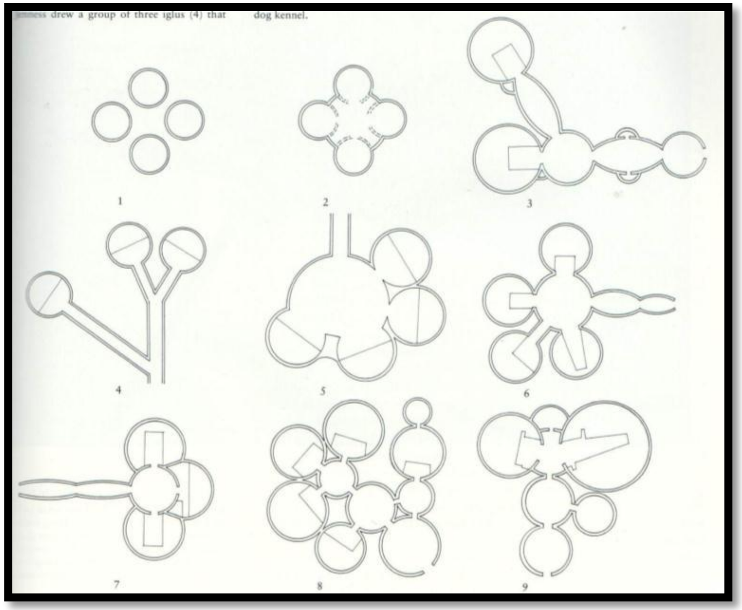
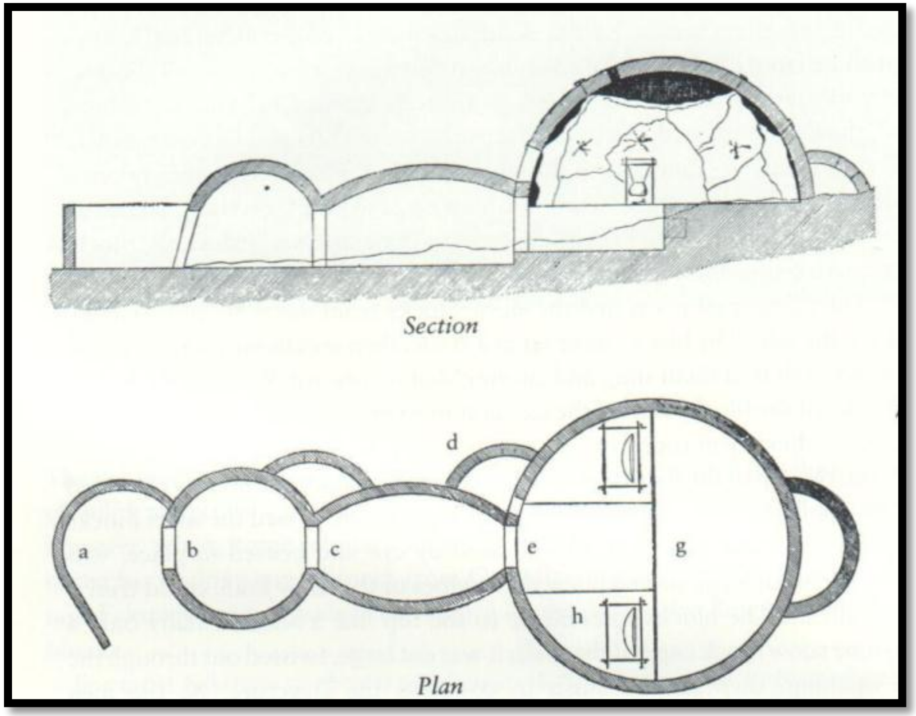
VERNACULAR STRATEGIES

CLIMATE AS THE STARTING POINT
FOR RETHINKING ARCHITECTURAL DESIGN

Bio-climatic Design: COLD VERNACULAR

Native American Architecture





- Local materials
- Heat retention
- Vestibule
- Stratification

Bio-climatic Design: COLD RULES

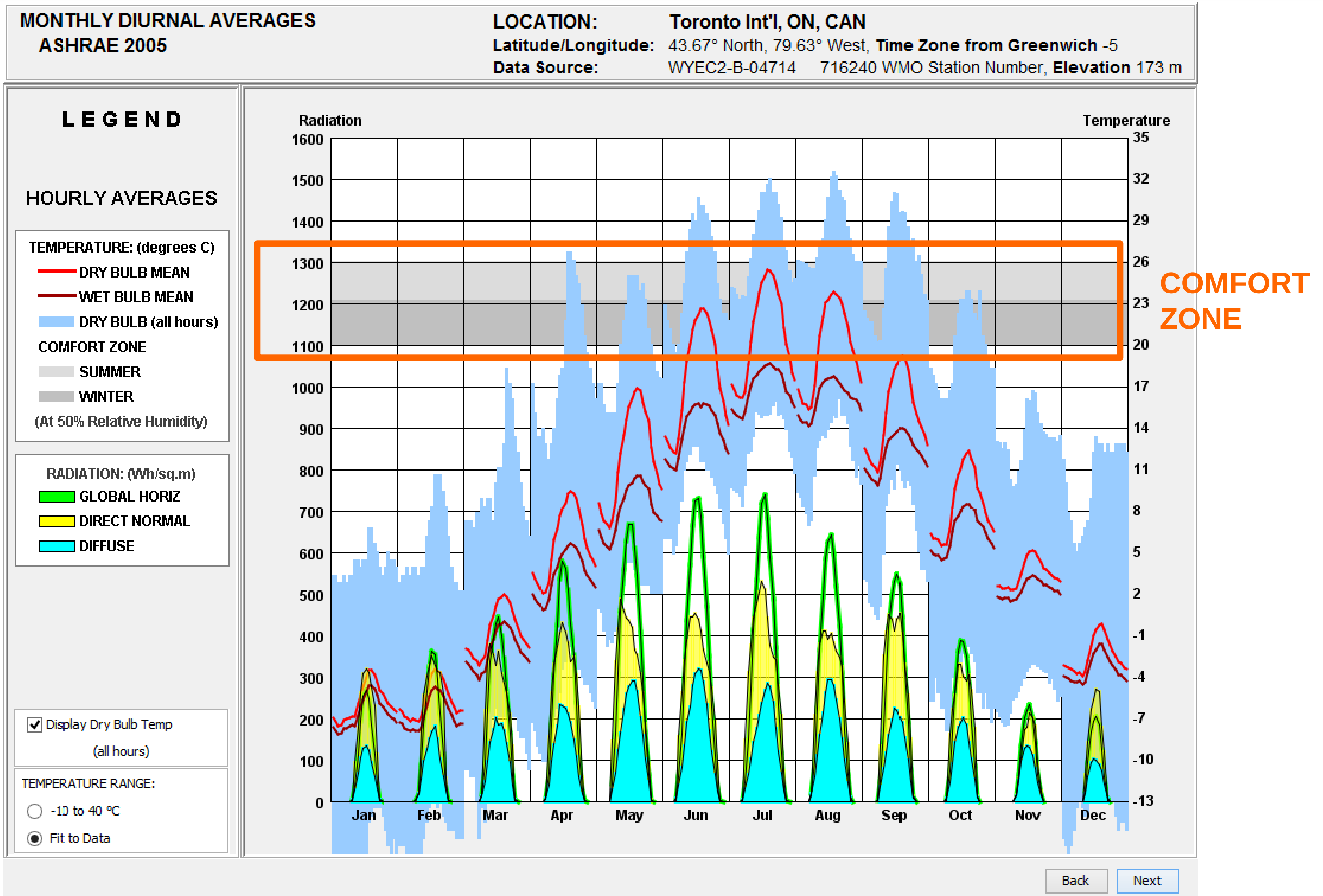
Where **winter** is the dominant season and concerns for conserving heat predominate all other concerns. **Heating degree days greatly exceed cooling degree days**.

RULES:

- First **INSULATE**
- *exceed* CODE requirements (DOUBLE??)
- minimize infiltration (build tight to reduce air changes)
- Then **INSOLATE**
- **ORIENT AND SITE THE BUILDING PROPERLY FOR THE SUN**
- maximize south facing windows for easier control
- fenestrate for **DIRECT GAIN**
- apply **THERMAL MASS** inside the building envelope to store the FREE SOLAR HEAT
- create a sheltered MICROCLIMATE to make it LESS cold

YMCA Environmental Learning Centre, Paradise Lake, Ontario

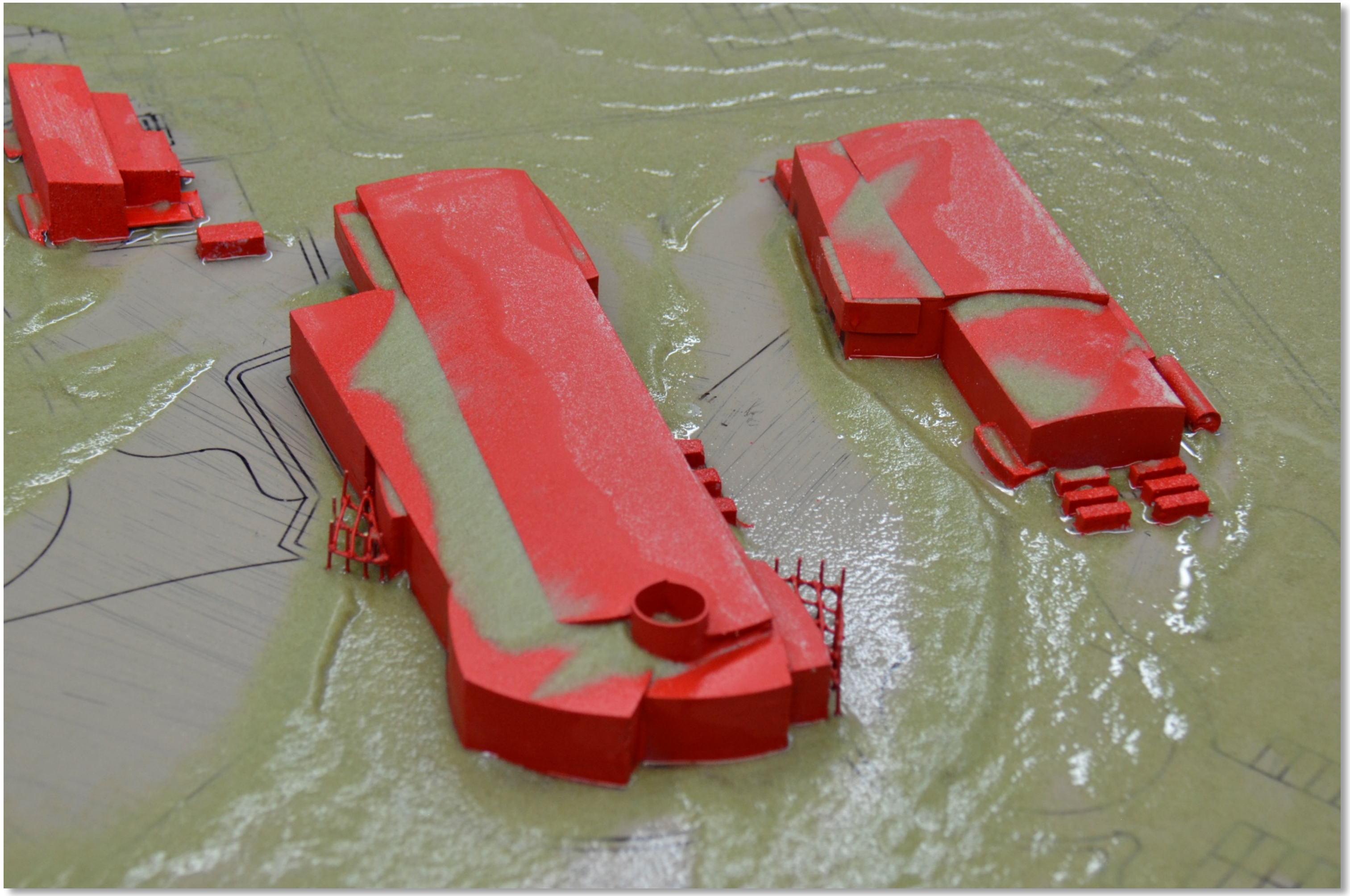
Climate Data for Toronto



The issue of snow

Certain roof shapes are more prone to snow buildup and can reduce the ease of insulation.

Physical modeling



Physical testing in a water flume can help to understand issues with roof shape, drifting and snow build up around entrances.

Bio-climatic Design: HOT-ARID RULES

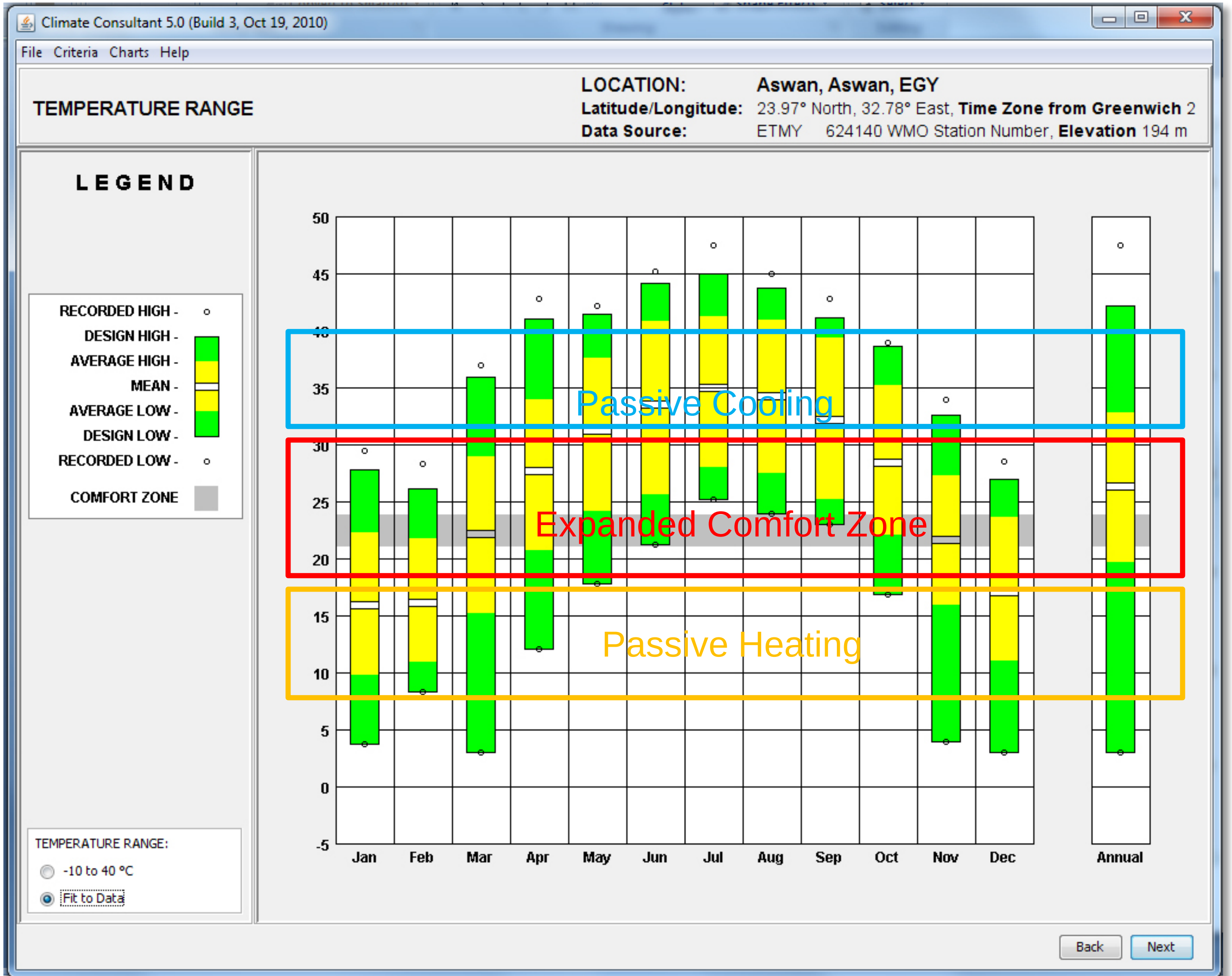
Where **very high summer temperatures** with great fluctuation predominate with **dry conditions** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

RULES:

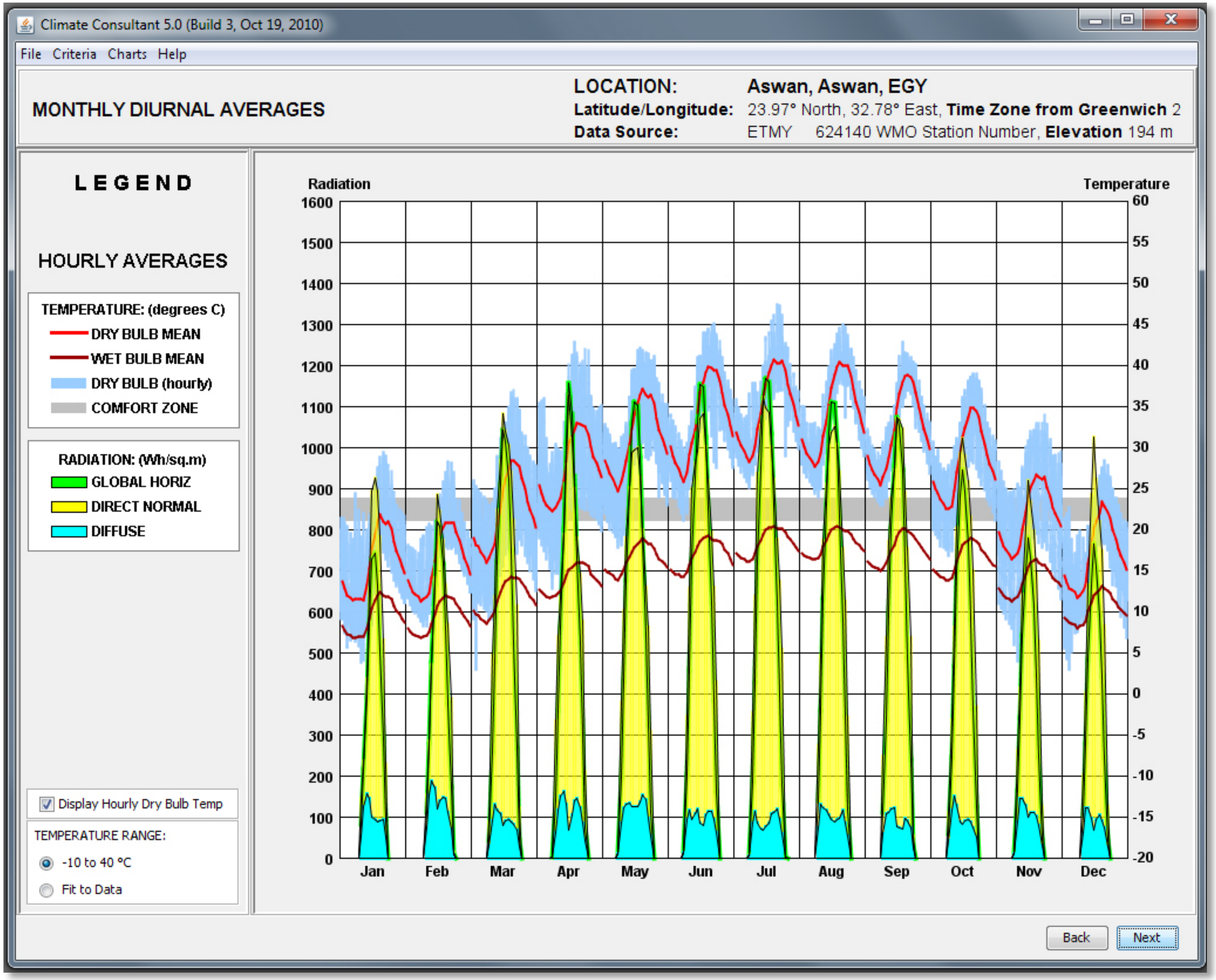
- **SOLAR AVOIDANCE**: keep DIRECT SOLAR GAIN out of the building
- avoid daytime ventilation
- promote nighttime flushing with cool evening air
- achieve daylighting by reflectance and use of LIGHT non-heat absorbing colours
- create a cooler MICROCLIMATE by using light / lightweight materials
- respect the DIURNAL CYCLE
- use heavy mass for walls and DO NOT INSULATE

Traditional House in Egypt

Bio-climatic Design: HOT-ARID

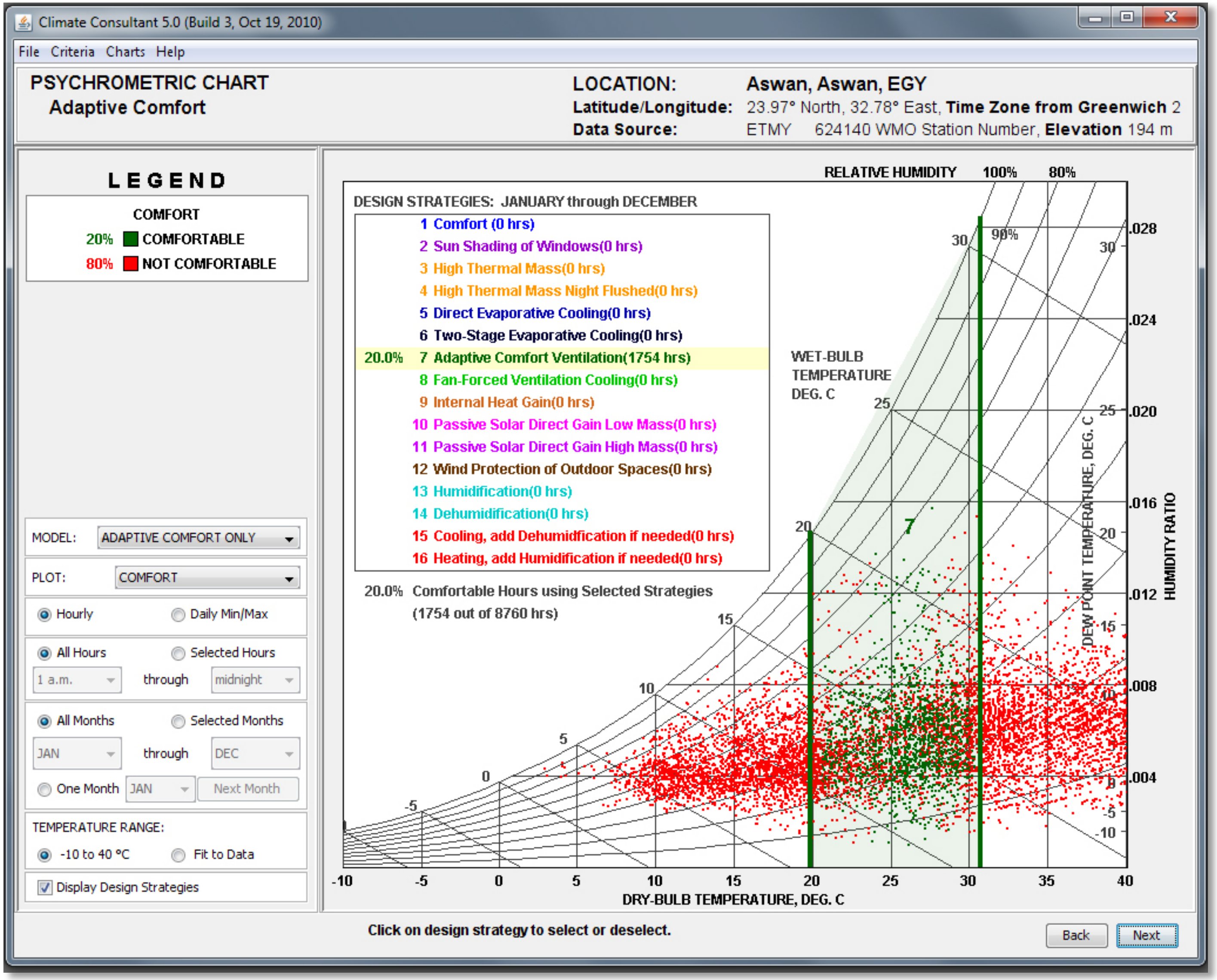


Bio-climatic Design: HOT-ARID



Note high levels of direct sun from chart.

Bio-climatic Design: HOT-ARID



Bio-climatic Design: HOT-HUMID

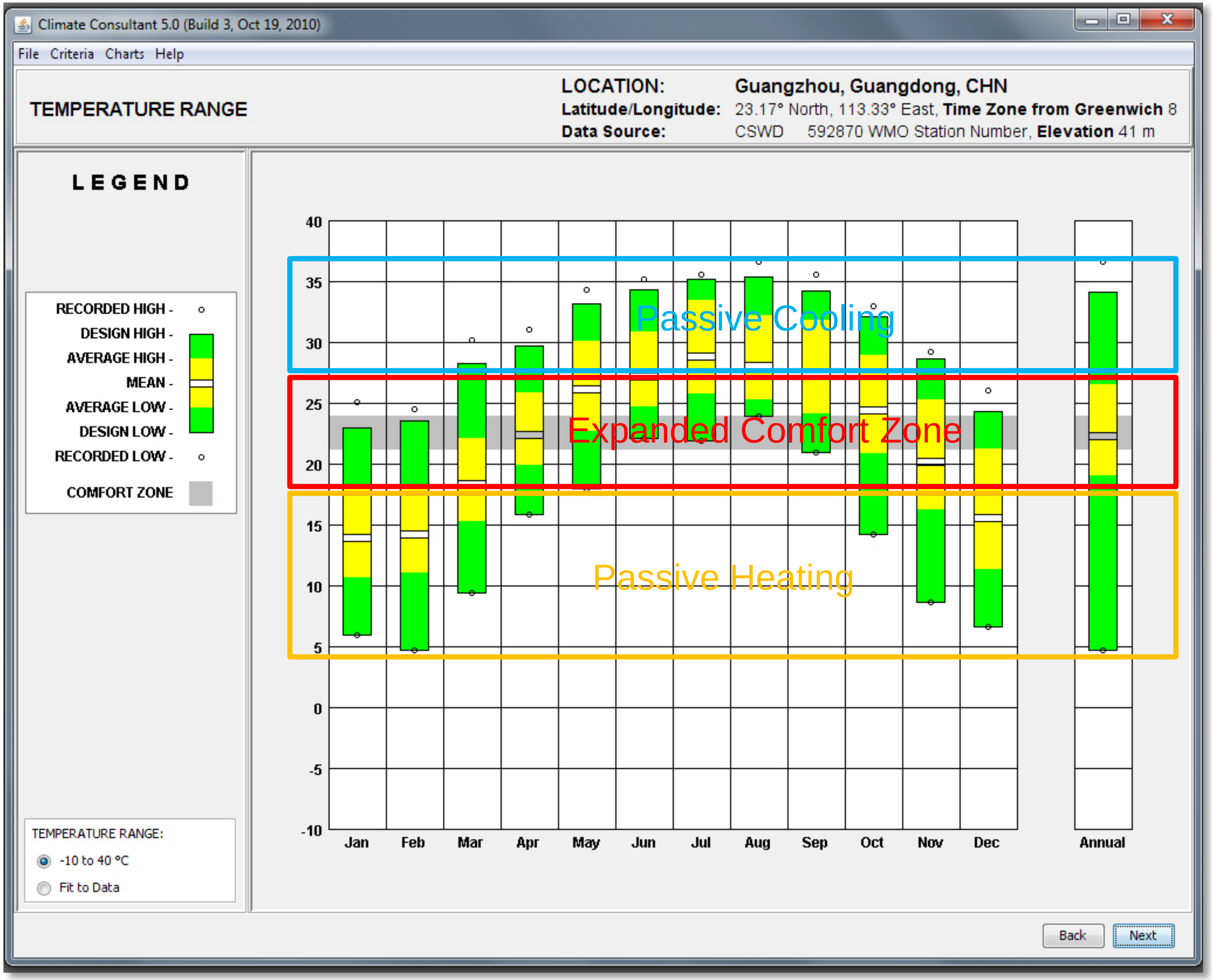
Where **warm to hot** stable conditions predominate with **high humidity** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

RULES:

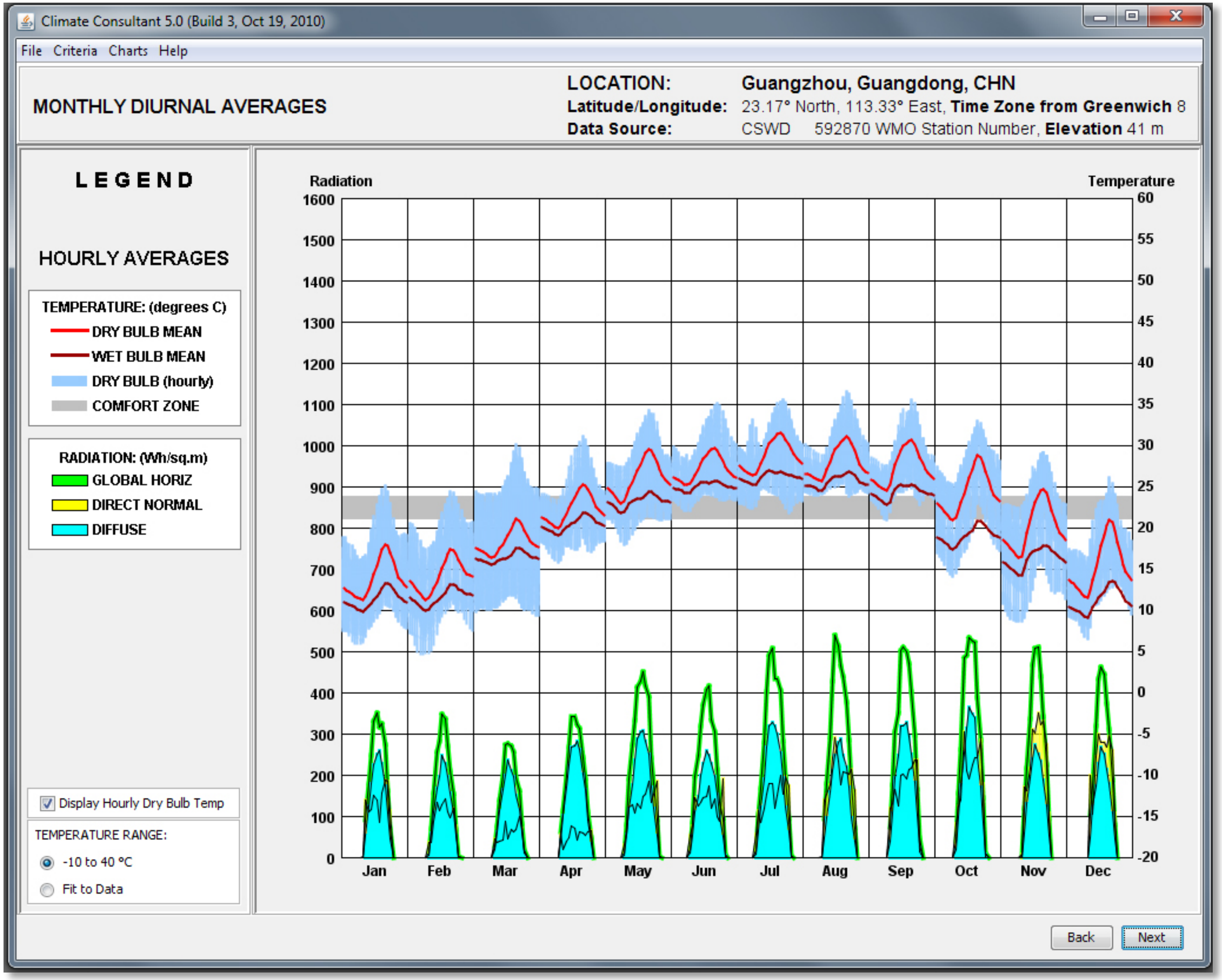
- **SOLAR AVOIDANCE** : large roofs with overhangs that shade walls and to allow windows open at all times
- **PROMOTE VENTILATION**
- **USE LIGHTWEIGHT MATERIALS** that do not hold heat and that will not promote condensation and dampness (mold/mildew)
- *eliminate basements and concrete*
- use STACK EFFECT to ventilate through high spaces
- use of COURTYARDS and semi-enclosed outside spaces
- use WATER FEATURES for cooling

House in Seaside, Florida

Bio-climatic Design: HOT-HUMID

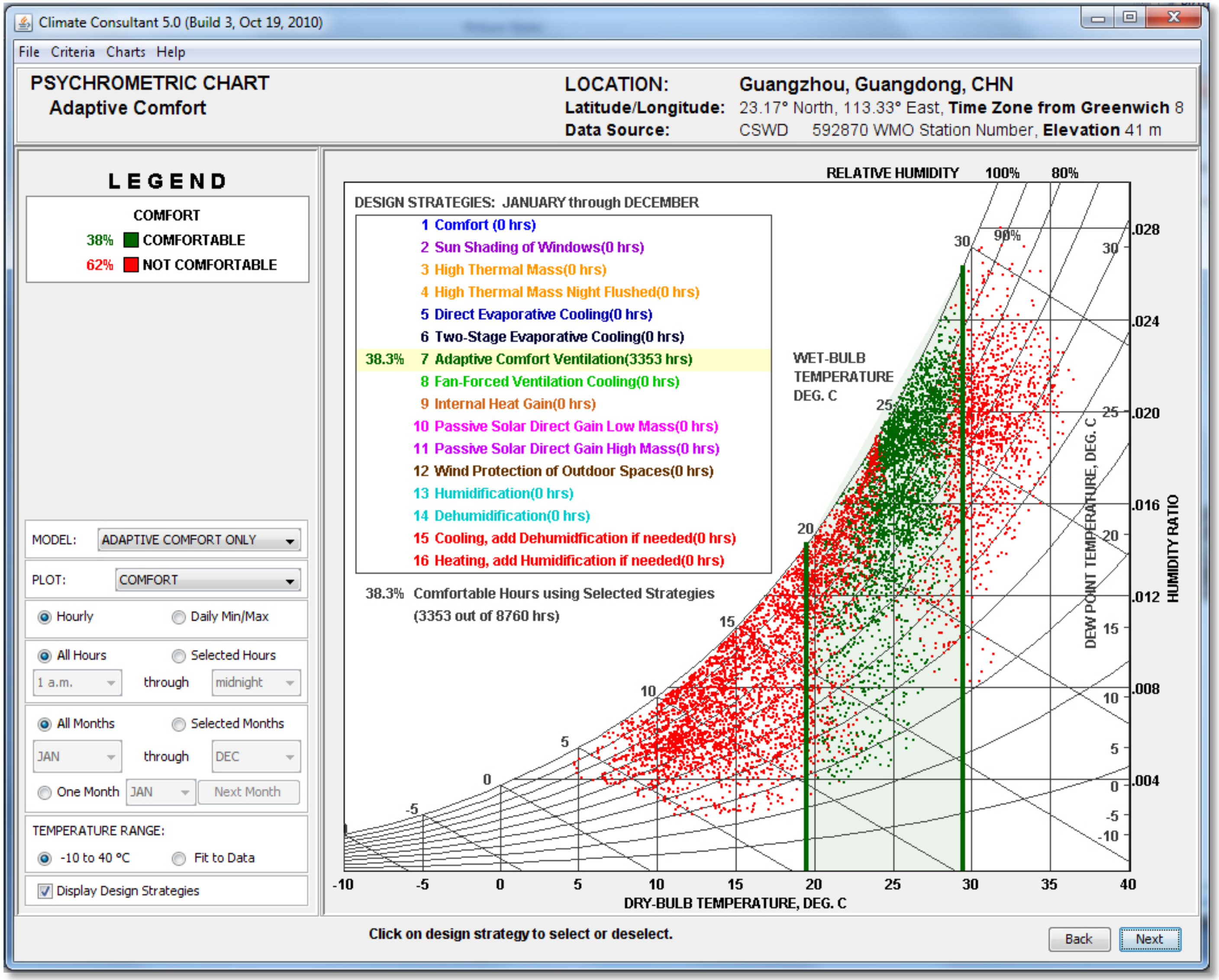


Bio-climatic Design: HOT-HUMID



Note lack of direct solar and hazy conditions.

Bio-climatic Design: HOT-HUMID



Bio-climatic Design: TEMPERATE

The summers are hot and humid, and the winters are cold. In much of the region the topography is generally flat, allowing cold winter winds to come in form the northwest and cool summer breezes to flow in from the southwest. **The four seasons are almost equally long.**

RULES:

- **BALANCE** strategies between COLD and HOT-HUMID

- maximize flexibility in order to be able to modify the envelope for varying climatic conditions

- understand the natural benefits of SOLAR ANGLES that shade during the warm months and allow for heating during the cool months

IslandWood Residence, Seattle, WA

CLIMATE RESPONSIVE

HEATING ↔ SUN

COOLING ↔ WIND

DAYLIGHTING ↔ LIGHT

PASSIVE STRATEGIES

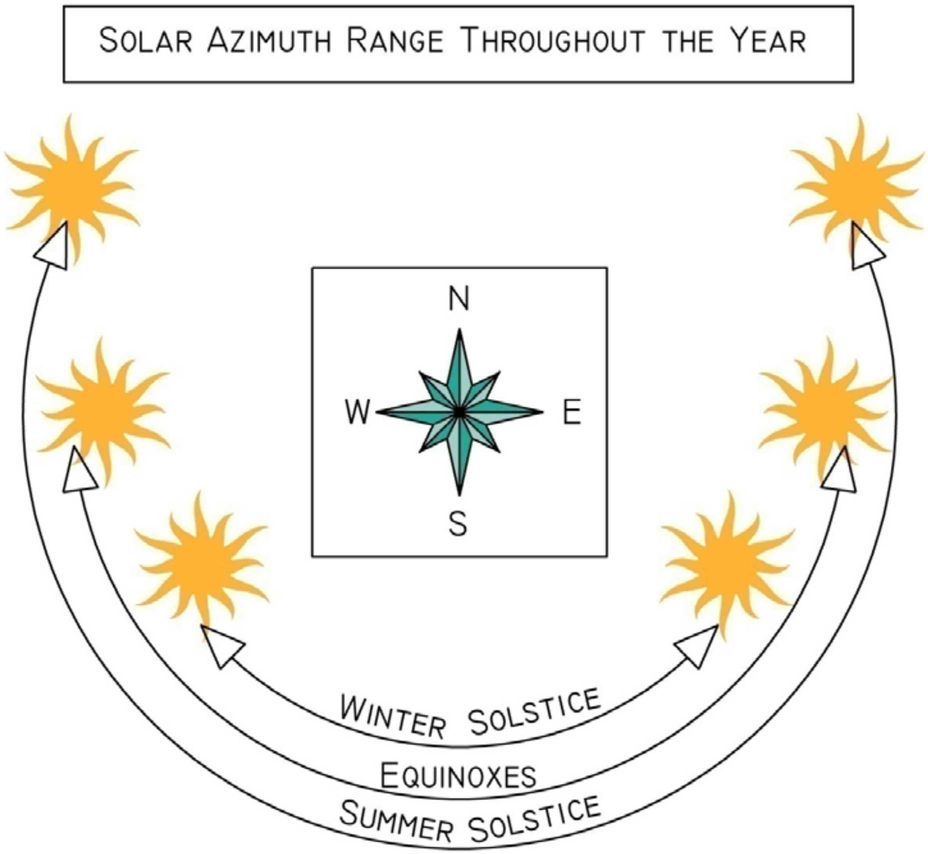
Begin with Passive Strategies for Climate Control to Reduce Energy Requirements

CONTROL STRATEGIES		CONDUCTION	CONVECTION	RADIATION	EVAPORATION	
WINTER	PROMOTE GAIN			Promote solar gain		HEATING
WINTER	RESIST LOSS	Minimize conductive heat flow	Minimize external air flow Minimize infiltration			HEATING
SUMMER	RESIST GAIN	Minimize conductive heat flow	Minimize infiltration	Minimize solar gain		COOLING
SUMMER	PROMOTE LOSS	Promote earth cooling	Promote ventilation	Promote radiant cooling	Promote evaporative cooling	COOLING
	HEAT SOURCES		Atmosphere	Sun		
	HEAT SINKS	Earth	Atmosphere	Sky	Atmosphere	

Strategies of Climate Control

(chart modeled after Watson "Climatic Building Design")

#1 Starting Point ORIENTATION – Locate the SUN



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

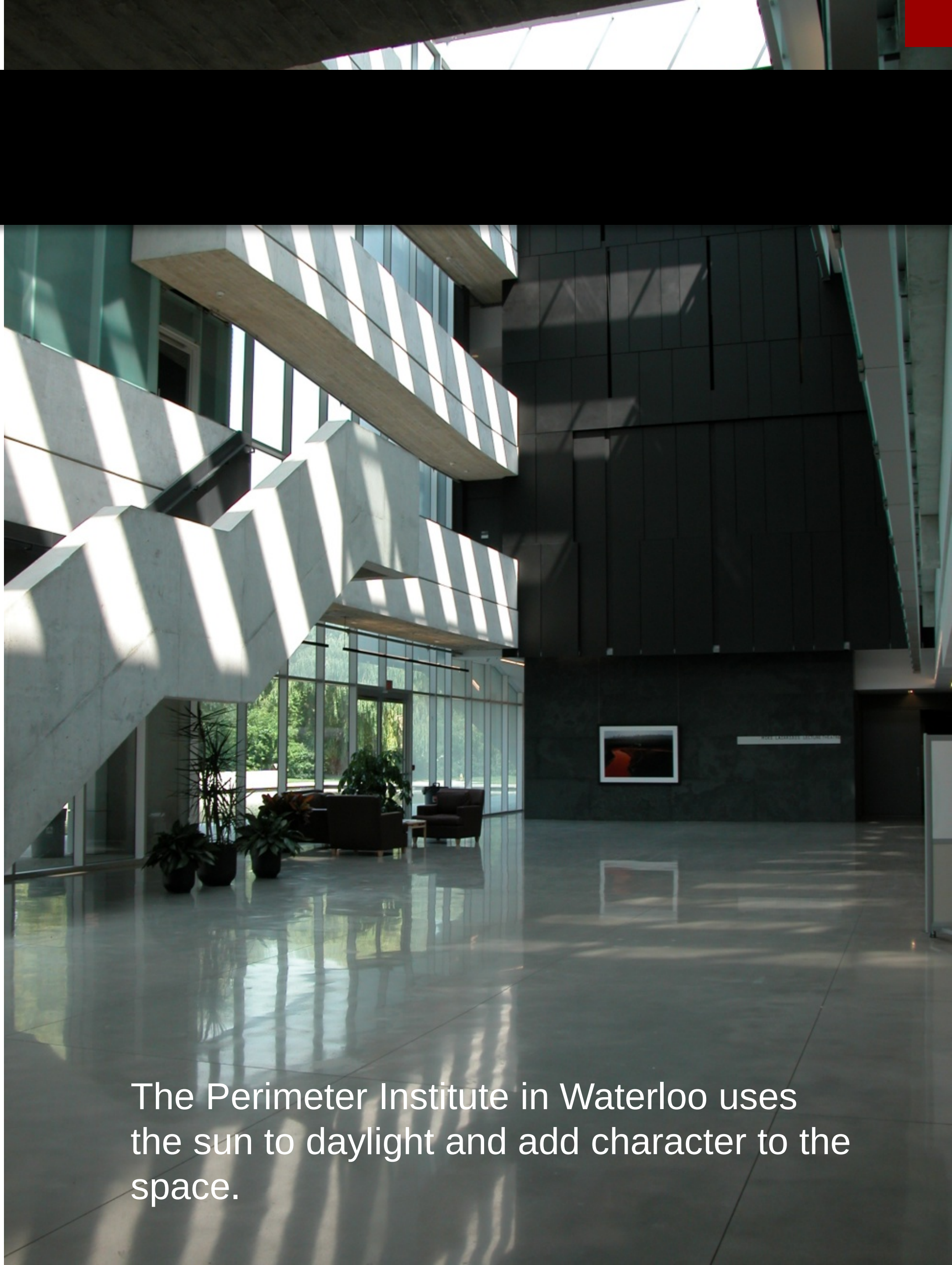
Solar Geometry

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

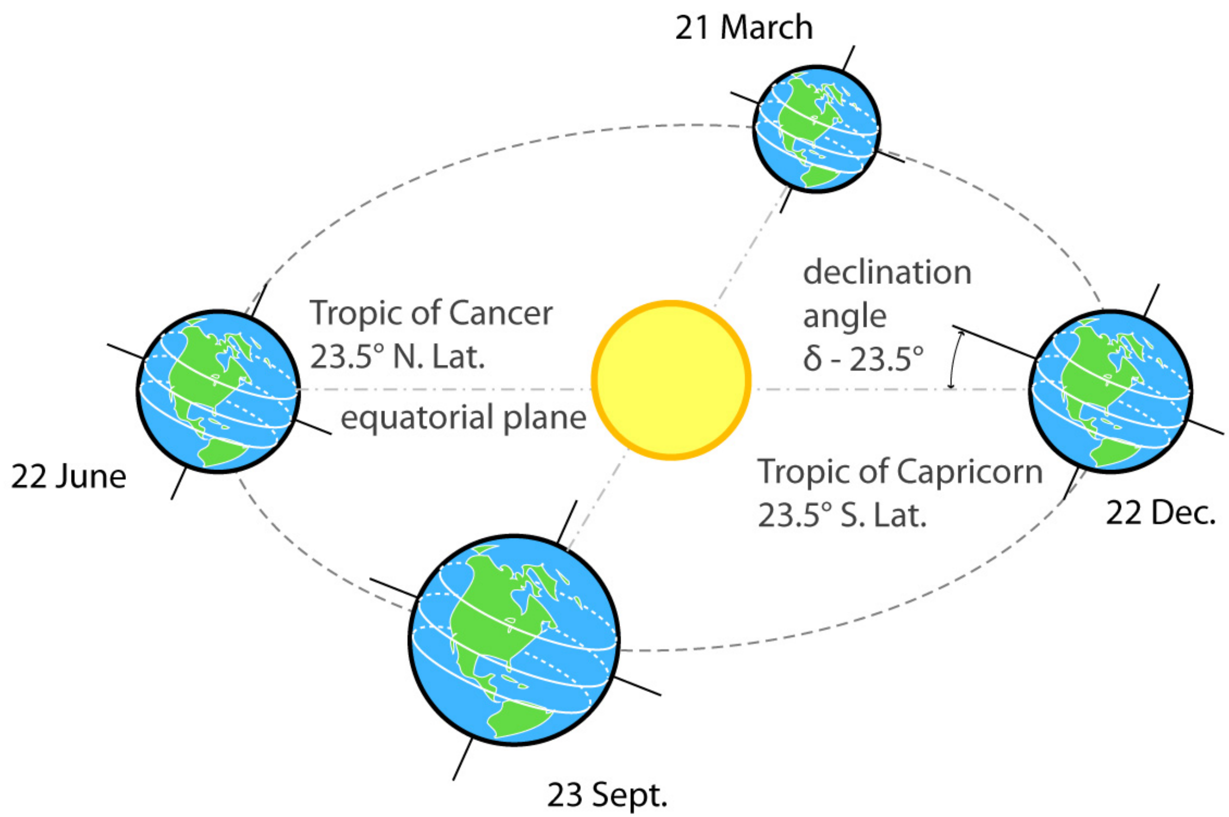
Understanding solar geometry is essential in order to:

- do passive building design (for heating and cooling)
- orient buildings properly
- understand seasonal changes in the building and its surroundings
- design shading devices
- use the sun to animate our architecture



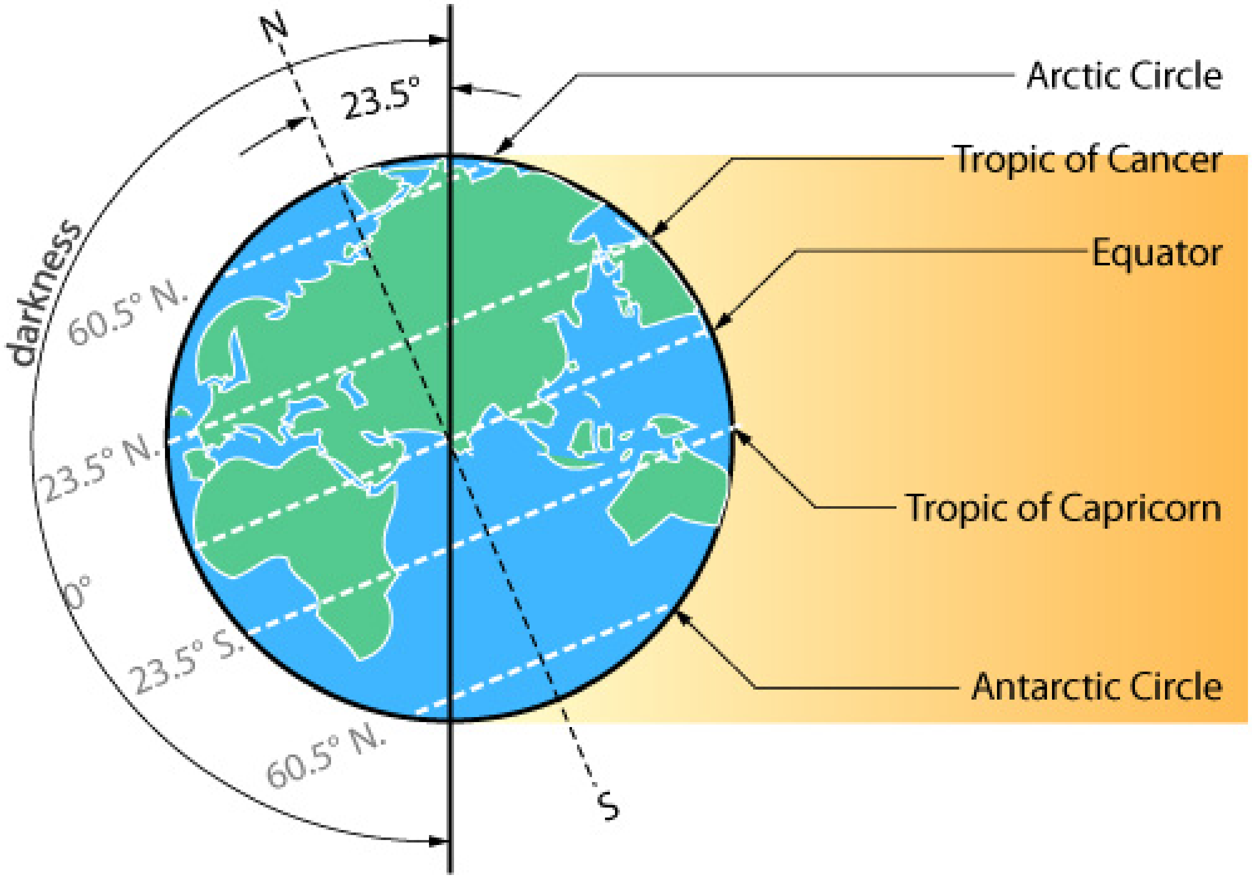
The Perimeter Institute in Waterloo uses the sun to daylight and add character to the space.

Solar Geometry



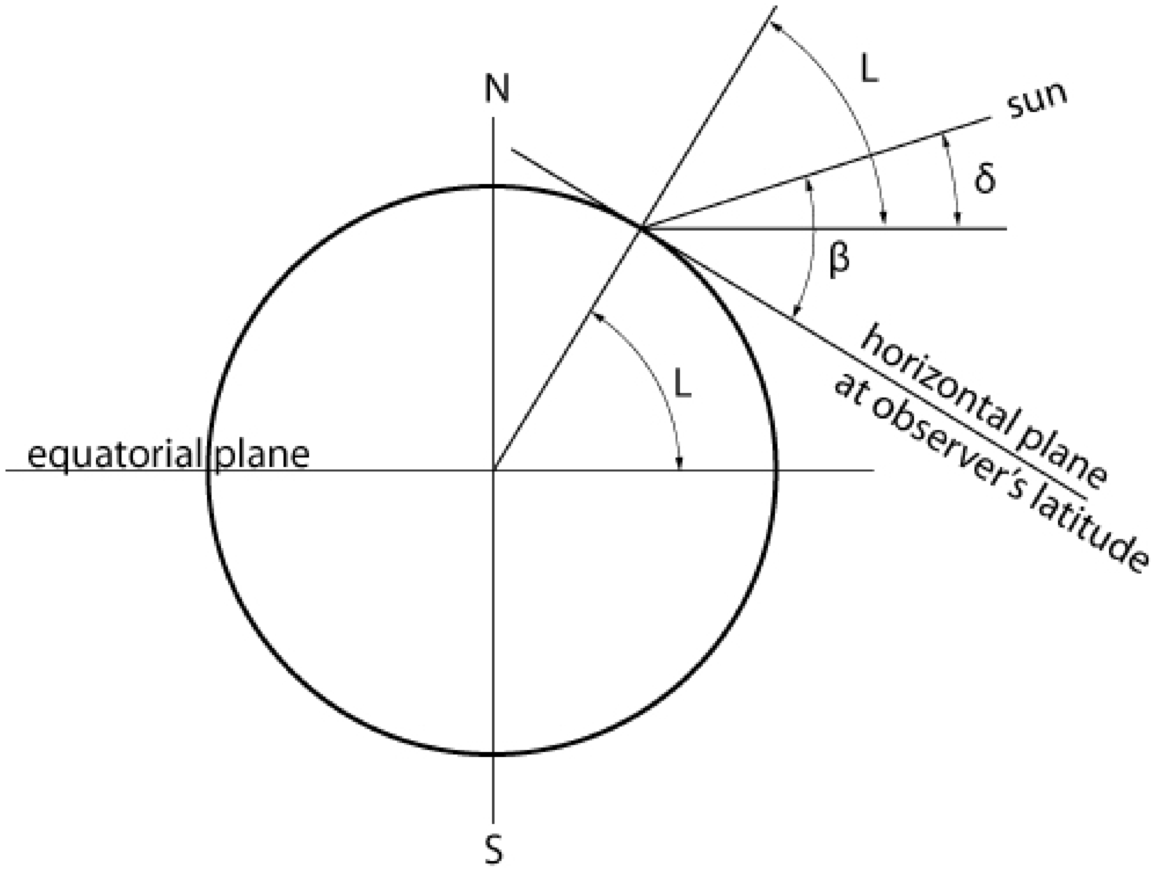
Earth's motion around the sun.

Solar Position



Earth relative to sun at winter solstice.

Solar Geometry Terms

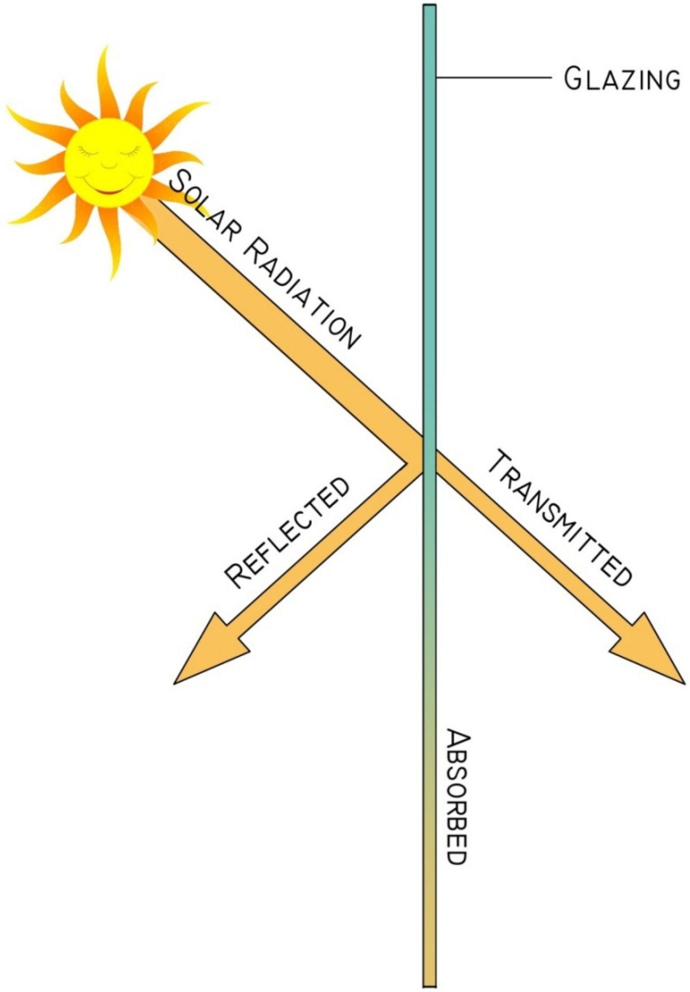


Relation between declination, altitude angle, and latitude.

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

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

Sun Angles



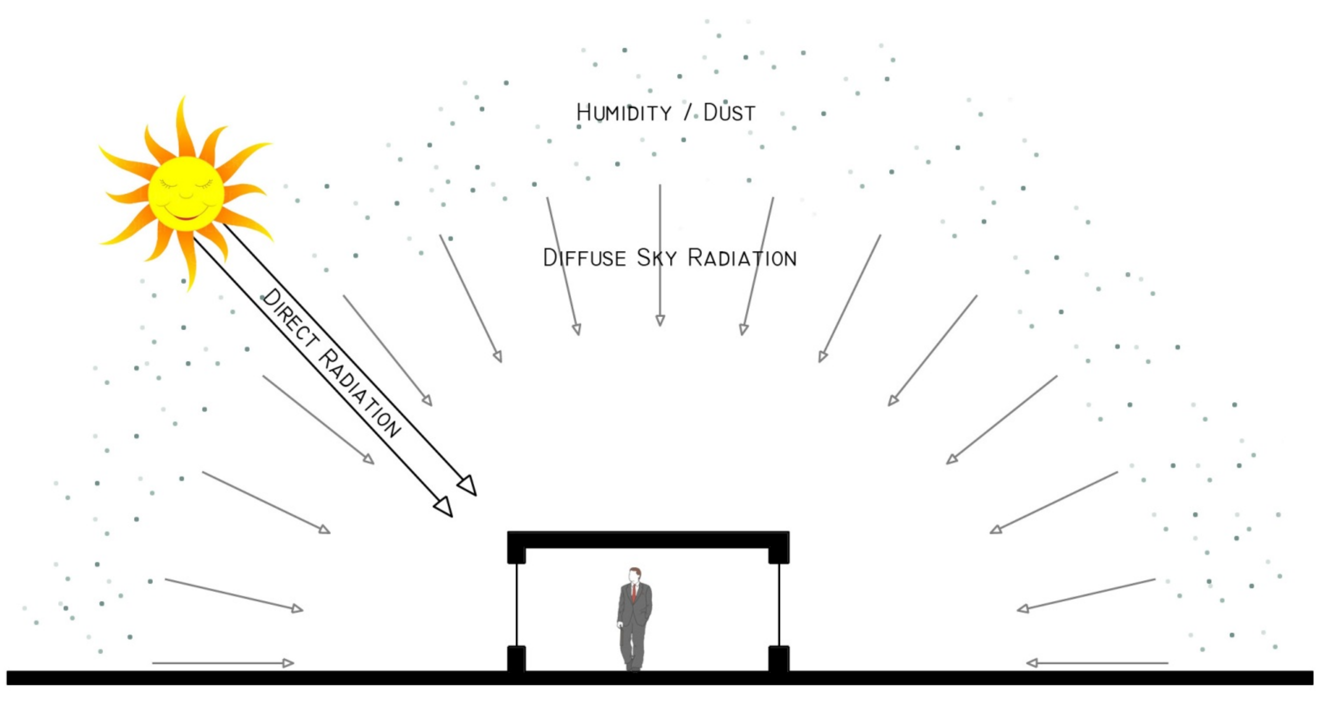
When sun strikes the glass part of the solar radiation is transmitted through the glass and proceeds to heat up the interior space.

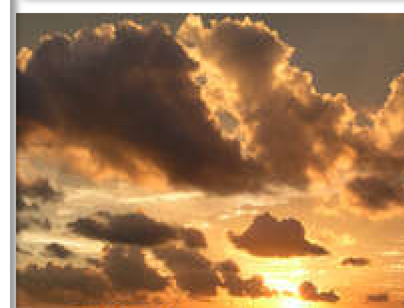
Part of the solar energy is reflected off of the glass. The amount is dependent on the angle of incidence.

Part of the solar energy is absorbed into the glass, then reradiated both inwards and outwards.

When looking to AVOID heat entering the building it is critical to prevent it from this initial transmission through the glass – as once the heat is in, it is IN.

Direct versus Diffuse Radiation



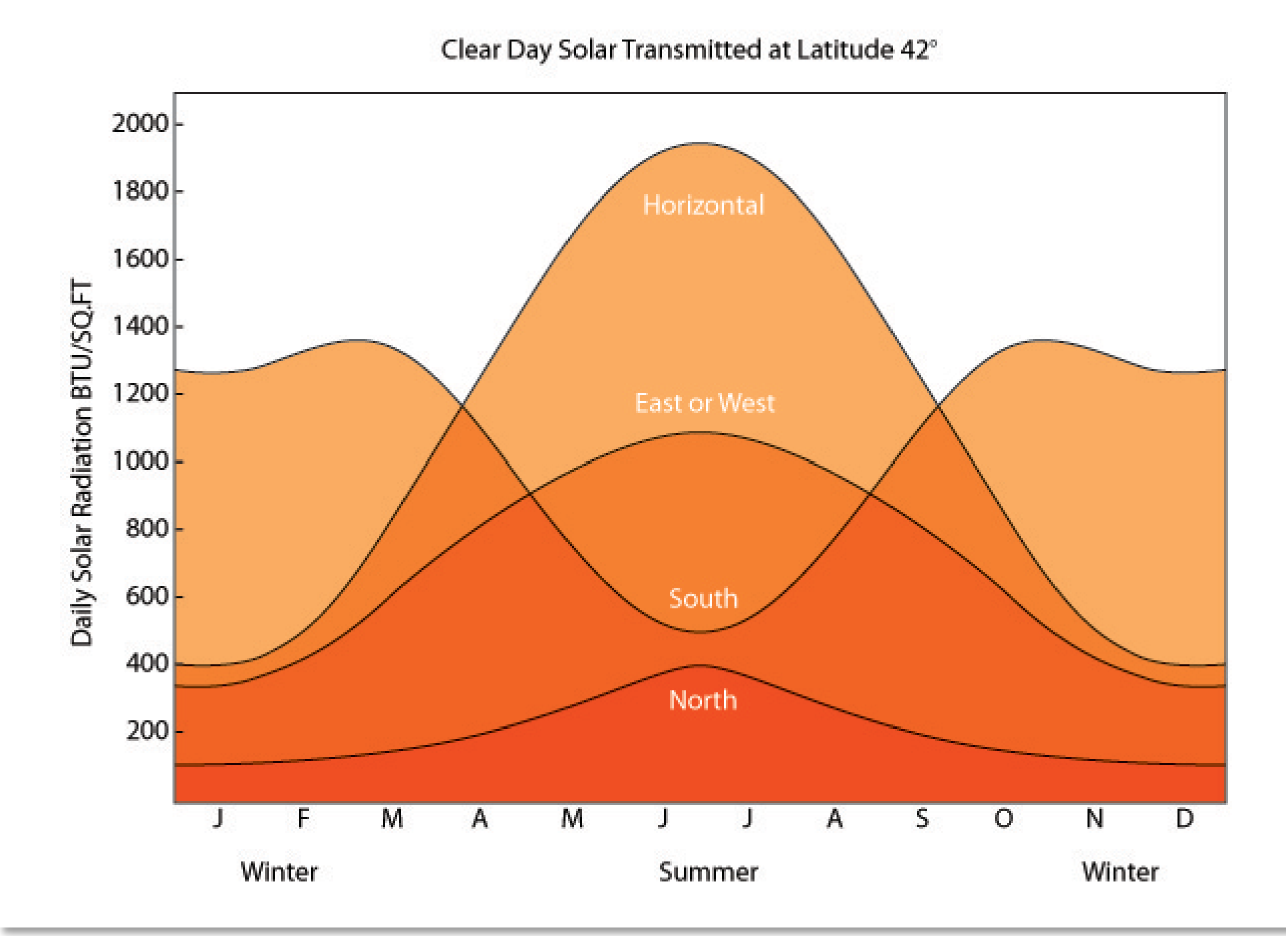


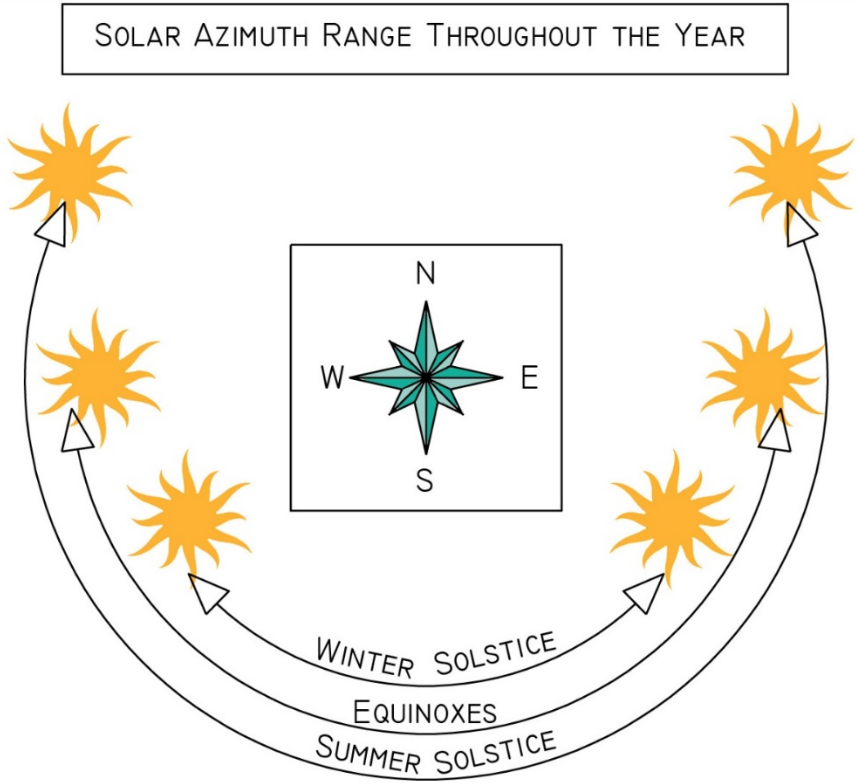
Solar Energy as a Function of Orientation

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.



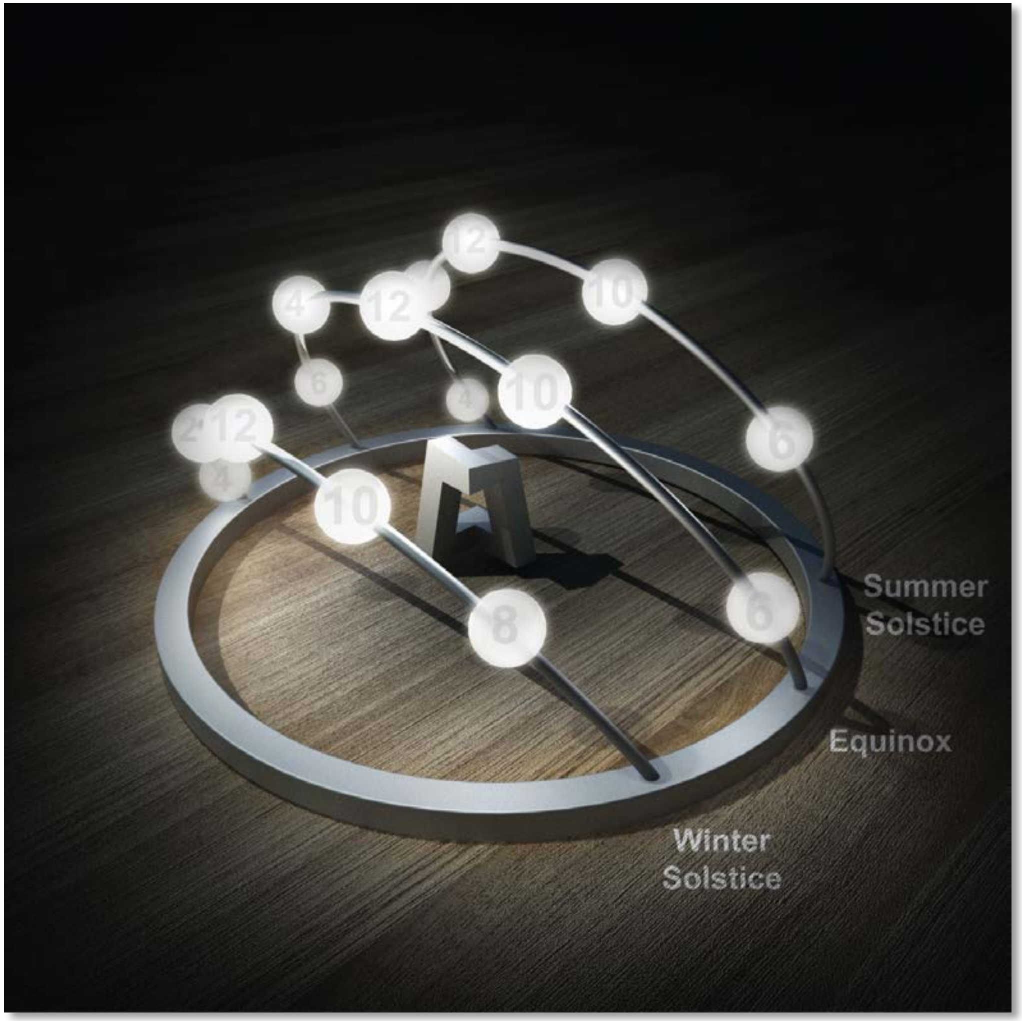


Since little winter heating can be expected from east and west windows, shading devices on those orientations can be designed purely on the basis of the summer requirement.

Solar Geometry

The local solar path affects:

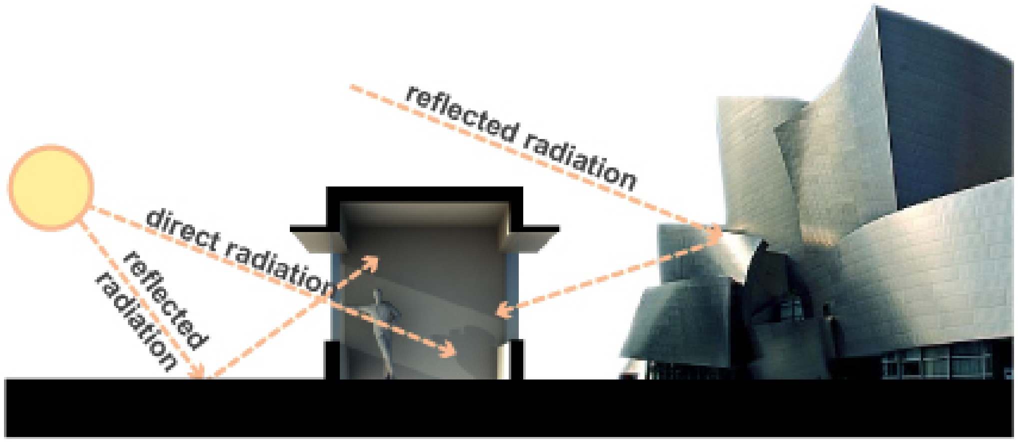
- Location of openings for passive solar heating
- Design of shading devices for cooling
- Means differentiated façade design



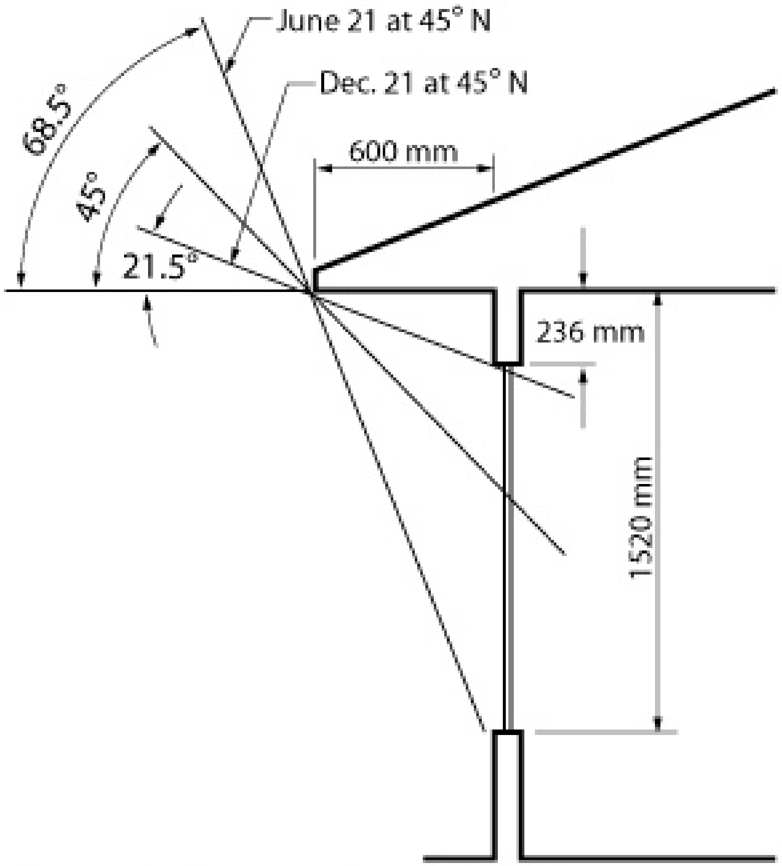
Types of Radiation

- Direct radiation
- Reflected radiation

Reflective glazing

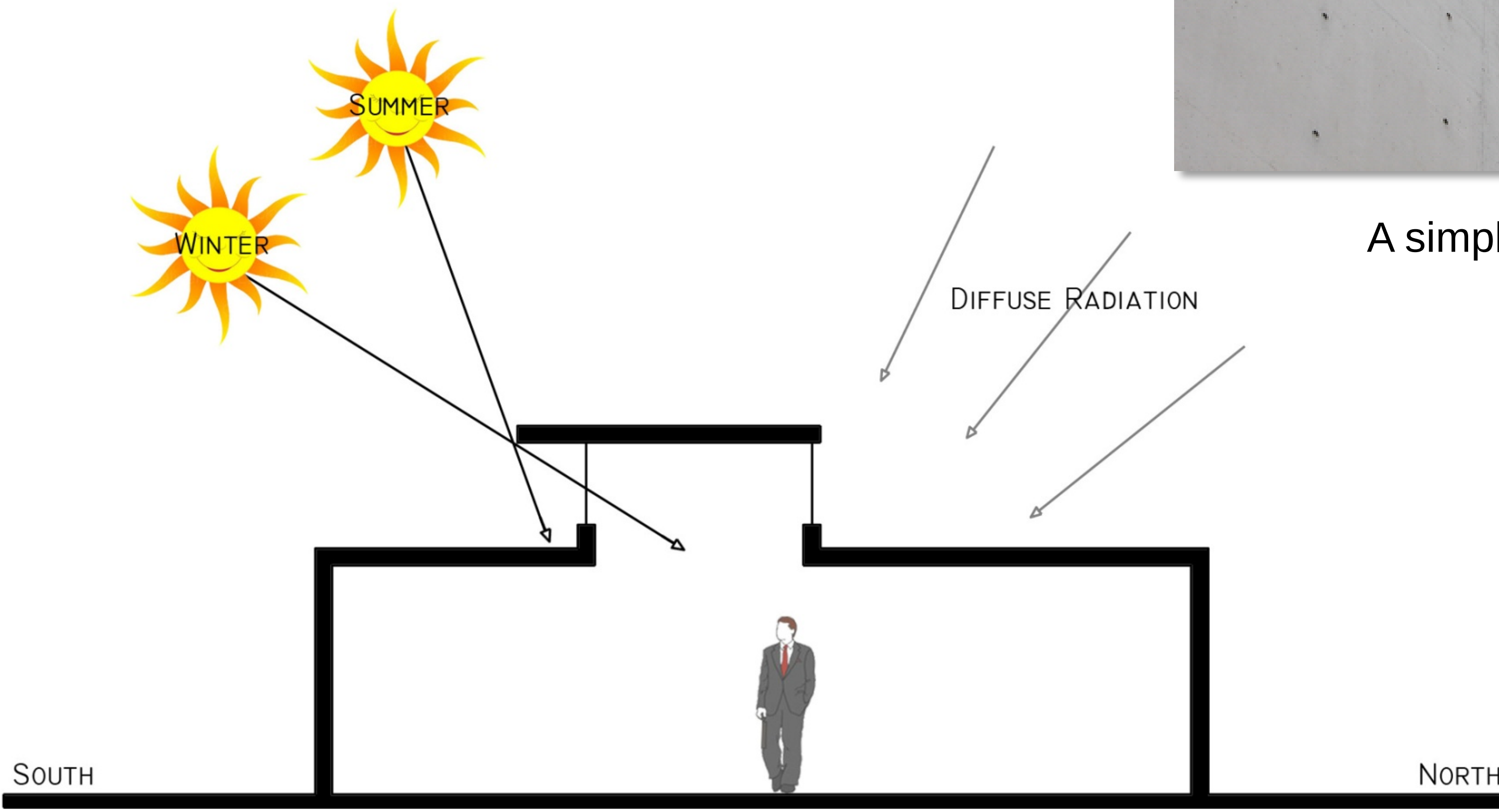


South Shading Device Basics

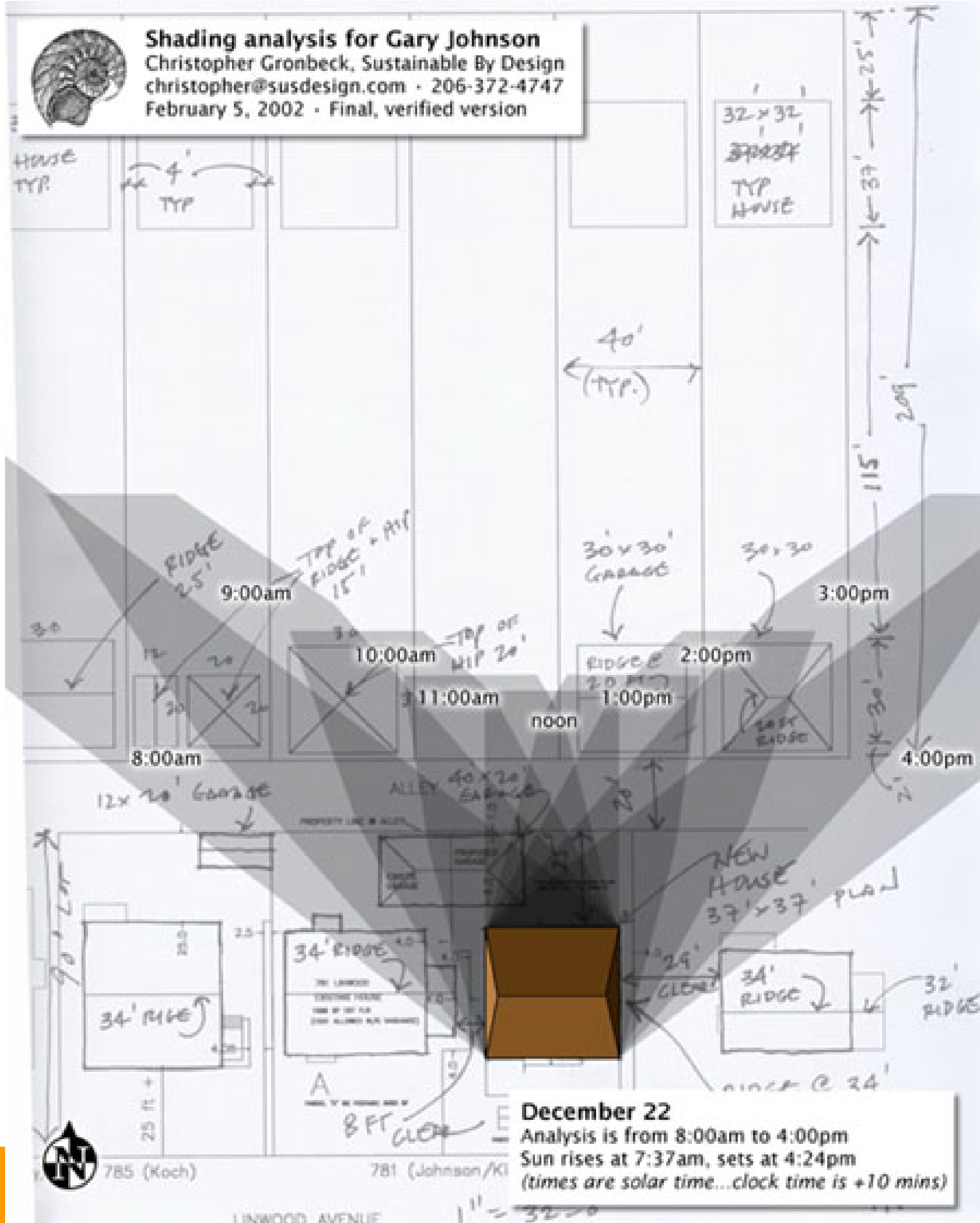


Shading angles for a south wall at 45°N

A simple roof overhang acts as a shading device.



CLERESTORY WINDOW

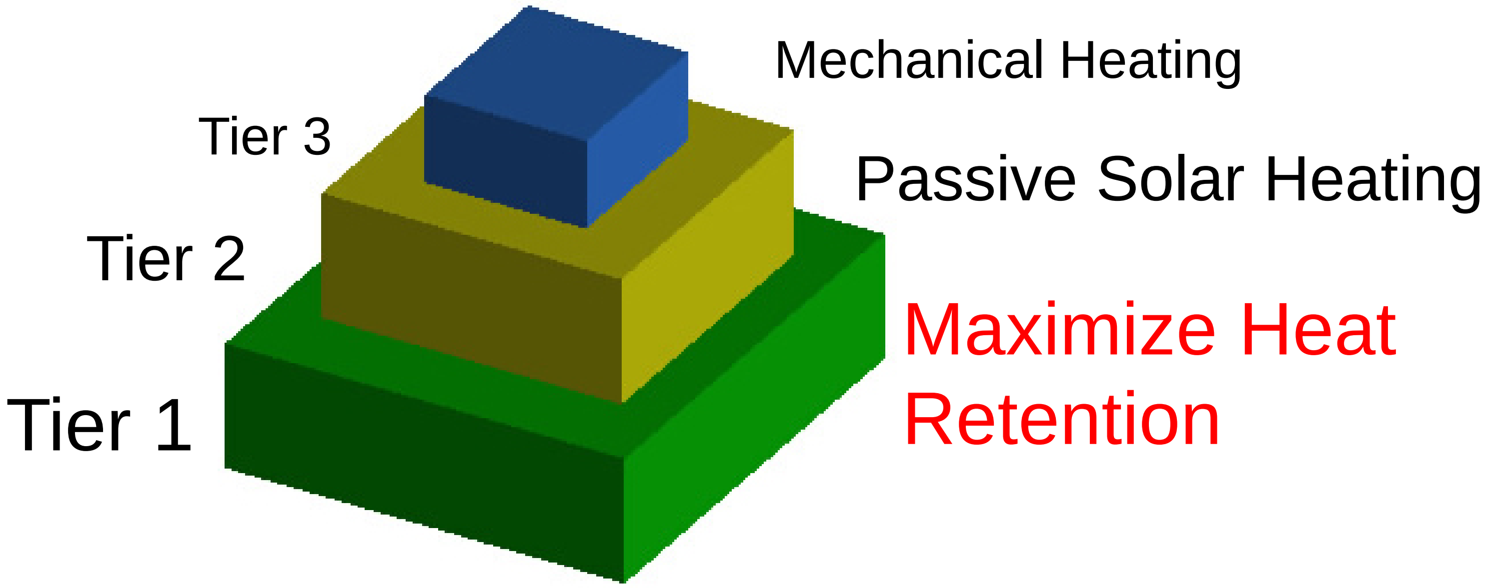


This type of analysis is a "must do" for every building that you design.

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

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)

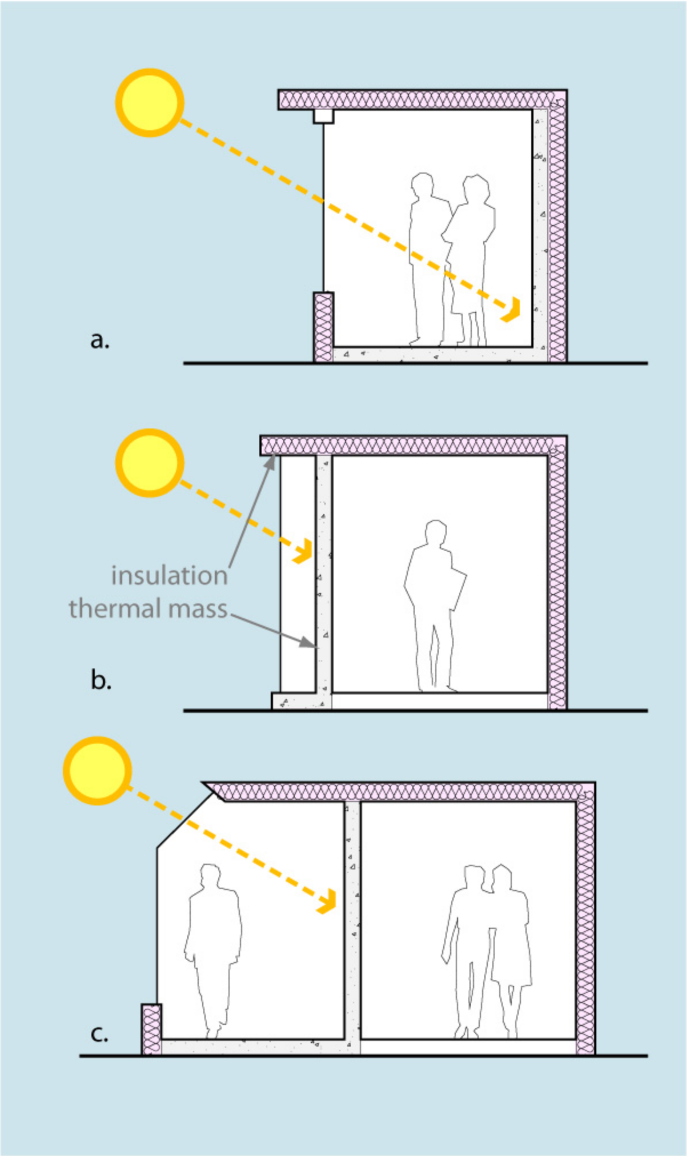
3 MAIN STRATEGIES:

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.

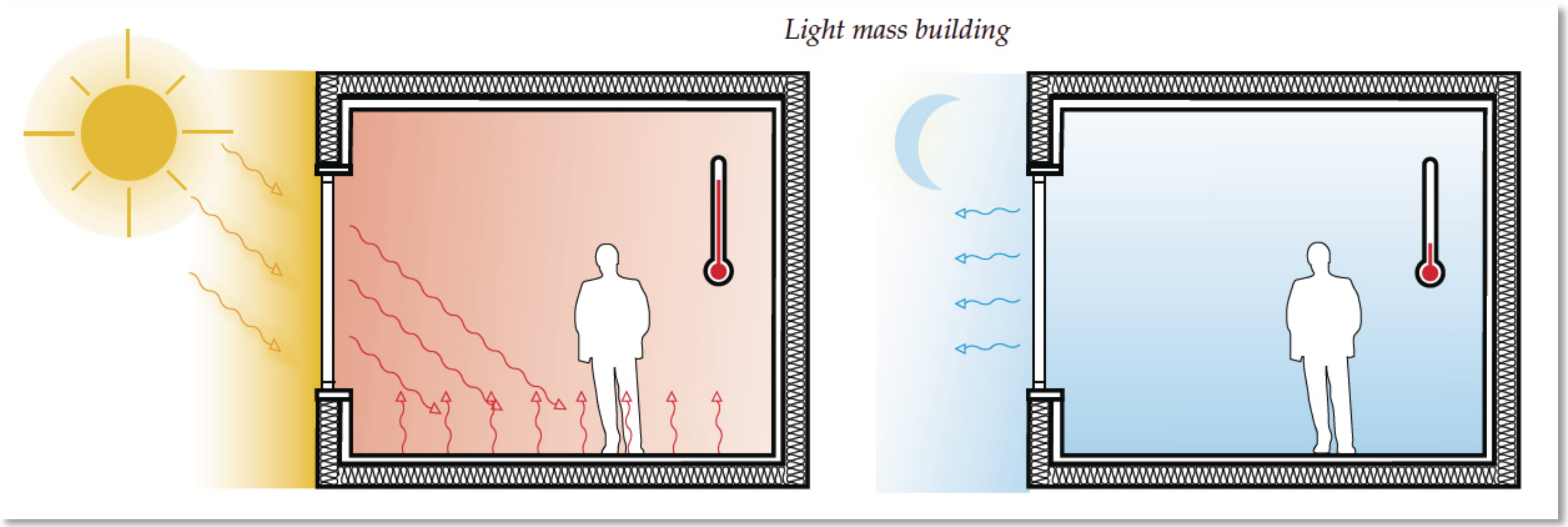
Just like water, free solar energy needs to be stored somewhere to be useful!

Problems with traditional placement of thermal mass

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

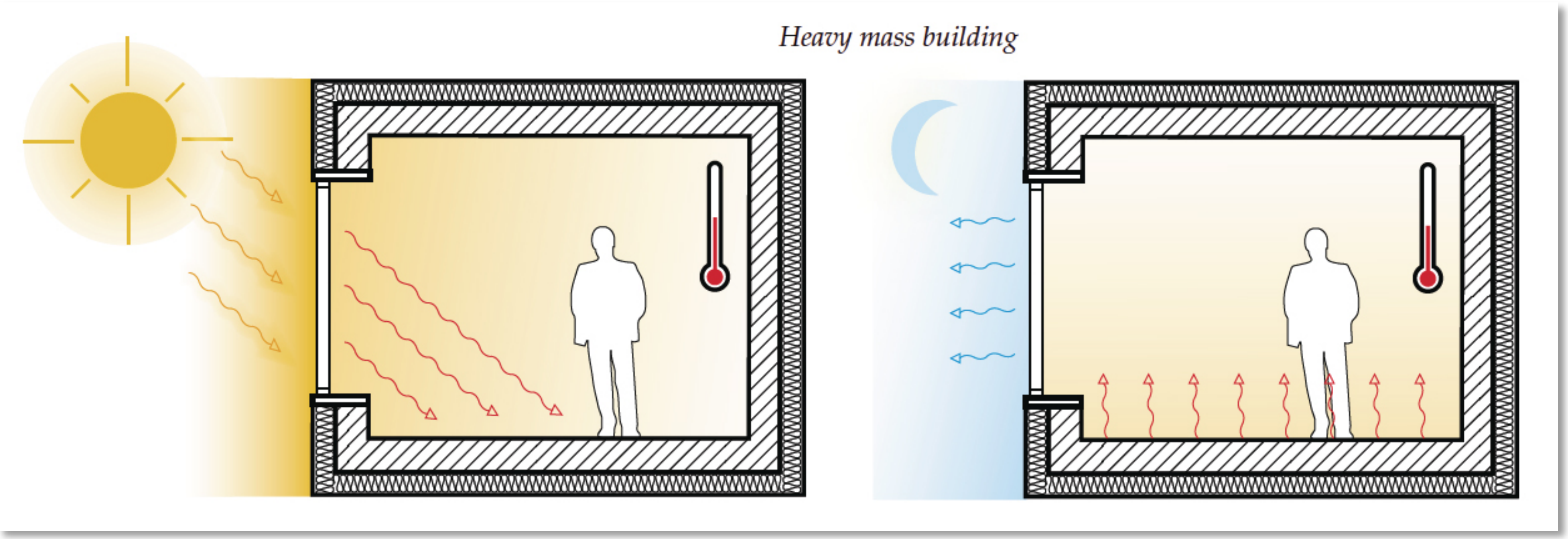
Thermal mass is needed on the INSIDE of the envelope – as floor and/or walls.

Light Mass Building Problems



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

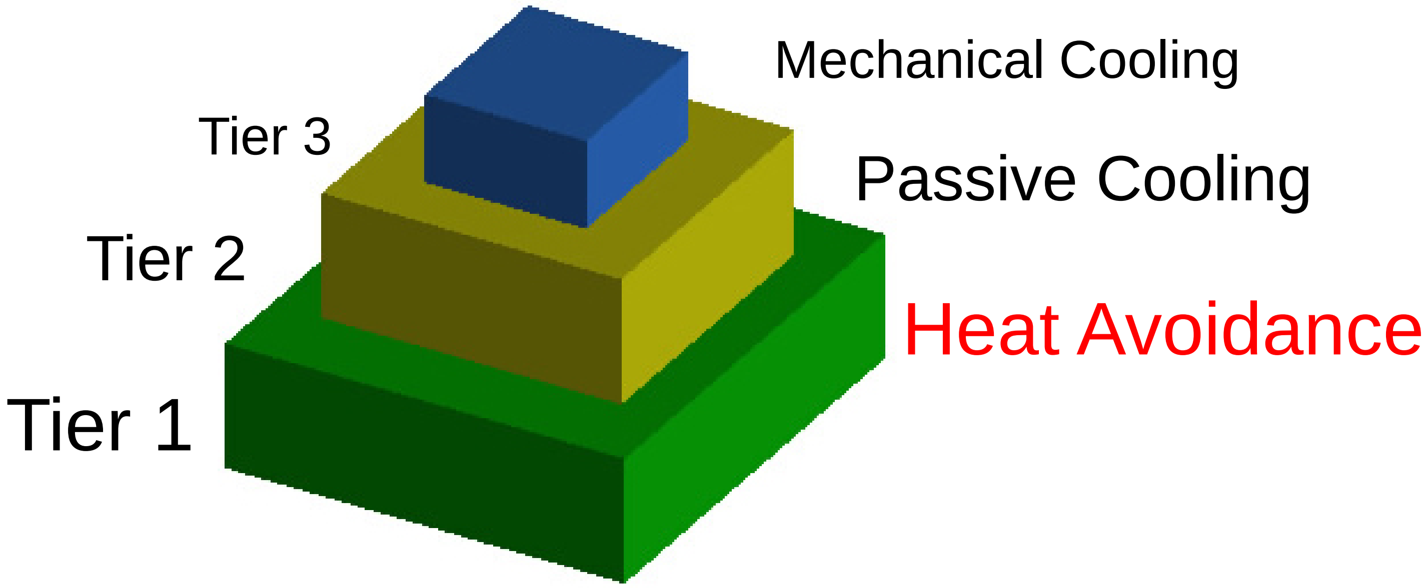
Heavy Mass Building Benefits



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

Reduce loads: Passive Cooling 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:
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

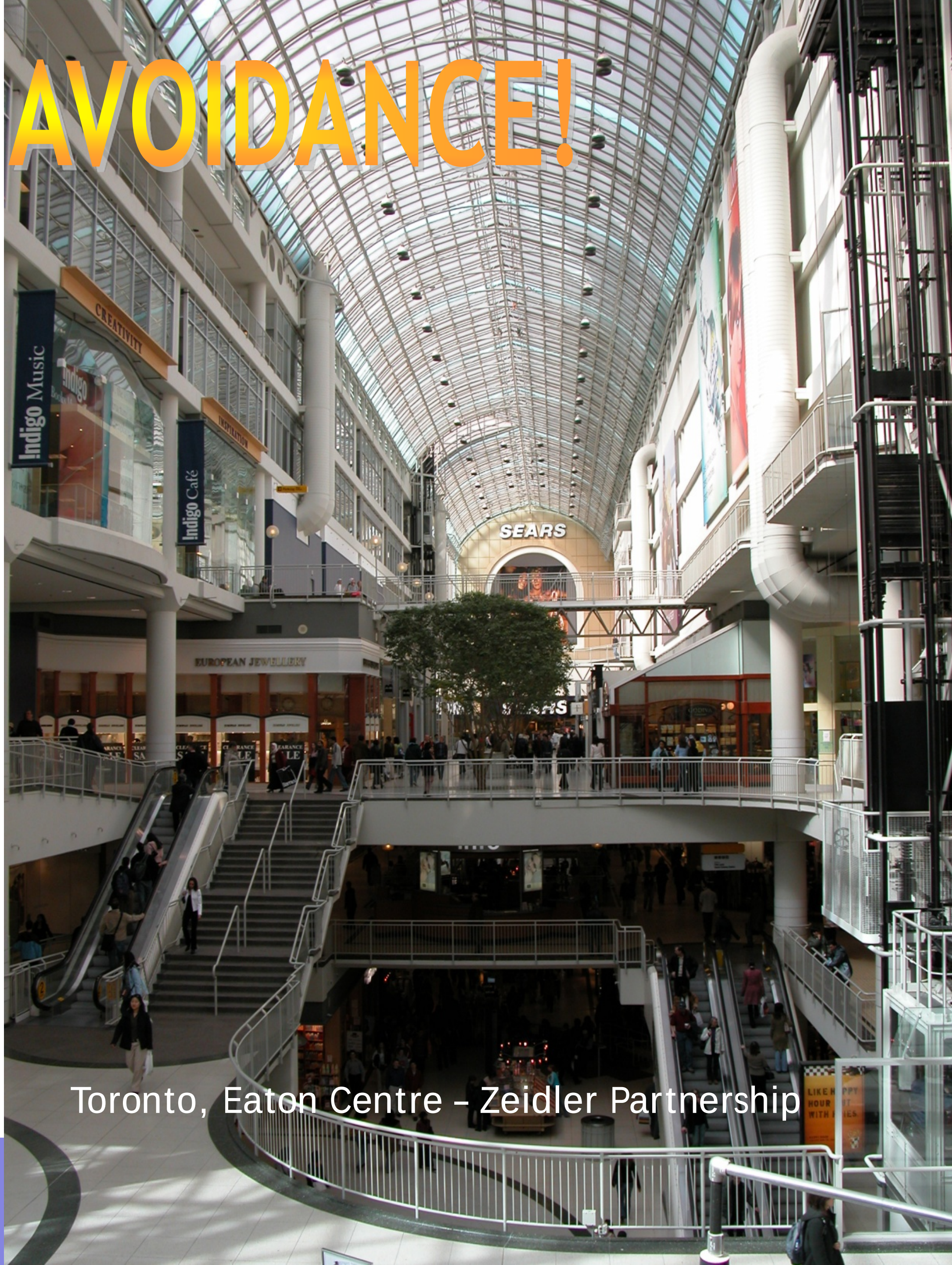
If you don't invite the heat in, you don't have to get rid of it…..

Think Heat AVOIDANCE!

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

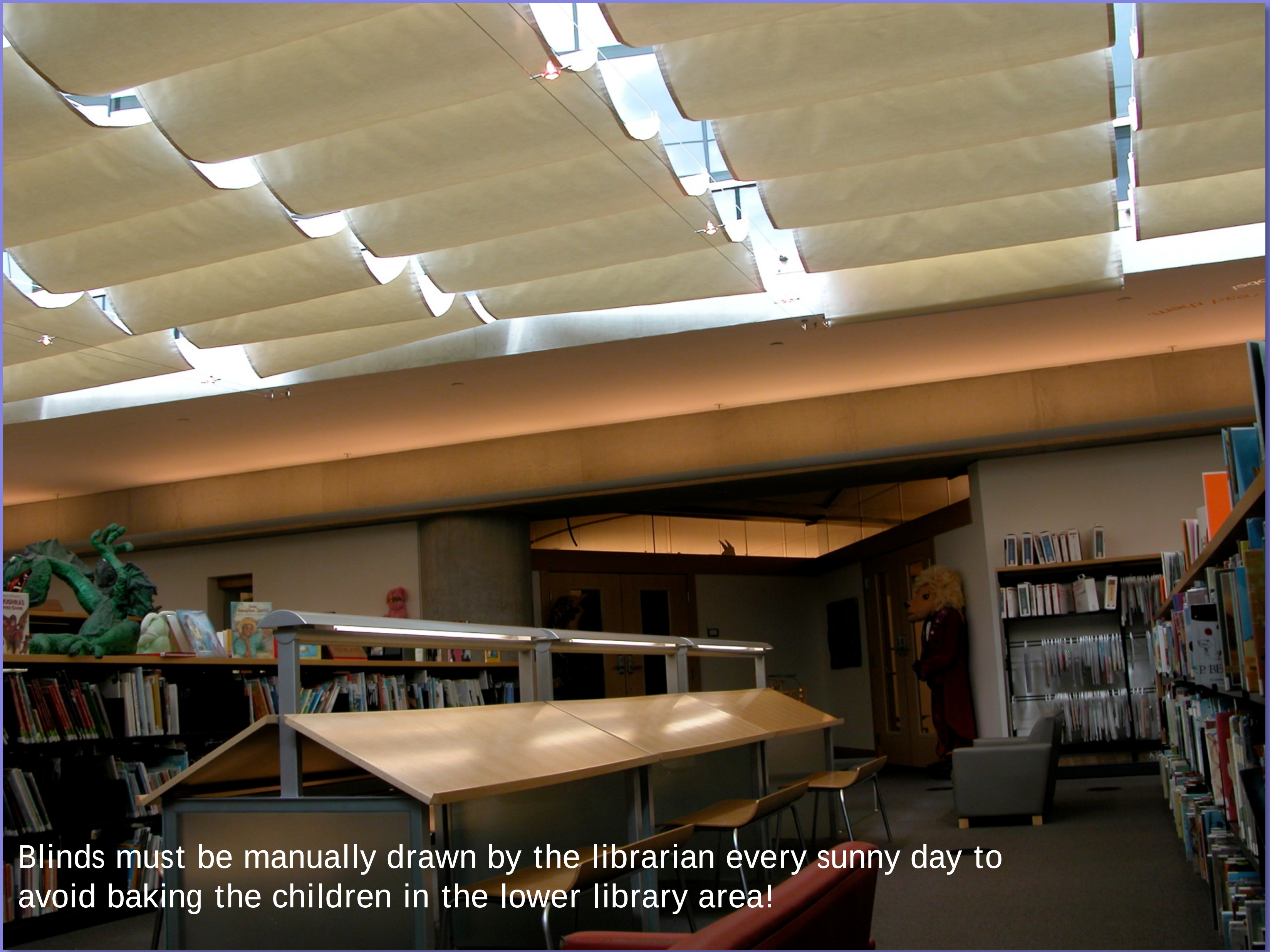
One way to avoid heat gain is by modifying the glazing.

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.



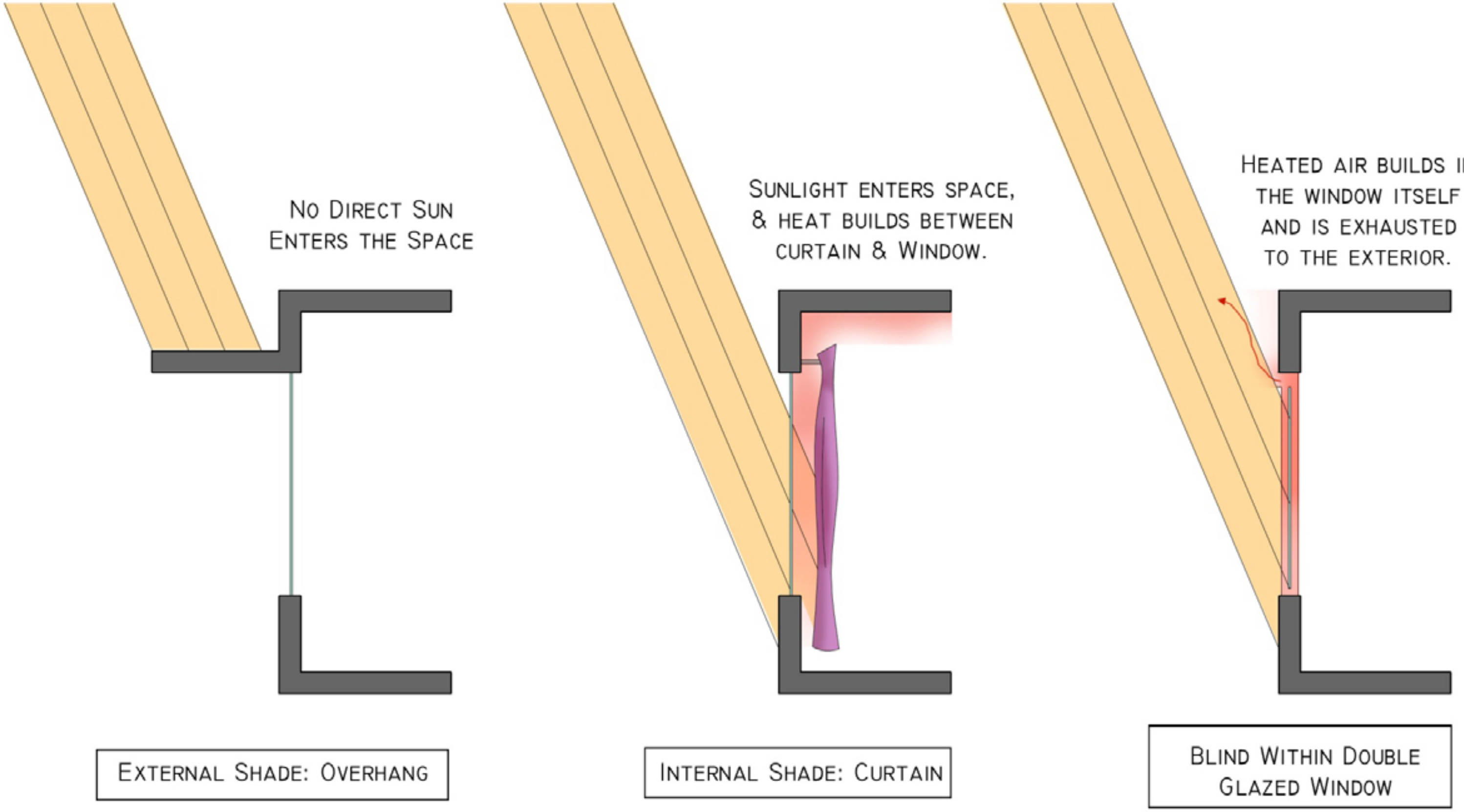
Toronto, Eaton Centre – Zeidler Partnership

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!

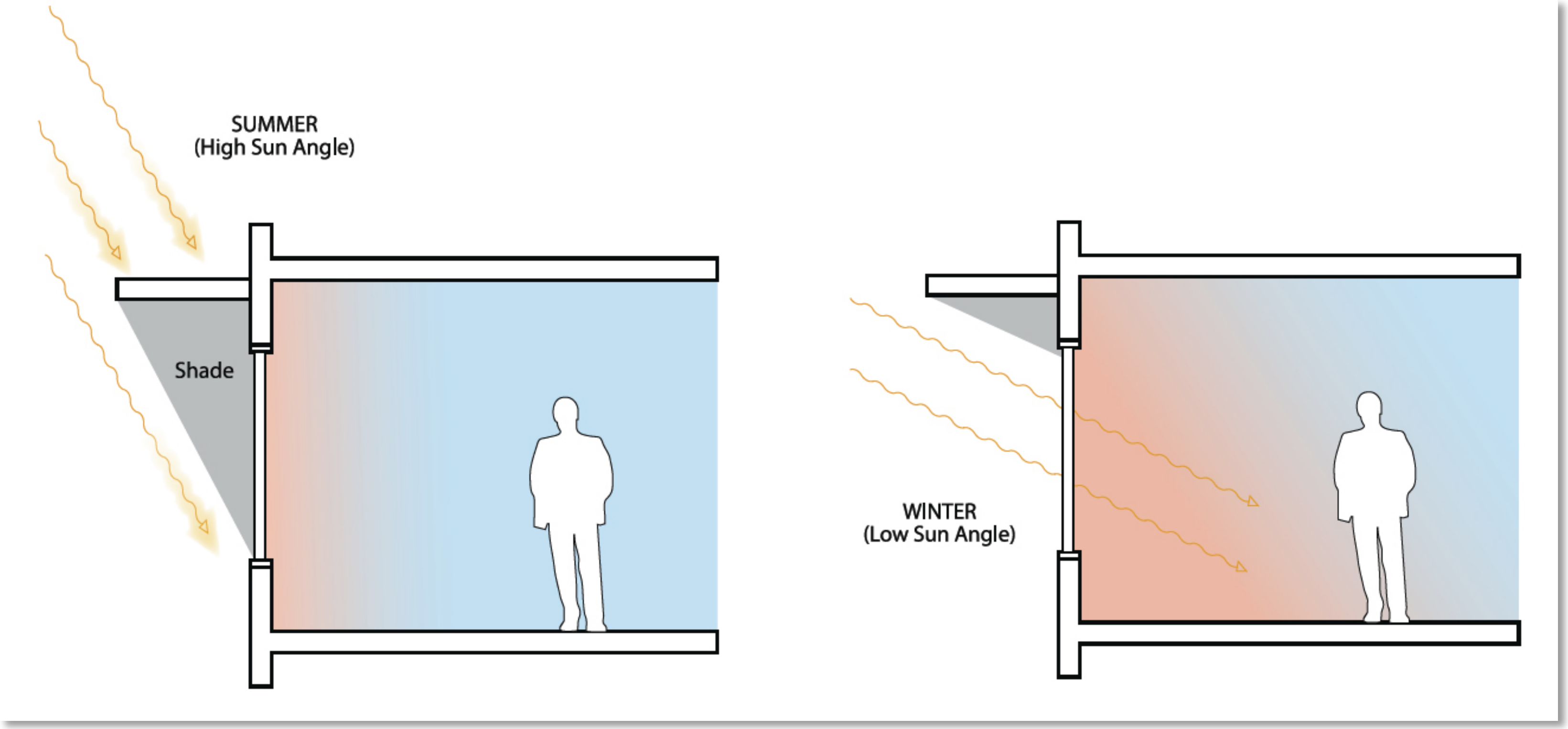
Interior vs Exterior Shades



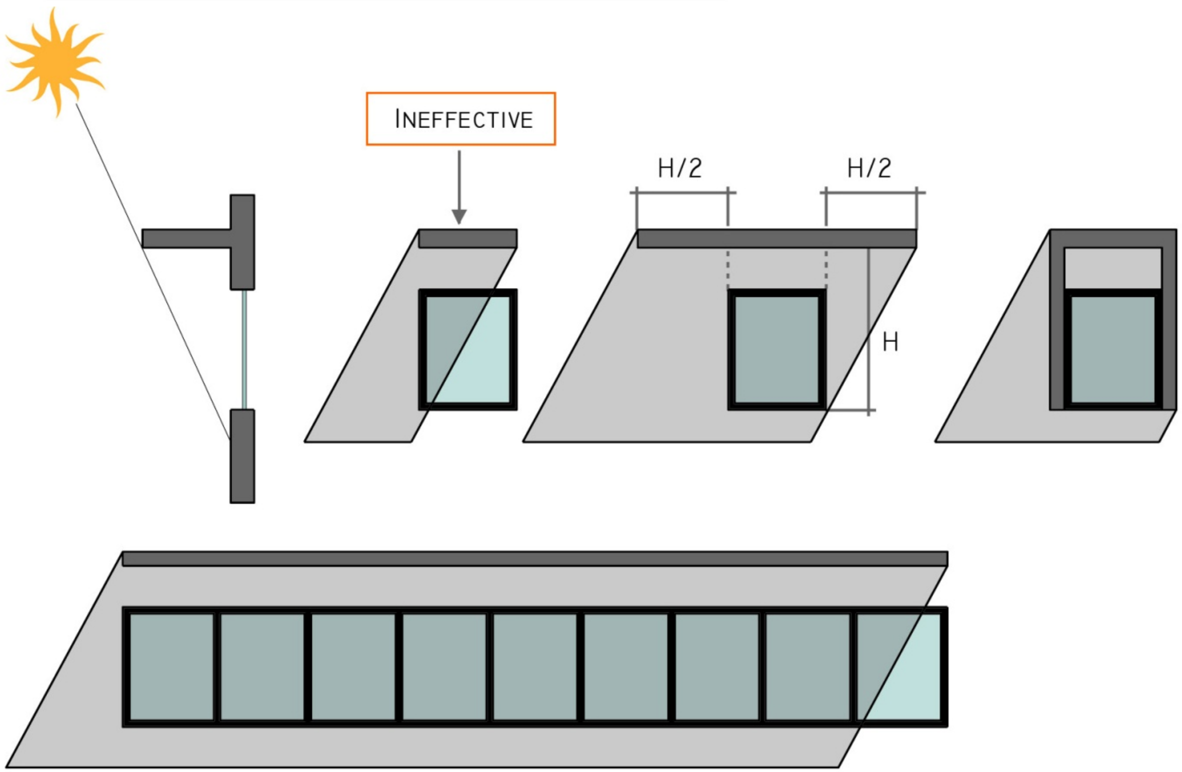
Once the heat is IN, it is IN!

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

South Façade Strategies

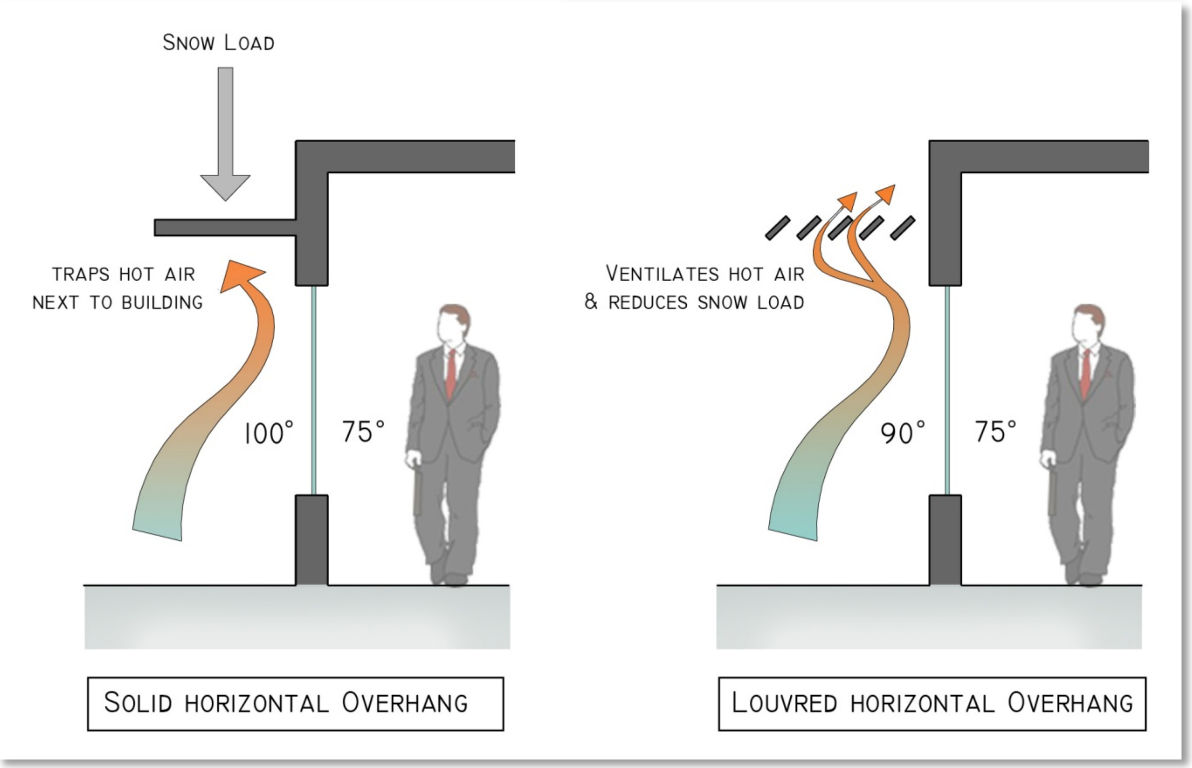


- South façade is the easiest to manage as simple overhangs can provide shade in the summer and permit entry in the winter.
- Need to design for August condition as June to August is normally a warm period.



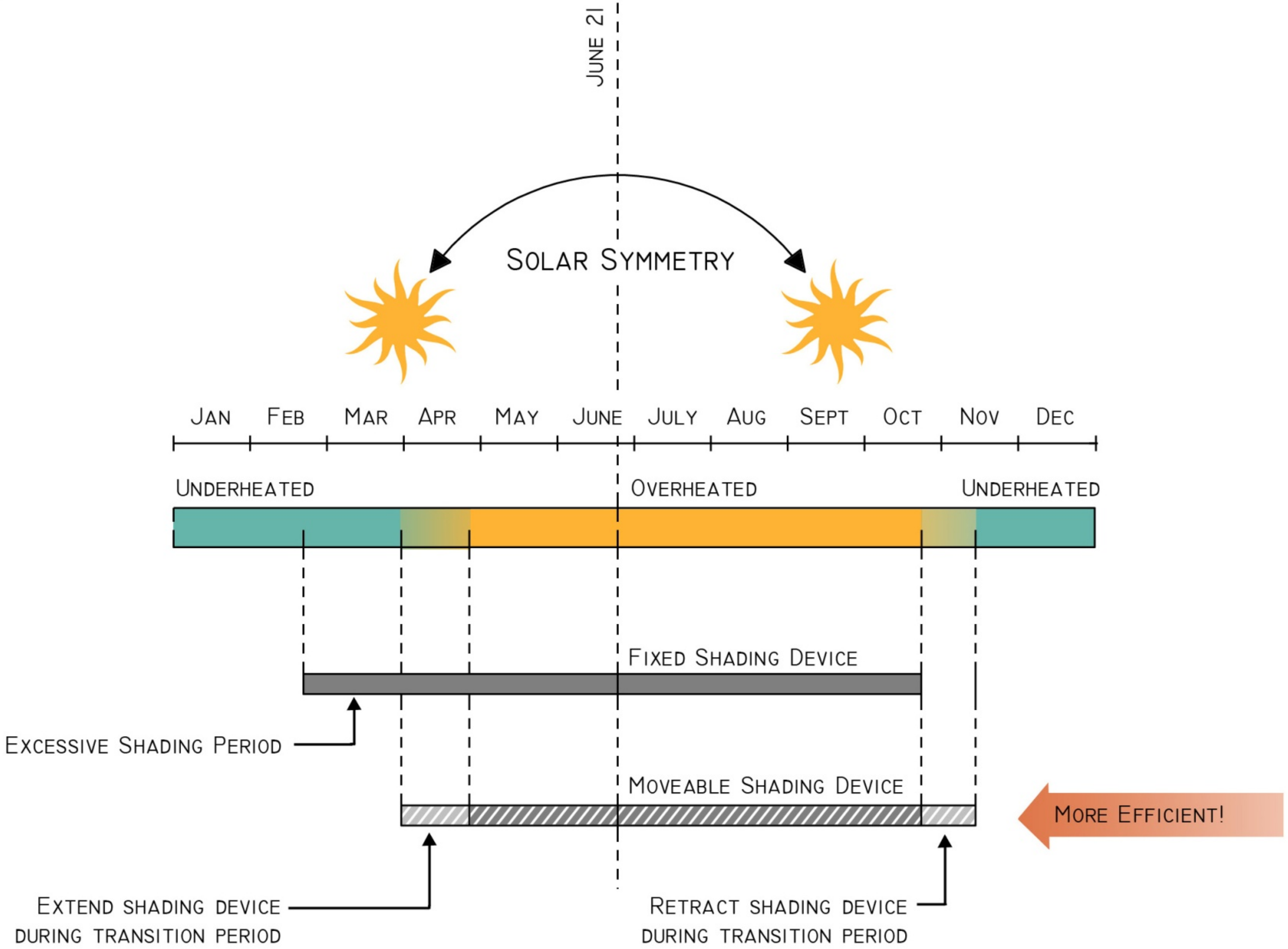
…extend device for full shading

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

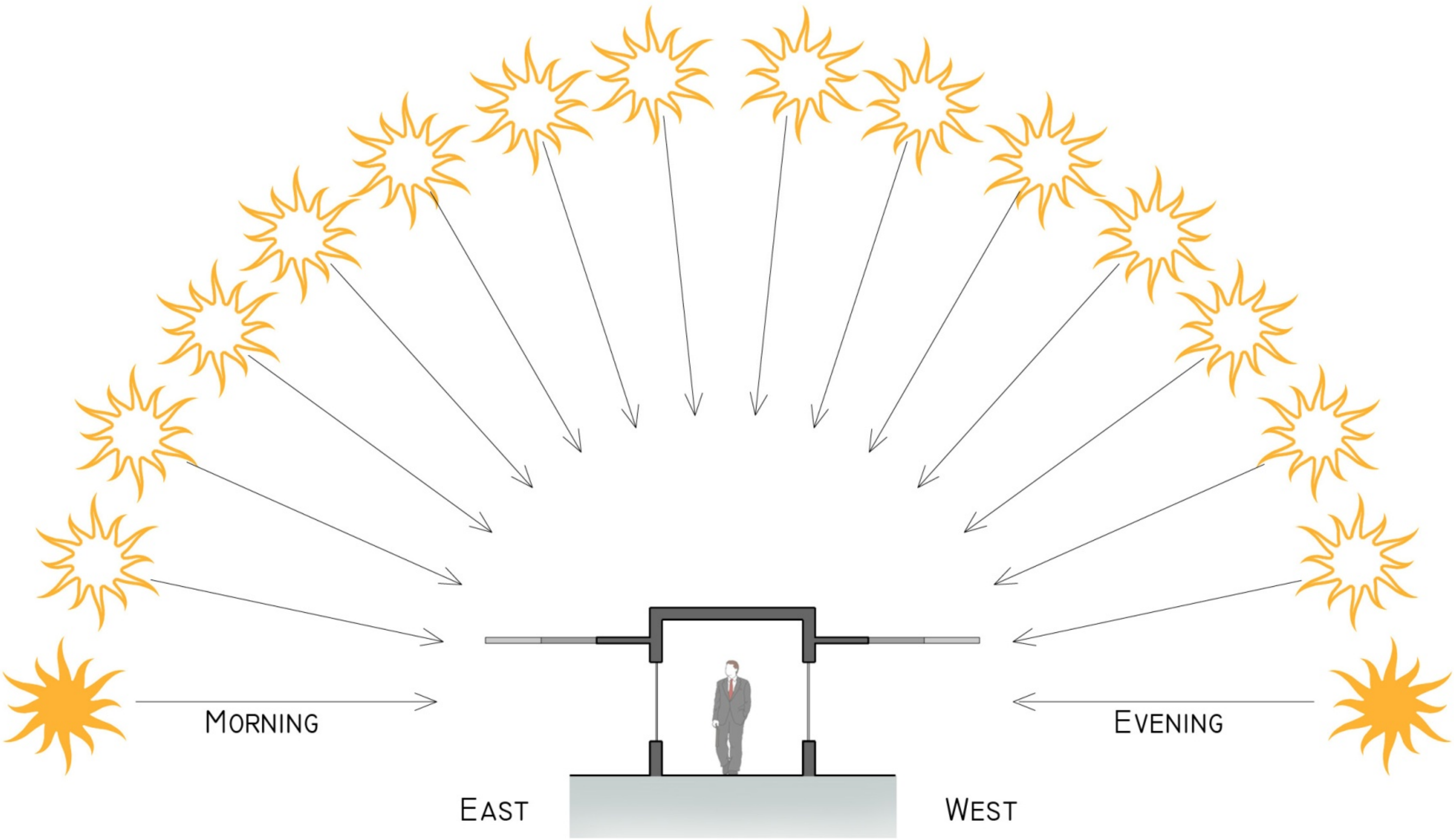


The above two use louvers or grates that will let snow, rain and wind through.

Preventing Overheating South Façade

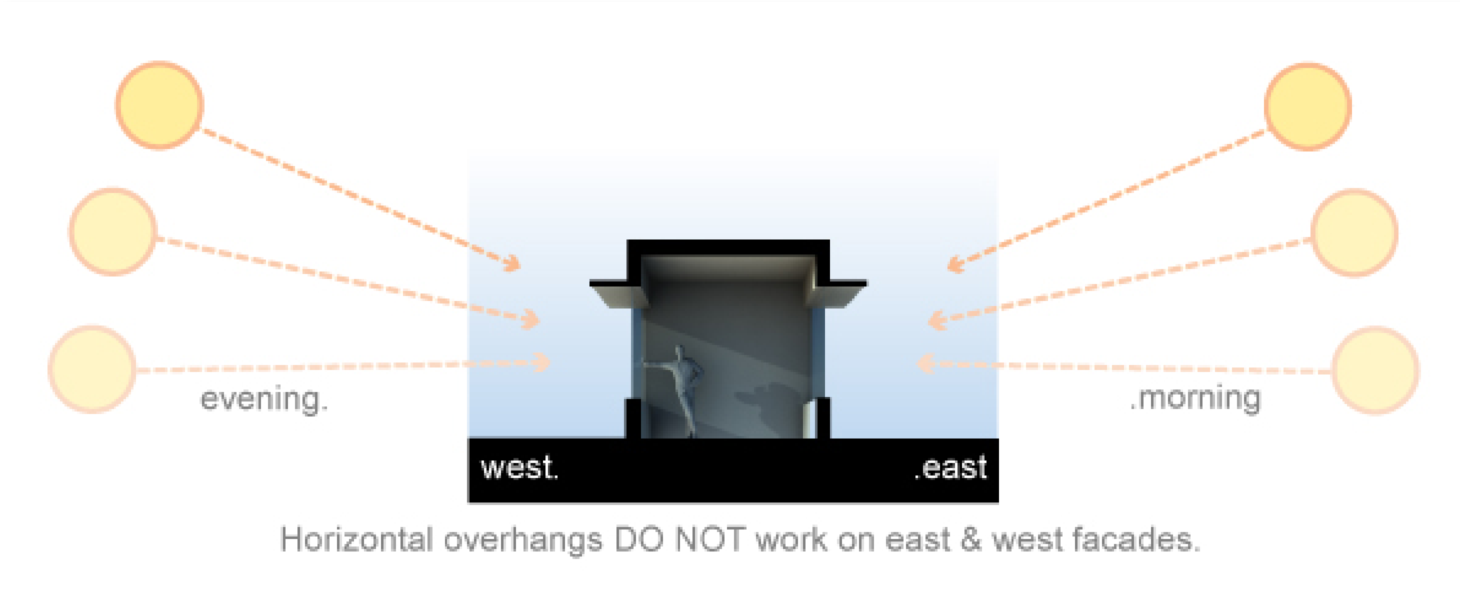


Shading Strategies for East and West Orientations



Horizontal Overhangs do NOT work on East & West Facades

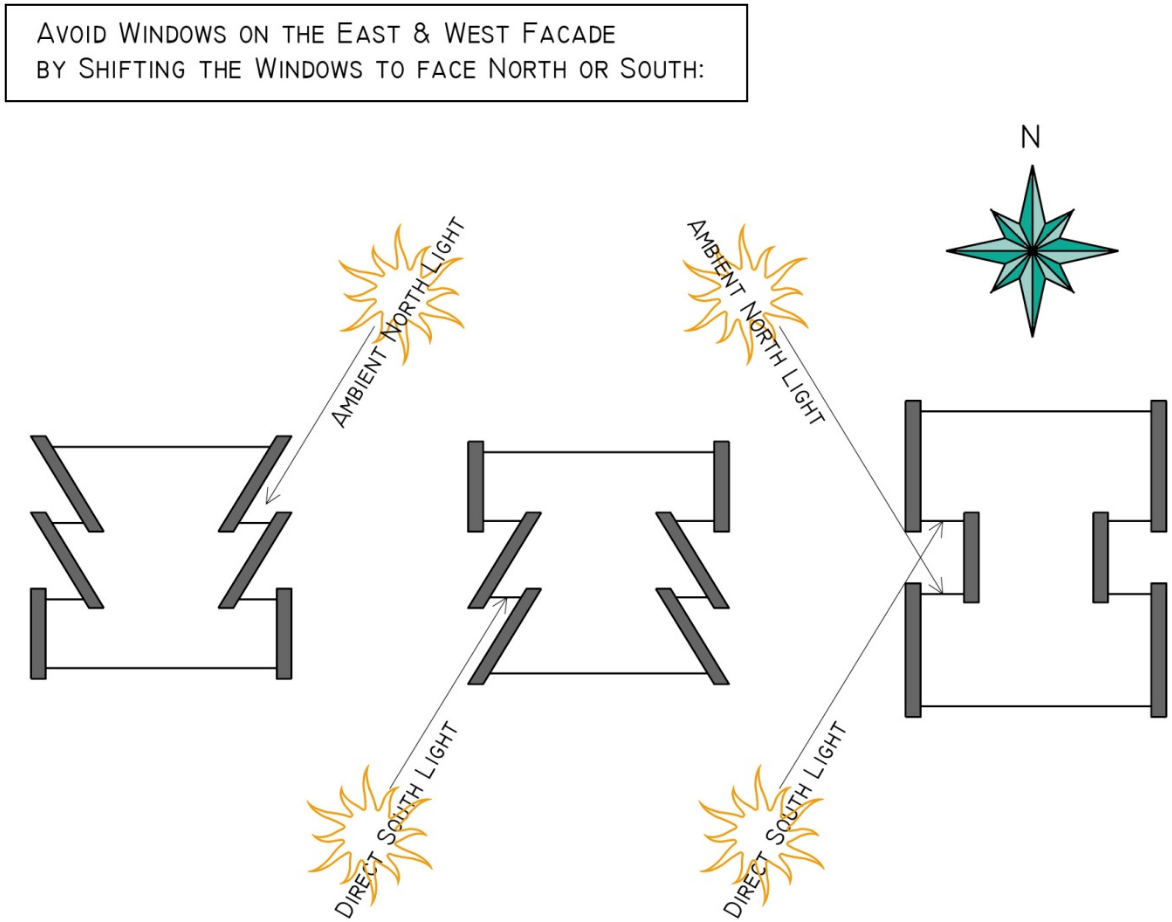
East and West Façade Strategies



East and west façade are both difficult to shade as the sun angles are low and <u>horizontal shades do not work</u>.

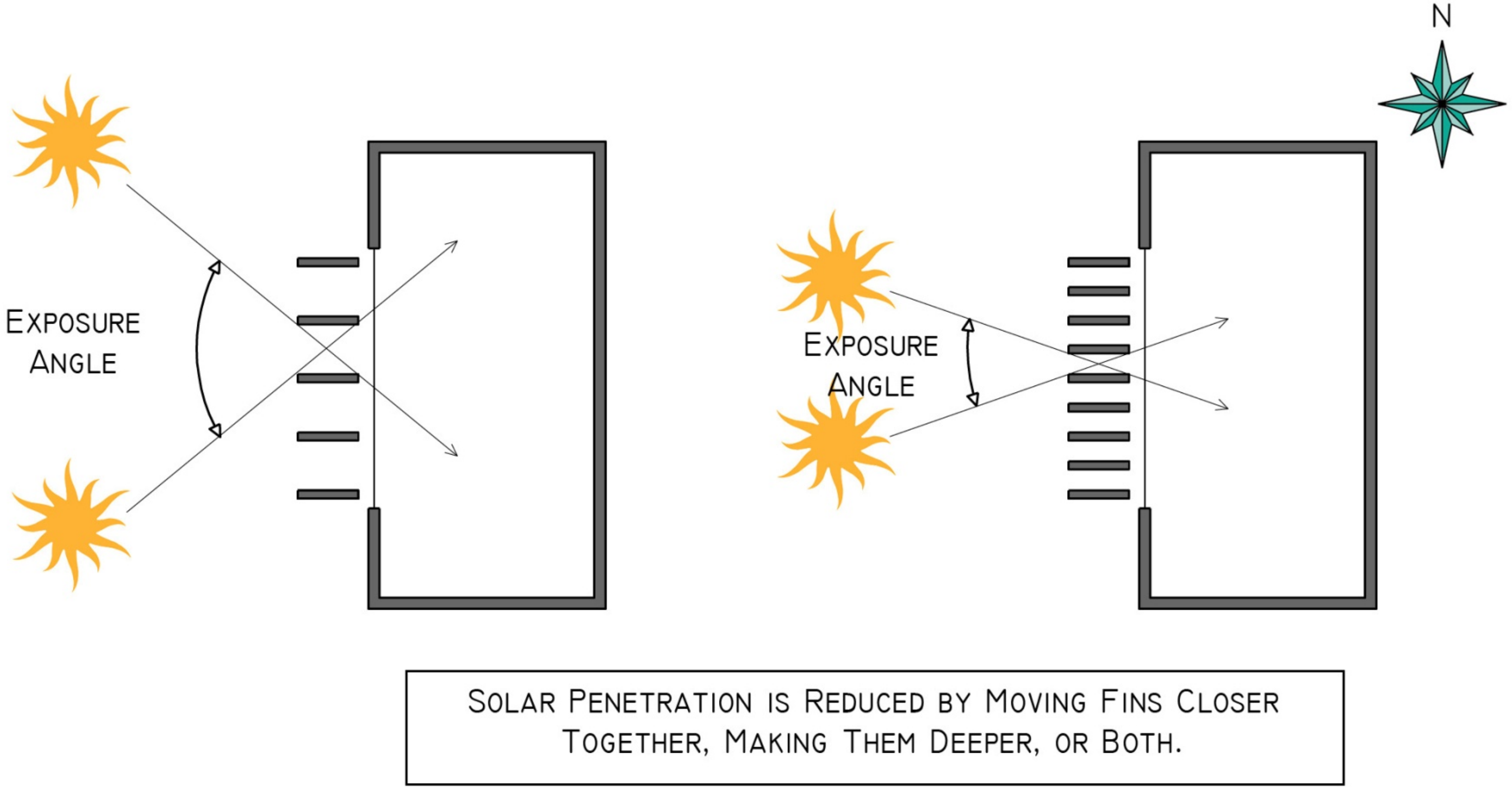
Shading Strategies for East and West Elevations

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



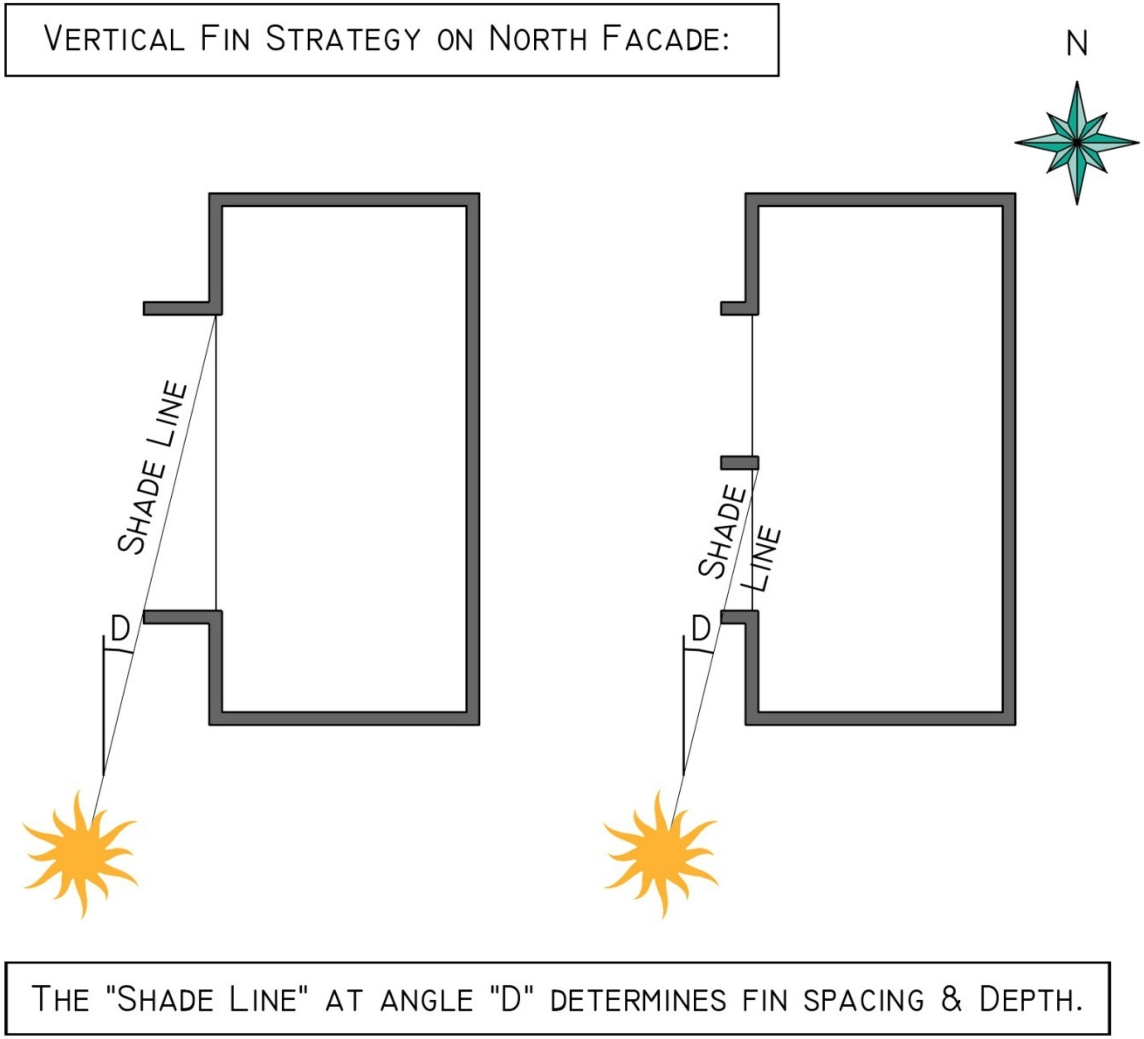
2. Next best solution is to have windows on the east and west façades face north or south

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.

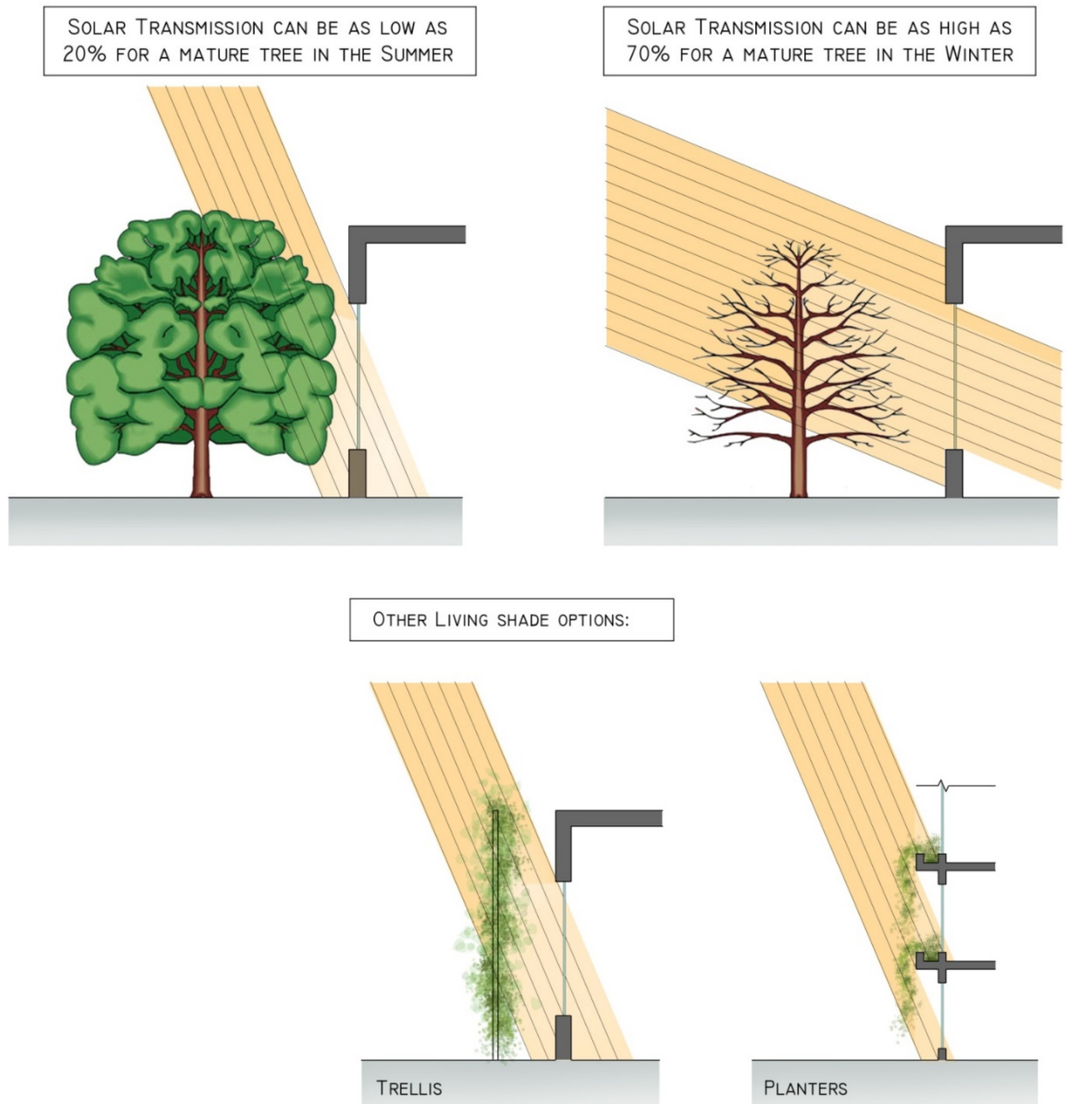
Shading Strategies for the North Elevation



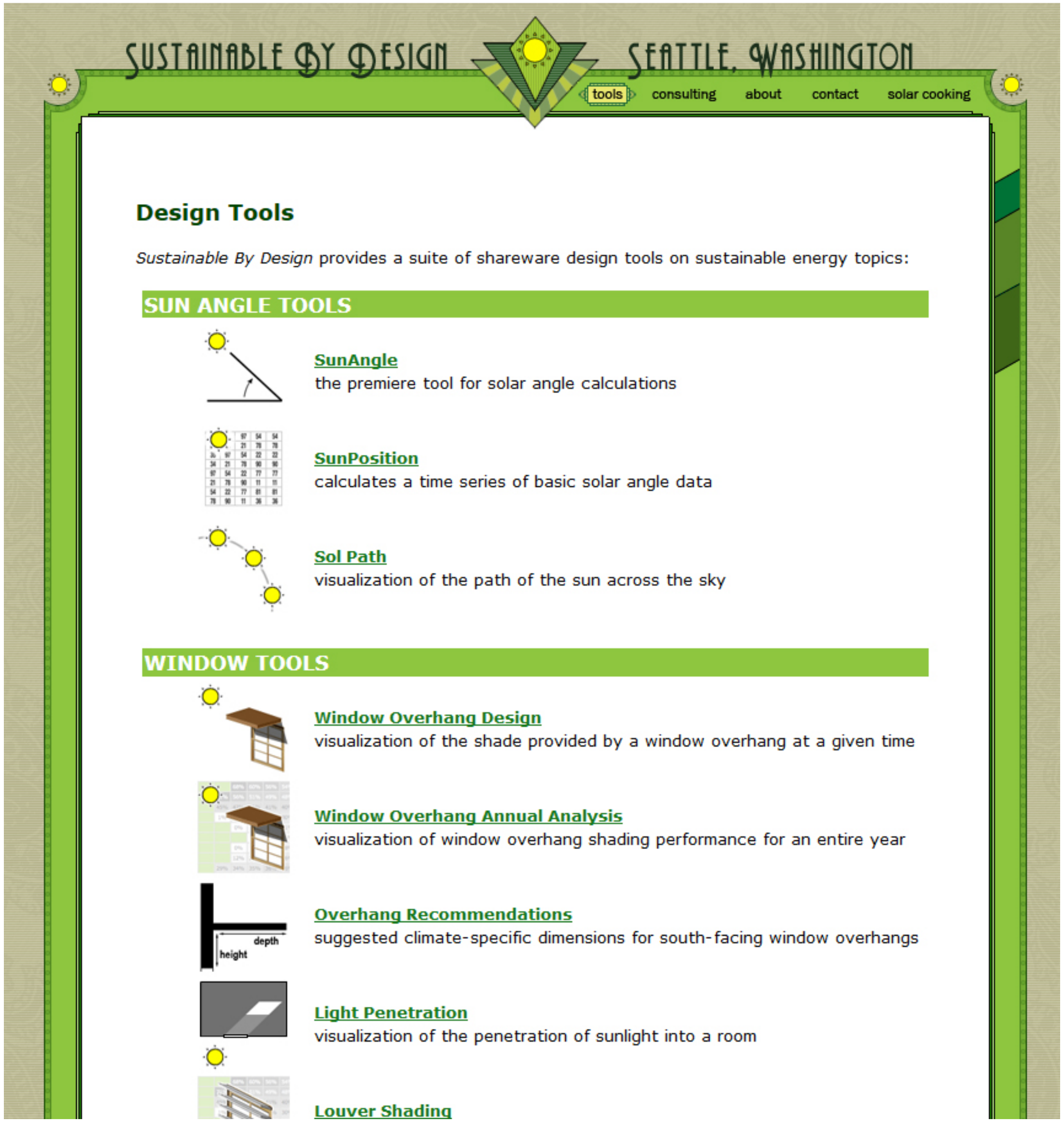
The sun also hits the façade from the north east and north west during the summer. Fins can be used to control this oblique light as well. It is a function of the latitude, window size and fin depth/frequency.

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.

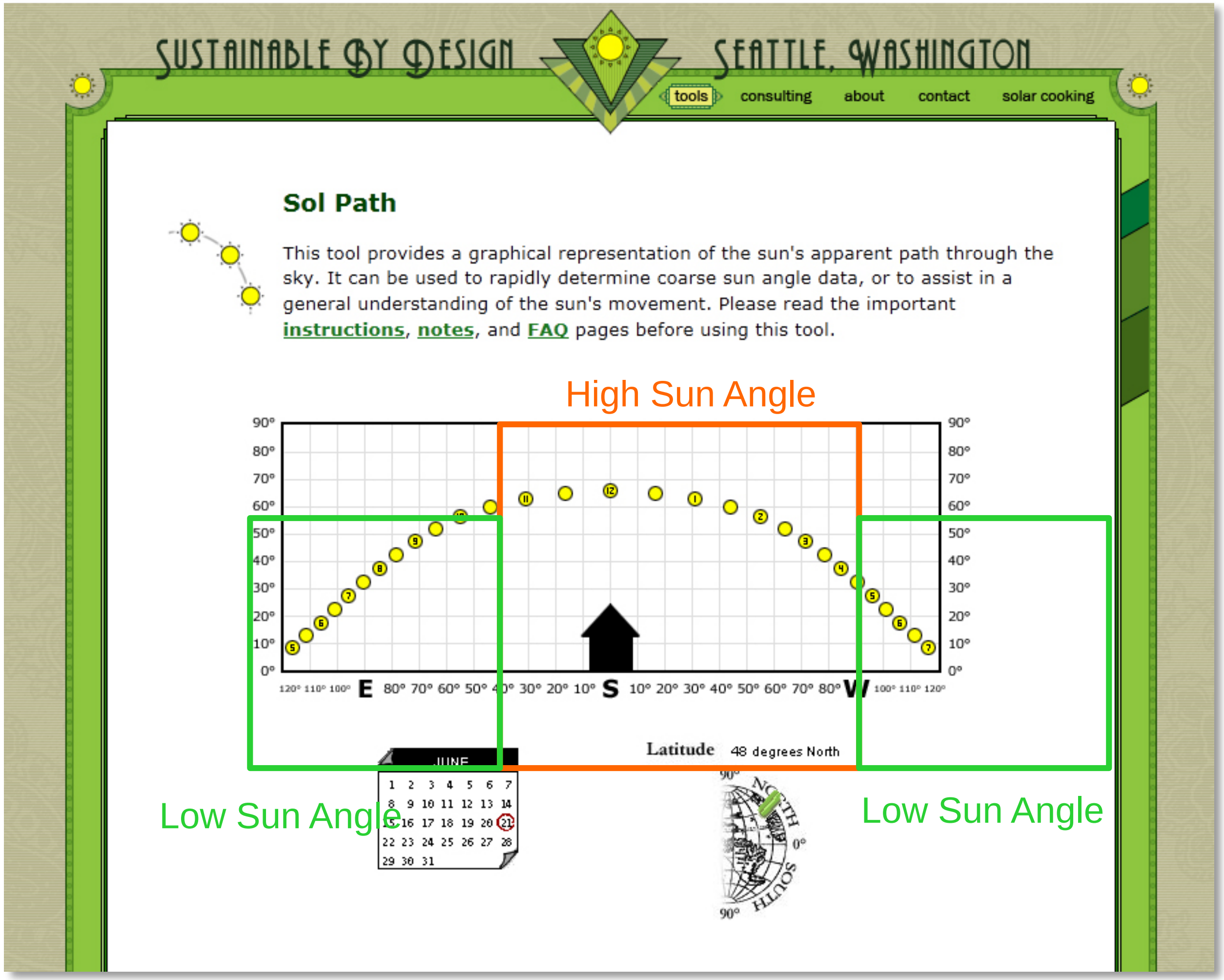


Helpful online tools



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

Shading Devices and the Envelope

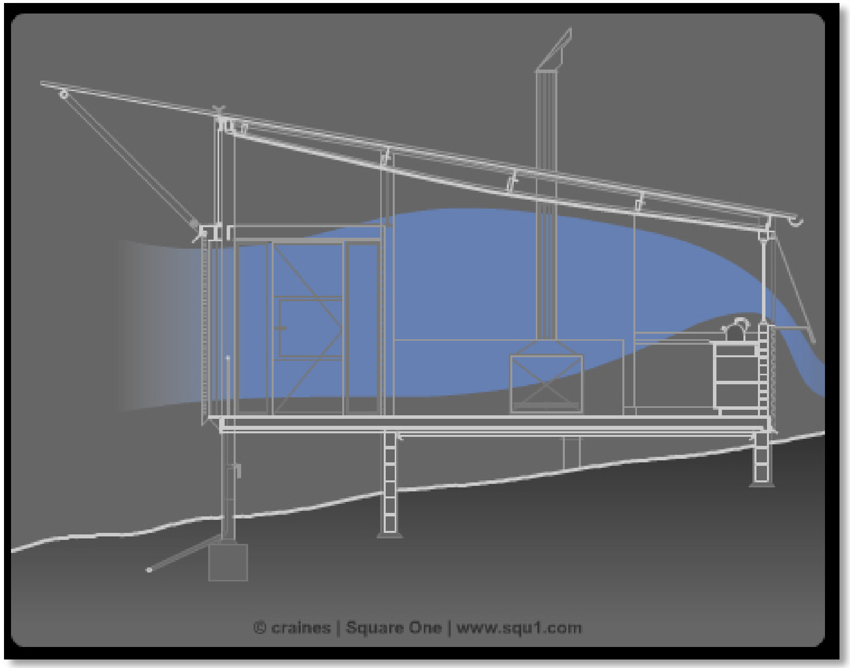
- Can be an extension of the roof
- On multi storey buildings normally attached to the envelope
- Can be incorporated into the curtain wall
- Must contend with snow loading
- Must be durable and low maintenance

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

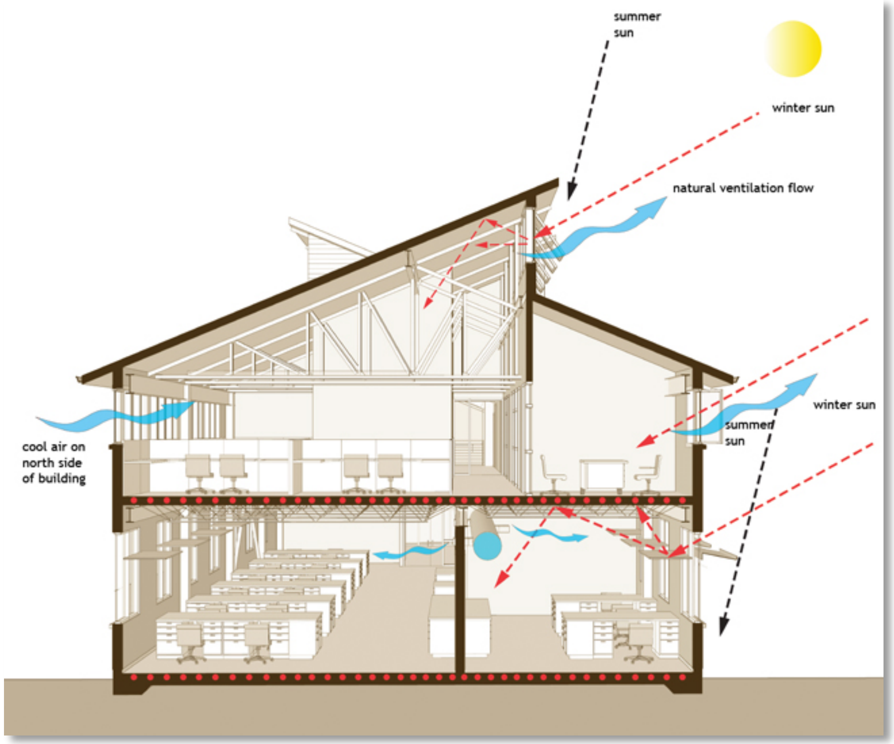
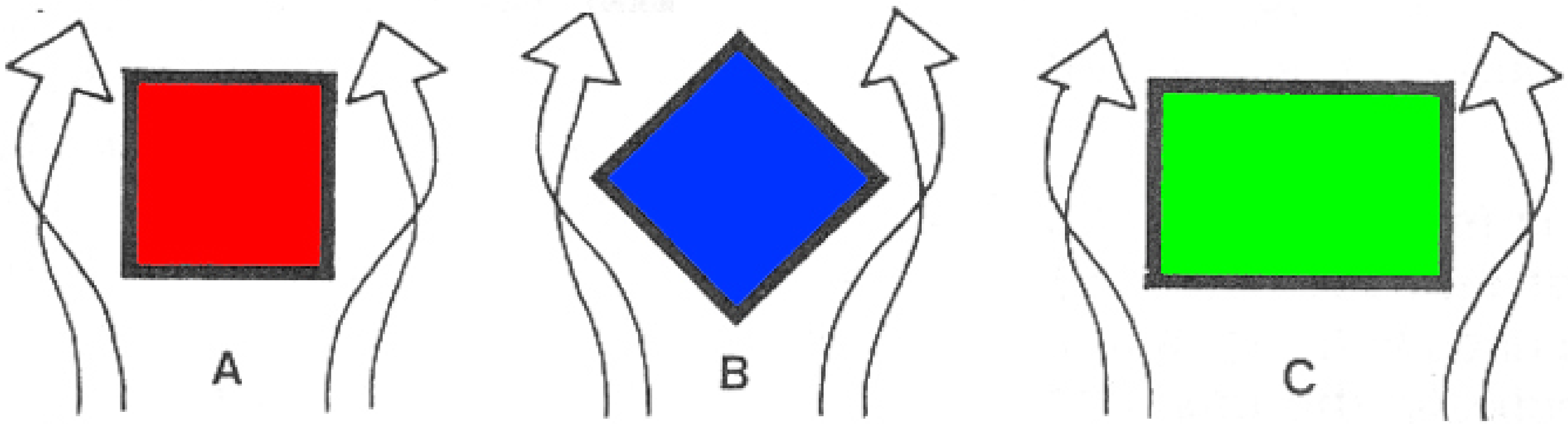


FIG. 10d. A compact form–in plan as well as section–is the first rule in minimizing wind exposure. Orientation is equally important: plan B has the same configuration and area as plan A, yet orientation increases its apparent width to the same as C when rotated 45°.



CBD

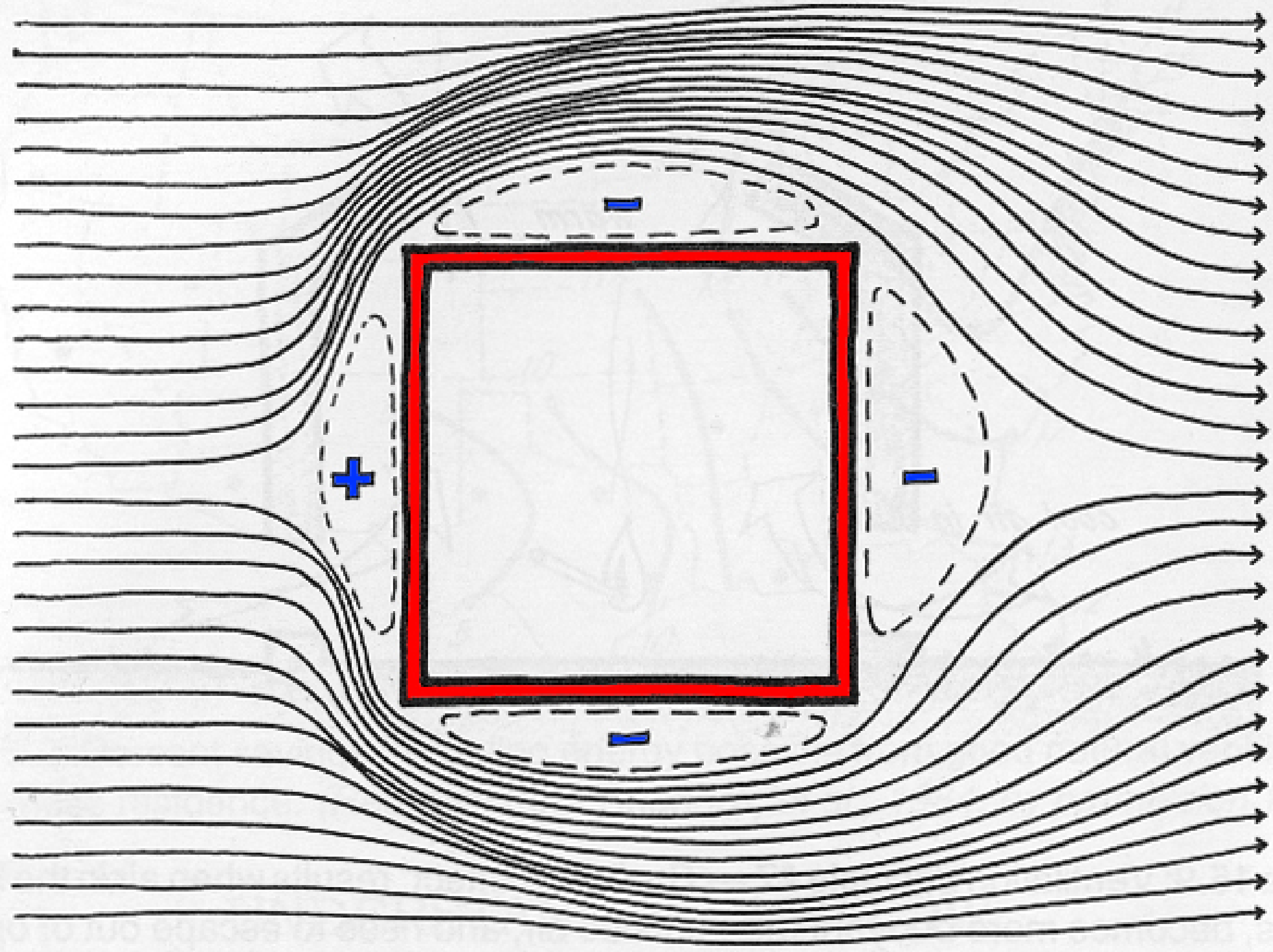


Figure 15.11: Low-pressure zones occur along the sides parallel to the wind and on the leeward side of the building. *(After Bowen, 1981.)*

HCL

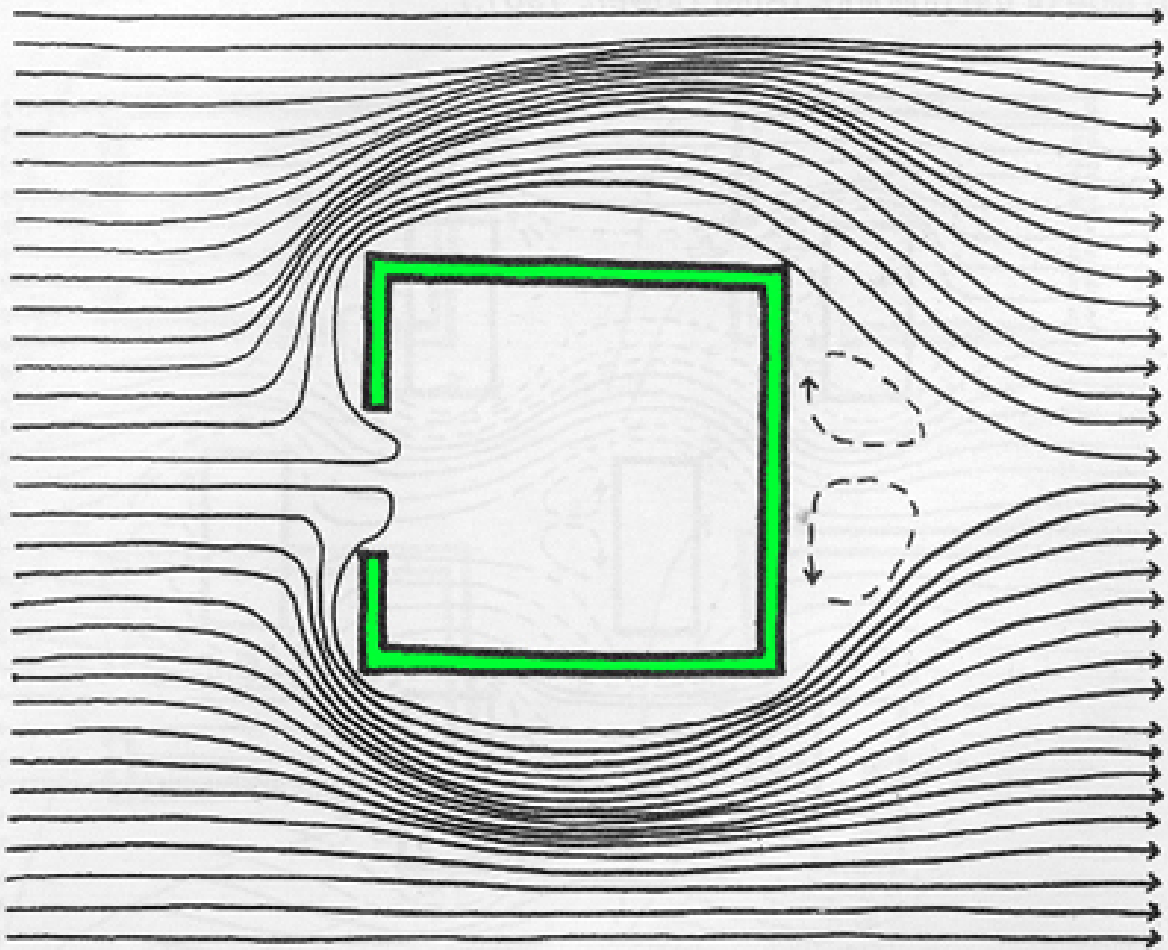


Figure 15.10: Ventilation principle #8 — Cross-ventilation requires an outlet as well as an inlet. (Analogy: water cannot be put into a bottle that is already full unless some old water is removed first — through a hole in the opposite end of the bottle, for example.)

HCL

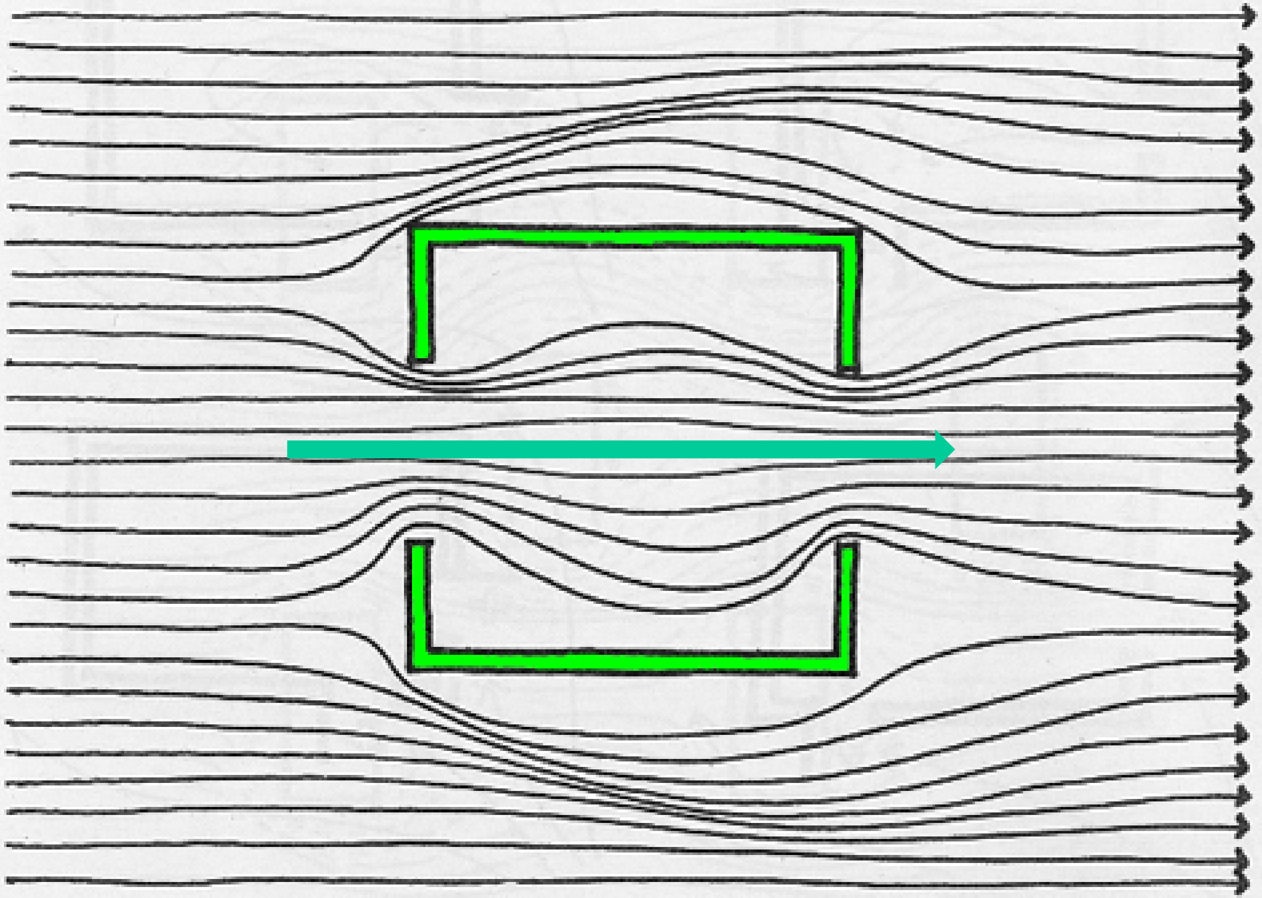


Figure 15.19: Openings of opposite walls relieve high pressure on the windward side, creating good cross-ventilation through the interior. Maximum *air exchange* is created when the inlet and outlet areas are equal, making this the optimum configuration when *building* cooling is the goals. *(After Bowen, 1981.)*

HCL

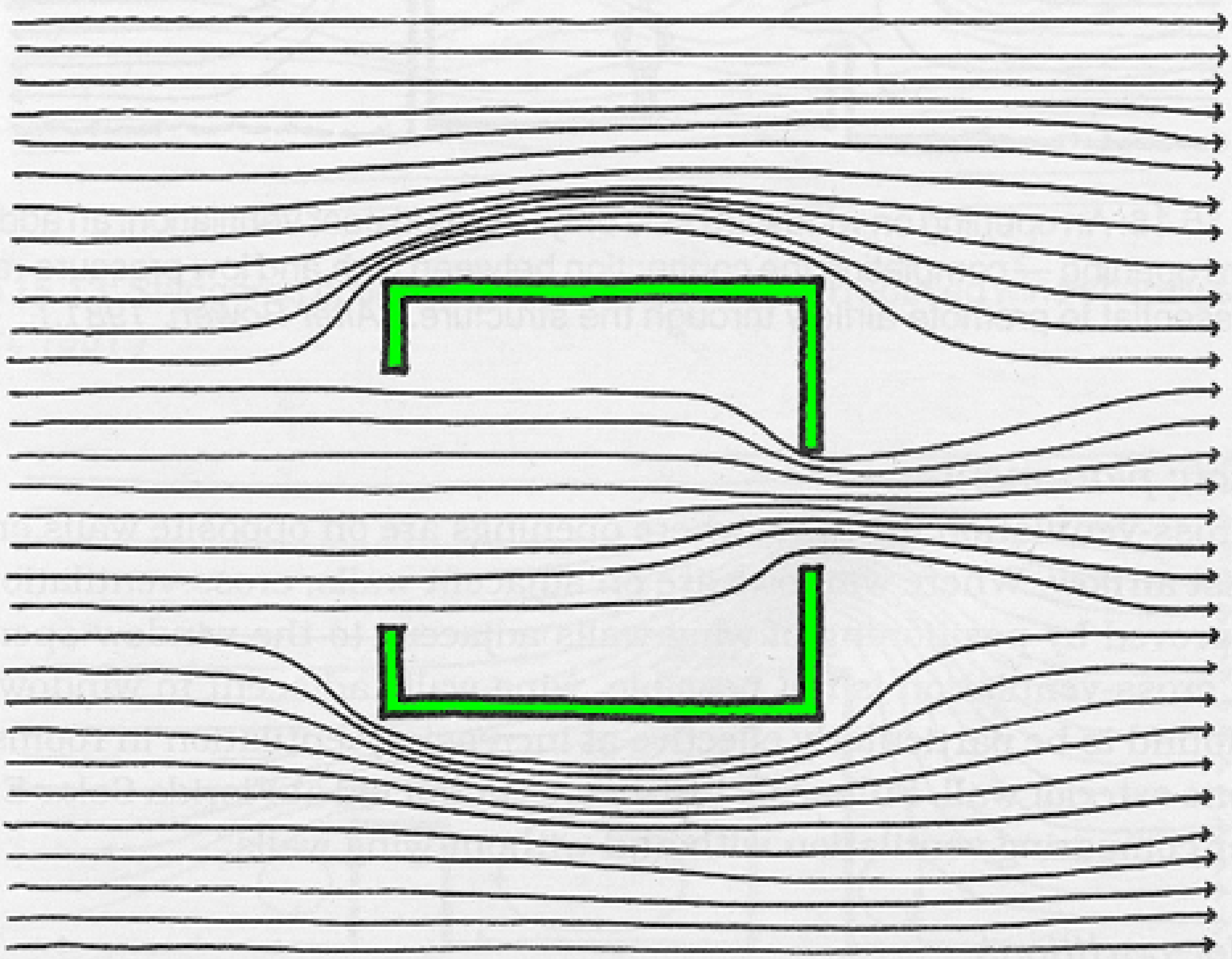


Figure 15.21: If the inlet is larger than the outlet, velocity in the room is reduced (although velocity outside just to leeward of the outlet is increased). This has potential for cooling a localized exterior area such as a patio. *(After Bowen, 1981.)*

HCL

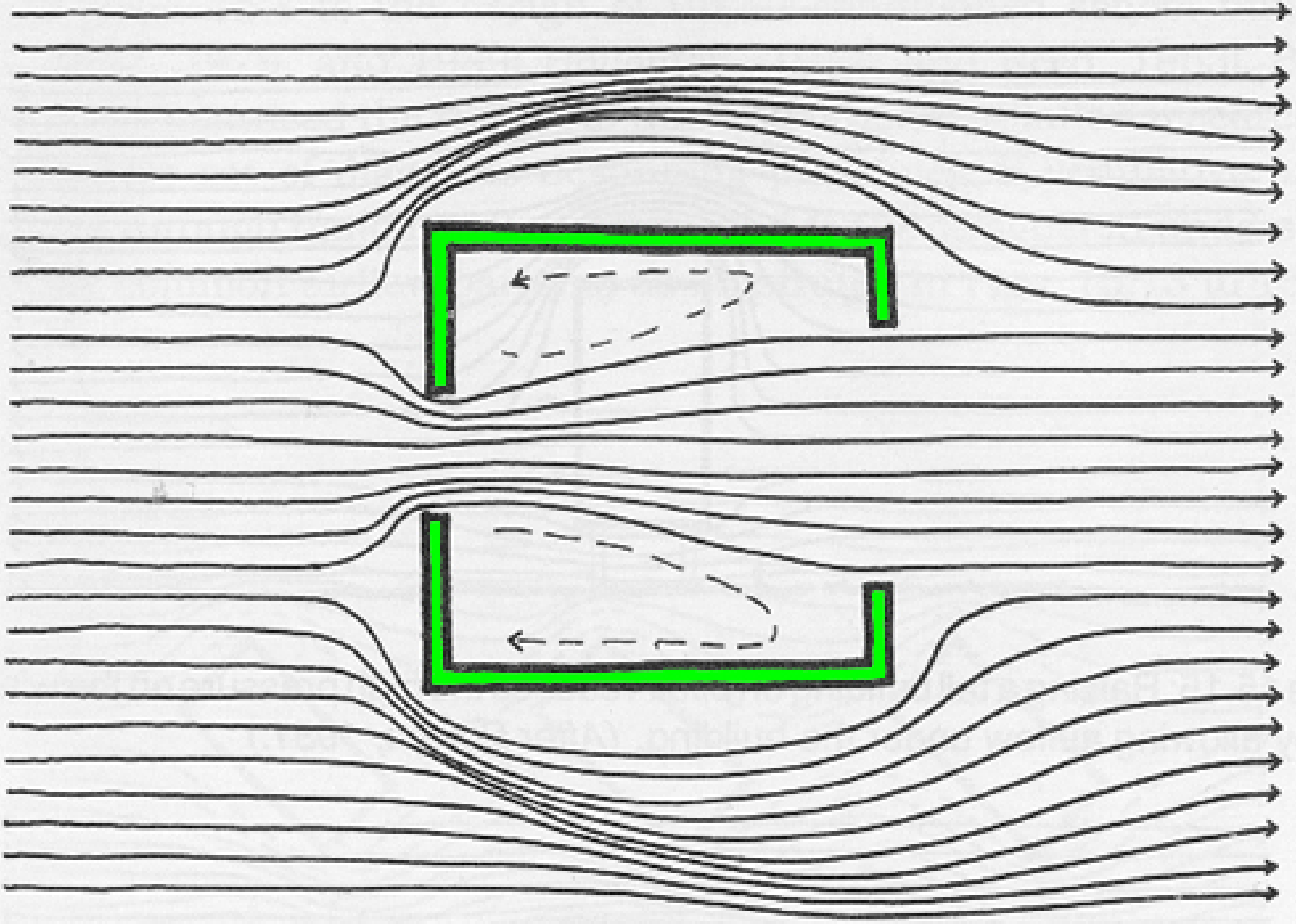


Figure 15.20: Maximum *interior airspeed* is created when the inlet is smaller than the outlet, making this the optimum configuration when *people* cooling is the goal. *(After Bowen, 1981.)*

HCL

IMPORTANT!

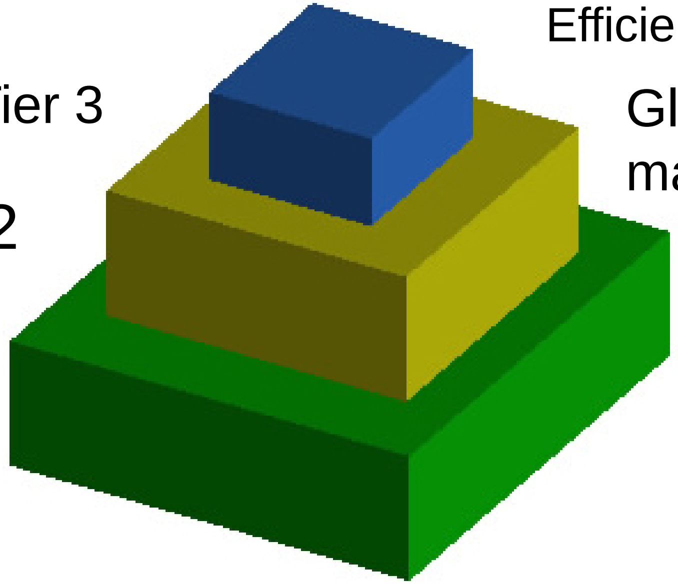
For natural ventilation to work you need:

<u>OPERABLE</u> WINDOWS – the more the better in our climate

<u>FLOW THROUGH ABILITY</u> – 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.

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

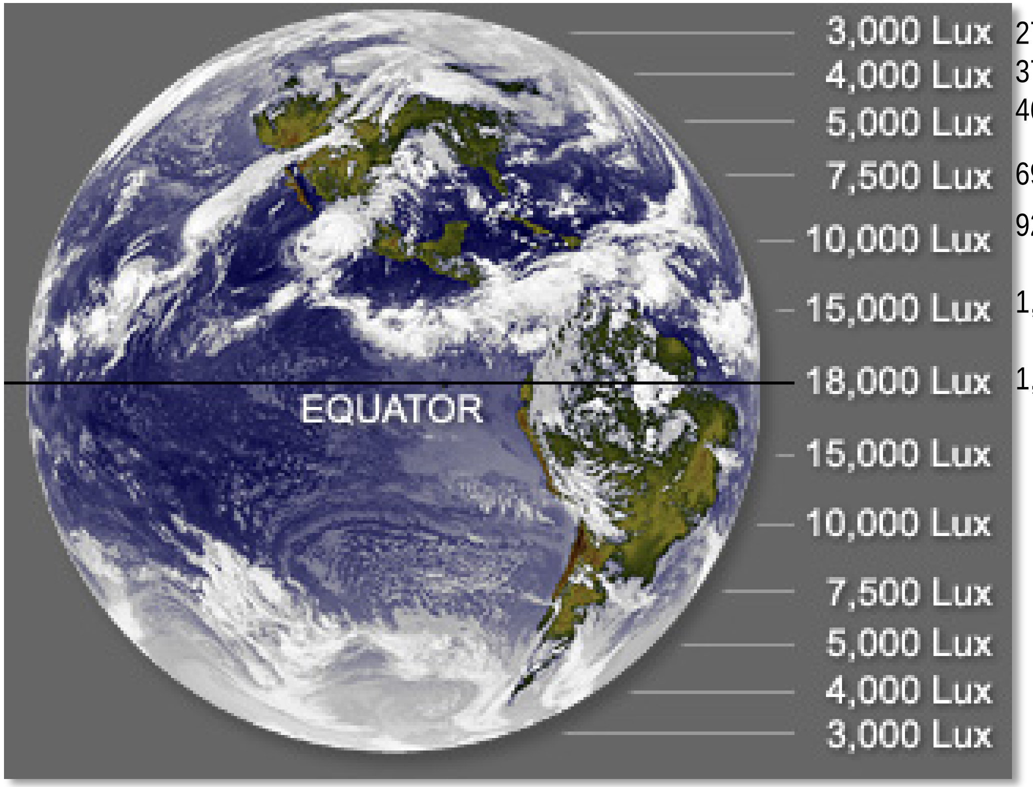
	Brightness (cd/sq. ft.)*	
Sidewalk on a dark night	0.0003	Poor vision
Sidewalk in moonlight	0.003	
Sidewalk under a dim streetlight	0.03	
Book illuminated by a candle	0.3	
Wall in an office	3	Normal indoor brightness
Well-illuminated drafting table	30	
Sidewalk on a cloudy day	300	Normal outdoor brightness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

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.

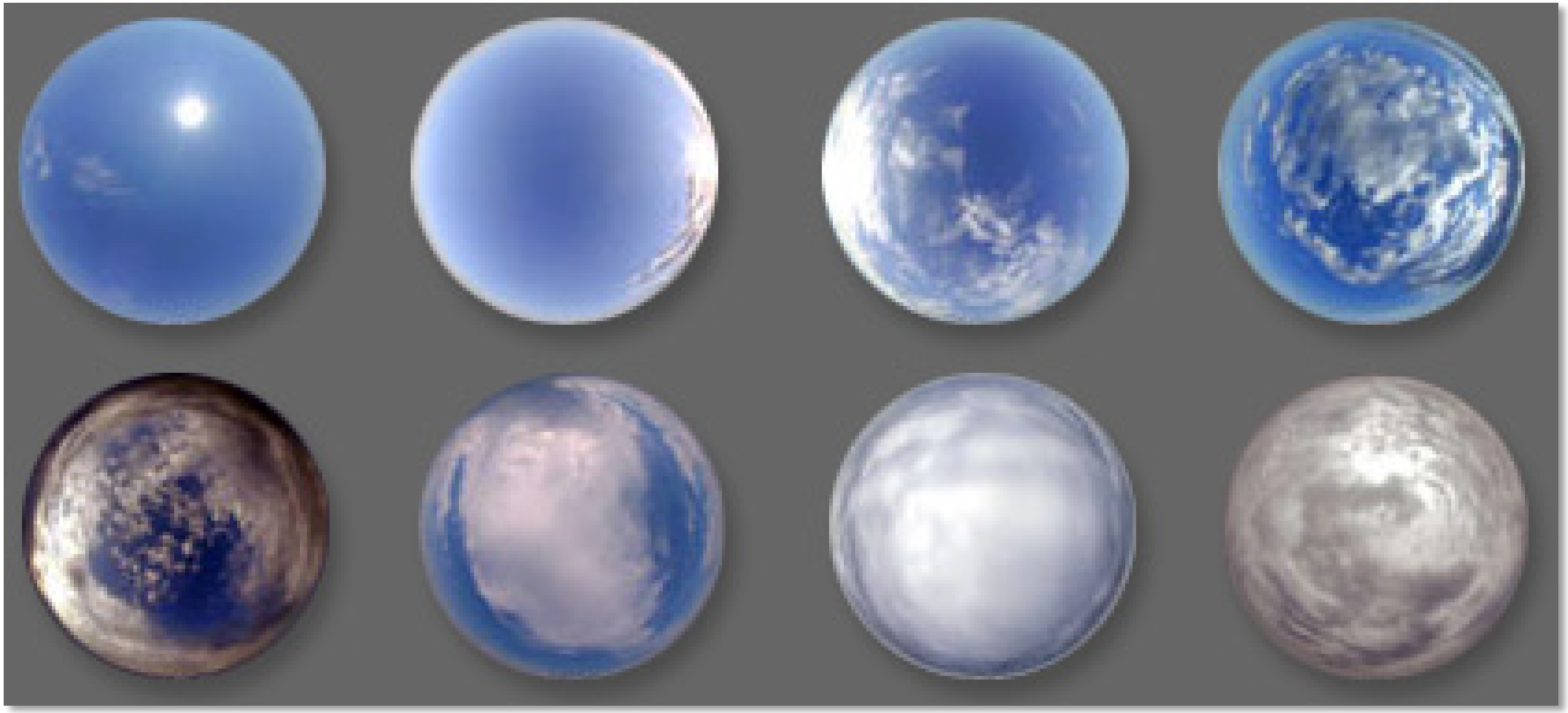
Design Sky Values

Design Sky values are derived from a statistical analysis of outdoor illuminance levels. They represent a horizontal illuminance level that is exceeded 85% of the time between the hours of 9am and 5pm throughout the working year. Thus they also represent a worst-case scenario that you can design to and be sure your building will meet the desired light levels at least 85% of the time.



279 footcandle
372 footcandle
465 footcandle
697 footcandle
929 footcandle
1,393 footcandle
1,672 footcandle

Sky Types



Examples of different sky distributions: These images are the result of taking photographs using a fish-eye lens. Such images capture the full hemisphere of the sky, with the horizon around the perimeter and the zenith in the centre.

The “sky dome” for the location must also be considered when designing for daylighting. Local obstructions to the sky dome will affect the amount and quality of light received.

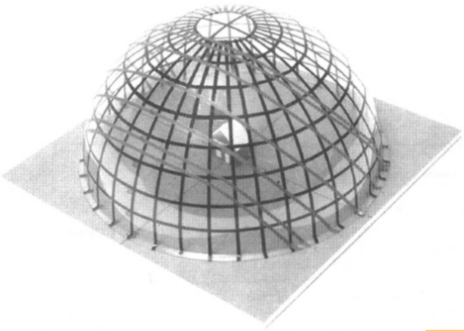
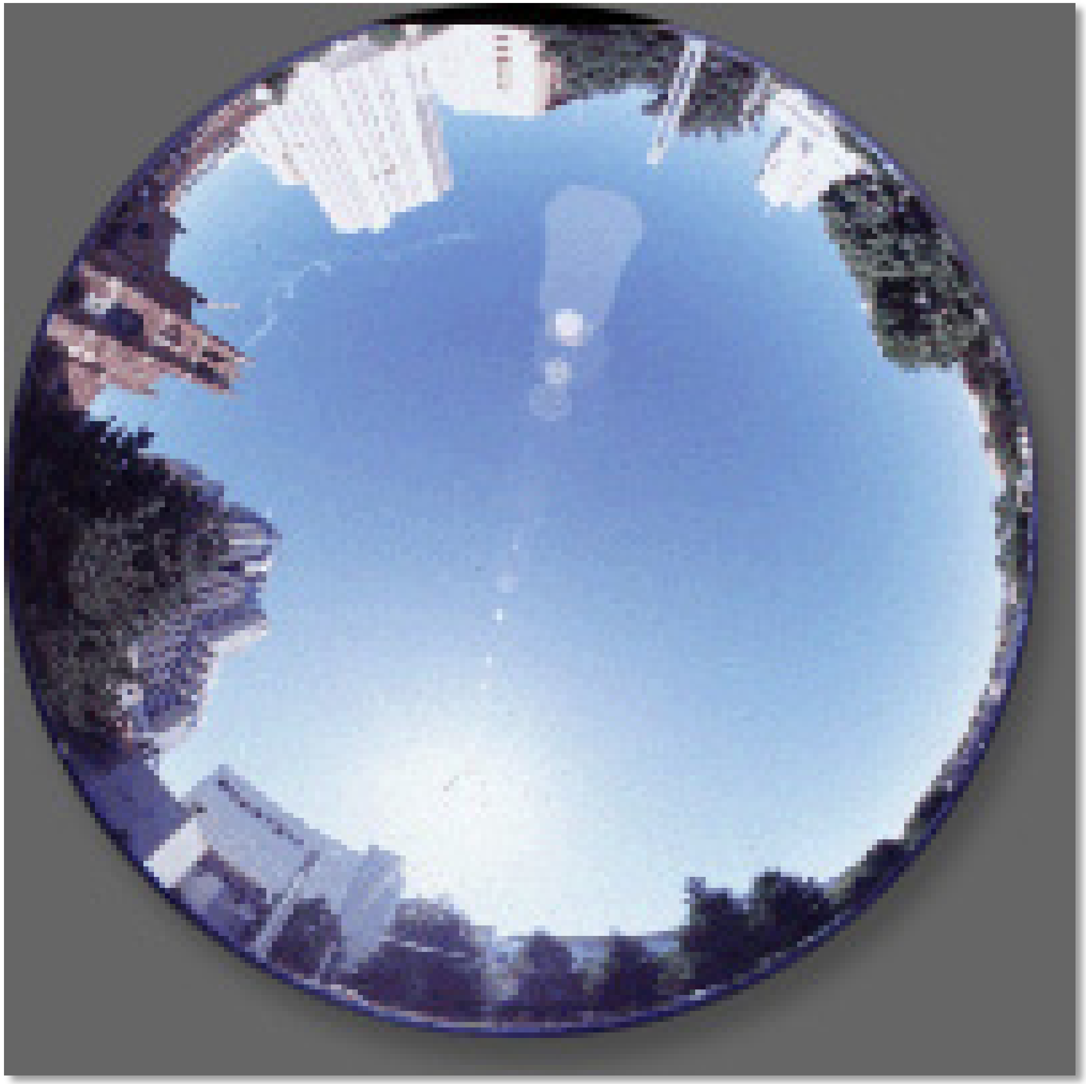
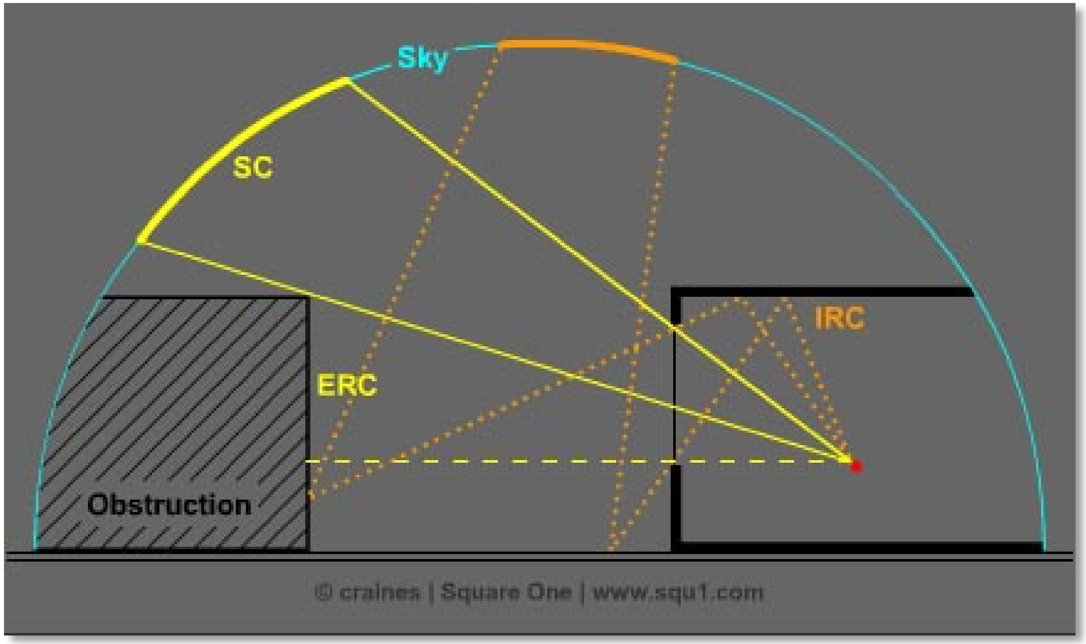


Figure 6.11b A model of the sky dome. The sun paths for the 21st day of each m
are shown. Only seven paths are needed for twelve months because of symmetry (i.
May 21 is the same path as July 21.

HCL



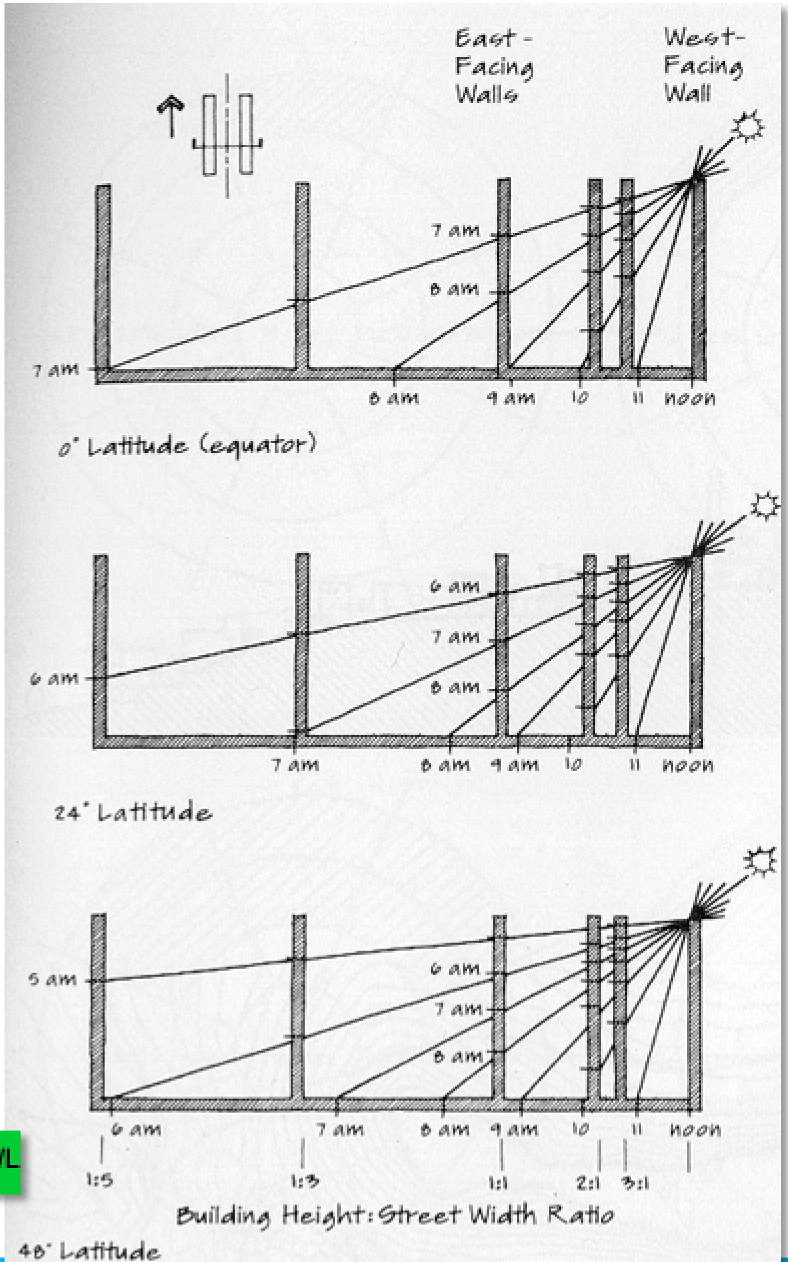


Unlike electric lighting, the total available light is fixed (in this case the worst-case Design Sky Illuminance), thus control over the amount of light is possible only by changing the means of transmission into the space through its apertures, and then to points deeper within the space by its distribution system. This means that architectural elements such as windows, skylights, lightshelves and even the reflectivity of internal surfaces are very important factors in daylighting design. So too are external elements such as site obstructions and applied shading devices.

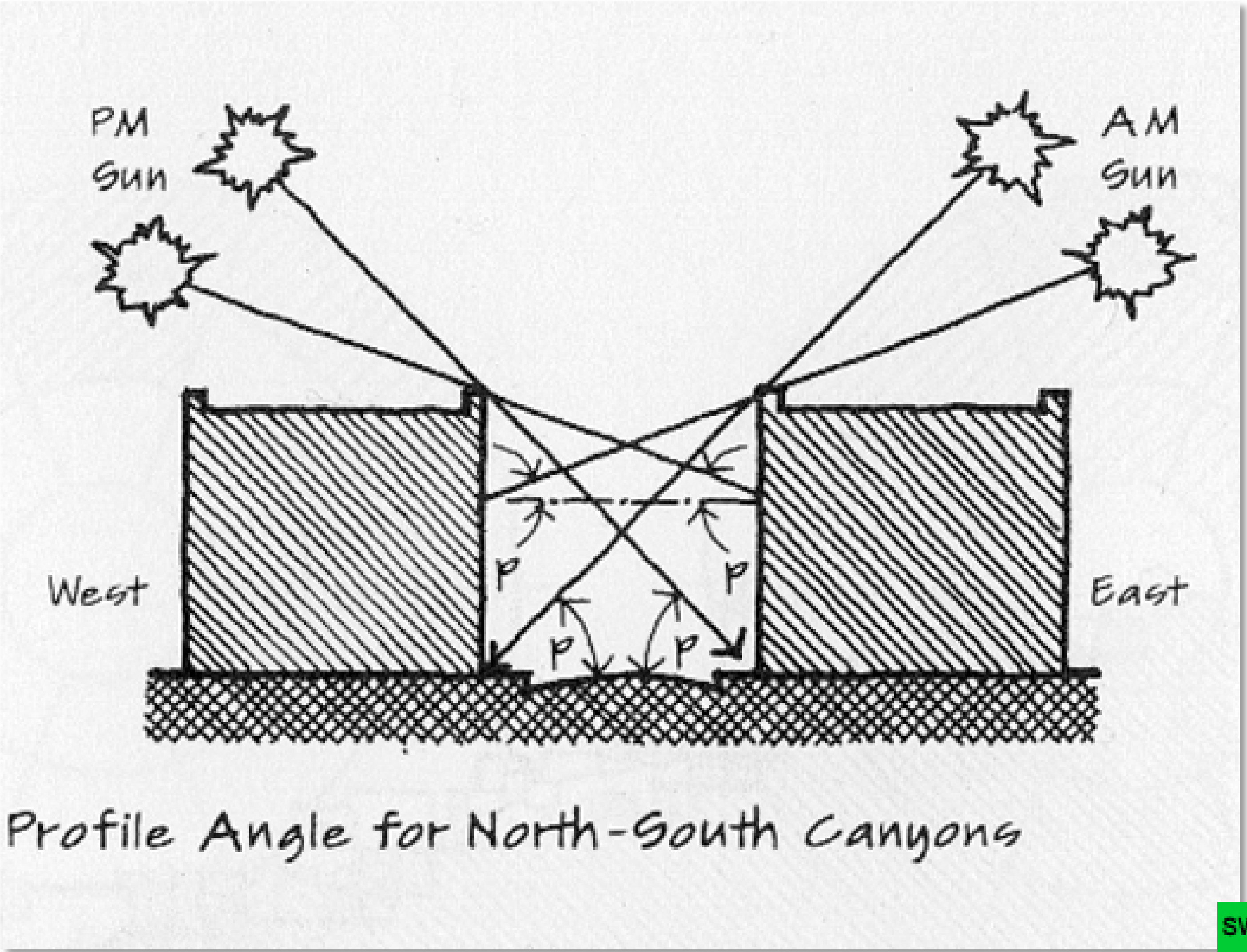
Building spacing and orientation will also need to be factored in when determining the amount of available light or sunlight for the building on its various sides.

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

SWL



Impact of Cross-Section on Shading Patterns, North-South Canyons on Jun 21


PM
Sun
AM
Sun
West
East
p
p
p
p
Profile Angle for North-South Canyons
SWL

North-south canyon on Avenue Road, north of St. Clair

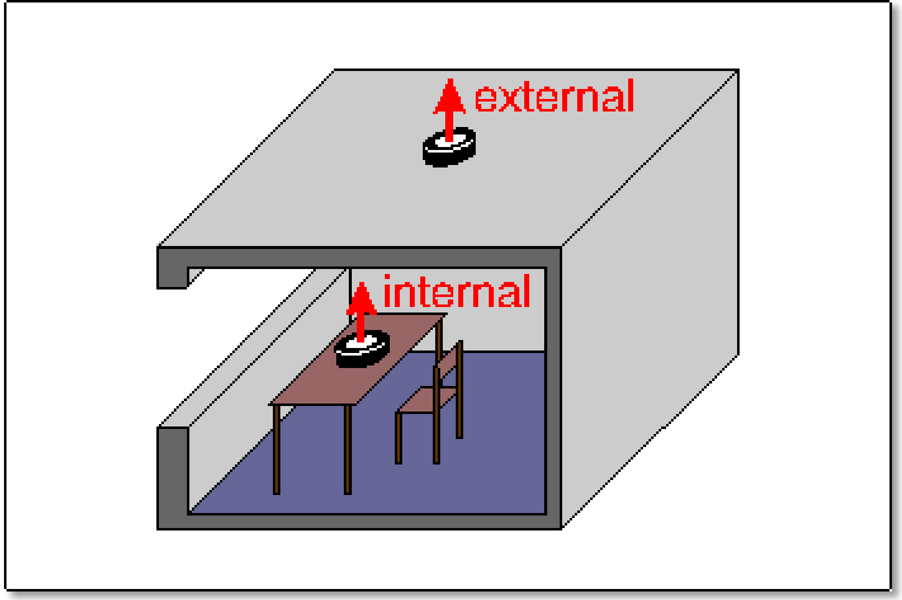
Looking due east between two tall apartment buildings. Daylight is limited in this direction as well.

Daylight Factor

The daylight factor (DF) is a very common and easy to understand measure for expressing the daylight availability in a room under the same sky conditions.

It describes the ratio of outside illuminance over inside illuminance, expressed in per cent. The higher the DF the more natural light is available in the room.

Range is usually 0 - 100%, but for most rooms is usually 1 - 10%.



The definition of a daylight factor

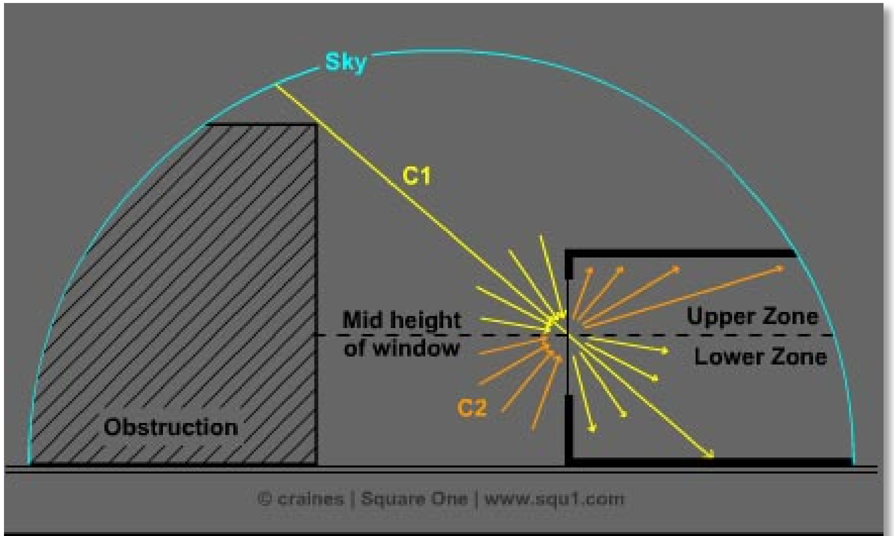


Figure 1 – Factors affecting the penetration of daylight into a space.

Daylight Factor

2% average daylight factor

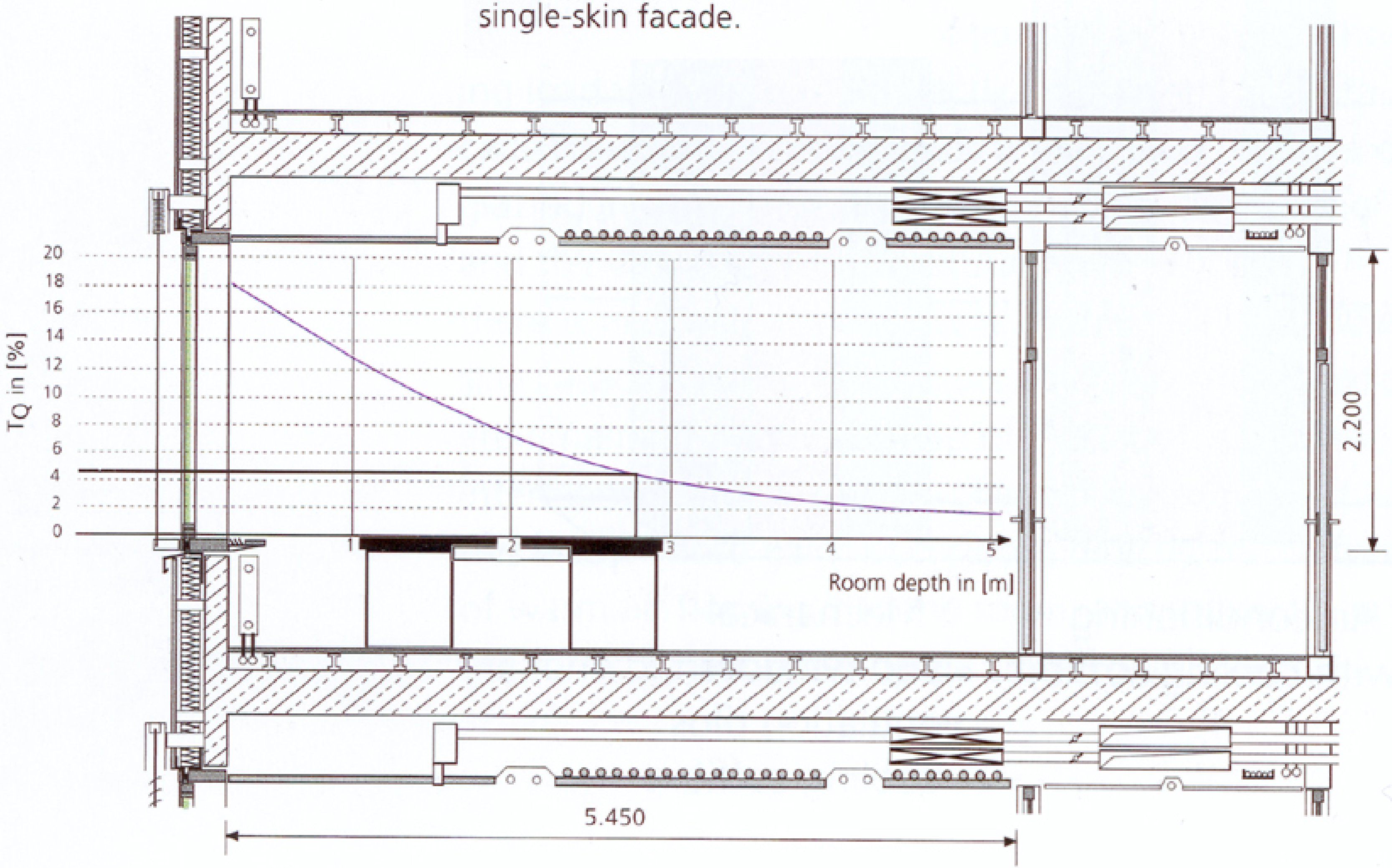
5% average daylight factor

Daylight Factor

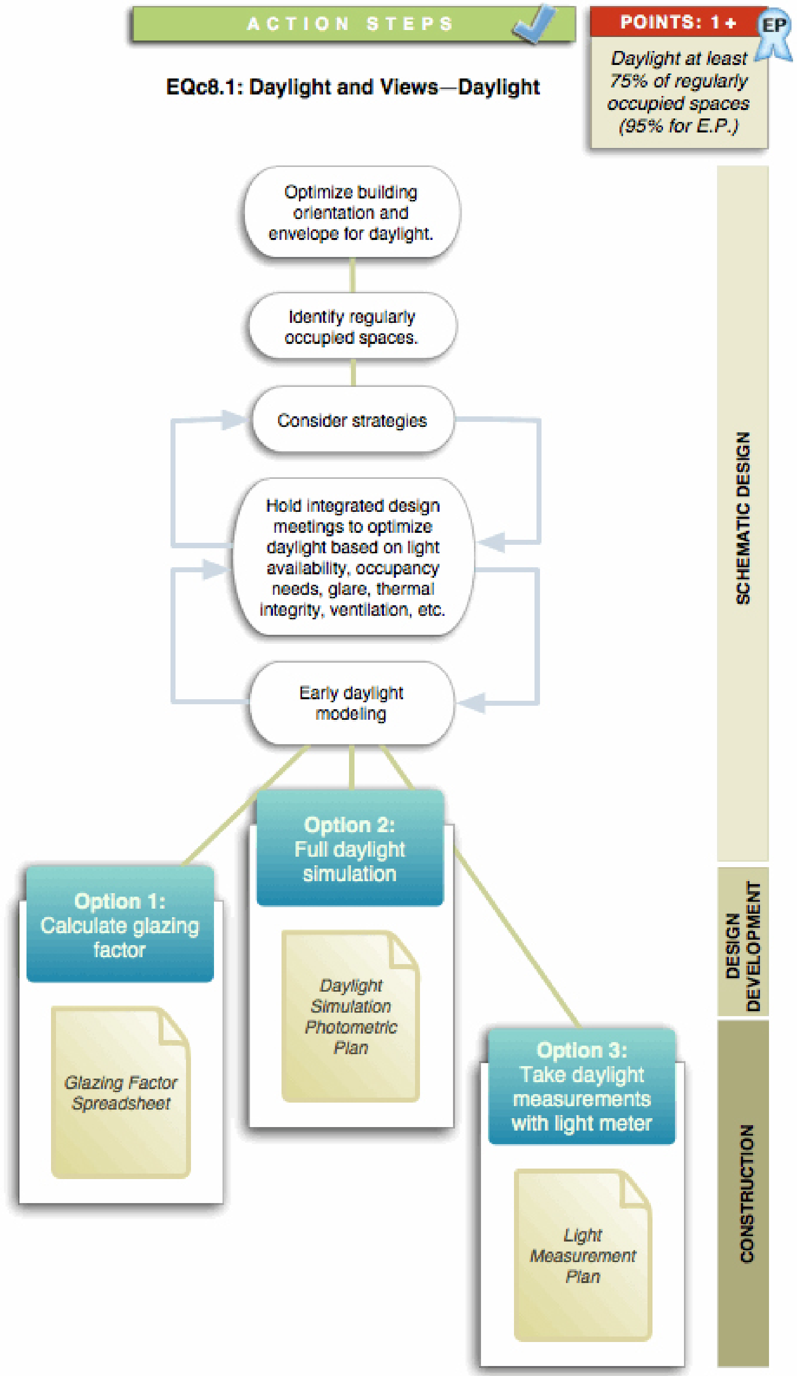
Building Type	Recommended Daylight Factor %
Dwellings	
Kitchen	2
Living room	1
Bedroom	0.5
Schools	2
Hospitals	1
Offices	
General	1 to 2
	2
Drawing offices	2
(on drawing boards)	6
Typing and computing	4
Laboratories	3 to 6
Factories	5
Art galleries	6
Churches	1 to 2
Public buildings	1

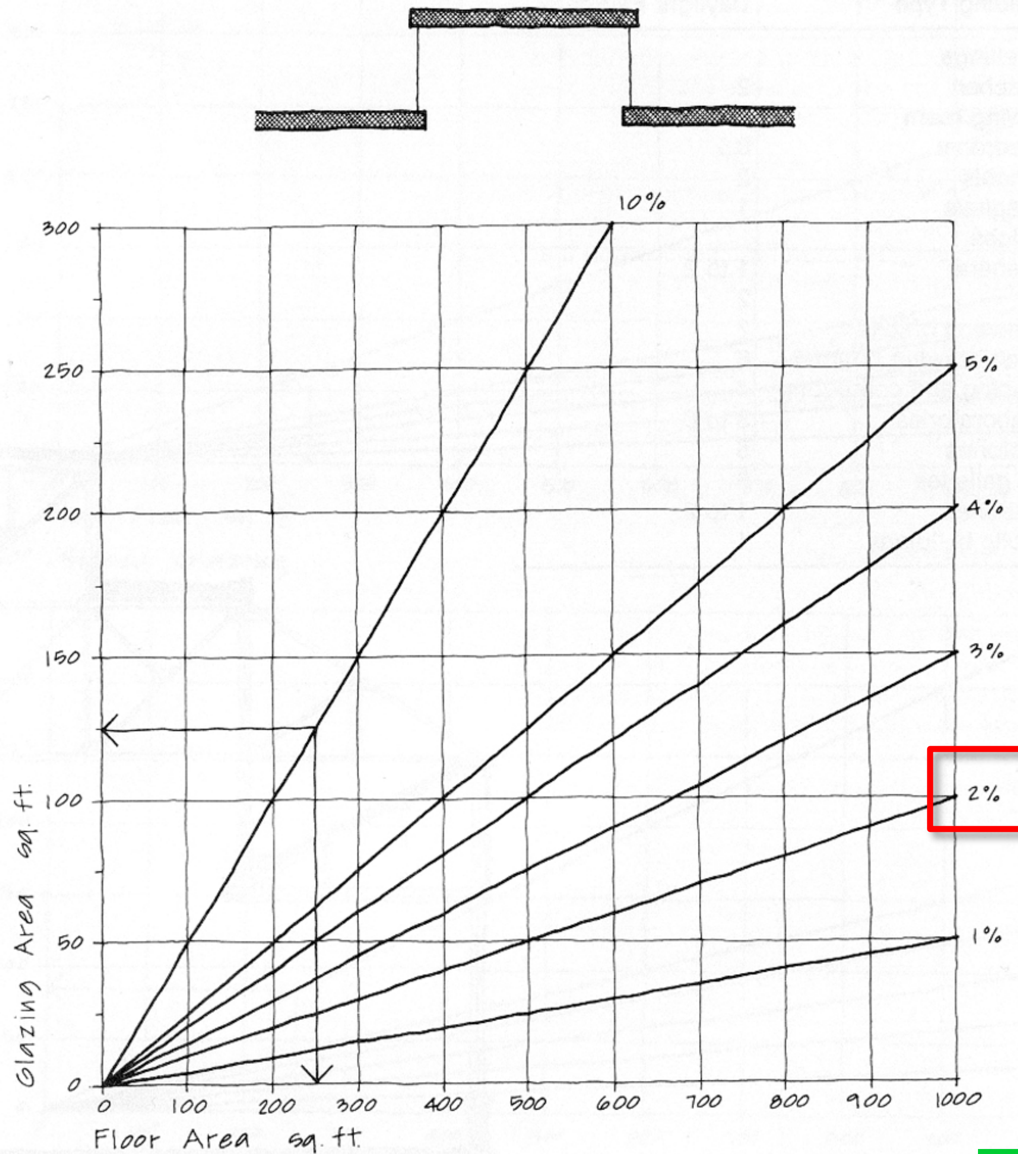
Note: LEED daylighting credits are tied to DF!

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



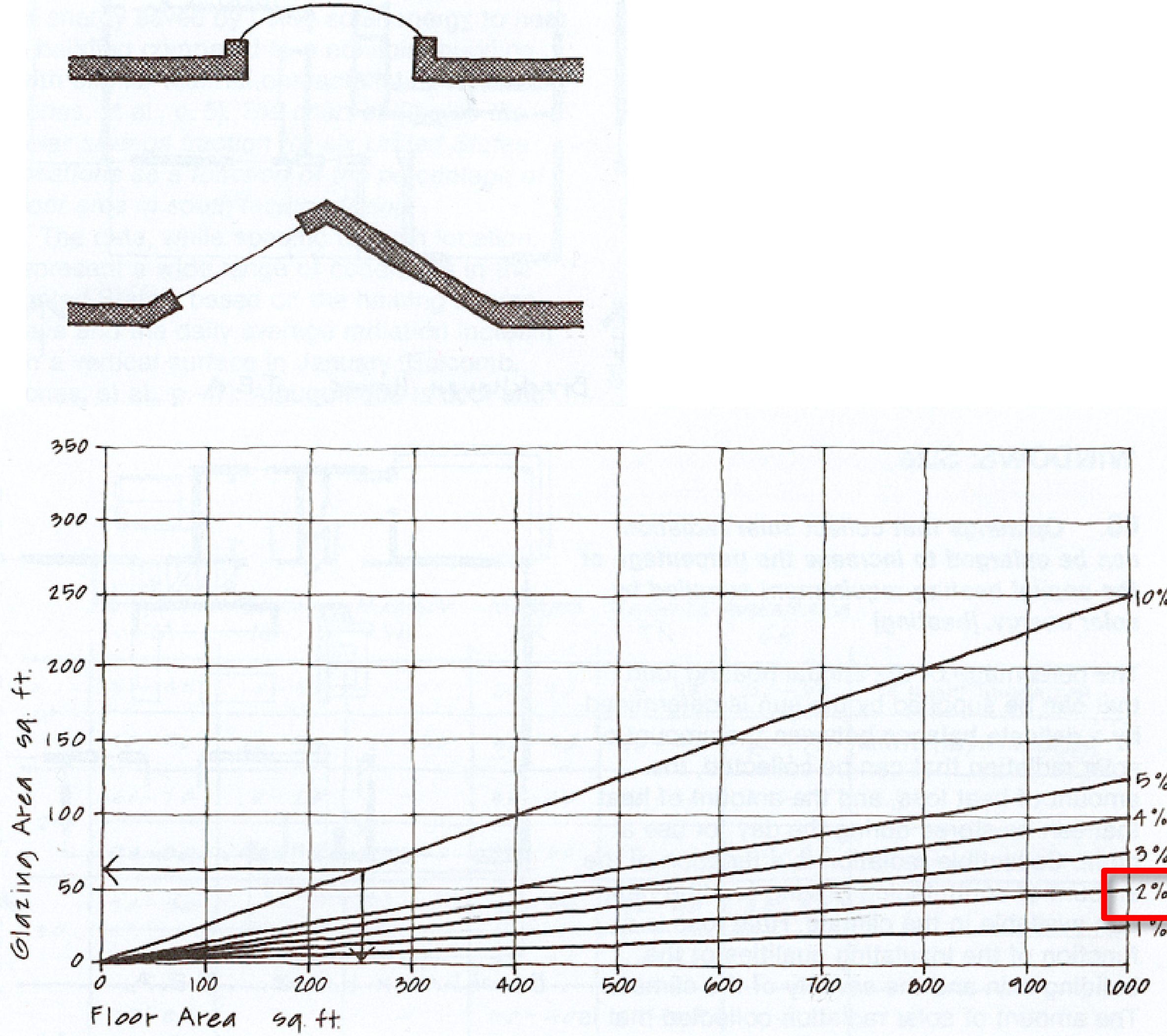
LEED requires a minimum Daylight Factor of 2% to qualify for any credits



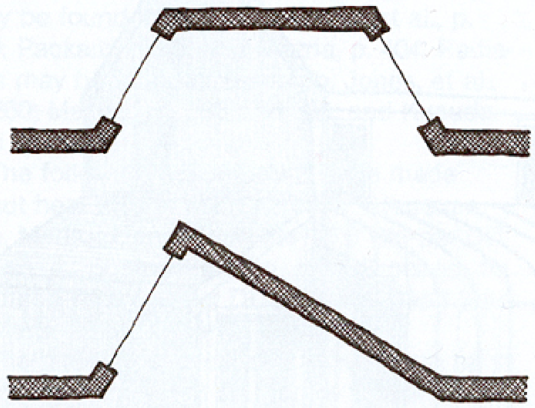


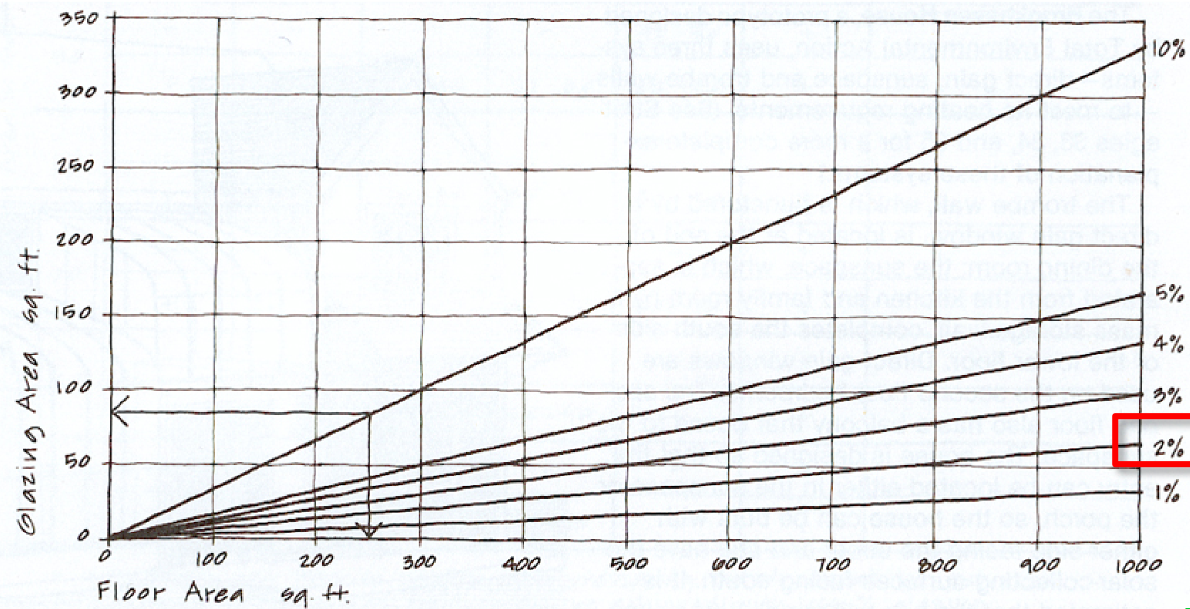
Daylight Factors for Sidelighting and Vertical Monitors

SWL



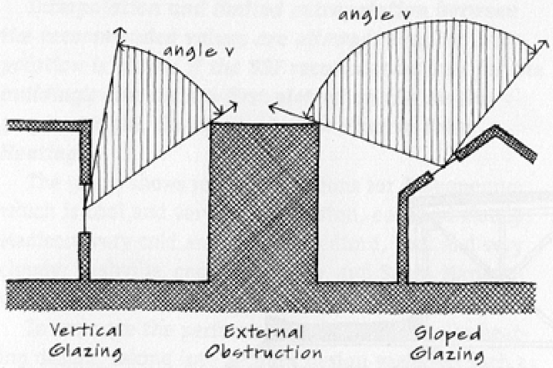
Daylight Factors for Horizontal and 30° Sloped Glazing





Daylight Factors for 60° Sloped Roof and Monitor Glazing

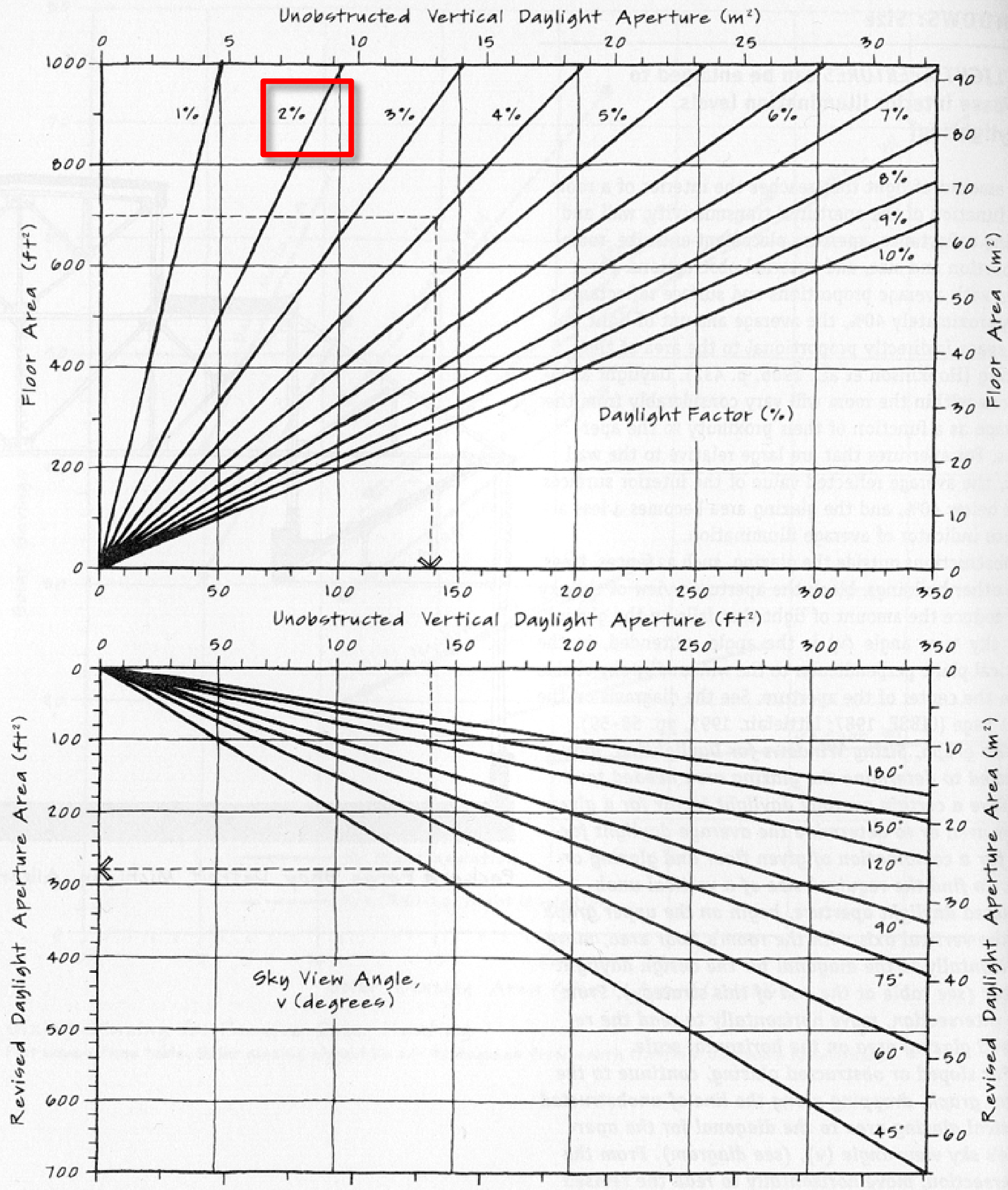
SWL



Sky View Angle (v) From Glazing

The graph assumes a 60% transmissivity for clear double glazing plus frame effects, a maintenance factor of 80%, an average room reflectance of 40%, and a fairly large room, about the size of a classroom. It was developed using a model from Littlefair (1988). If other glazing and frame types with poorer visible light transmission are used (Strategy 101), the glazing area will need to be increased proportionally. Because room size and proportions affect the pattern of internal reflections, light in small rooms is reflected more times before reaching the work plane than light in large rooms. ***For small rooms, such as bedrooms and private offices, increase the glazing size from the graph by up to 60%. For very large rooms, such as a gymnasium, reduce the glazing size by up to 30%.***

For sidelighting, the daylight factors apply to a floor zone with a maximum depth into the room of 2.5 times the height of the window wall (Strategy 71). For toplighting, the floor area associated with the glazing can be estimated by projecting 45° lines from the opening to the floor. If more than one opening type is used for the same area, the daylight factors may be added. An example of using more than one opening type is Albert Kahn's use of sidelighting and monitors in the **Packard Forge Shop** in Detroit, Michigan (Hildebrand, 1974, p. 57).



Sizing Windows for Daylighting

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

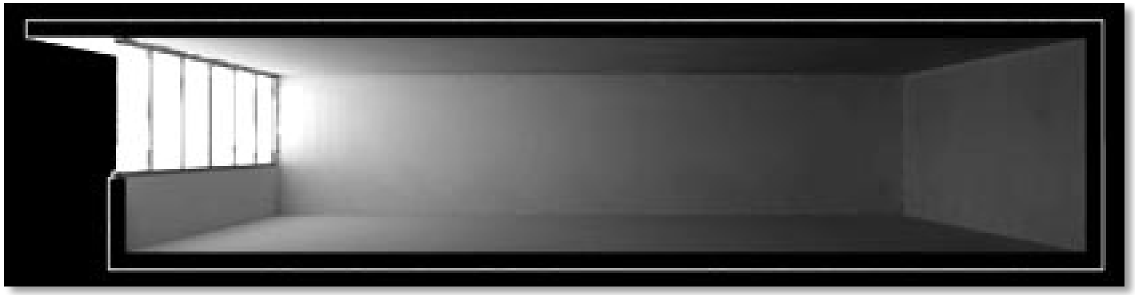
Solar Reflectance of Finishes

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

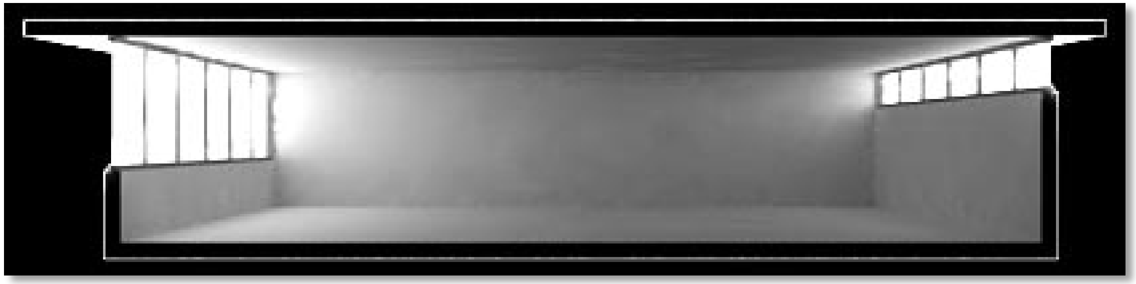
SWL

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

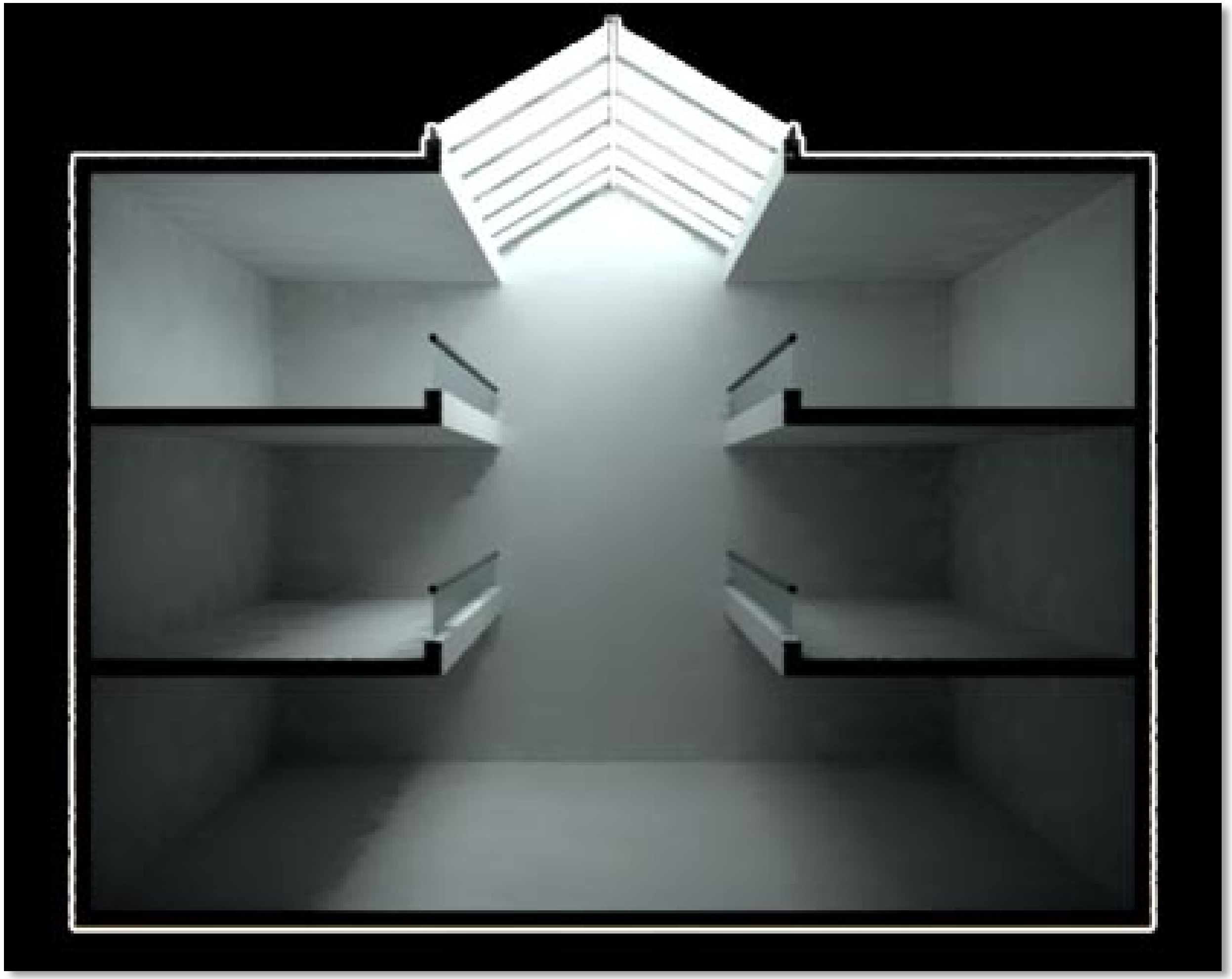
Skylight

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…

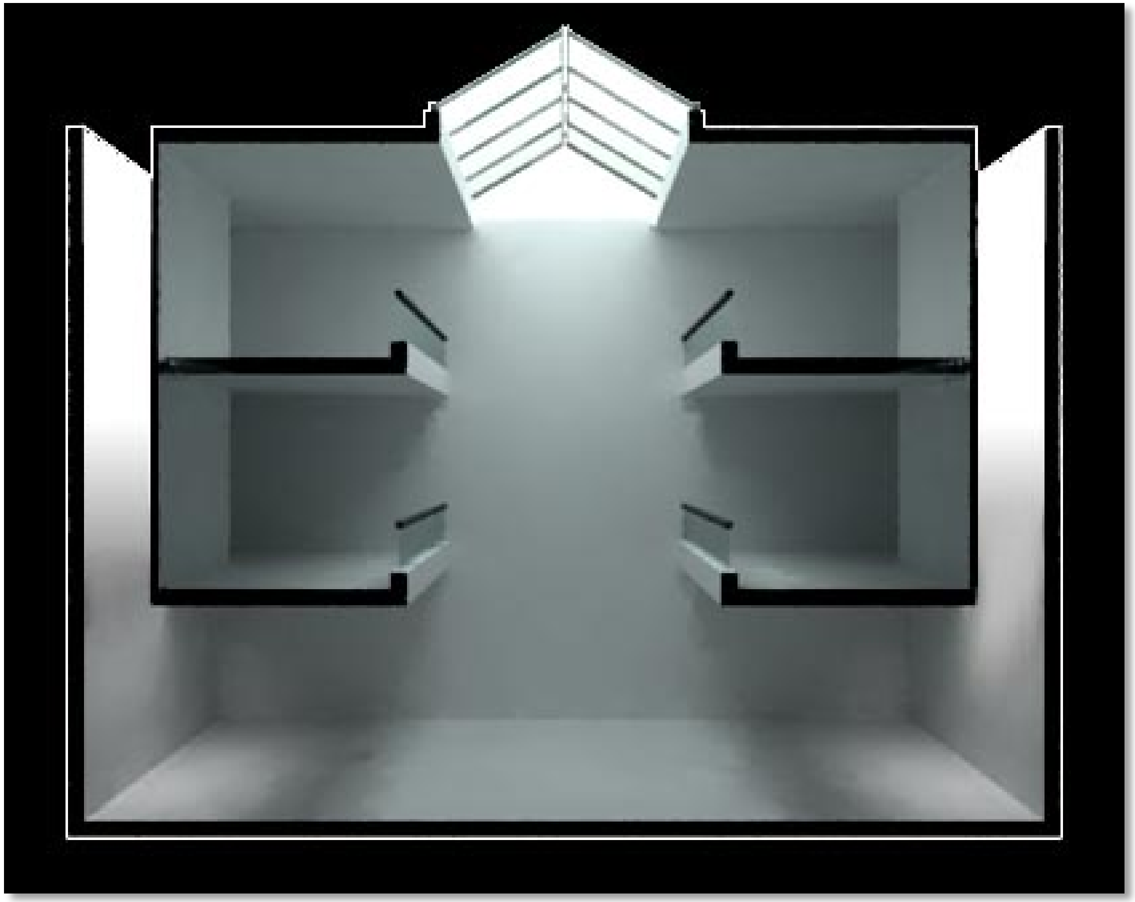
Images from squ1.com



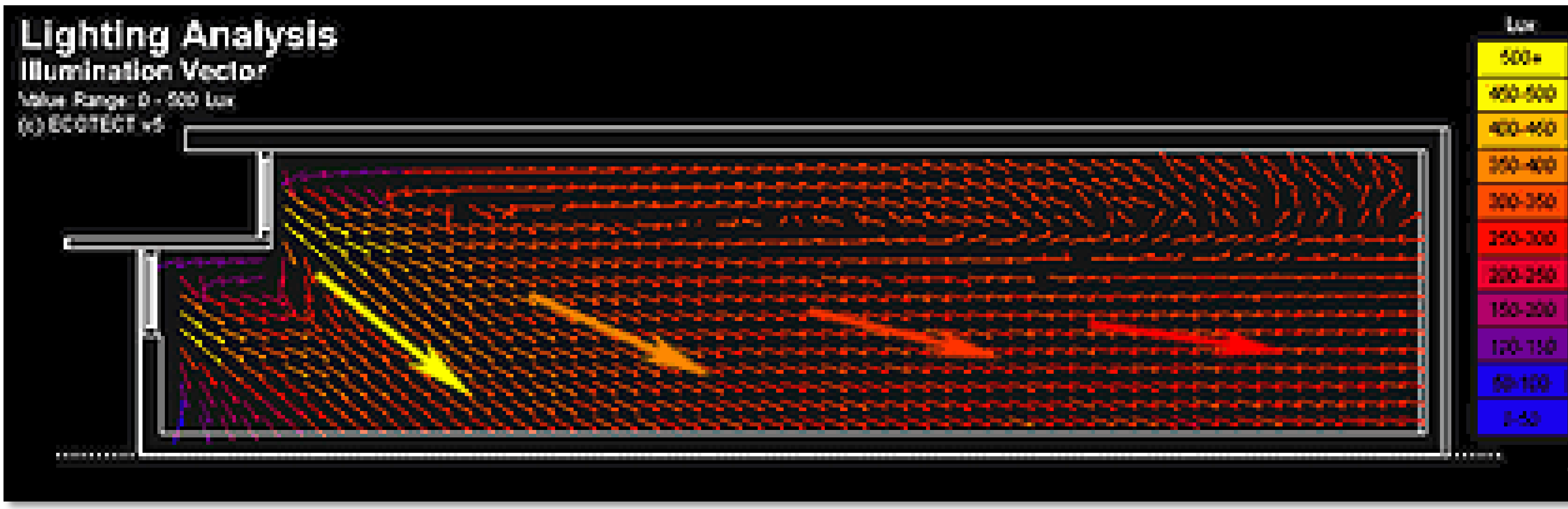
For distribution concerns think of bright vs. dark spots as well as room use. These images are for overcast bright sky conditions – so no sharp shadows…

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



Cross section from ECOTECT showing how illumination vectors become more horizontal as sidelight travels deeper into a space.

Light intensity and distribution within the space must also be addressed as light is not uniform. This affects USE placement as well as supplementary and TASK lighting.

Designing Openings

This splayed opening distributes light more widely than a deep cut would.