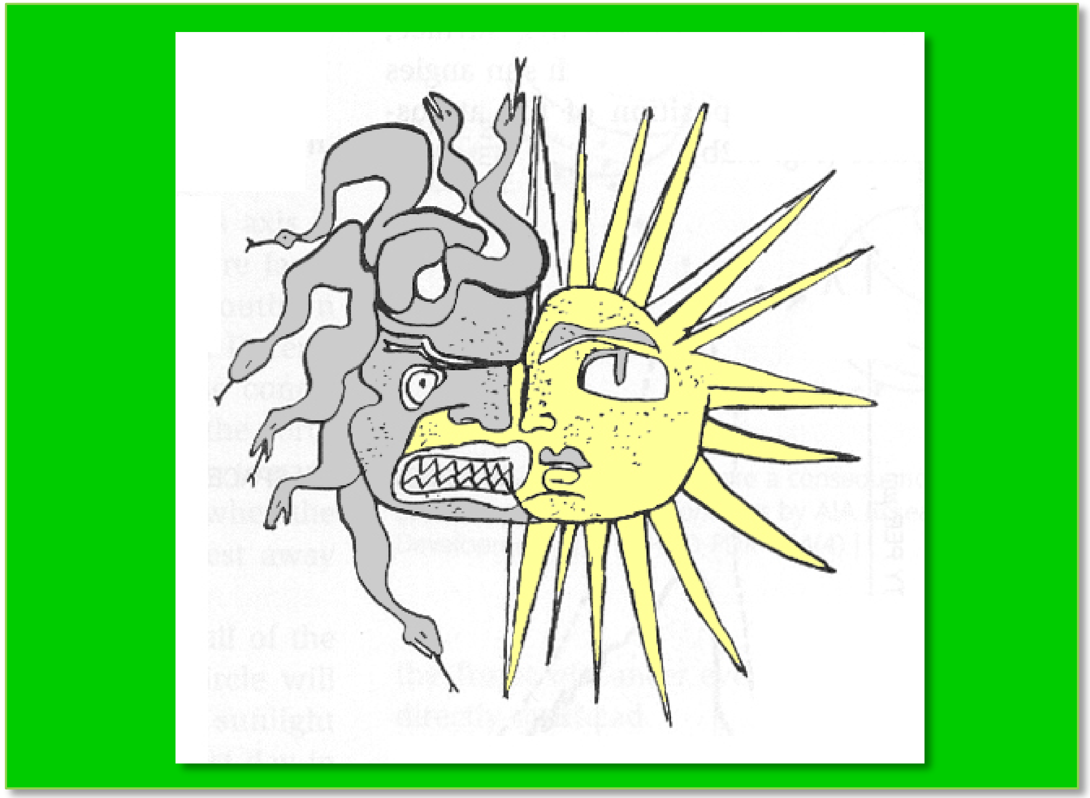
THE EVOLUTION TOWARDS CONTEMPORARY CLIMATE RESPONSIVE DESIGN: Part Two



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!

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

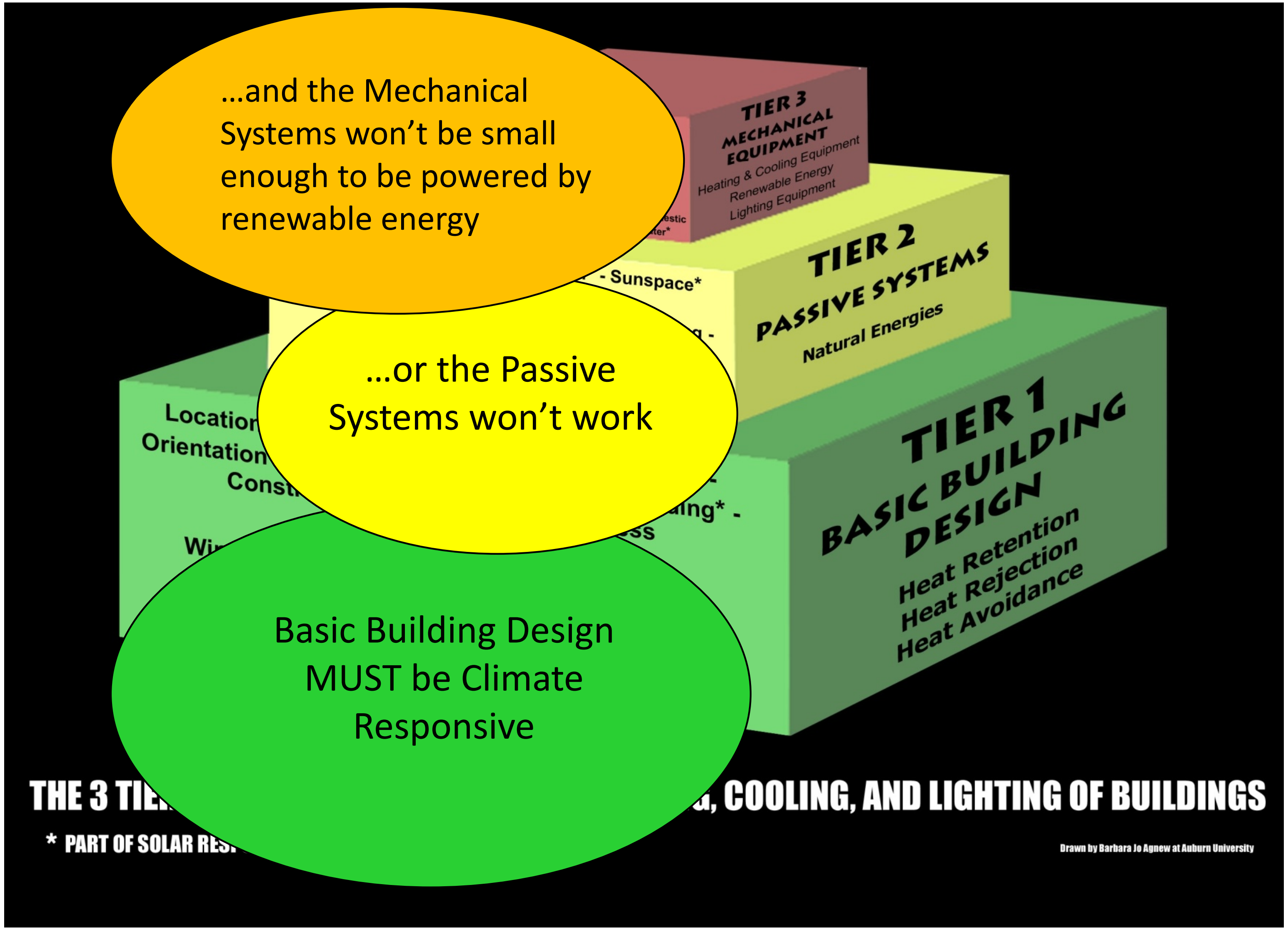


Image: Norbert Lechner, "Heating, Cooling, Lighting"

Energy vs Greenhouse Gas Emissions

In BUILDINGS, for the sake of argument

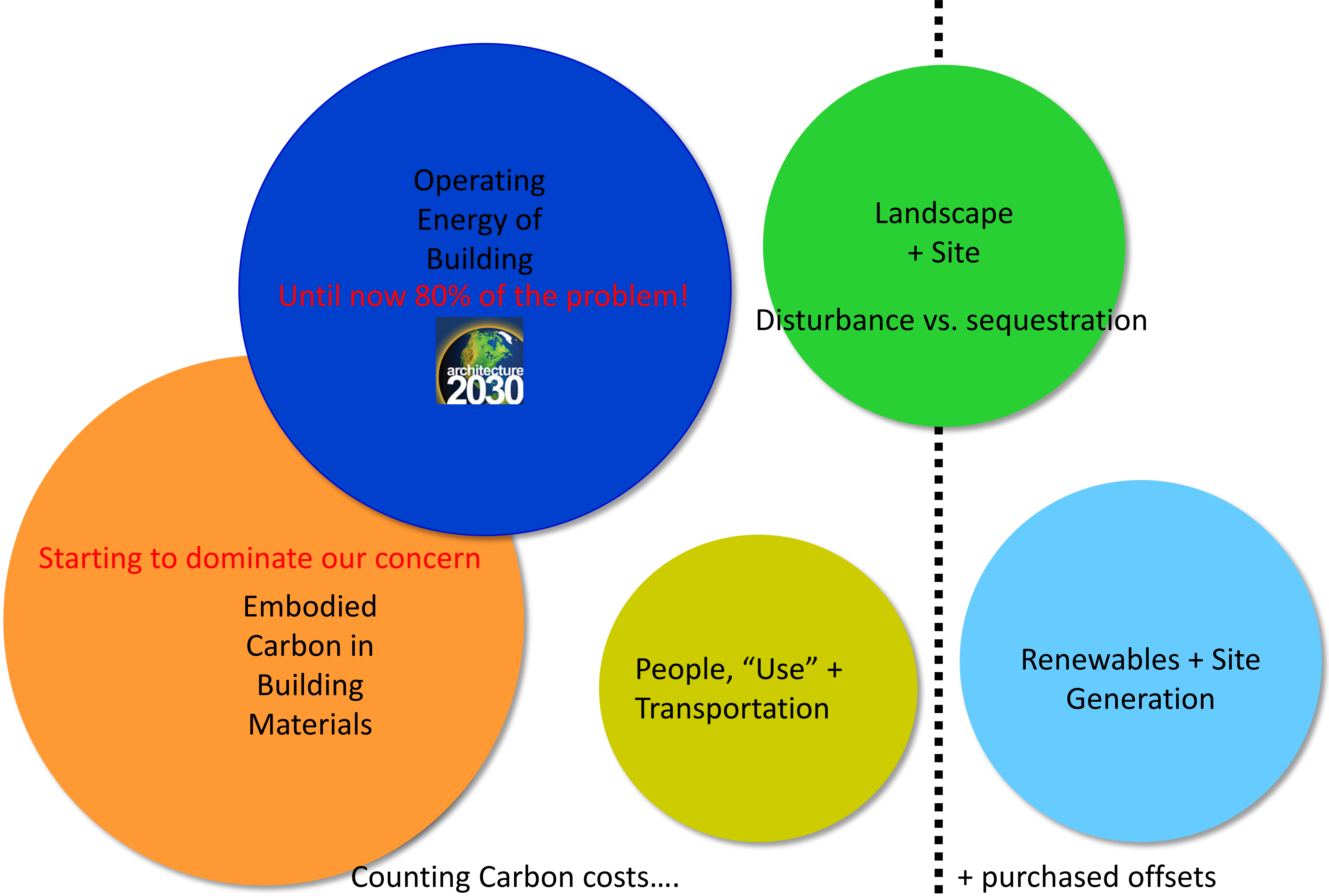
ENERGY CONSUMPTION = GHG EMISSIONS

BUILDING ENERGY IS COMPRISED OF

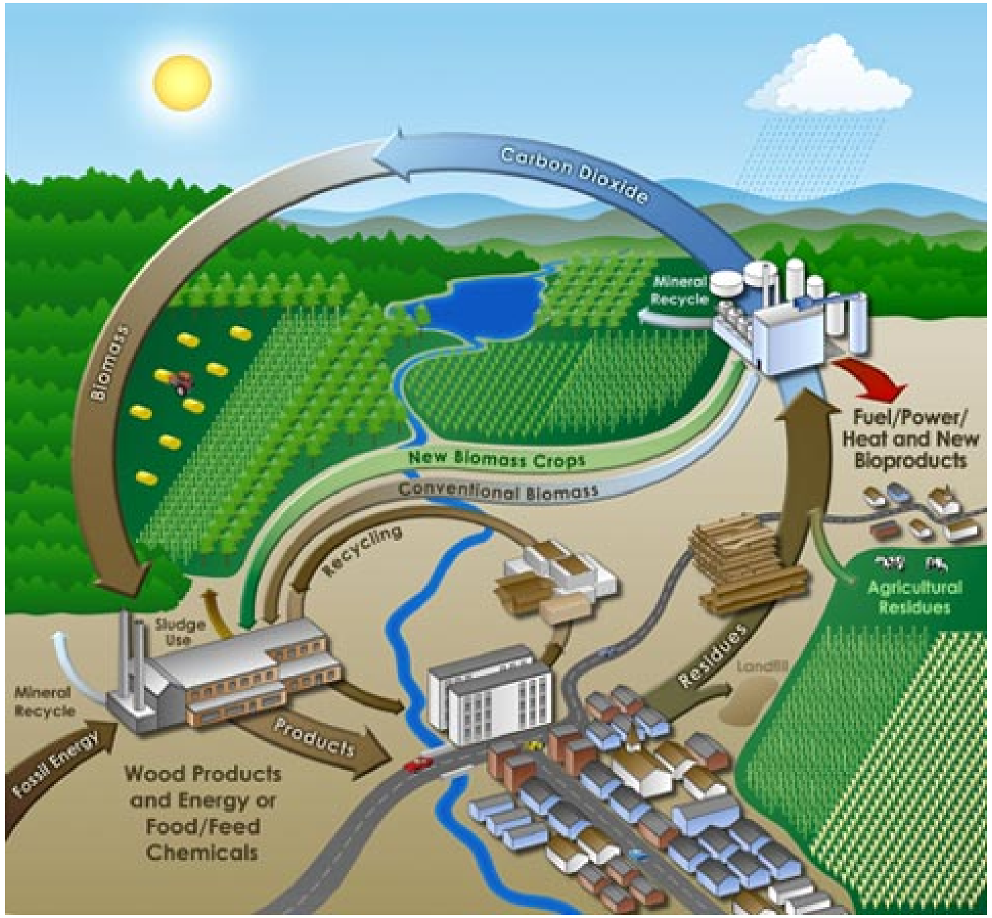
EMBODIED ENERGY

+

OPERATING ENERGY


Operating
Energy of
Building
Until now 80% of the problem!
architecture
2030
Landscape
+ Site
Disturbance vs. sequestration
Starting to dominate our concern
Embodied
Carbon in
Building
Materials
People, “Use” +
Transportation
Renewables + Site
Generation
Counting Carbon costs….
+ purchased offsets

Buildings / Processes and the Carbon Cycle:



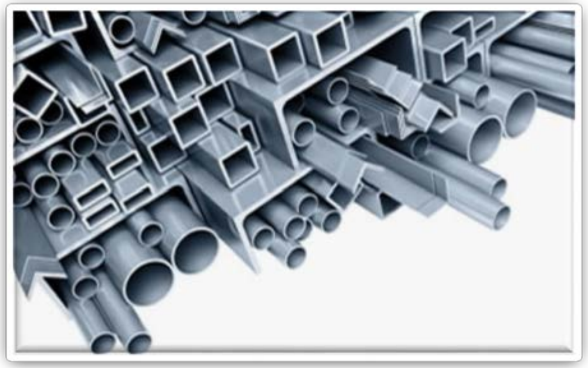
http://www.repp.org/bioenergy/bioenergy-cycle-med2.jpg

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.
After, we target embodied energy which gives us immediate payback.

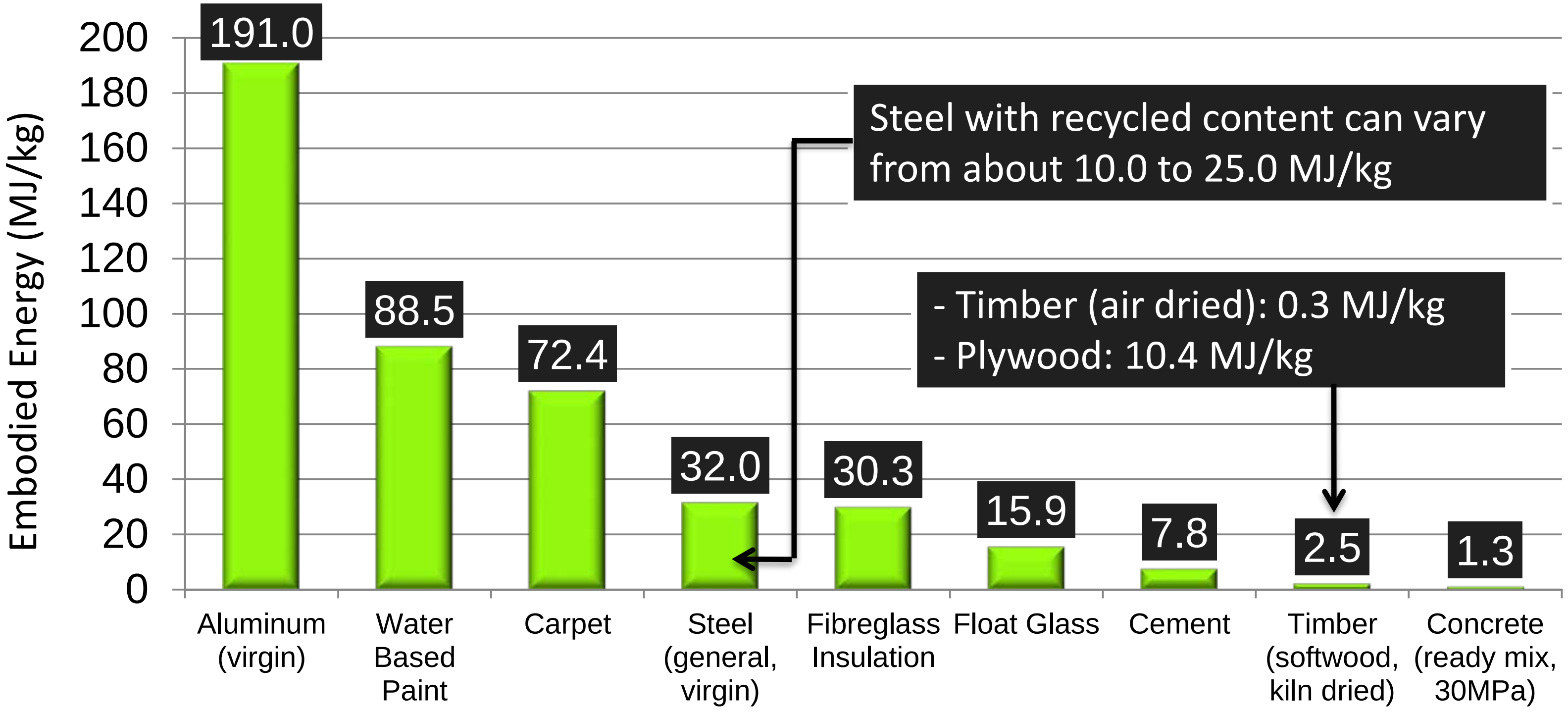
Energy Use in Buildings

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



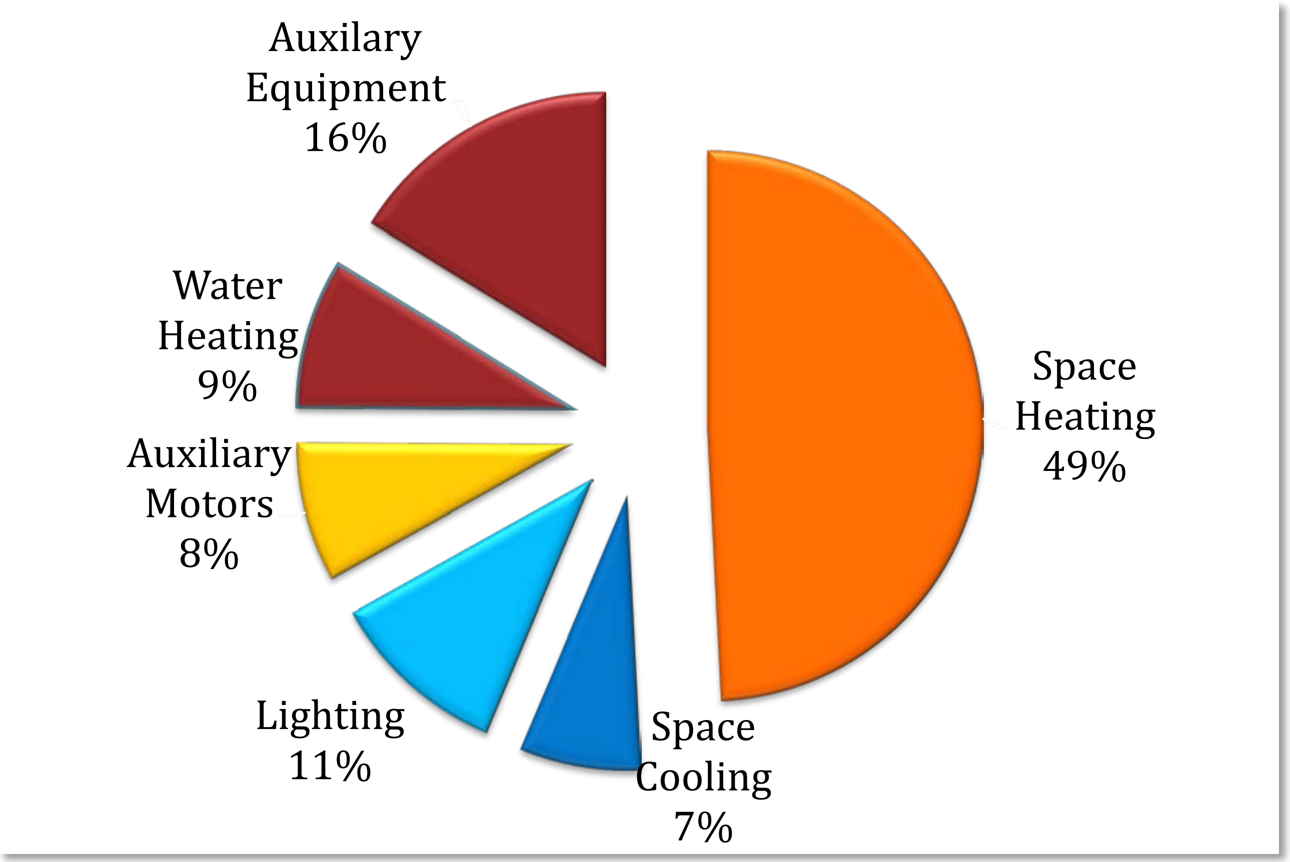
Initial Embodied Energy of Building Materials Per Unit Mass



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

Energy Use in Buildings: Operating Energy

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



Source: Natural Resources Canada, 2006

Three Key Steps – IN ORDER:

REDUCING OPERATING ENERGY

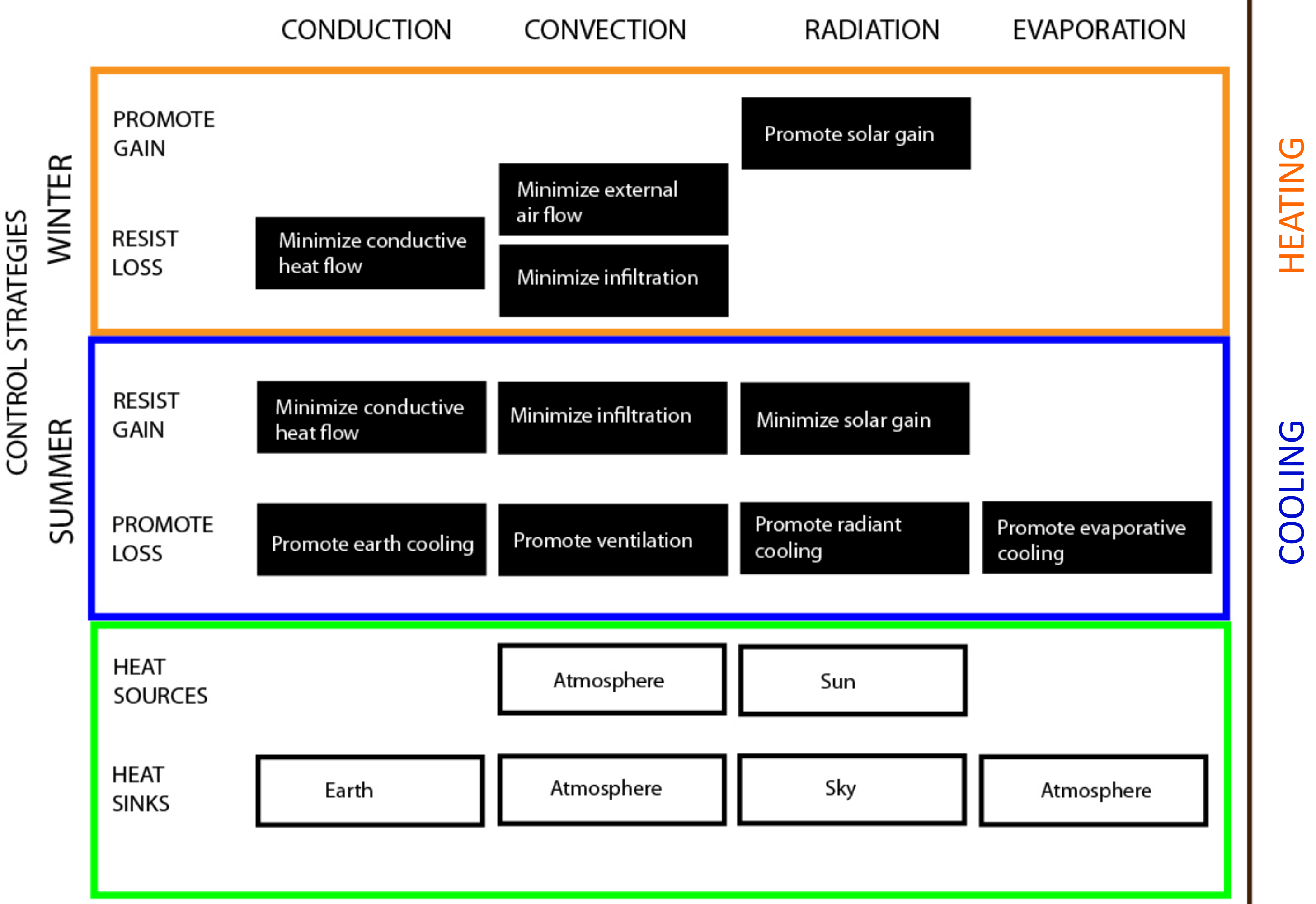
#1 - Reduce loads/demand first
(conservation, passive design, daylighting, shading, orientation, etc.)

#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

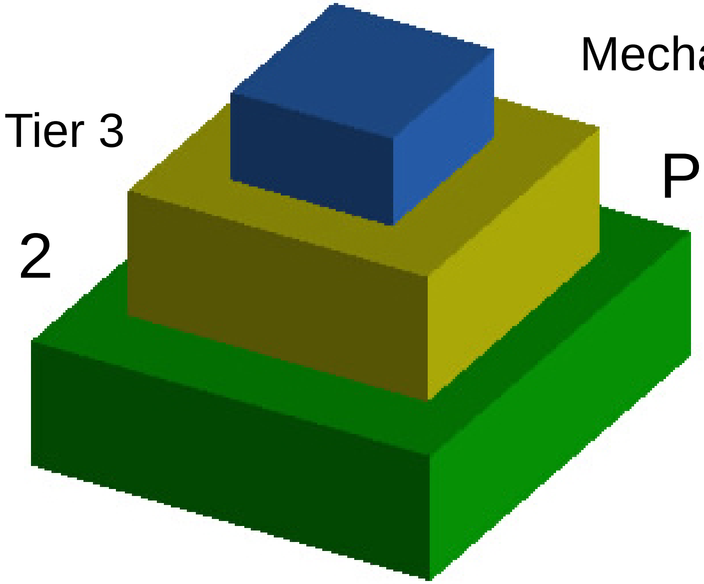
COOLING ↔ WIND

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)

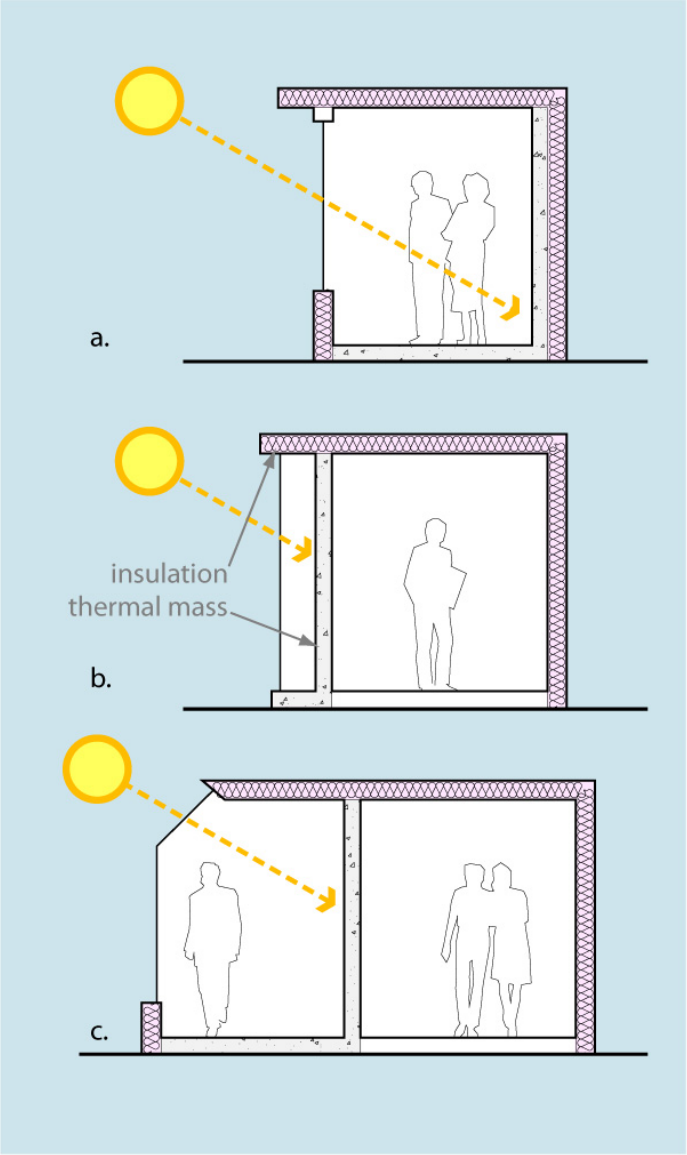
3 MAIN STRATEGIES:

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.

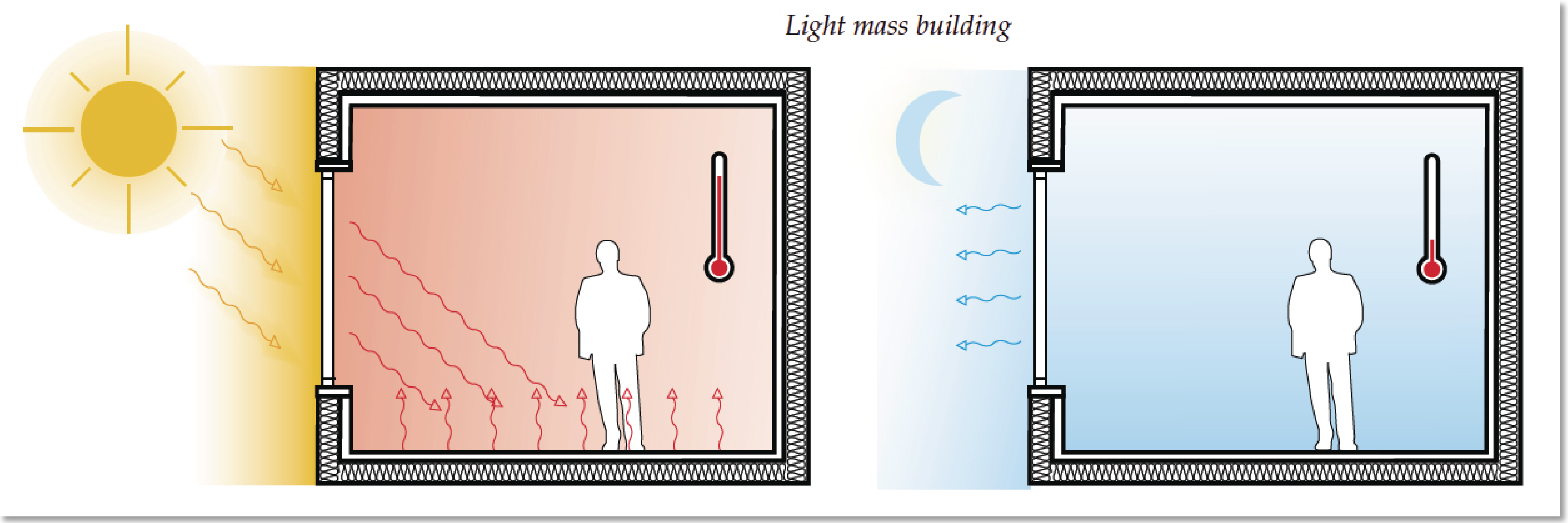
Just like water, free solar energy needs to be stored somewhere to be useful!

Problems with traditional placement of thermal mass

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

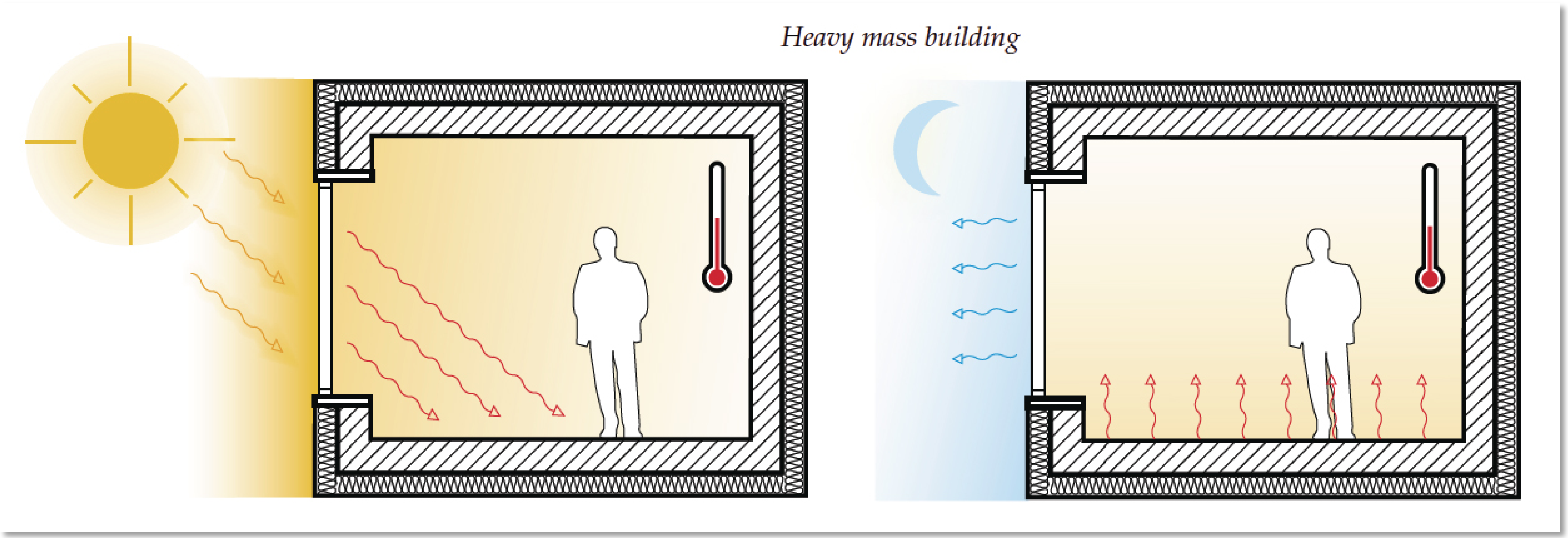
Proper thermal mass placement runs counter to the standard method of residential construction in Canada.

Light Mass Building Problems



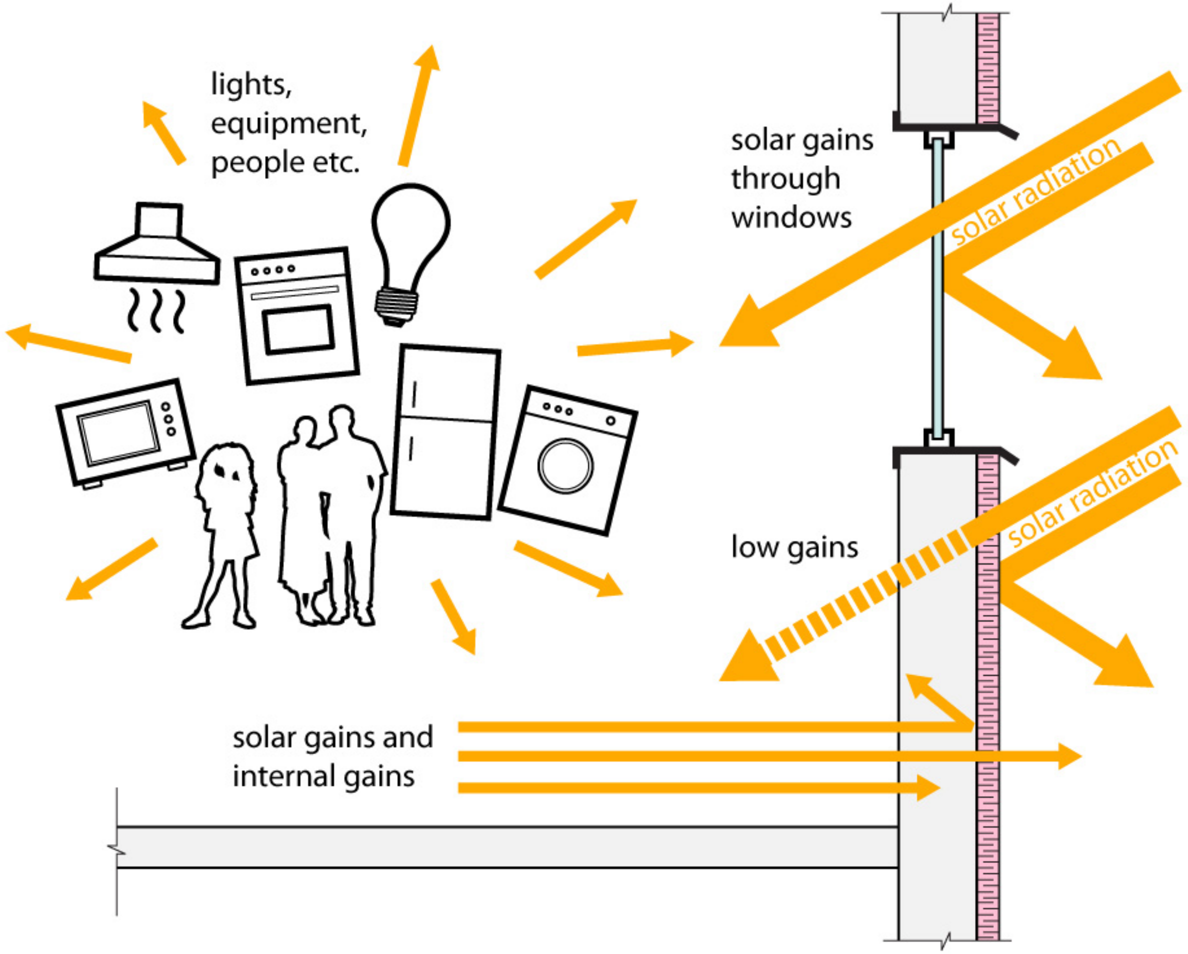
- Wide swings of temperature from day to night
- Excess heat absorbed by human occupants
- Uncomfortably cold at night

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

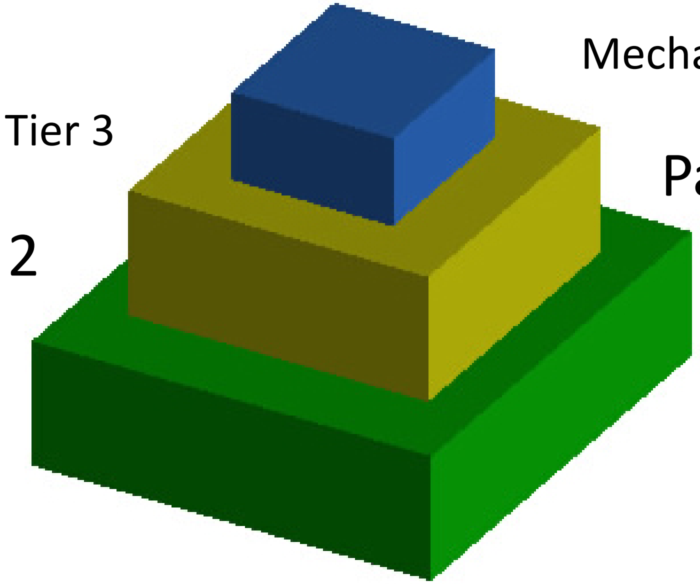


If the insulation is on the OUTSIDE of the building envelope (and thermal mass element), the heat that gets in STAYS in.

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:

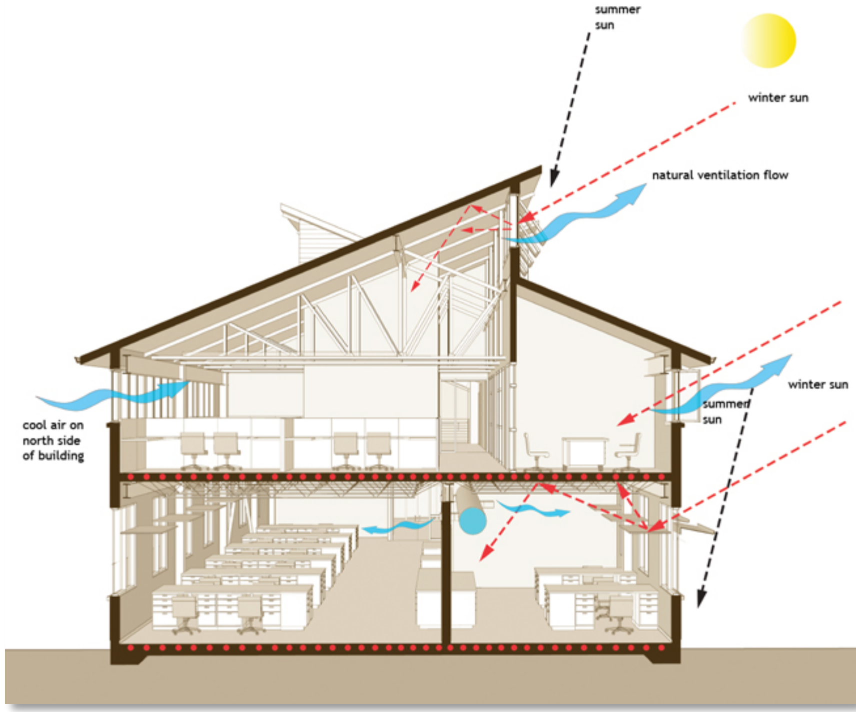


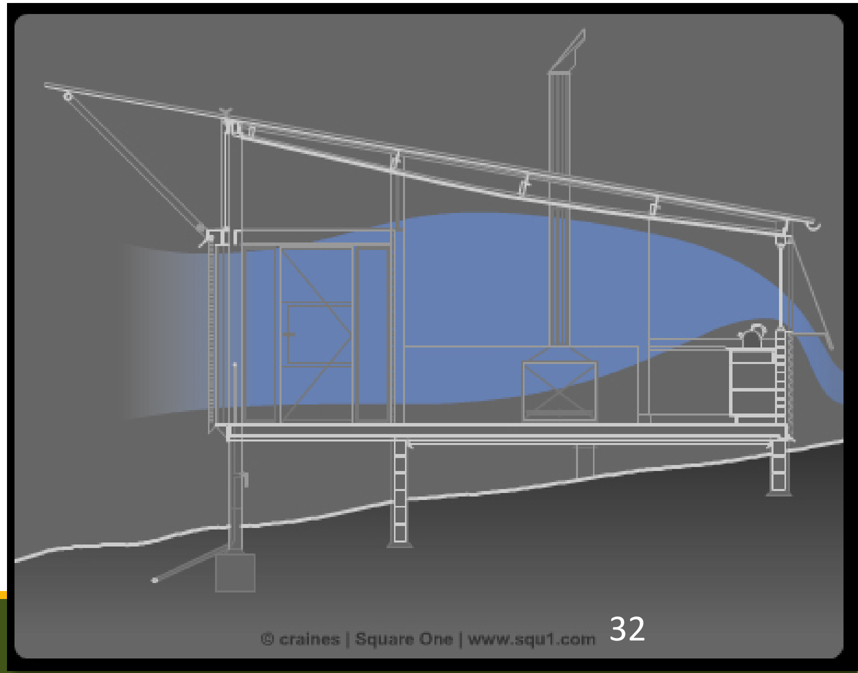
Maximize the amount of energy required for mechanical cooling that comes from renewable sources.

Source: Lechner. Heating, Cooling, Lighting.

Passive Cooling Strategies:
Passive Cooling

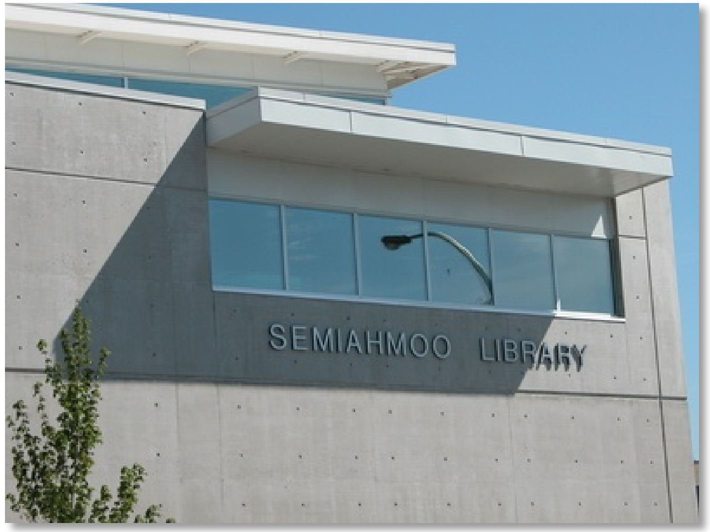
1. design for maximum ventilation
2. design plans as open as possible for unrestricted air flow
3. use easily operable windows at low levels with high level clerestory windows to induce stack effect cooling





Passive Cooling Strategies:
Heat Avoidance

1. shade windows from the sun during hot months
2. design materials and plantings to <u>cool the local microclimate</u>
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.

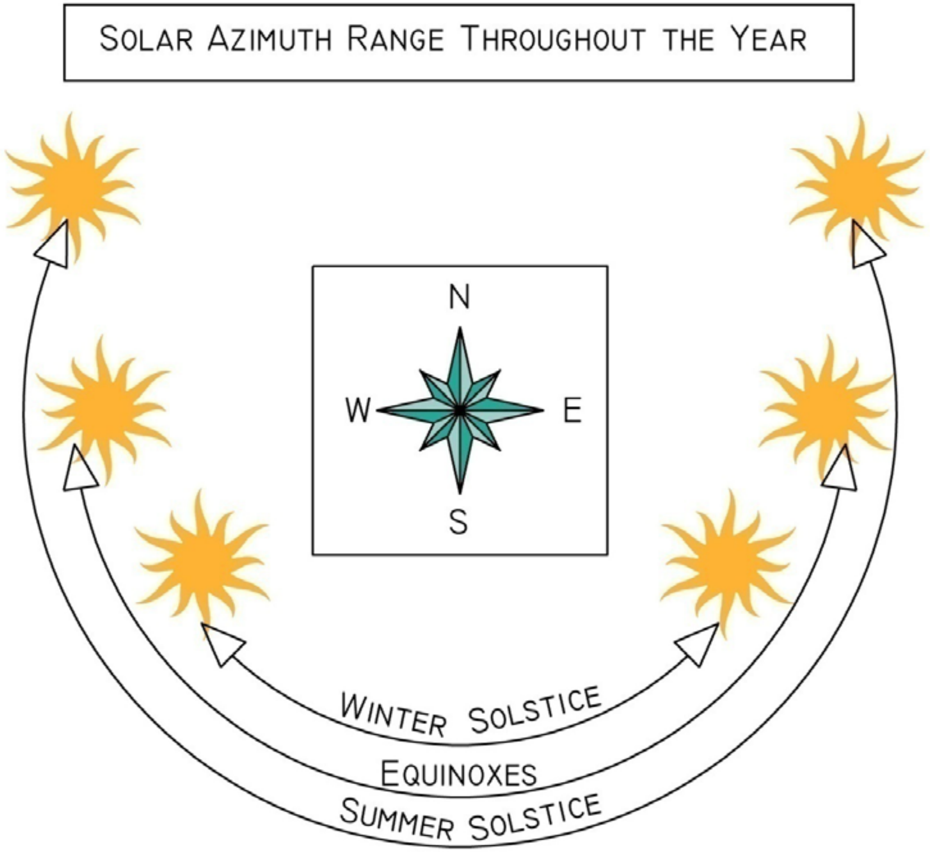
Atrium buildings have long had issues with solar gain, so some of the glass is opaque to give the appearance of "sky" without the solar gain.

Toronto, Eaton Centre – Zeidler Partnership


Salt Lake City Library, Moshe Safdie

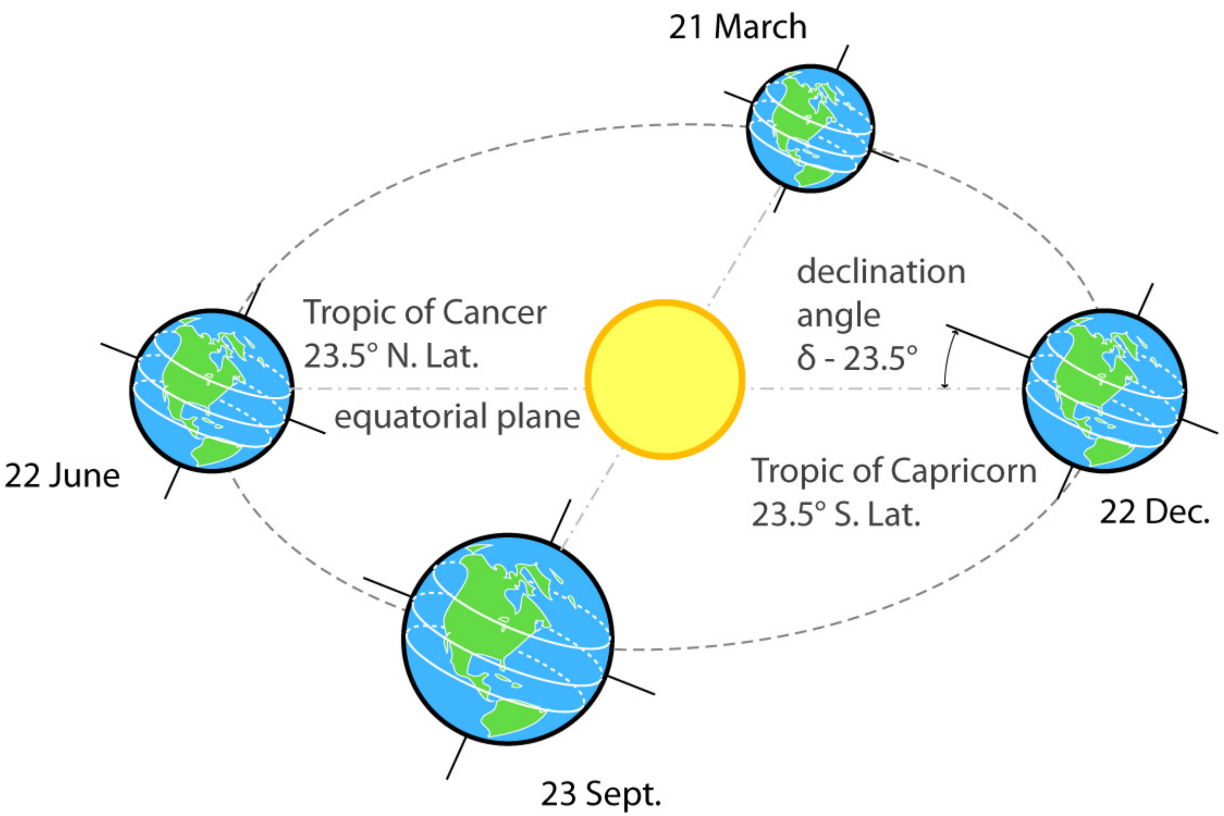
Blinds must be manually drawn by the librarian every sunny day to avoid baking the children in the lower library area!

#1 Starting Point ORIENTATION – Locate the SUN



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

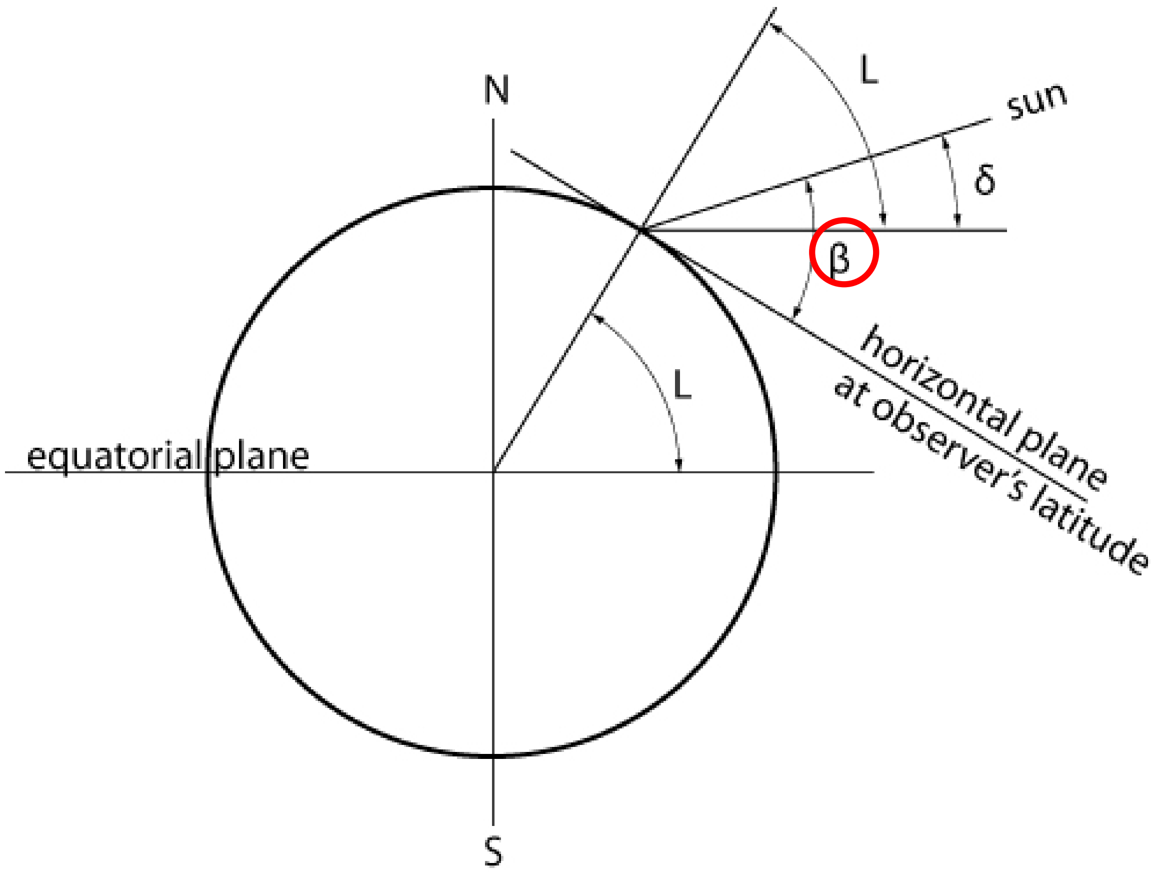
Solar Geometry



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 Geometry

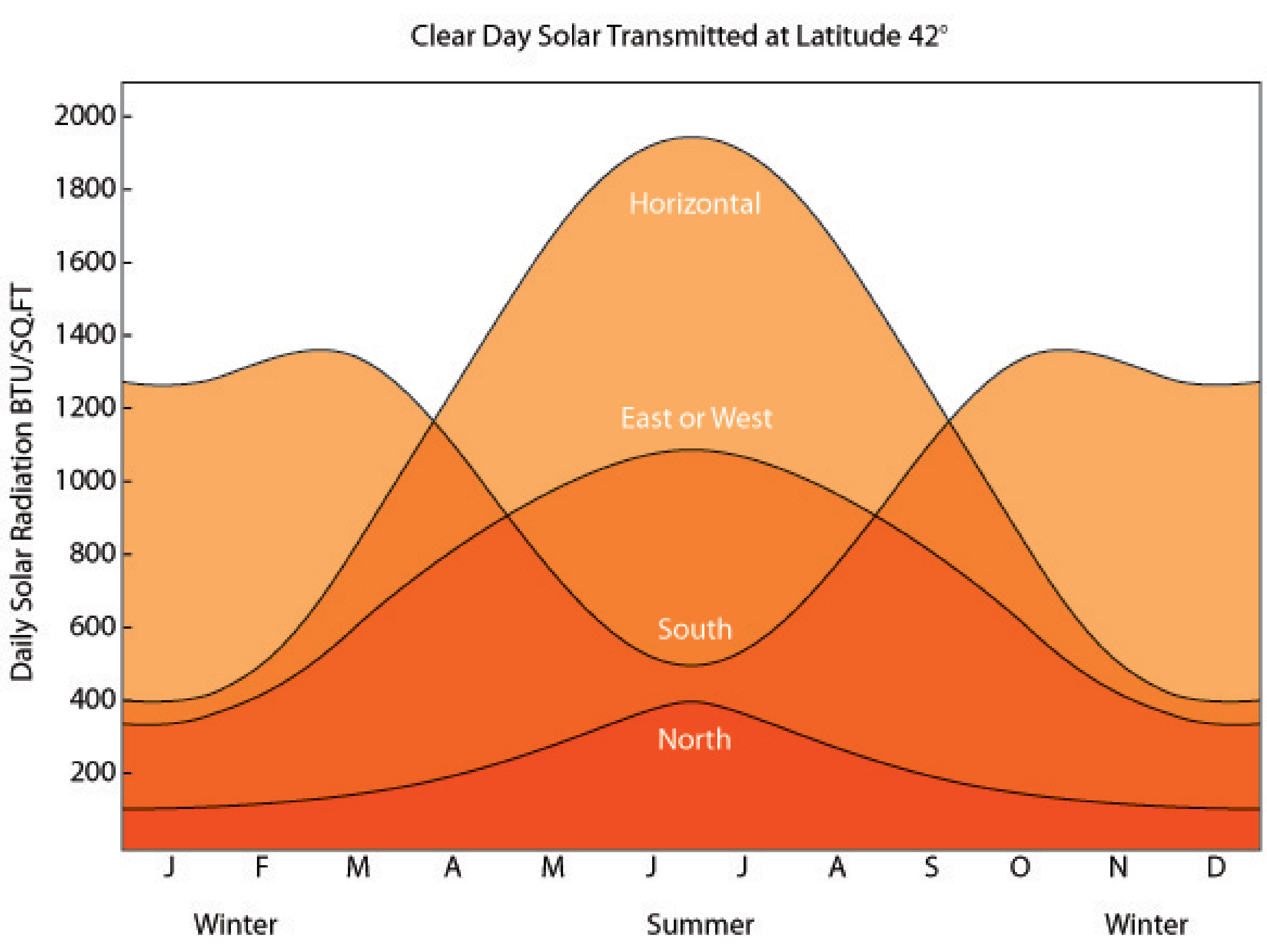
In studying Solar Geometry we are going to figure out how to use the sun's natural path in summer vs. winter to provide FREE heat in the Winter, and to reduce required COOLING in the summer.

Solar 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.

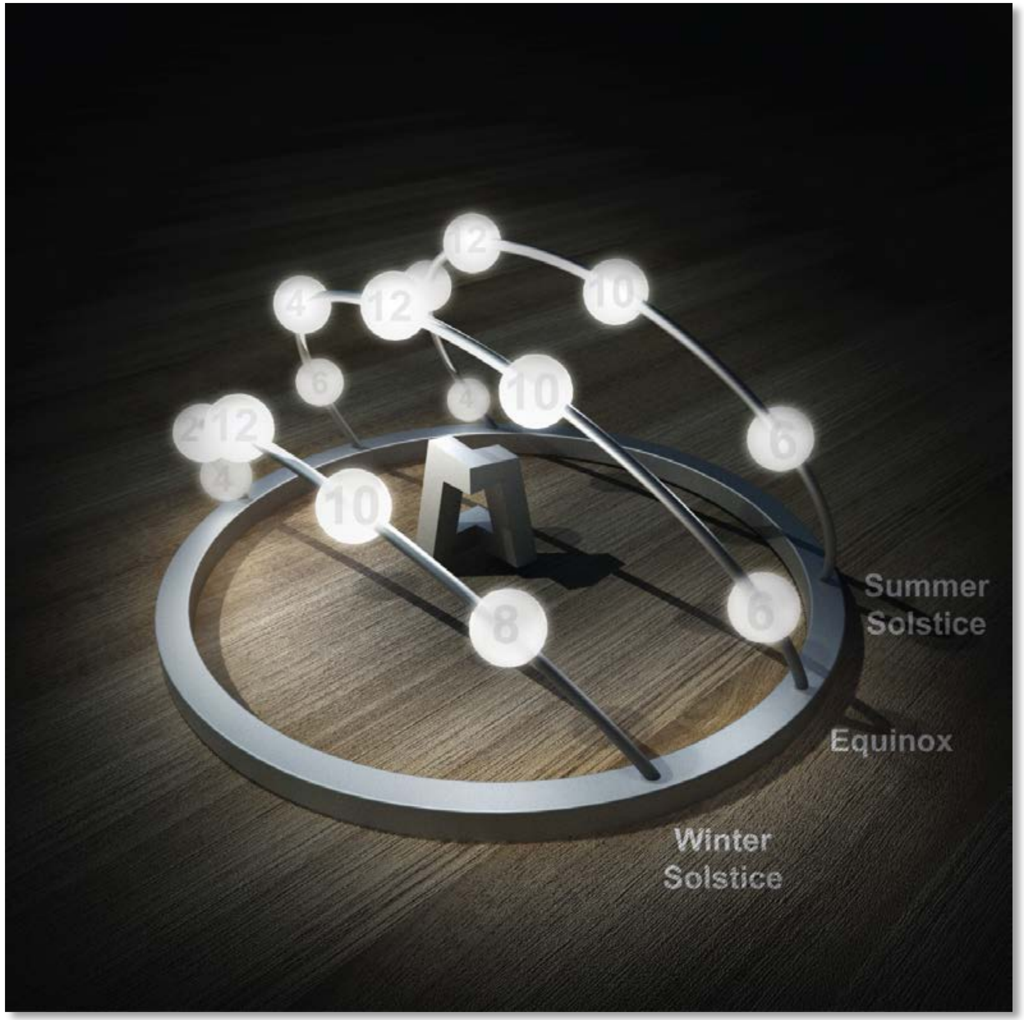
East and West glazing collects almost 3 times the solar radiation of south window.



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



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.

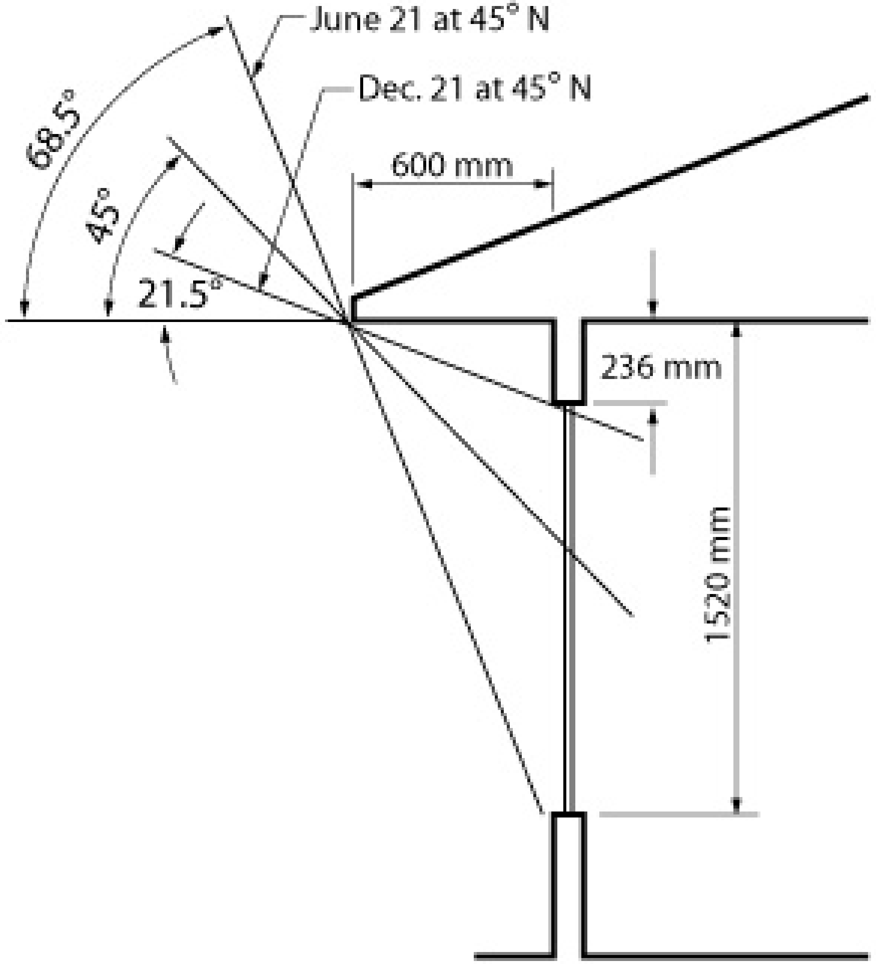
†Transmittance of insulating and laminated glass varies widely depending on whether or not one or more surfaces are treated with reflective films.

Solar geometry 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.

South Shading Device Basics



Shading angles for a south wall at 45°N

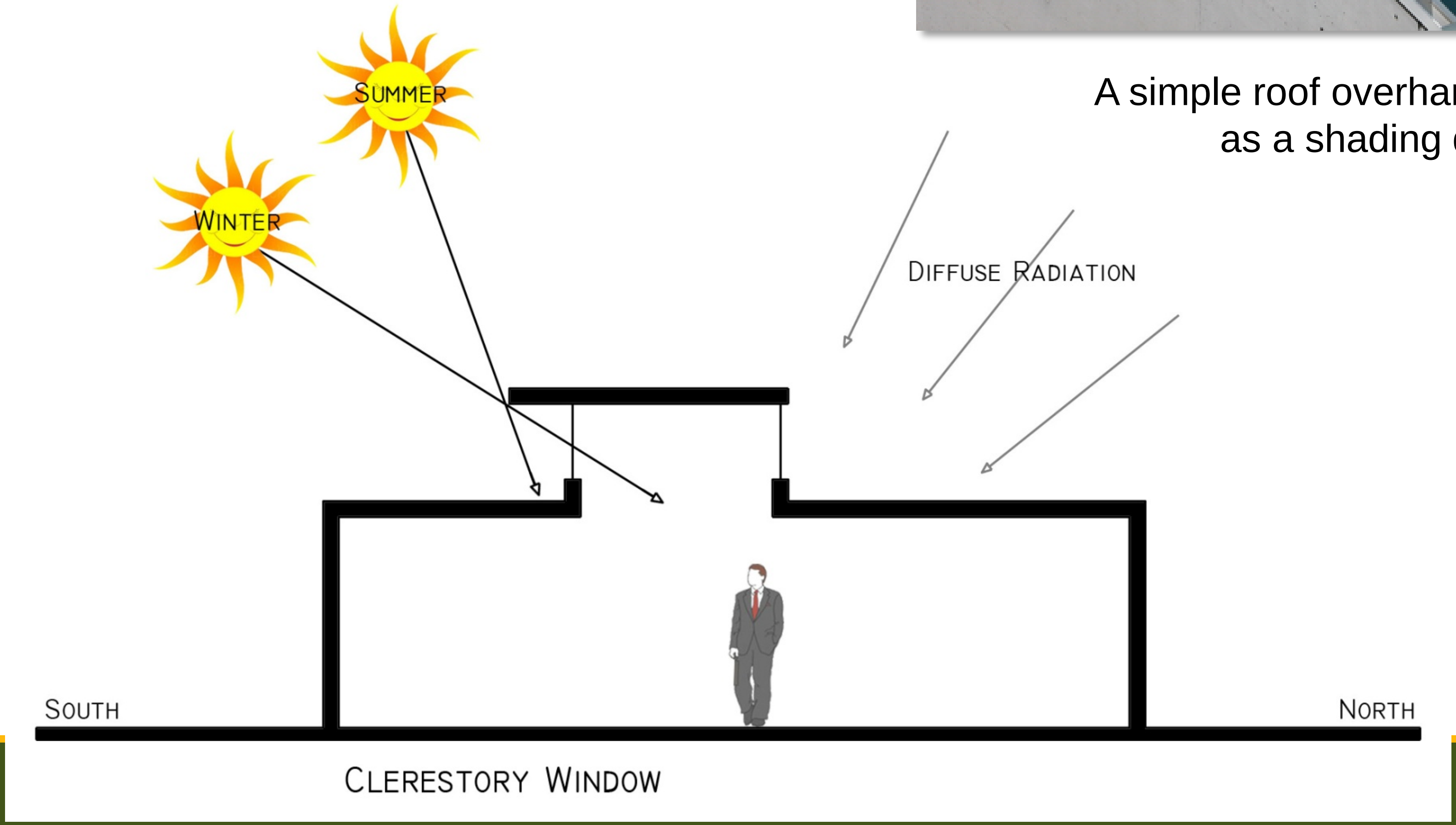
South facing windows are the EASIEST for control of sun penetration.

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

Shading devices can be simple horizontal projections.

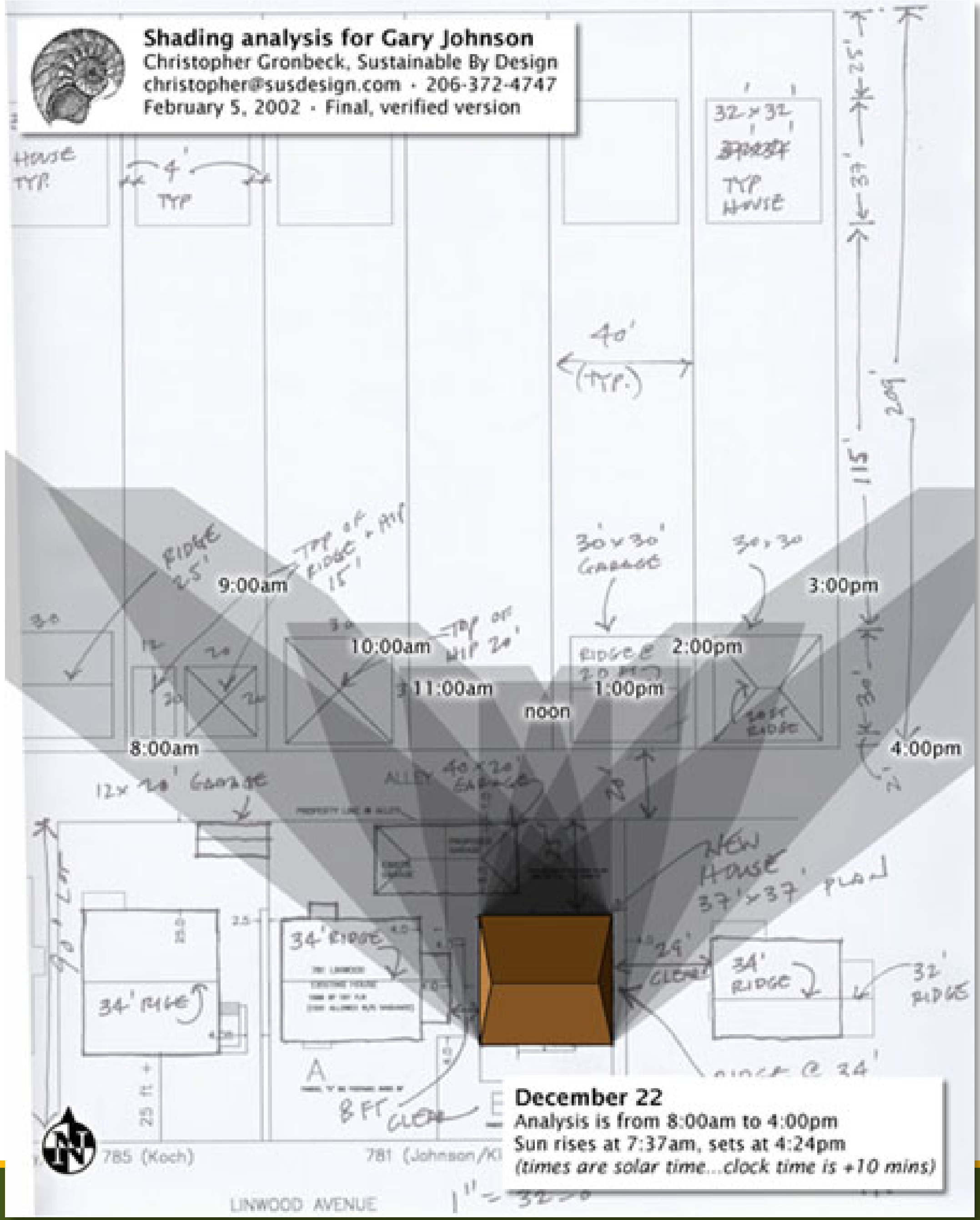
Calculation of size is pretty simple.

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.

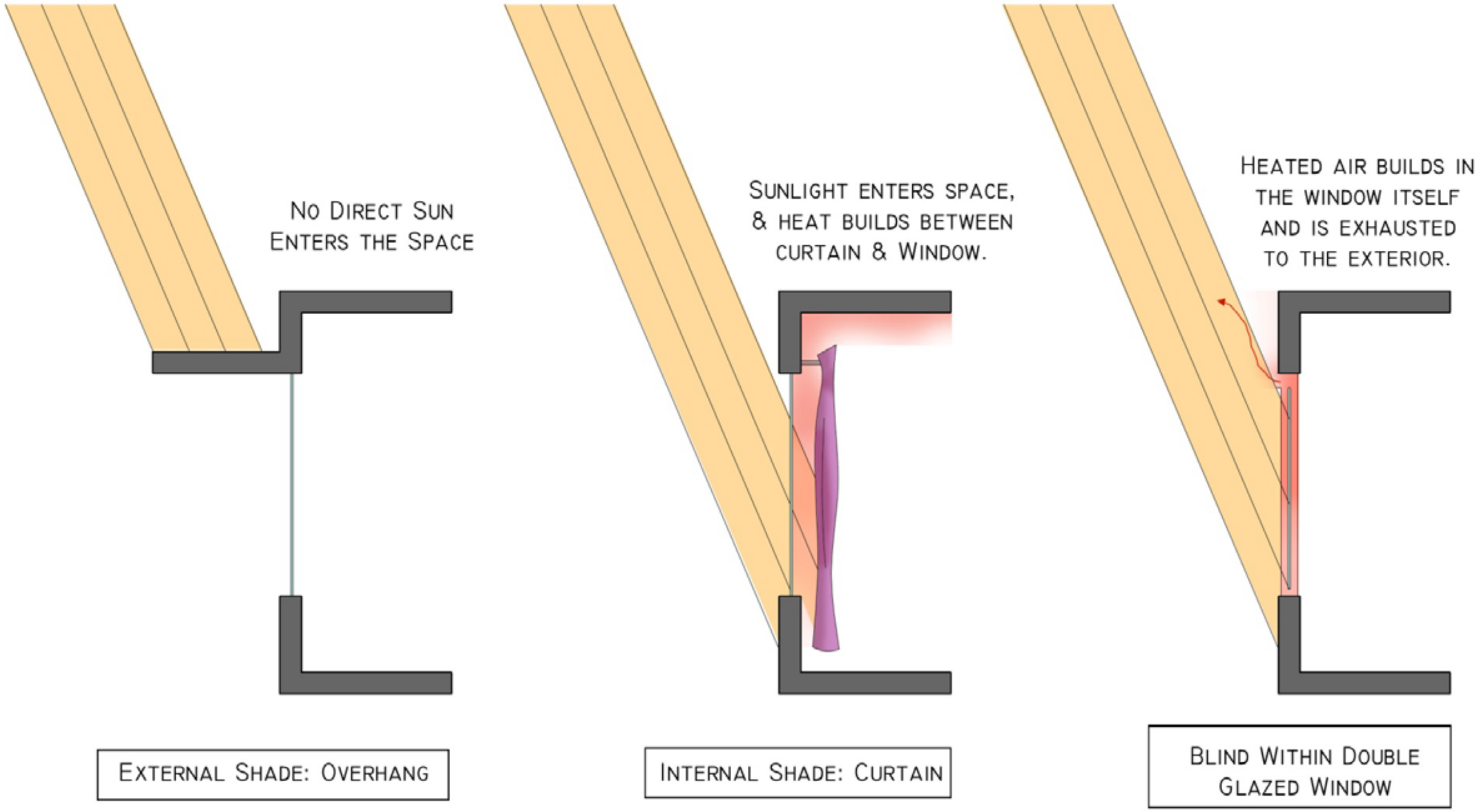
When we design our elevations to be solar responsive, this will mean having different facade treatments to respond to sun angles and the degree of exposure of the facade.



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.

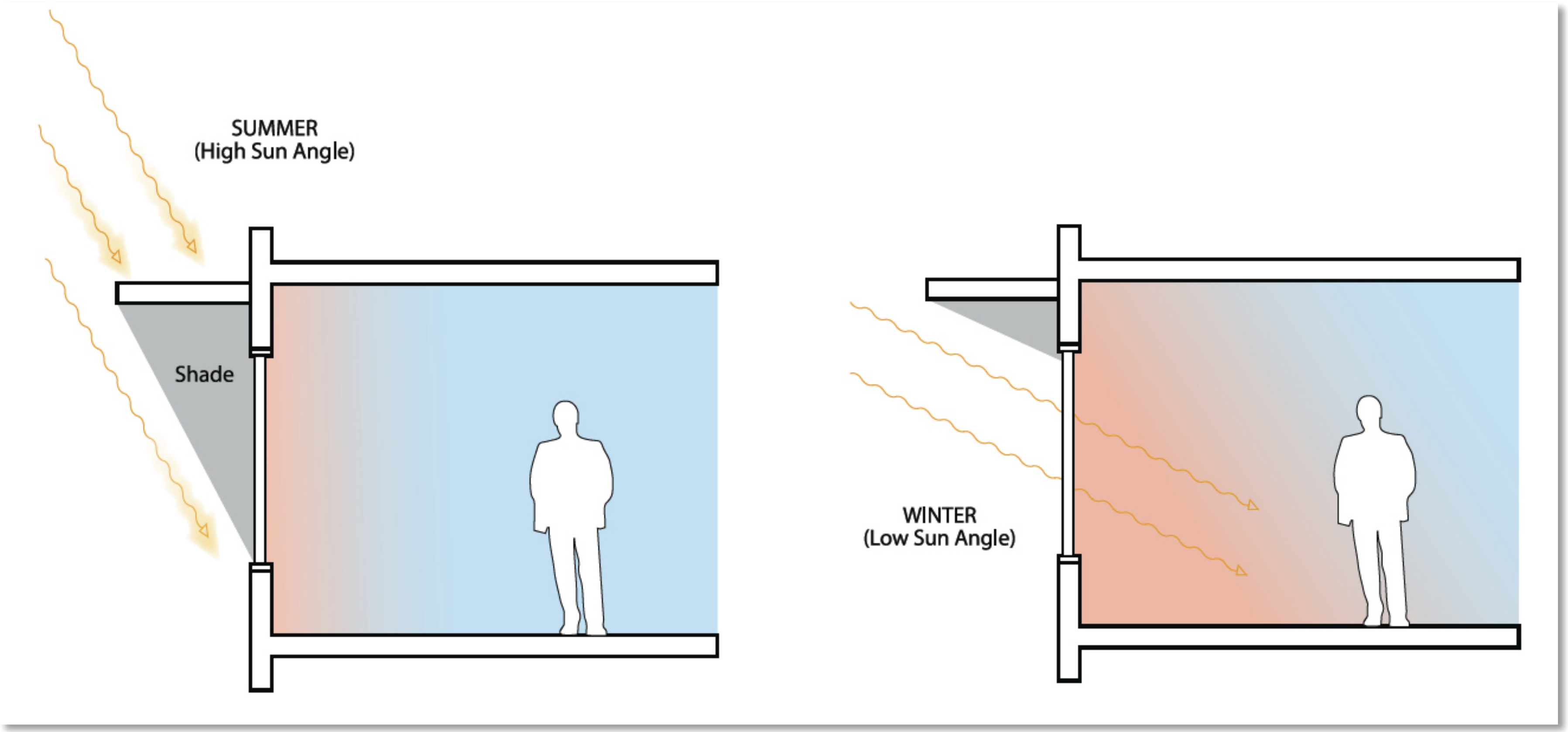
Interior vs Exterior Shades



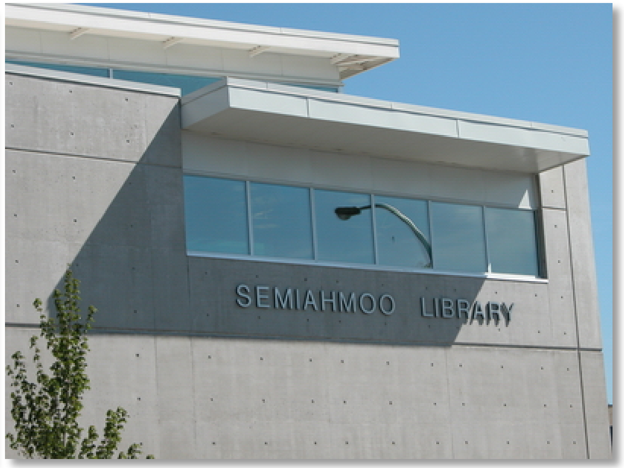
Once the heat is IN, it is IN!

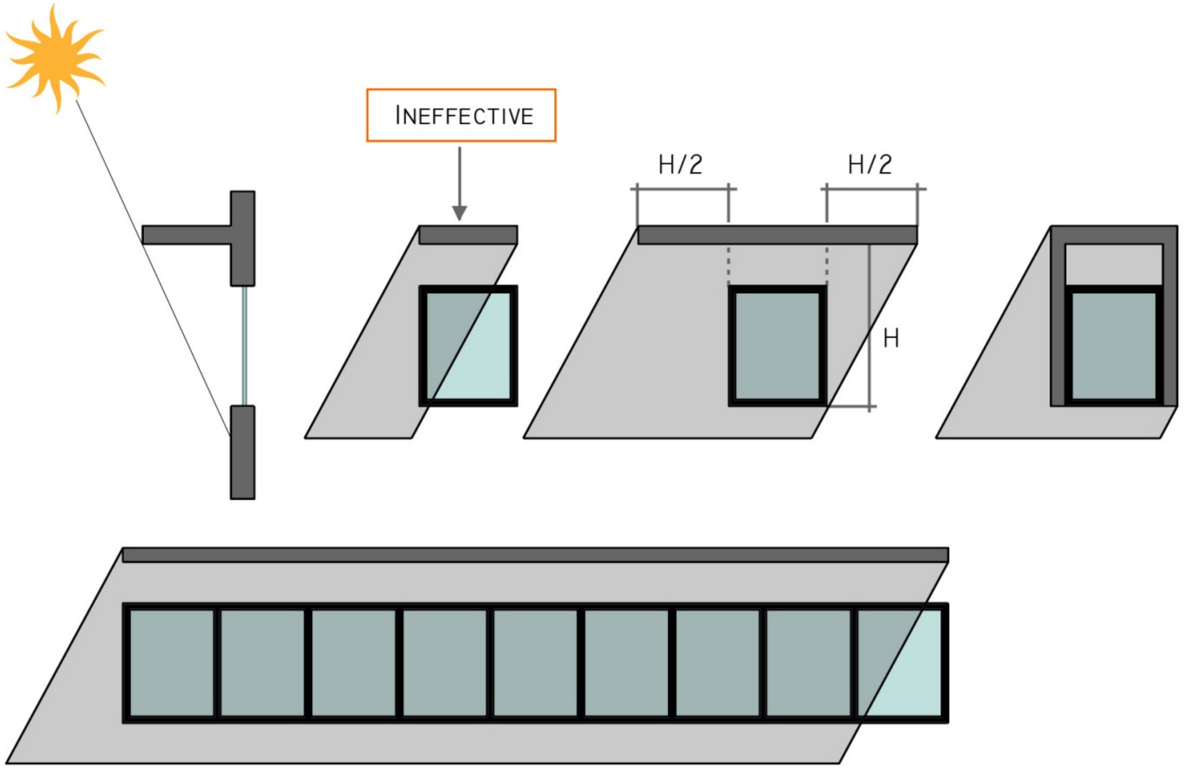
Internal blinds are good for glare, but not preventing solar gain.

South Façade Strategies



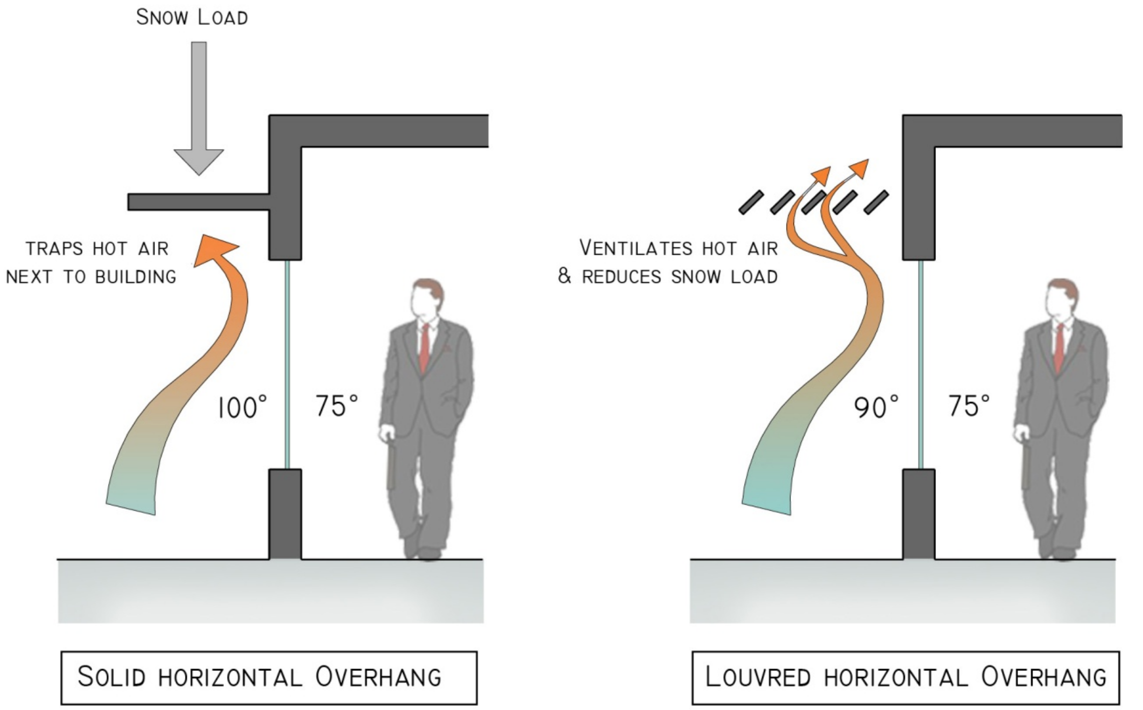
- South façade is the easiest to manage as simple overhangs can provide shade in the summer and permit entry in the winter.
- Need to design for August condition as June to August is normally a warm period.





…extend device for full shading

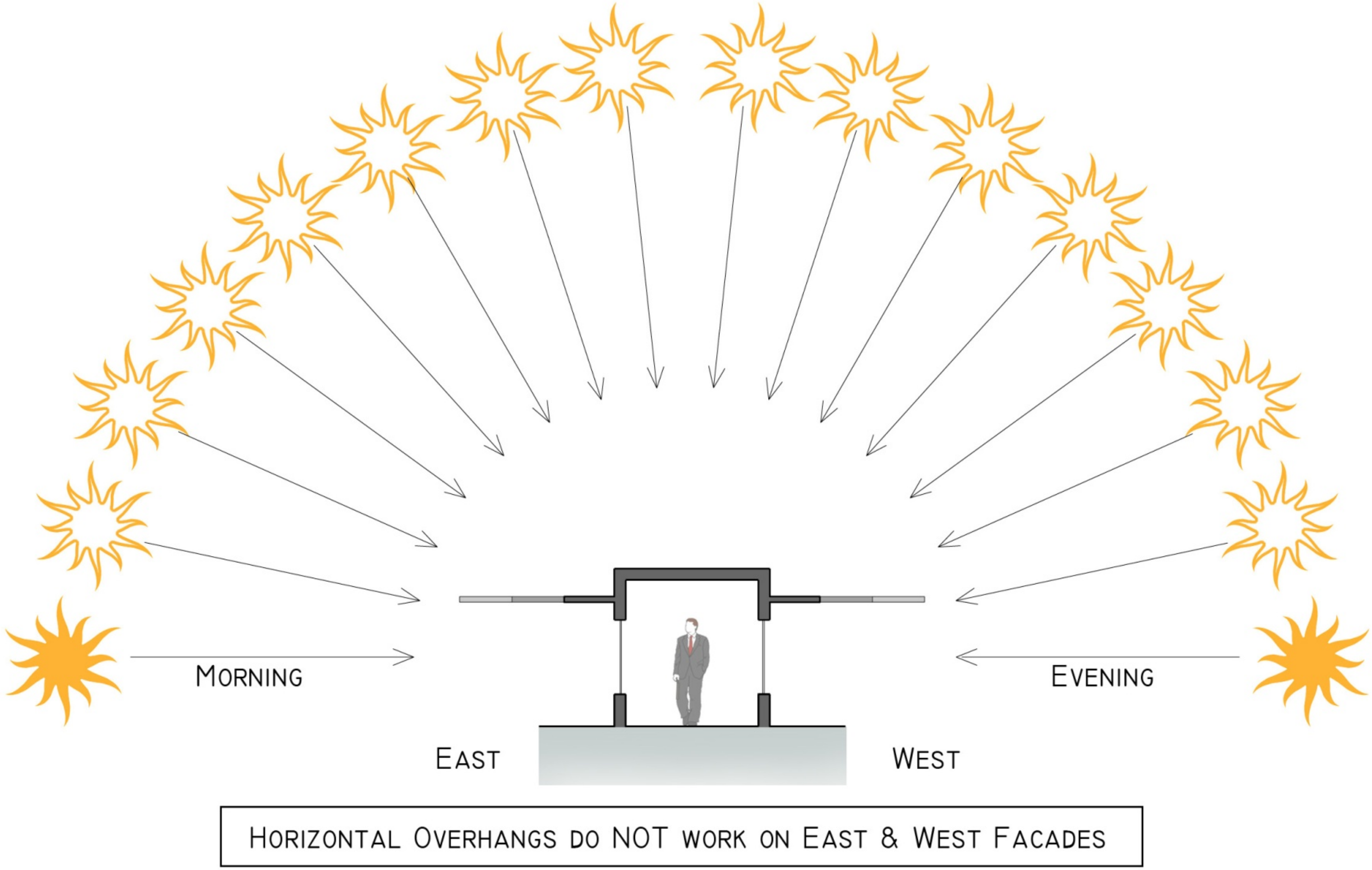
This one uses ceramic fritted glass that is sloped, to allow some light but shed rain and wet snow.



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.

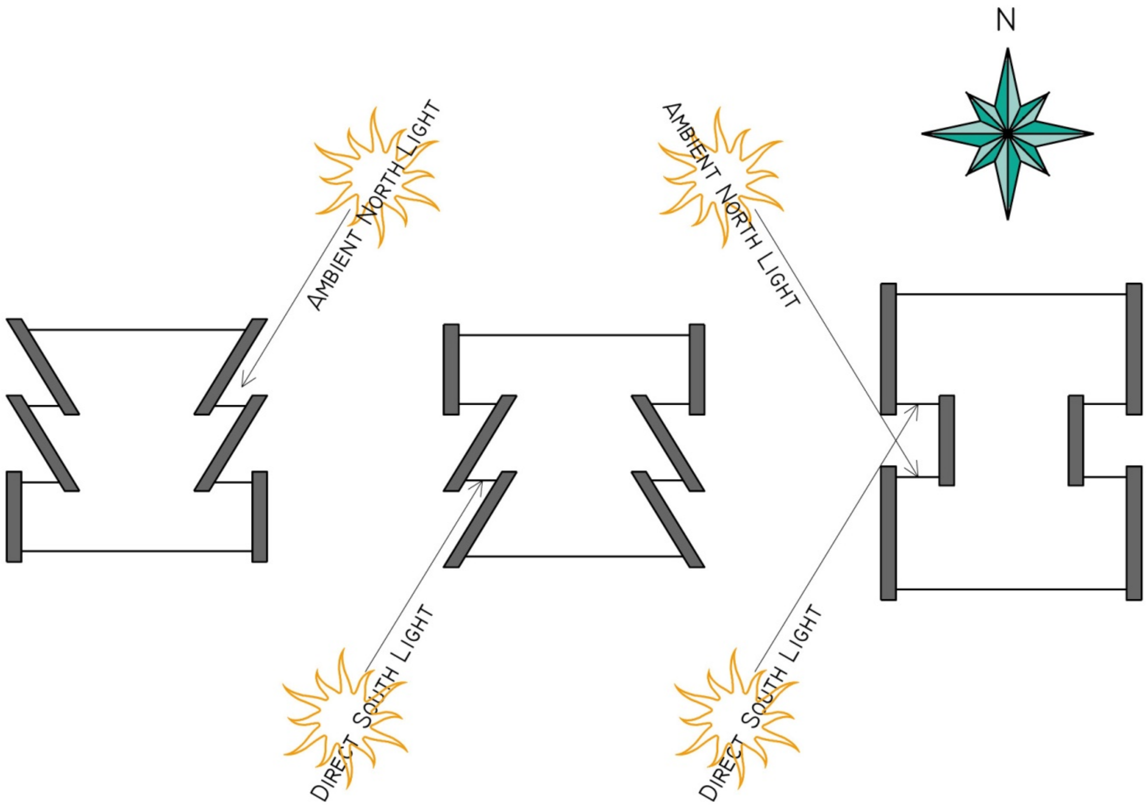
Shading Strategies for East and West Orientations



Shading Strategies for East and West Elevations

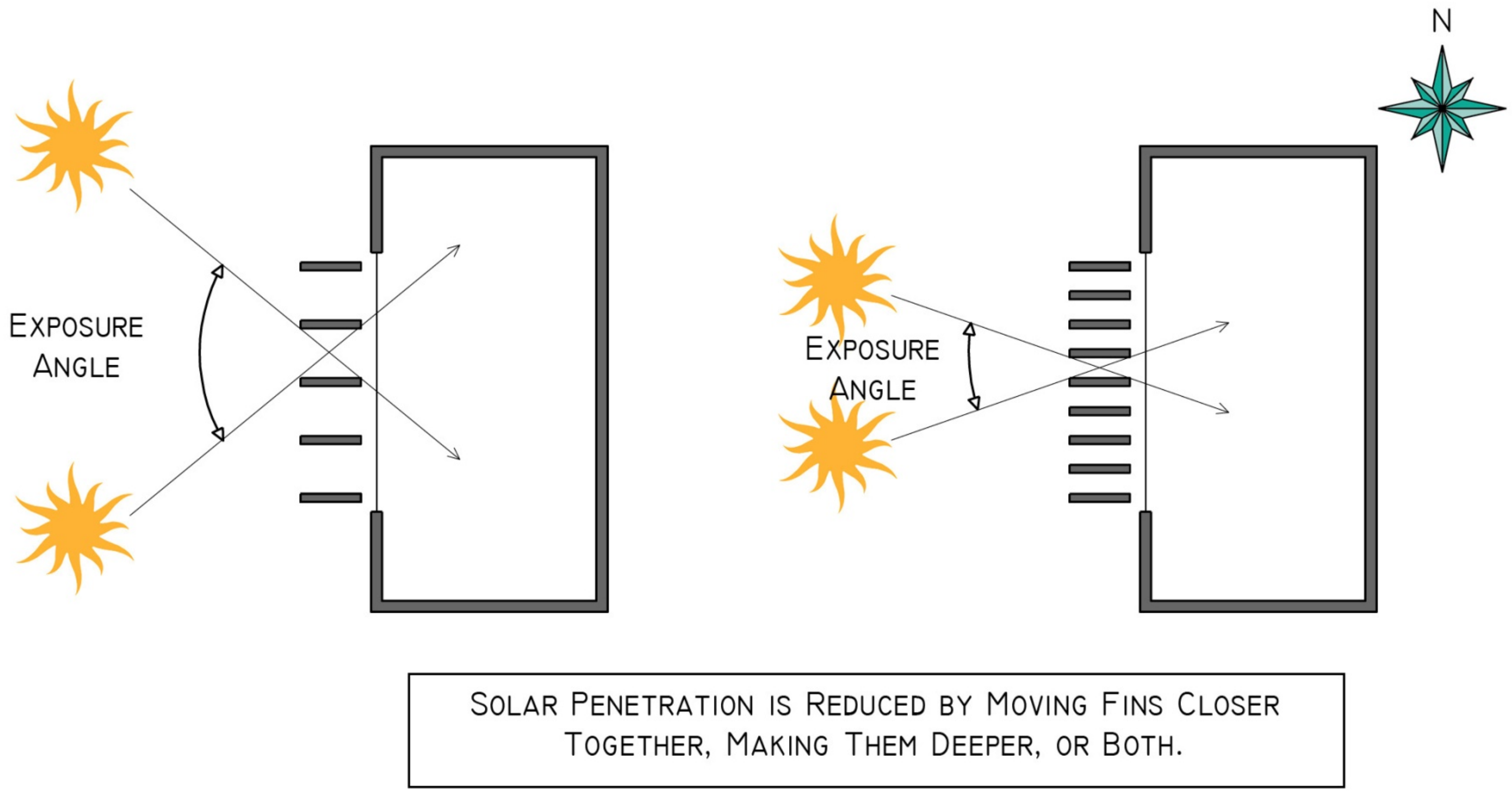
Avoid Windows on the East & West Facade
by Shifting the Windows to face North or South:

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



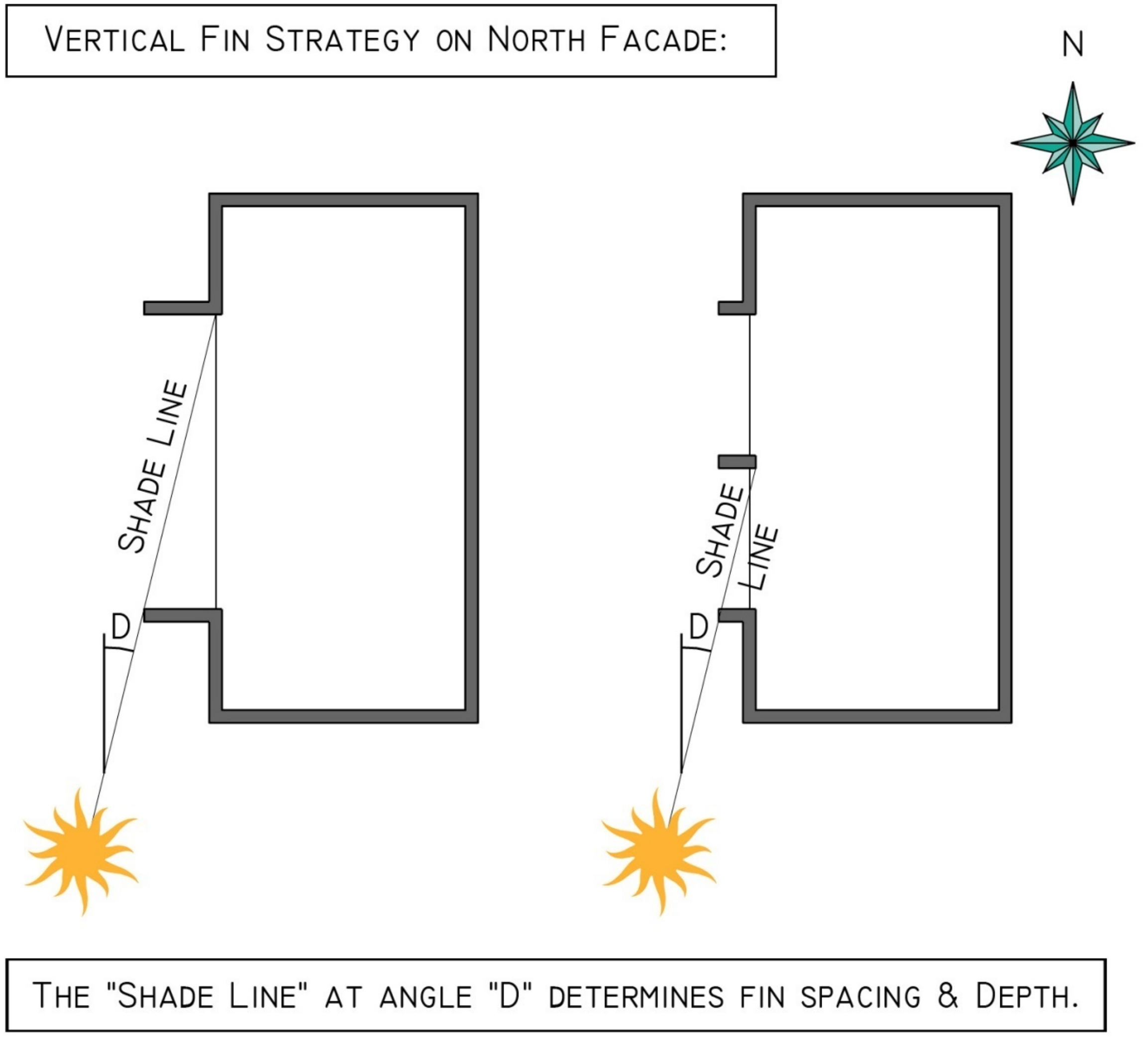
2. Next best solution is to have windows on the east and west façades face north or south

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.

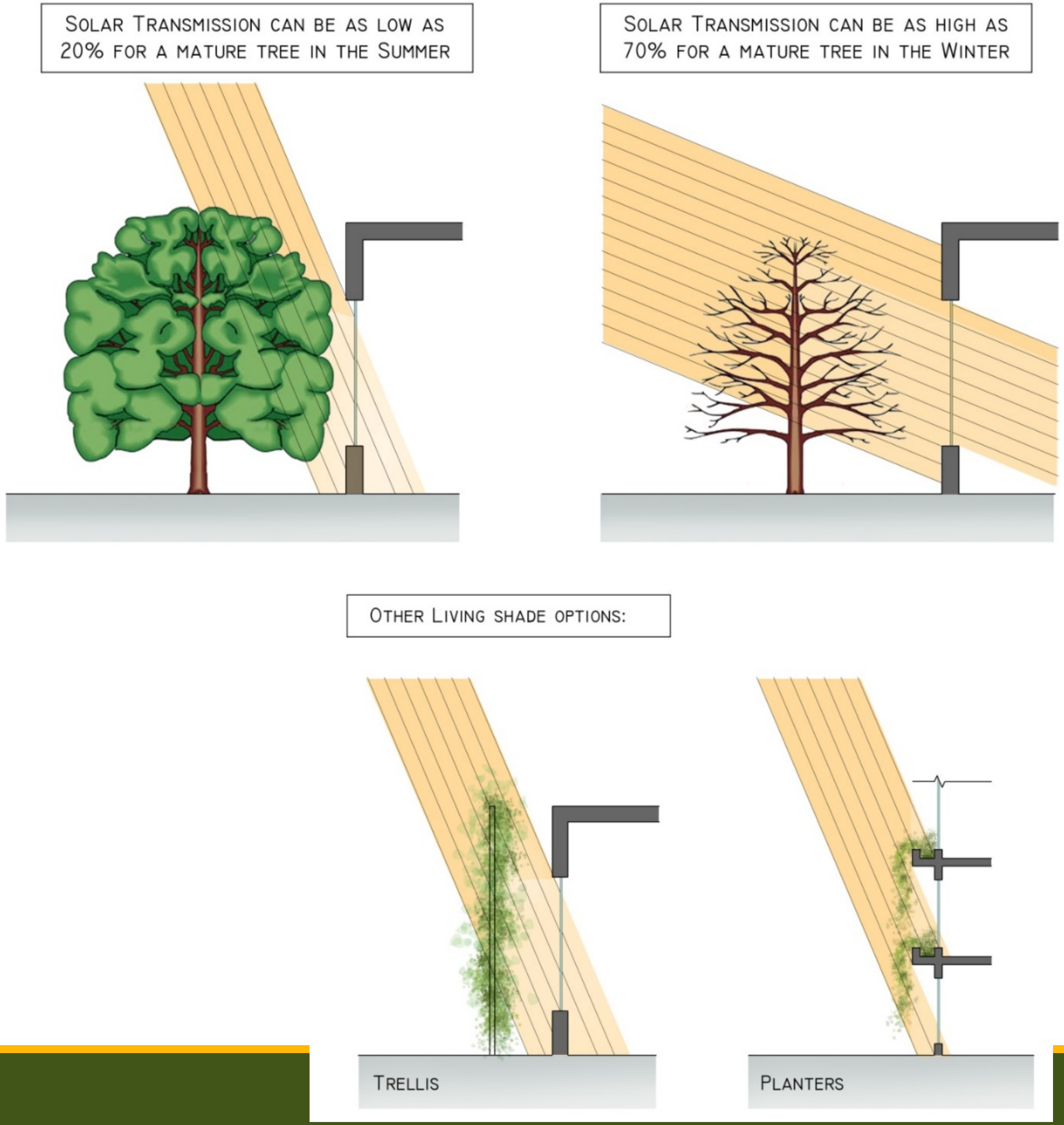
Shading Strategies for the North Elevation



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

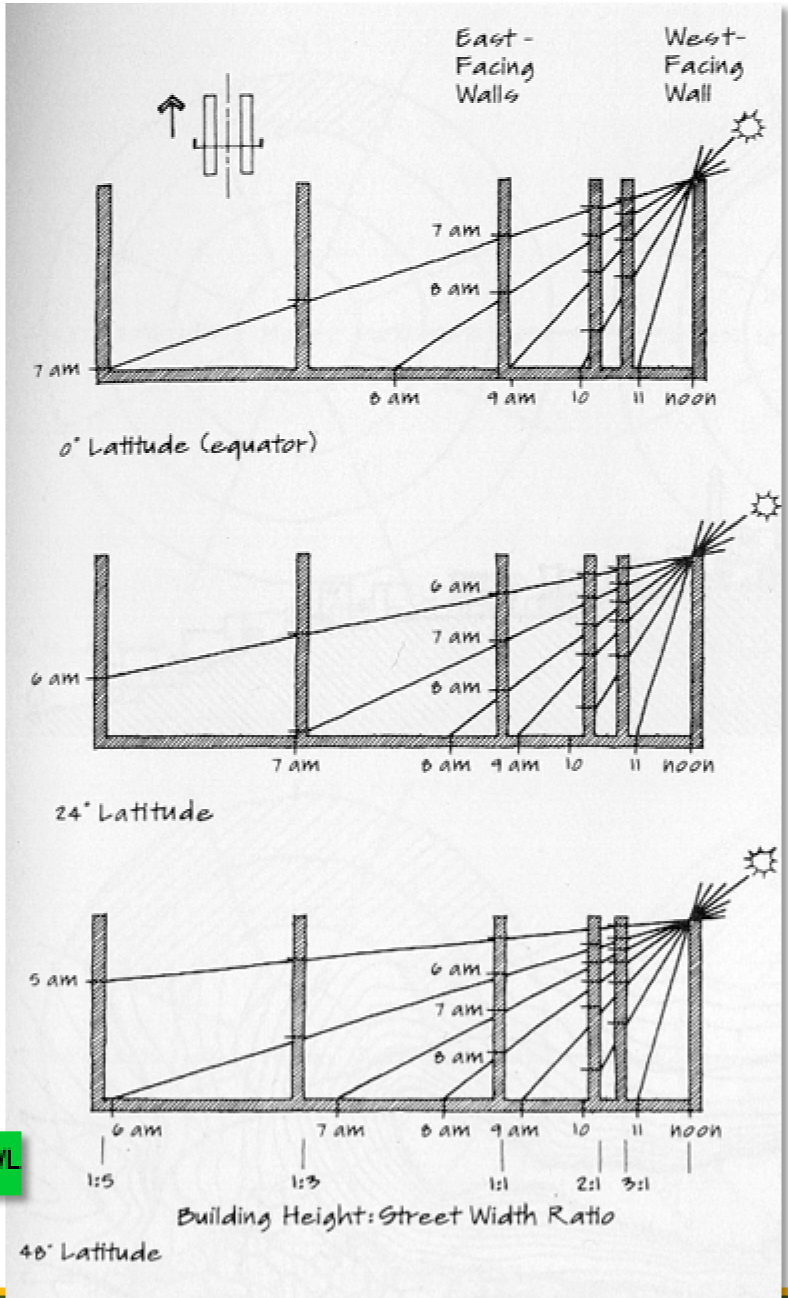
Living Awnings such as deciduous trees and trellises with deciduous vines are very good shading devices. They are in phase with the thermal year – gain and lose leaves in response to temperature changes.



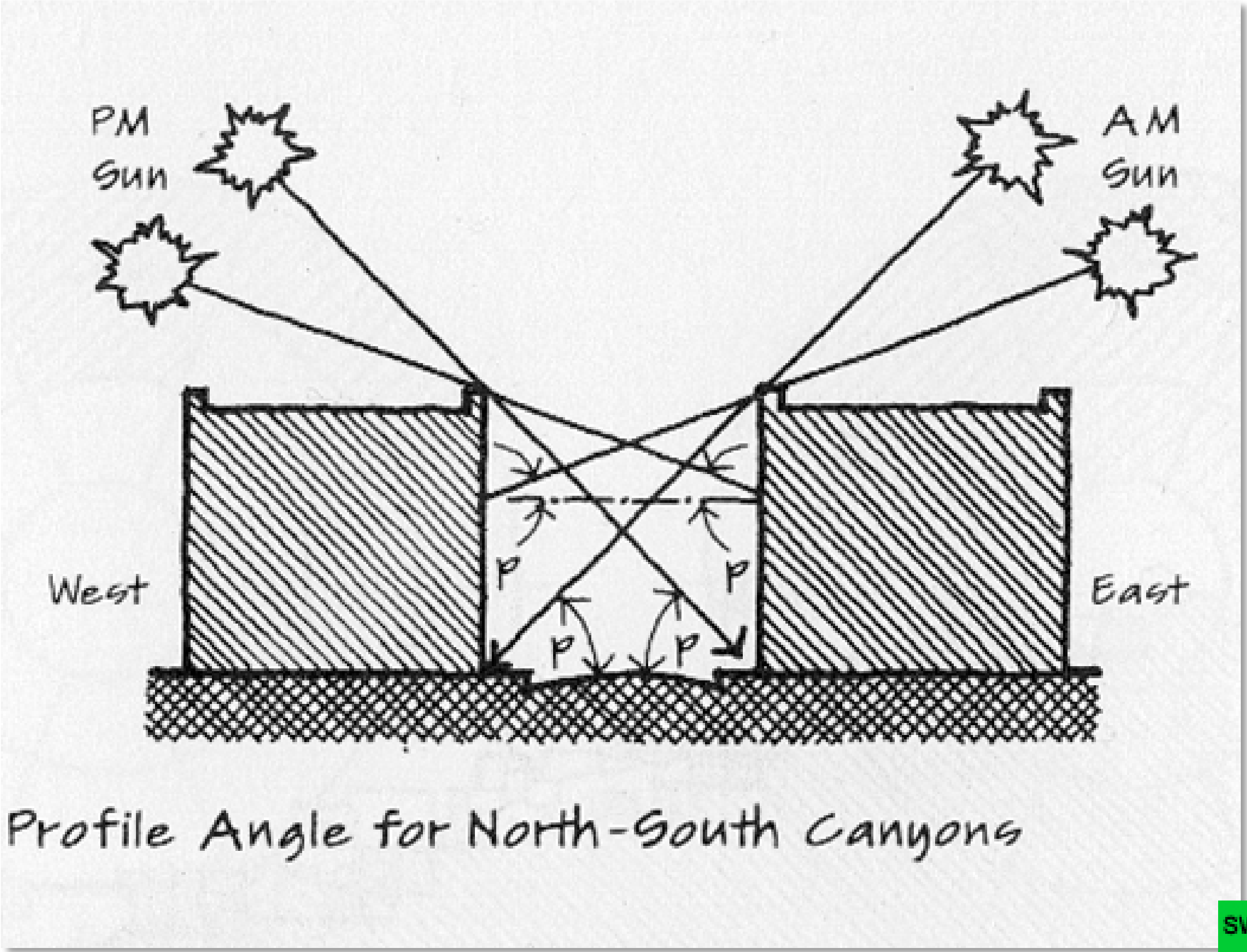
Building spacing and orientation will also need to be factored in when determining the amount of available light or sunlight for the building on its various sides.

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
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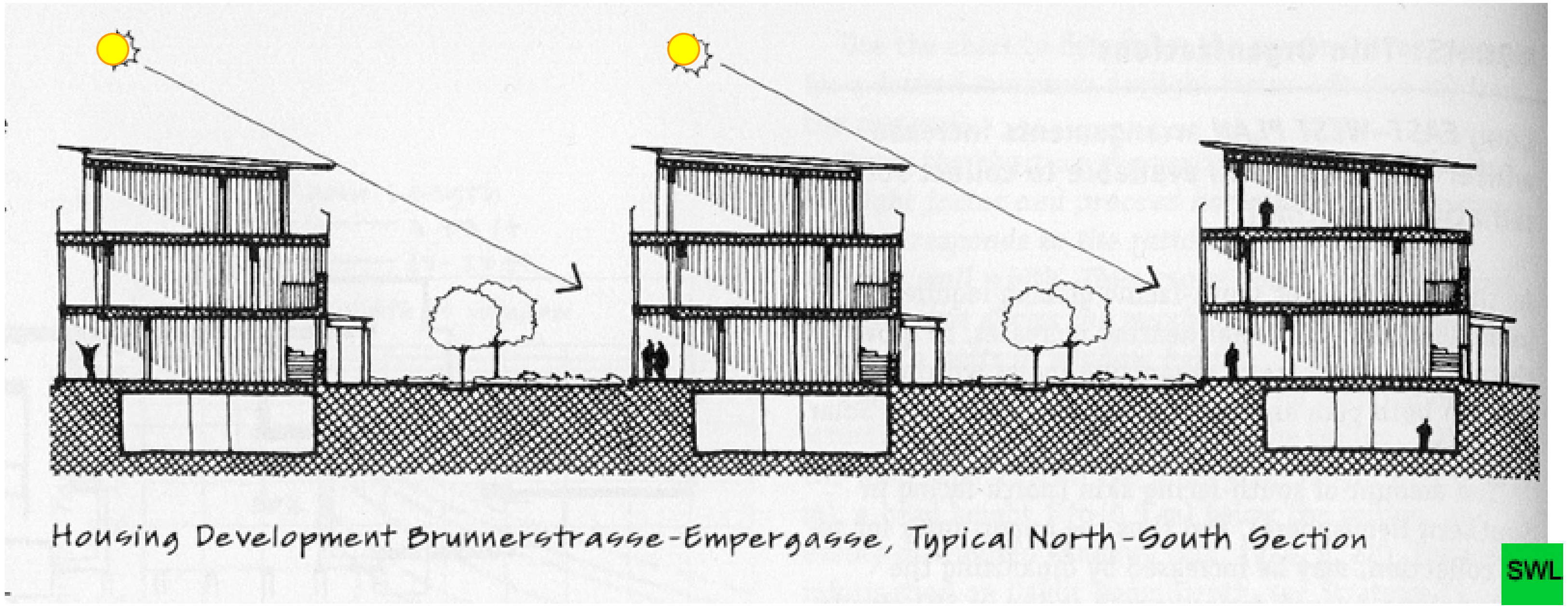
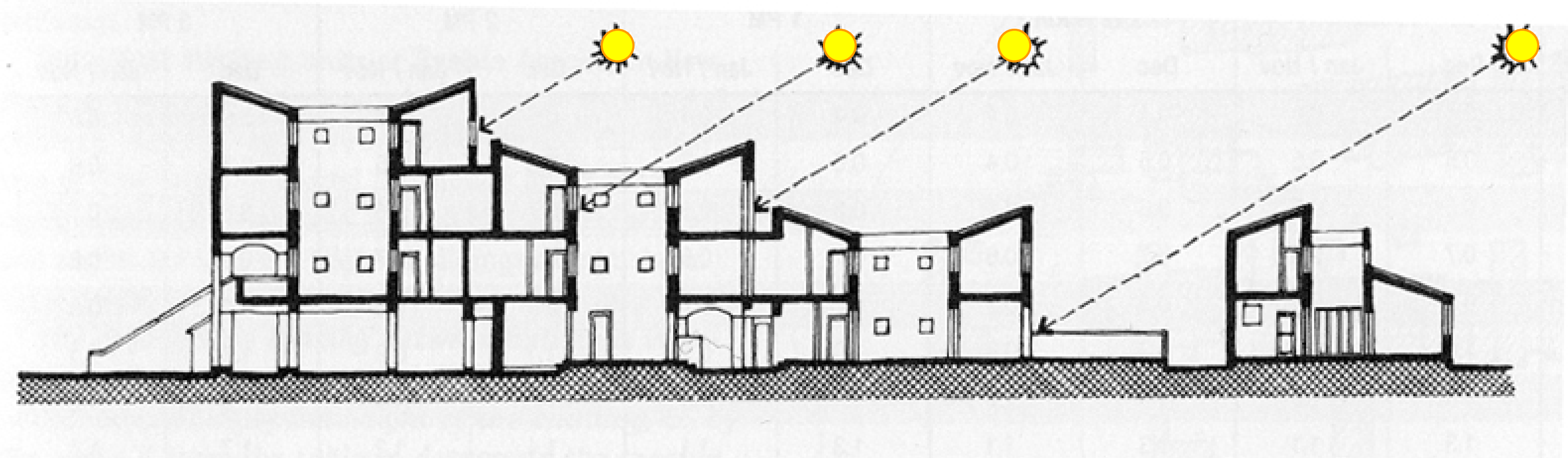
p
Profile Angle for North-South Canyons

SWL

Solar Access



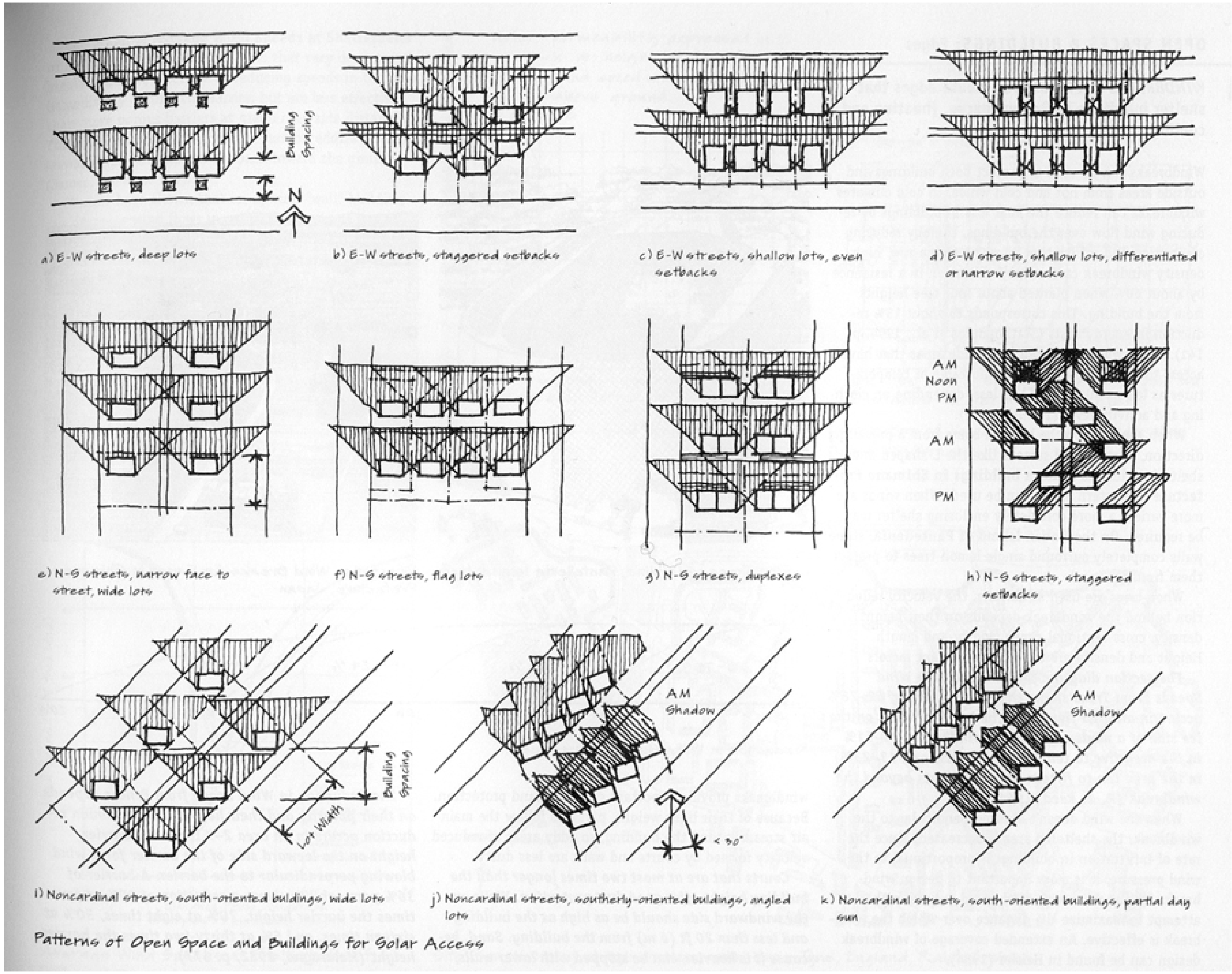
Better solar access is possible with east-west street sections as the south face of the building will get sun for most of the day. Street spacing is adjusted so that the buildings do not block each other's south light when the angles are lowest in the winter (for good design).



North-South Section, Public Housing Estate, Giudecca Island, Venice, Italy, Gino Valle

SWL

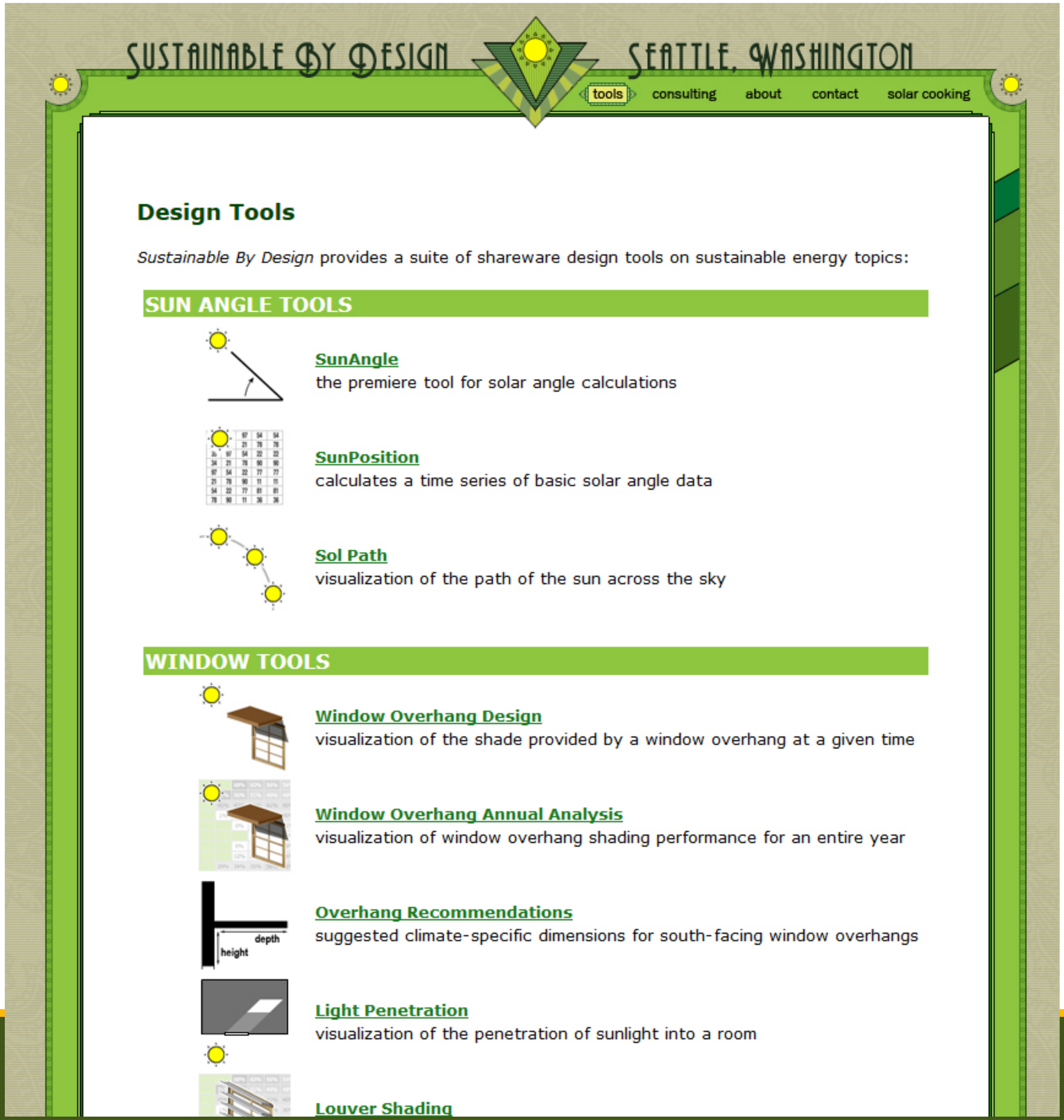
For more complicated sections, the building height and section is adjusted to allow south light to penetrate into various exposures of the building -- in this case through courtyards and clerestory windows.



Street Layouts

- In cold climates the shadows and sun angles are the lowest in the winter when we really want to let the sun/heat in
- Buildings must be spaced far enough apart so that they don’t shadow each other
- The sun angles are low enough though that the sun will penetrate deep into the building if the windows are properly located.

Helpful online tools



SUSTAINABLE BY DESIGN SEATTLE, WASHINGTON

tools consulting about contact solar cooking

Design Tools

Sustainable By Design provides a suite of shareware design tools on sustainable energy topics:

SUN ANGLE TOOLS

SunAngle
the premiere tool for solar angle calculations

SunPosition
calculates a time series of basic solar angle data

Sol Path
visualization of the path of the sun across the sky

WINDOW TOOLS

Window Overhang Design
visualization of the shade provided by a window overhang at a given time

Window Overhang Annual Analysis
visualization of window overhang shading performance for an entire year

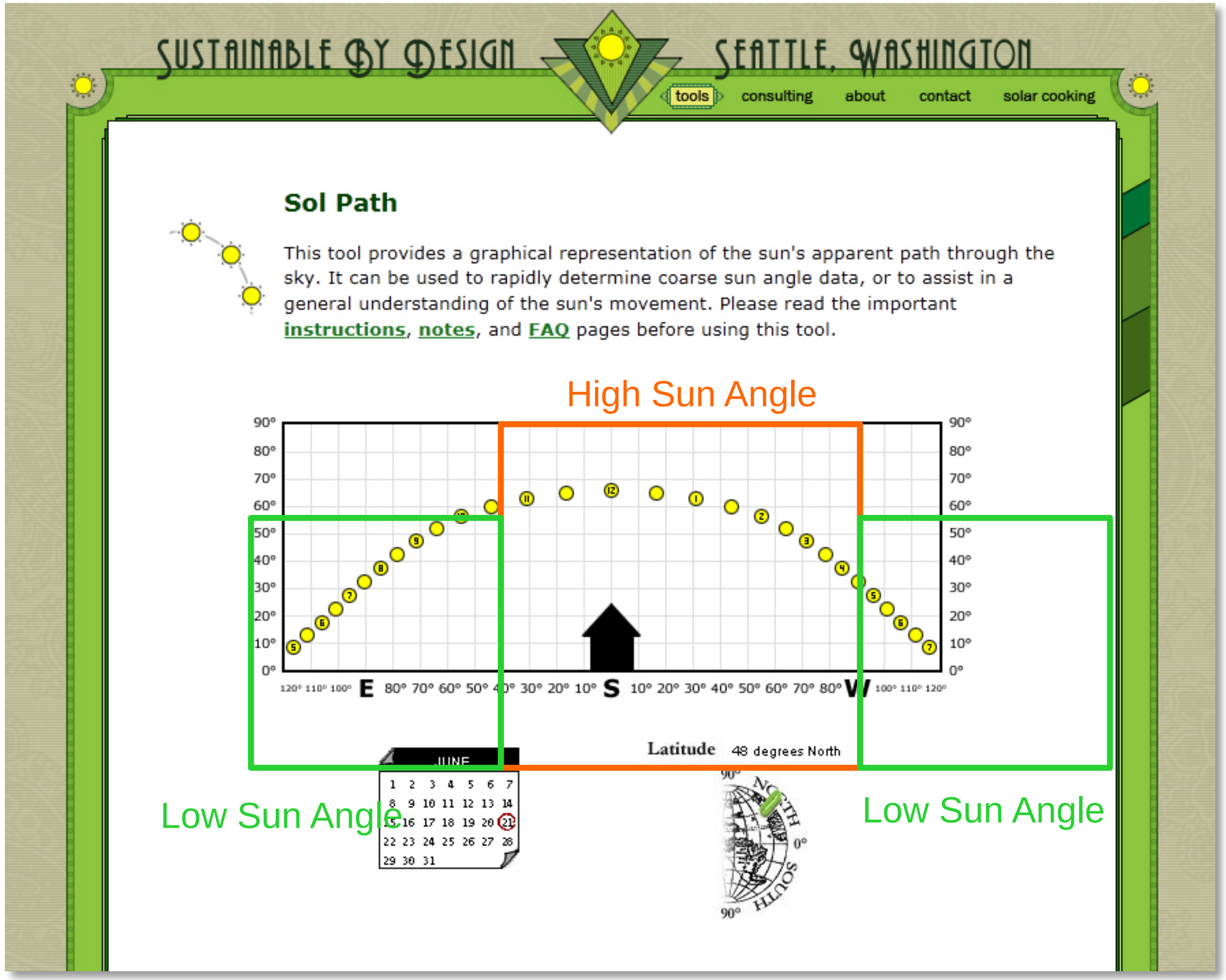
Overhang Recommendations
suggested climate-specific dimensions for south-facing window overhangs

Light Penetration
visualization of the penetration of sunlight into a room

Louver Shading

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

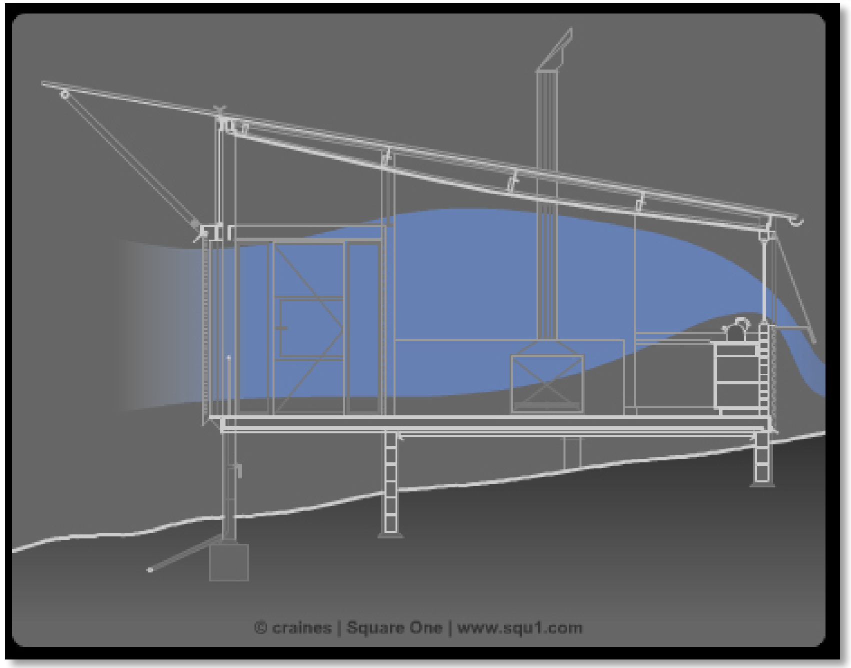
Terasan Gas, Surrey, BC

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

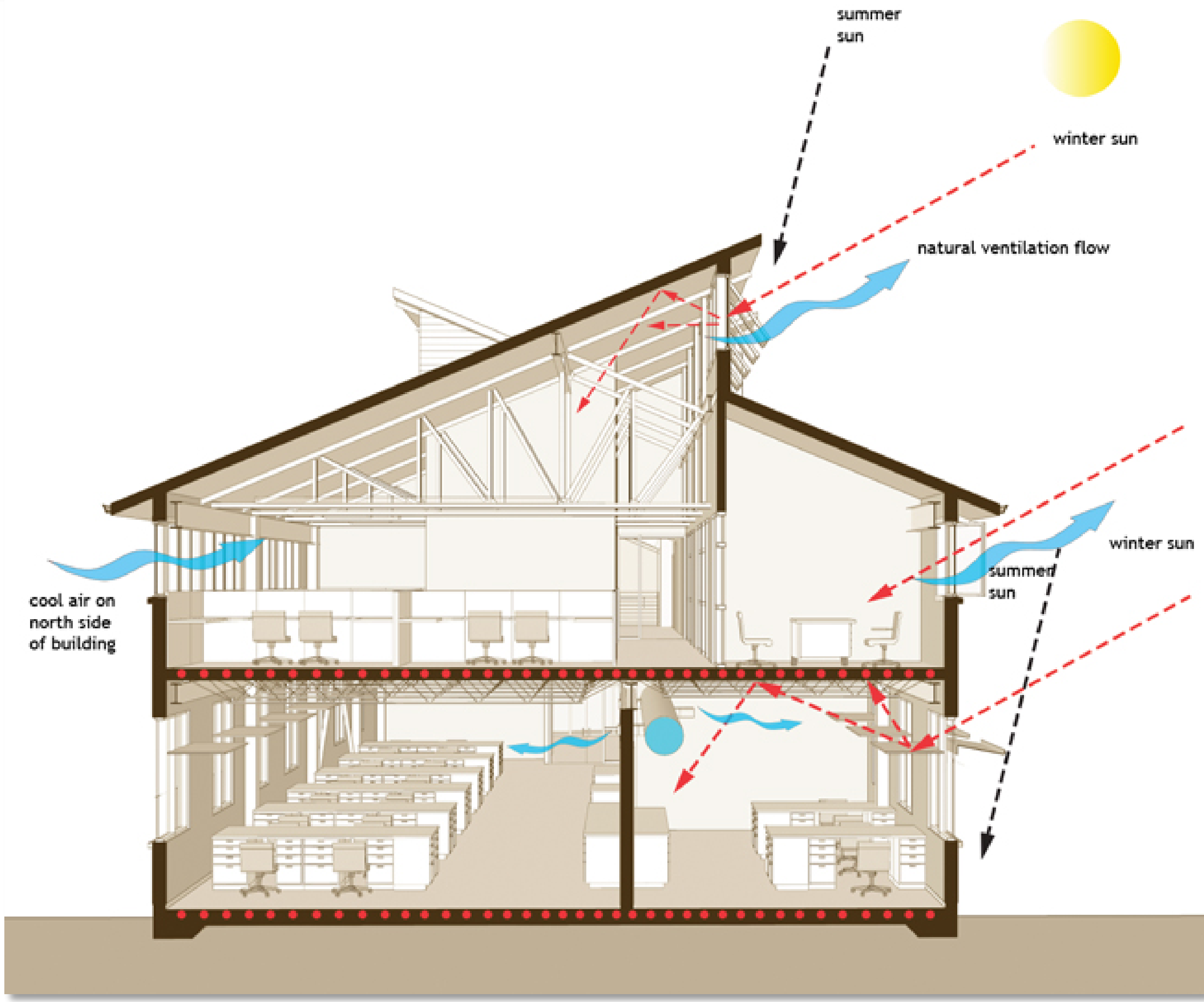


The elimination of A/C is one of the most effective ways to reduce operating energy.

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



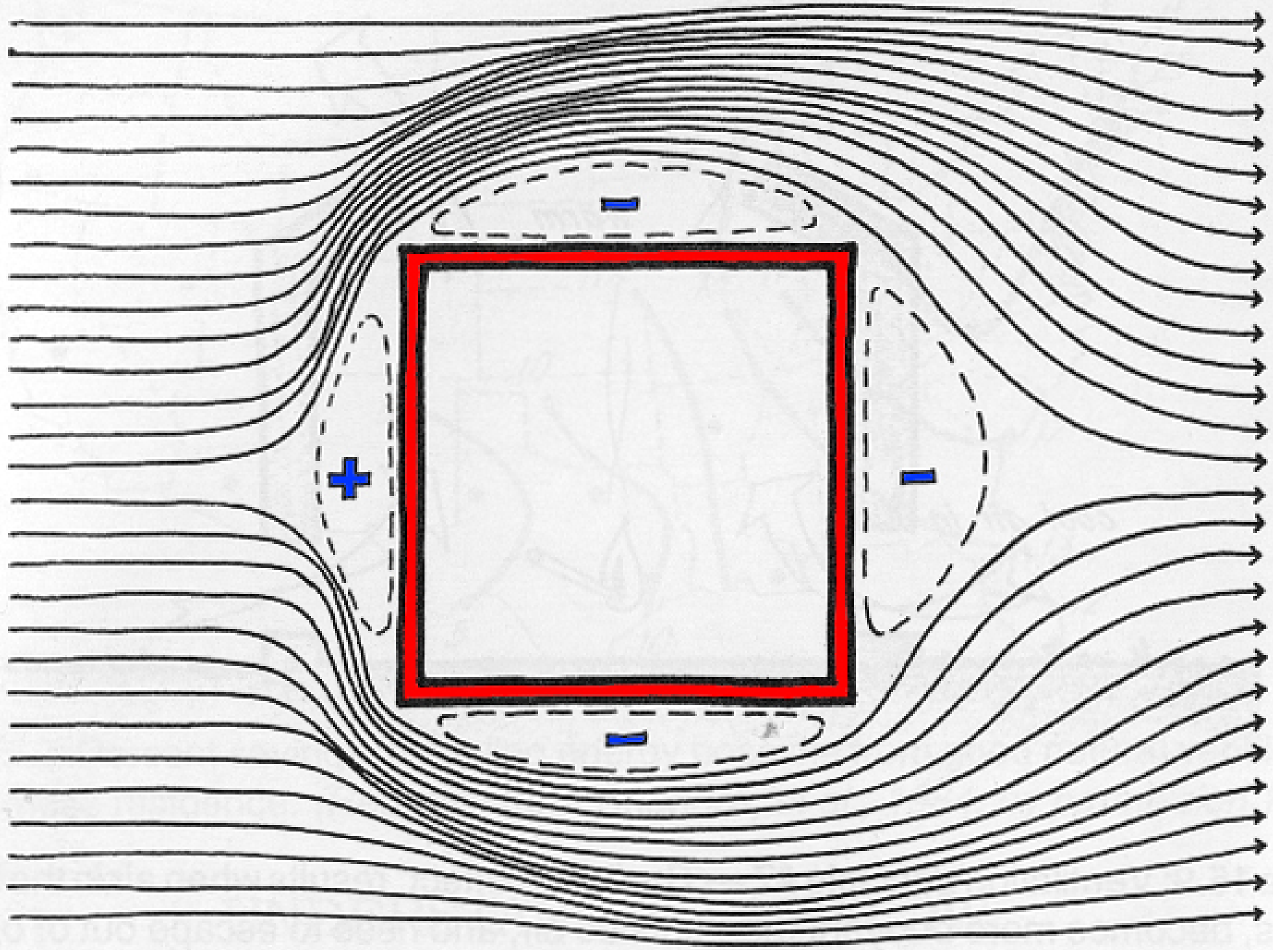


Figure 15.11: Low-pressure zones occur along the sides parallel to the wind and on the leeward side of the building. *(After Bowen, 1981.)*

HCL

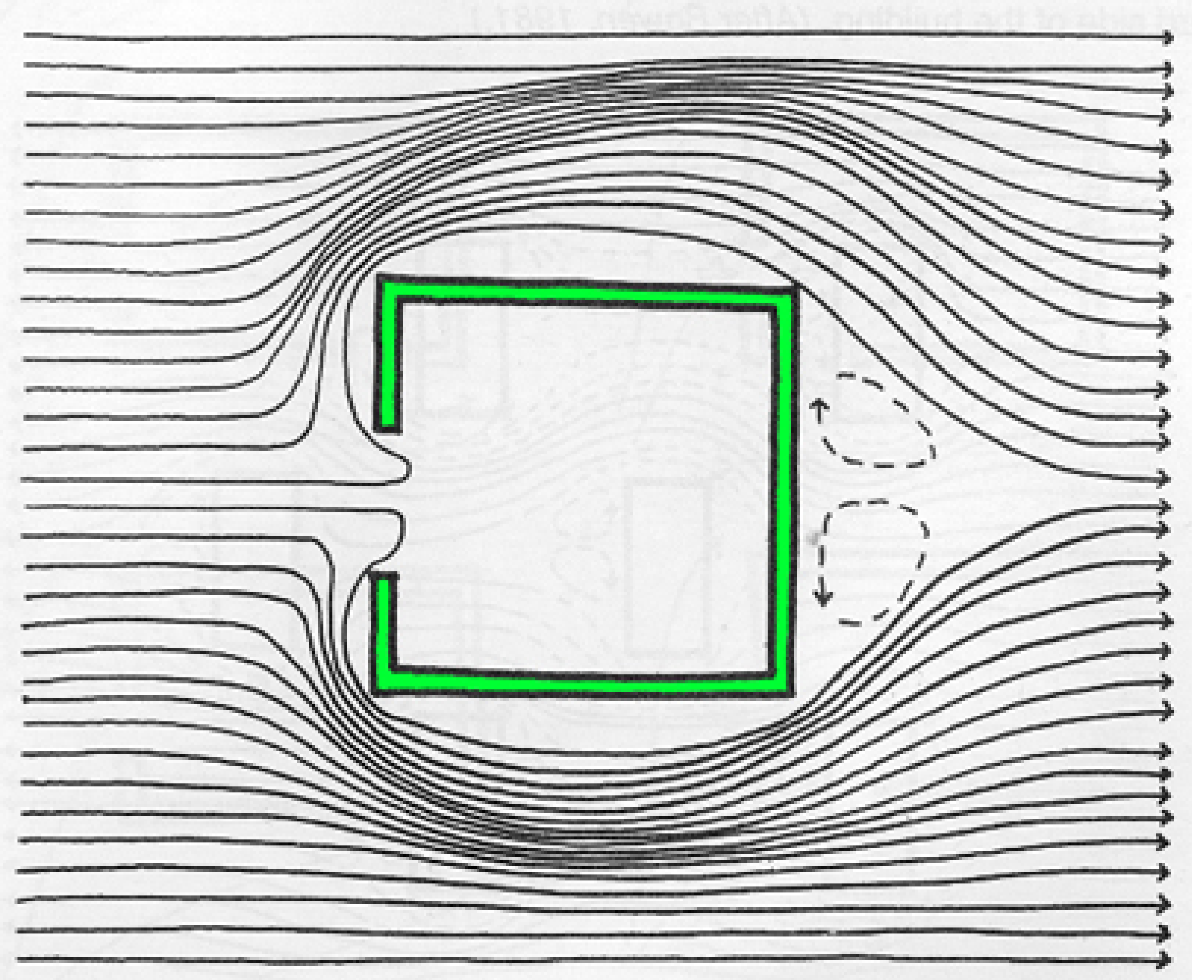


Figure 15.10: Ventilation principle #8 — Cross-ventilation requires an outlet as well as an inlet. (Analogy: water cannot be put into a bottle that is already full unless some old water is removed first — through a hole in the opposite end of the bottle, for example.)

HCL

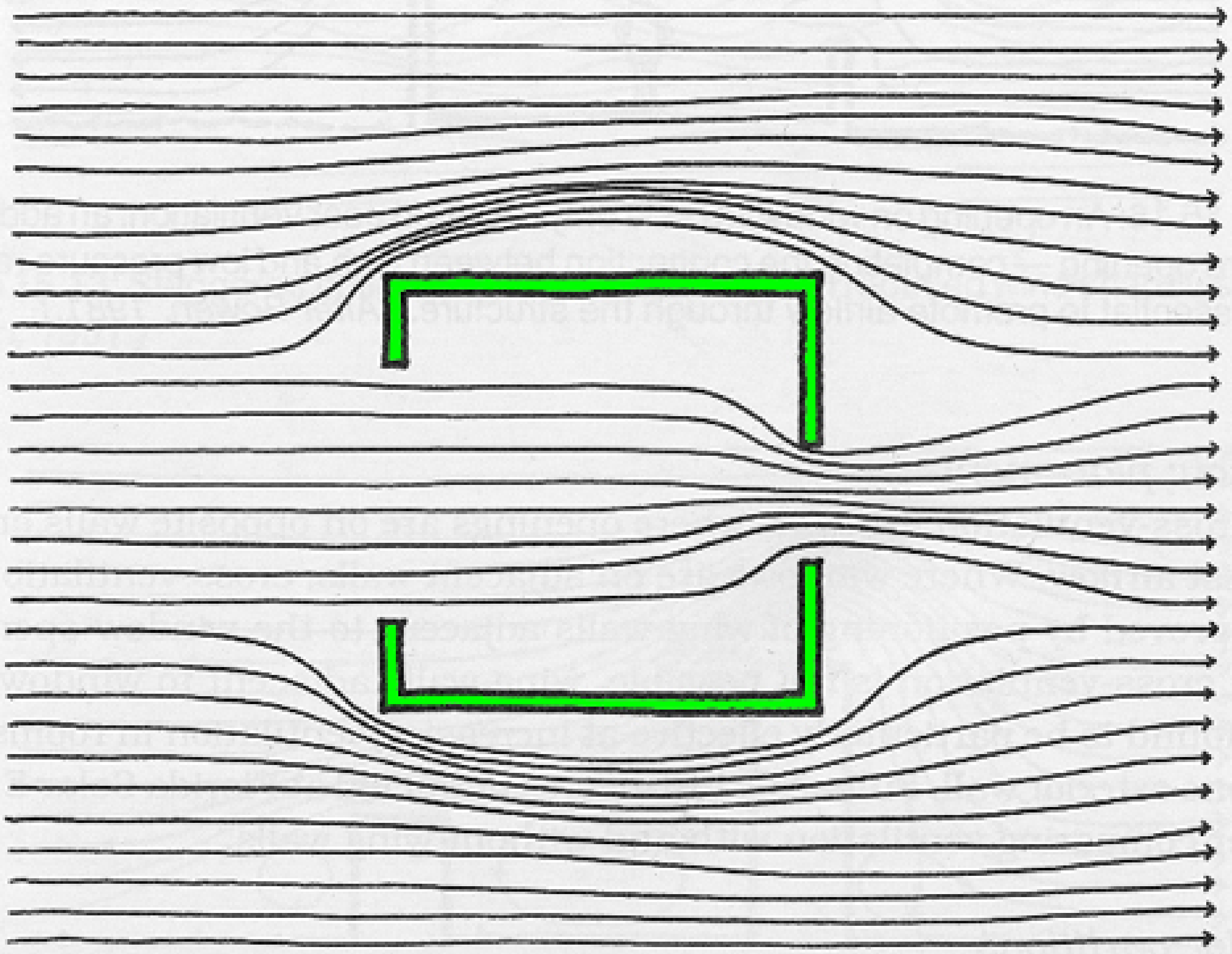


Figure 15.21: If the inlet is larger than the outlet, velocity in the room is reduced (although velocity outside just to leeward of the outlet is increased). This has potential for cooling a localized exterior area such as a patio. *(After Bowen, 1981.)*

HCL

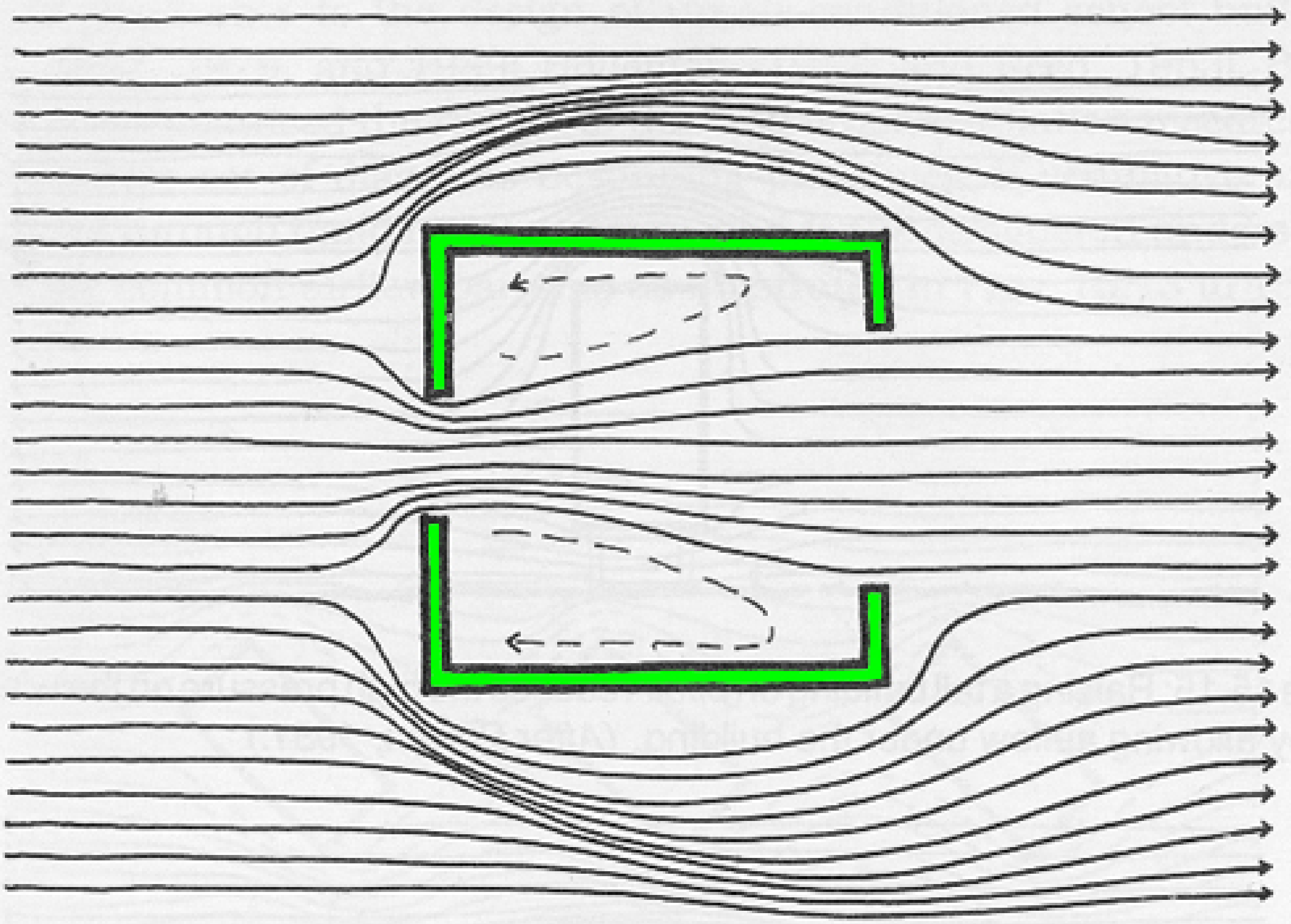
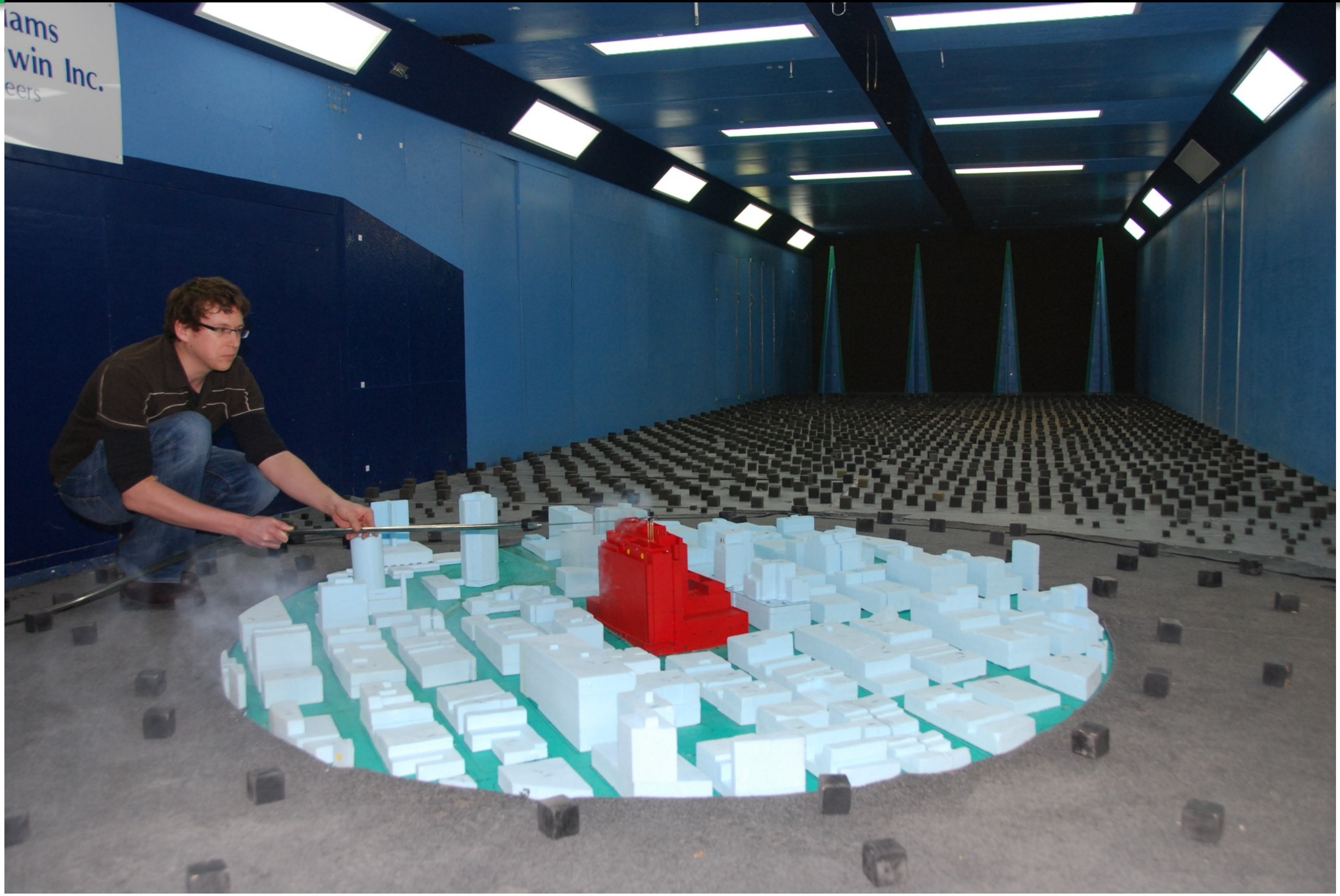


Figure 15.20: Maximum *interior airspeed* is created when the inlet is smaller than the outlet, making this the optimum configuration when *people* cooling is the goal. *(After Bowen, 1981.)*

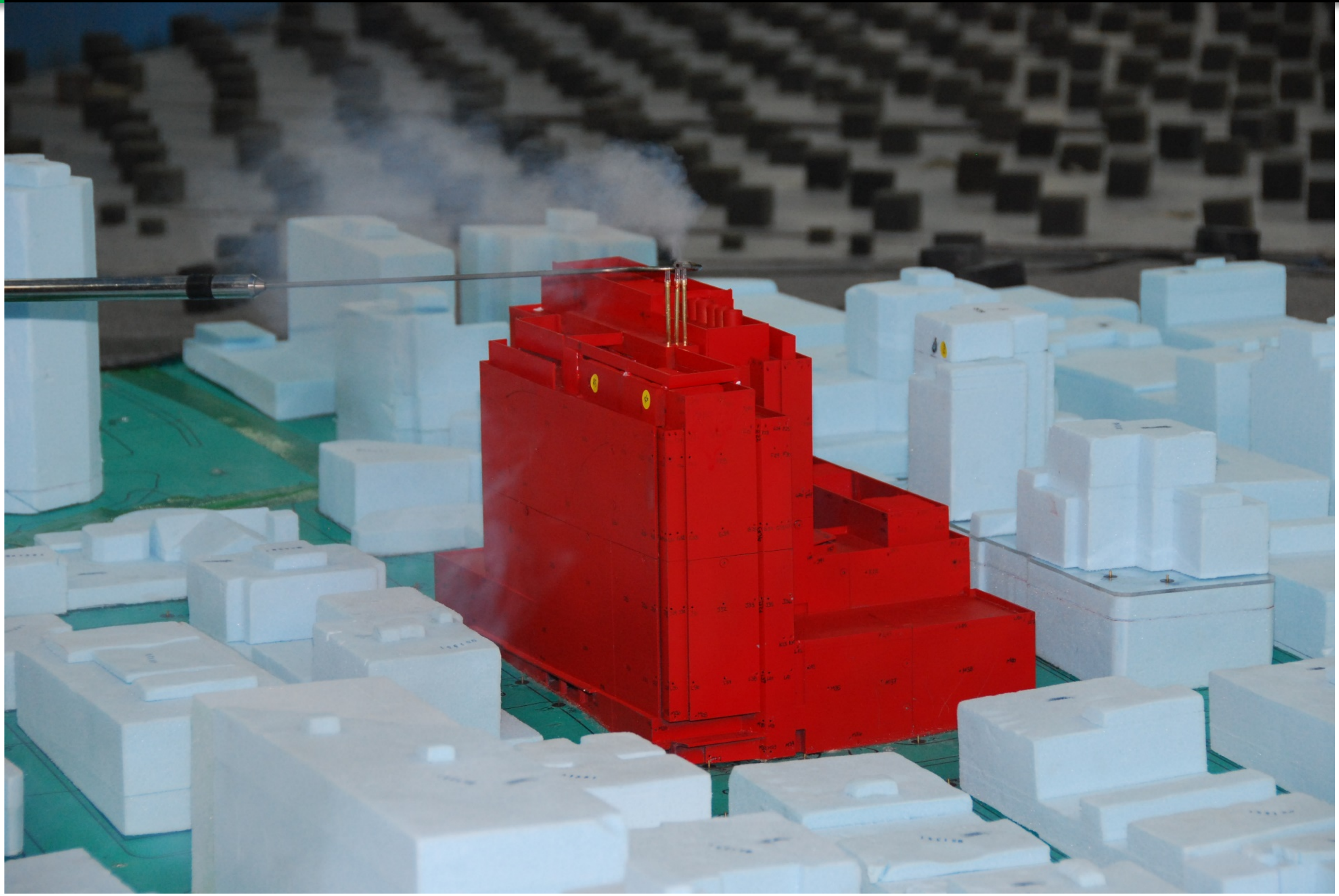
HCL

Wind Tunnel

Wind Tunnel

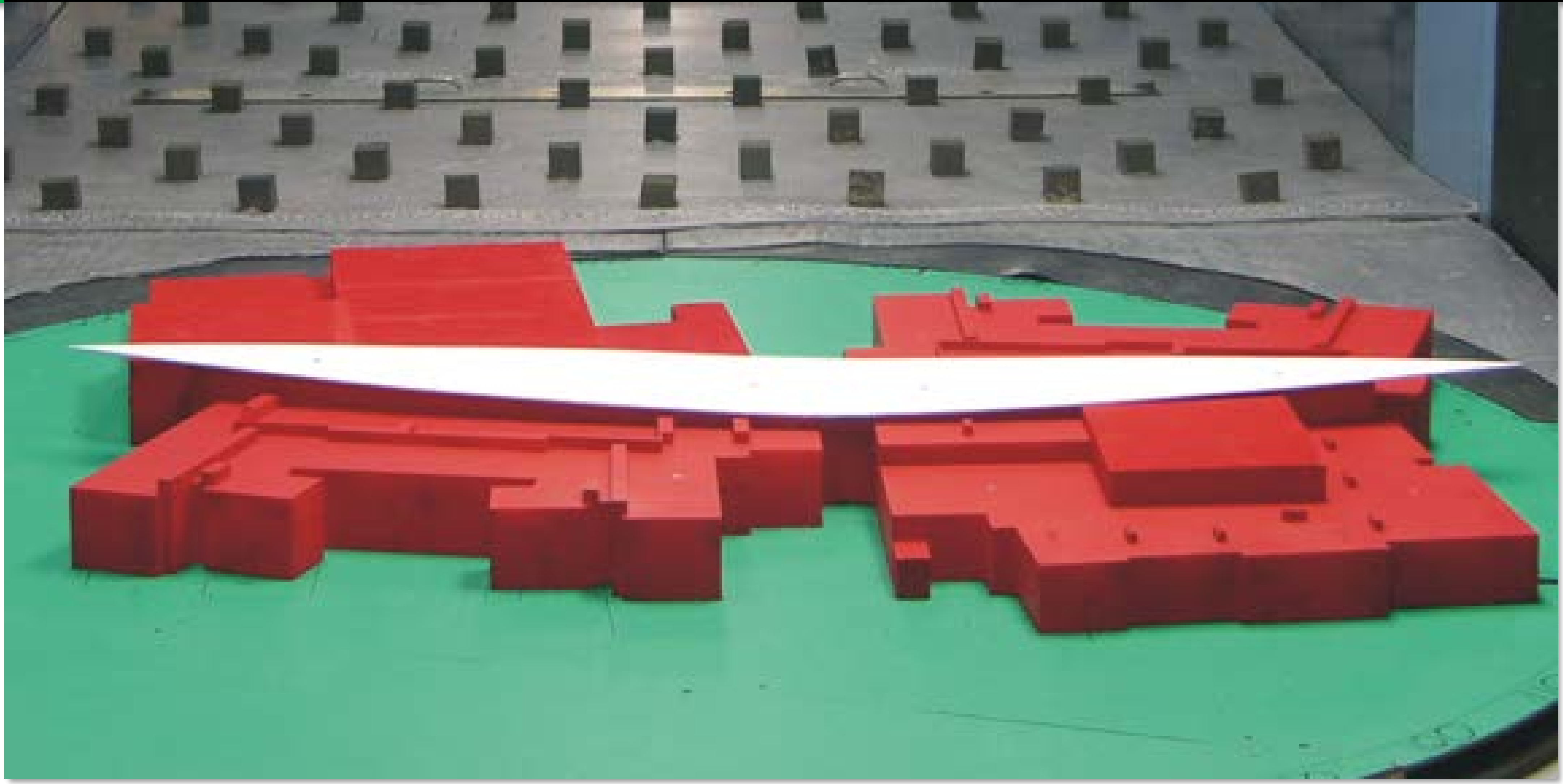


Wind Tunnel

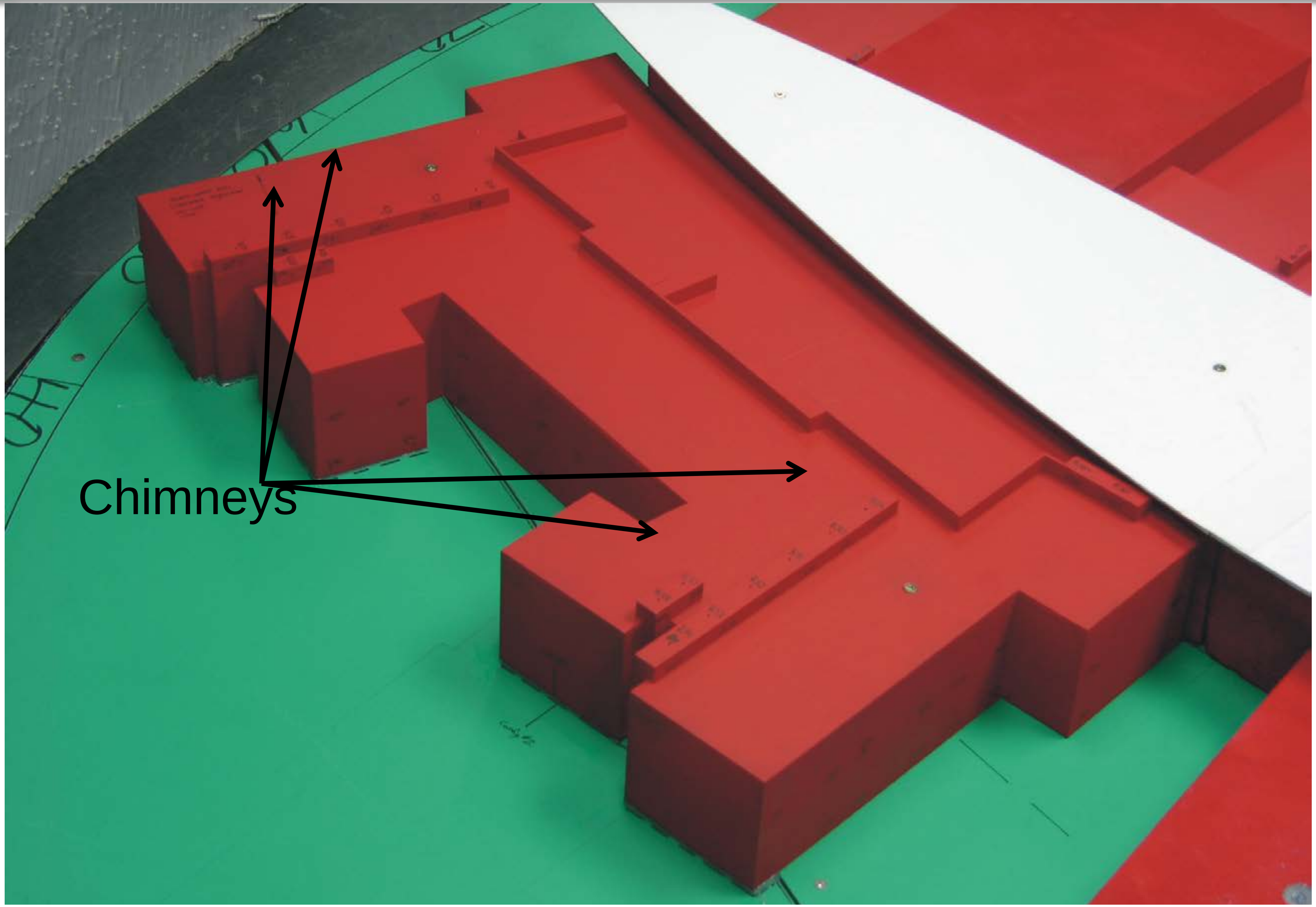


Wind Tunnel

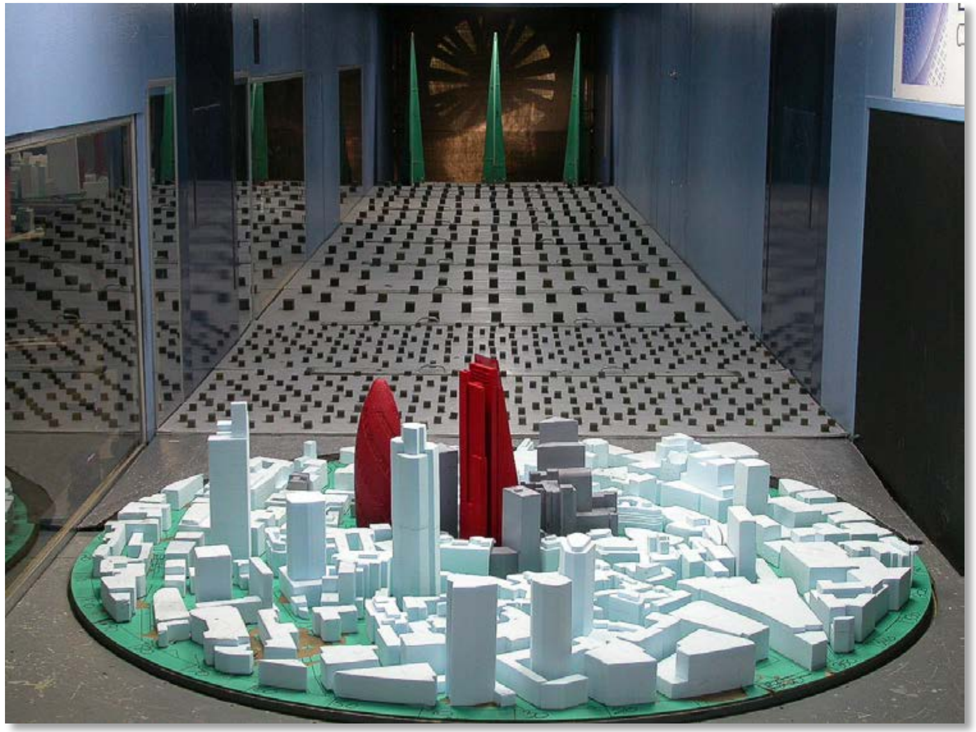
Wind tunnel model

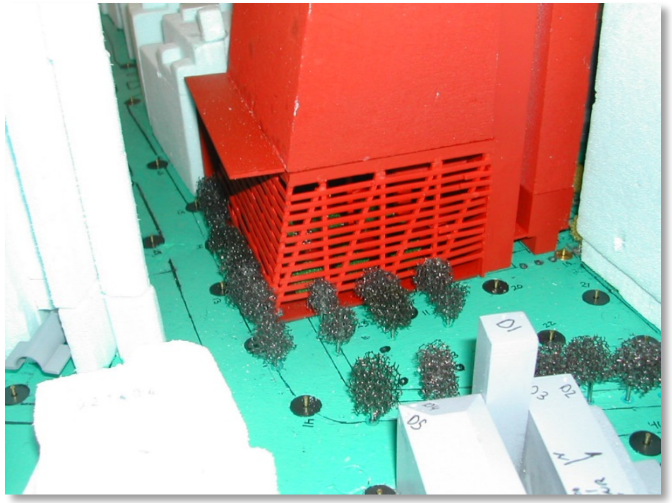


Windtunnel Measurements



Urban situation easy to check

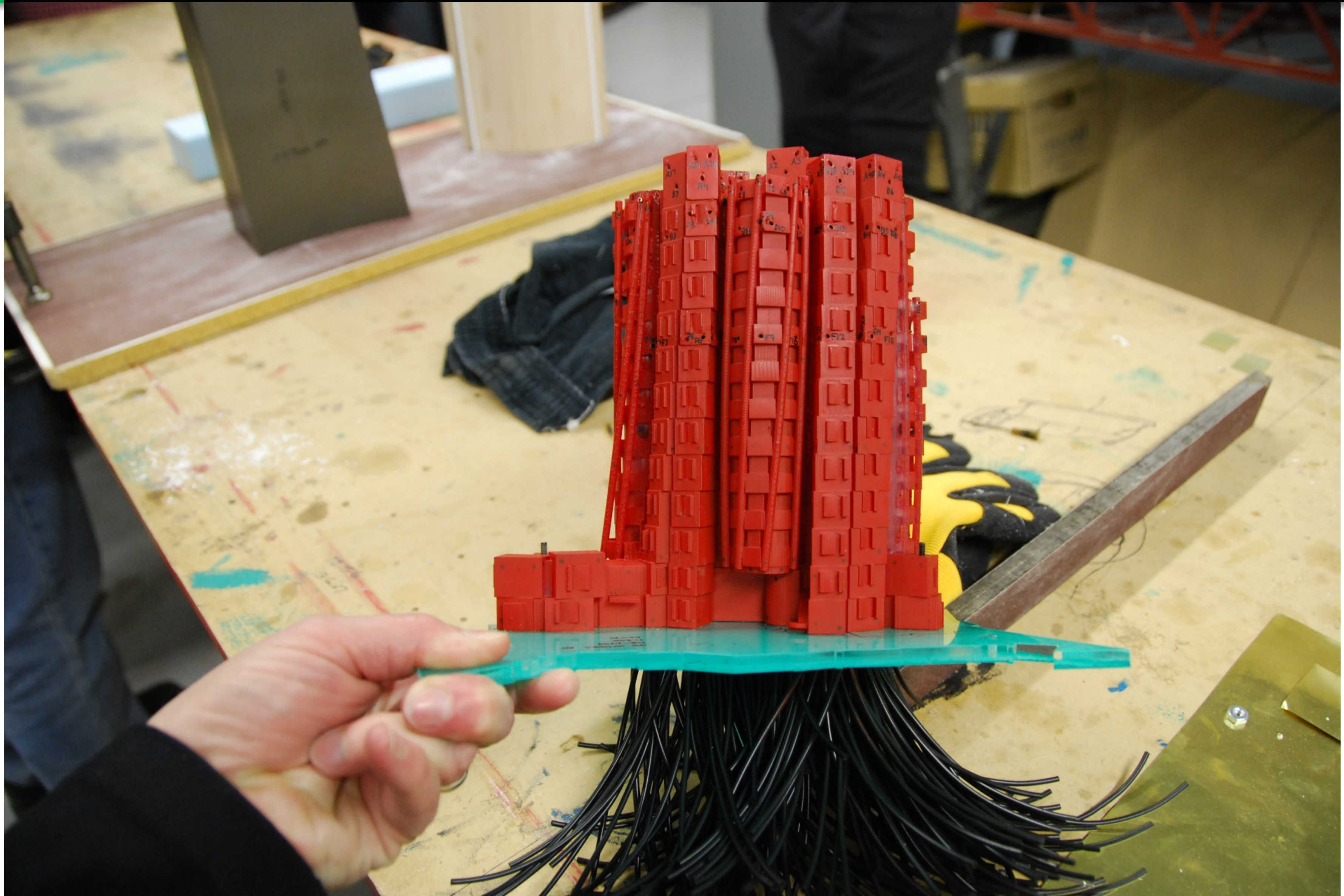




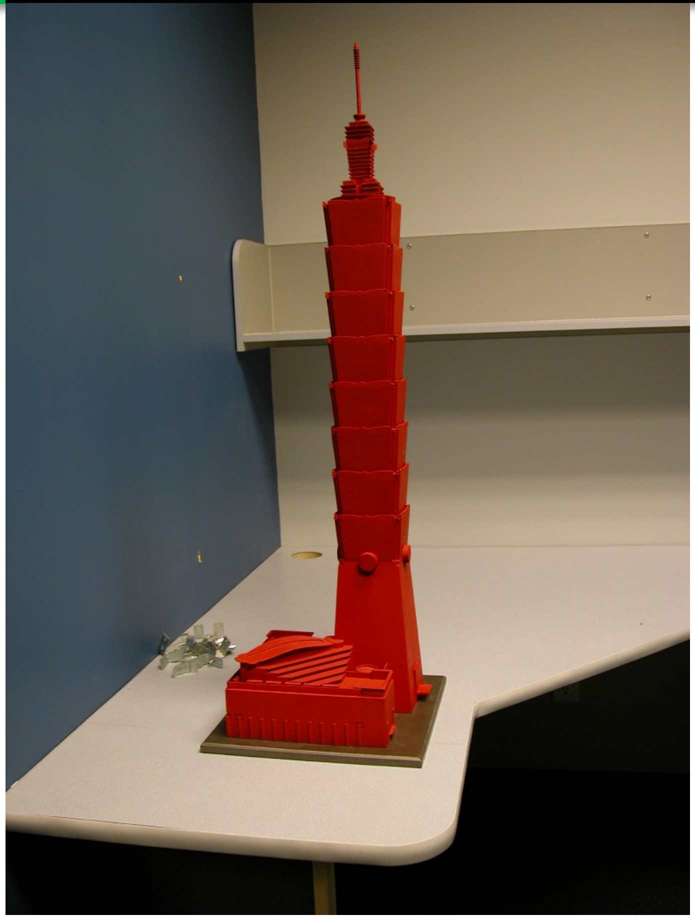
Models for the Leadenhall Building that include Swiss Re, previously modeled + site condition at base of buildings

Model Shop at RWDI Wind Engineers

Specially constructed models

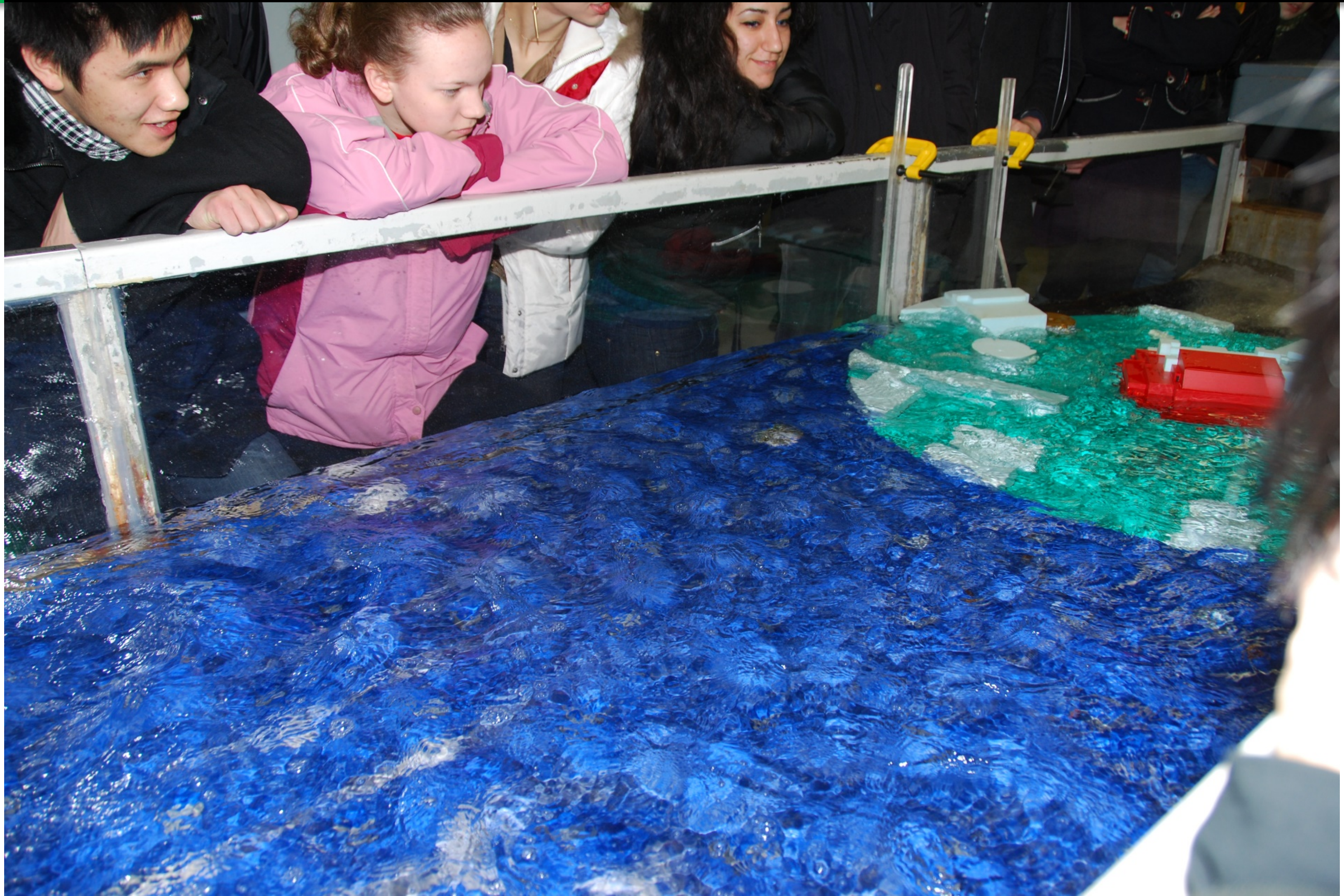


World class facility

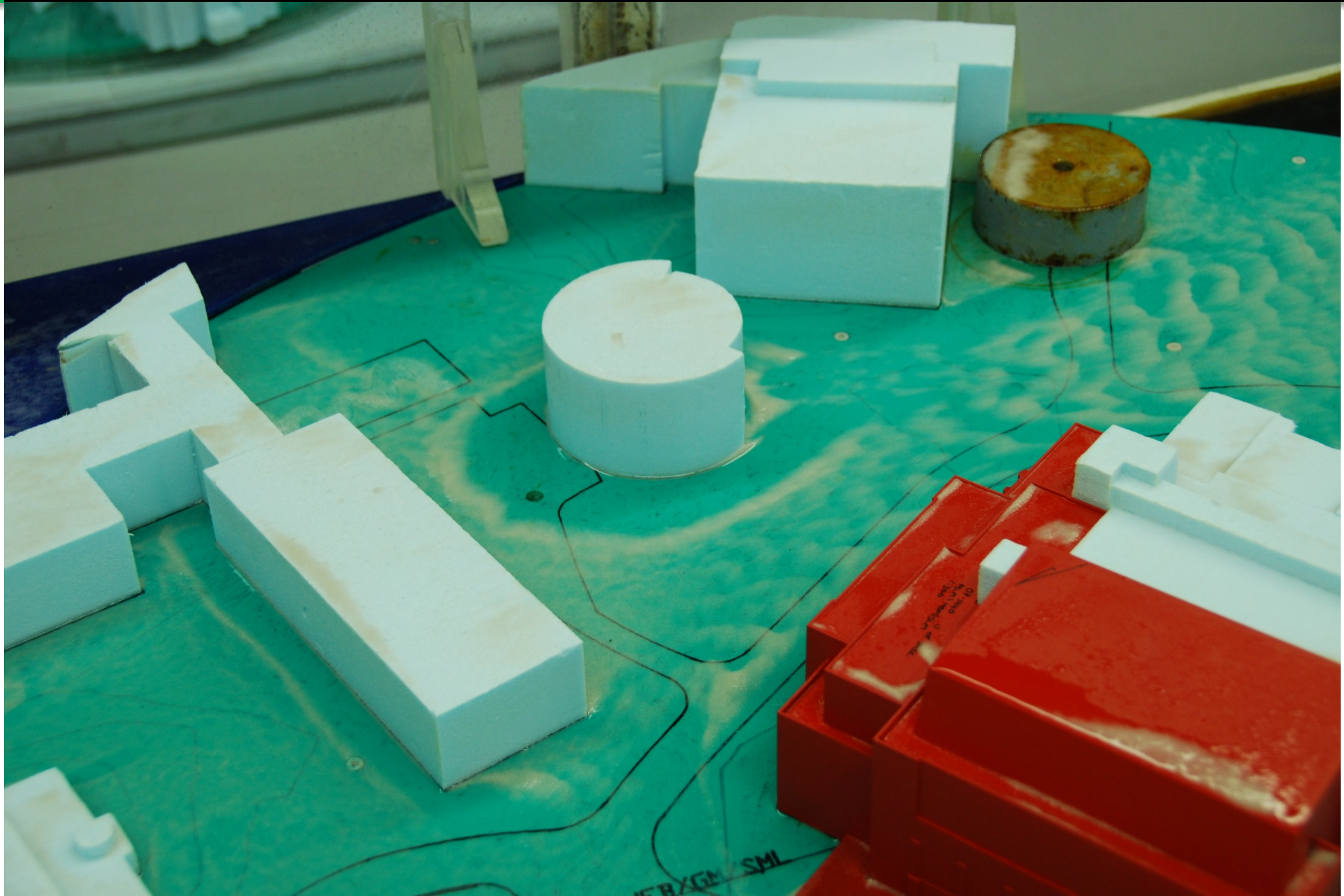


Water Flume

Water Flume



Water Flume



IMPORTANT!

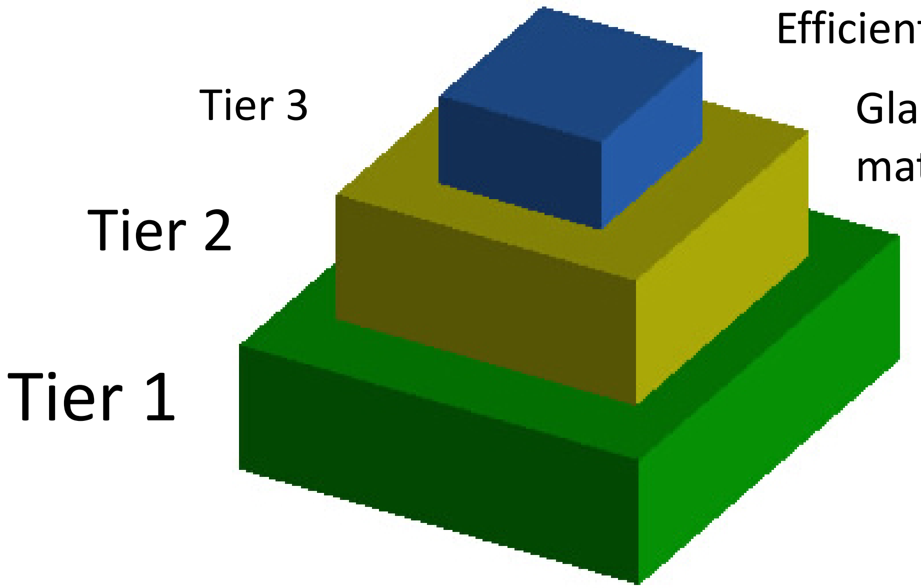
For natural ventilation to work you need:

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.

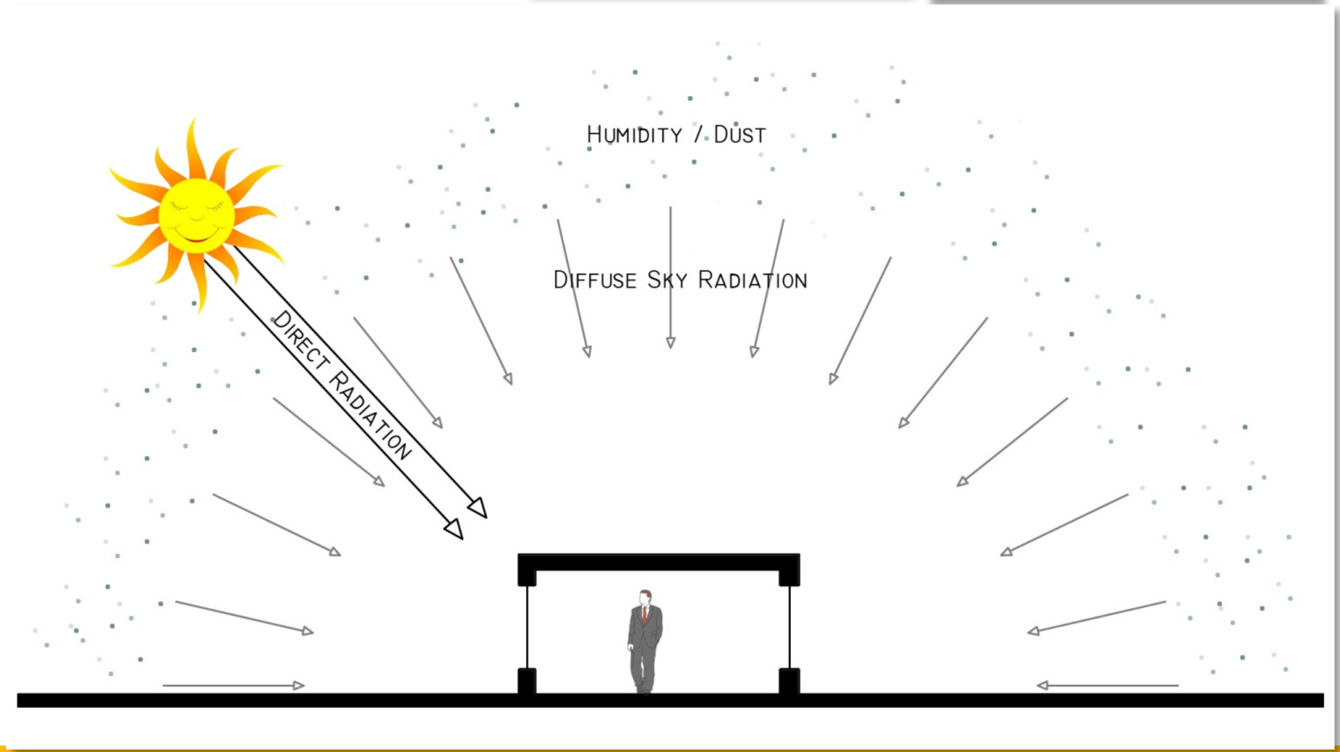
DIRECT SUNLIGHT is about **FREE HEAT**. 

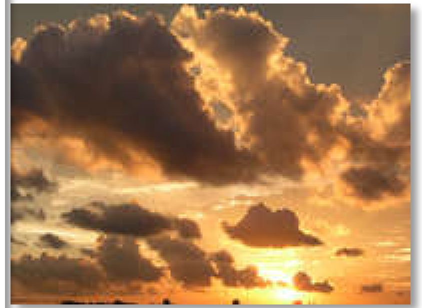
DAYLIGHT (diffuse light) is about **FREE LIGHT.** 

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

The Function of the Atmosphere

Direct versus Diffuse Radiation





Passive Lighting Strategies:
Energy efficiency and renewables

- use energy efficient light fixtures (and effectively!)

- use occupant sensors ***<u>combined with light level sensors</u>***

- 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

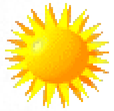
Daylighting is **environmentally advantageous** because it:

- 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	
Sidewalk in moonlight	0.003	Poor vision
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.

Daylight Factor

2% average daylight factor

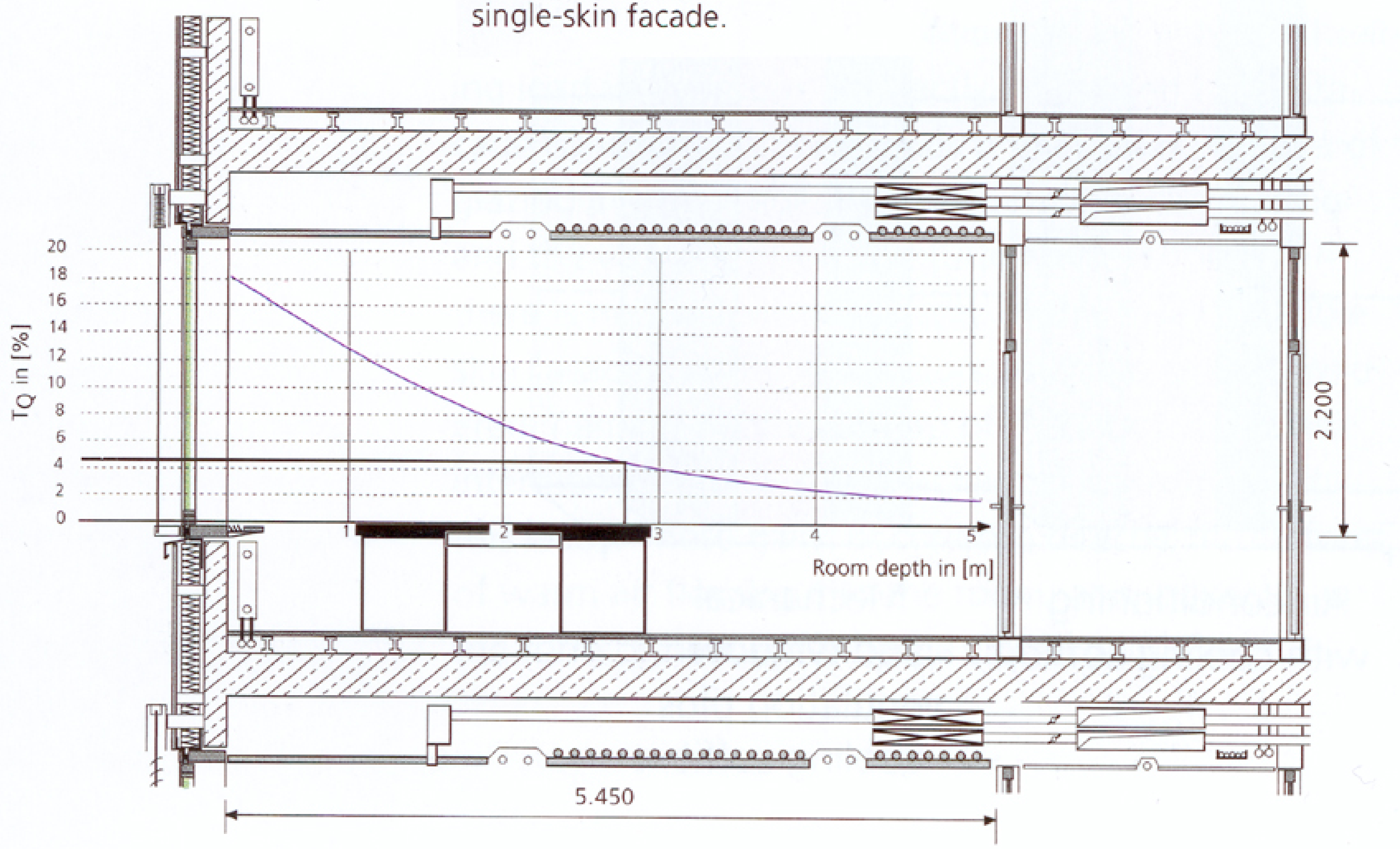
5% average daylight factor

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

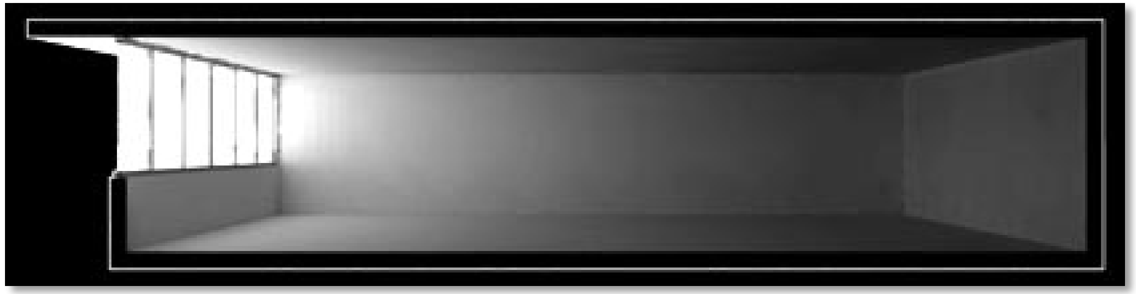
Solar Reflectance of Finishes

SWL

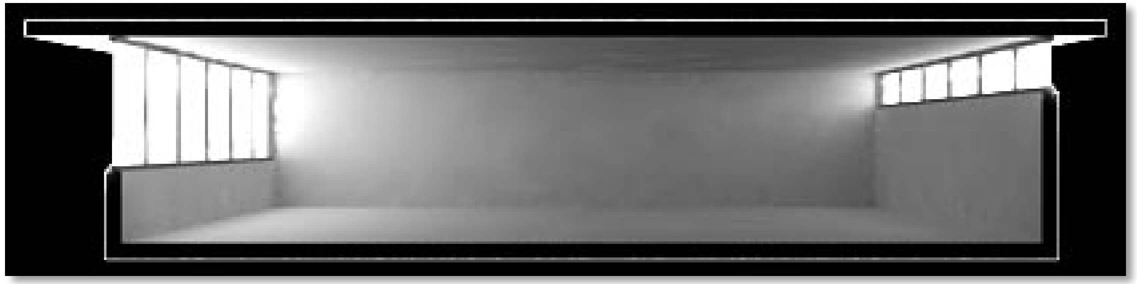
Not only the material, but also the texture of the finish affects reflectance.

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

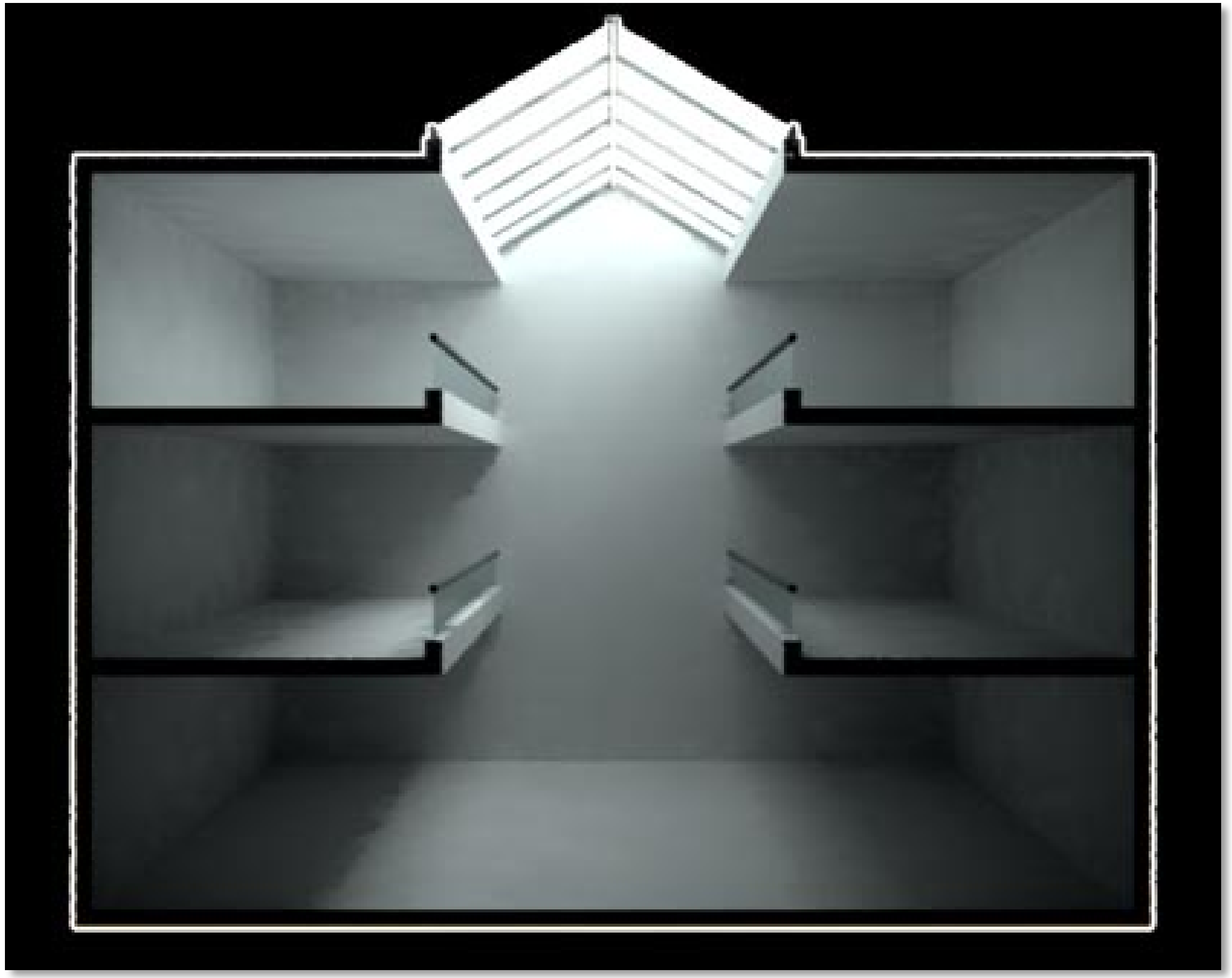
Skylight

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.

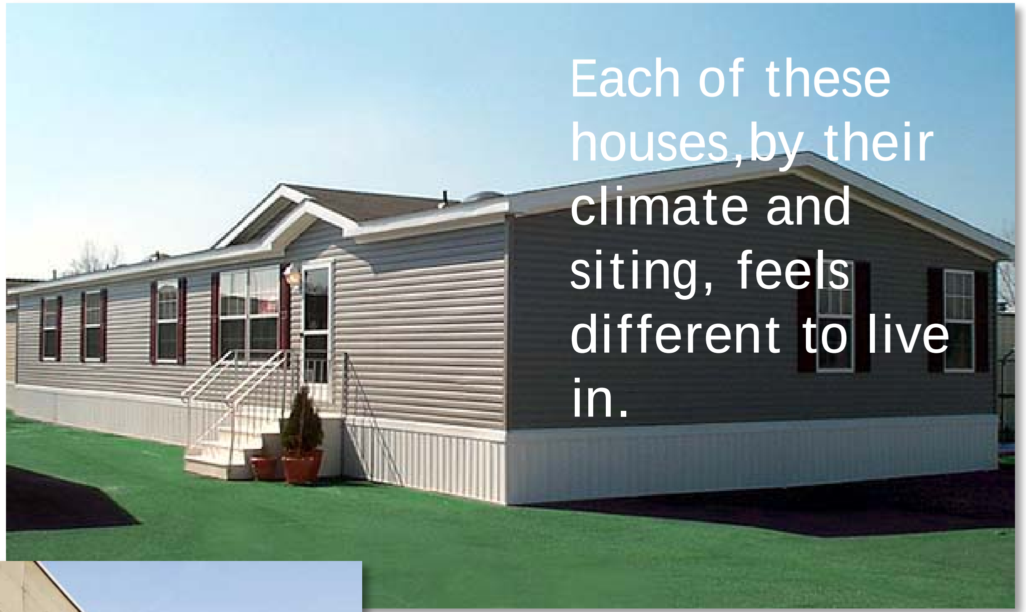
Images from squ1.com

Lightwell – provides more light directed to the lower floors

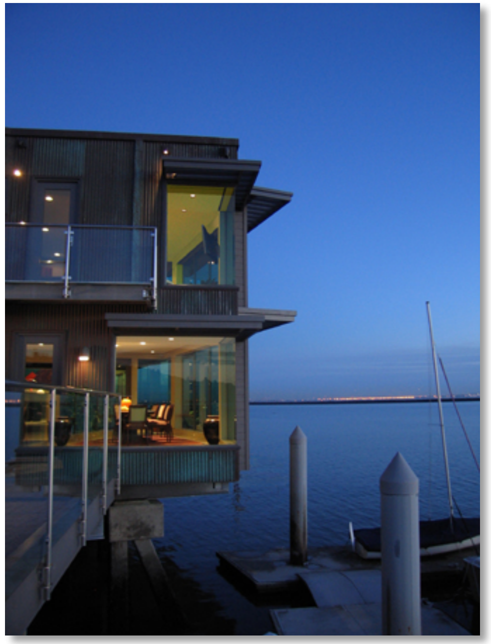
Accentuate the Positive:
Climate Responsive Design

Basic understanding of the 4 climate design zones tells us that certain building types obviously do not belong in certain places...

…but there are more aspects to consider...



Each of these houses,by their climate and siting, feels different to live in.



Take even the best house and place it in the middle of an asphalt parking lot, and see what happens...

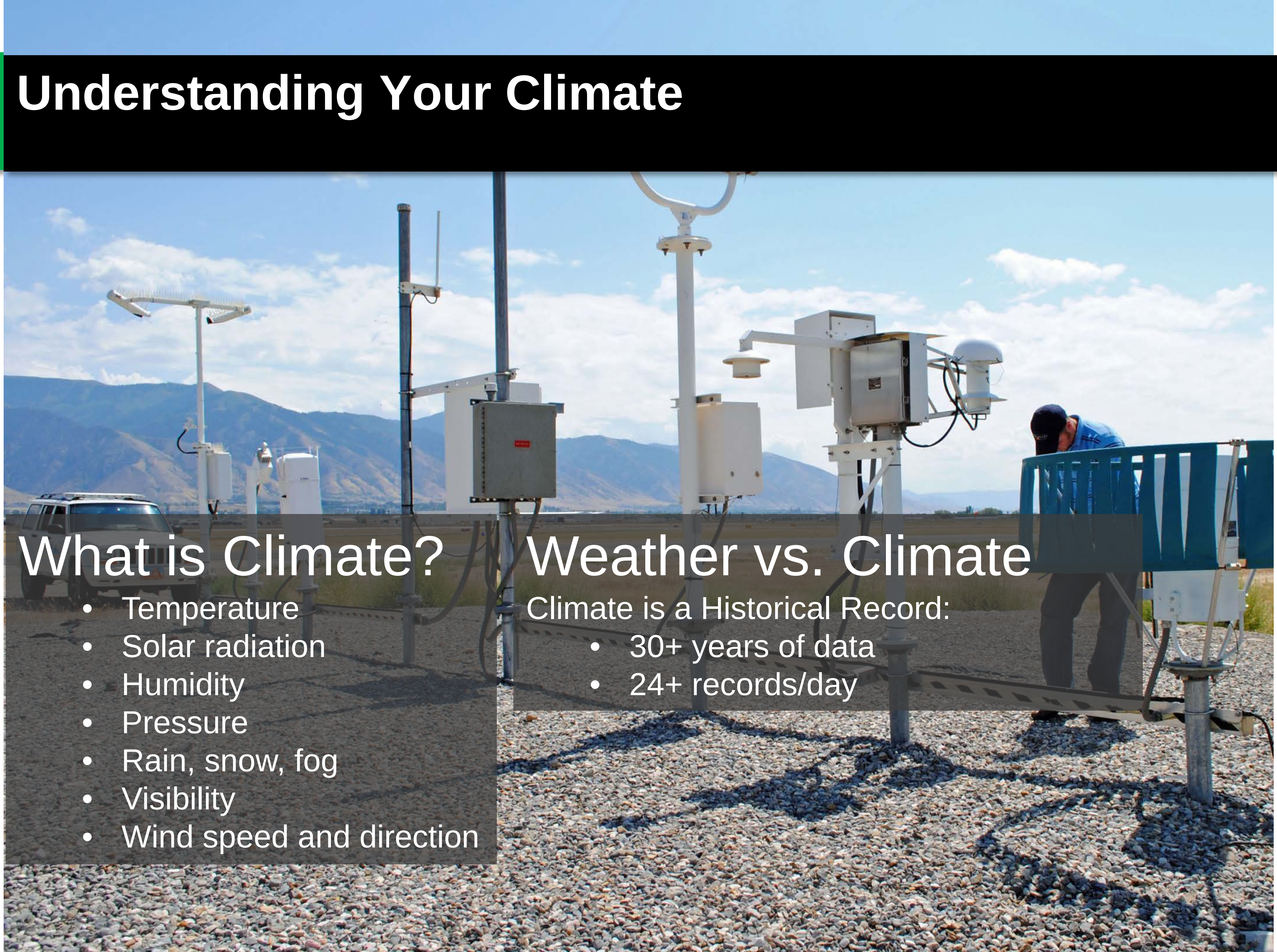
The Story of the Wandering Booth

This is a parking attendant's booth that I found on the internet. Let's move it around and see what happens….


McDonald's
マクドナルド
McDonald's
McDonald's
Hugendubel


www.tibetsupport.org

Understanding Your Climate



What is Climate?

- Temperature
- Solar radiation
- Humidity
- Pressure
- Rain, snow, fog
- Visibility
- Wind speed and direction

Weather vs. Climate

Climate is a Historical Record:

- 30+ years of data
- 24+ records/day

Climate – Other Considerations

- Climate is a 4-D problem (varies in space and time).
- Weather stations provide only a 1-D answer (time series at a single point in space).
- Surface-based measurements (e.g., airport weather stations) are influenced more strongly by the underlying surface than large-scale phenomena.
- Measurements at an airport do not necessarily reflect conditions in the surrounding urban area.
- Local factors that influence meteorology are always changing, as are global weather patterns.

Climate Consultant

http://www.energy-design-tools.aud.ucla.edu/

Climate Consultant 6 is a free tool available from the above address.

You will need to download .epw climate data for your city from this website

http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm

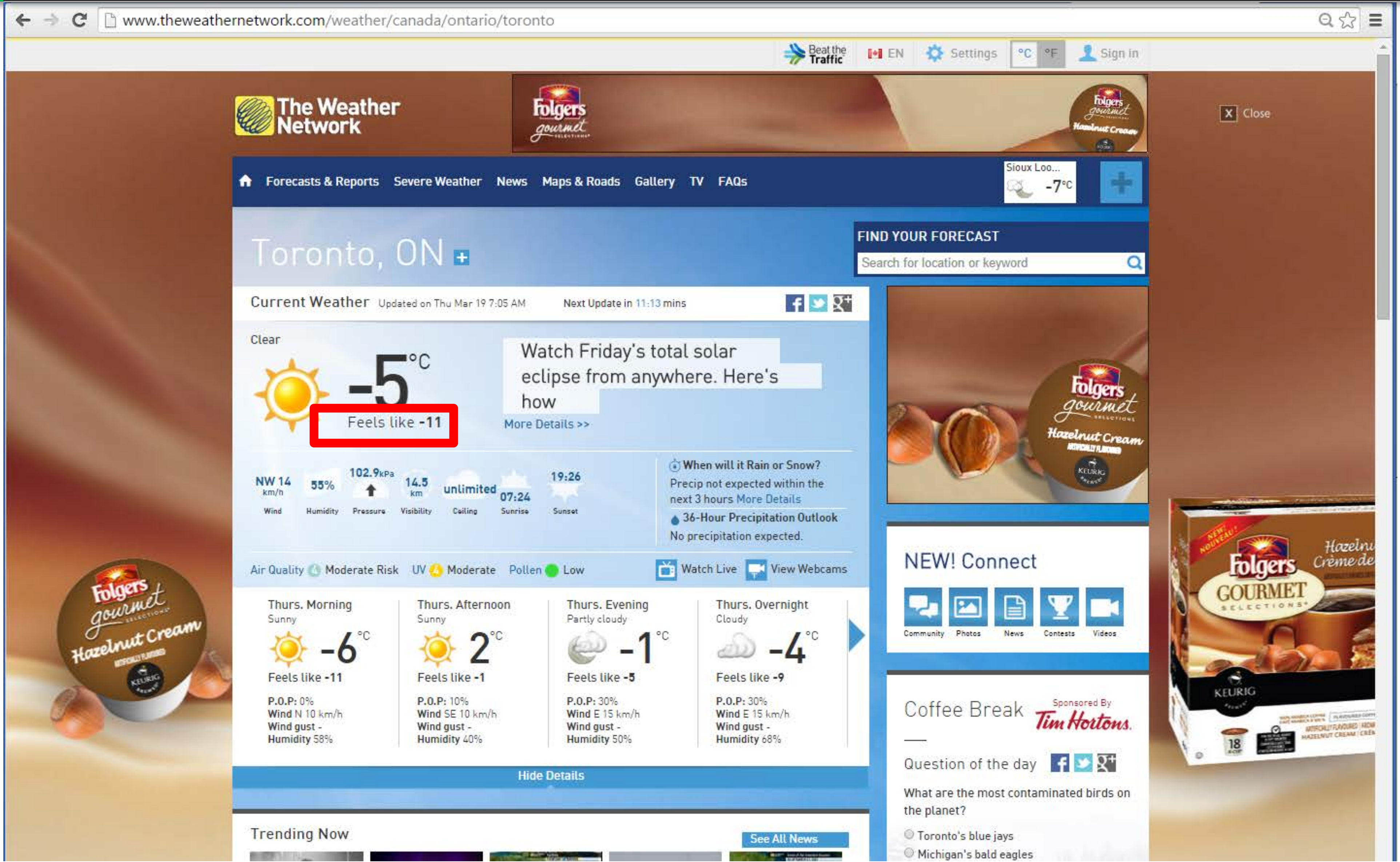
ASHRAE

The American Society of Heating, Refrigerating and Air-Conditioning Engineers is an American professional association seeking to advance heating, ventilation, air conditioning and refrigeration systems design and construction.

Choose Comfort Model

- Buildings are designed for their use, occupancy or occupants
- Normally it is the people that need to be comfortable in doing their tasks, not the building
- Some uses can accommodate a much higher range of temperatures than others
- Decide if using a fully automated heating AND cooling system
- Can the building **eliminate an A/C system** due to climate?
- Can the building **use passive solar to heat** the building?
- Can the building **use passive ventilation** to cool the building?
- Can the building **take advantage of daylight** to light the building?

Thermal Comfort Models



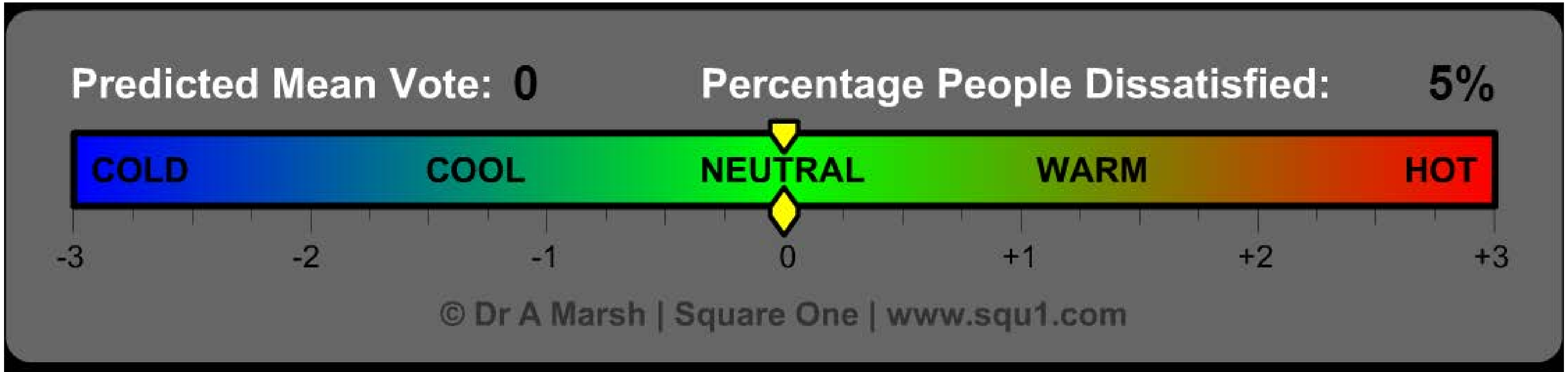
PMV/PPD

Predicted Mean Vote (PMV)

Study asked subject to rate there thermal sensation on a scale of -3 to 3, 0 is optimal when exposed to a combination of air temperature, mean radiant temperature, relative humidity, air speed, metabolic rate, and clothing insulation.

Predicted Percentage of Dissatisfied (PPD)

The relation of PMV to estimate the PPD. ASHRAE-55 requires at least 80%.



PMV/PPD – Mean Radiant Temperature

The mean radiant temperature (MRT) is a means of expressing the influence of surface temperatures on occupant comfort.

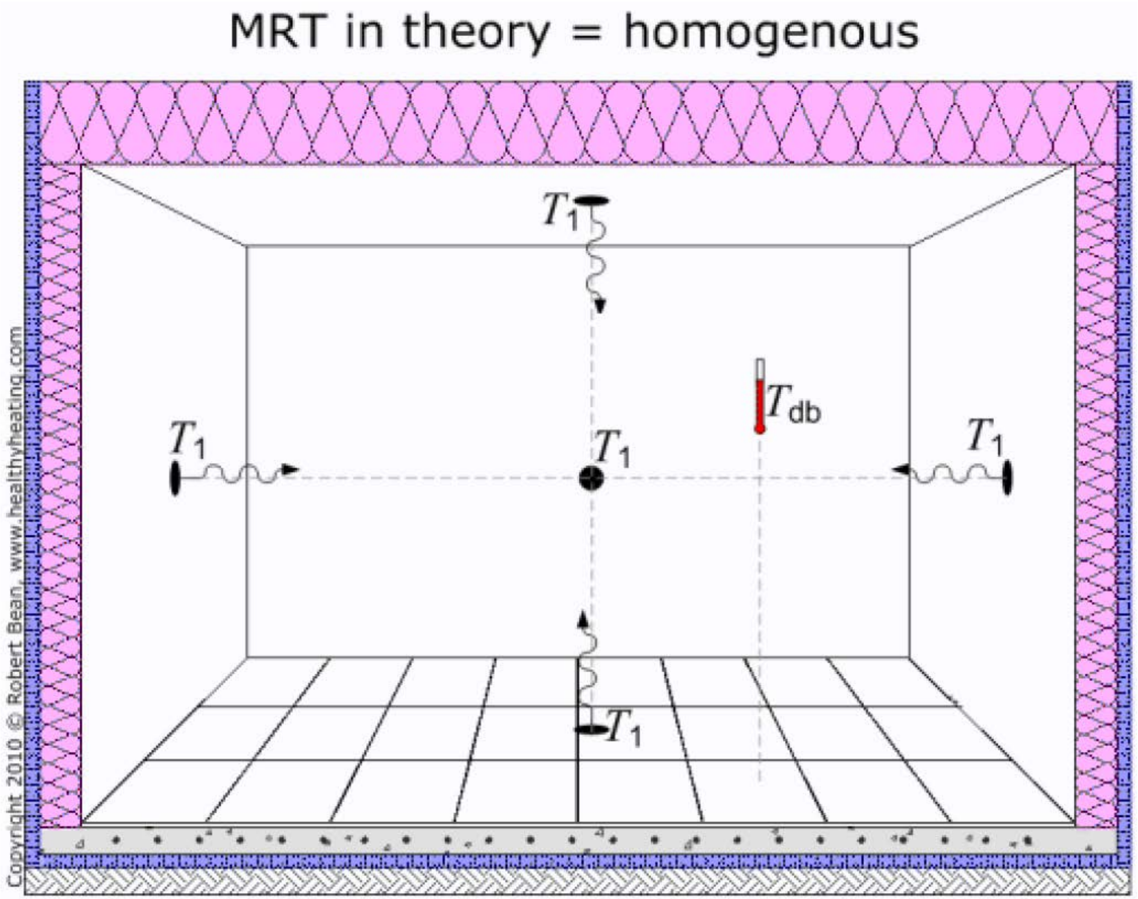
$$T_{mr} = T_1A_1 + T_2A_2 + \ldots + T_NA_N \,/\, (A_1 + A_2 + \ldots + A_N)$$

where,

T_{mr} = mean radiant temperature, °R

T_N = surface temperature of surface N, °R (calculated or measured)

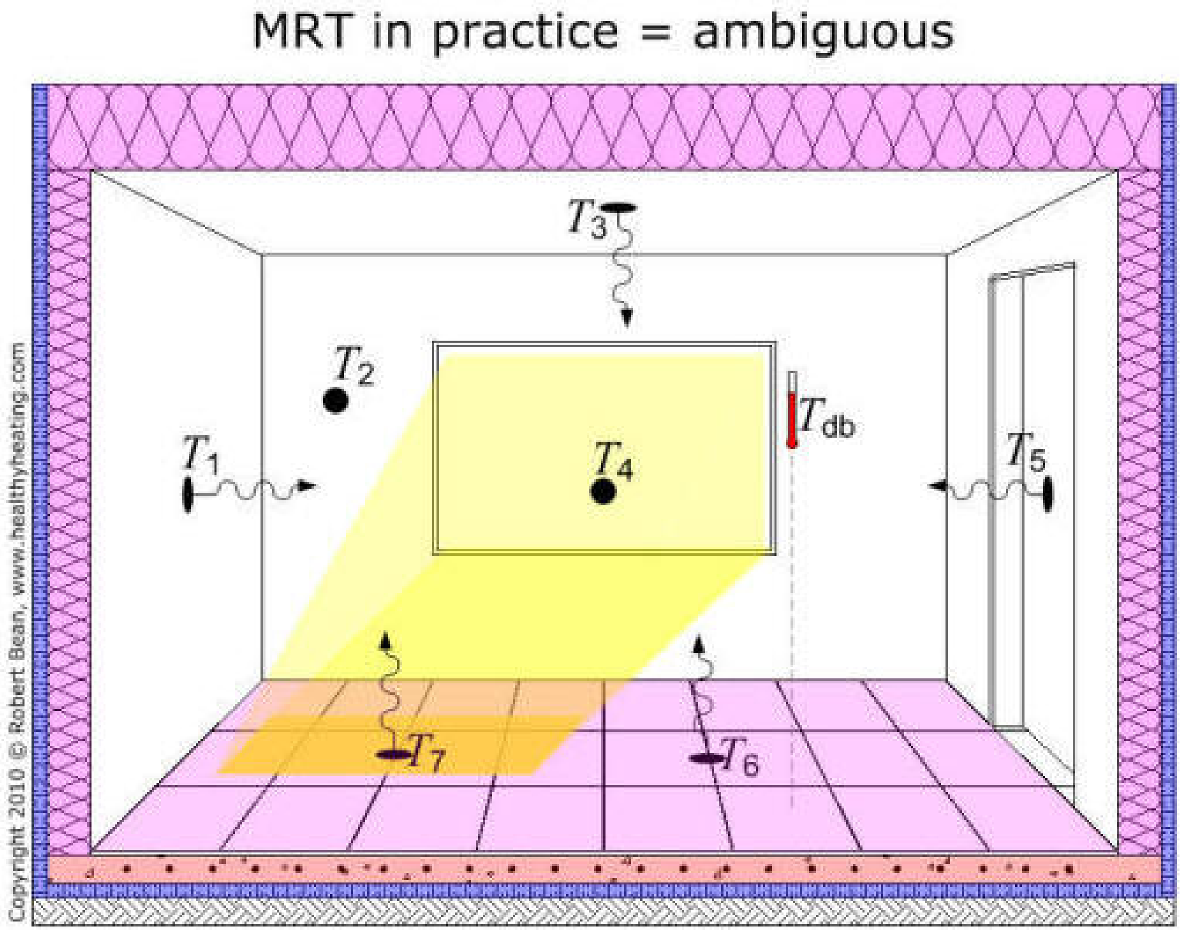
A_N = area of surface



http://www.healthyheating.com/Definitions/Mean%20Radiant.htm#.VQnM6I7F8Zs.

PMV/PPD – Mean Radiant Temperature

However...

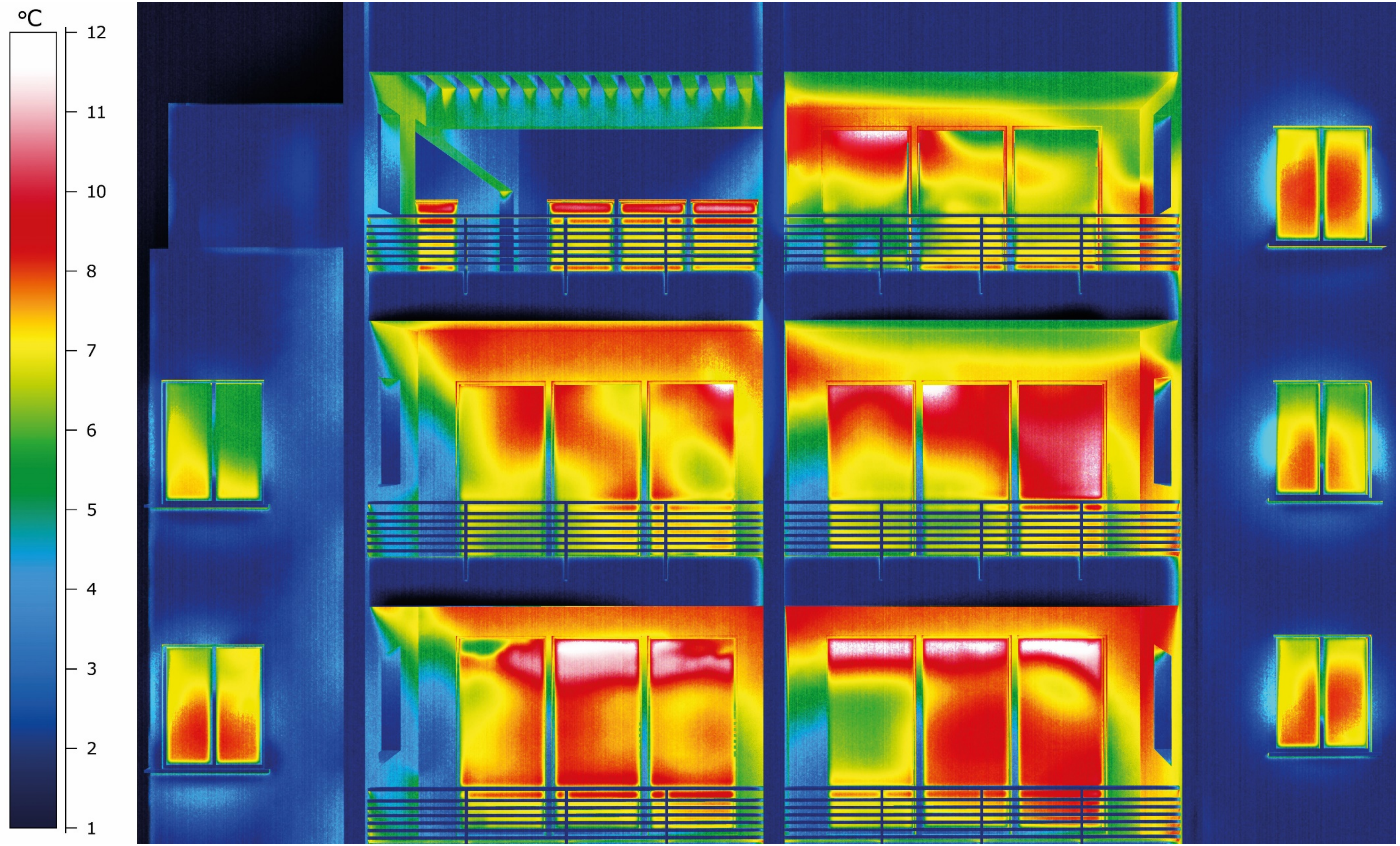


http://www.healthyheating.com/Definitions/Mean%20Radiant.htm#.VQnM6I7F8Zs.

PMV/PPD – Mean Radiant Temperature

Air Temperature = MRT is ok for interior spaces but really begins to fall apart at the perimeter largely due to thermal bridging (the walls feel cold) & direct solar gain (the sun feels hot).

PMV/PPD – Mean Radiant Temperature



https://testoltd.wordpress.com/2013/03/26/thermal-imaging-resolution-matters-simply-see-more/

ASHRAE ADAPTIVE COMFORT

The adaptive model is based on the idea that outdoor climate influences indoor comfort because

humans can adapt

to different temperatures during different times of the year.

ASHRAE ADAPTIVE COMFORT

Field studies were used to show that access to environmental controls, and past thermal history influence building occupants' thermal expectations and preferences.

Choose Comfort Model

ASHRAE Handbook of Comfort Fundamentals 2005

For people dressed in normal winter clothes,

Effective Temperatures of 68°F (20°C) to 74°F (23.3°C) (measured at 50% relative humidity), which means the temperatures decrease slightly as humidity rises.

The upper humidity limit is 64°F (17.8°C) Wet Bulb and a lower Dew Point of 36F (2.2°C).

If people are dressed in light weight summer clothes then this comfort zone shifts 5°F (2.8°C) warmer.

ASHRAE Standard 55-2004 Using Predicted Mean Vote Model

Thermal comfort is based on dry bulb temperature, clothing level (clo), metabolic activity (met), air velocity, humidity, and mean radiant temperature.

Indoors it is assumed that mean radiant temperature is close to dry bulb temperature.

The zone in which most people are comfortable is calculated using the PMV model.

In **residential settings** people adapt clothing to match the season and feel comfortable in higher air velocities and so have wider comfort range than in buildings with centralized HVAC systems.

Adaptive Comfort Model in ASHRAE Standard 55-2004

In naturally ventilated spaces where occupants can open and close windows, their thermal response will depend in part on the outdoor climate, and may have a wider comfort range than in buildings with centralized HVAC systems.

This model assumes occupants adapt their clothing to thermal conditions, and are sedentary.

There must be no mechanical Cooling System, so this method does not apply if a Mechanical Heating System is in operation.

The ability to completely eliminate a Mechanical Cooling System has great potential for Carbon savings, but comfort must be maintained passively.

EPW Weather Data for 1000s of Locations

Climate Consultant 5.4 (Build 5, Mar 11, 2013)

File Criteria Charts Help

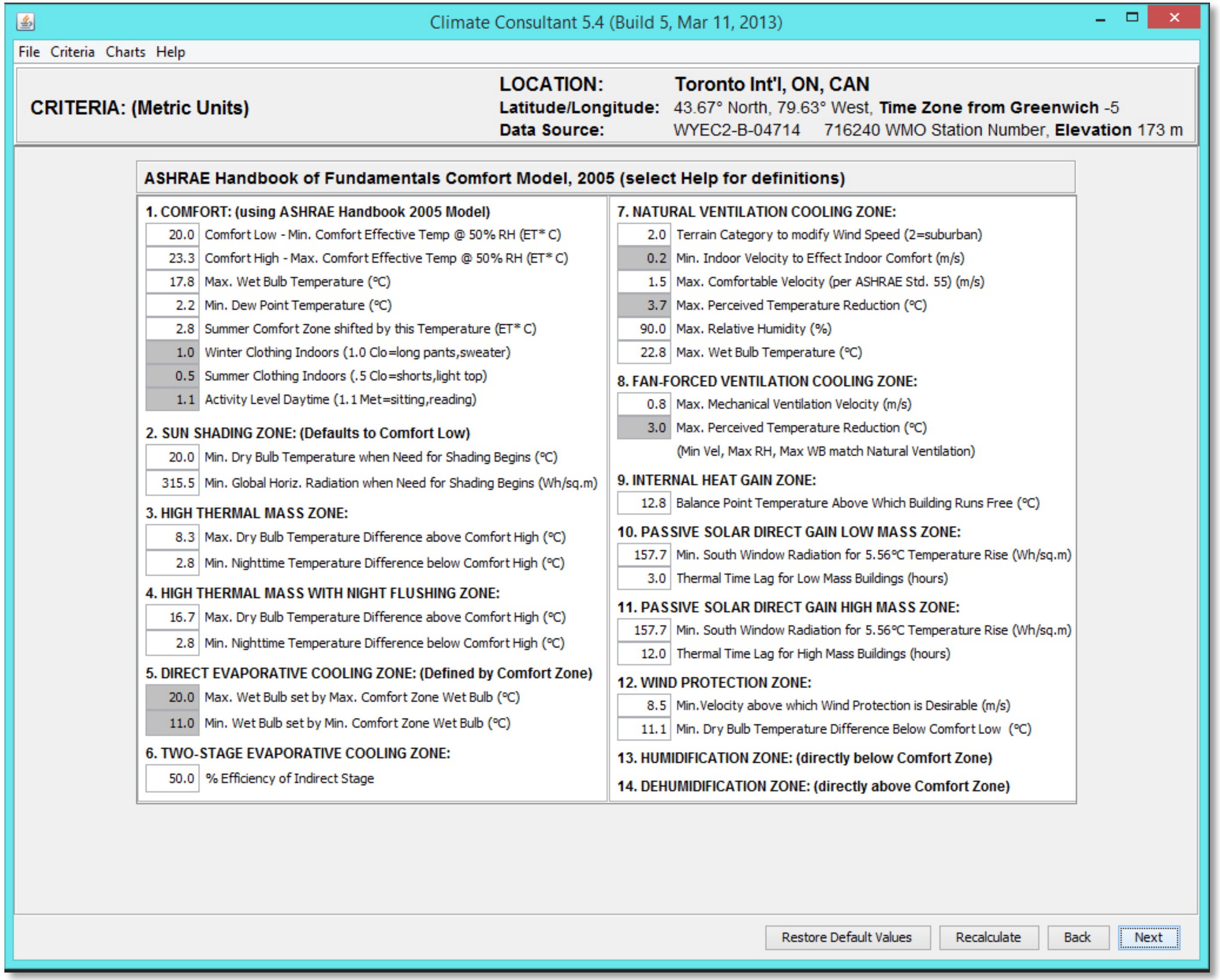
WEATHER DATA SUMMARY

LOCATION: Toronto Int'l, ON, CAN
Latitude/Longitude: 43.67° North, 79.63° West, **Time Zone from Greenwich** -5
Data Source: WYEC2-B-04714 716240 WMO Station Number, **Elevation** 173 m

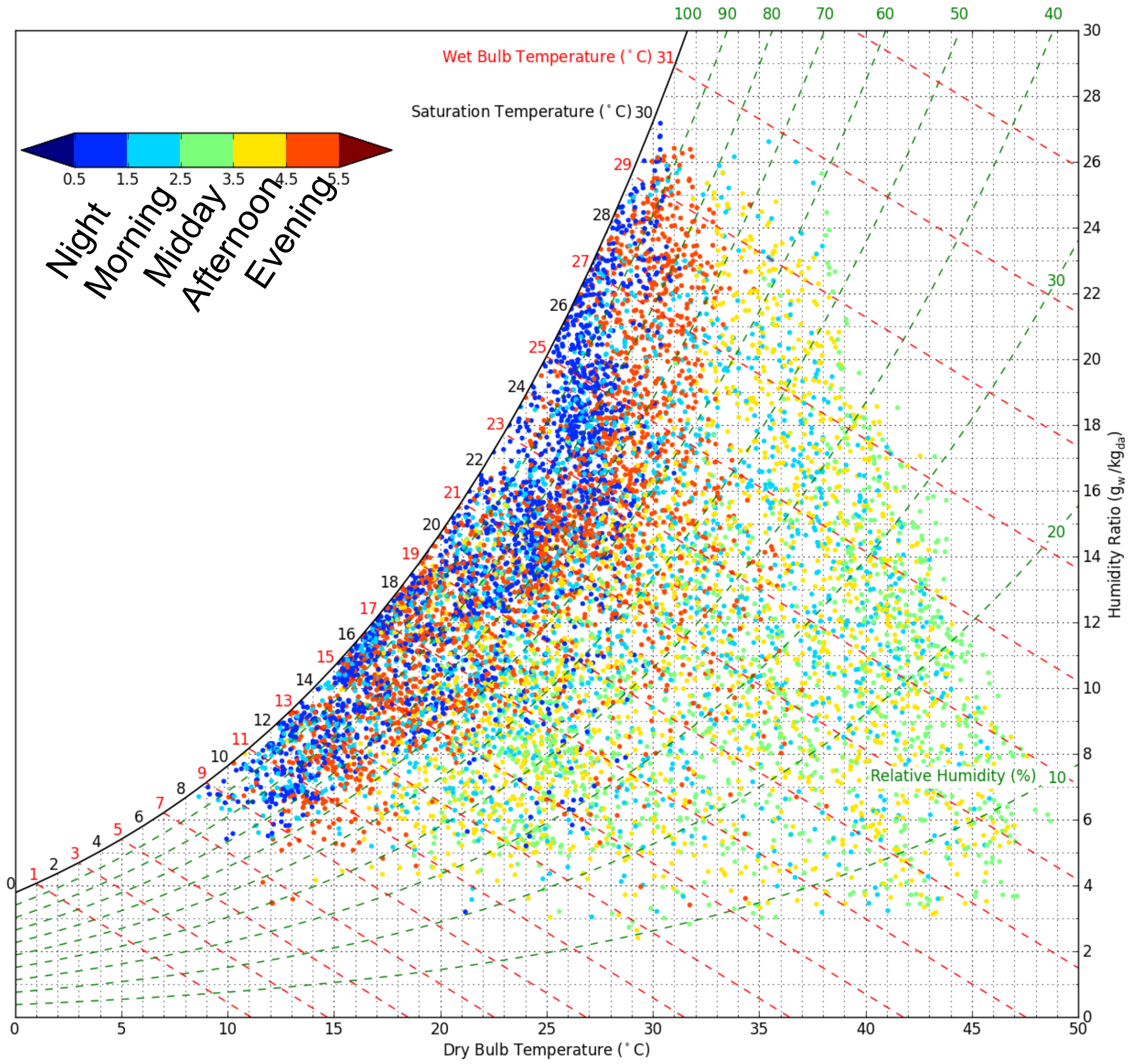
MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	161	221	268	329	384	404	405	376	333	239	136	122	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	230	265	270	307	324	323	361	316	347	249	130	172	Wh/sq.m
Diffuse Radiation (Avg Hourly)	85	112	127	143	172	185	164	178	141	126	86	67	Wh/sq.m
Global Horiz Radiation (Max Hourly)	474	651	875	931	974	1003	980	907	827	655	516	417	Wh/sq.m
Direct Normal Radiation (Max Hourly)	879	947	1022	1028	959	948	927	932	931	870	861	872	Wh/sq.m
Diffuse Radiation (Max Hourly)	238	368	439	431	594	545	458	431	385	328	250	195	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	1468	2262	3181	4347	5599	6138	6035	5163	4099	2568	1300	1072	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	2097	2703	3207	4041	4728	4918	5384	4336	4251	2663	1249	1519	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	783	1151	1506	1900	2513	2818	2441	2453	1745	1358	818	591	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	18043	24998	30402	37172	43543	45839	45796	42702	37681	27169	15572	13688	lux
Direct Normal Illumination (Avg Hourly)	22576	27019	28334	32402	34319	34073	37965	33408	36306	25747	13364	17190	lux
Dry Bulb Temperature (Avg Monthly)	-5	-5	0	5	11	17	20	19	14	8	3	-2	degrees C
Dew Point Temperature (Avg Monthly)	-8	-9	-4	0	4	11	14	13	10	4	0	-5	degrees C
Relative Humidity (Avg Monthly)	78	75	74	70	62	68	70	70	75	77	83	79	percent
Wind Direction (Monthly Mode)	250	270	270	90	340	0	330	340	330	250	250	250	degrees
Wind Speed (Avg Monthly)	4	5	5	4	4	3	3	2	3	4	4	5	m/s
Ground Temperature (Avg Monthly of 3 Depths)	0	-1	0	0	5	10	14	15	15	12	7	3	degrees C

Back Next

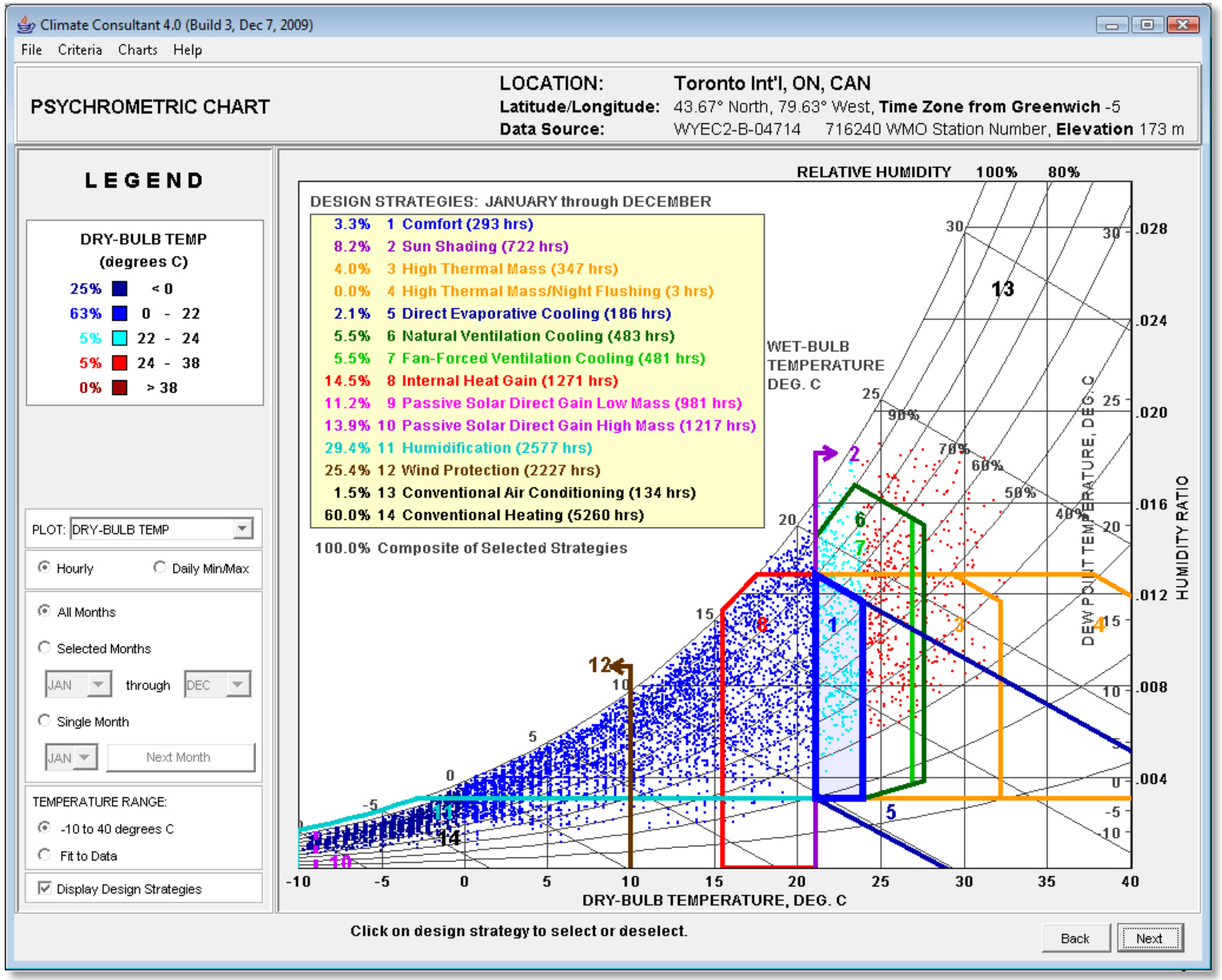
Setting the Project Criteria



The Psychrometric Chart

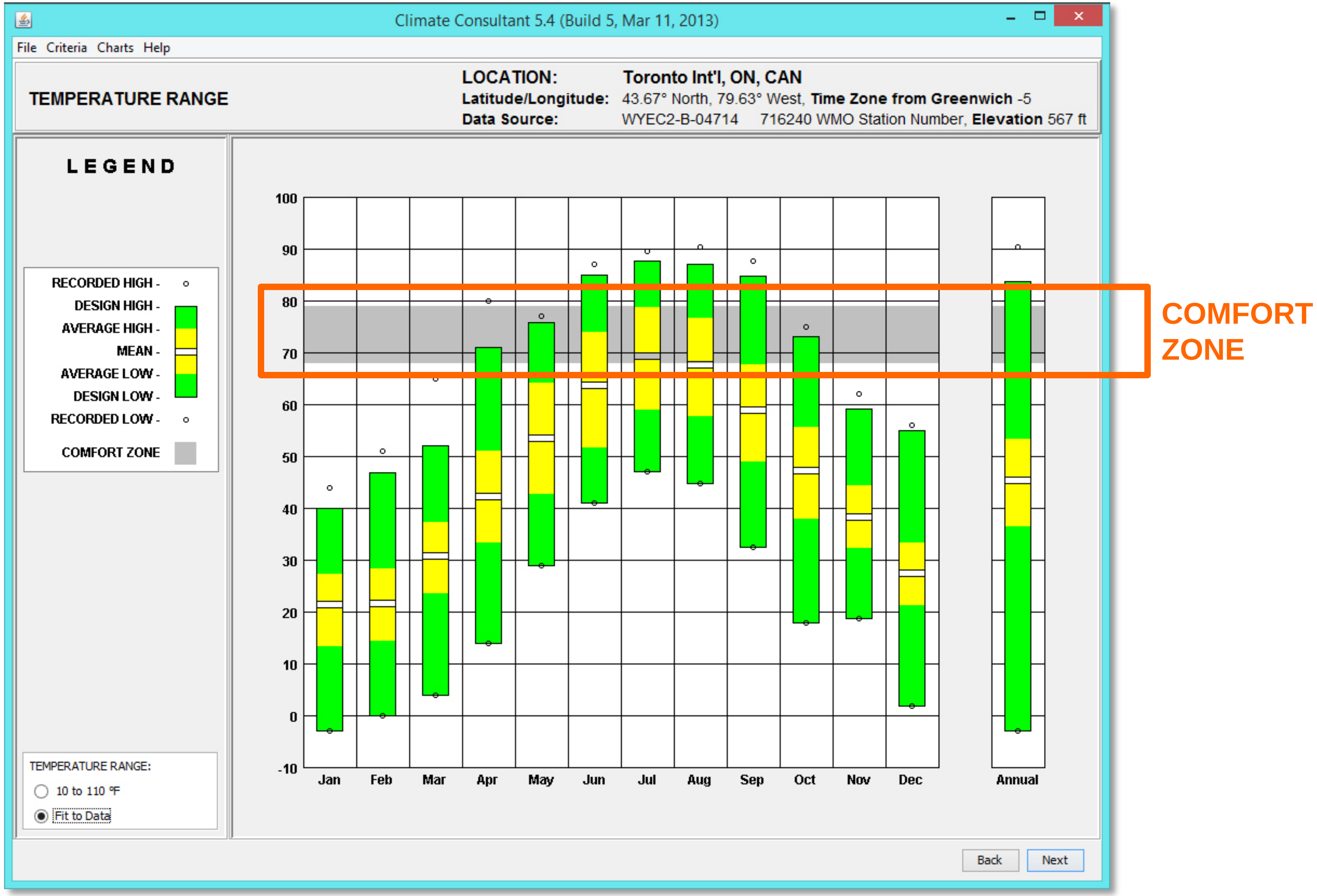


Psychrometric Chart

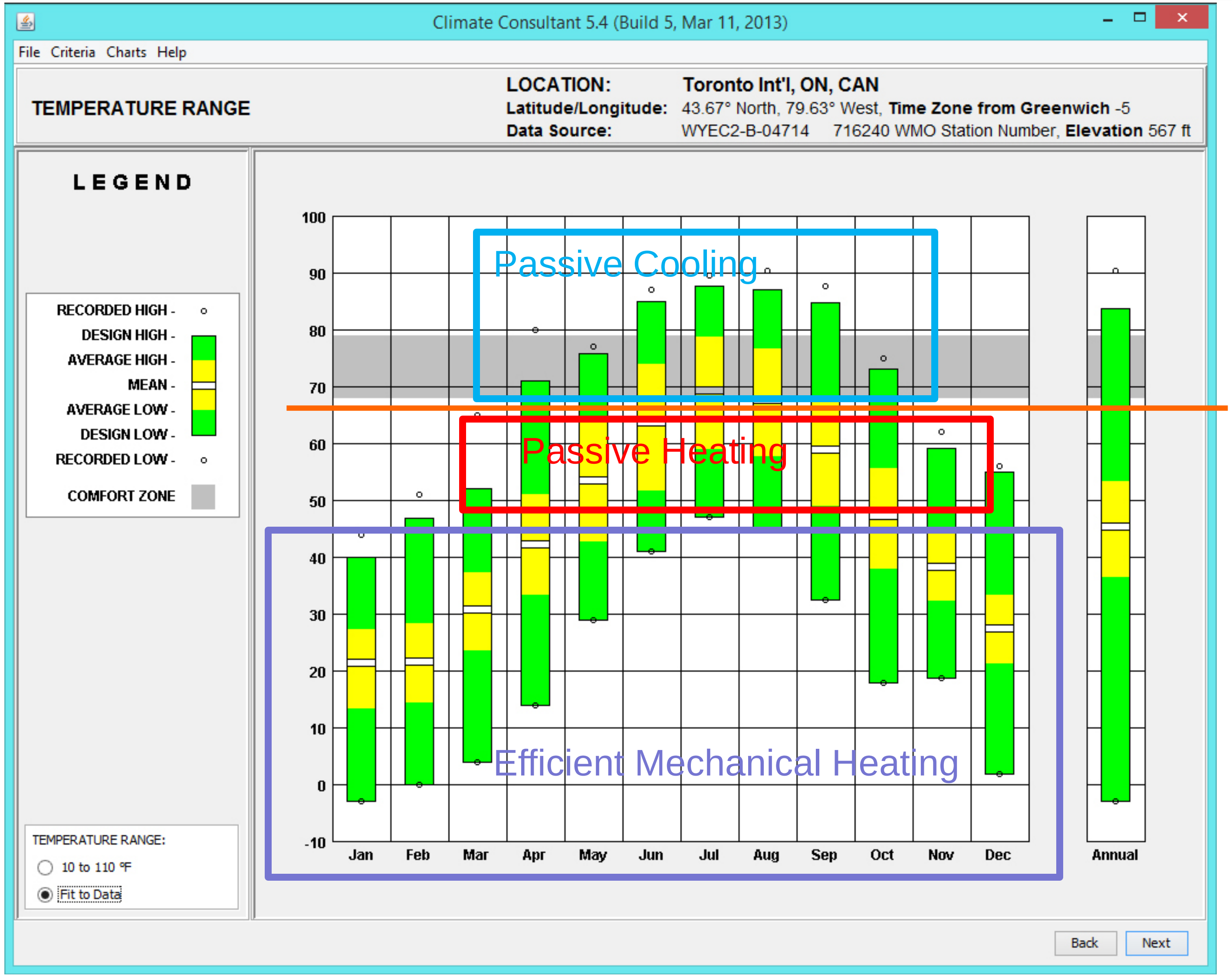


The chart helps to identify climate based strategies to achieve comfort.

Climate Data for Toronto

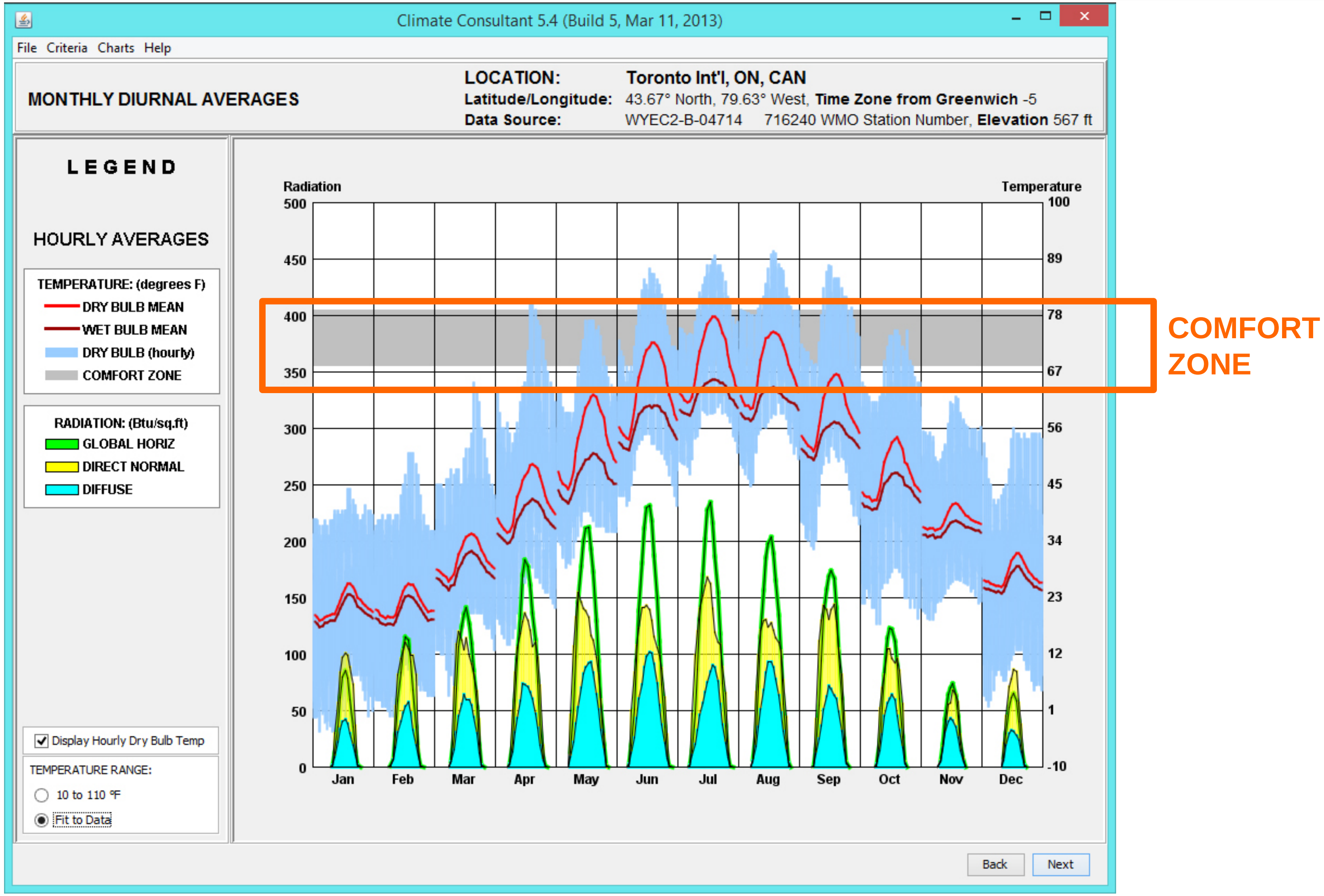


Climate Data for Toronto

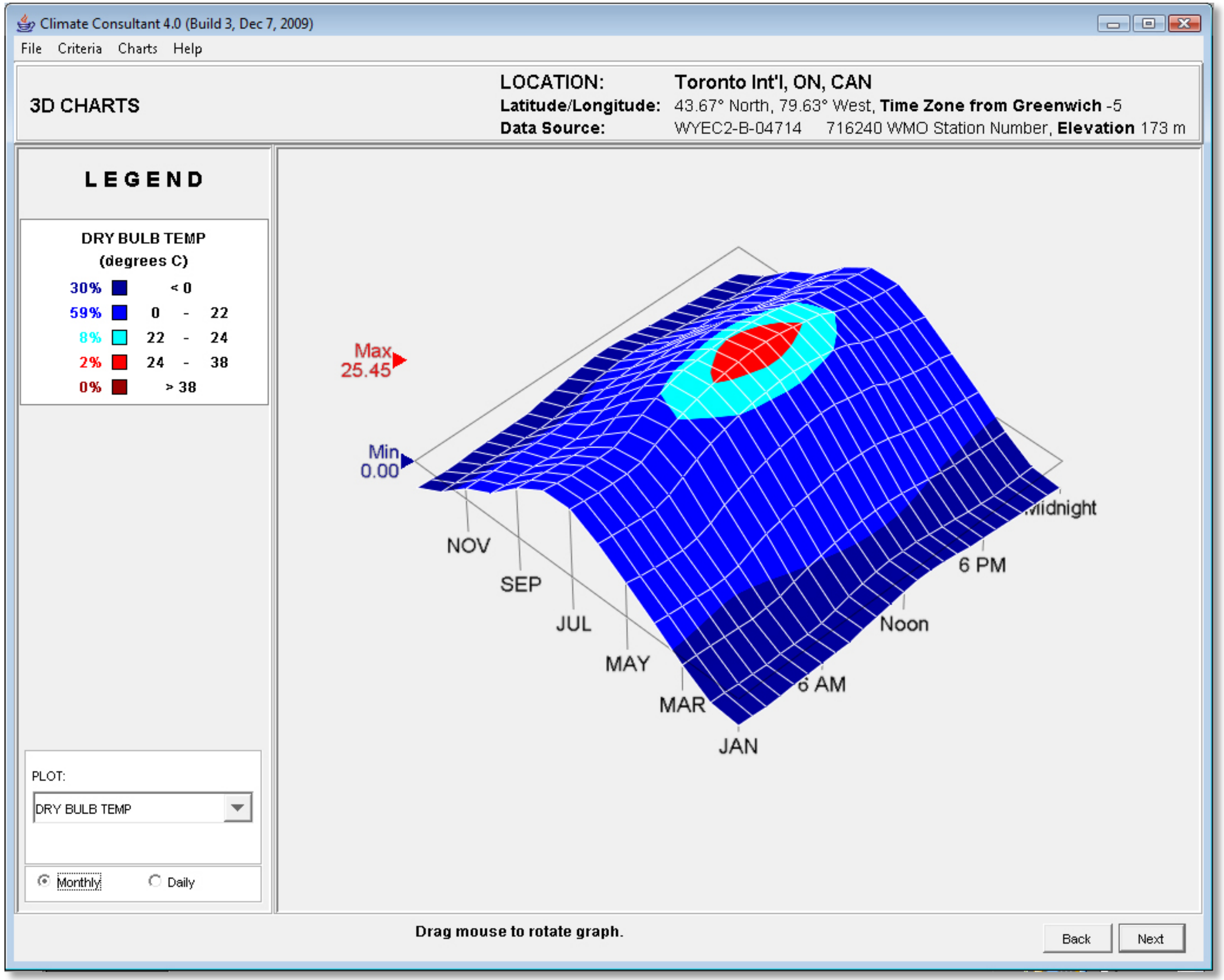


18ºC is the base point for measuring Heating vs Cooling Degree days

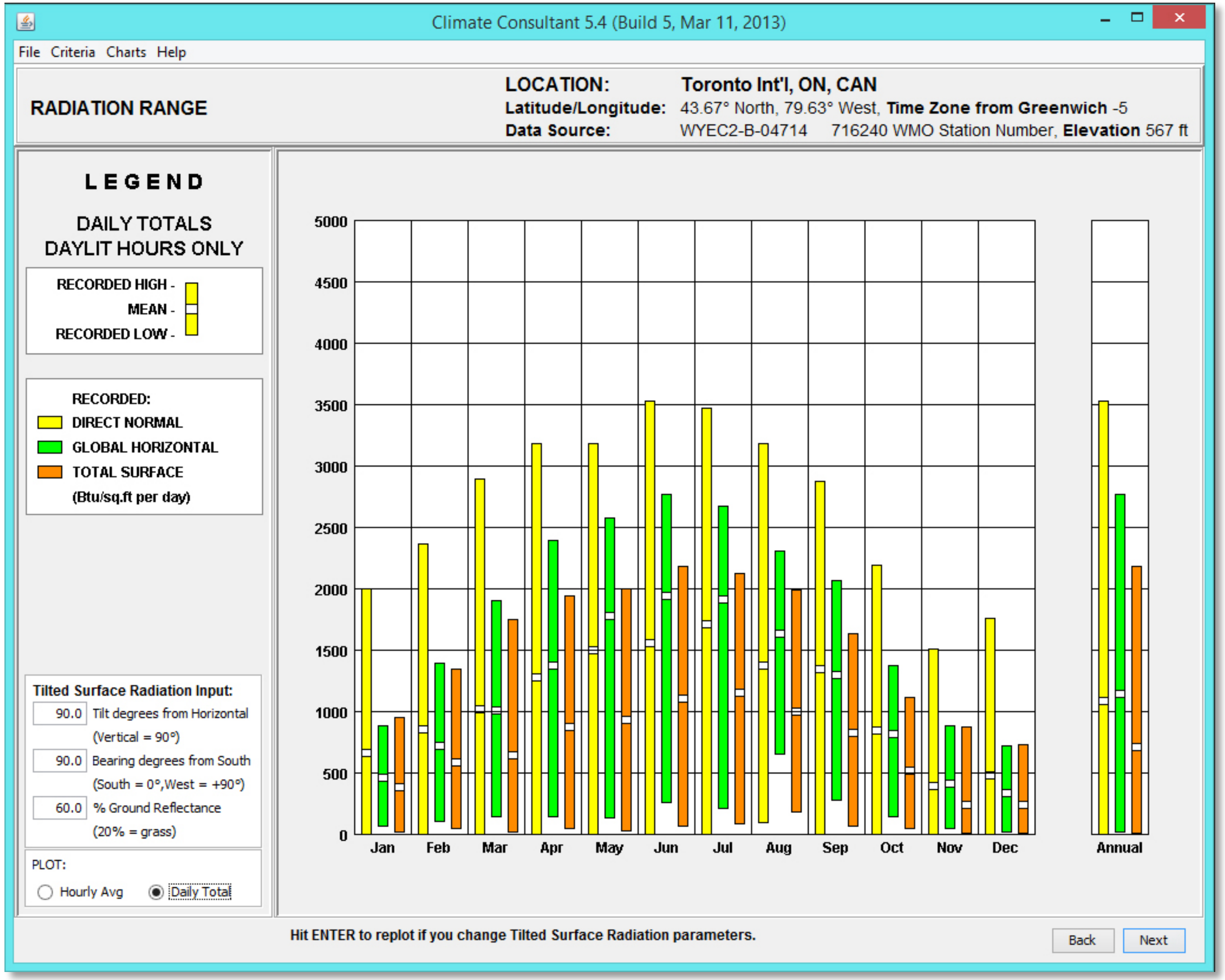
Climate Data for Toronto



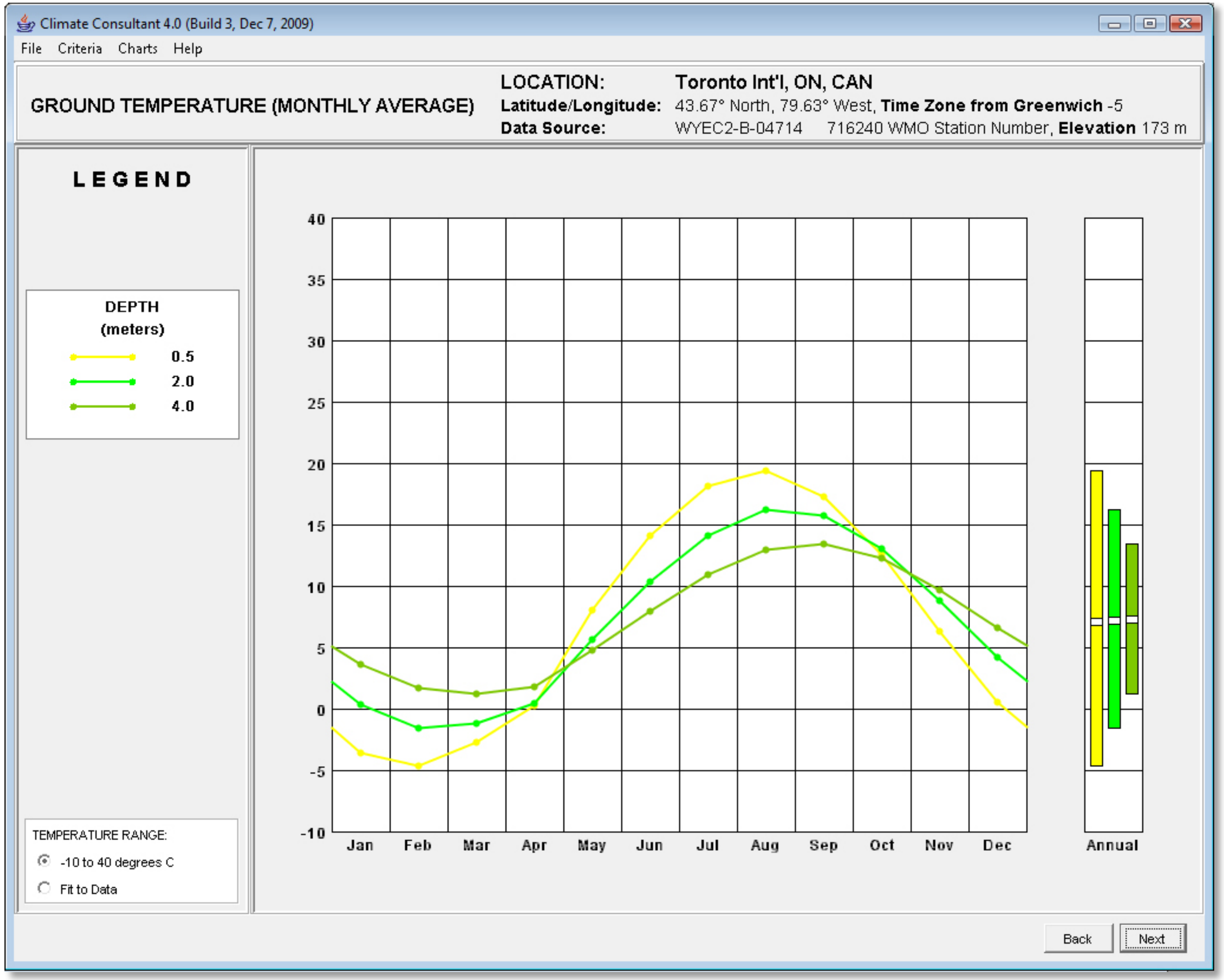
Temperature Range for Toronto



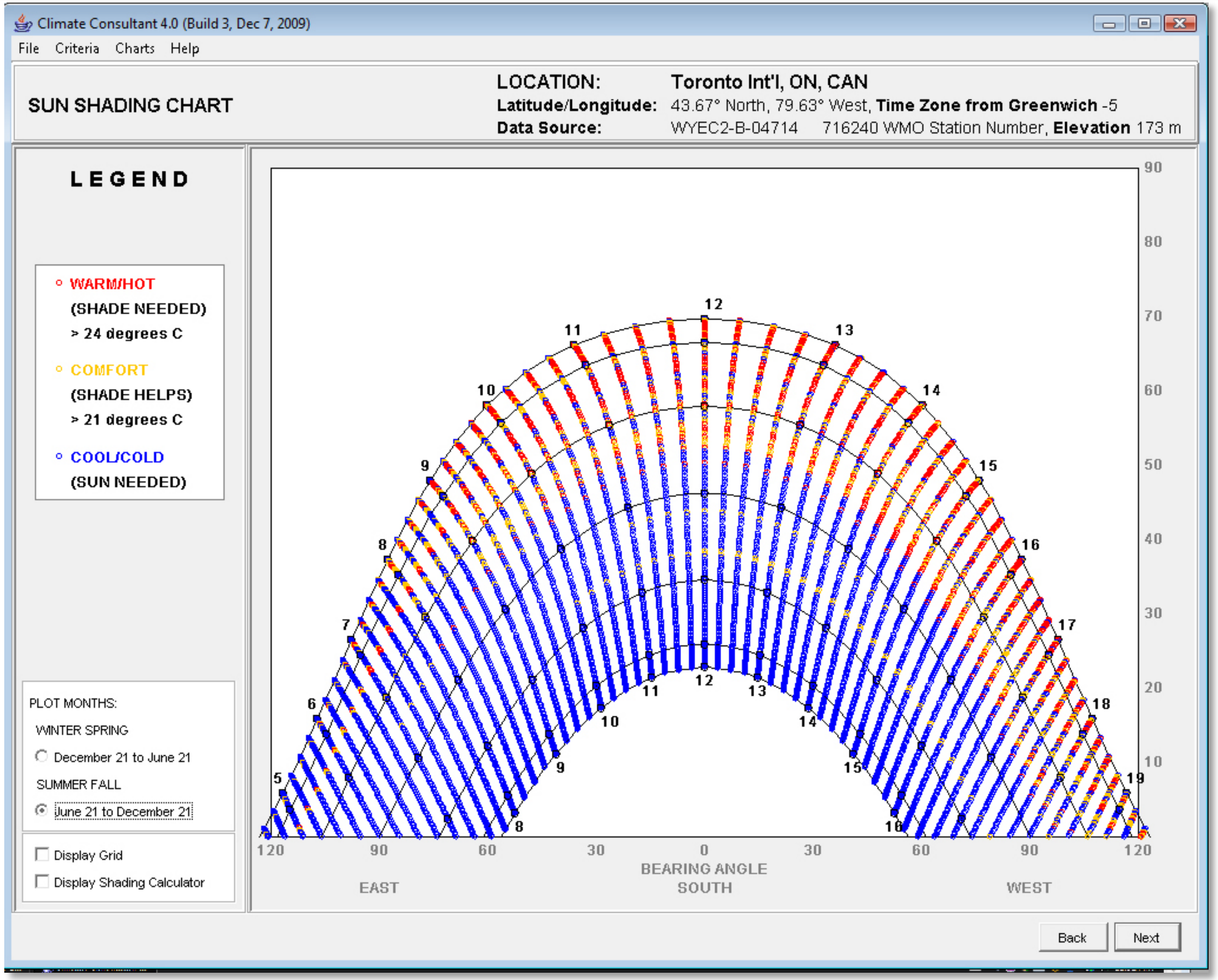
Toronto Solar Radiation Range



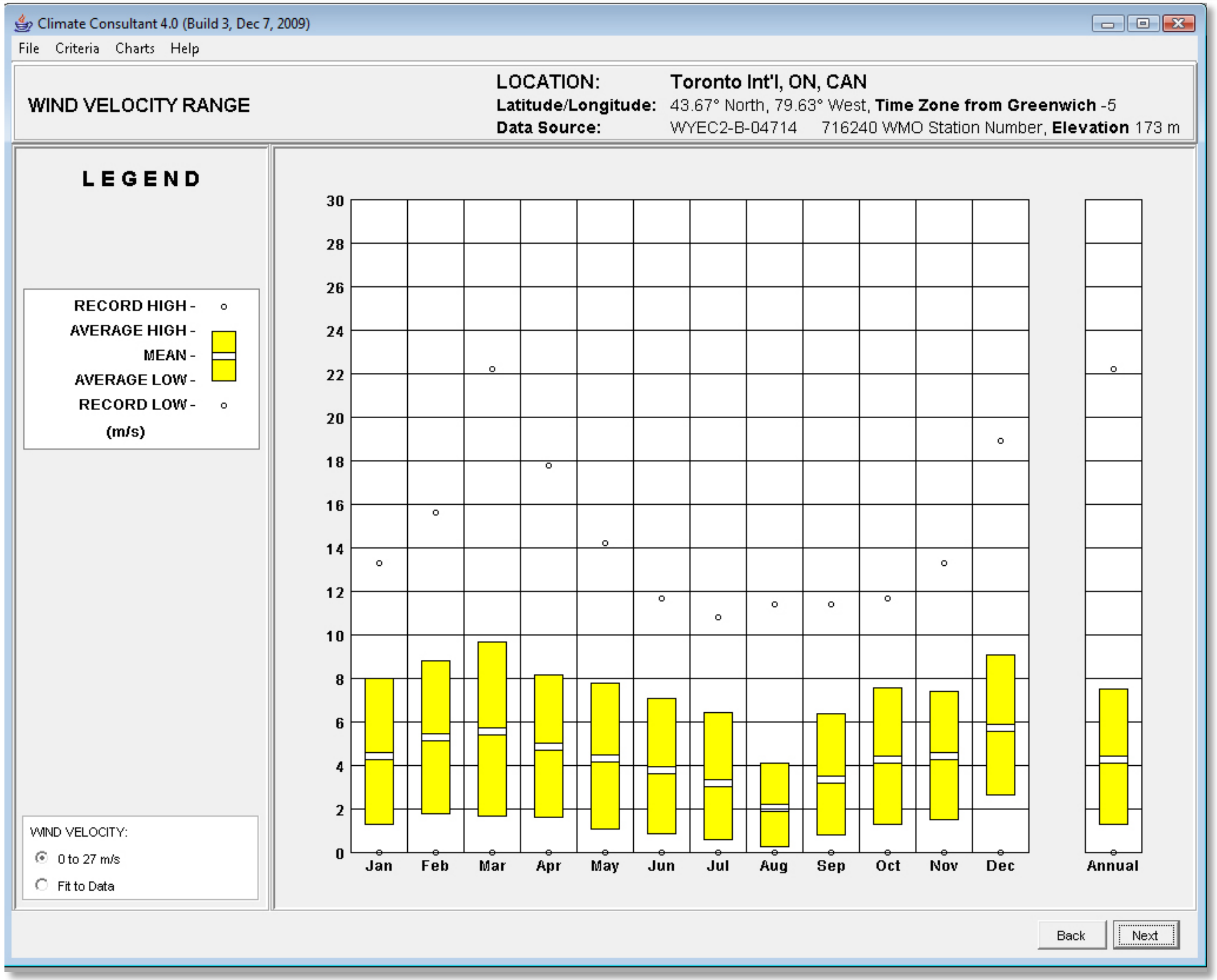
Ground Temperature for Toronto



Sun Shading Chart



Wind Speed



Climate Consultant 4.0 (Build 3, Dec 7, 2009)
File Criteria Charts Help
WIND VELOCITY RANGE
LOCATION: Toronto Int'l, ON, CAN
Latitude/Longitude: 43.67° North, 79.63° West, Time Zone from Greenwich -5
Data Source: WYEC2-B-04714 716240 WMO Station Number, Elevation 173 m
LEGEND
RECORD HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORD LOW -
(m/s)
WIND VELOCITY:
0 to 27 m/s
Fit to Data
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual
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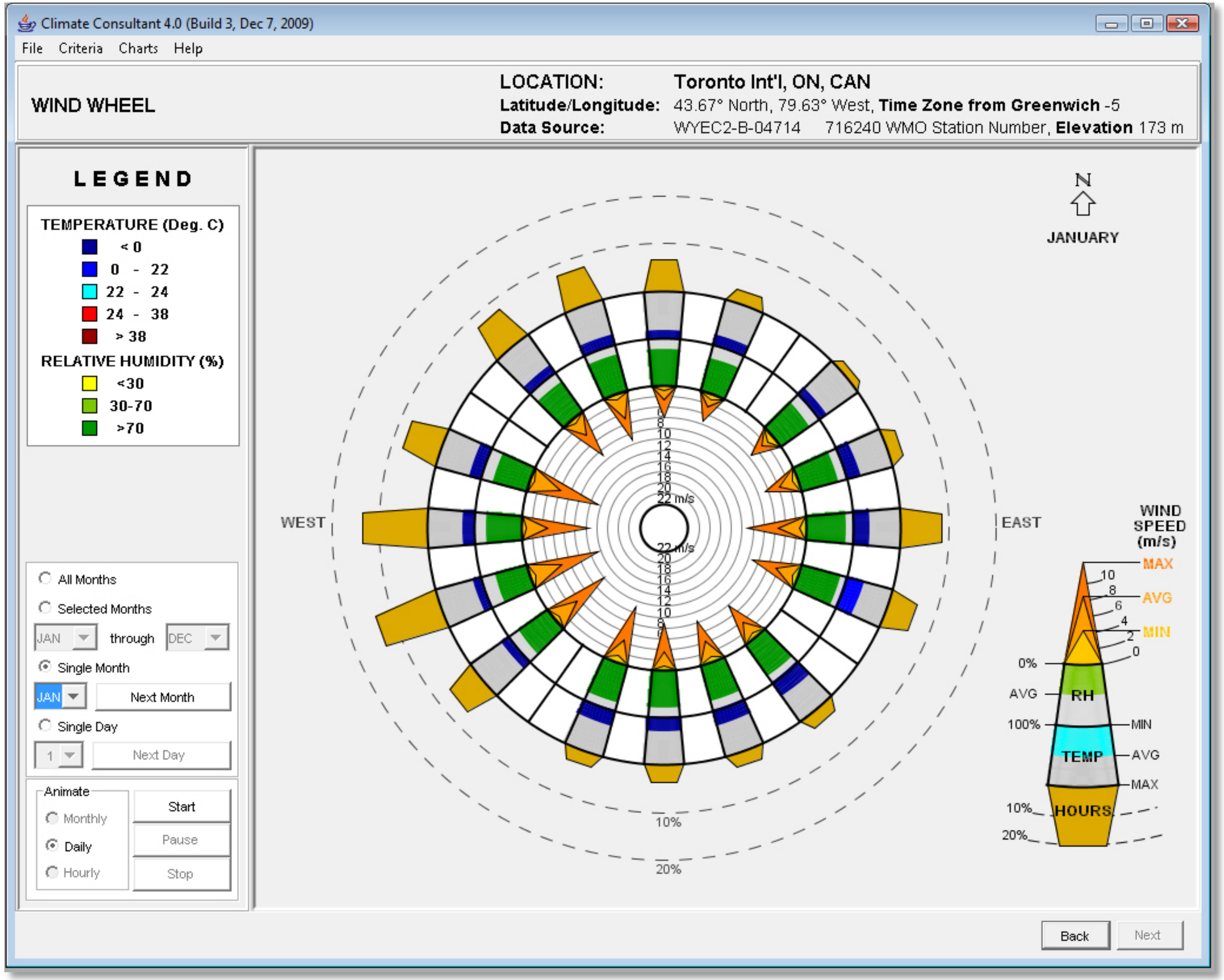
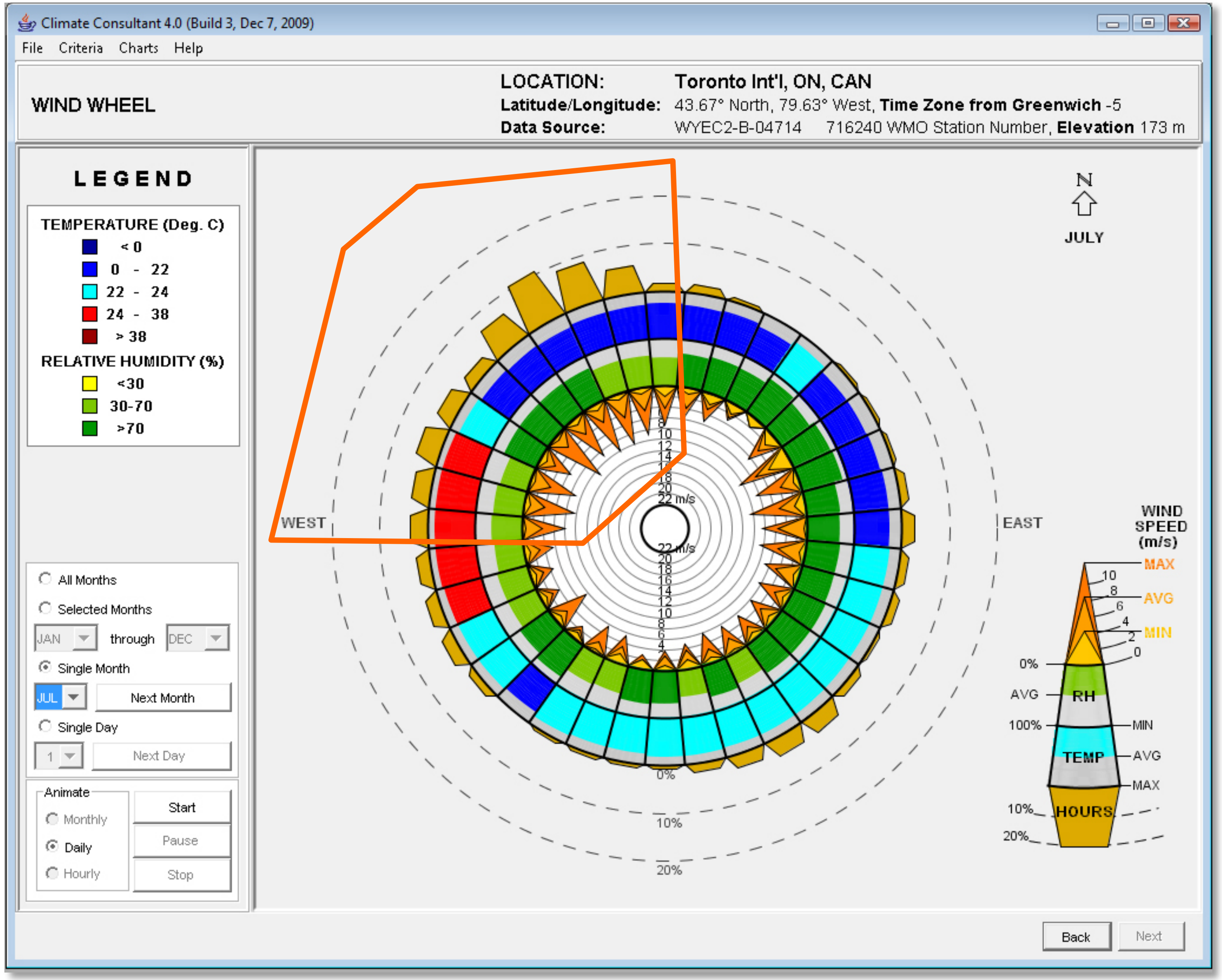
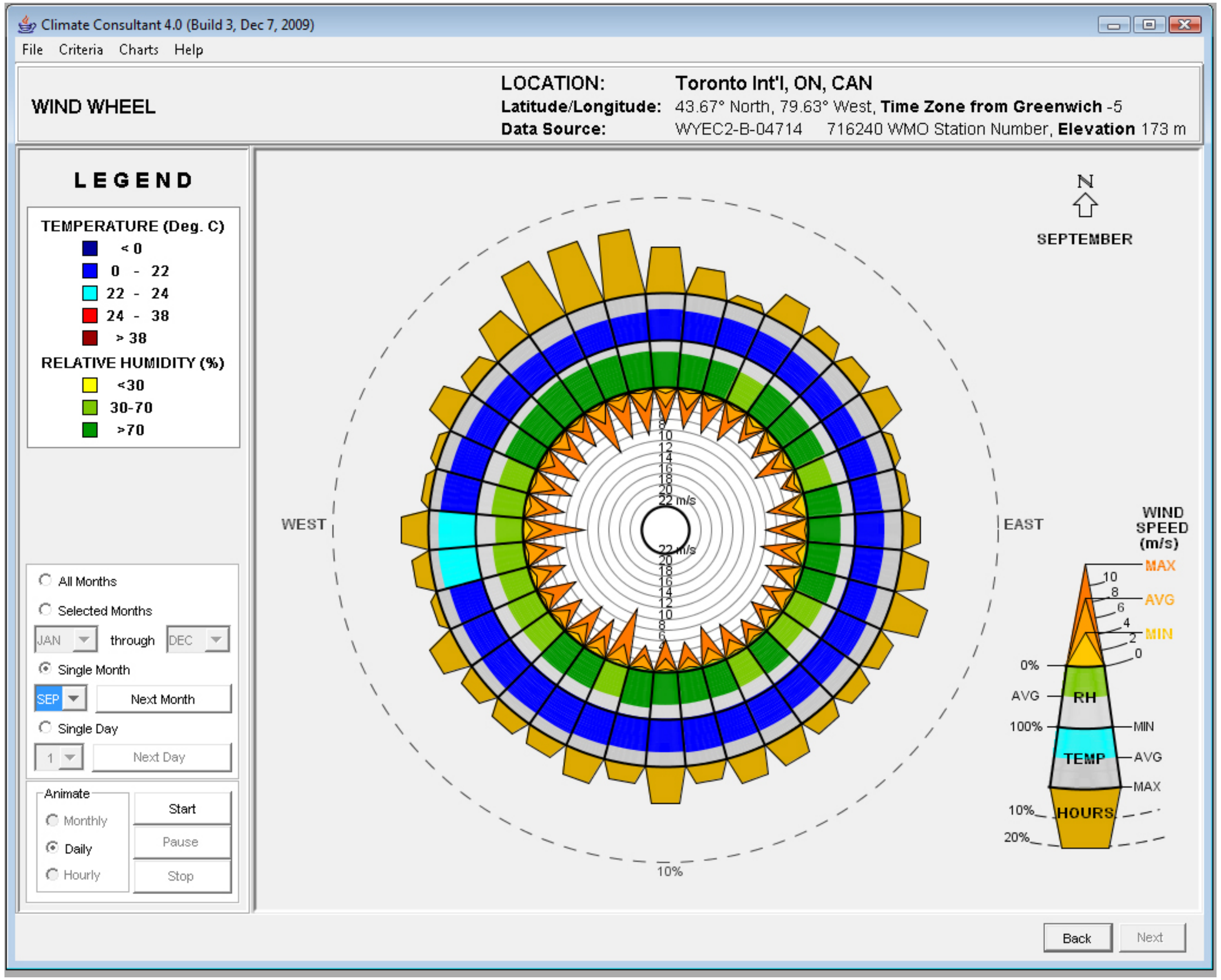
January Wind Wheel/Rose for Toronto



July Wind Wheel/Rose for Toronto



September Wind Wheel/Rose for Toronto



Source of EPW (*EnergyPlus Weather* Format) Data

Story of TMY data gathering:

- Means **T**ypical **M**eteorological **Y**ear
- Collection of typical months of various years to constitute a complete year of data
- Is getting out of date as does not reflect recent climate changes
- Most accurate for solar, temperature and wind
- Not very accurate for precipitation

Bio-climatic Design: HOT-ARID RULES

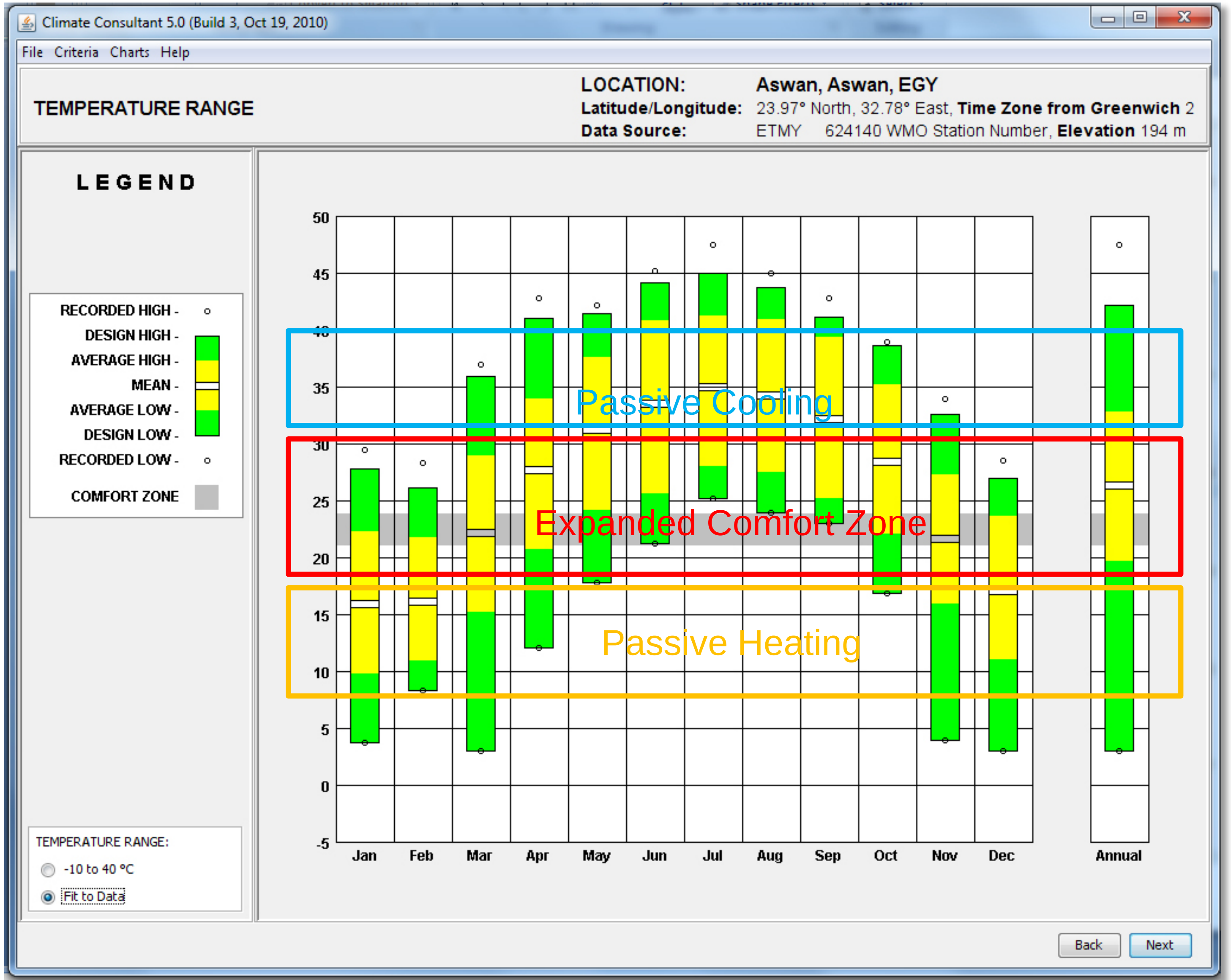
Where **very high summer temperatures** with great fluctuation predominate with **dry conditions** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

RULES:

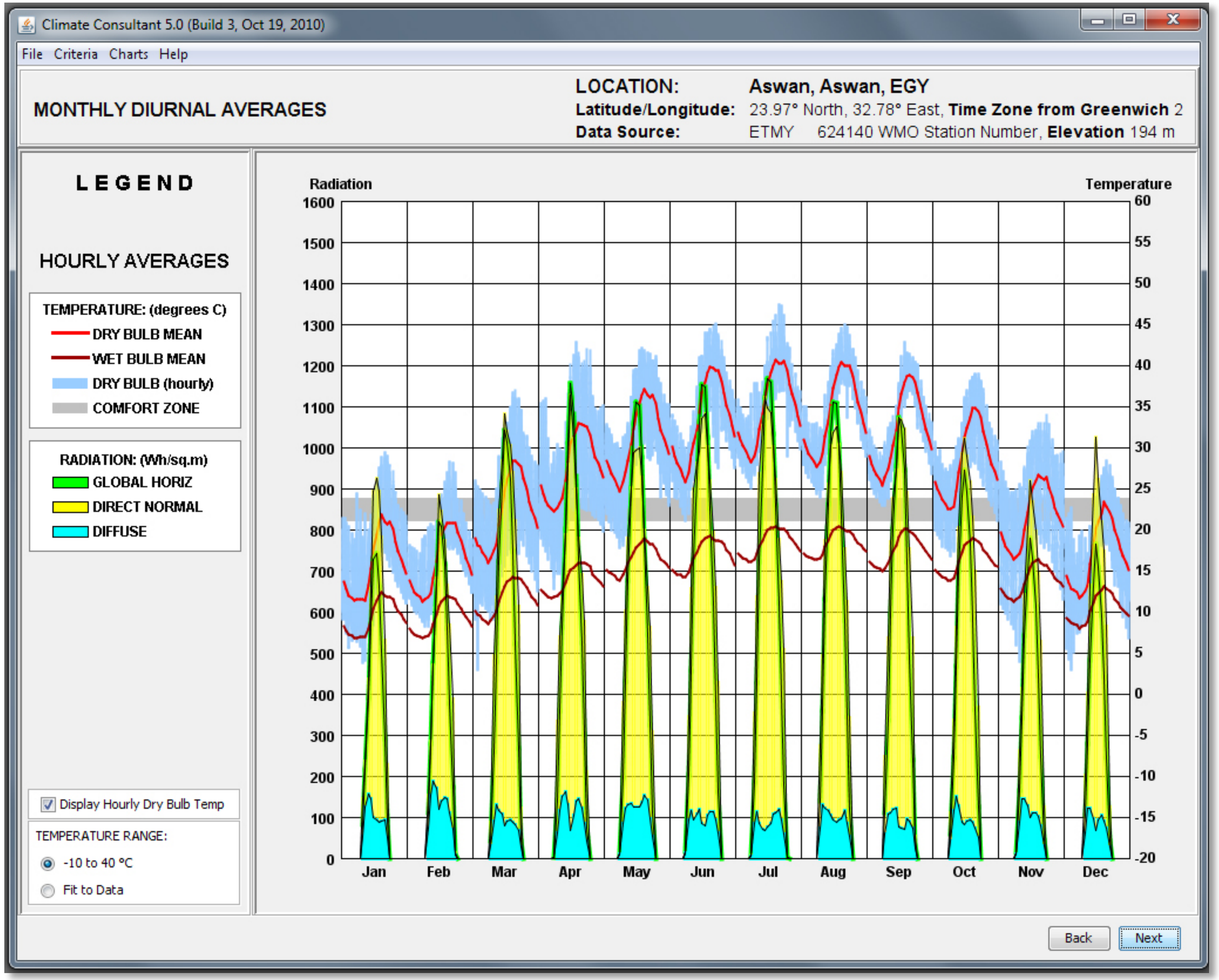
- **SOLAR AVOIDANCE**: keep DIRECT SOLAR GAIN out of the building
- avoid daytime ventilation
- promote nighttime flushing with cool evening air
- achieve daylighting by reflectance and use of LIGHT non-heat absorbing colours
- create a cooler MICROCLIMATE by using light / lightweight materials
- respect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

Traditional House in Egypt

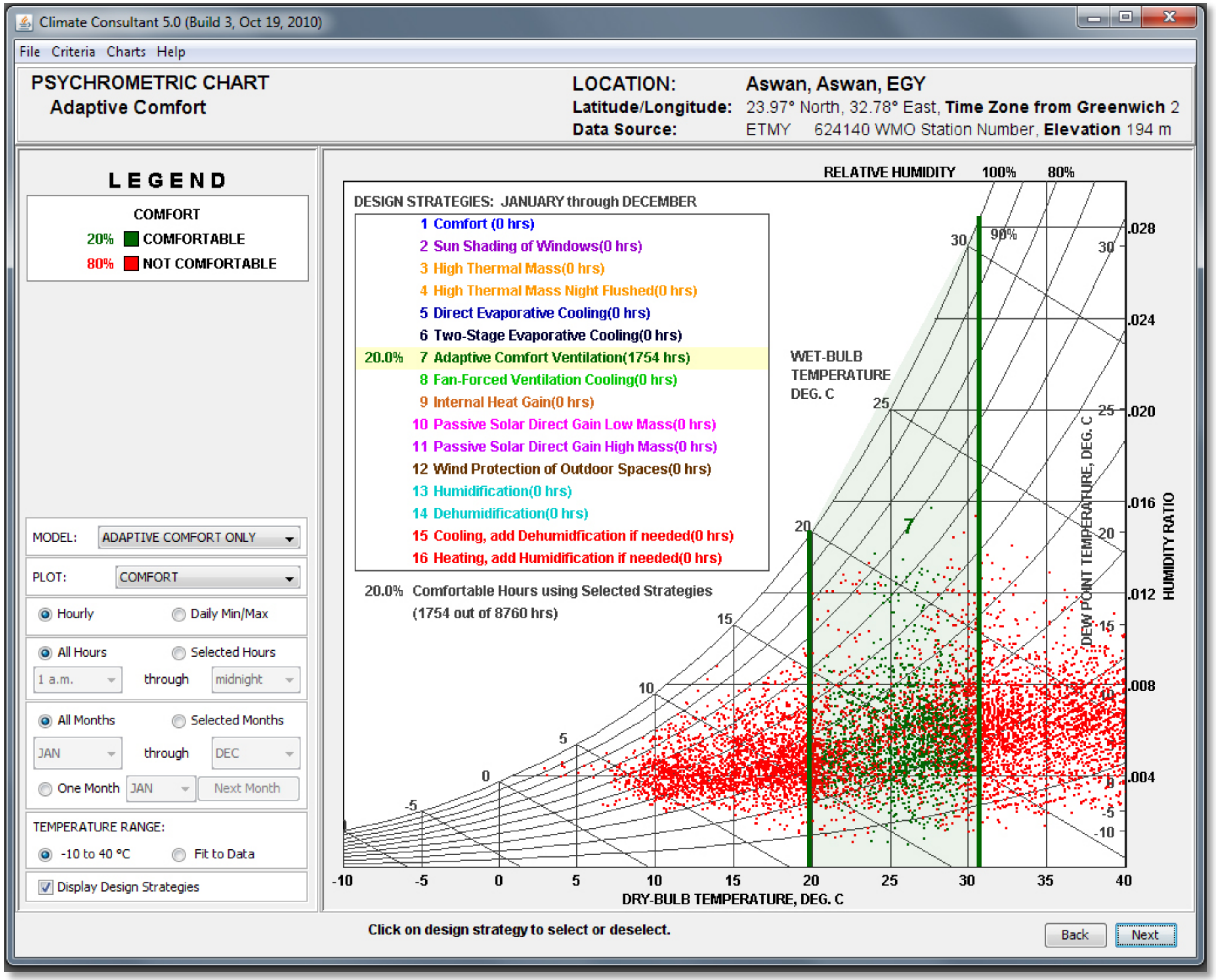
Bio-climatic Design: HOT-ARID



Bio-climatic Design: HOT-ARID



Bio-climatic Design: HOT-ARID



Bio-climatic Design: HOT-HUMID

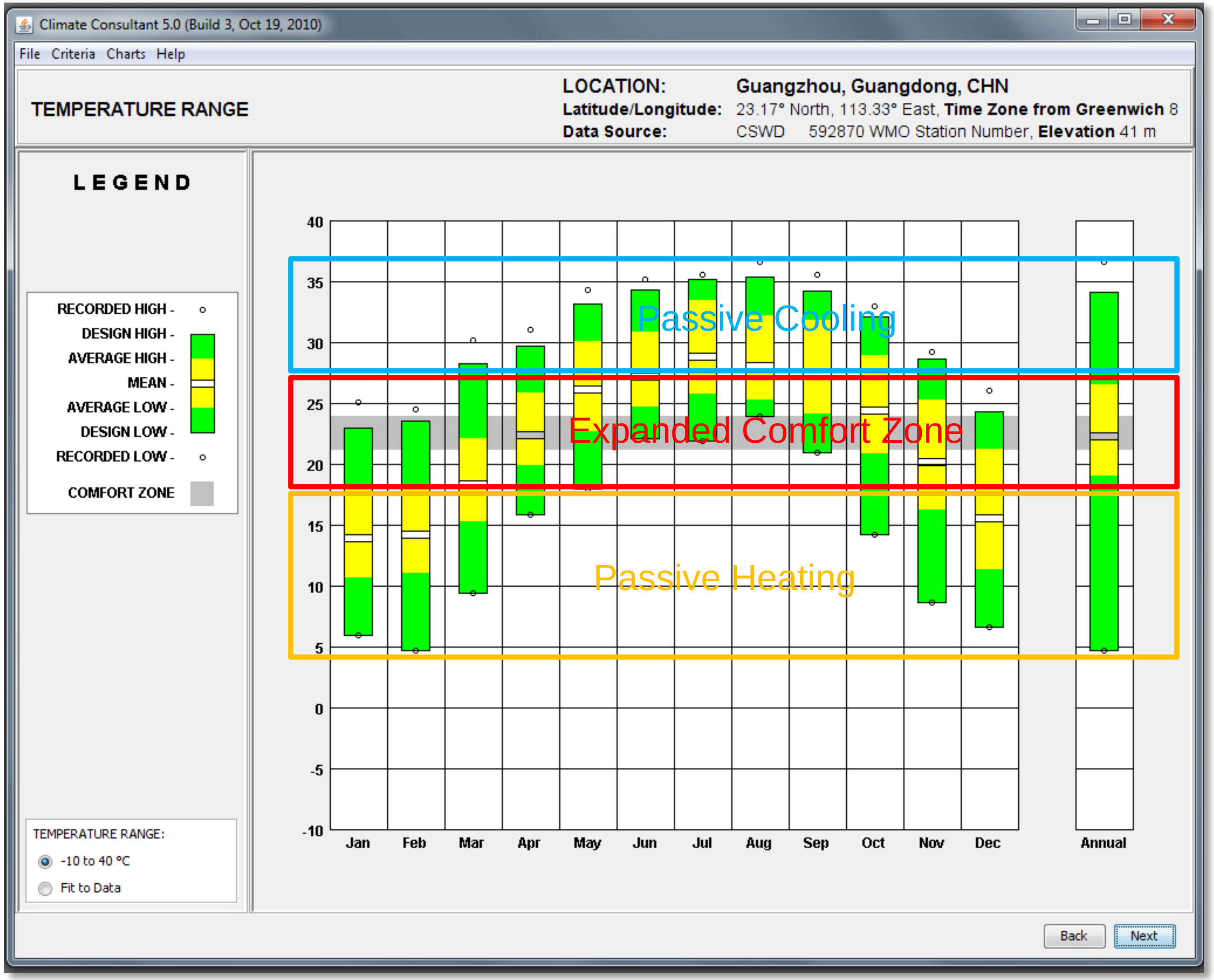
Where **warm to hot** stable conditions predominate with **high humidity** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

RULES:

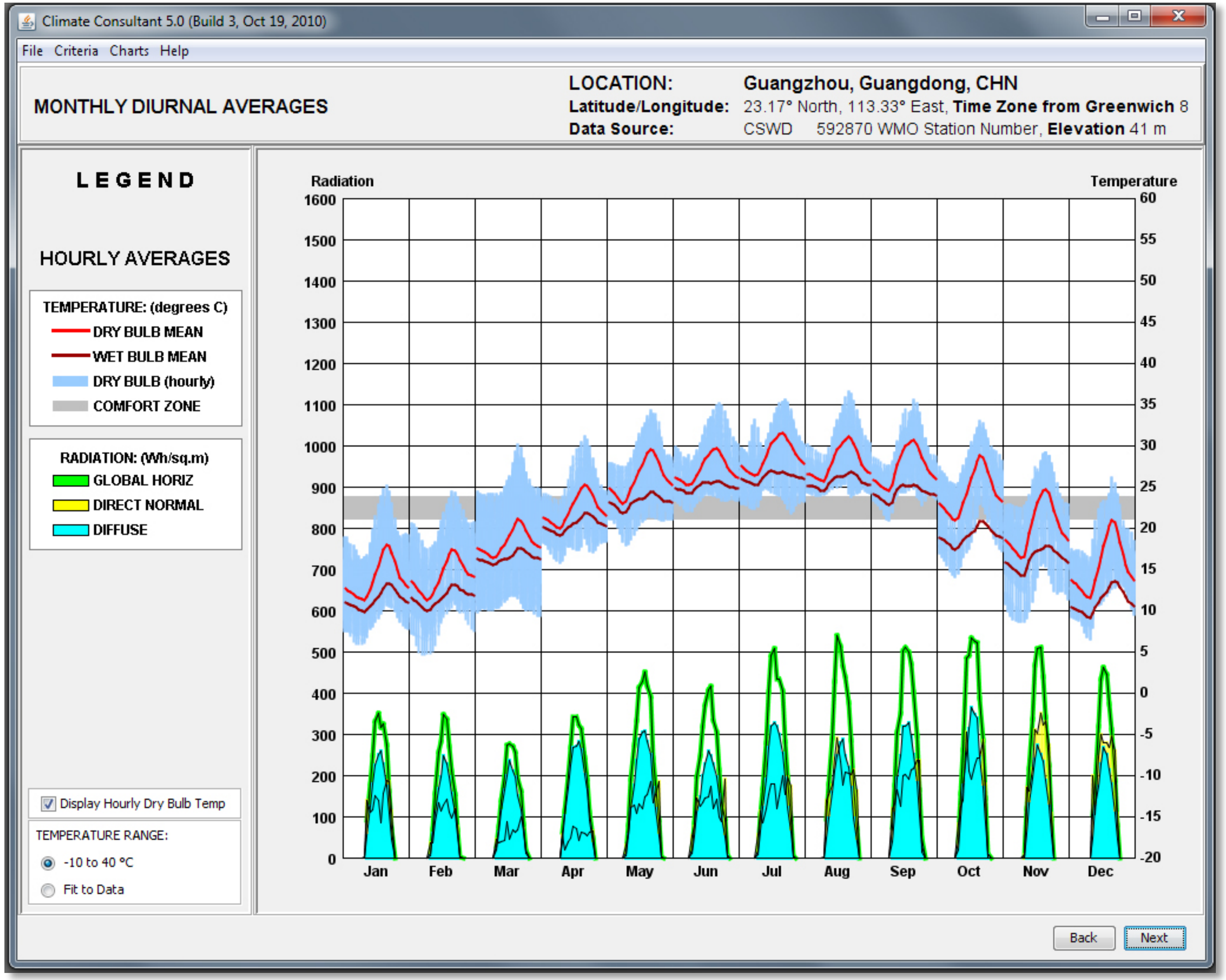
- **SOLAR AVOIDANCE** : large roofs with overhangs that shade walls and to allow windows open at all times
- **PROMOTE VENTILATION**
- **USE LIGHTWEIGHT MATERIALS** that do not hold heat and that will not promote condensation and dampness (mold/mildew)
- *eliminate basements and concrete*
- use STACK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

House in Seaside, Florida

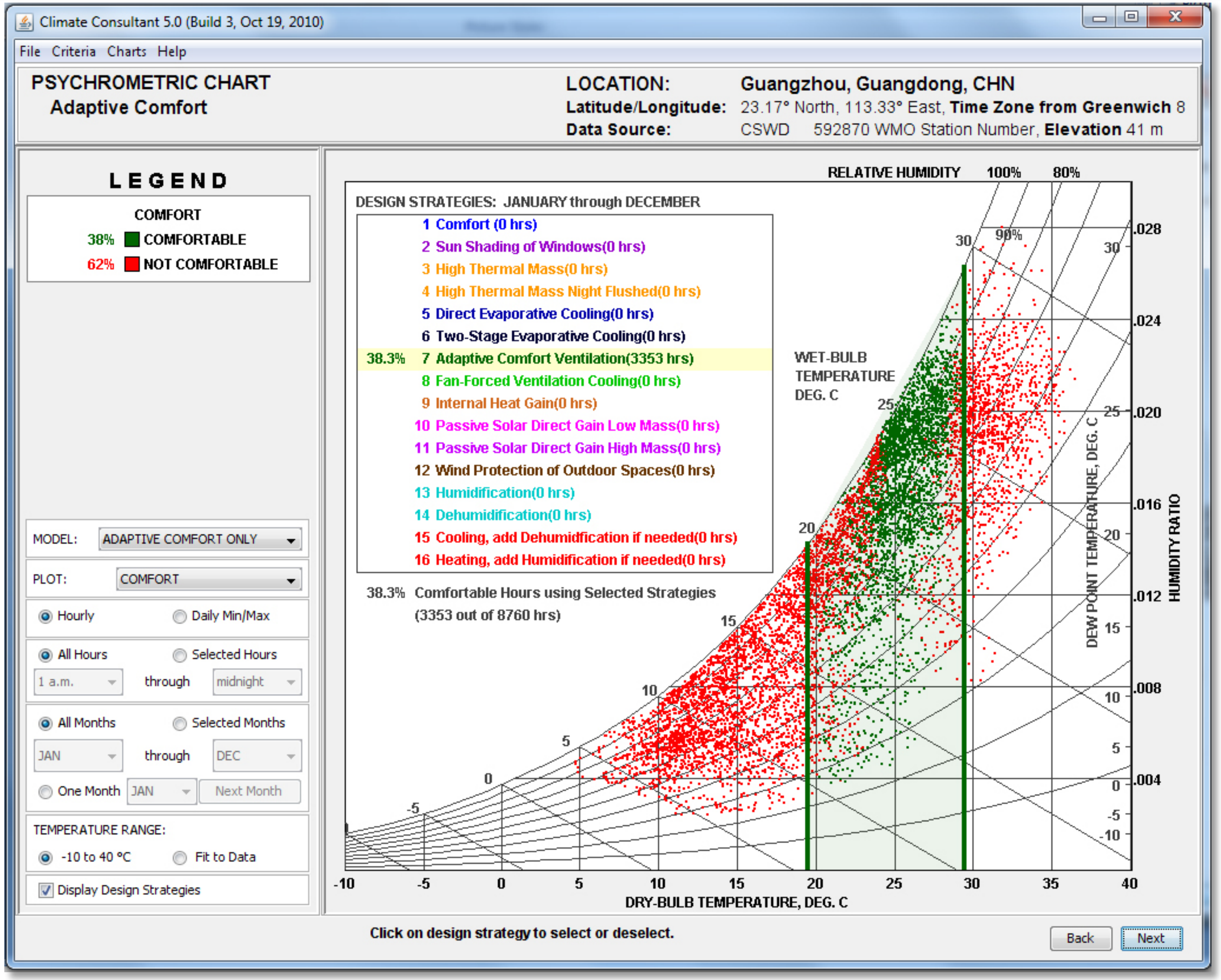
Bio-climatic Design: HOT-HUMID



Bio-climatic Design: HOT-HUMID



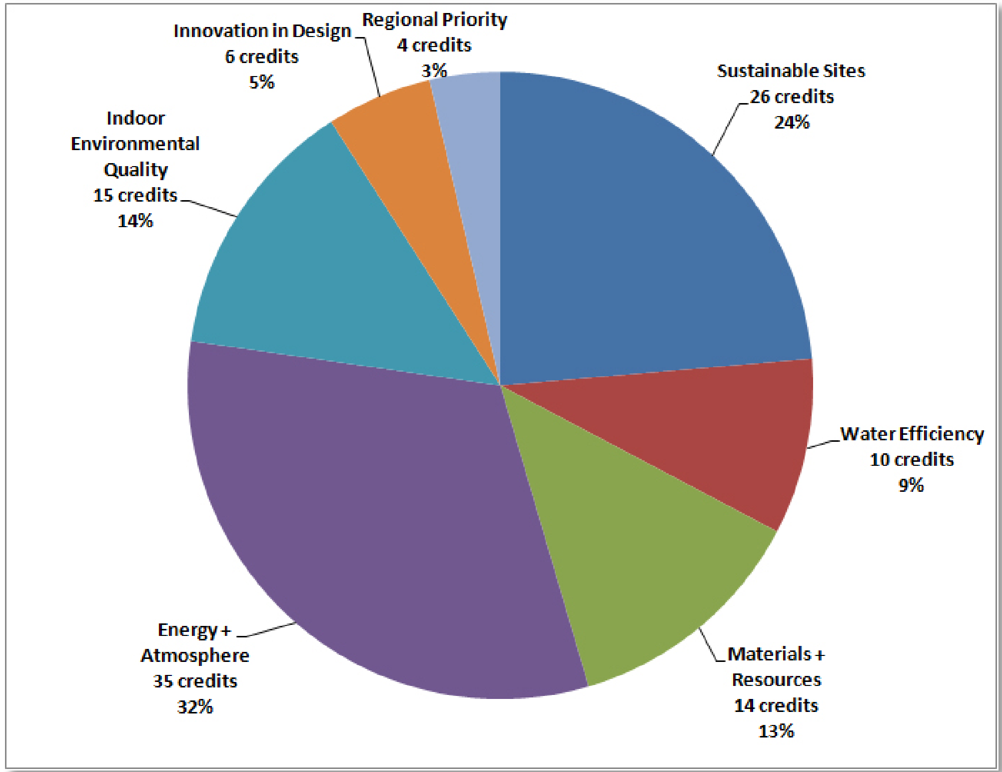
Bio-climatic Design: HOT-HUMID



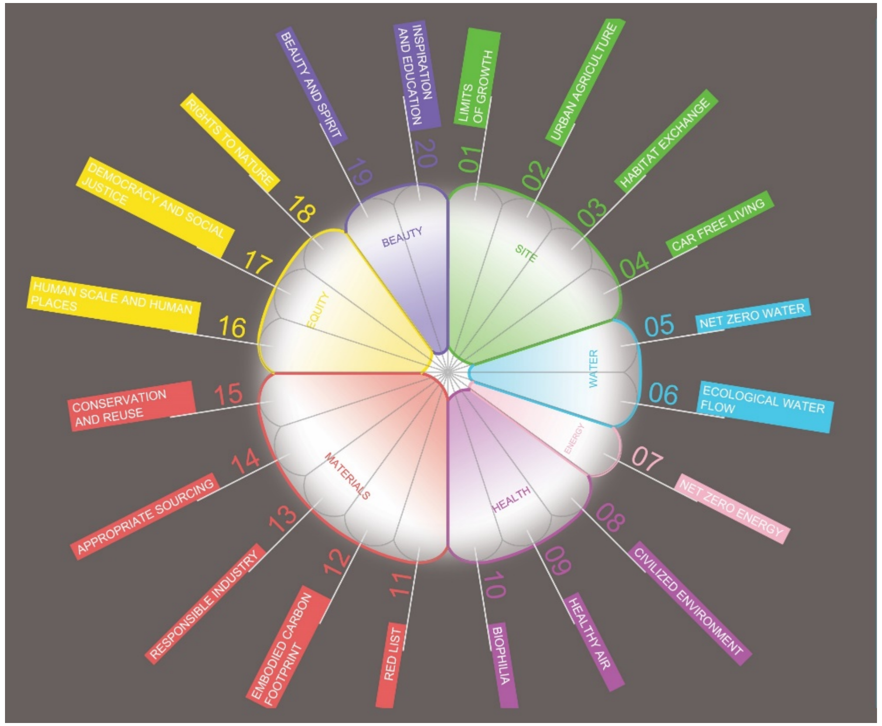
Green Building Rating Systems

In order to be able to more accurately compare and report on “green buildings”, several rating systems were developed:

- LEED (Leadership in Energy and Environmental Design)
- Living Building Challenge



LEED Awards Platinum, Gold, Silver and Certified levels

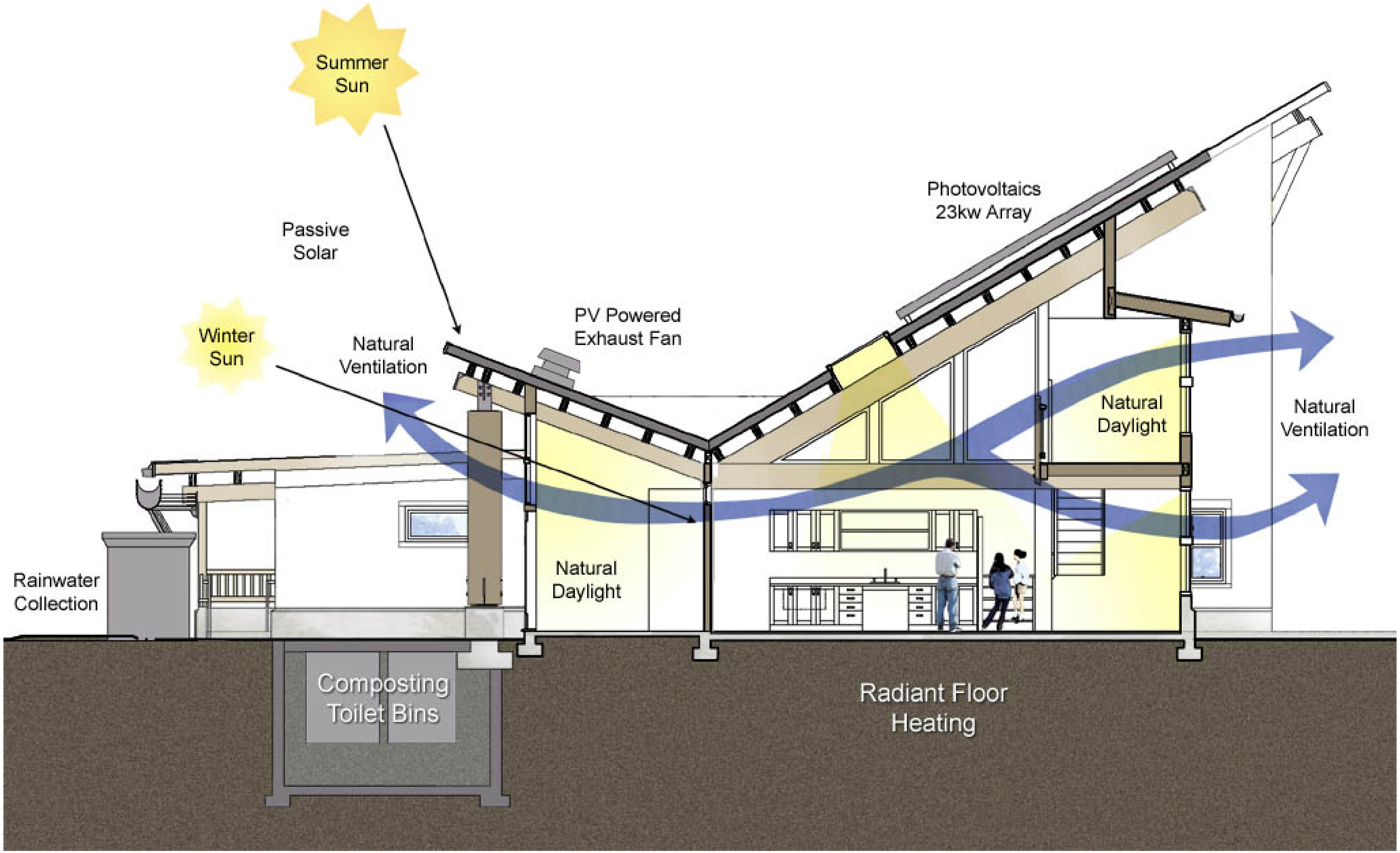


Living Building Challenge aims for carbon neutral energy and net zero water

IslandWood is an education center, on Bainbridge Island near Seattle, Washington. It was awarded LEED™ Gold Certification in 2002.

Mithun Architects

KEEN Engineering (Stantec)



http://www.designshare.com/index.php/projects/islandwood/images

- Exploration of passive heating systems
- Solar orientation, creation of “solar meadow” to ensure solar gain
- Large overhangs to prevent overheating
- Natural ventilation
- Solar hot water heating
- Photovoltaic panels

Porch zones that are covered to allow use during rain events which are pretty common in Seattle.

- Rainwater collection from all roofs – use water for irrigation
- Composting toilets
- Waterless urinals and low flush toilets
- Living Machine to treat blackwater to tertiary level of purification

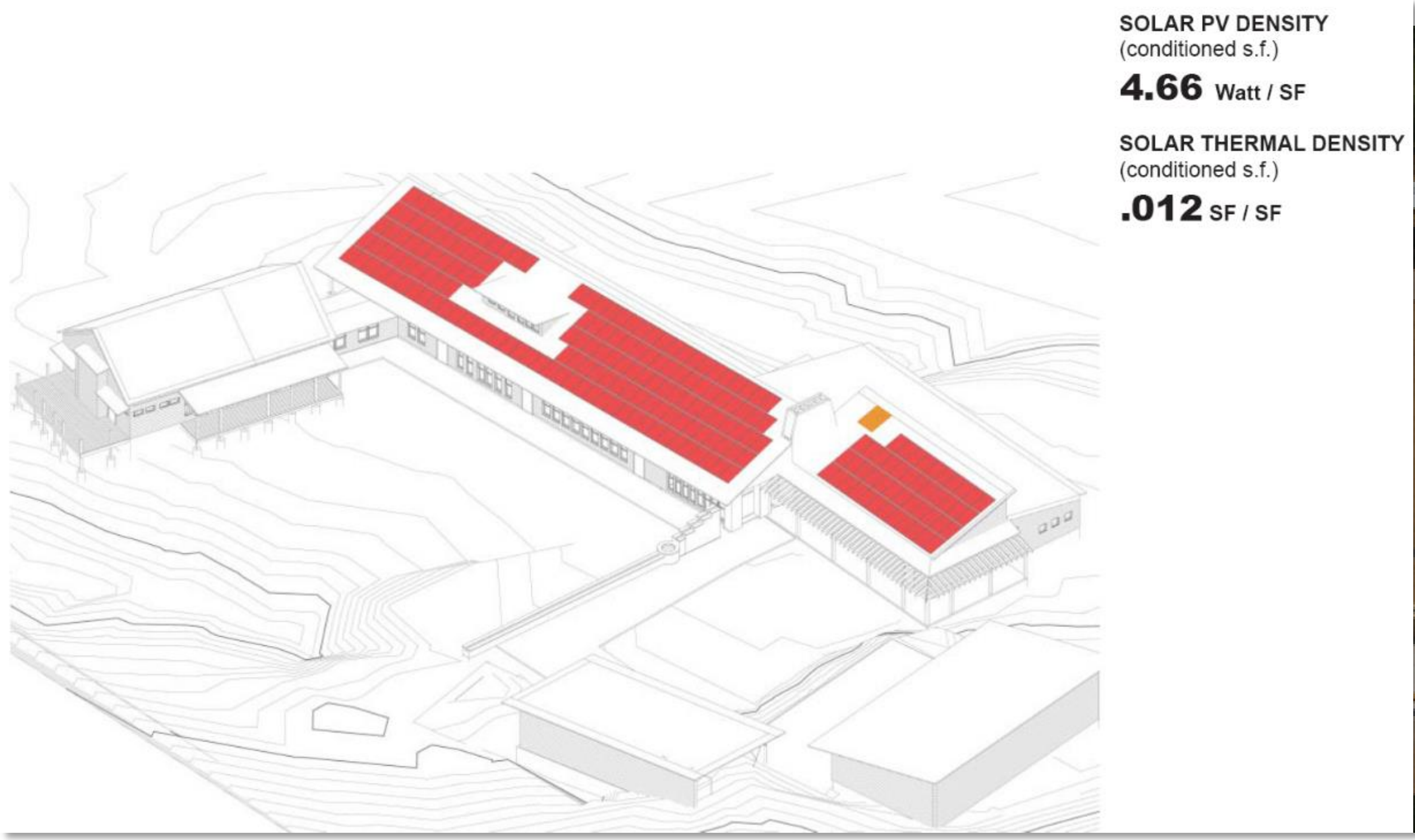
Extensive use of natural materials like wood

Spaces use natural lighting where possible to cut down on use of electricity

Aldo Leopold Legacy Center
Baraboo, Wisconsin

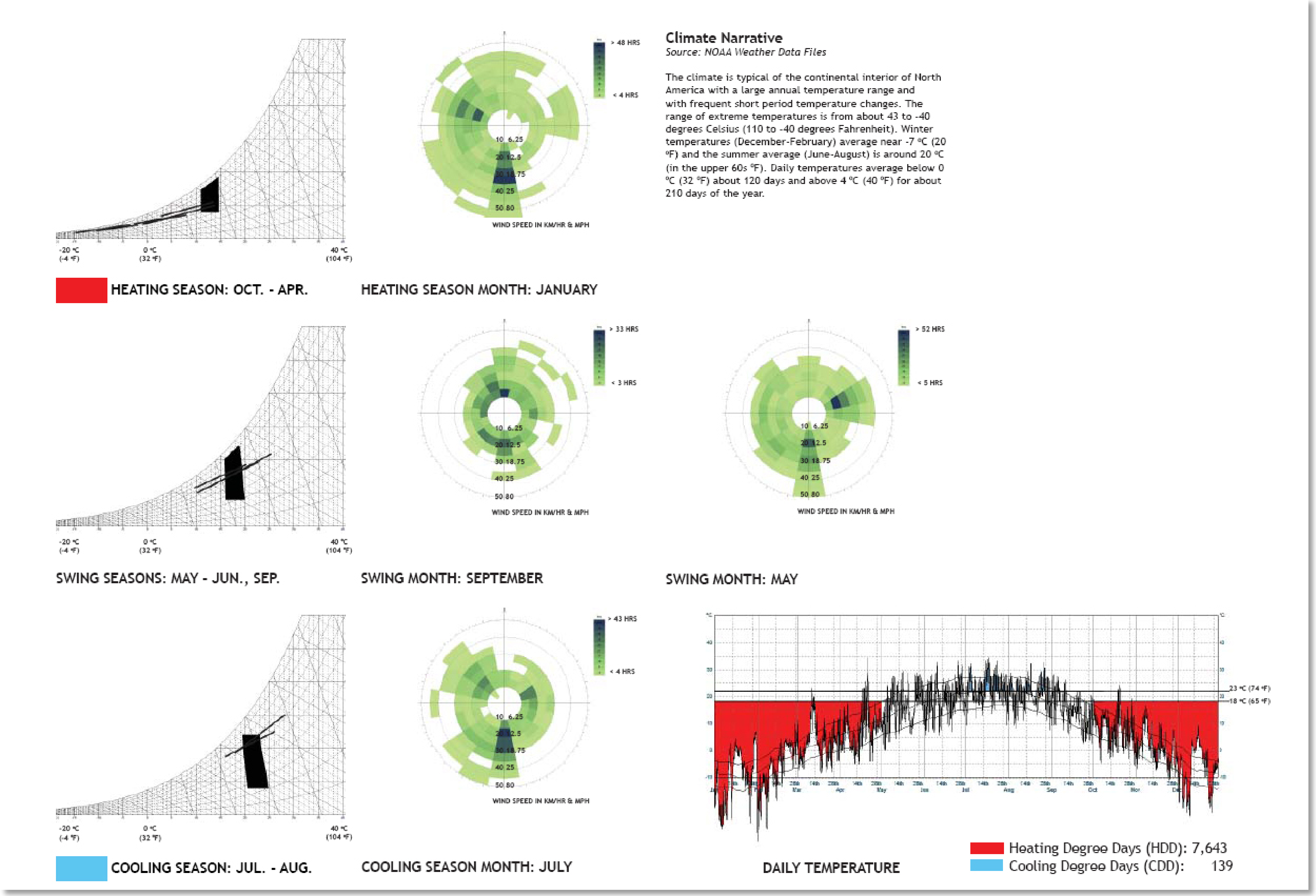
Aim was for Net Zero Operating Energy

The Kubala Washatko Architects
LEED^{TM} Platinum 2007

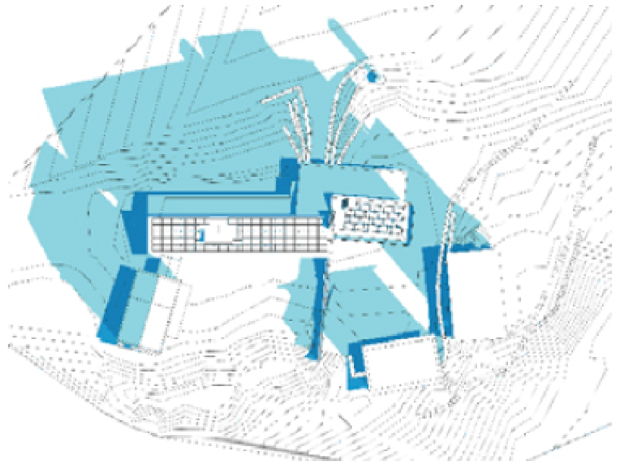


- Establish solar budget:
  3,000 photovoltaic array; 50,000 kWh per year
- Set maximum building energy demand to fall within solar budget:
  8,600 Sq. Ft. building; 5.7 kWh per SF per year

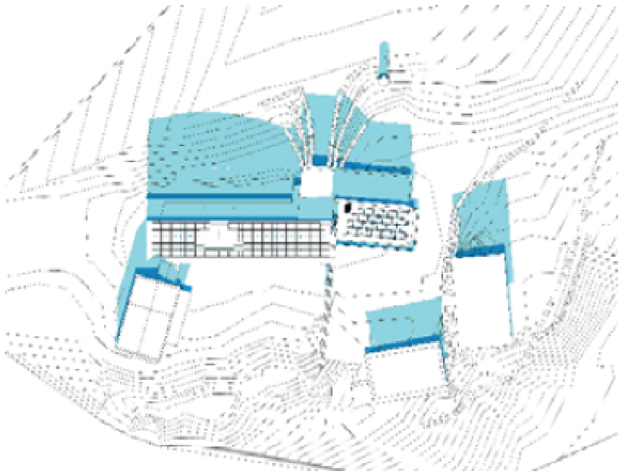
A $US250,000 PV array was included at the outset of the project budget and the building was designed to operate within the amount of electricity that this would generate.



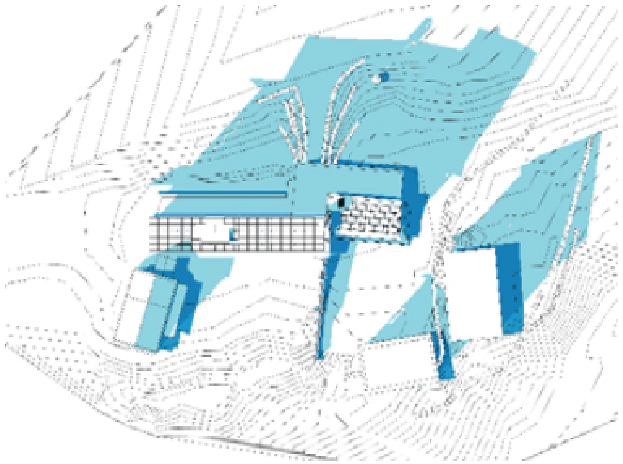
A complete climate analysis was conducted prior to any design work being conducted.



9:00 am



Noon



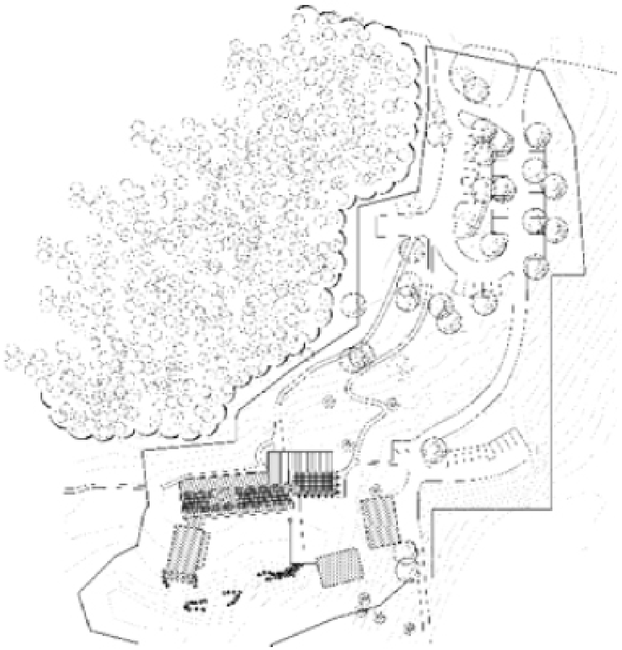
3:00 pm

Site Shading Study

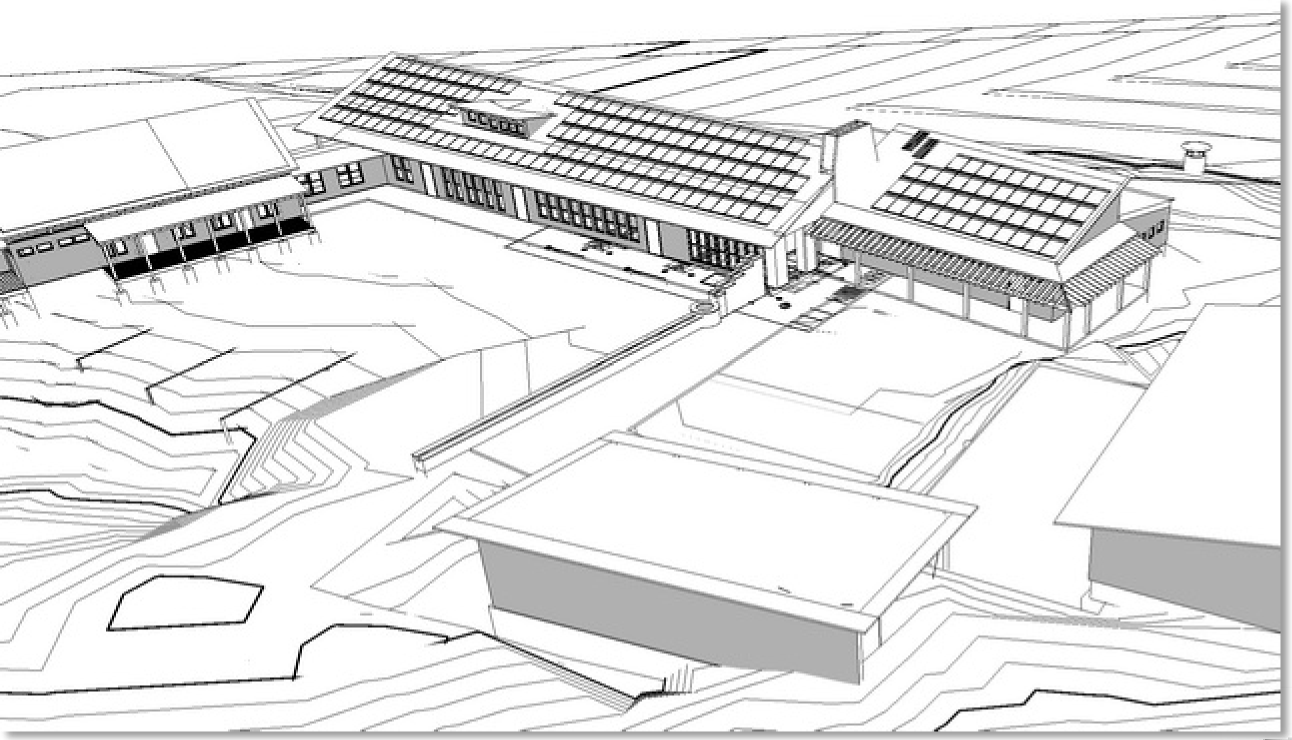
- June 21
- December 21

Ariel Image from South

Source: ____________



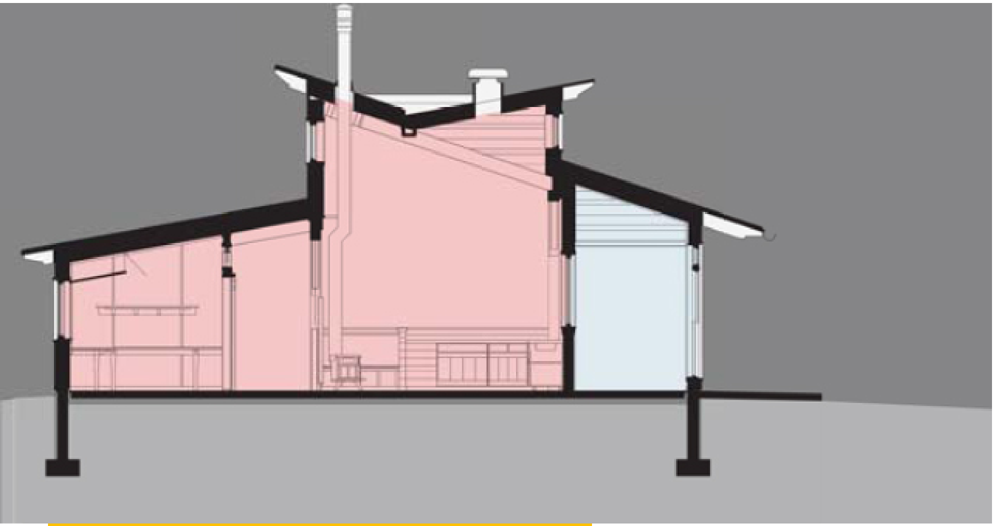
A solar analysis and ongoing solar analyses were conducted to ensure that the sun use for heating and solar avoidance were being maximized.



The South elevation is designed to capture energy.

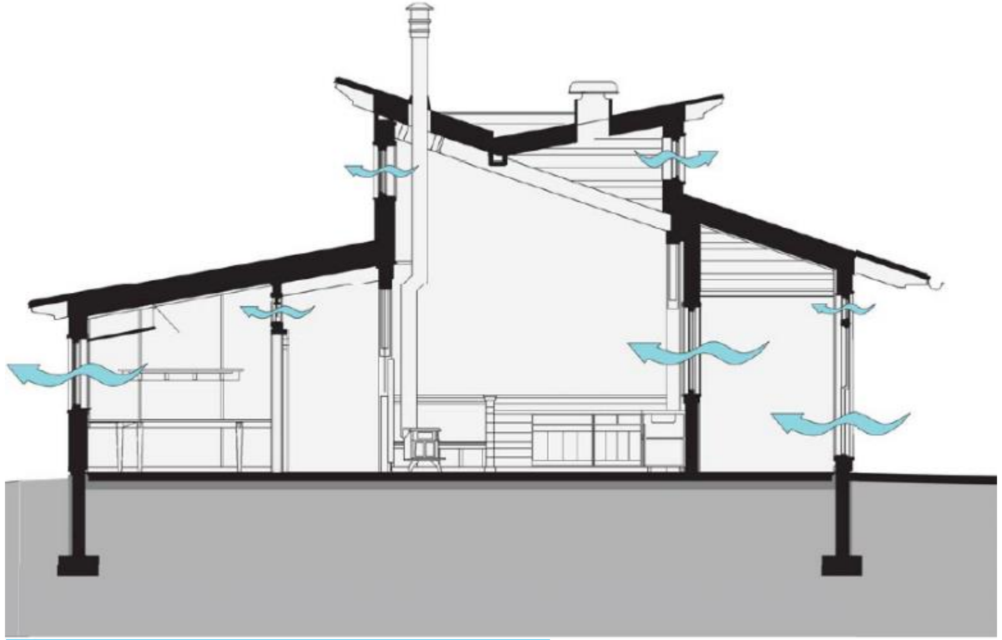
The North elevation is designed for thermal resistance, daylighting and ventilation.

The buildings were arranged in a U shape around a solar meadow that ensured access to sun for passive solar heating and energy collection.

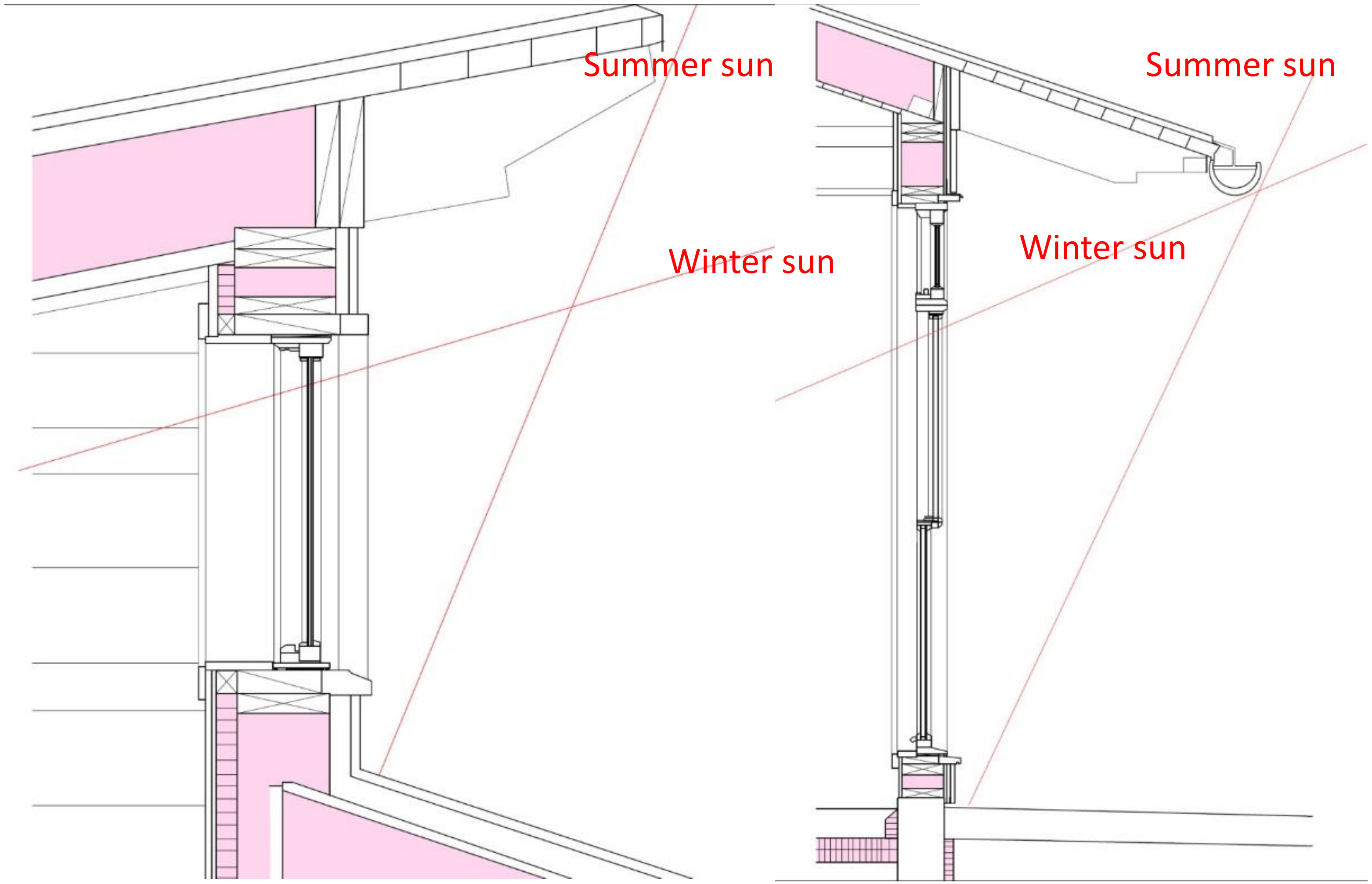


Passive Heating

- Start with bioclimatic design
- Program Thermal Zones
- All perimeter zones (no interior zones – skin load dominated building)
- Daylight all occupied zones
- Natural ventilation in all occupied zones
- Double code insulation levels
- Passive solar heating
- Shade windows during summer

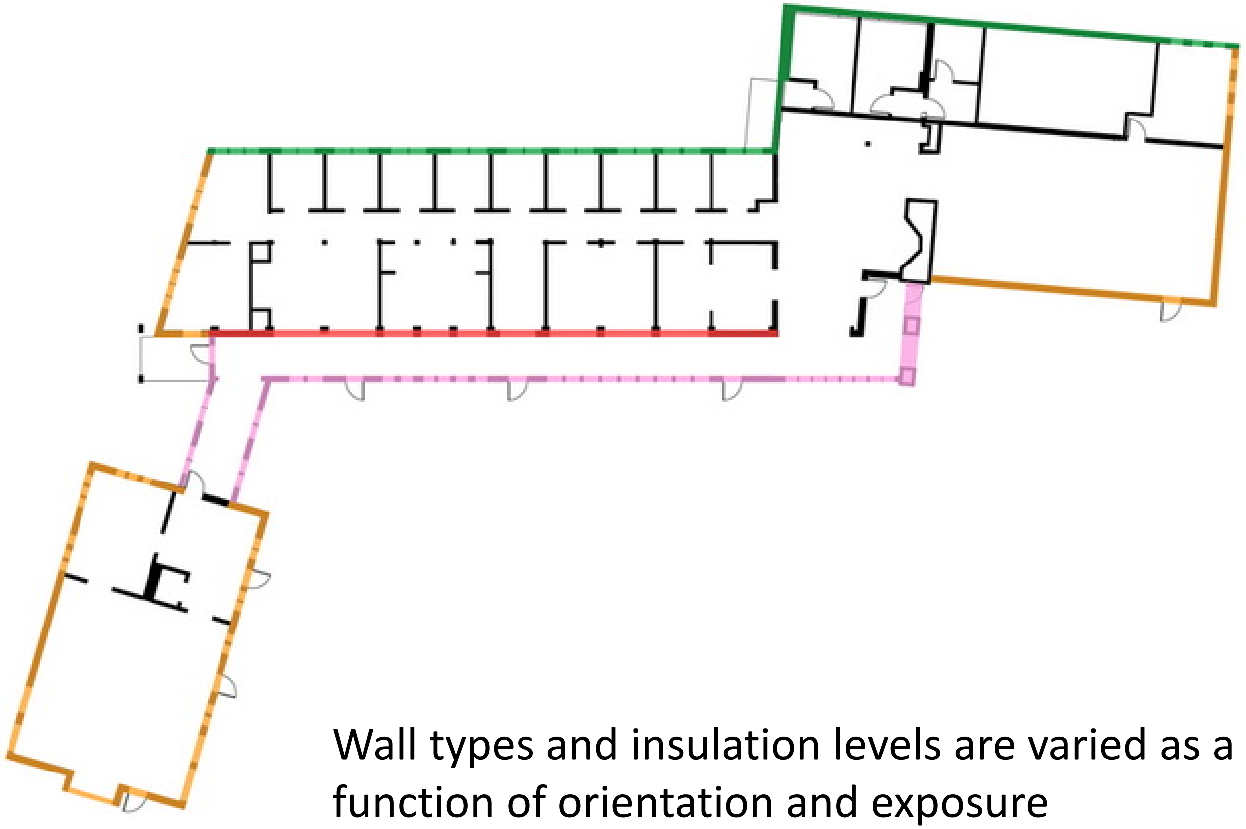


Passive Cooling



Basic first tier principle of HEAT AVOIDANCE.

Passive cooling strategies use a combination of roof overhangs to shade the windows during the summer in combination with operable windows to promote natural ventilation.



Wall types and insulation levels are varied as a function of orientation and exposure

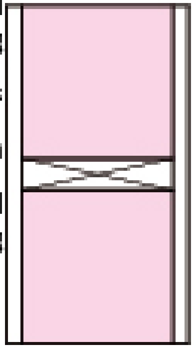
Wall Type A
Interior to Exterior

-1x Interior Wood Siding

-2x8 Wood Studs

-Sprayed Insulation

-1x Interior Wood Siding



Wall Type B
Interior to Exterior

-1x Interior Wood Siding

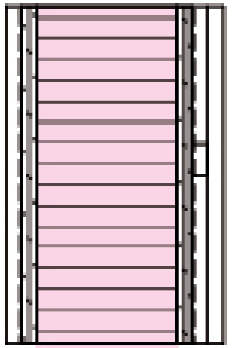
-Vapor Barrier

-8 1/4" Structural Insulated Panel

- Air Barrier

-Air Space w/ Vertical Furring Strip

-1x Flatboard Exterior Wood Siding



Wall Type C
Interior to Exterior

-1x Interior Wood Siding

-Vapor Barrier

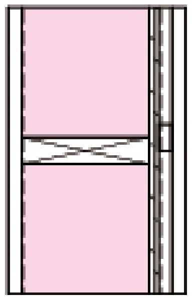
-2x8 Stud Walls with Sprayed Insulation

-1/2" Exterior Wall Sheathing

- Air Barrier

-Air Space w/ Vertical Furring Strip

-1x Flatboard Exterior Wood Siding



Wall Type D
Interior to Exterior

-1x Interior Wood Siding

-Vapor Barrier

-1 1/2" Rigid Insulation

-2x8 Stud Walls with Sprayed Insulation

-1/2" Exterior Wall Sheathing

- Air Barrier

-Air Space w/ Vertical Furring Strip

-1x Flatboard Exterior Wood Siding