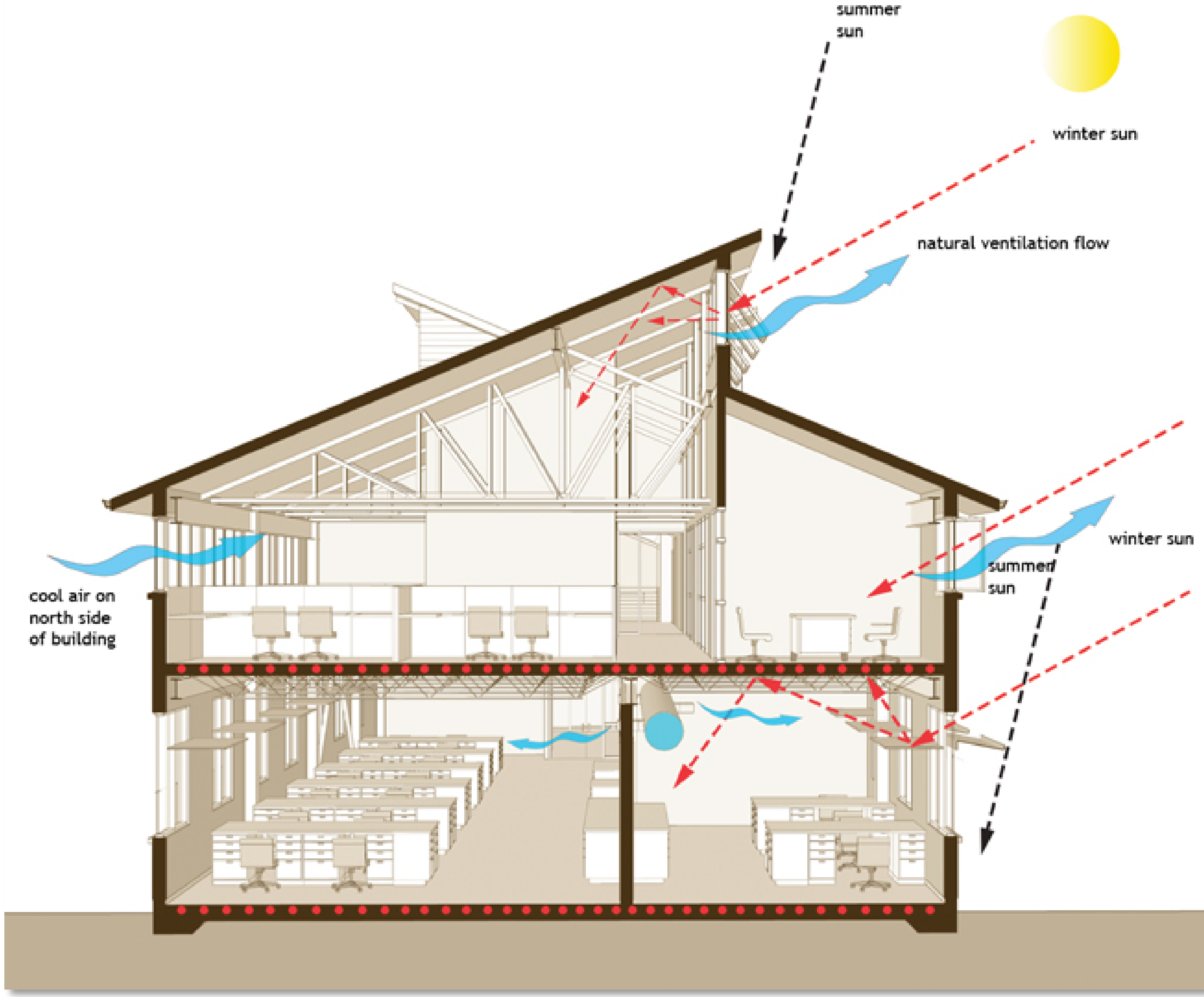
The elimination of A/C is one of the most effective ways to reduce operating energy.



It will only work if the occupants are indeed comfortable. Otherwise they will install less efficient A/C systems to solve their comfort problems.

Passive Cooling Strategies: Ventilation

- Use easily operable windows at low levels with high level clerestory windows to induce stack effect cooling
- Windows must be OPERABLE
- Glass area does not equal ventilation area
- Insect screens reduce air flow
- Window choice must allow operation during rain events



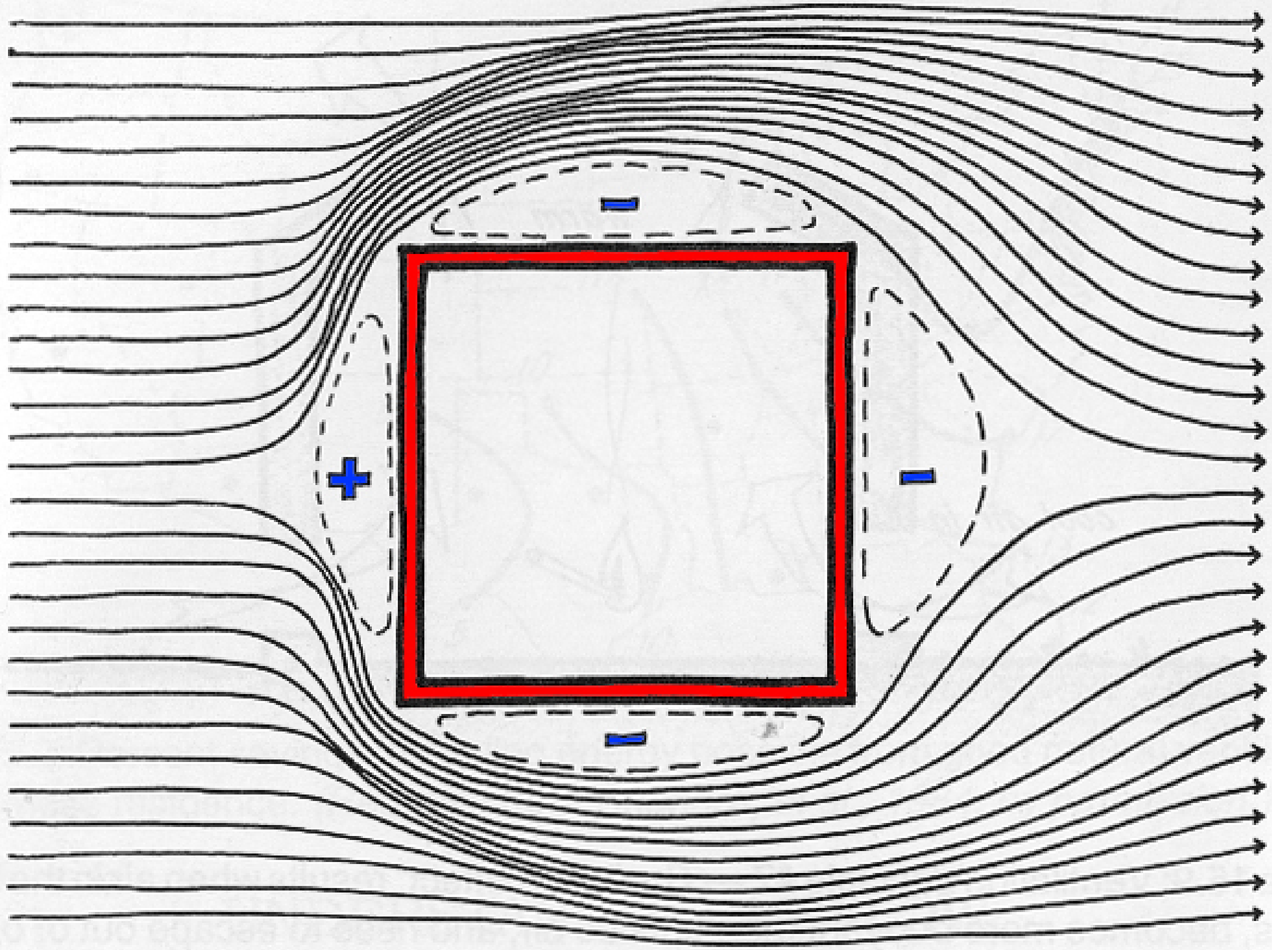


Figure 15.11: Low-pressure zones occur along the sides parallel to the wind and on the leeward side of the building. *(After Bowen, 1981.)*

HCL

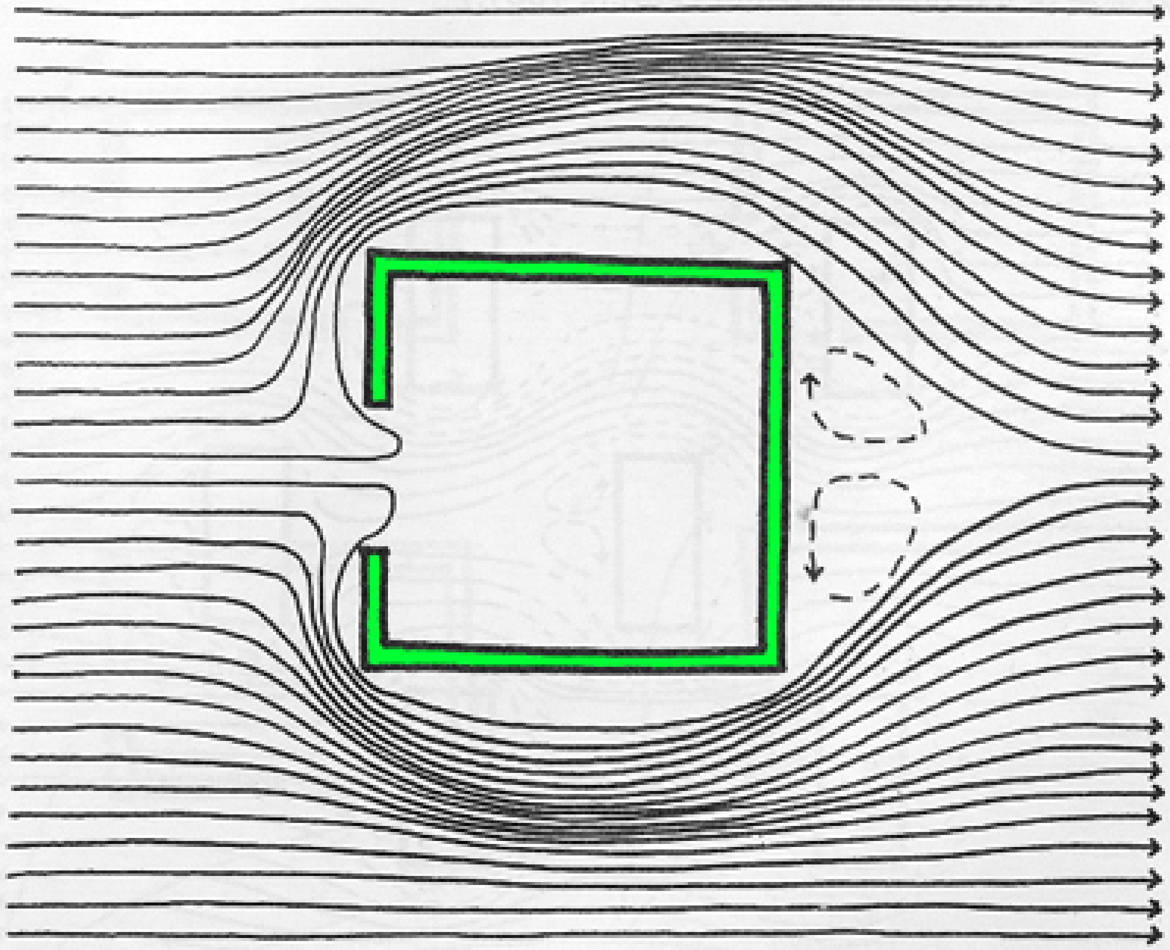


Figure 15.10: Ventilation principle #8 — Cross-ventilation requires an outlet as well as an inlet. (Analogy: water cannot be put into a bottle that is already full unless some old water is removed first — through a hole in the opposite end of the bottle, for example.)

HCL

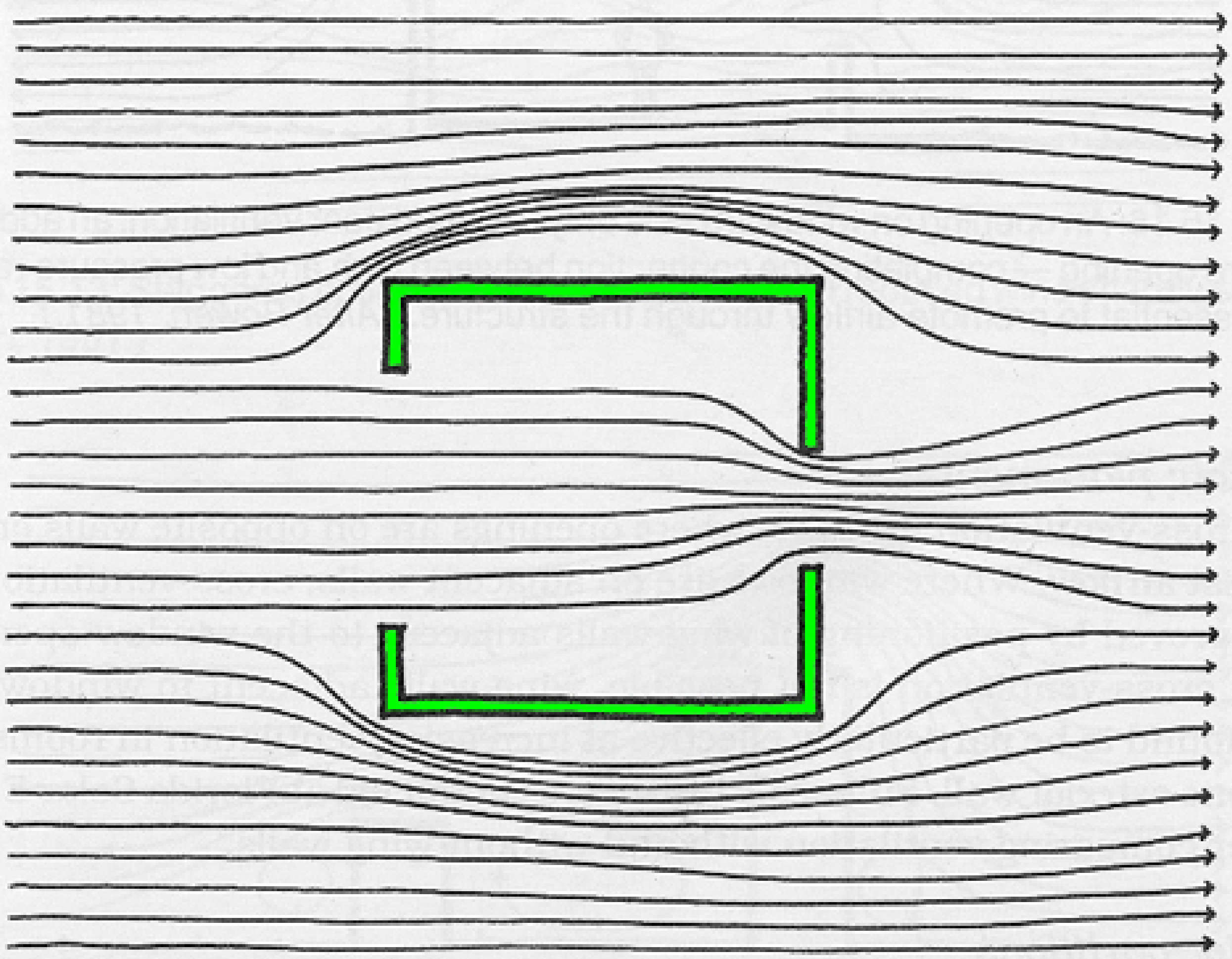


Figure 15.21: If the inlet is larger than the outlet, velocity in the room is reduced (although velocity outside just to leeward of the outlet is increased). This has potential for cooling a localized exterior area such as a patio. *(After Bowen, 1981.)*

HCL

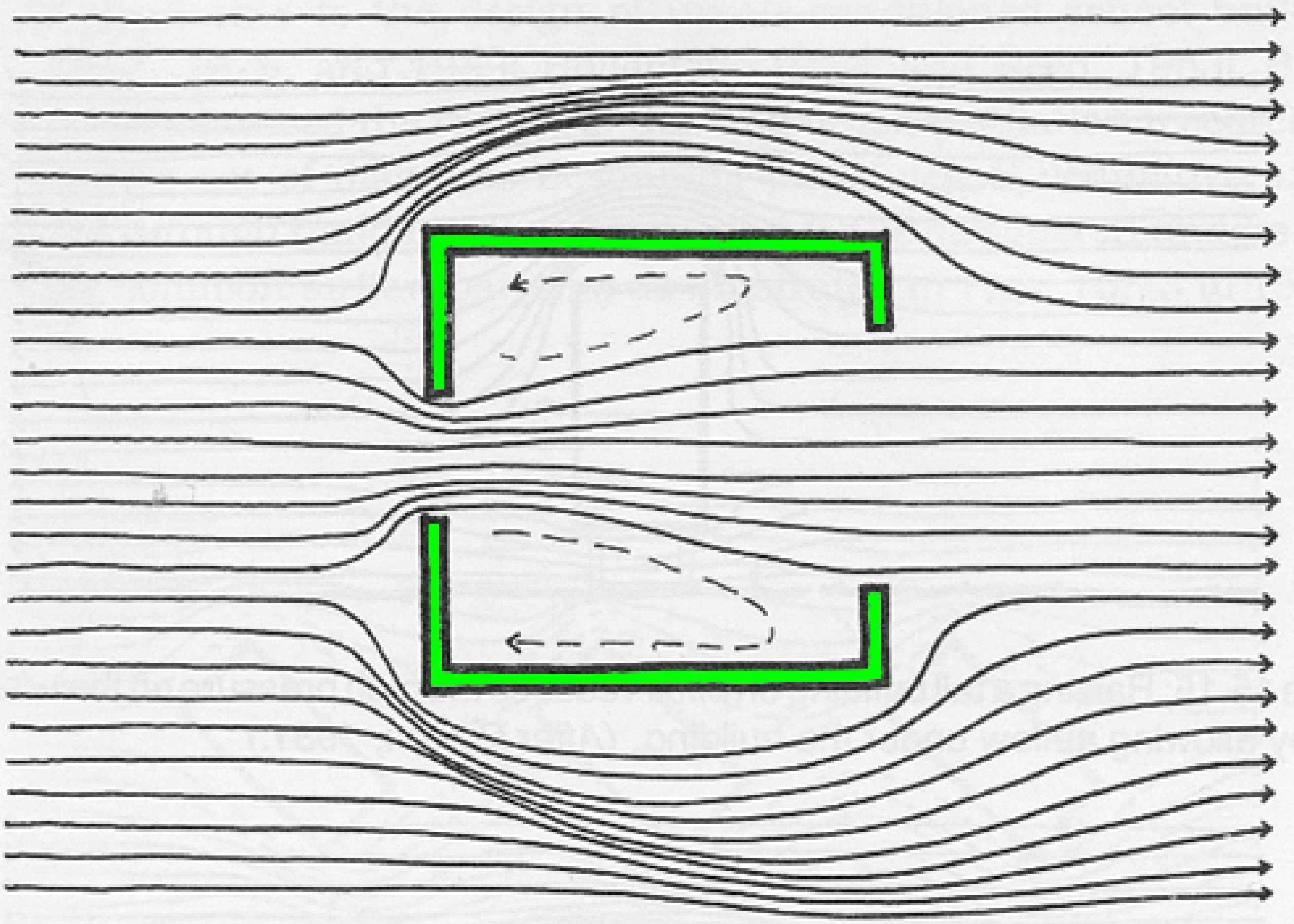


Figure 15.20: Maximum *interior airspeed* is created when the inlet is smaller than the outlet, making this the optimum configuration when *people* cooling is the goal. *(After Bowen, 1981.)*

HCL

IMPORTANT!

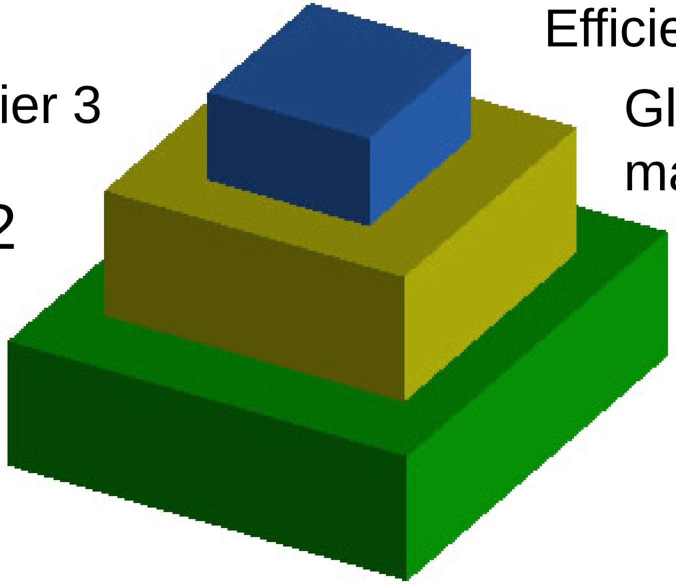
For natural ventilation to work you need:

OPERABLE WINDOWS – the more the better in our climate

FLOW THROUGH ABILITY – air must be able to *move*

Reduce loads: Daylighting

The tiered approach to reducing carbon with **DAYLIGHTING**:



Efficient artificial Lighting w/ sensors

Glare, color, reflectivity and material concerns

Orientation and planning of building to allow light to reach maximum no. of spaces

Use energy efficient fixtures!

Maximize the amount of energy/electricity required for artificial lighting that comes from renewable sources.

Source: Lechner. Heating, Cooling, Lighting.

Daylighting does not = Sunlighting

Daylighting is about bringing natural LIGHT into a space.

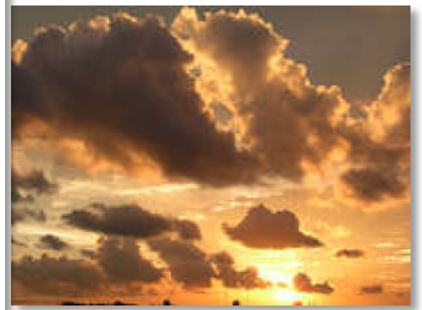
Many daylit spaces do not WANT or NEED direct sunlight.

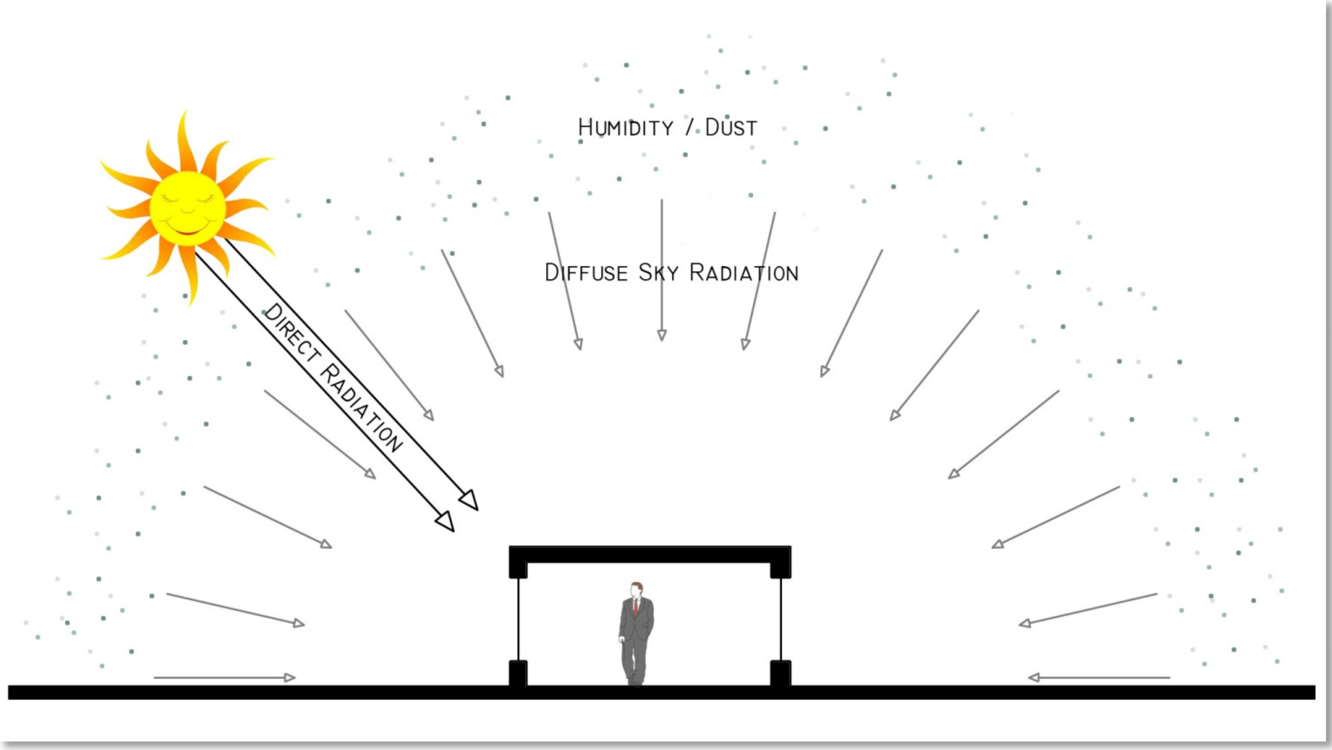
DIRECT SUNLIGHT is about **FREE HEAT**. 

DAYLIGHT (diffuse light) is about **FREE LIGHT.** 

Daylighting concepts prefer ***diffuse*** *or* ***indirect*** lighting.

Direct versus Diffuse Radiation





Passive Lighting Strategies:
Energy efficiency and renewables

- use energy efficient light fixtures (and effectively!)
- use occupant sensors ***combined with light level sensors***
- aim to only have lights switch on only when daylight is insufficient
- provide electricity via renewable means: wind, PV, Combined Heat and Power plants

Lights on due to occupant sensors when there is adequate daylight – WASTES ENERGY!

Environmental advantages of daylighting

Daylighting is **environmentally advantageous** because it:

- reduces the need for electric lighting
- therefore reducing the energy needed to power the lights
- reducing the heat generated from the lights
- reducing the cooling required for the space

TABLE 12.5 COMMONLY EXPERIENCED BRIGHTNESS LEVELS

	Brightness (cd/sq. ft.)*	
Sidewalk on a dark night	0.0003	Poor vision
Sidewalk in moonlight	0.003	
Sidewalk under a dim streetlight	0.03	
Book illuminated by a candle	0.3	
Wall in an office	3	Normal indoor brightness
Well-illuminated drafting table	30	
Sidewalk on a cloudy day	300	Normal outdoor brightness
Fresh snow on a sunny day	3,000	
500-watt incandescent lamp	30,000	Blinding glare

*For S.I., (cd/sq. m.) ≈ (cd/sq. ft.) × 11

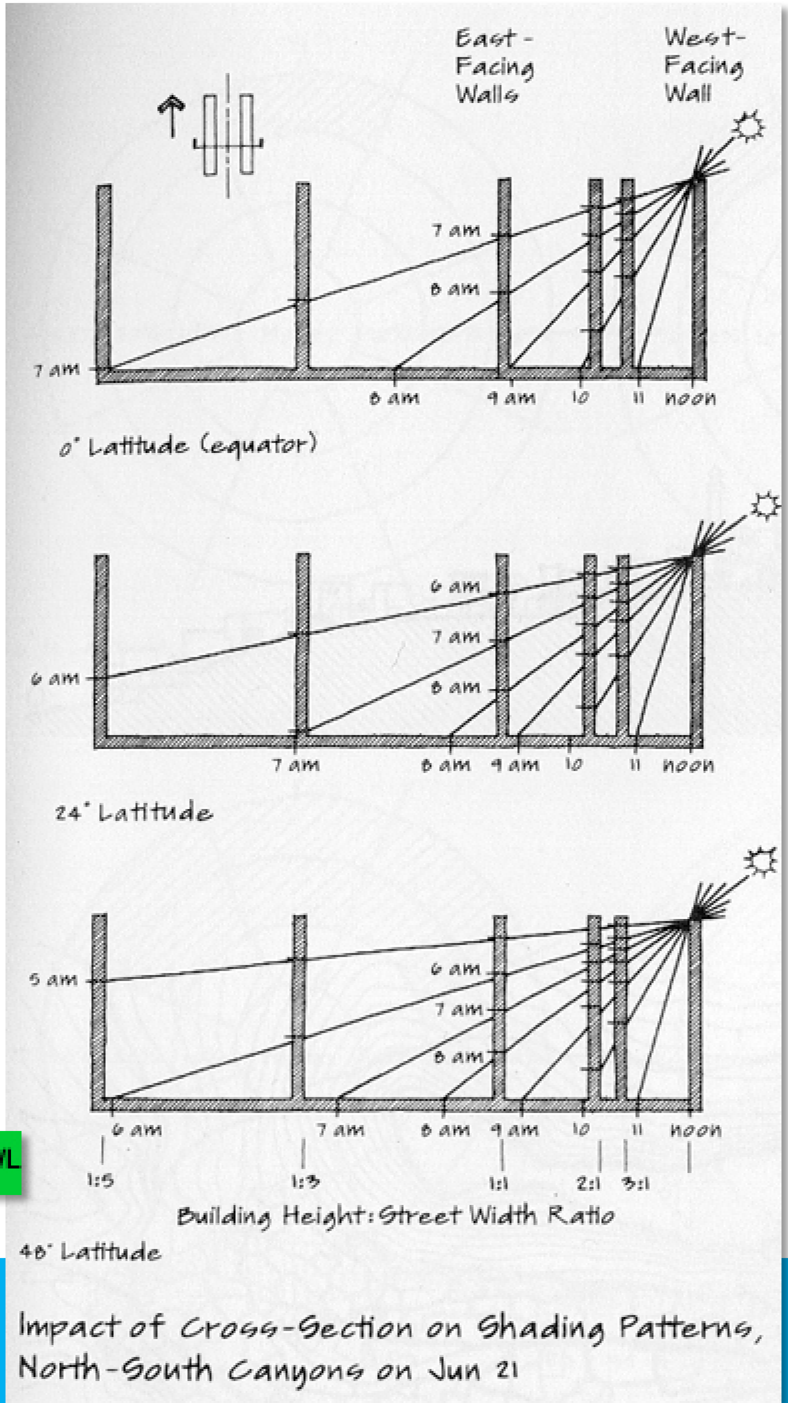
HCL

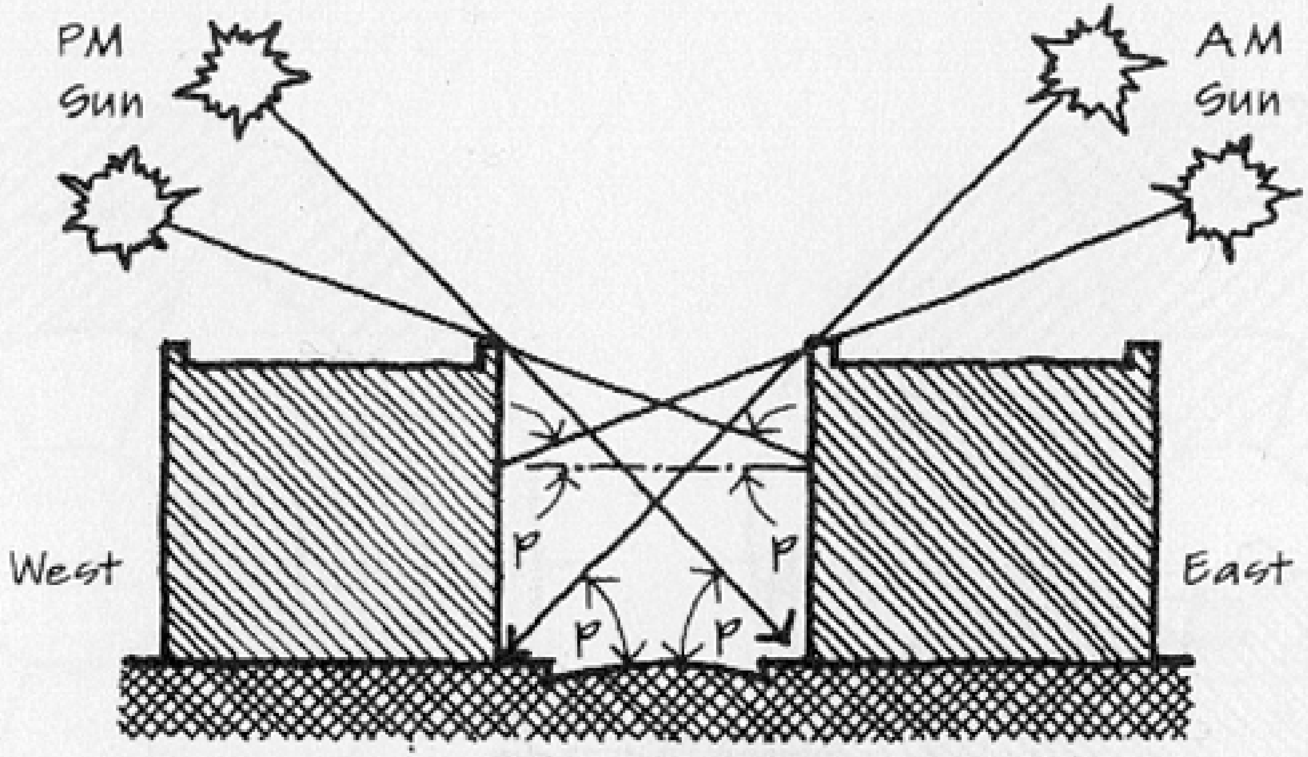
LUMINANCE (production/reflection): The luminous intensity (photometric brightness) of a light source or reflecting surface including factors of reflection, transmission and emission. Units are candelas per sq.ft. or per sq.m.

Building spacing and orientation will also need to be factored in when determining the amount of available light or sunlight for the building on its various sides.

North-south canyon in housing development at Yonge and 401, Toronto

SWL





Profile Angle for North-South Canyons

SWL

Daylight Factor

2% average daylight factor

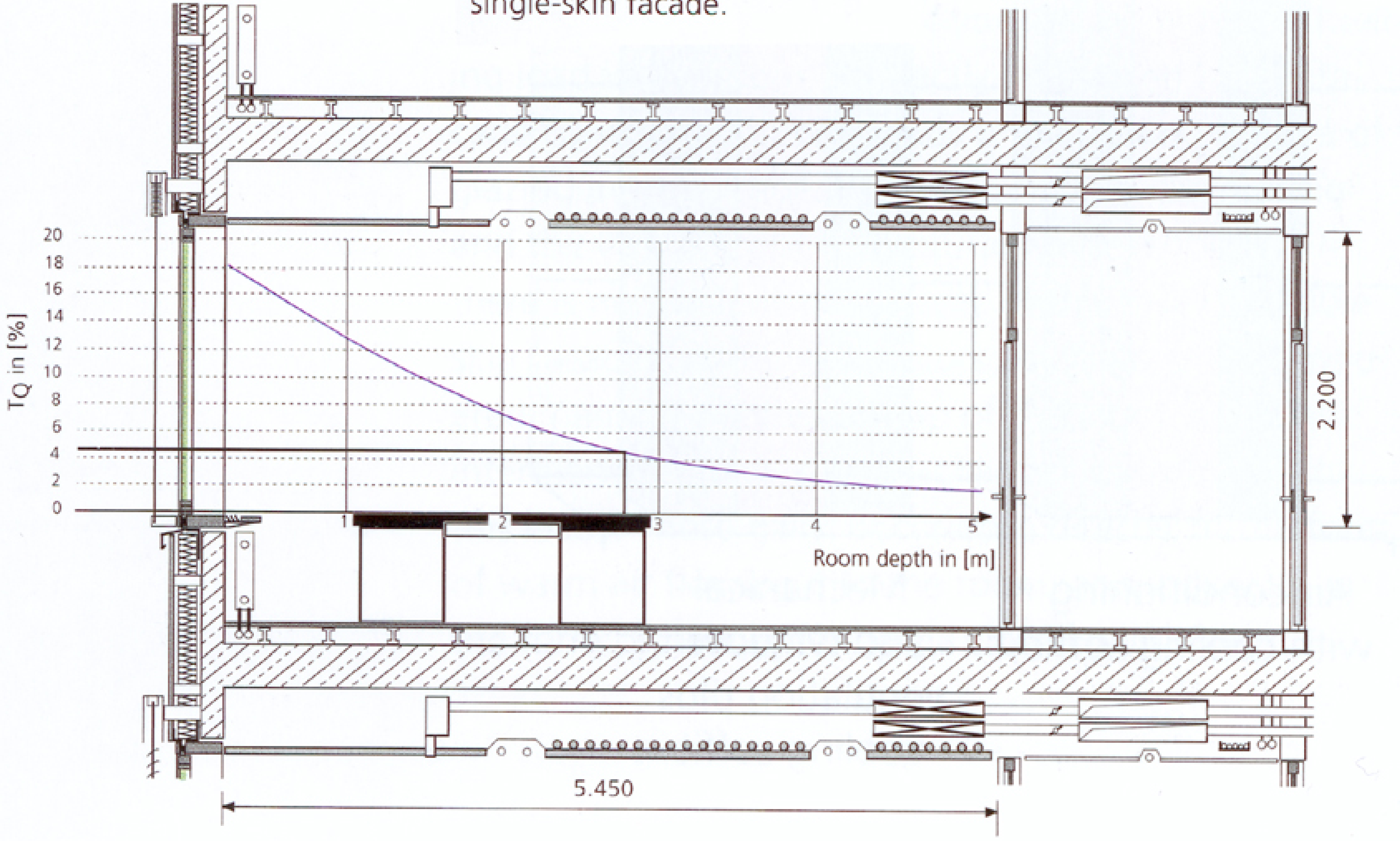
5% average daylight factor

Daylight Factor

Building Type	Recommended Daylight Factor %
Dwellings	
Kitchen	2
Living room	1
Bedroom	0.5
Schools	2
Hospitals	1
Offices	
General	1 to 2
	2
Drawing offices	2
(on drawing boards)	6
Typing and computing	4
Laboratories	3 to 6
Factories	5
Art galleries	6
Churches	1 to 2
Public buildings	1

Note: LEED daylighting credits are tied to DF!

6-1 Daylight-factor curve over the depth of a room with a single-skin facade.



Reflectance of Materials + Colours

Surface	Recommended Reflectance (%)
Ceilings	70-80
Walls	40-80
Floors	20-40

Recommended Finish Reflectances

Color	Reflectance (%)
white	80-90
pale yellow & rose	80
pale beige & lilac	70
pale blue & green	70-75
mustard yellow	35
medium brown	25
medium blue & green	20-30
black	10

Daylight Reflectance of Colors

SWL

Reflector Finish	Reflectance (%)
Concrete	30-50
Old snow	40-70
New snow	80-90
Polished aluminum	75-95
Aliminized mylar	60-80
Polished stainless steel	60-80
White porcelain enamel	70-77
Acrylic with aluminized backing	85
Aluminum foil	86
Electroplated Silver, new	96

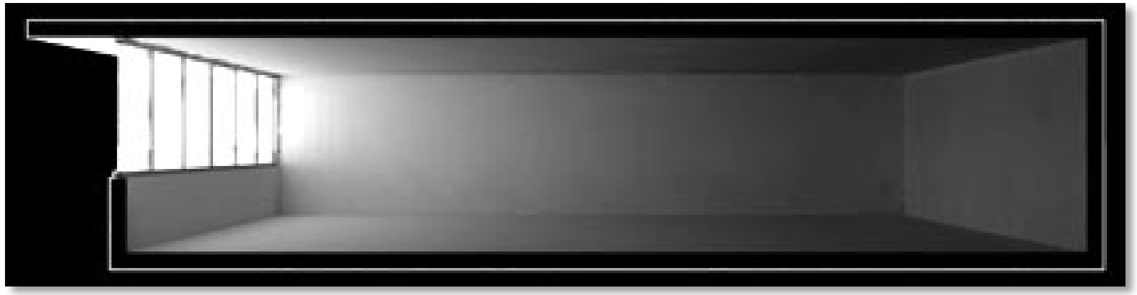
Solar Reflectance of Finishes

Not only the material, but also the texture of the finish affects reflectance.

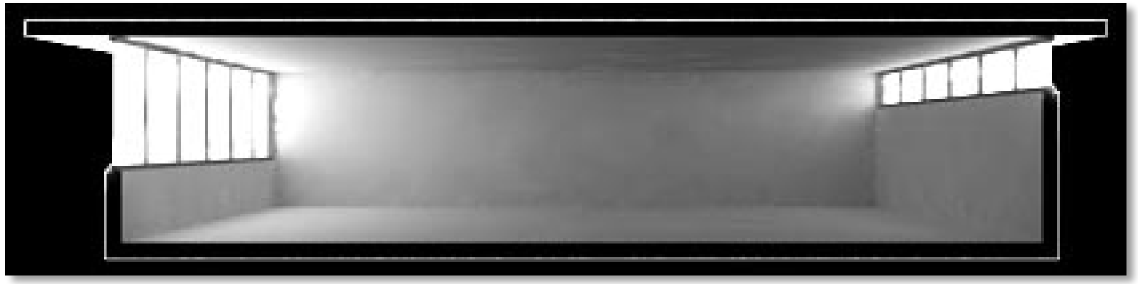
SWL

Window Types + Light Distribution

Window



Windows both sides



Lightshelf

For distribution concerns think of bright vs. dark spots as well as room use. These images are for overcast bright sky conditions

Images from squ1.com

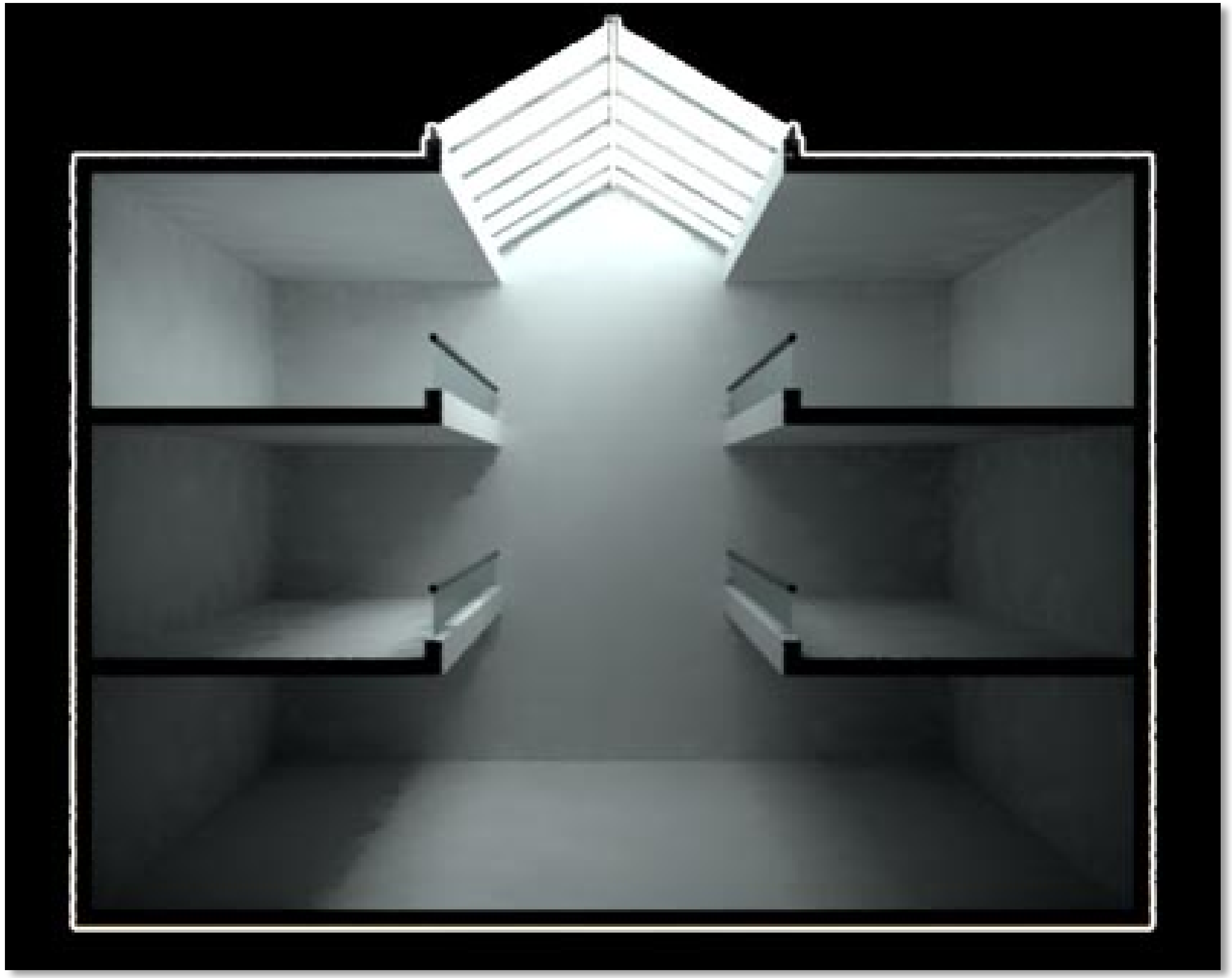
Skylight

Roof monitor

Sawtooth

For distribution concerns think of bright vs. dark spots as well as room use. These images are for overcast bright sky conditions – so no sharp shadows…

Images from squ1.com



For distribution concerns think of bright vs. dark spots as well as room use. These images are for overcast bright sky conditions – so no sharp shadows…

Spaces nearer the top floor are appreciably brighter. More supplementary light is needed on the lower floors.

Images from squ1.com

Lightwell – provides more light directed to the lower floors