Accentuate the Positive: Climate Responsive Design

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Produced By: OAA

Developed By: aia seattle

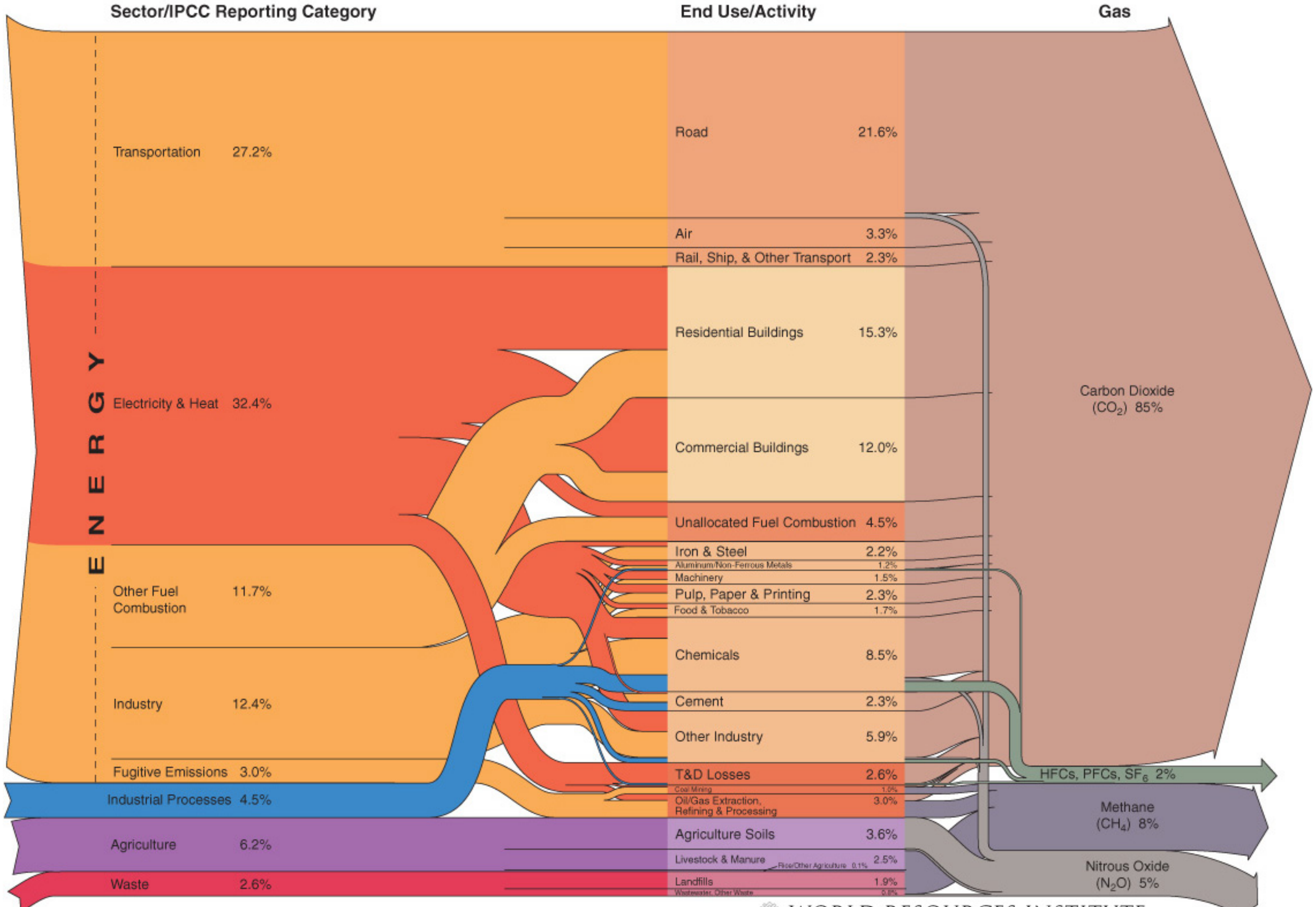
In partnership with: architecture 2030

The Global Warming Pie....

These values look at <u>Secondary **Energy Use** by Sector in Canada (2006)</u>
(*energy used by the final consumer i.e. operating energy*)

Emissions and their Sources

U.S. GHG Emissions Flow Chart



WORLD RESOURCES INSTITUTE

Technological advances have allowed us to build anything…

Photo:National Trust

The Glass House New Canaan Connecticut 1949, by architect Phillip Johnson who coined the term “International Style”

Conventional construction:
Boxes hooked up to life support

In Florida turn the dial one way,

in Maine turn it the other.

Think Building Green.com

CONNECTICUT

ARIZONA

NEW MEXICO

FLORIDA

Opportunities to Work With and Harvest Climate

Roughly….

The Sun = Free Heat, Light, Cooling & Ventilation

The Wind = Free Ventilation & Cooling

Rain & Snow = Free Water & Cooling

There is lots that can and must be done at the OUTSET of a project with respect to the Climate, Building Siting and Orientation that can HELP to reduce energy.

If not done you will spend a lot of time and energy working to correct these bad decisions.

Good decisions at the start can be built upon ….

Bad decisions at the start need to be corrected ….

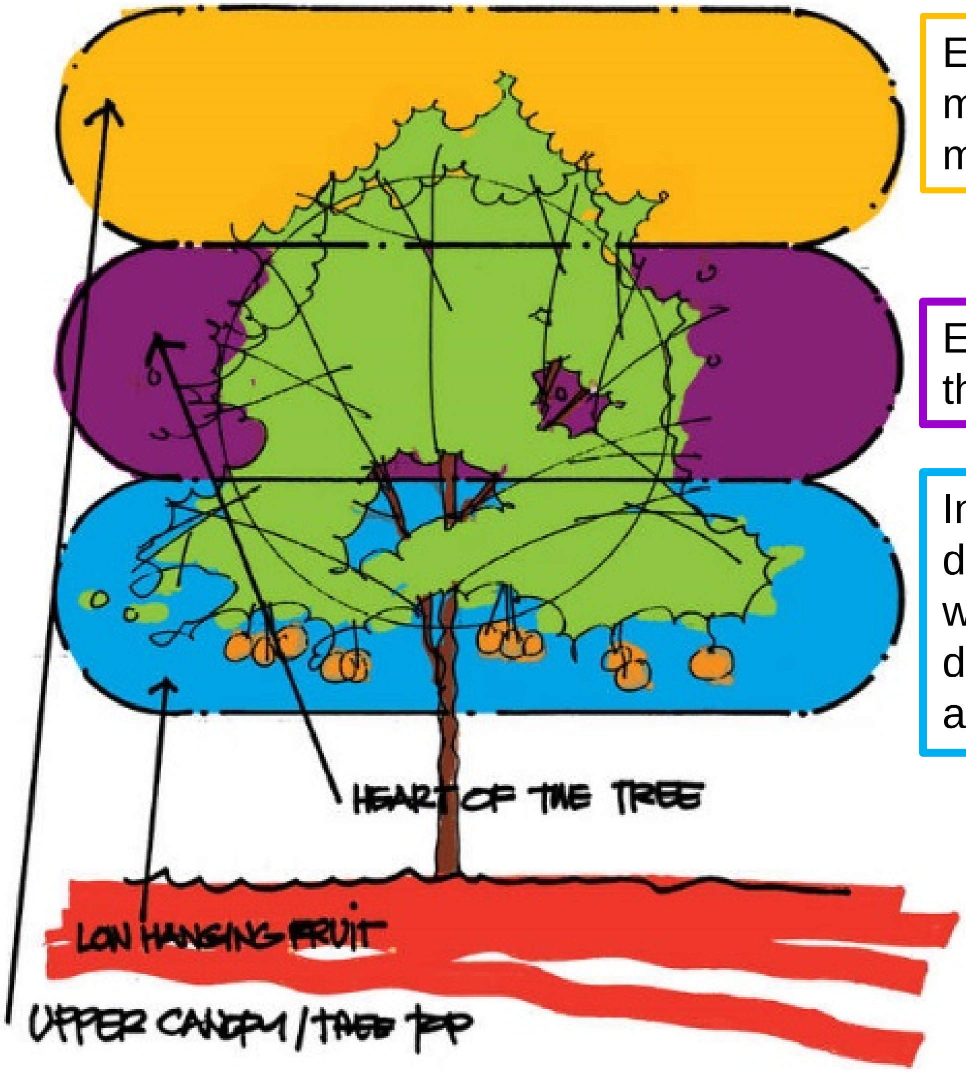
Must Understand What Climate Responsive Design can Impact

Climate responsive design means designing to work with the local climate.

This can mean shaping massing, materials, etc. to:

- **Reduce snow accumulations at entrances / exits**
- **Store coolth generated at night to the day**
- **Passive solar heating**
- **Wind driven natural ventilation**
- **Locations of windows, atria, skylights etc. to benefit daylighting**
    - **These also impact natural ventilation**
- **Locating pollutant/odour sources downwind from building intakes**
- **Providing adequate snow melt run-off capacity**
- **Burying the water pipes deep enough**
- **Using a ground exchange system to pre-heat / pre-cool intake air**

Low Hanging Fruit



Expensive systems such as PV, micro wind turbines, various mechanical and electrical equipment

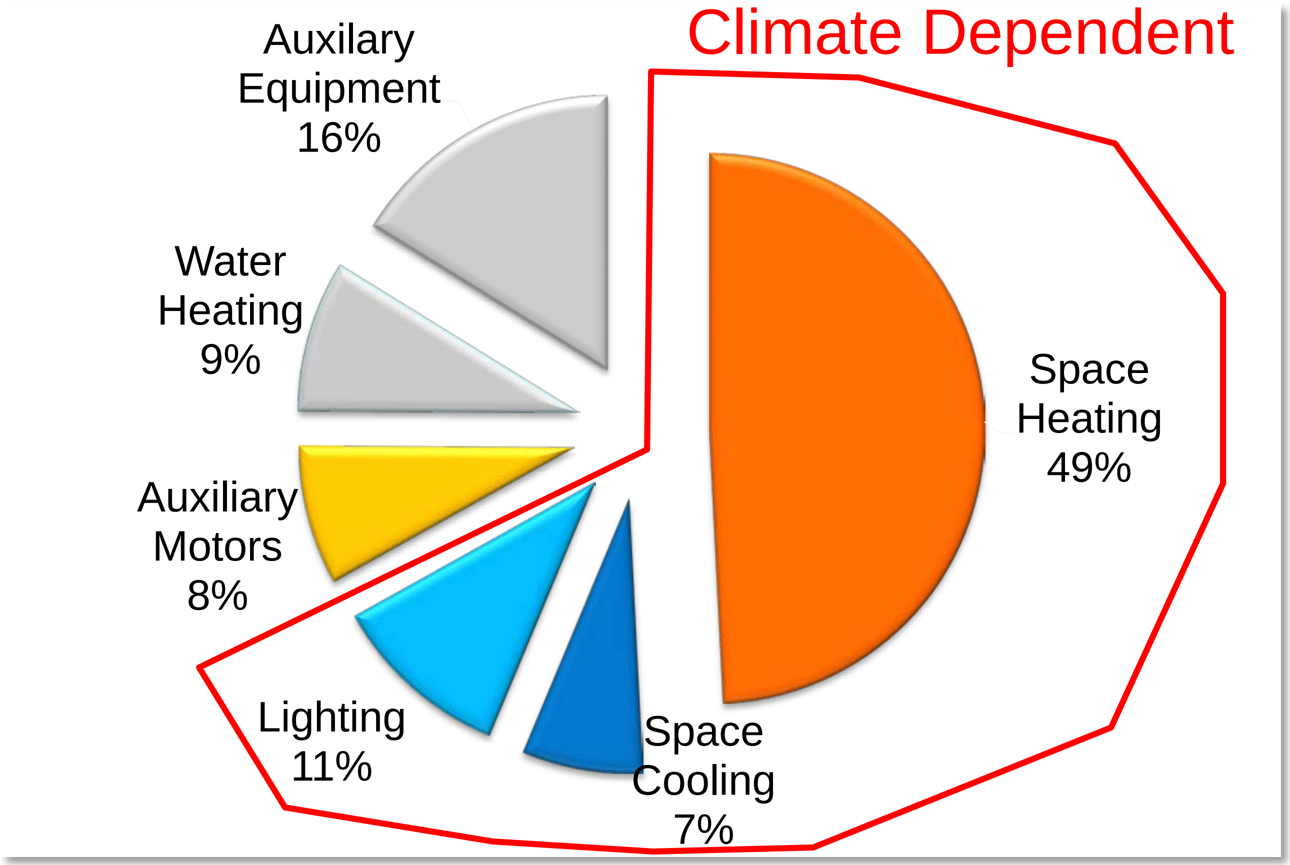
Extra insulation, better windows, thermal mass, shading devices.

Initial site and climate based design decisions that really cost nothing but will benefit the project: climate, defining comfort, orientation, adjacencies, massing, landscaping

www.amdgarchitects.com

Energy Use in Buildings: Operating Energy

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



Source: Natural Resources Canada, 2006

OAA 2030™
A partner program of the AIA+2030 Professional Series™

Operating Energy of Building

architecture 2030

80% of the problem!

Landscape + Site

Disturbance vs. sequestration

Embodied Carbon in Building Materials

People, “Use” + Transportation

Renewables + Site Generation

Counting Carbon costs….

+ purchased offsets

Operating Energy of Building

80% of the problem!

Building envelope performance directly impacts operating energy

Embodied Carbon in Building Materials

Building envelope material selection and sourcing directly impacts embodied energy

OPERATING ENERGY IS CLIMATE DEPENDENT

Three Key Steps – IN ORDER:

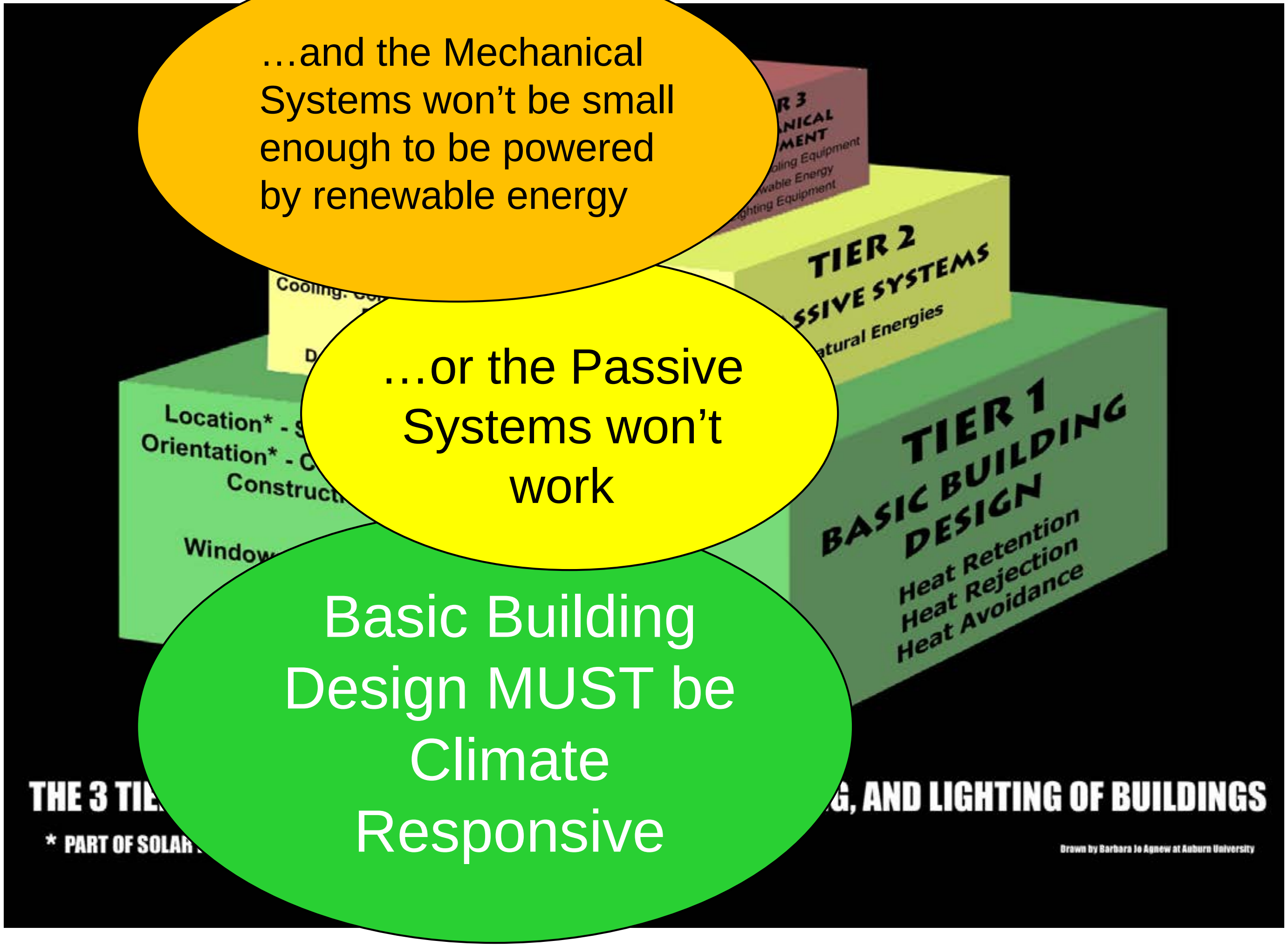
#1 - Reduce loads/demand first

(conservation, passive design, daylighting, shading, orientation, etc. with CLIMATE RESPONSIVE DESIGN)

#2 - **Meet loads efficiently and *effectively*** (energy efficient lighting, high-efficiency MEP equipment, controls, etc.) to reduce energy requirements, in order to

#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.)

Carbon Reduction: The Tier Approach



…and the Mechanical Systems won't be small enough to be powered by renewable energy

…or the Passive Systems won't work

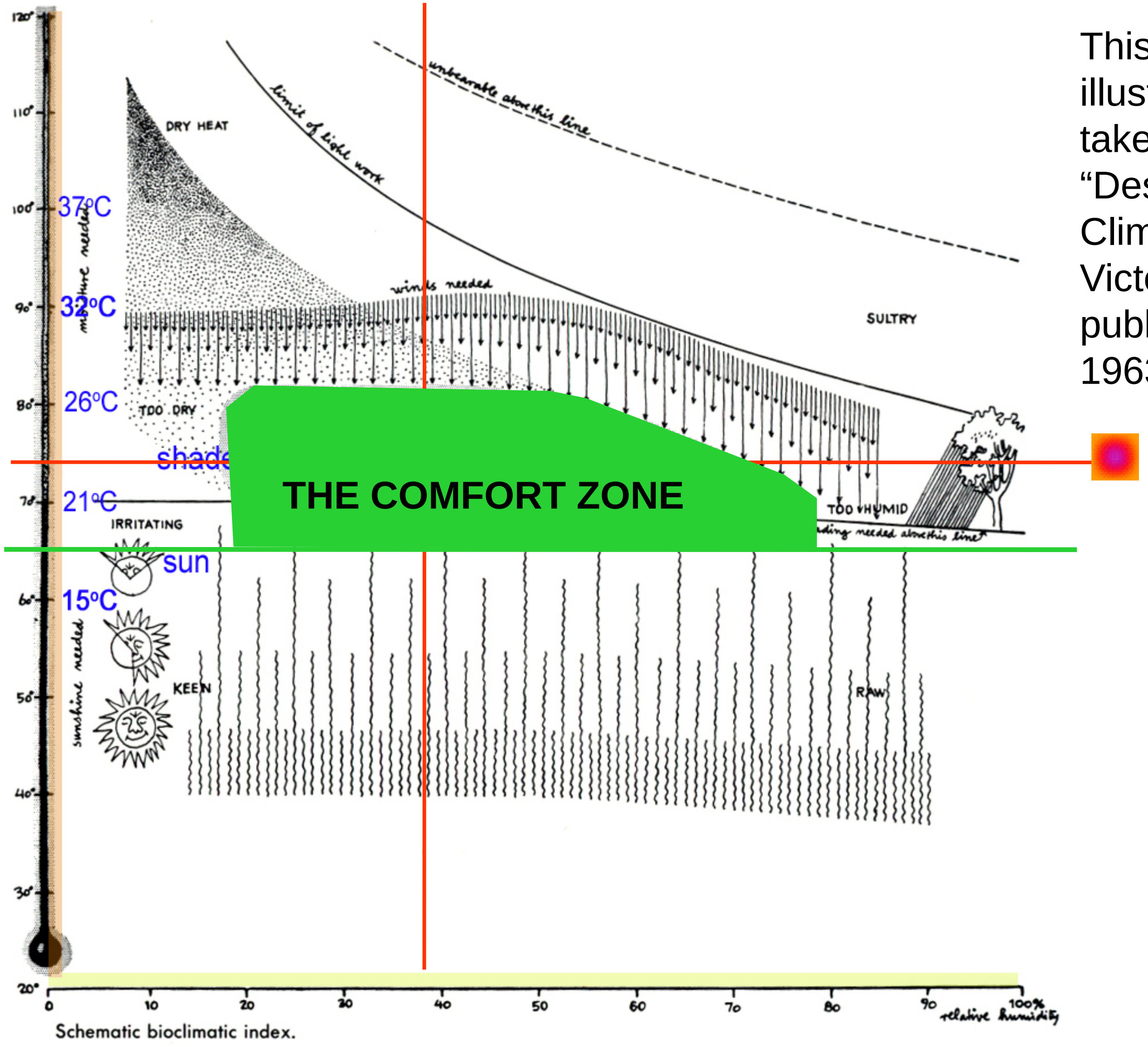
Basic Building Design MUST be Climate Responsive

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

Climate as the Starting Point for a Climate Responsive Design

Designing to the **Comfort Zone** vs. Comfort Point:

REDUCING OPERATING ENERGY



This famous illustration is taken from “Design with Climate”, by Victor Olgyay, published in 1963.

Passive Bio-climatic Design: COMFORT ZONE

IDEALLY comfort expectations may have to be reassessed to allow for the wider “zone” that is characteristic of buildings that are not exclusively controlled via mechanical systems.

Creation of new **“buffer spaces”** to make a hierarchy of comfort levels within buildings.

Require **higher occupant involvement** to adjust the building to modify the temperature and air flow.

North American Bio-climatic Design:

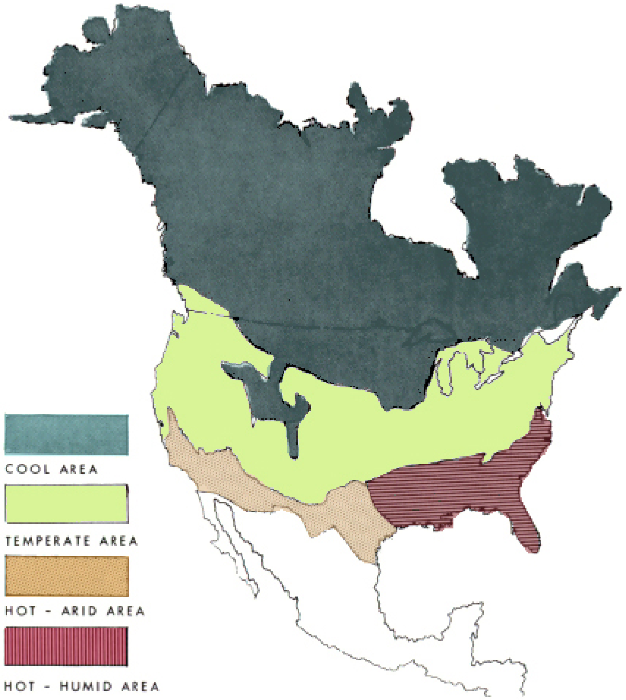
Design must first acknowledge regional, local and microclimate impacts on the building and site.

COLD

TEMPERATE

HOT-ARID

HOT-HUMID

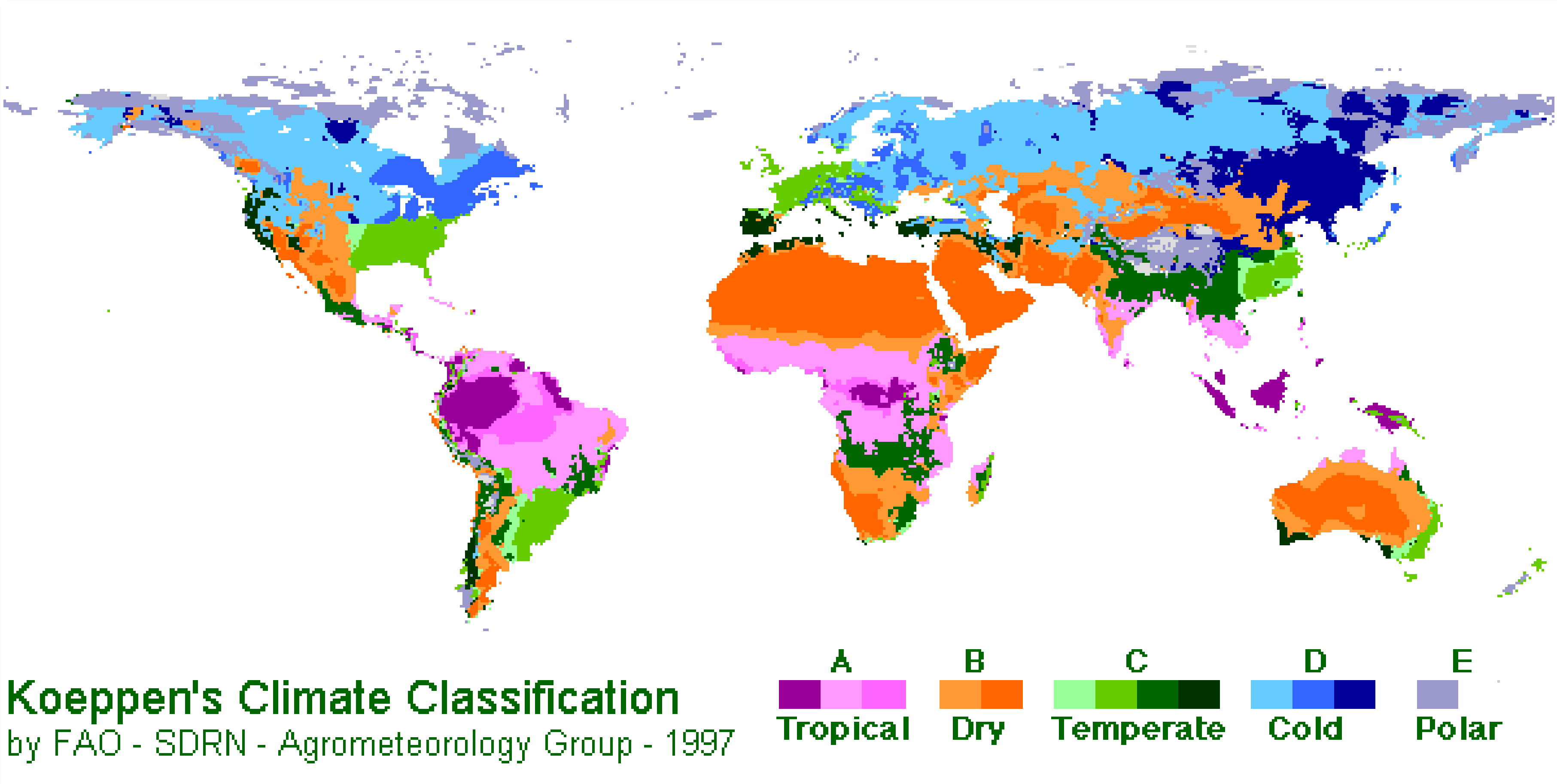


11. Regional climate zones of the North American continent.

Image: 1963 “Design With Climate”, Victor Olgyay.

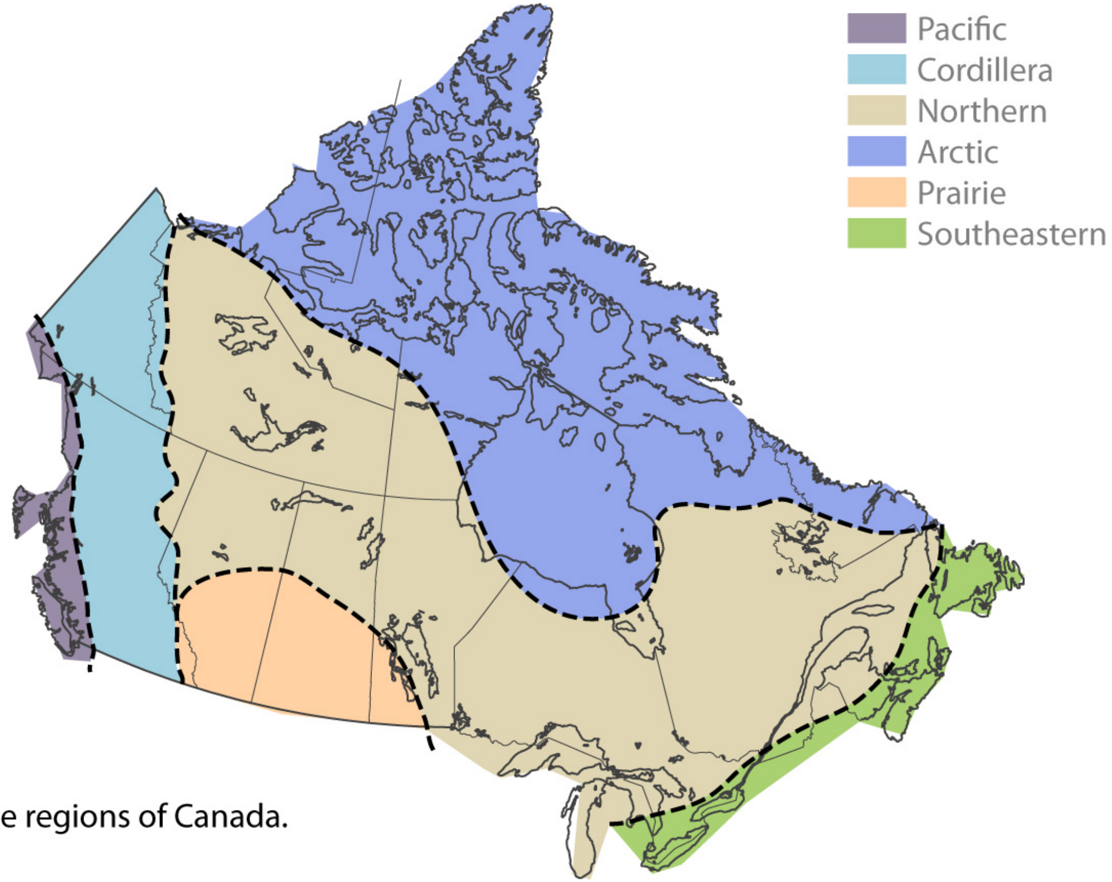
Global Bio-climatic Design:

Design must first acknowledge regional, local and microclimate impacts on the building and site.



Koeppen's Climate Classification
by FAO - SDRN - Agrometeorology Group - 1997

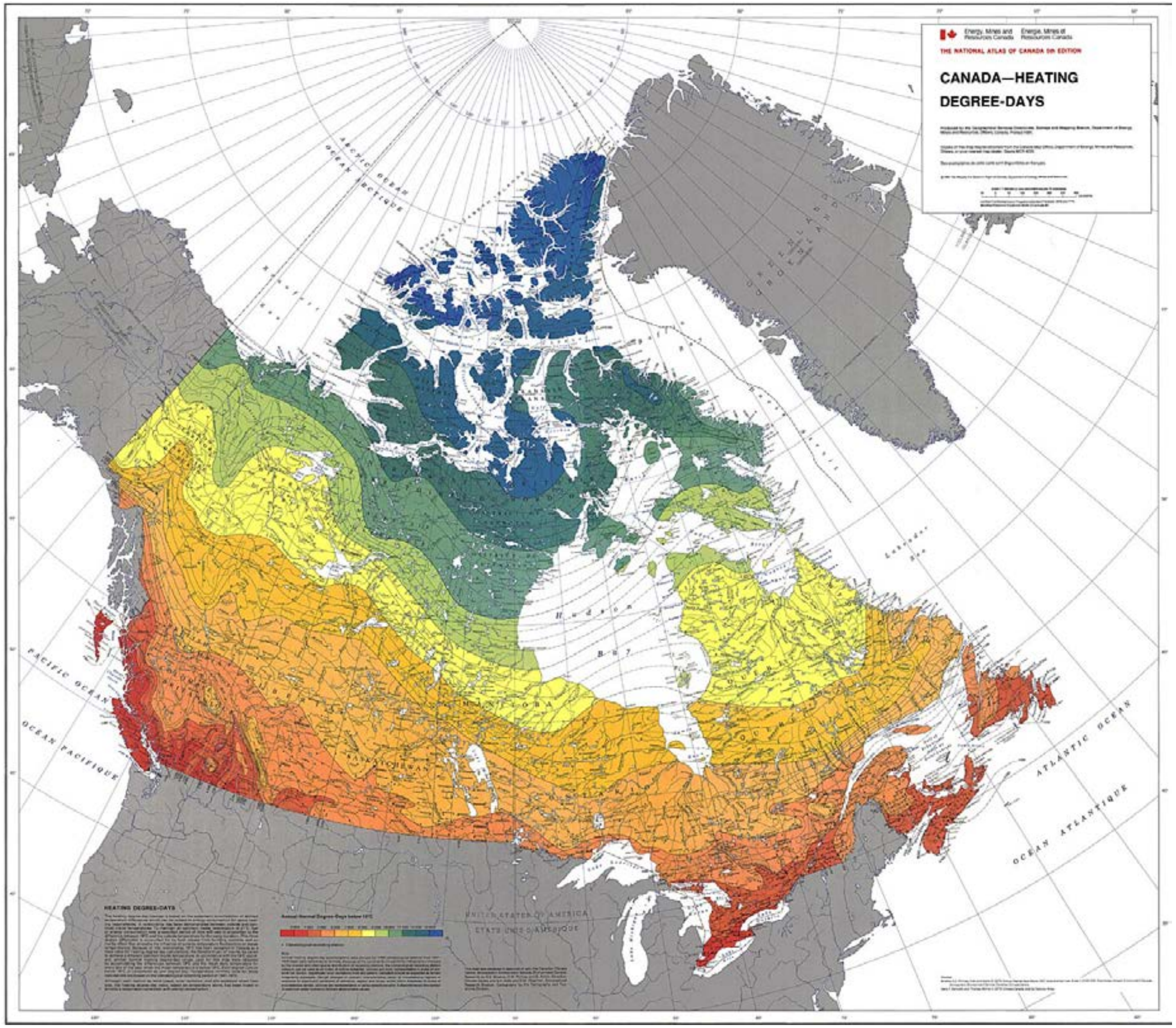
The climate regions of Canada



Climate regions of Canada.

Even within Canada, there exist variations in climate, enough to require very different envelope design practices and regulations. This mostly concerns insulation and water penetration, as well as humidity concerns.

Heating and Cooling Degree Days

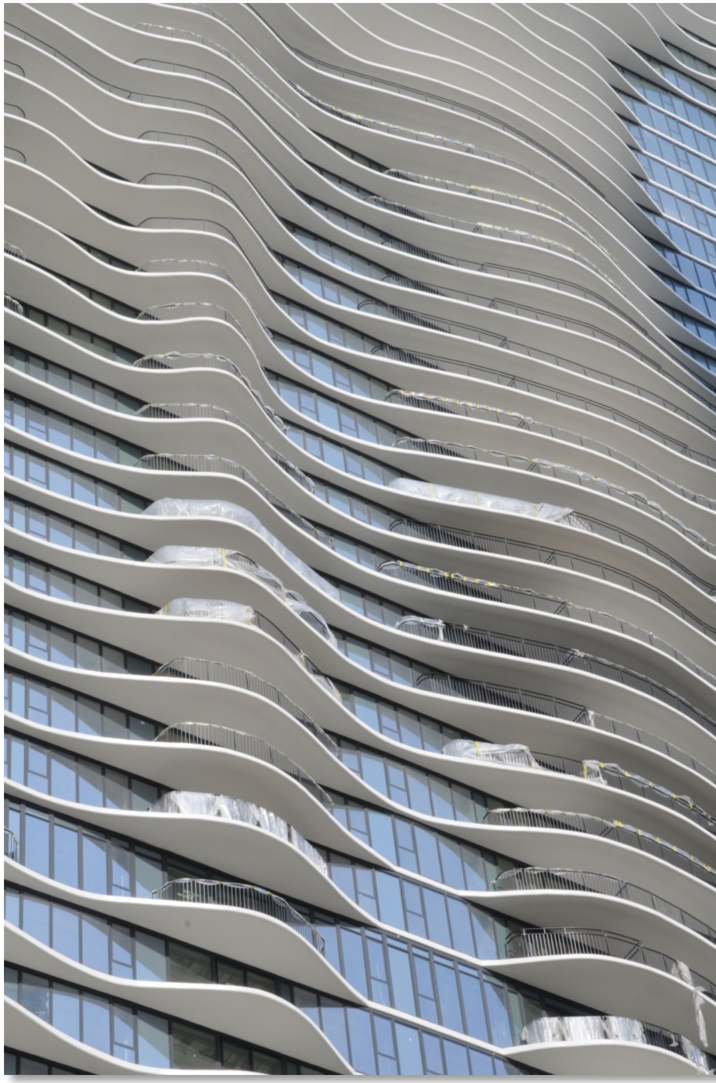


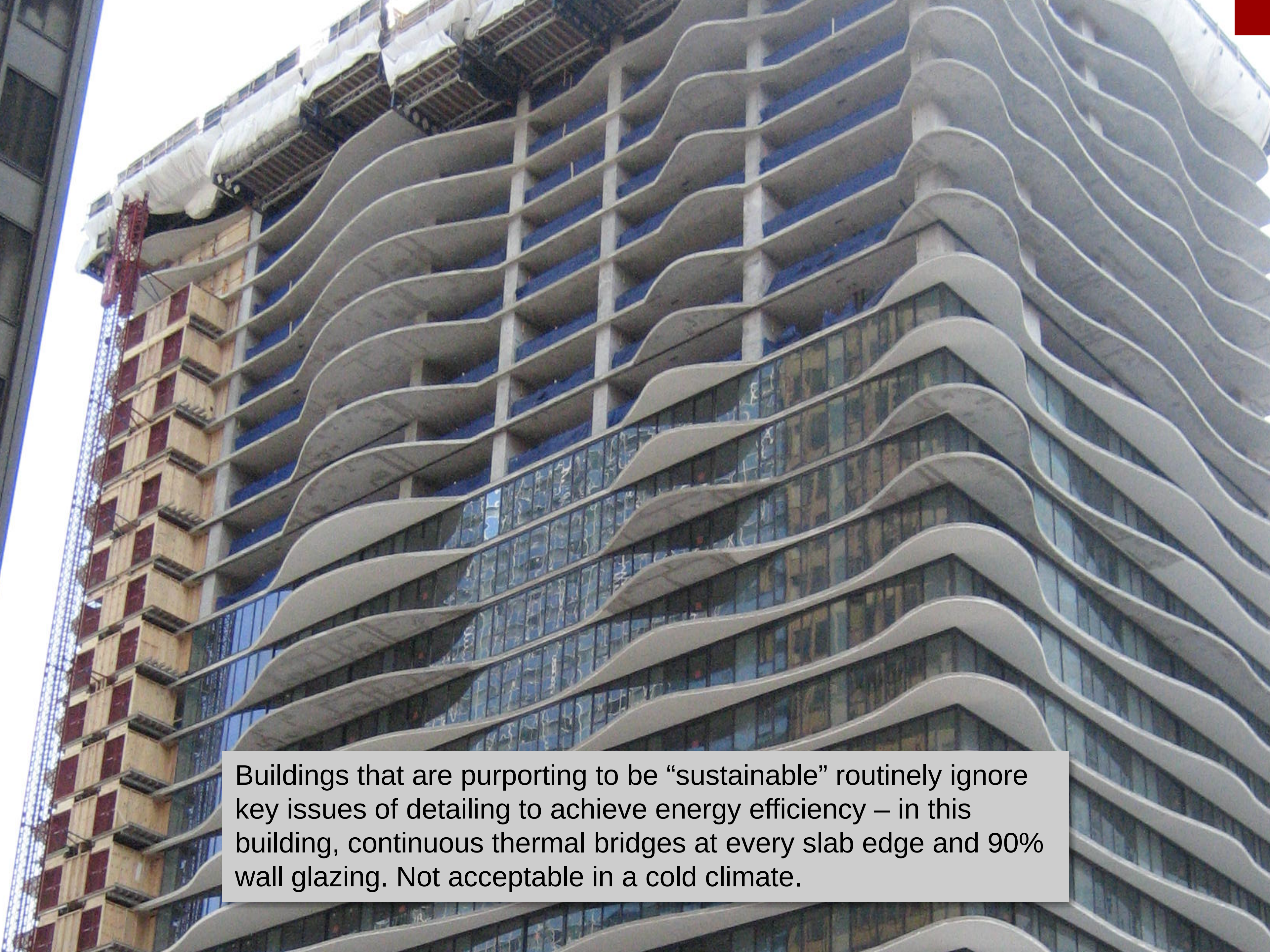
This map shows the annual sum of heating degree days (an indicator of building heating needs). Data for period 1941 to 1970.

Determine if the climate is *heating* or *cooling* dominated …this will set out your **primary strategy**.

The Controversial “Cover” of Greensource Magazine

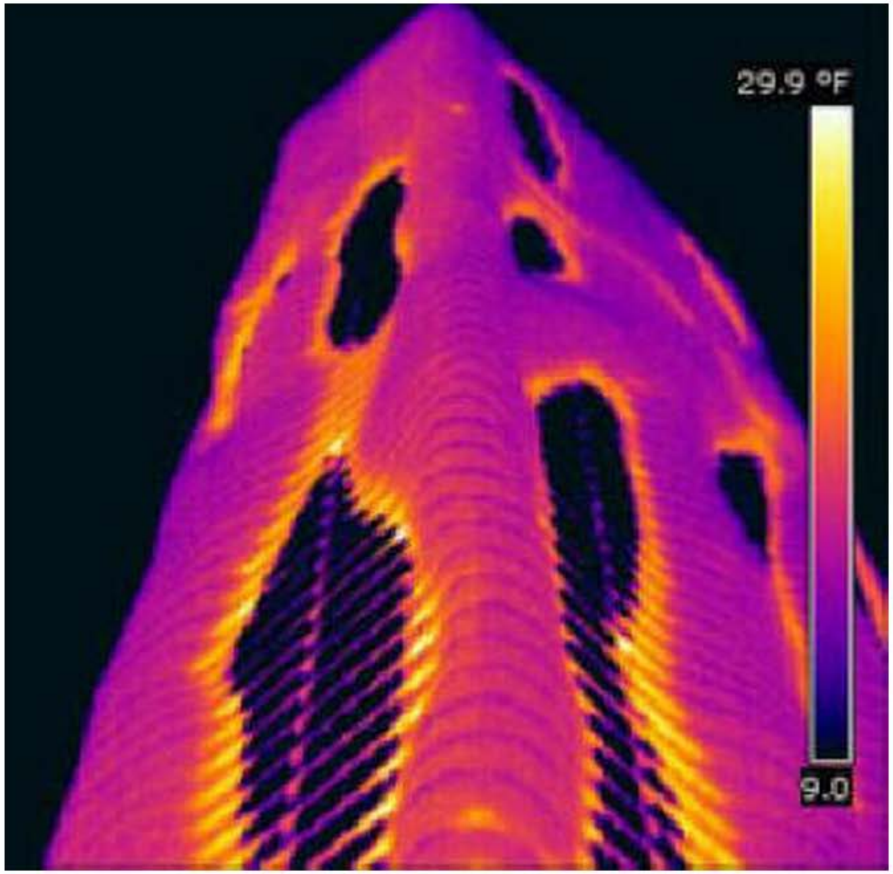
A “sustainable” Chicago residential skyscraper – going for LEED





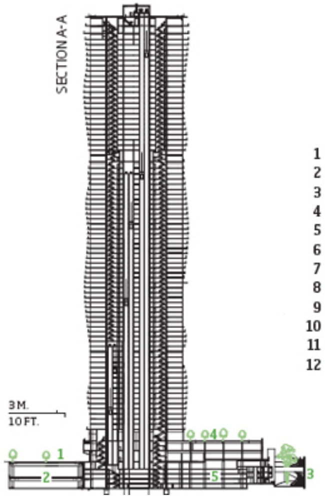
Buildings that are purporting to be “sustainable” routinely ignore key issues of detailing to achieve energy efficiency – in this building, continuous thermal bridges at every slab edge and 90% wall glazing. Not acceptable in a cold climate.

The Controversial “Cover” of Greensource Magazine



http://www.healthyheating.com/Definitions/Mean%20Radiant_pg4.htm#.VQ8iKo7F8Zs

Chicago Climate Data



1 Upper Columbus Drive
2 Lower Columbus Drive
3 Stair to Harbor Park
4 Roof garden
5 Parking
6 Living/dining room
7 Den
8 Kitchen
9 Bedroom
10 Master bedroom
11 Great room
12 Dining room

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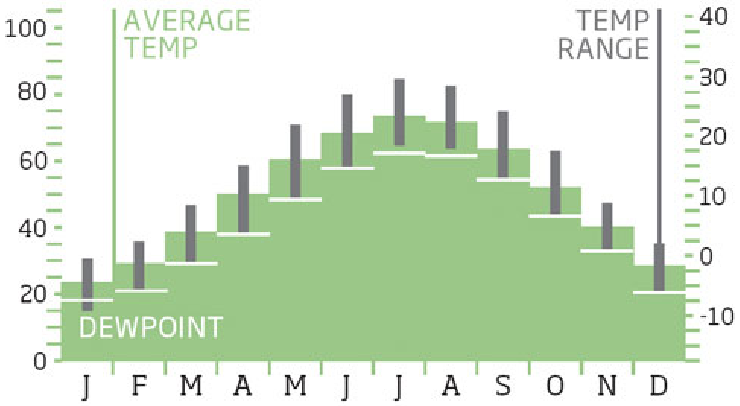
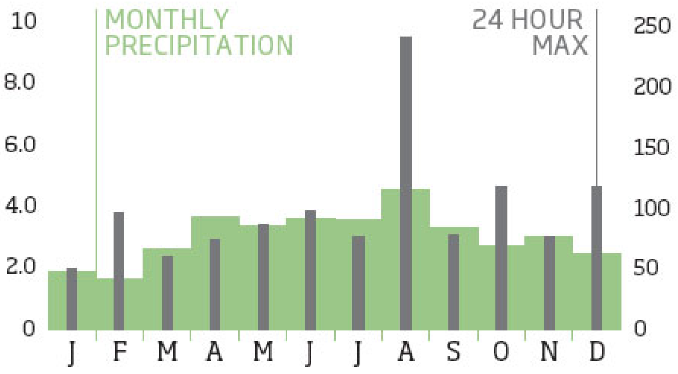
TEMPERATURES & DEW POINTS
FAHRENHEIT/CELSIUS



PRECIPITATION
INCHES/MILLIMETERS



Heading degree days 6,479 F (3,582 C)

Cooling degree days 782F (417 C)

Solving the thermal bridge

The “classic” bad balcony detail results in heat loss as well as moisture and mold problems.

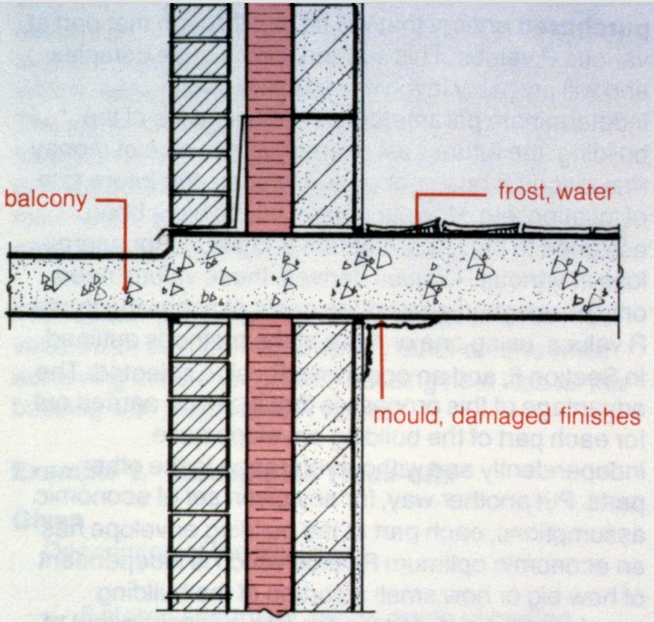
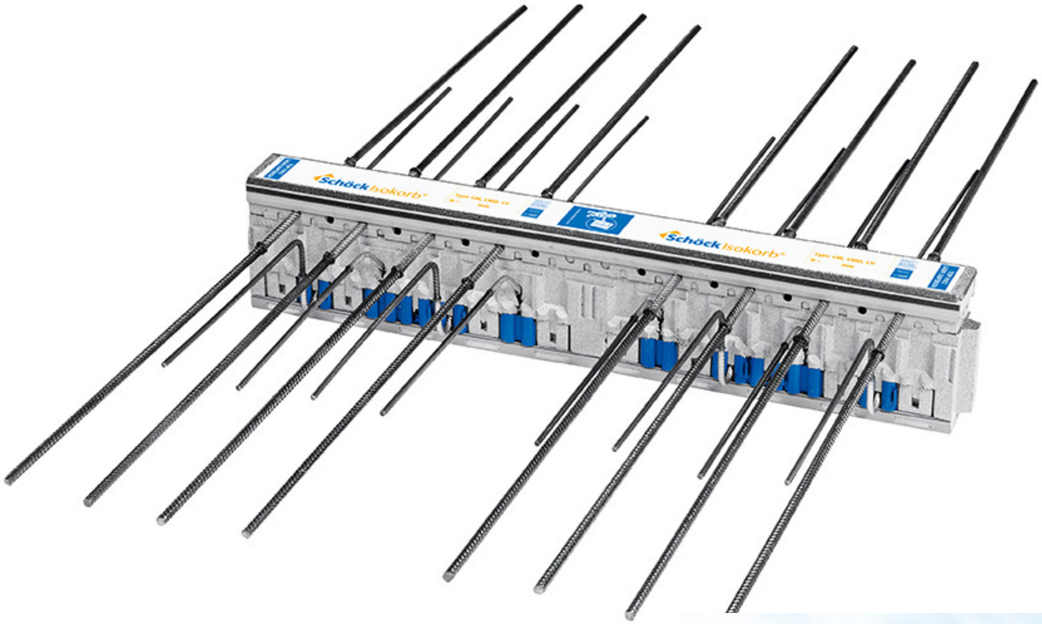


Figure 2.8A **Effect of Thermal Bridge When Indoor Relative Humidity is Appreciable (above 20% RH in midwinter)**

Off the Shelf Thermal Break Products



Can work if they are not “value engineered” out of the project.

Schock Isokorb

Climate - It all starts here…

In the built environment, meteorology is the start of all design …

Structural design / response

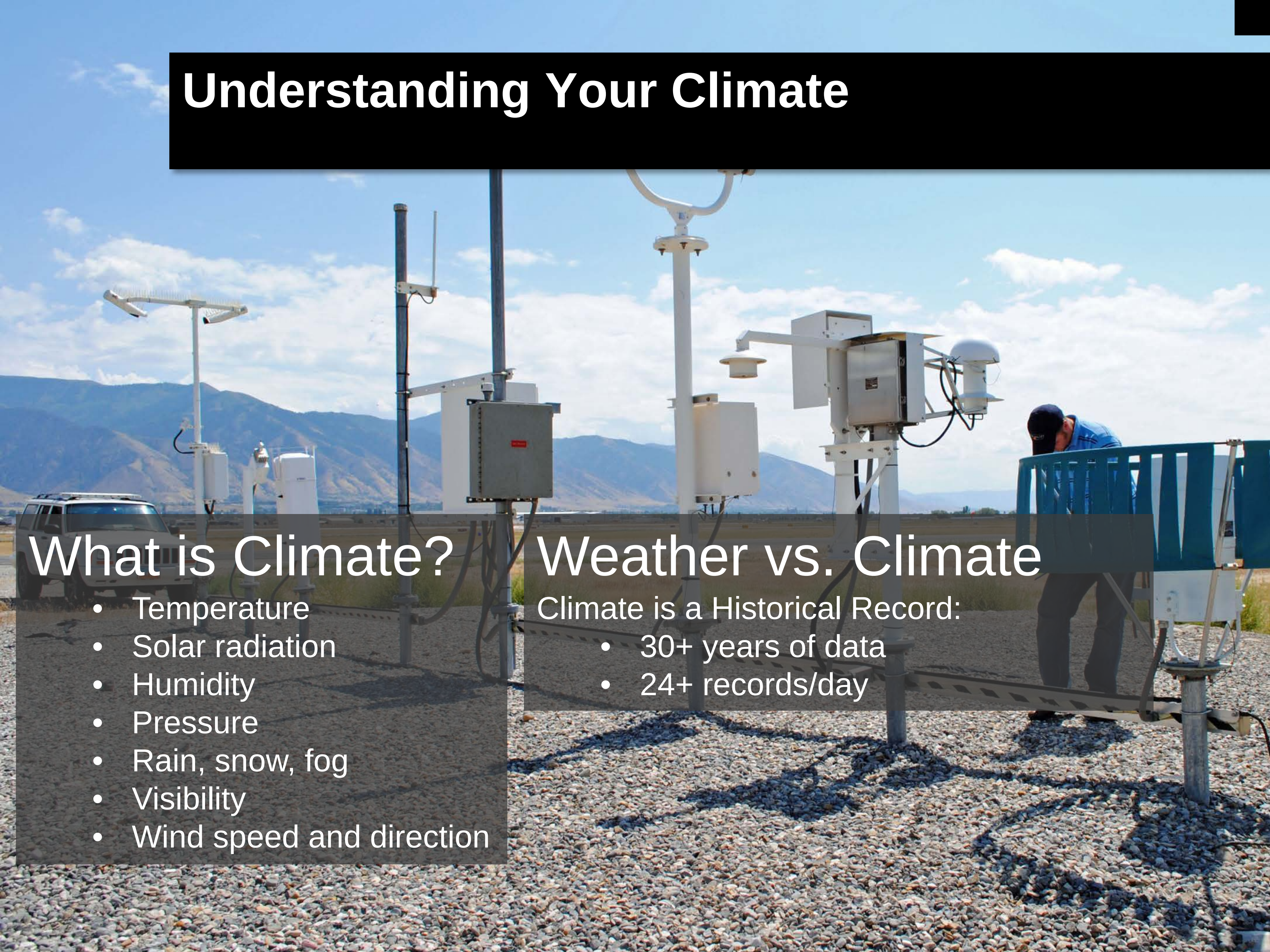
Pedestrian comfort

Air quality / plume dispersion

Energy demand / heating and cooling loads

etc.

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 Consultant

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

Climate Consultant 5 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

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?

Choose Comfort Model

California Energy Code Comfort Model (Default)

For the purpose of sizing residential heating and cooling systems the indoor Dry Bulb Design Conditions should be between 68°F (20°C) to 75°F (23.9°C).

No Humidity limits are specified in the Code, so 80% Relative Humidity and 66°F (18.9°C) Wet Bulb is used for the upper limit and 27°F (-2.8°C) Dew Point is used for the lower limit (but these can be changed on the Criteria screen).

YOU LIKELY WANT TO SWITCH AWAY FROM THIS DEFAULT IN A COLD CLIMATE.

Choose Comfort Model

ASHRAE Handbook of Comfort Fundamentals 2005

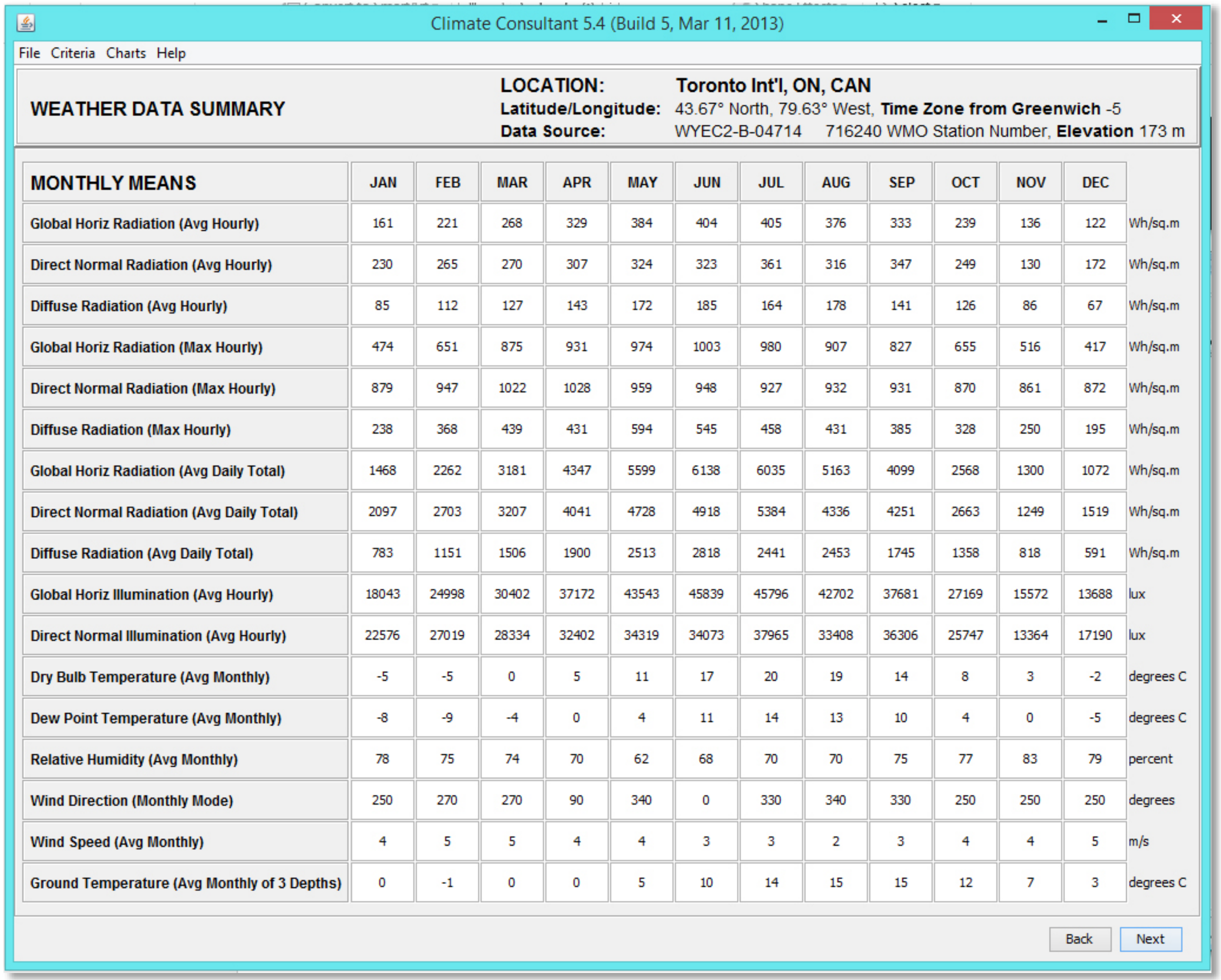
For people dressed in normal winter clothes,

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.

EPW Weather Data for 1000s of Locations

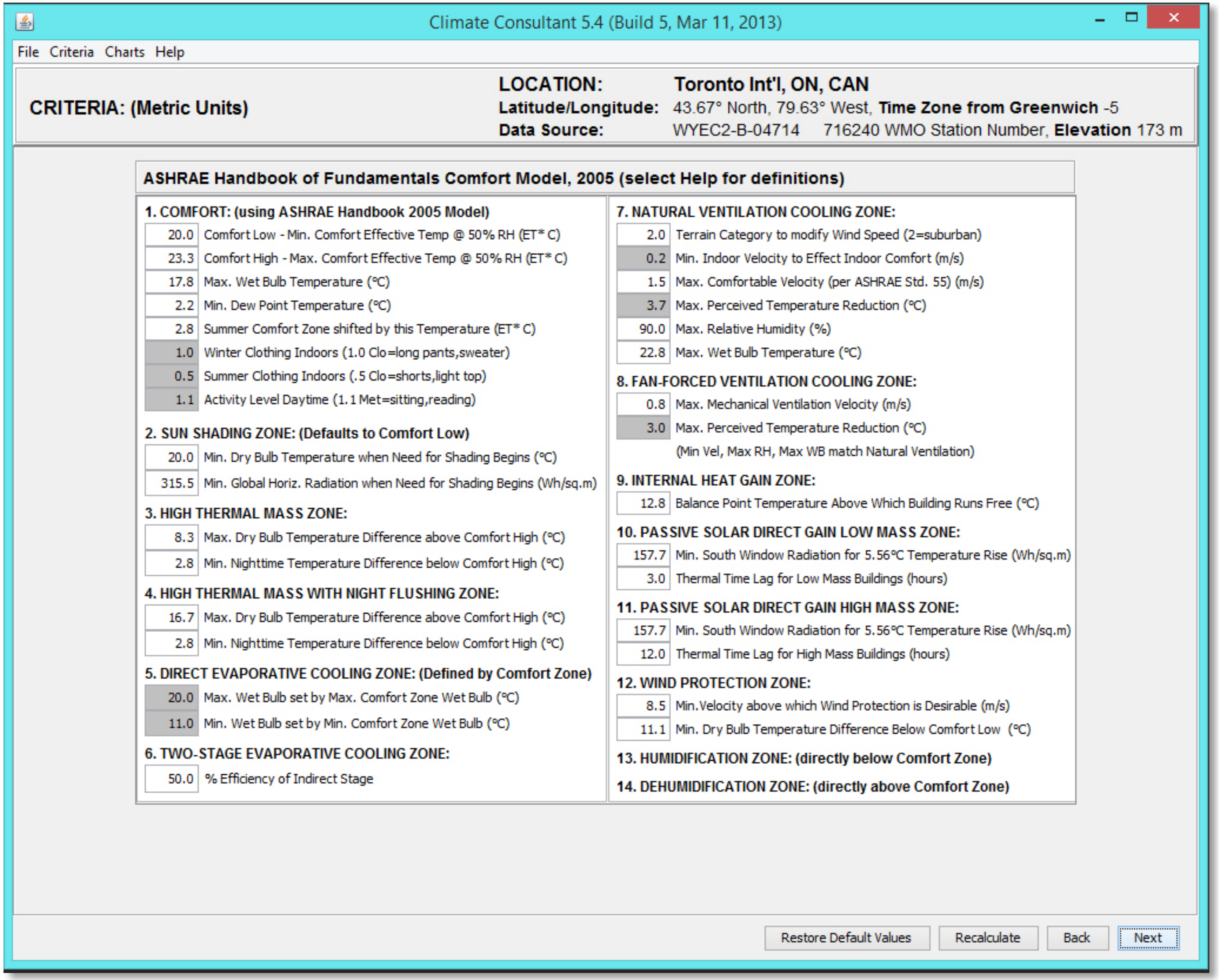


WEATHER DATA SUMMARY

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

Setting the Project Criteria



CRITERIA: (Metric Units)

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ASHRAE Handbook of Fundamentals Comfort Model, 2005 (select Help for definitions)

1. COMFORT: (using ASHRAE Handbook 2005 Model)
20.0 Comfort Low - Min. Comfort Effective Temp @ 50% RH (ET* C)
23.3 Comfort High - Max. Comfort Effective Temp @ 50% RH (ET* C)
17.8 Max. Wet Bulb Temperature (°C)
2.2 Min. Dew Point Temperature (°C)
2.8 Summer Comfort Zone shifted by this Temperature (ET* C)
1.0 Winter Clothing Indoors (1.0 Clo=long pants,sweater)
0.5 Summer Clothing Indoors (.5 Clo=shorts,light top)
1.1 Activity Level Daytime (1.1 Met=sitting,reading)

2. SUN SHADING ZONE: (Defaults to Comfort Low)
20.0 Min. Dry Bulb Temperature when Need for Shading Begins (°C)
315.5 Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)

3. HIGH THERMAL MASS ZONE:
8.3 Max. Dry Bulb Temperature Difference above Comfort High (°C)
2.8 Min. Nighttime Temperature Difference below Comfort High (°C)

4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:
16.7 Max. Dry Bulb Temperature Difference above Comfort High (°C)
2.8 Min. Nighttime Temperature Difference below Comfort High (°C)

5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)
20.0 Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (°C)
11.0 Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (°C)

6. TWO-STAGE EVAPORATIVE COOLING ZONE:
50.0 % Efficiency of Indirect Stage

7. NATURAL VENTILATION COOLING ZONE:
2.0 Terrain Category to modify Wind Speed (2=suburban)
0.2 Min. Indoor Velocity to Effect Indoor Comfort (m/s)
1.5 Max. Comfortable Velocity (per ASHRAE Std. 55) (m/s)
3.7 Max. Perceived Temperature Reduction (°C)
90.0 Max. Relative Humidity (%)
22.8 Max. Wet Bulb Temperature (°C)

8. FAN-FORCED VENTILATION COOLING ZONE:
0.8 Max. Mechanical Ventilation Velocity (m/s)
3.0 Max. Perceived Temperature Reduction (°C)
(Min Vel, Max RH, Max WB match Natural Ventilation)

9. INTERNAL HEAT GAIN ZONE:
12.8 Balance Point Temperature Above Which Building Runs Free (°C)

10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:
157.7 Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
3.0 Thermal Time Lag for Low Mass Buildings (hours)

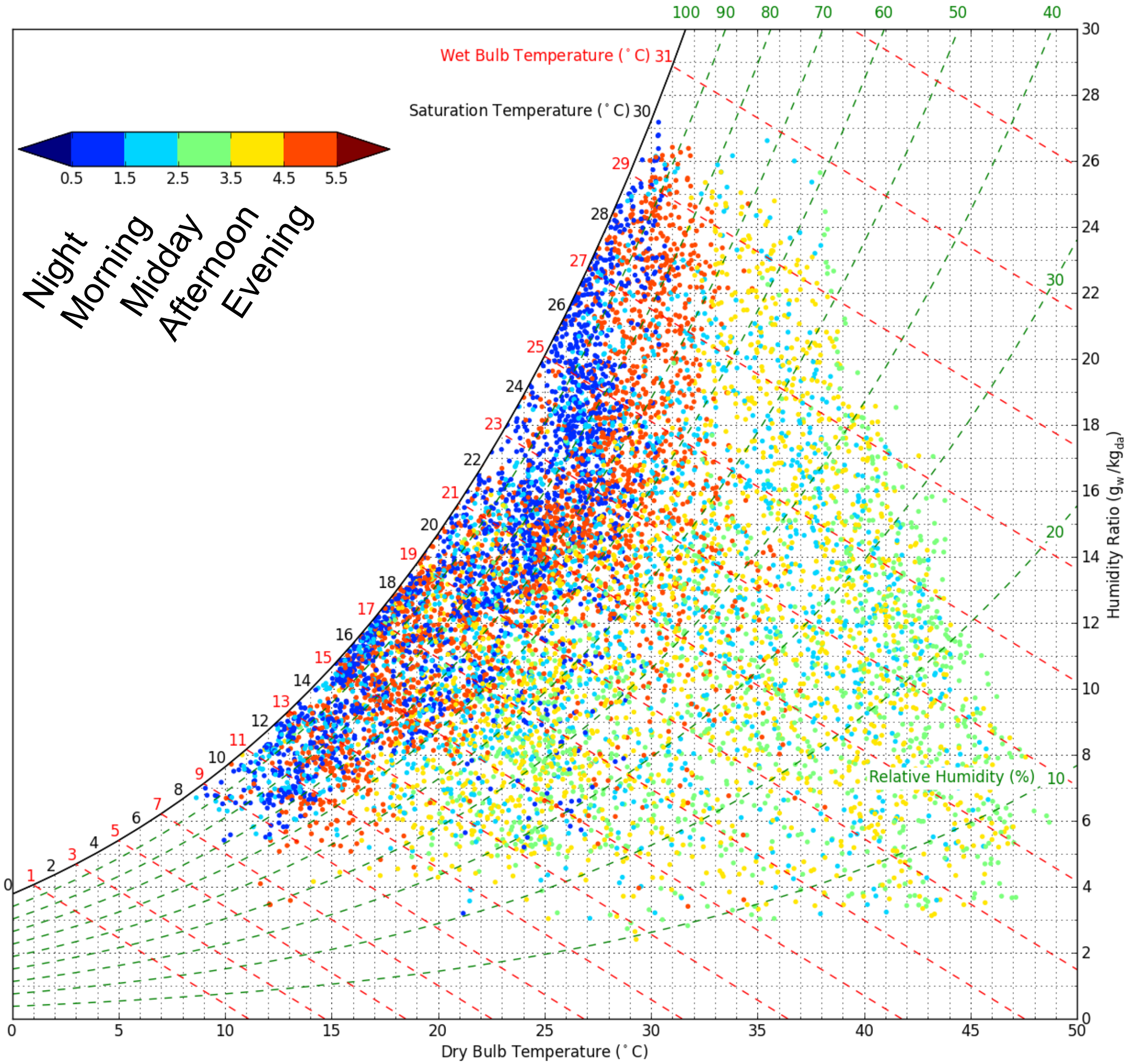
11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:
157.7 Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
12.0 Thermal Time Lag for High Mass Buildings (hours)

12. WIND PROTECTION ZONE:
8.5 Min.Velocity above which Wind Protection is Desirable (m/s)
11.1 Min. Dry Bulb Temperature Difference Below Comfort Low (°C)

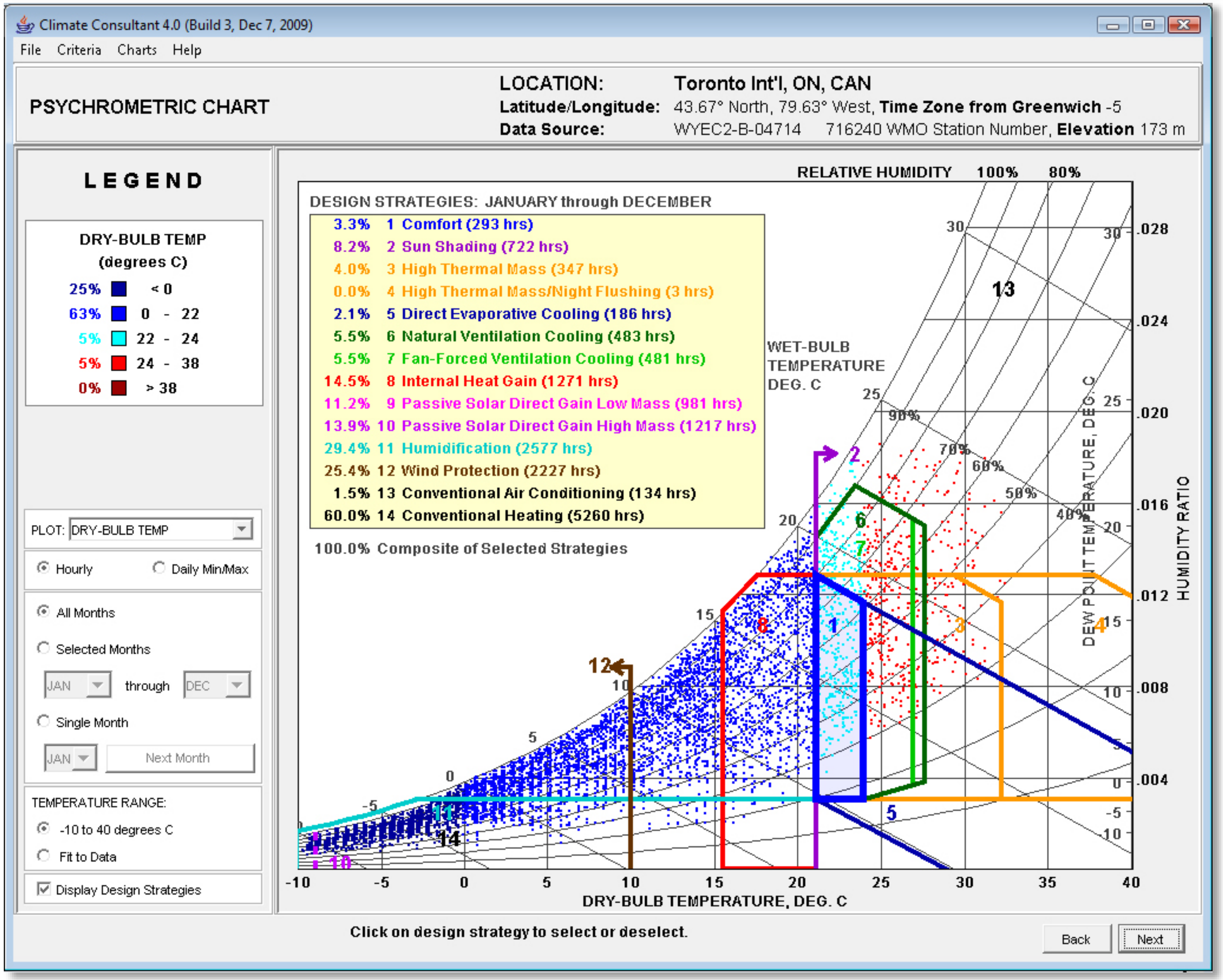
13. HUMIDIFICATION ZONE: (directly below Comfort Zone)

14. DEHUMIDIFICATION ZONE: (directly above Comfort Zone)

The Psychrometric Chart



Psychrometric Chart



PSYCHROMETRIC CHART

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LEGEND

DRY-BULB TEMP (degrees C)

25%	■	< 0
63%	■	0 - 22
5%	■	22 - 24
5%	■	24 - 38
0%	■	> 38

PLOT: DRY-BULB TEMP

● Hourly ○ Daily Min/Max

● All Months

○ Selected Months

JAN through DEC

○ Single Month

JAN Next Month

TEMPERATURE RANGE:

● -10 to 40 degrees C

○ Fit to Data

☑ Display Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

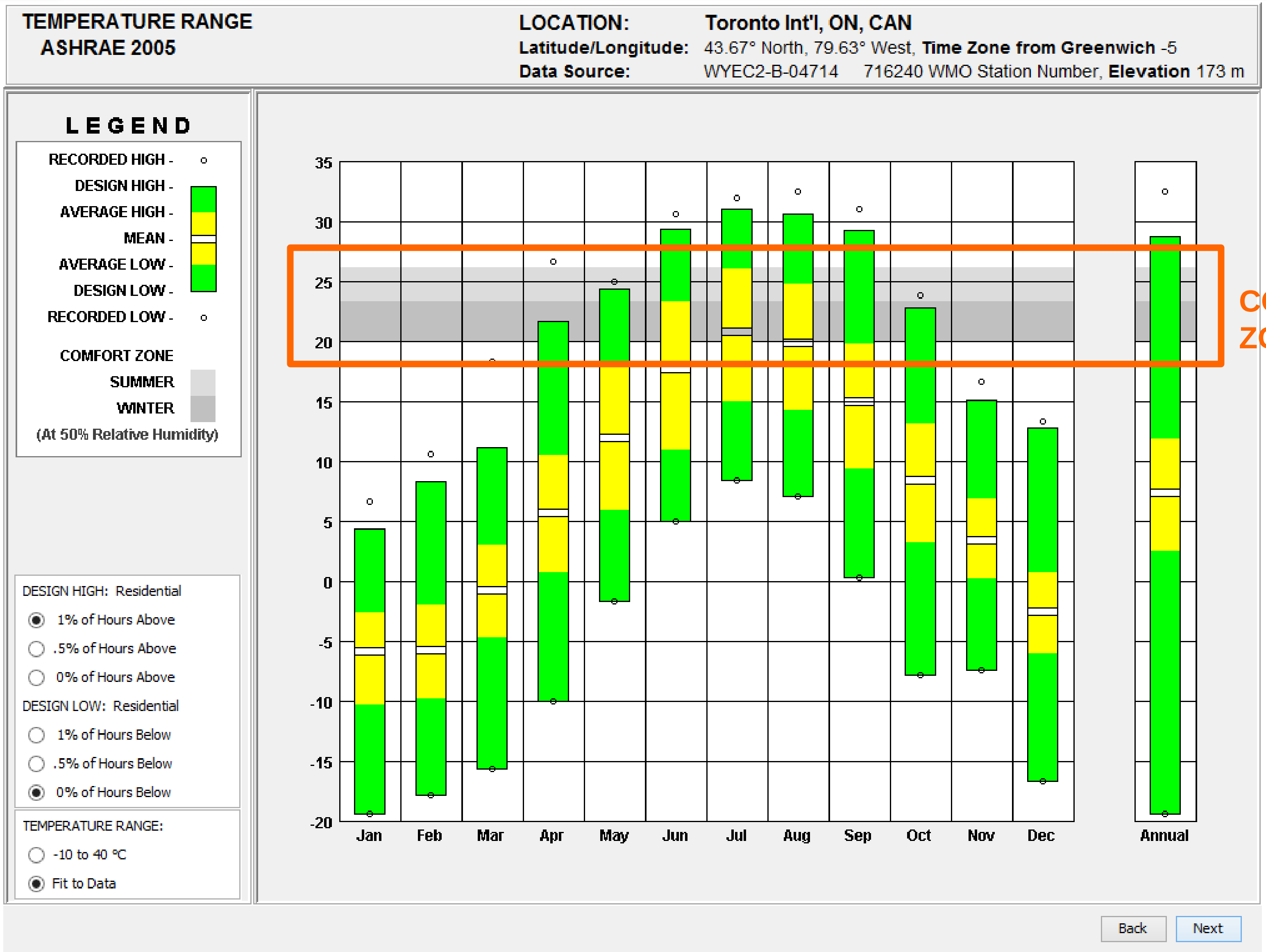
3.3%	1	Comfort (293 hrs)
8.2%	2	Sun Shading (722 hrs)
4.0%	3	High Thermal Mass (347 hrs)
0.0%	4	High Thermal Mass/Night Flushing (3 hrs)
2.1%	5	Direct Evaporative Cooling (186 hrs)
5.5%	6	Natural Ventilation Cooling (483 hrs)
5.5%	7	Fan-Forced Ventilation Cooling (481 hrs)
14.5%	8	Internal Heat Gain (1271 hrs)
11.2%	9	Passive Solar Direct Gain Low Mass (981 hrs)
13.9%	10	Passive Solar Direct Gain High Mass (1217 hrs)
29.4%	11	Humidification (2577 hrs)
25.4%	12	Wind Protection (2227 hrs)
1.5%	13	Conventional Air Conditioning (134 hrs)
60.0%	14	Conventional Heating (5260 hrs)

100.0% Composite of Selected Strategies

Click on design strategy to select or deselect.

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

Climate Data for Toronto



TEMPERATURE RANGE
ASHRAE 2005

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LEGEND

RECORDED HIGH - ○
DESIGN HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
DESIGN LOW -
RECORDED LOW - ○

COMFORT ZONE
SUMMER
WINTER
(At 50% Relative Humidity)

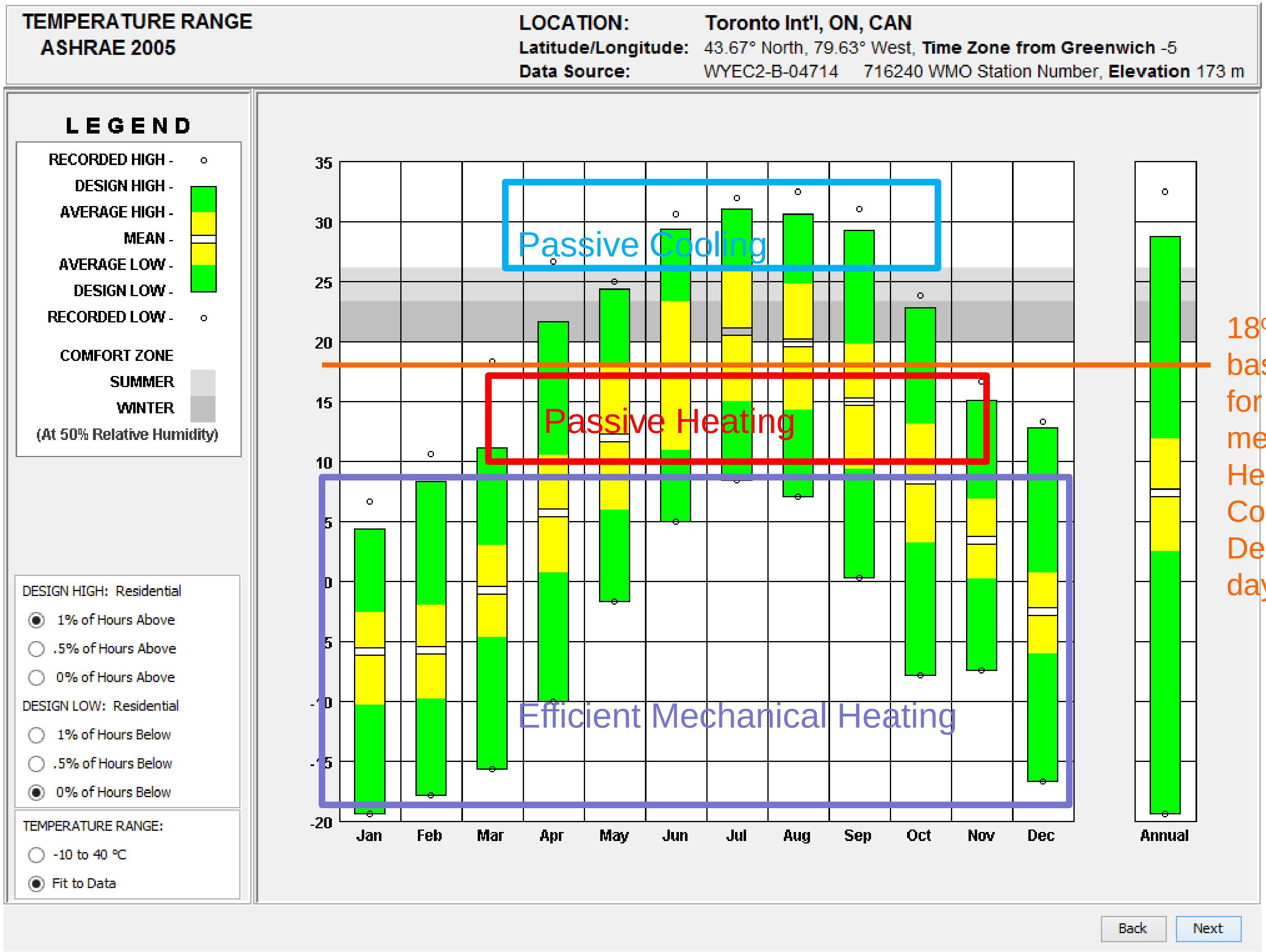
DESIGN HIGH: Residential
● 1% of Hours Above
○ .5% of Hours Above
○ 0% of Hours Above

DESIGN LOW: Residential
○ 1% of Hours Below
○ .5% of Hours Below
● 0% of Hours Below

TEMPERATURE RANGE:
○ -10 to 40 °C
● Fit to Data

COMFORT ZONE

Climate Data for Toronto



TEMPERATURE RANGE
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LEGEND

RECORDED HIGH - ○
DESIGN HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
DESIGN LOW -
RECORDED LOW - ○

COMFORT ZONE
SUMMER
WINTER
(At 50% Relative Humidity)

DESIGN HIGH: Residential
● 1% of Hours Above
○ .5% of Hours Above
○ 0% of Hours Above

DESIGN LOW: Residential
○ 1% of Hours Below
○ .5% of Hours Below
● 0% of Hours Below

TEMPERATURE RANGE:
○ -10 to 40 °C
● Fit to Data

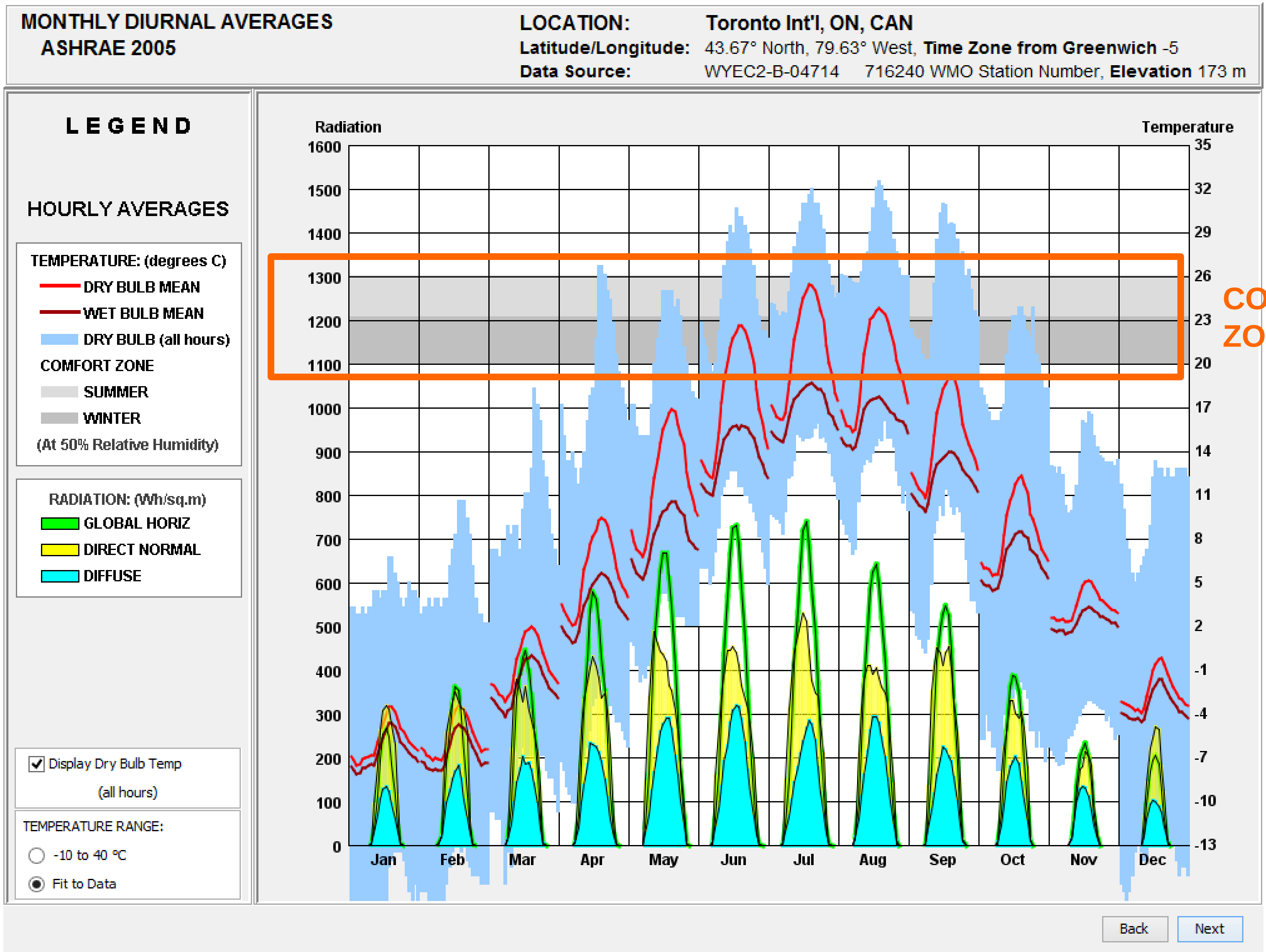
Passive Cooling

Passive Heating

Efficient Mechanical Heating

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

Climate Data for Toronto



MONTHLY DIURNAL AVERAGES
ASHRAE 2005

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

HOURLY AVERAGES

TEMPERATURE: (degrees C)
- 🟥 DRY BULB MEAN
- 🟥 WET BULB MEAN
- 🟦 DRY BULB (all hours)

COMFORT ZONE
- ▨ SUMMER
- ▨ WINTER

(At 50% Relative Humidity)

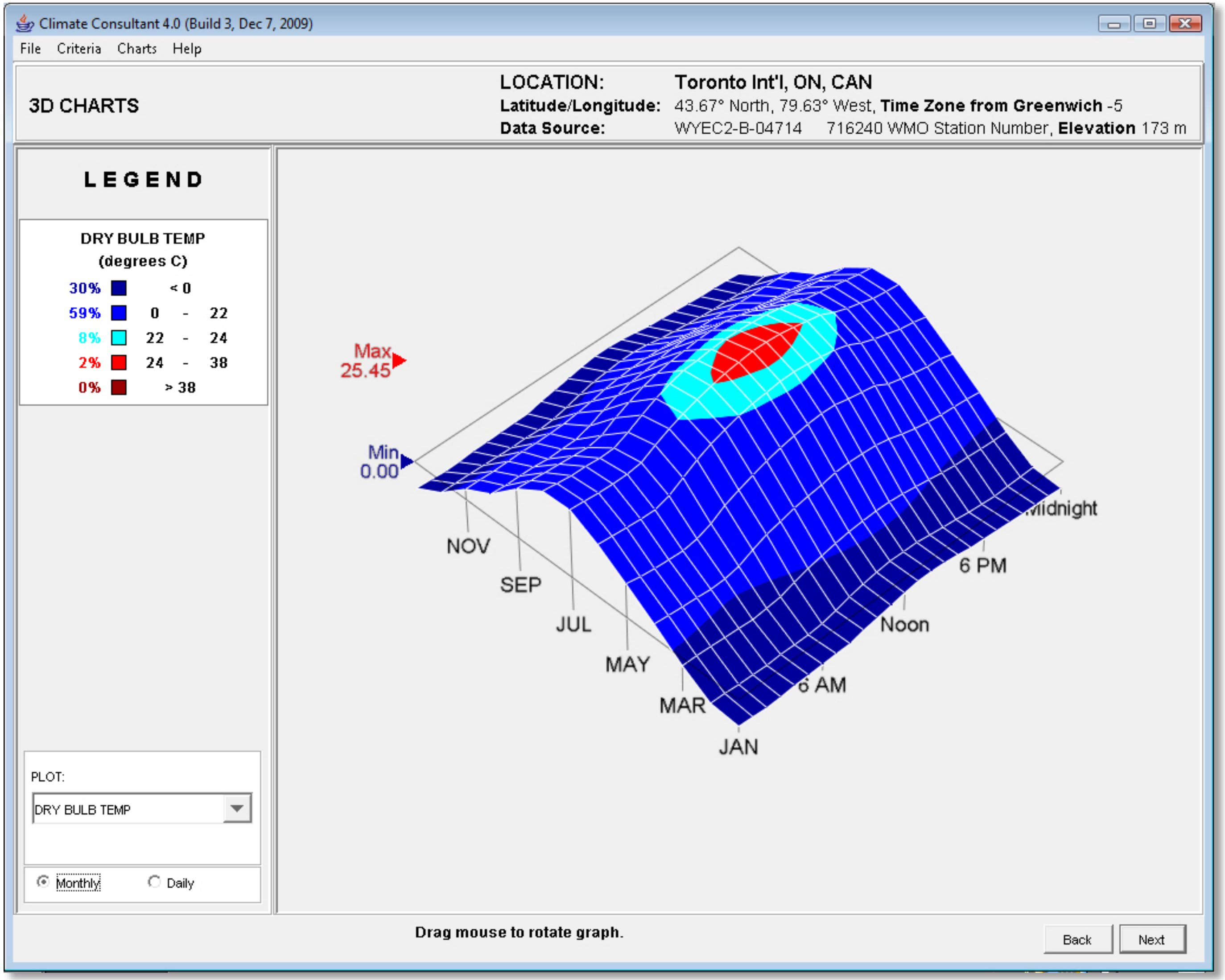
RADIATION: (Wh/sq.m)
- 🟩 GLOBAL HORIZ
- 🟨 DIRECT NORMAL
- 🟦 DIFFUSE

☑ Display Dry Bulb Temp (all hours)

TEMPERATURE RANGE:
○ -10 to 40 °C
● Fit to Data

COMFORT ZONE

Temperature Range for Toronto



Climate Consultant 4.0 (Build 3, Dec 7, 2009)

File Criteria Charts Help

3D CHARTS

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

DRY BULB TEMP
(degrees C)

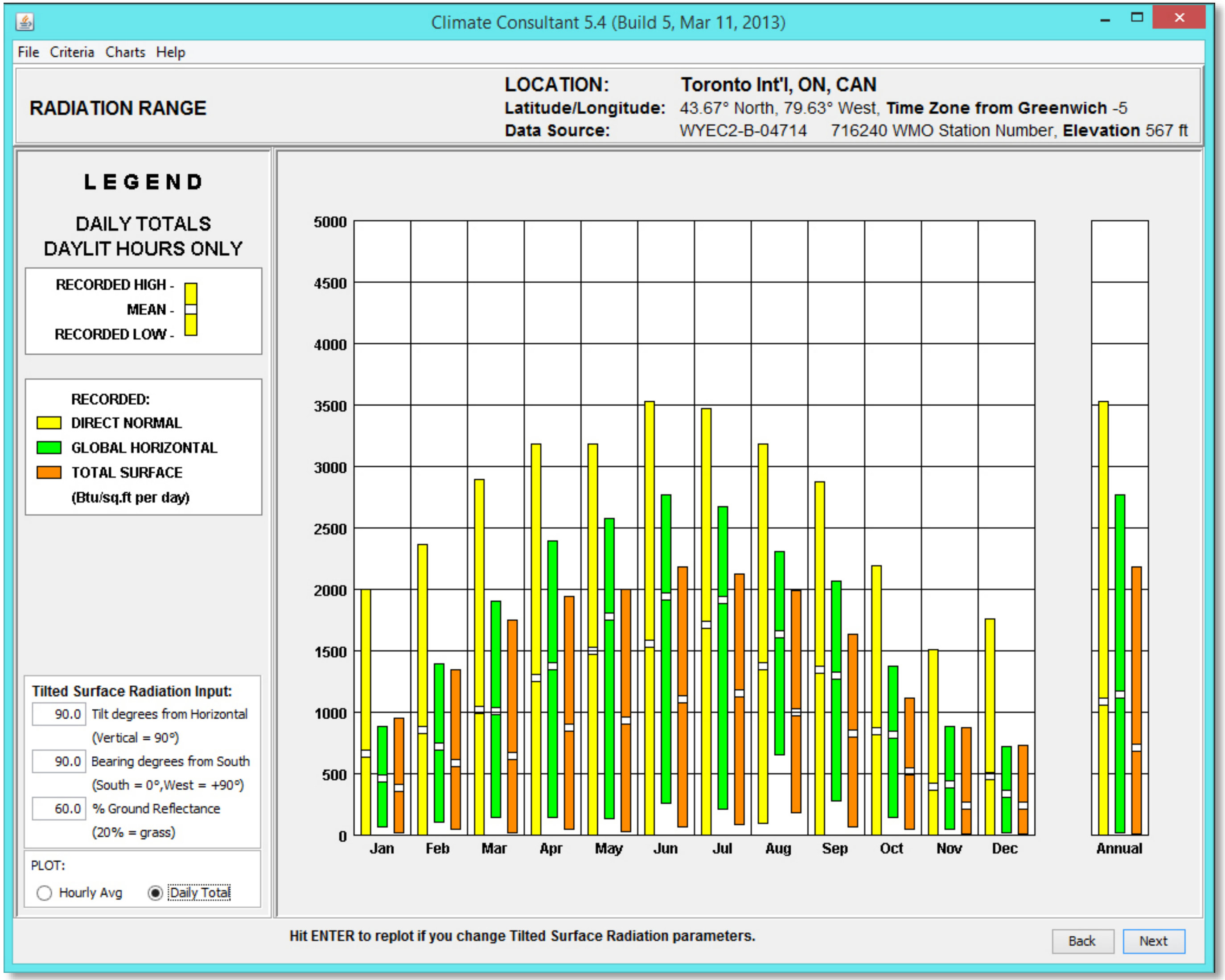
30%	🟦	< 0
59%	🟦	0 - 22
8%	🟦	22 - 24
2%	🟥	24 - 38
0%	🟥	> 38

PLOT: DRY BULB TEMP

● Monthly ○ Daily

Drag mouse to rotate graph.

Toronto Solar Radiation Range



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

File Criteria Charts Help

RADIATION 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** 567 ft

LEGEND

DAILY TOTALS
DAYLIT HOURS ONLY

RECORDED HIGH -
MEAN -
RECORDED LOW -

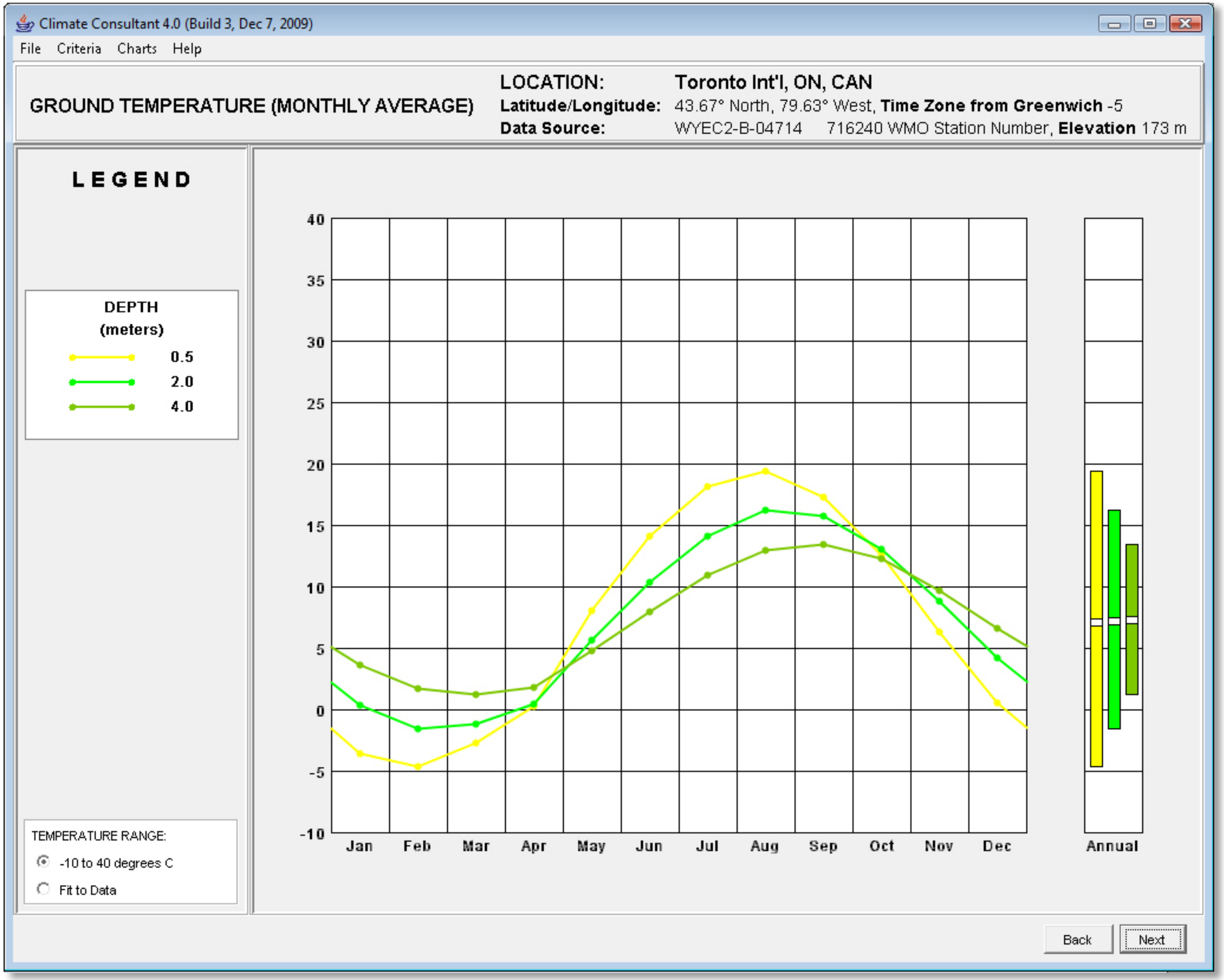
RECORDED:
🟨 DIRECT NORMAL
🟩 GLOBAL HORIZONTAL
🟧 TOTAL SURFACE
(Btu/sq.ft per day)

Tilted Surface Radiation Input:
90.0 Tilt degrees from Horizontal (Vertical = 90°)
90.0 Bearing degrees from South (South = 0°,West = +90°)
60.0 % Ground Reflectance (20% = grass)

PLOT:
○ Hourly Avg ● Daily Total

Hit ENTER to replot if you change Tilted Surface Radiation parameters.

Ground Temperature for Toronto



Climate Consultant 4.0 (Build 3, Dec 7, 2009)

GROUND TEMPERATURE (MONTHLY AVERAGE)

LOCATION: Toronto Int'l, ON, CAN

Latitude/Longitude: 43.67° North, 79.63° West, **Time Zone from Greenwich** -5

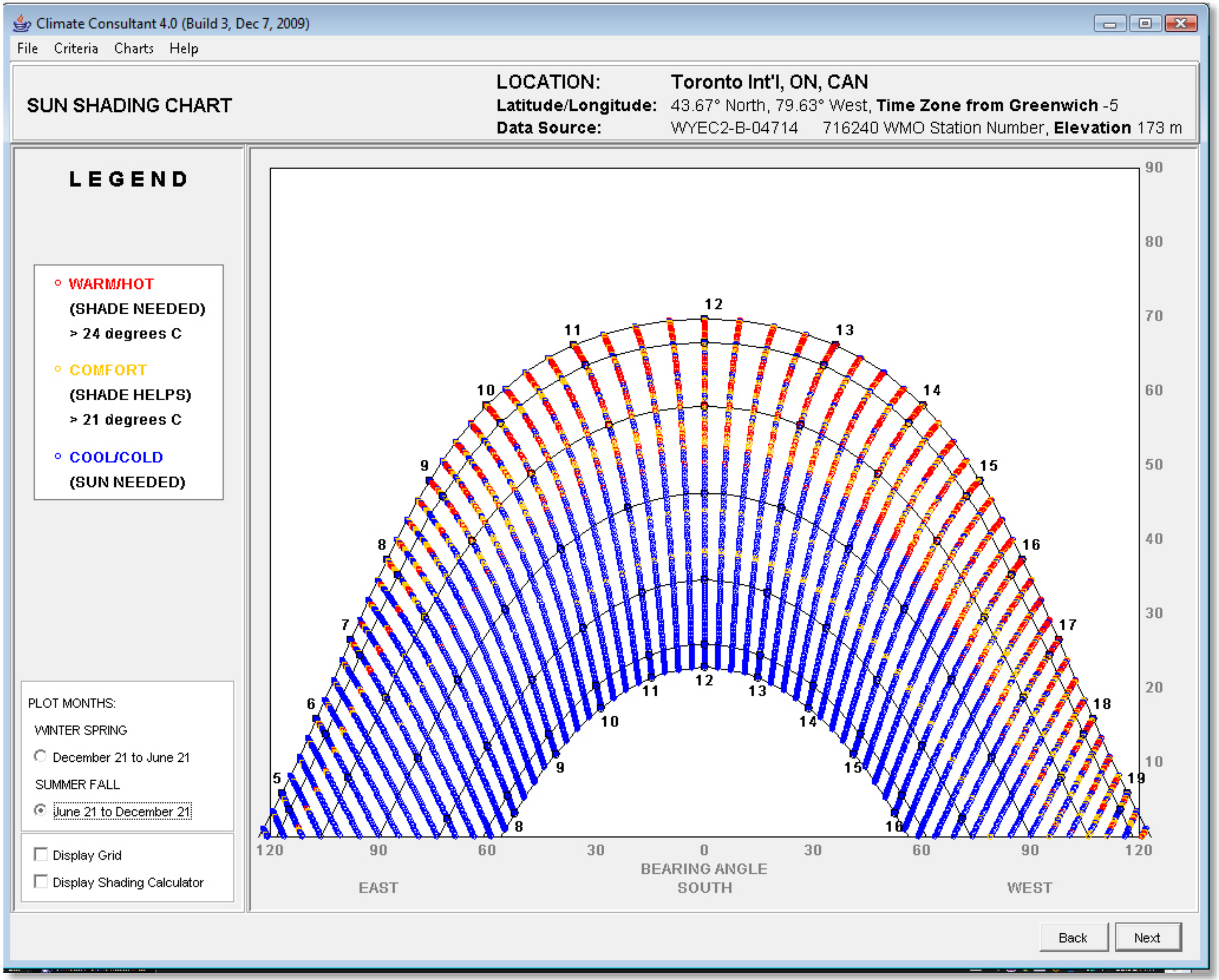
Data Source: WYEC2-B-04714 716240 WMO Station Number, **Elevation** 173 m

TEMPERATURE RANGE:

● -10 to 40 degrees C

○ Fit to Data

Sun Shading Chart



Climate Consultant 4.0 (Build 3, Dec 7, 2009)

File Criteria Charts Help

SUN SHADING CHART

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

- WARM/HOT (SHADE NEEDED) > 24 degrees C
- COMFORT (SHADE HELPS) > 21 degrees C
- COOL/COLD (SUN NEEDED)

PLOT MONTHS:

WINTER SPRING

○ December 21 to June 21

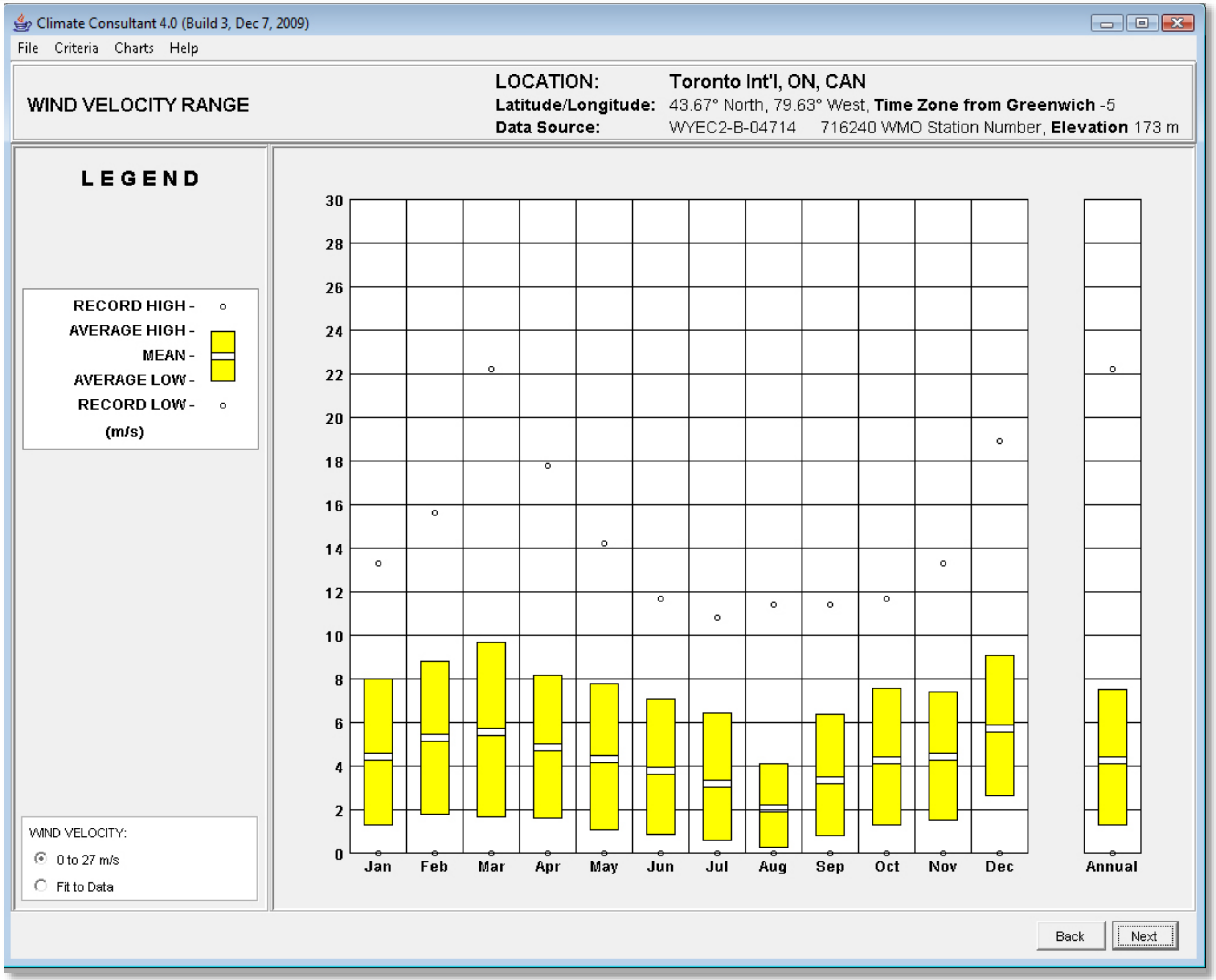
SUMMER FALL

● June 21 to December 21

☐ Display Grid

☐ Display Shading Calculator

Wind Speed

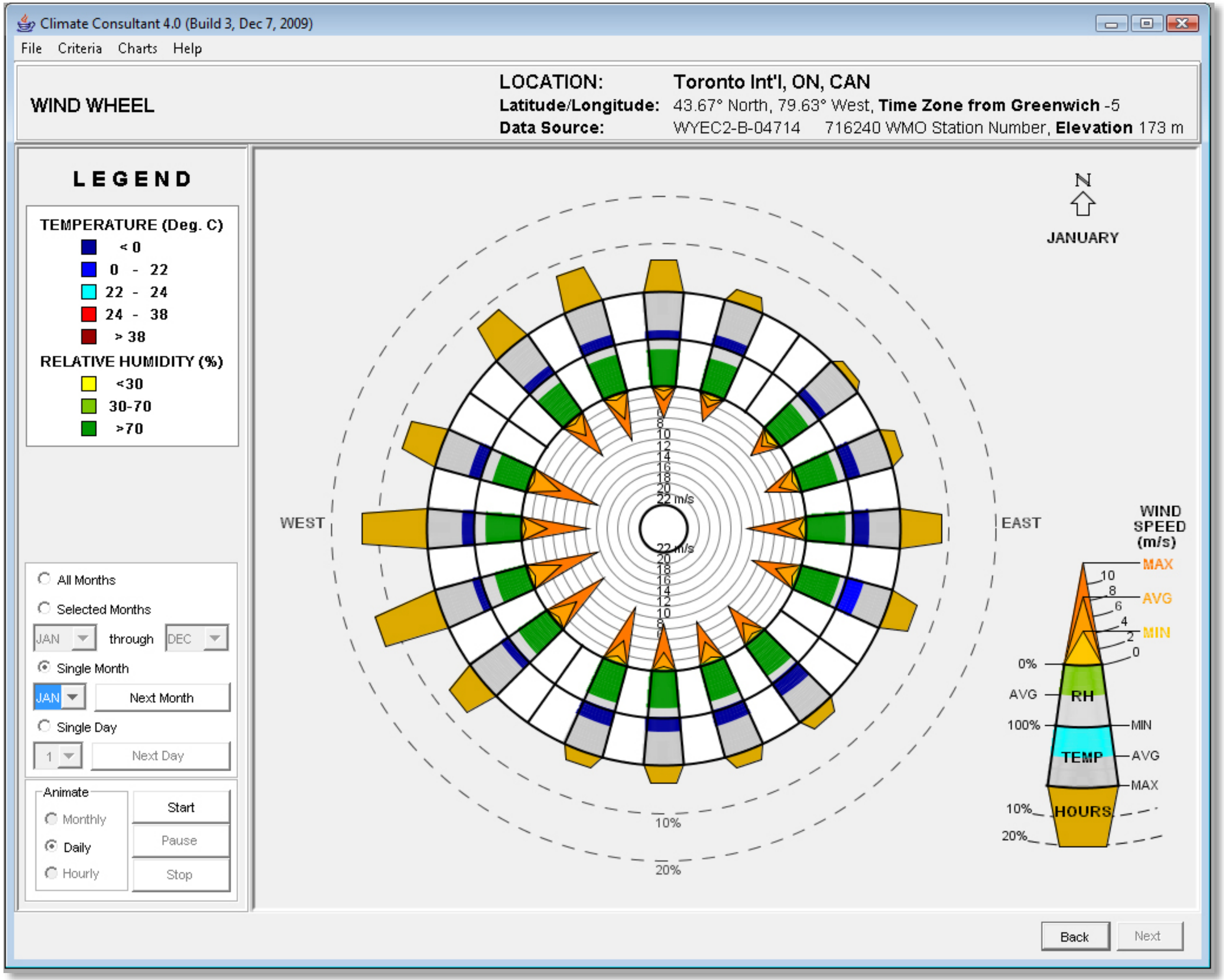


WIND VELOCITY RANGE

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

WIND VELOCITY:
● 0 to 27 m/s
○ Fit to Data

January Wind Wheel/Rose for Toronto



Climate Consultant 4.0 (Build 3, Dec 7, 2009)

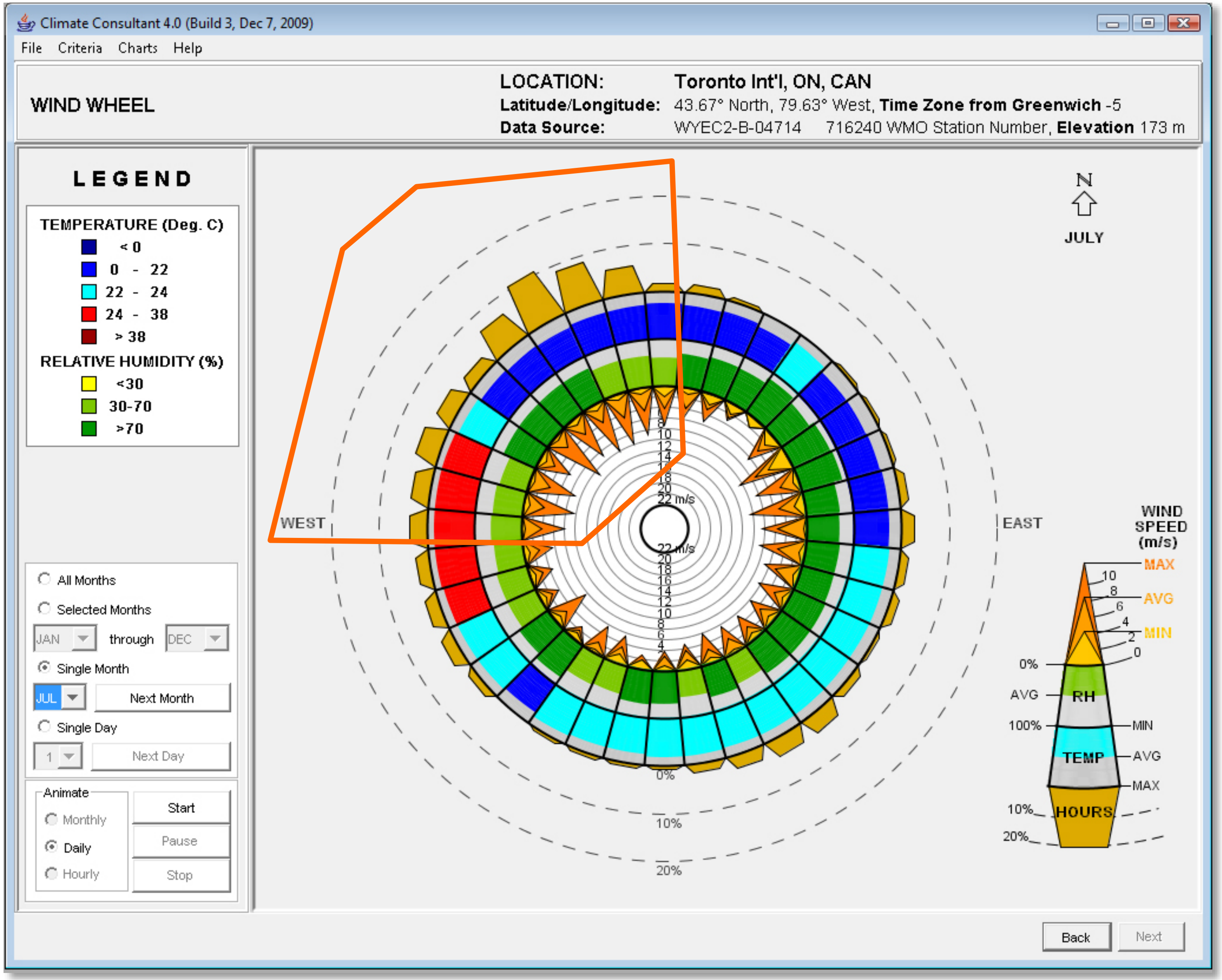
WIND WHEEL

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

● Single Month: JAN

Animate: ● Daily

July Wind Wheel/Rose for Toronto



WIND WHEEL

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

TEMPERATURE (Deg. C)

🟦	< 0
🟦	0 - 22
🟦	22 - 24
🟥	24 - 38
🟥	> 38

RELATIVE HUMIDITY (%)

🟨	<30
🟩	30-70
🟩	>70

○ All Months

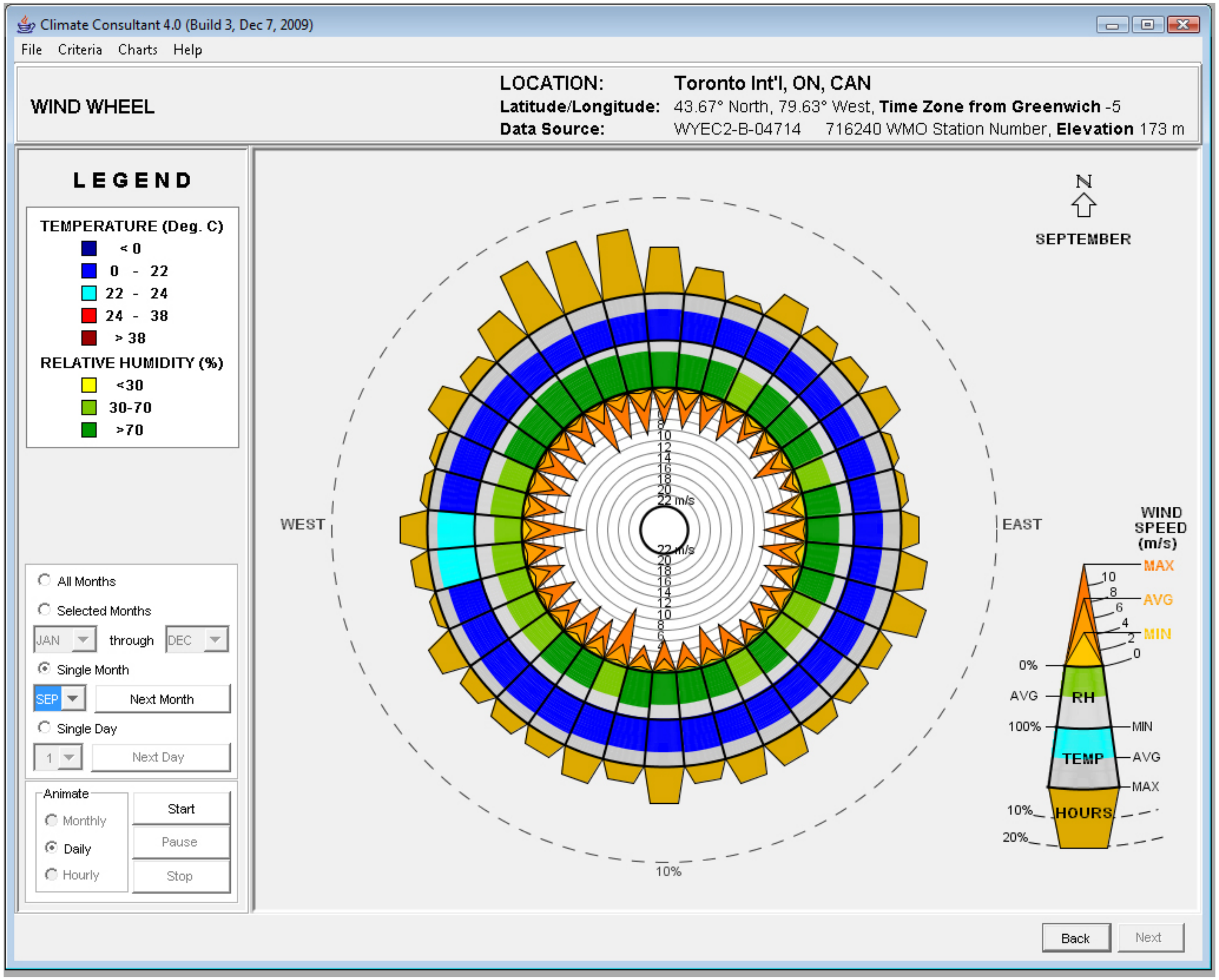
○ Selected Months JAN through DEC

● Single Month JUL

○ Single Day 1

Animate: ○ Monthly ● Daily ○ Hourly

September Wind Wheel/Rose for Toronto



Climate Consultant 4.0 (Build 3, Dec 7, 2009)

WIND WHEEL

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

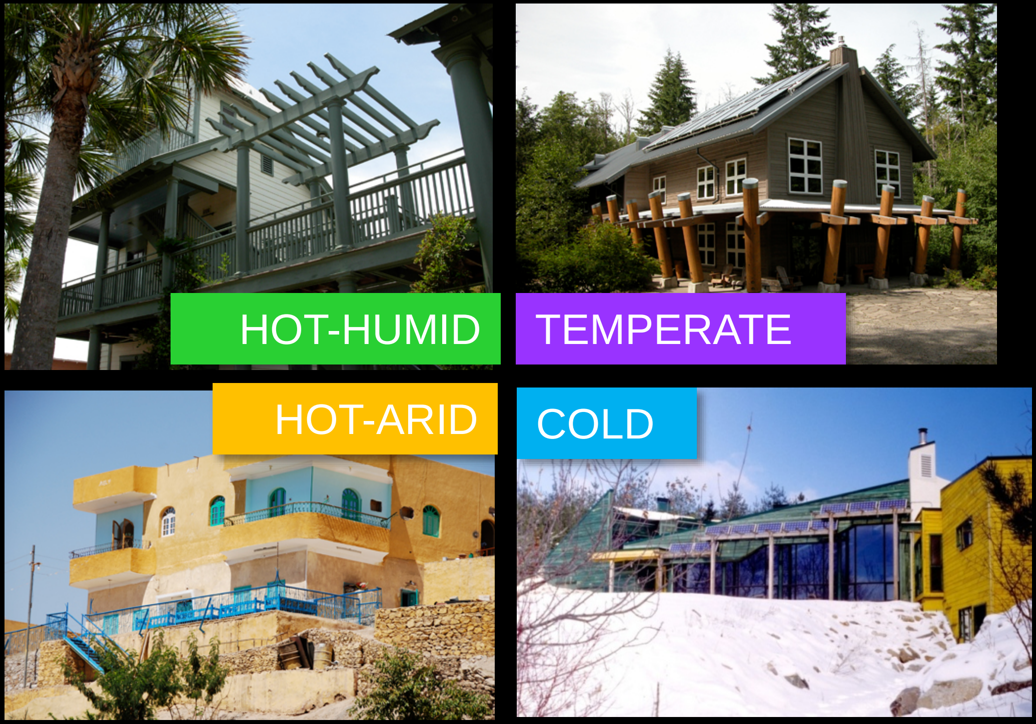
TEMPERATURE (Deg. C)
- 🟦 < 0
- 🟦 0 - 22
- 🟦 22 - 24
- 🟥 24 - 38
- 🟥 > 38

RELATIVE HUMIDITY (%)
- 🟨 <30
- 🟩 30-70
- 🟩 >70

○ All Months
○ Selected Months
JAN through DEC
● Single Month
SEP
○ Single Day
1

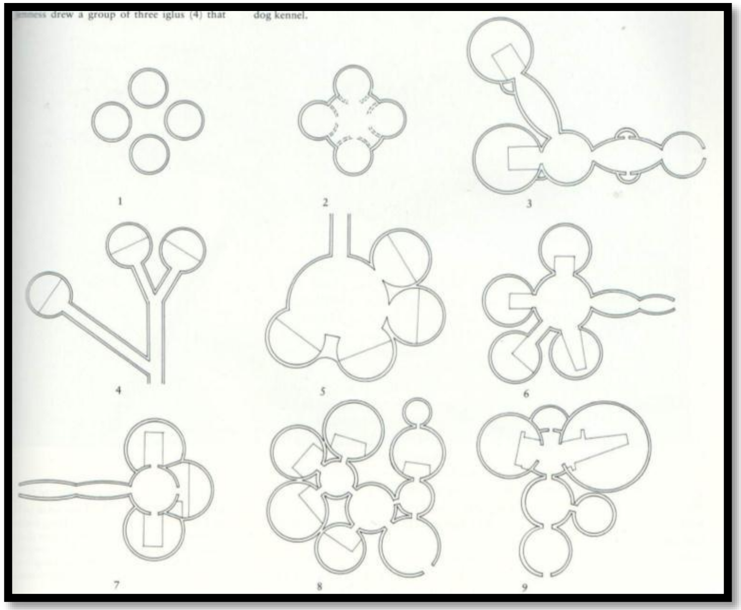
Animate
○ Monthly
● Daily
○ Hourly

VERNACULAR STRATEGIES

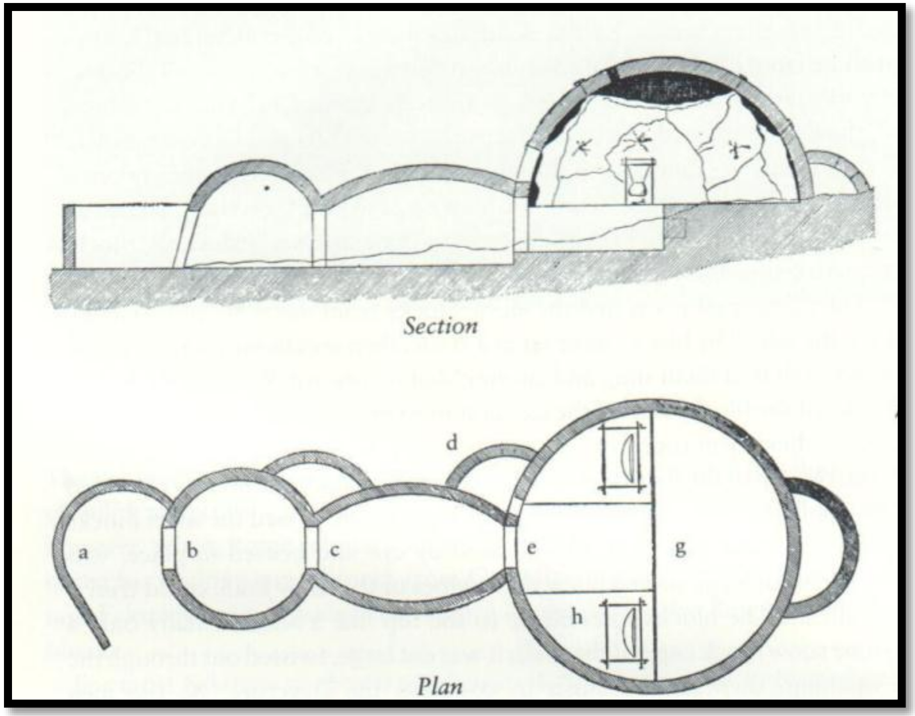


CLIMATE AS THE STARTING POINT
FOR RETHINKING ARCHITECTURAL DESIGN

Bio-climatic Design: COLD VERNACULAR



Native American Architecture



- Local materials
- Heat retention
- Vestibule
- Stratification

Bio-climatic Design: COLD RULES

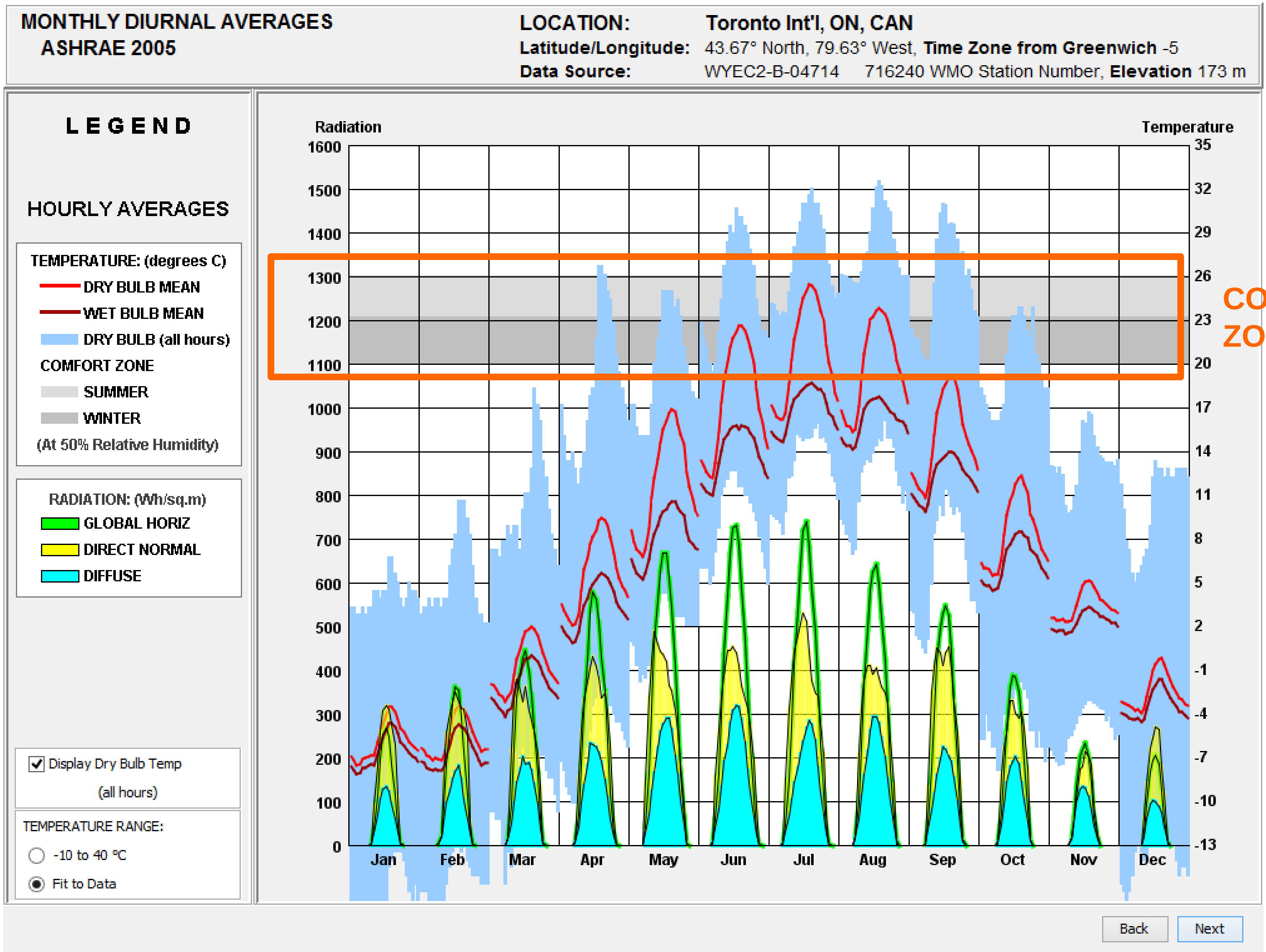
Where **winter** is the dominant season and concerns for conserving heat predominate all other concerns. **Heating degree days greatly exceed cooling degree days**.

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



MONTHLY DIURNAL AVERAGES
ASHRAE 2005

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

HOURLY AVERAGES

TEMPERATURE: (degrees C)
- 🟥 DRY BULB MEAN
- 🟥 WET BULB MEAN
- 🟦 DRY BULB (all hours)

COMFORT ZONE
- ▨ SUMMER
- ▨ WINTER

(At 50% Relative Humidity)

RADIATION: (Wh/sq.m)
- 🟩 GLOBAL HORIZ
- 🟨 DIRECT NORMAL
- 🟦 DIFFUSE

☑ Display Dry Bulb Temp (all hours)

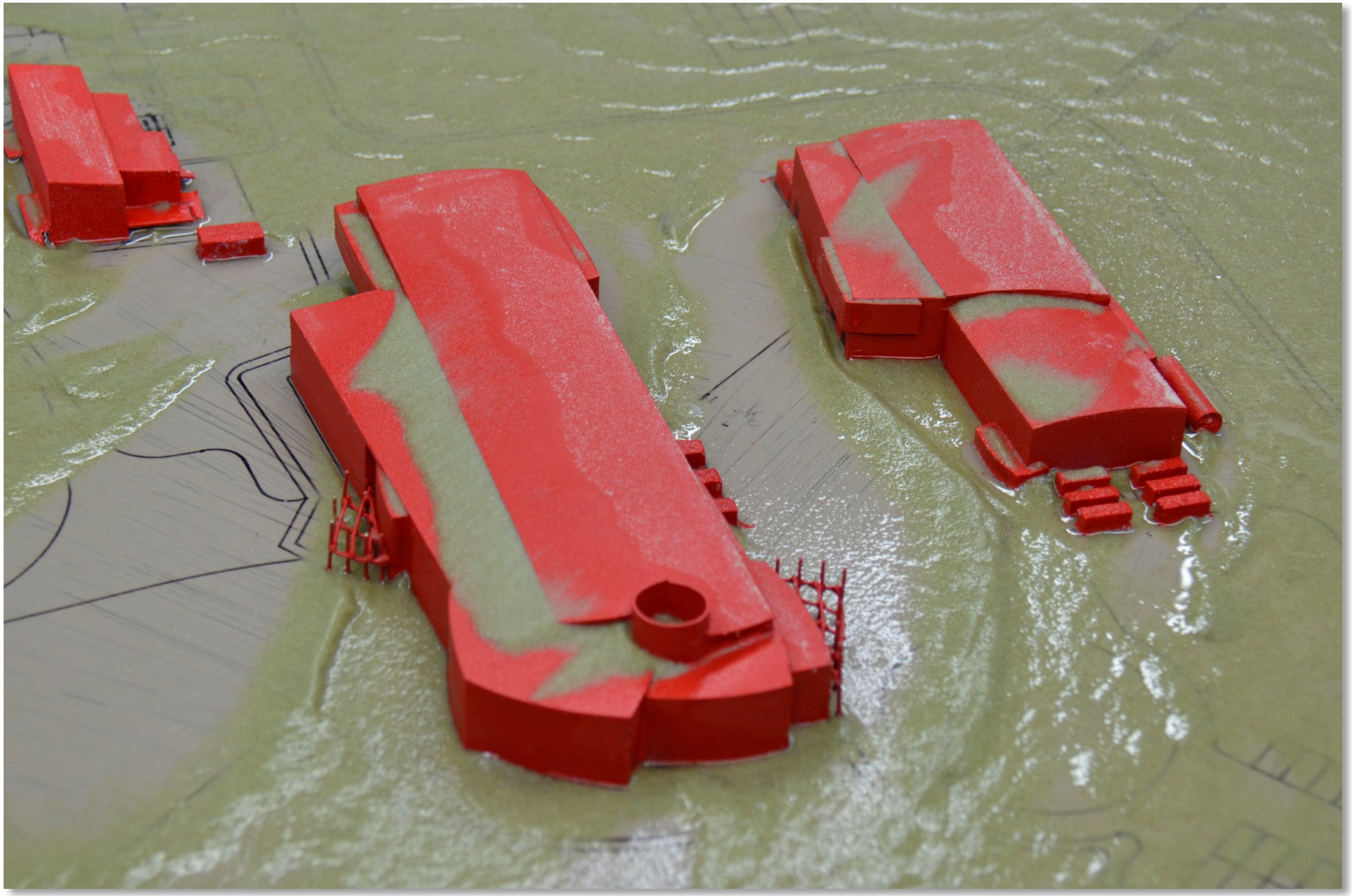
TEMPERATURE RANGE:
- ○ -10 to 40 °C
- ● Fit to Data

COMFORT ZONE

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

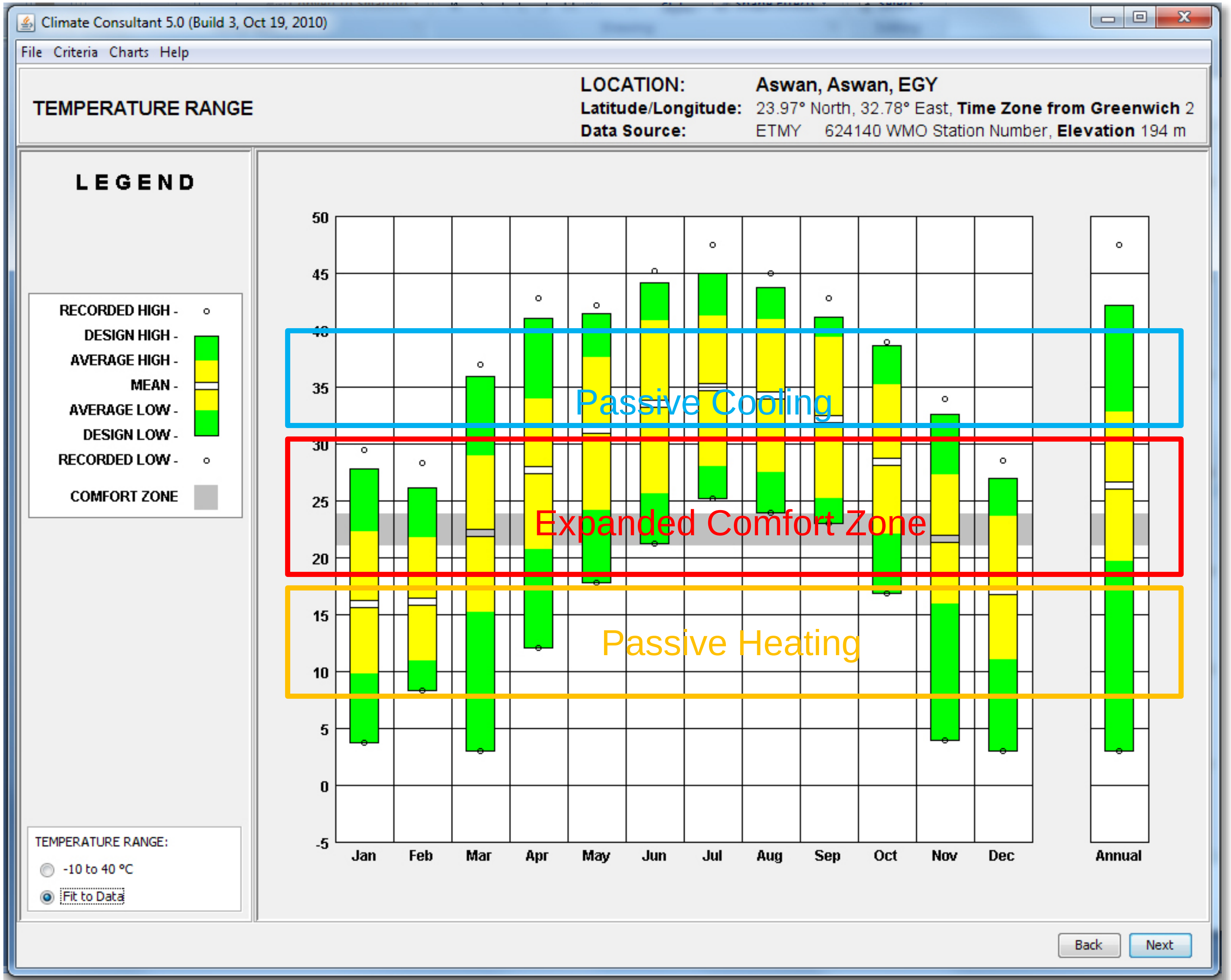
Where **very high summer temperatures** with great fluctuation predominate with **dry conditions** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

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



Climate Consultant 5.0 (Build 3, Oct 19, 2010)

File Criteria Charts Help

TEMPERATURE RANGE

LOCATION: Aswan, Aswan, EGY
Latitude/Longitude: 23.97° North, 32.78° East, **Time Zone from Greenwich** 2
Data Source: ETMY 624140 WMO Station Number, **Elevation** 194 m

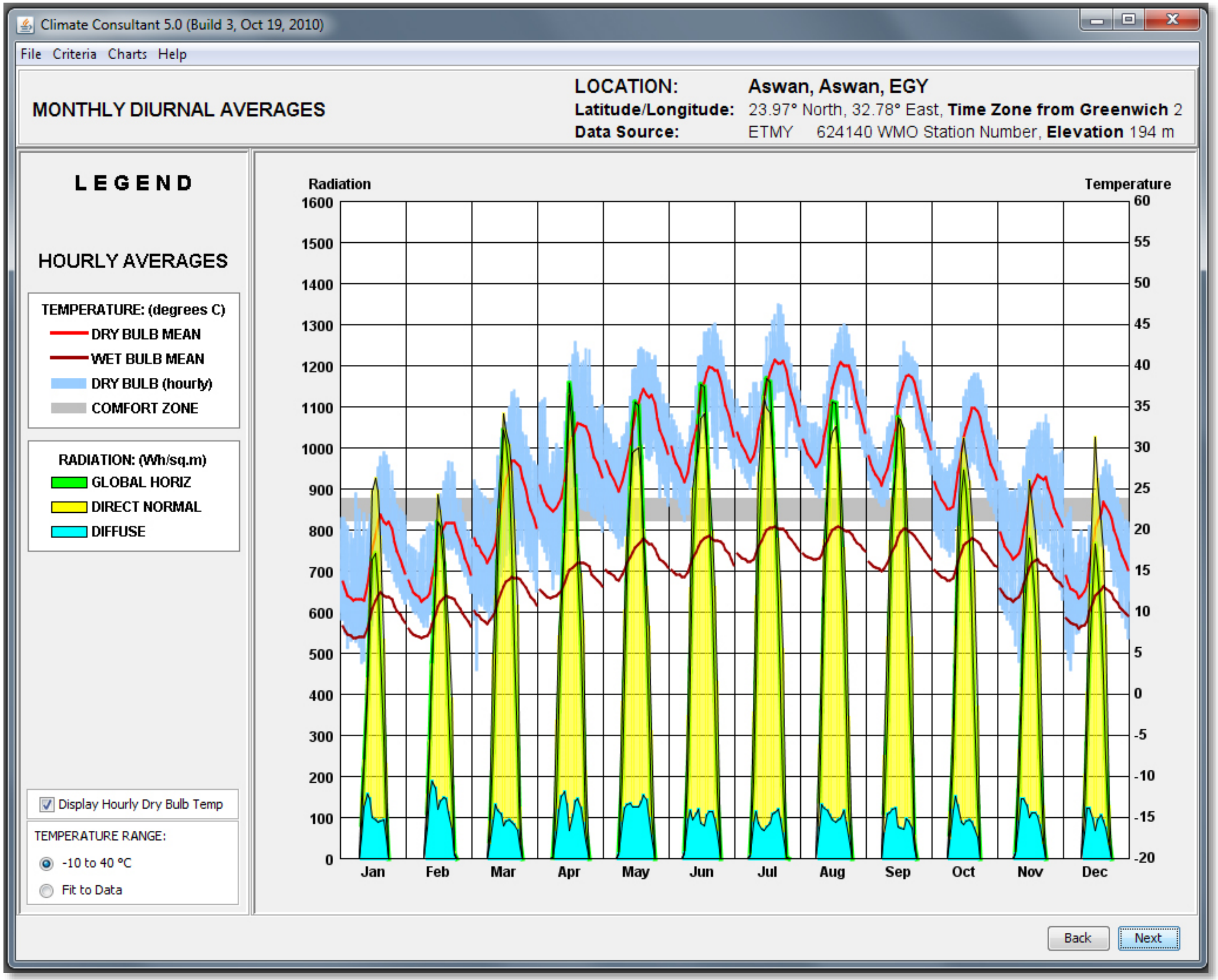
LEGEND

RECORDED HIGH -	○
DESIGN HIGH -	🟩
AVERAGE HIGH -	🟨
MEAN -	▭
AVERAGE LOW -	🟨
DESIGN LOW -	🟩
RECORDED LOW -	○
COMFORT ZONE	▨

TEMPERATURE RANGE:
○ -10 to 40 °C
● Fit to Data

Back Next

Bio-climatic Design: **HOT-ARID**



Climate Consultant 5.0 (Build 3, Oct 19, 2010)

MONTHLY DIURNAL AVERAGES

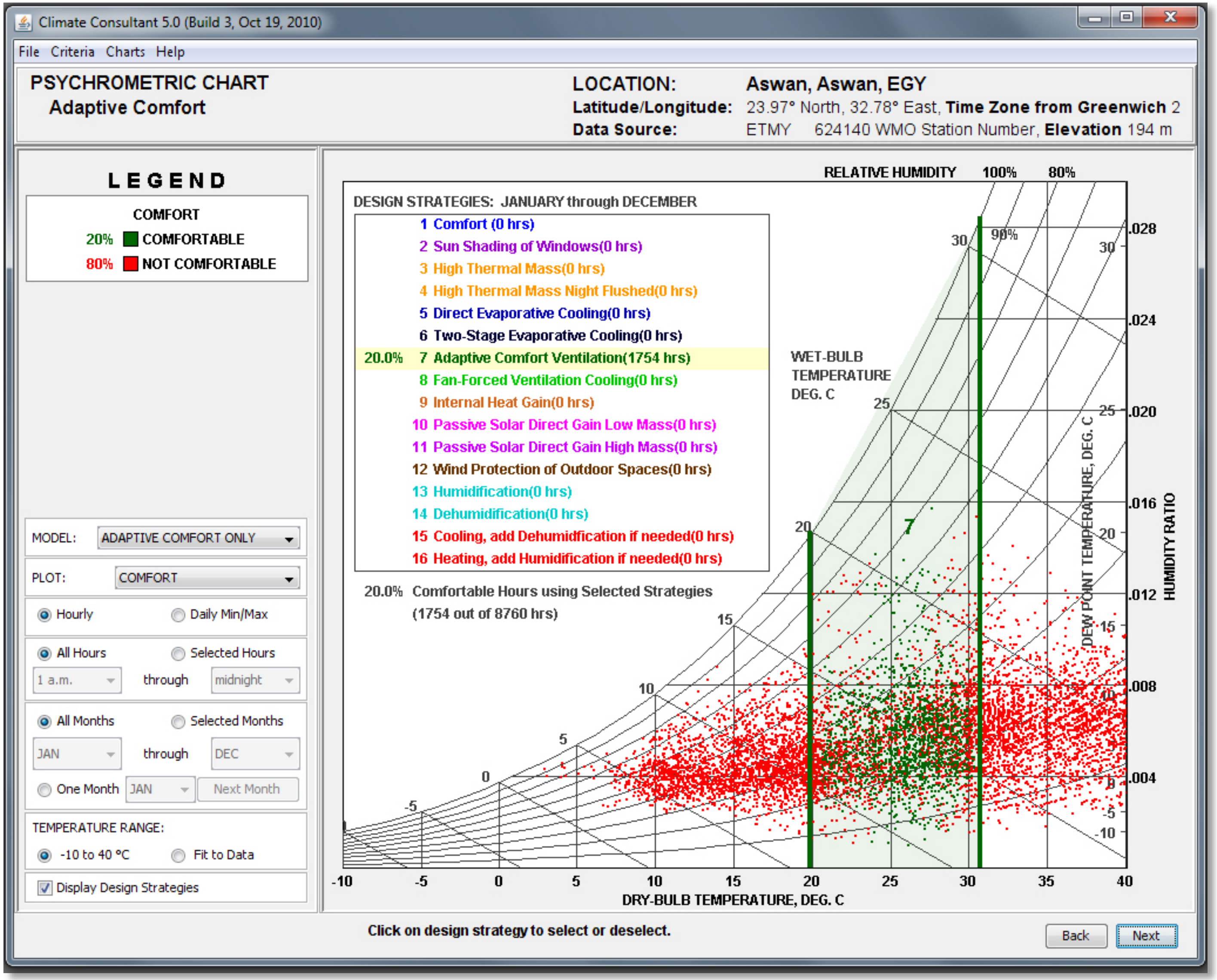
LOCATION: Aswan, Aswan, EGY
Latitude/Longitude: 23.97° North, 32.78° East, **Time Zone from Greenwich** 2
Data Source: ETMY 624140 WMO Station Number, **Elevation** 194 m

☑ Display Hourly Dry Bulb Temp

TEMPERATURE RANGE:
● -10 to 40 °C
○ Fit to Data

Note high levels of direct sun from chart.

Bio-climatic Design: HOT-ARID



Climate Consultant 5.0 (Build 3, Oct 19, 2010)

PSYCHROMETRIC CHART
Adaptive Comfort

LOCATION: **Aswan, Aswan, EGY**
Latitude/Longitude: 23.97° North, 32.78° East, **Time Zone from Greenwich** 2
Data Source: ETMY 624140 WMO Station Number, **Elevation** 194 m

LEGEND

COMFORT
20% 🟩 COMFORTABLE
80% 🟥 NOT COMFORTABLE

MODEL: ADAPTIVE COMFORT ONLY
PLOT: COMFORT
● Hourly ○ Daily Min/Max
● All Hours ○ Selected Hours
1 a.m. through midnight
● All Months ○ Selected Months
JAN through DEC
○ One Month JAN Next Month
TEMPERATURE RANGE:
● -10 to 40 °C ○ Fit to Data
☑ Display Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

1 Comfort (0 hrs)
2 Sun Shading of Windows(0 hrs)
3 High Thermal Mass(0 hrs)
4 High Thermal Mass Night Flushed(0 hrs)
5 Direct Evaporative Cooling(0 hrs)
6 Two-Stage Evaporative Cooling(0 hrs)
20.0% 7 Adaptive Comfort Ventilation(1754 hrs)
8 Fan-Forced Ventilation Cooling(0 hrs)
9 Internal Heat Gain(0 hrs)
10 Passive Solar Direct Gain Low Mass(0 hrs)
11 Passive Solar Direct Gain High Mass(0 hrs)
12 Wind Protection of Outdoor Spaces(0 hrs)
13 Humidification(0 hrs)
14 Dehumidification(0 hrs)
15 Cooling, add Dehumidfication if needed(0 hrs)
16 Heating, add Humidification if needed(0 hrs)

20.0% Comfortable Hours using Selected Strategies
(1754 out of 8760 hrs)

Click on design strategy to select or deselect.

Bio-climatic Design: HOT-HUMID

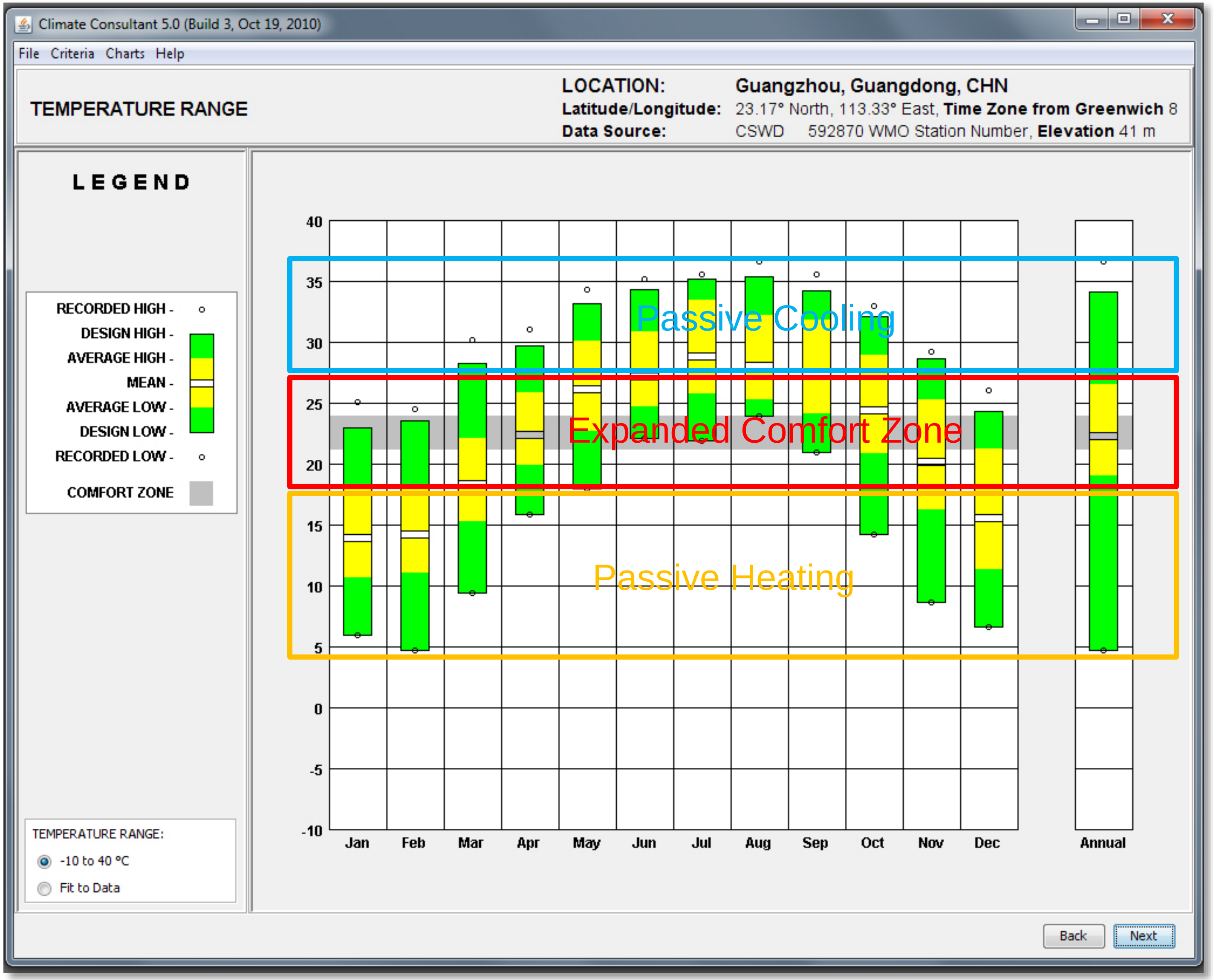
Where **warm to hot** stable conditions predominate with **high humidity** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

House in Seaside, Florida

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

Bio-climatic Design: HOT-HUMID



Climate Consultant 5.0 (Build 3, Oct 19, 2010)

TEMPERATURE RANGE

LOCATION: Guangzhou, Guangdong, CHN
Latitude/Longitude: 23.17° North, 113.33° East, **Time Zone from Greenwich** 8
Data Source: CSWD 592870 WMO Station Number, **Elevation** 41 m

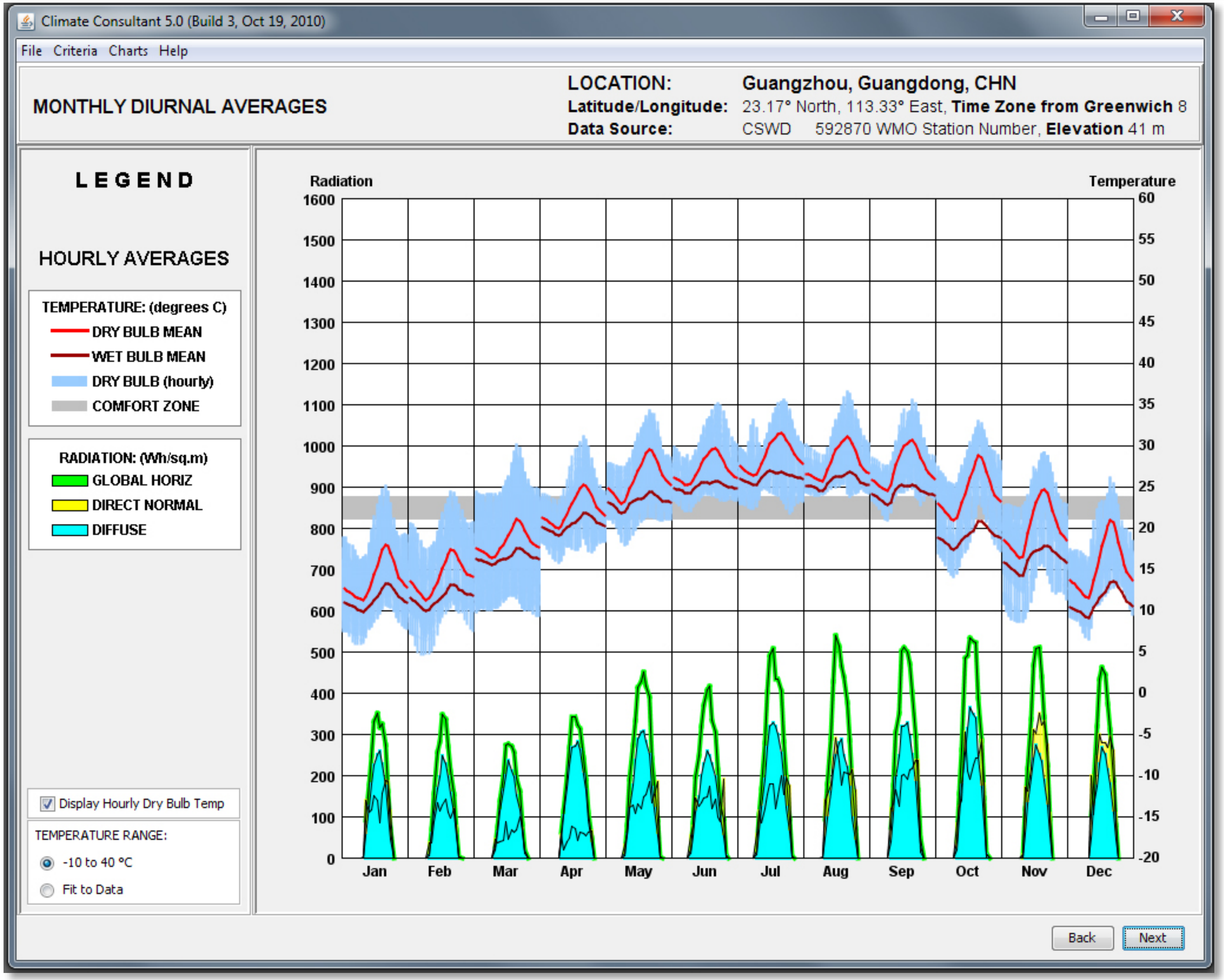
LEGEND

- RECORDED HIGH - ○
- DESIGN HIGH -
- AVERAGE HIGH -
- MEAN -
- AVERAGE LOW -
- DESIGN LOW -
- RECORDED LOW - ○
- COMFORT ZONE ▨

TEMPERATURE RANGE:

● -10 to 40 °C
○ Fit to Data

Bio-climatic Design: HOT-HUMID



Climate Consultant 5.0 (Build 3, Oct 19, 2010)

MONTHLY DIURNAL AVERAGES

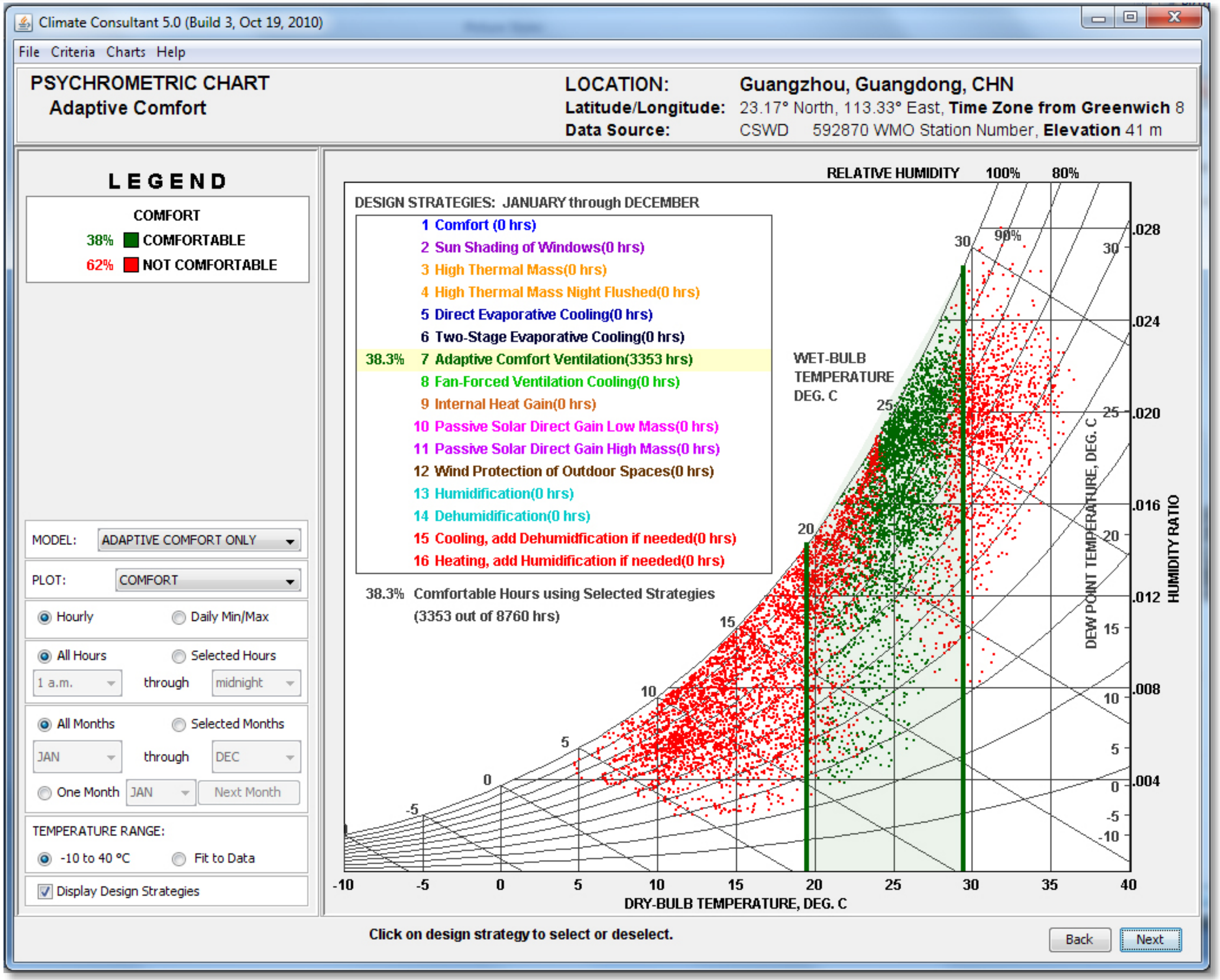
LOCATION: Guangzhou, Guangdong, CHN
Latitude/Longitude: 23.17° North, 113.33° East, **Time Zone from Greenwich** 8
Data Source: CSWD 592870 WMO Station Number, **Elevation** 41 m

☑ Display Hourly Dry Bulb Temp

TEMPERATURE RANGE:
● -10 to 40 °C
○ Fit to Data

Note lack of direct solar and hazy conditions.

Bio-climatic Design: HOT-HUMID



Climate Consultant 5.0 (Build 3, Oct 19, 2010)

PSYCHROMETRIC CHART

Adaptive Comfort

LOCATION: **Guangzhou, Guangdong, CHN**

Latitude/Longitude: 23.17° North, 113.33° East, **Time Zone from Greenwich** 8

Data Source: CSWD 592870 WMO Station Number, **Elevation** 41 m

LEGEND

COMFORT

38% 🟩 COMFORTABLE

62% 🟥 NOT COMFORTABLE

MODEL: ADAPTIVE COMFORT ONLY

PLOT: COMFORT

● Hourly ○ Daily Min/Max

● All Hours ○ Selected Hours

1 a.m. through midnight

● All Months ○ Selected Months

JAN through DEC

○ One Month JAN Next Month

TEMPERATURE RANGE:

● -10 to 40 °C ○ Fit to Data

☑ Display Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER

1 Comfort (0 hrs)
2 Sun Shading of Windows(0 hrs)
3 High Thermal Mass(0 hrs)
4 High Thermal Mass Night Flushed(0 hrs)
5 Direct Evaporative Cooling(0 hrs)
6 Two-Stage Evaporative Cooling(0 hrs)
38.3% 7 Adaptive Comfort Ventilation(3353 hrs)
8 Fan-Forced Ventilation Cooling(0 hrs)
9 Internal Heat Gain(0 hrs)
10 Passive Solar Direct Gain Low Mass(0 hrs)
11 Passive Solar Direct Gain High Mass(0 hrs)
12 Wind Protection of Outdoor Spaces(0 hrs)
13 Humidification(0 hrs)
14 Dehumidification(0 hrs)
15 Cooling, add Dehumidfication if needed(0 hrs)
16 Heating, add Humidification if needed(0 hrs)

38.3% Comfortable Hours using Selected Strategies (3353 out of 8760 hrs)

Click on design strategy to select or deselect.

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.**

IslandWood Residence, Seattle, WA

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

CLIMATE RESPONSIVE

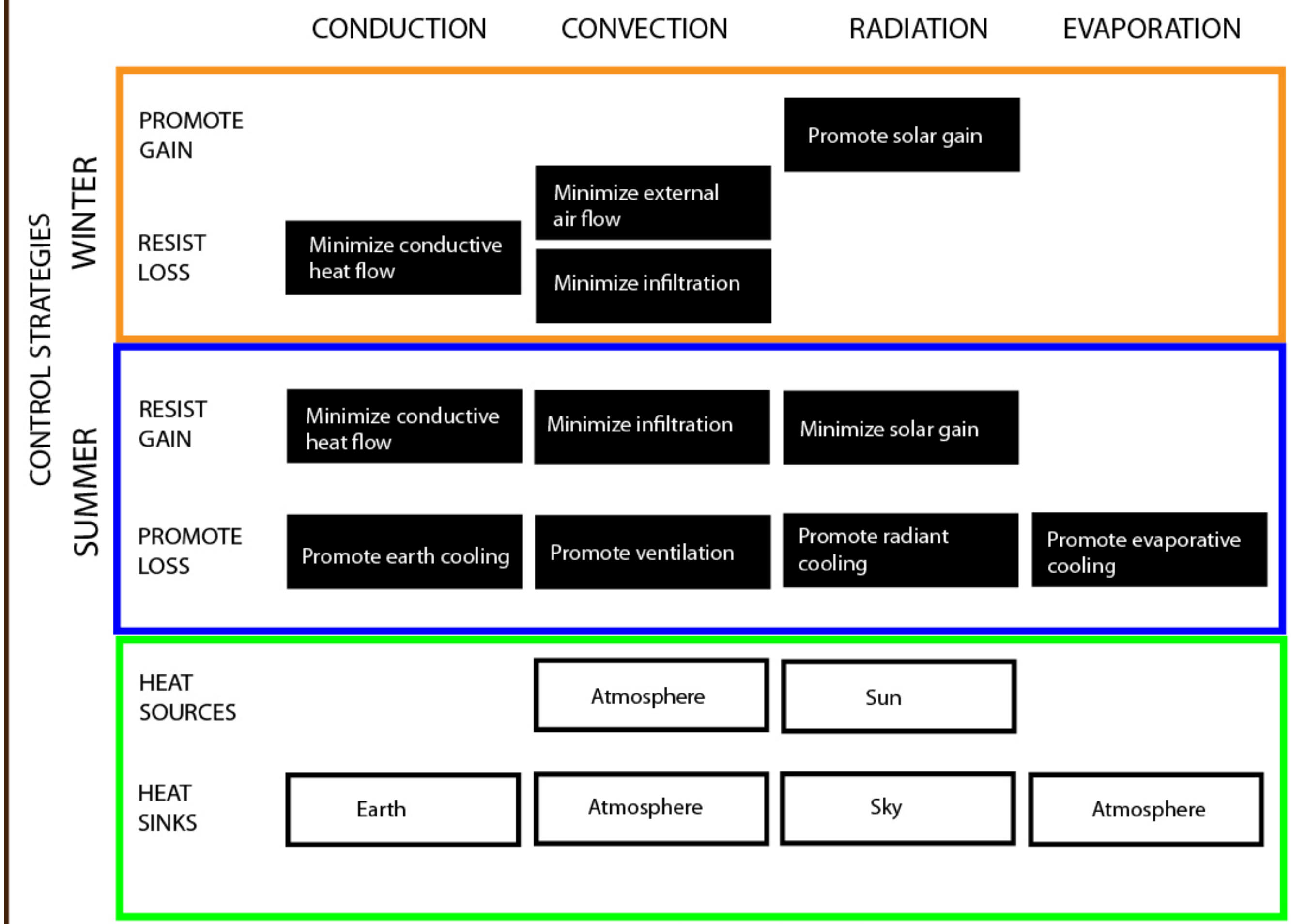
HEATING ↔ SUN

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	
	RESIST LOSS	Minimize conductive heat flow	Minimize external air flow Minimize infiltration		
SUMMER	RESIST GAIN	Minimize conductive heat flow	Minimize infiltration	Minimize solar gain	
	PROMOTE LOSS	Promote earth cooling	Promote ventilation	Promote radiant cooling	Promote evaporative cooling
	HEAT SOURCES		Atmosphere	Sun	
	HEAT SINKS	Earth	Atmosphere	Sky	Atmosphere

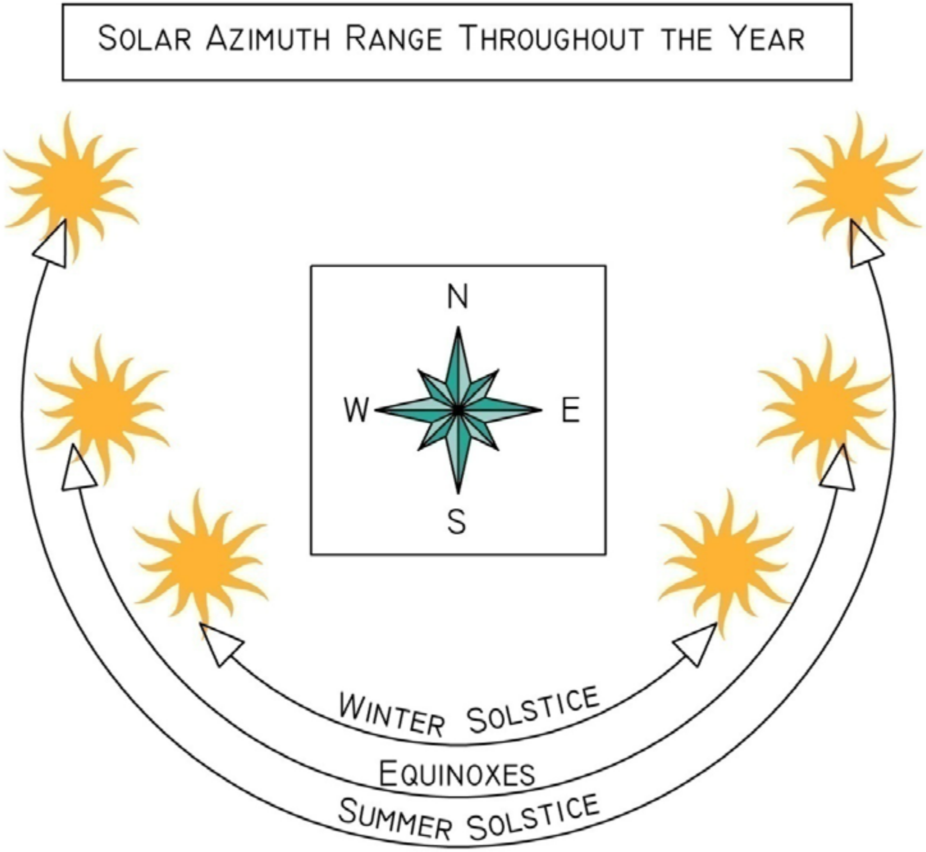
HEATING

COOLING

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

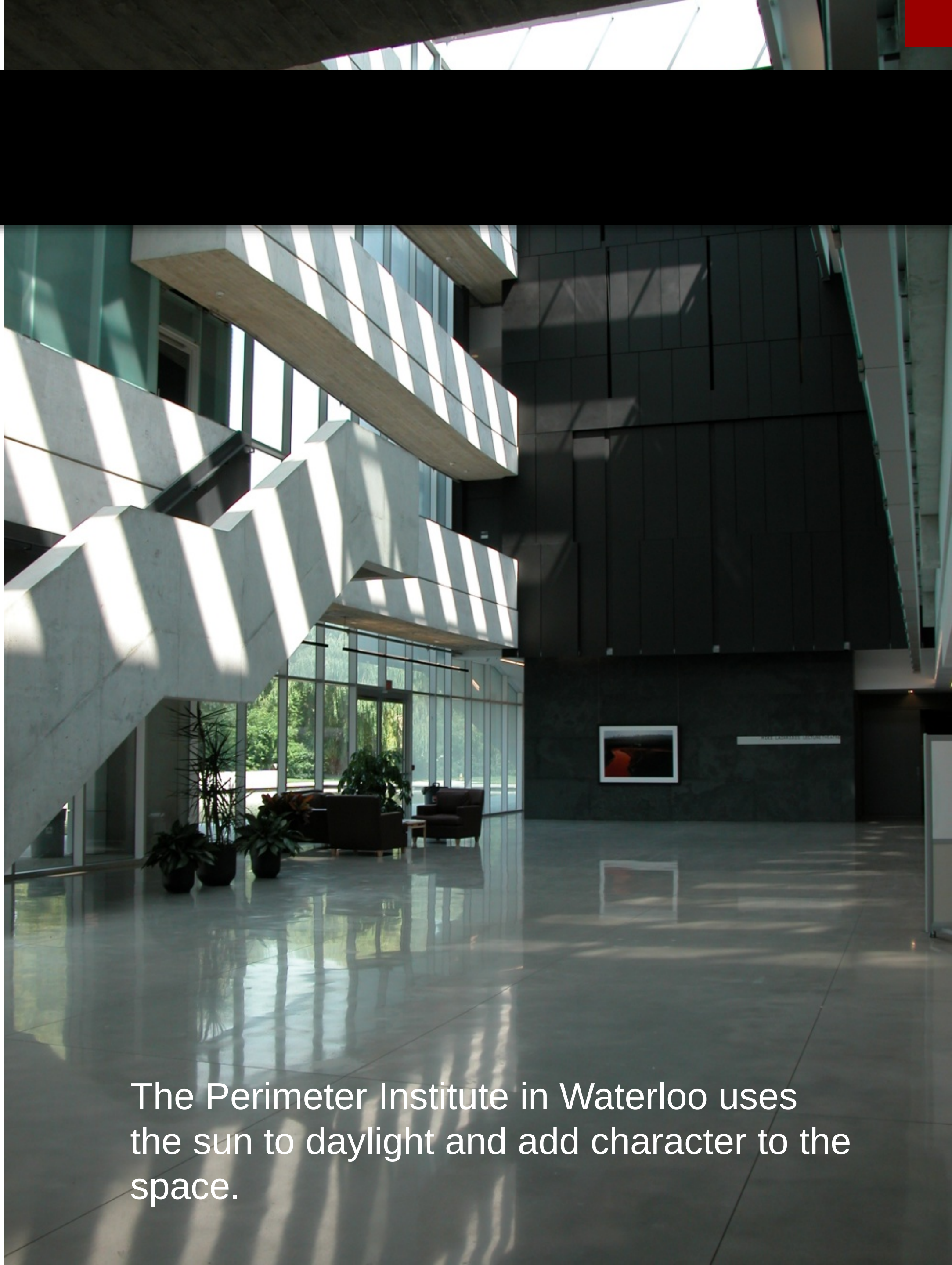
Solar Geometry

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

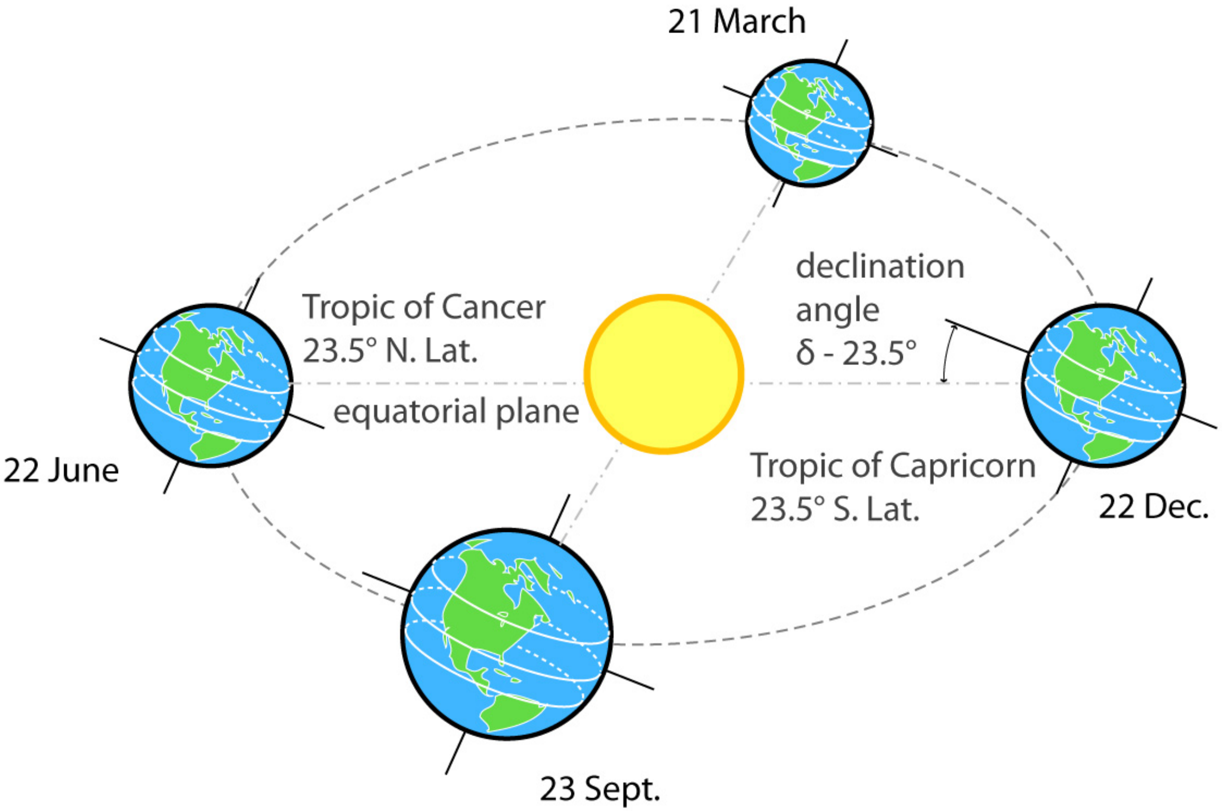
Understanding solar geometry is essential in order to:

- 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



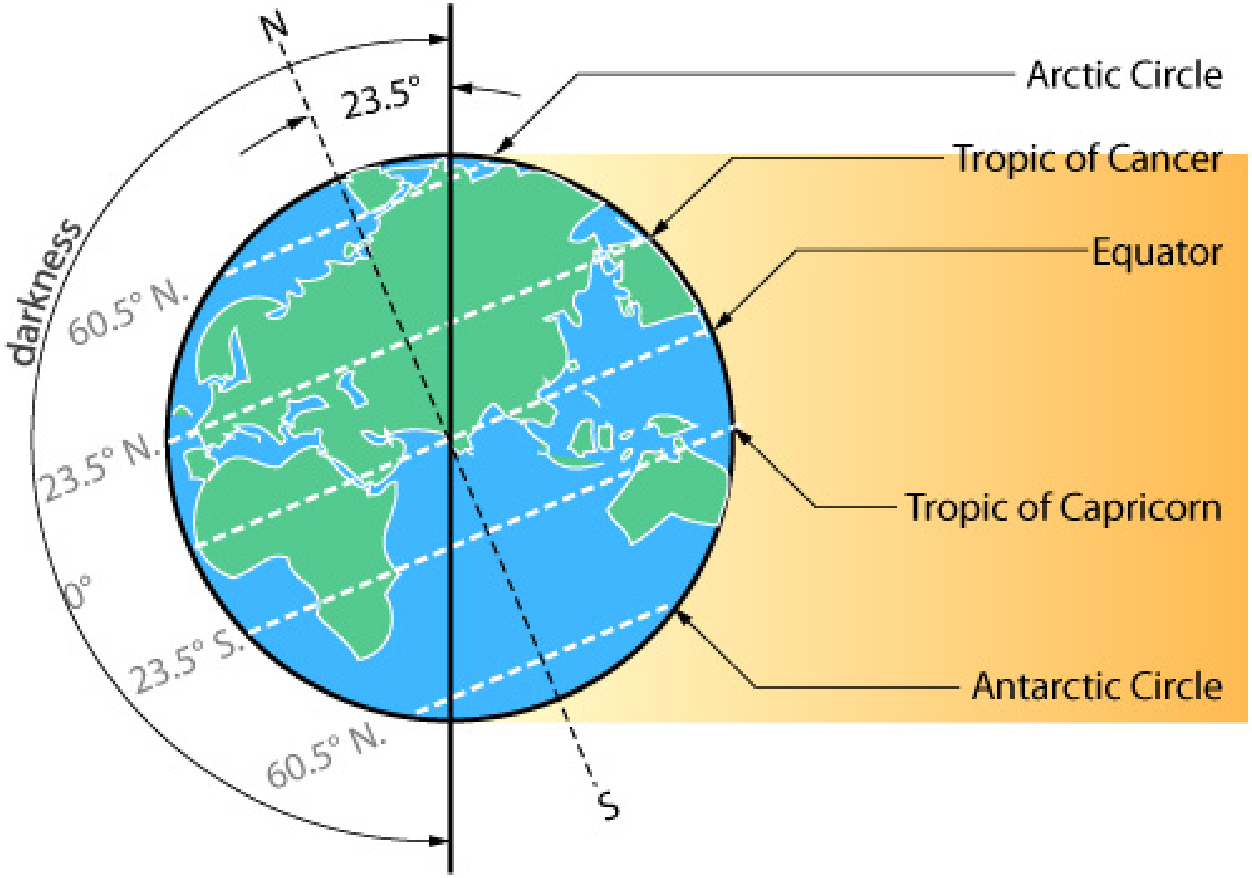
The Perimeter Institute in Waterloo uses the sun to daylight and add character to the space.

Solar Geometry



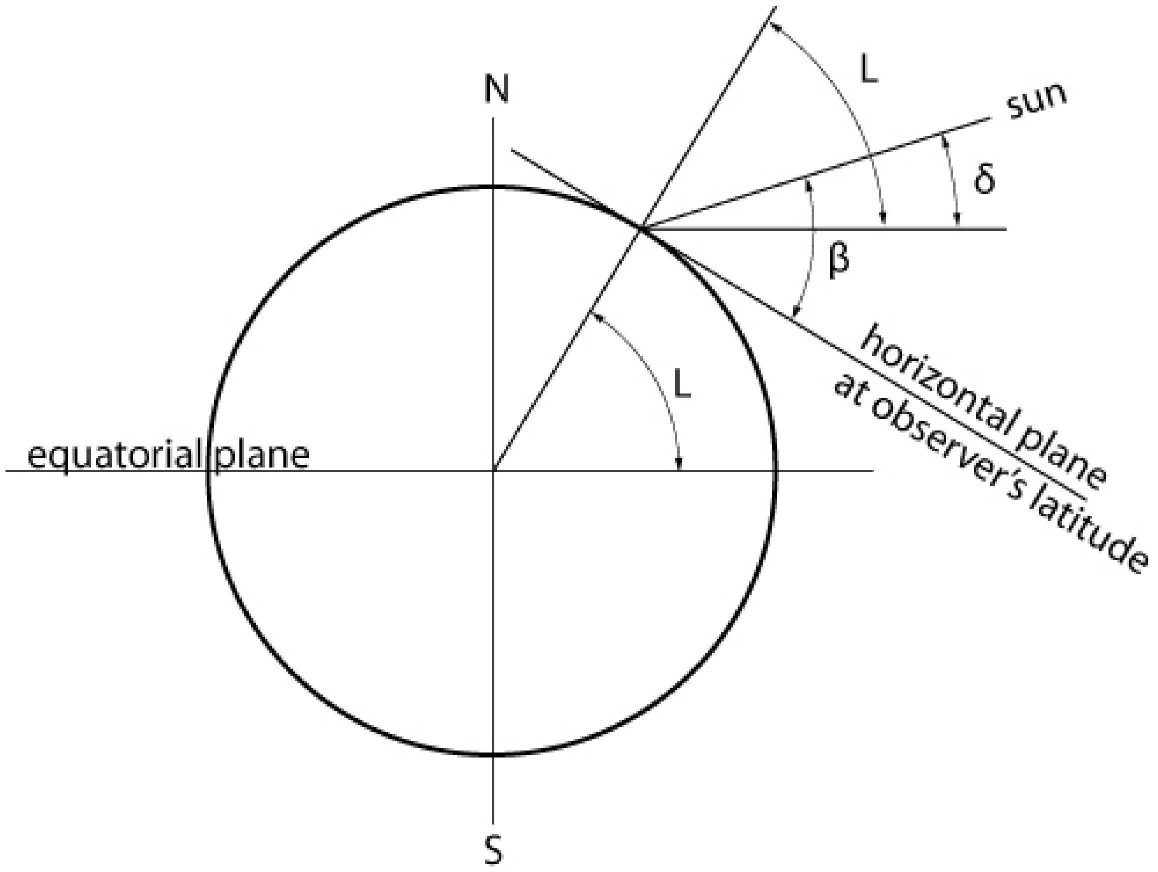
Earth's motion around the sun.

Solar Position



Earth relative to sun at winter solstice.

Solar Geometry Terms

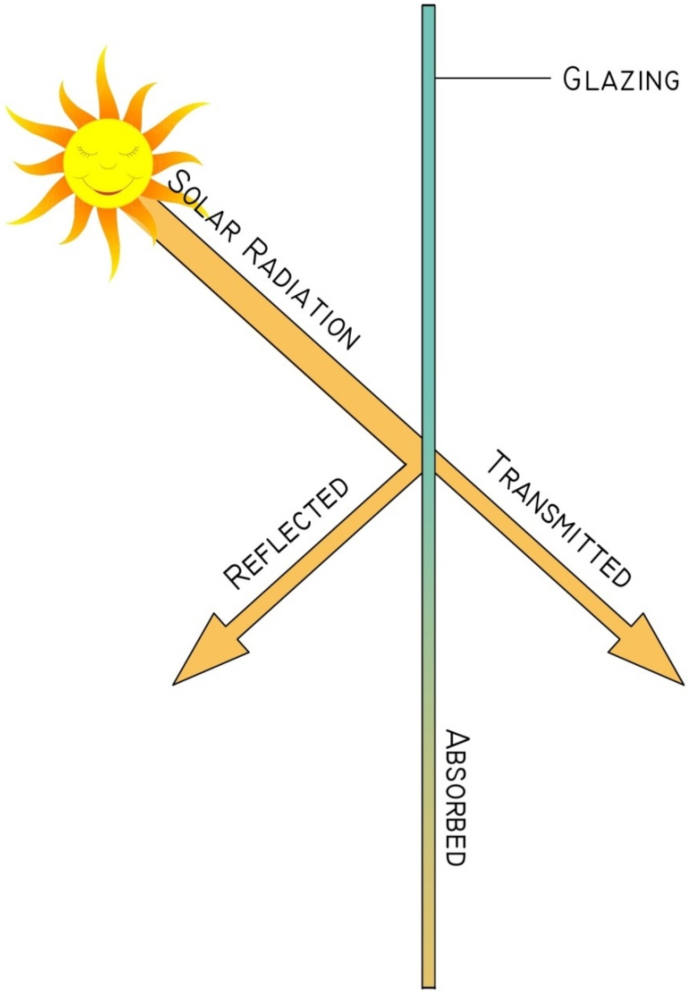


Relation between declination, altitude angle, and latitude.

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



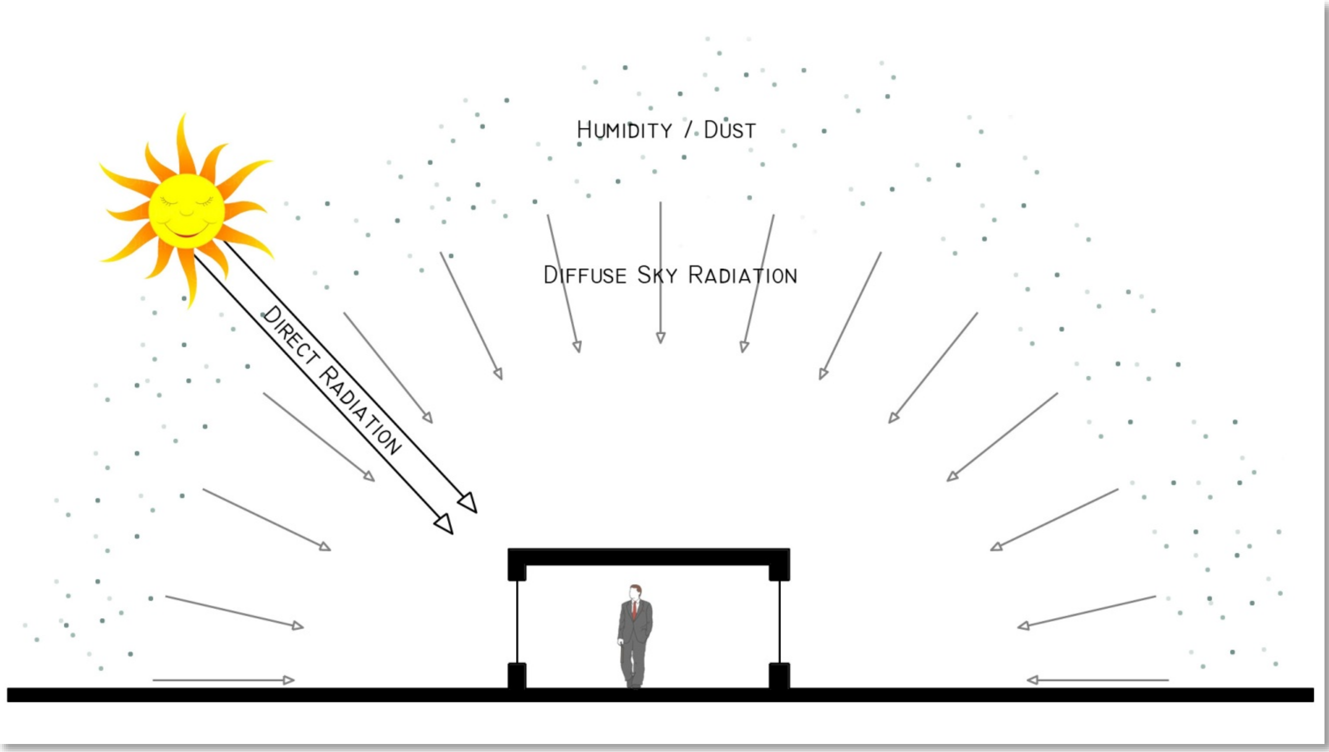
When sun strikes the glass part of the solar radiation is transmitted through the glass and proceeds to heat up the interior space.

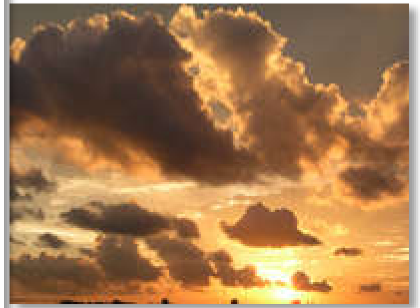
Part of the solar energy is reflected off of the glass. The amount is dependent on the angle of incidence.

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



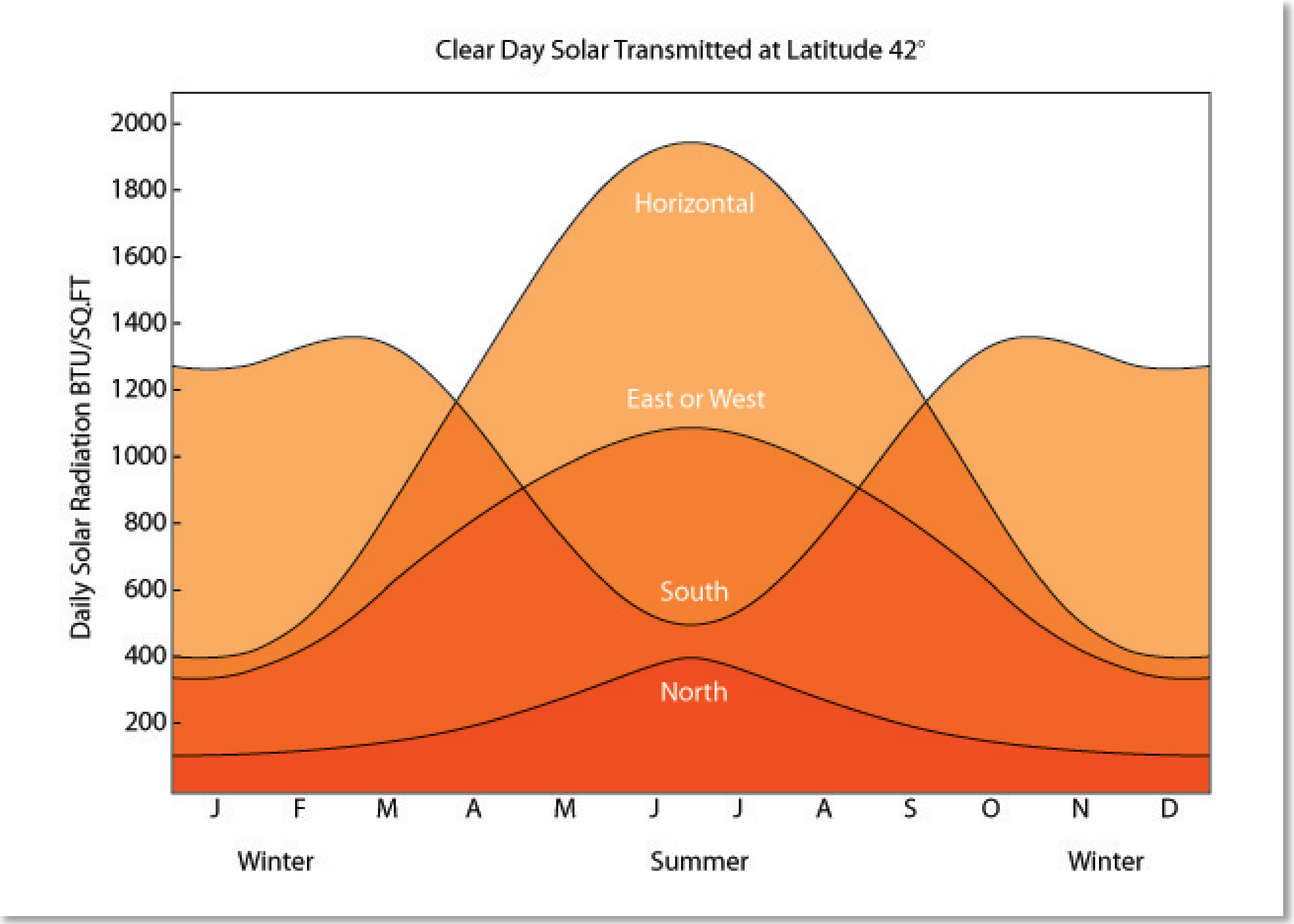


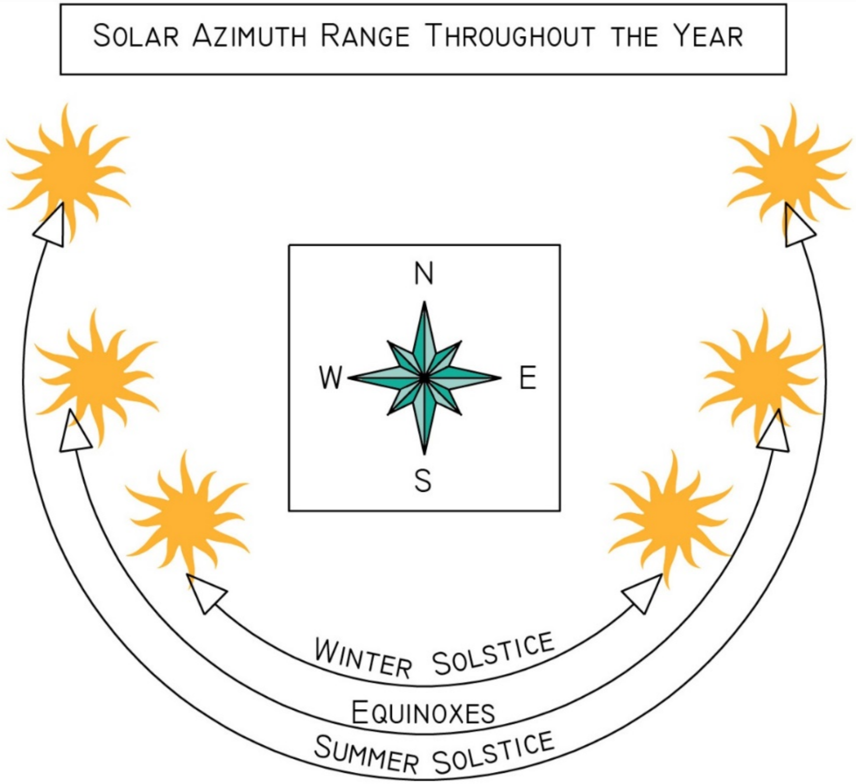
Solar Energy as a Function of Orientation

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.



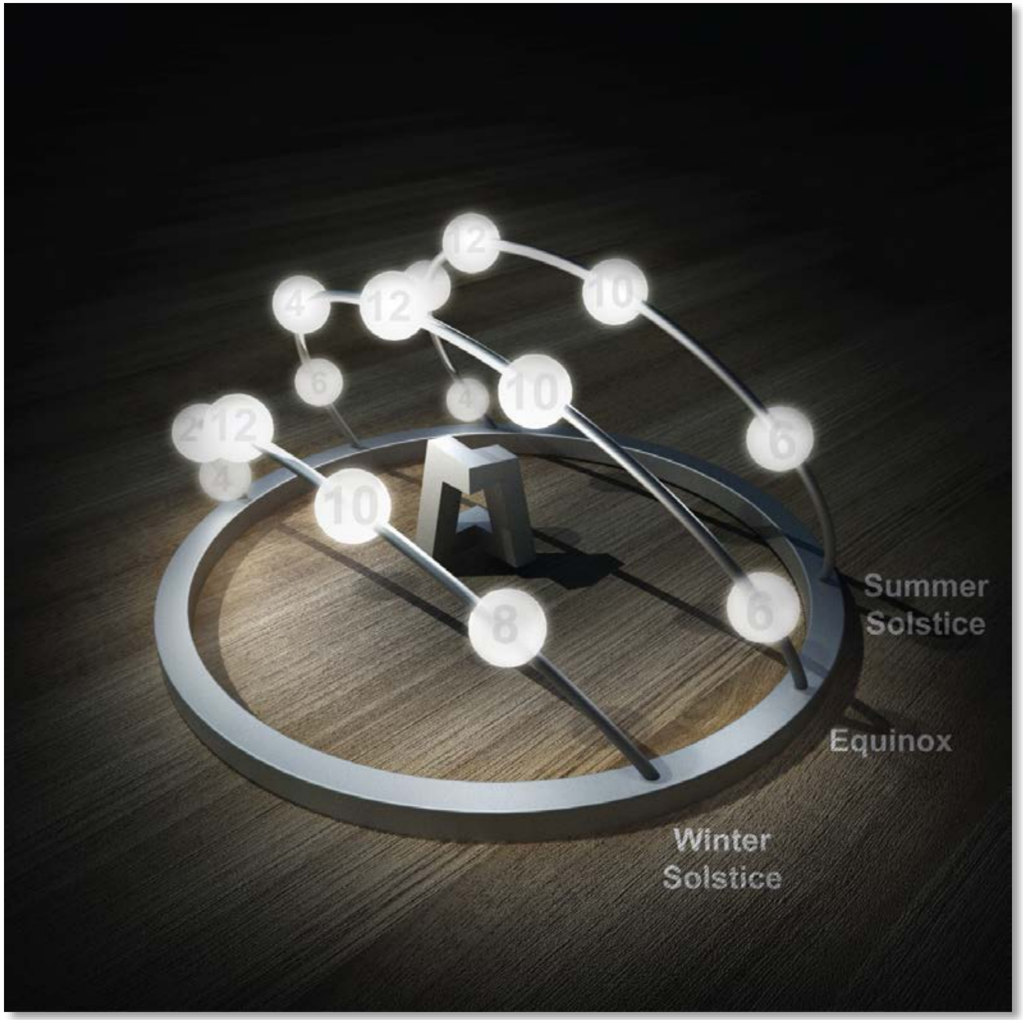


Since little winter heating can be expected from east and west windows, shading devices on those orientations can be designed purely on the basis of the summer requirement.

Solar Geometry

The local solar path affects:

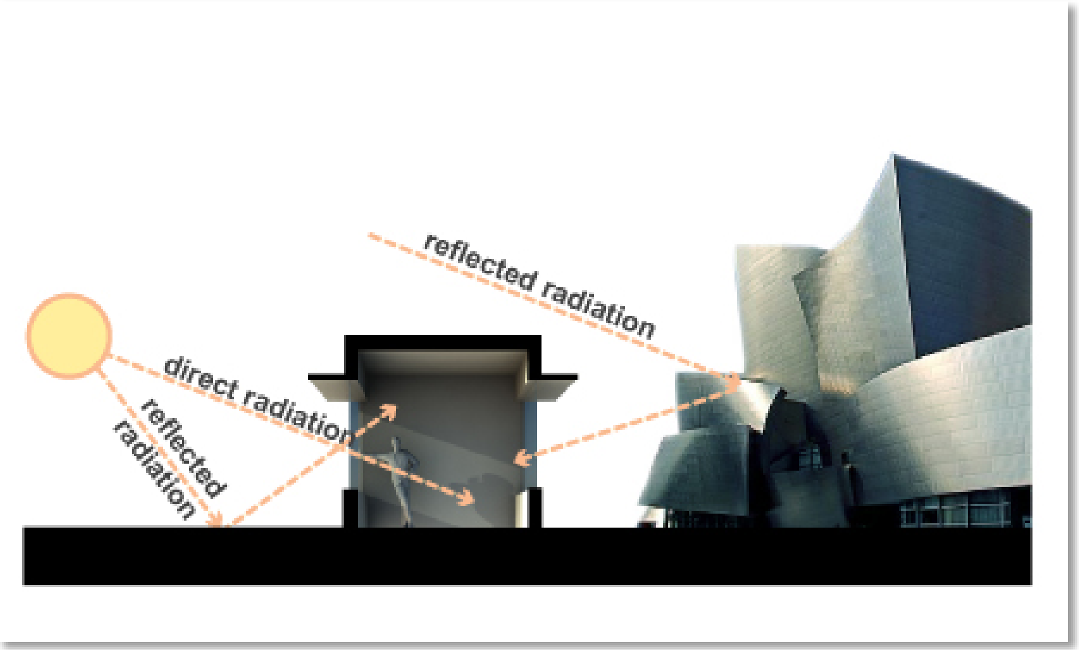
- Location of openings for passive solar heating
- Design of shading devices for cooling
- Means differentiated façade design



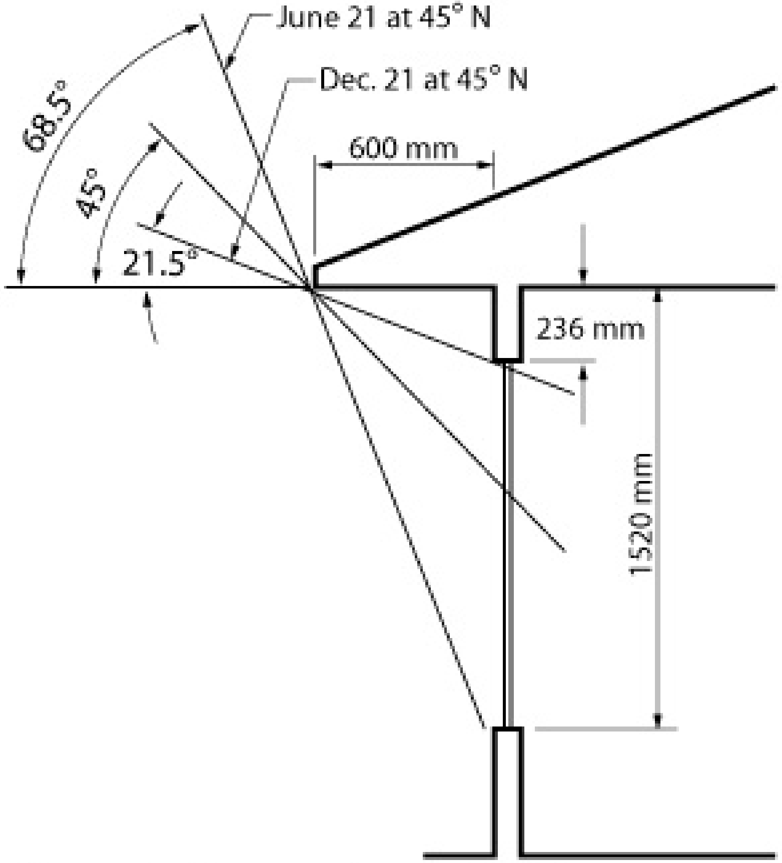
Types of Radiation

- Direct radiation
- Reflected radiation

Reflective glazing

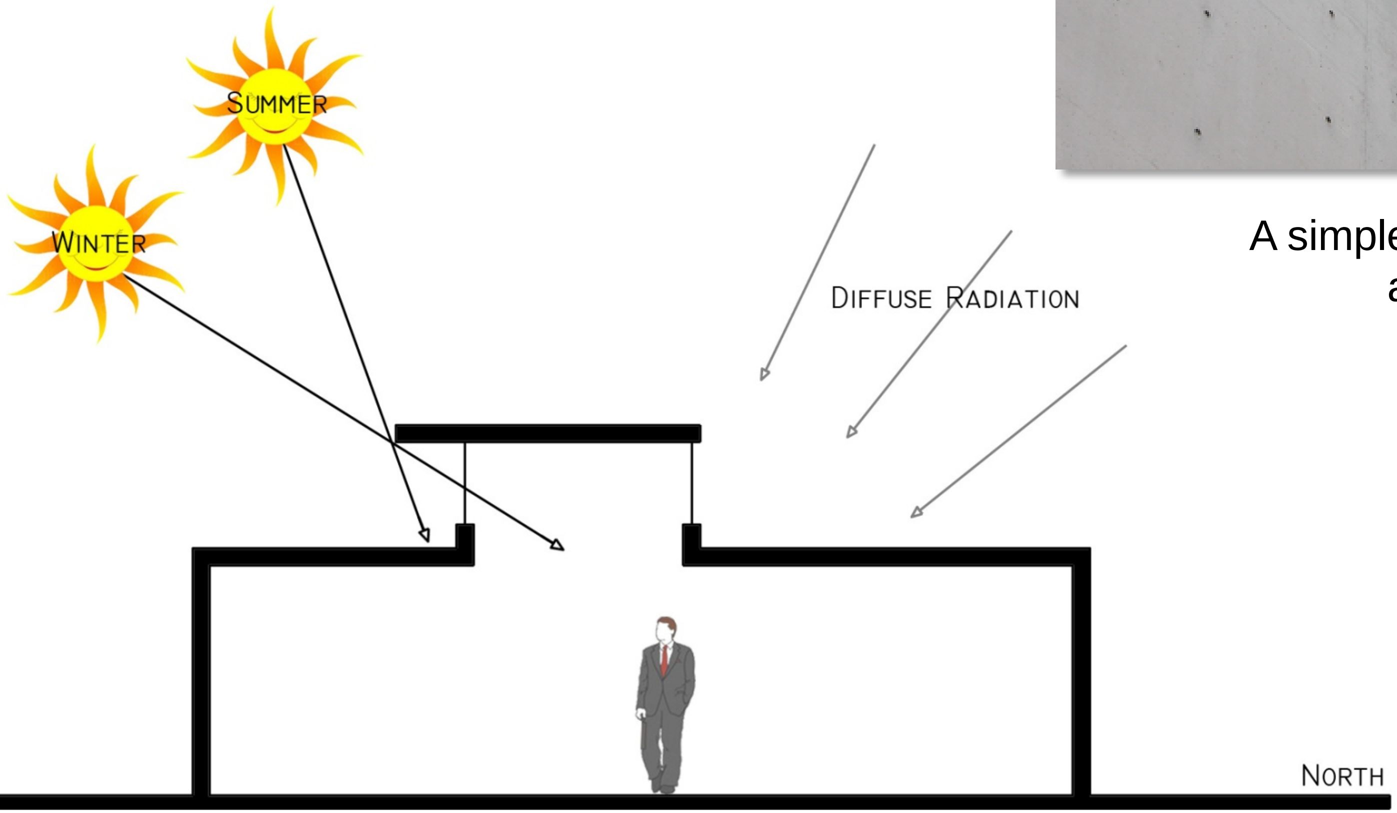


South Shading Device Basics



Shading angles for a south wall at 45°N

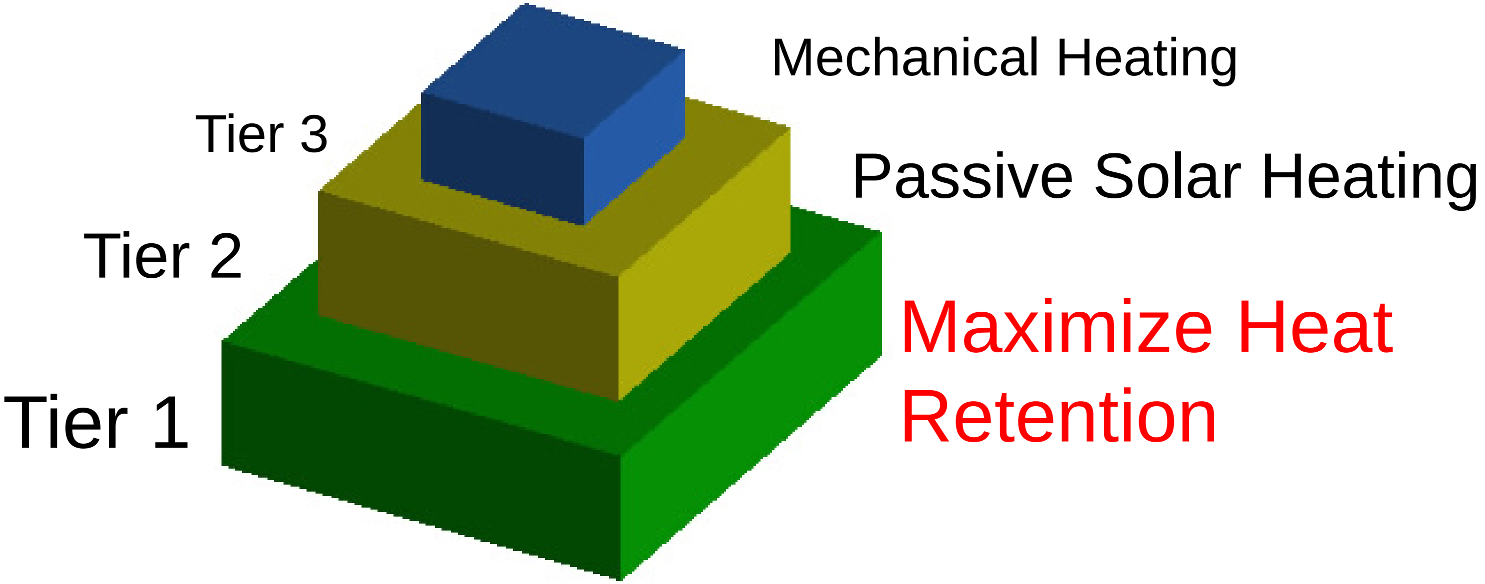
A simple roof overhang acts as a shading device.



Clerestory Window

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)

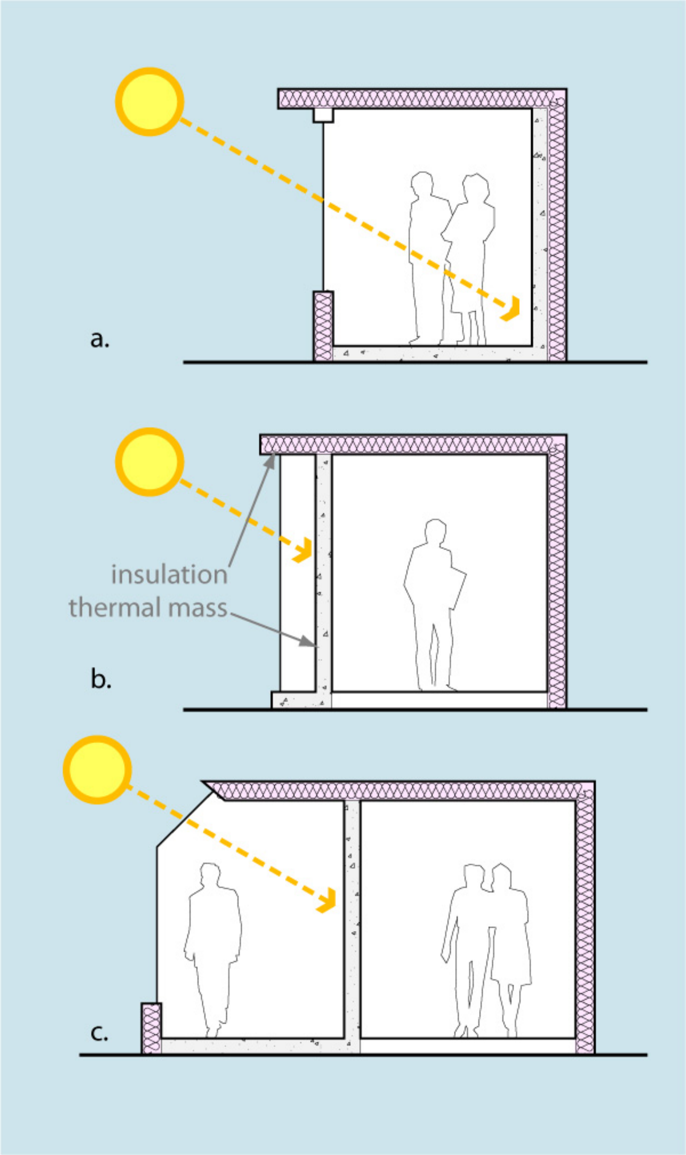
3 MAIN STRATEGIES:

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.

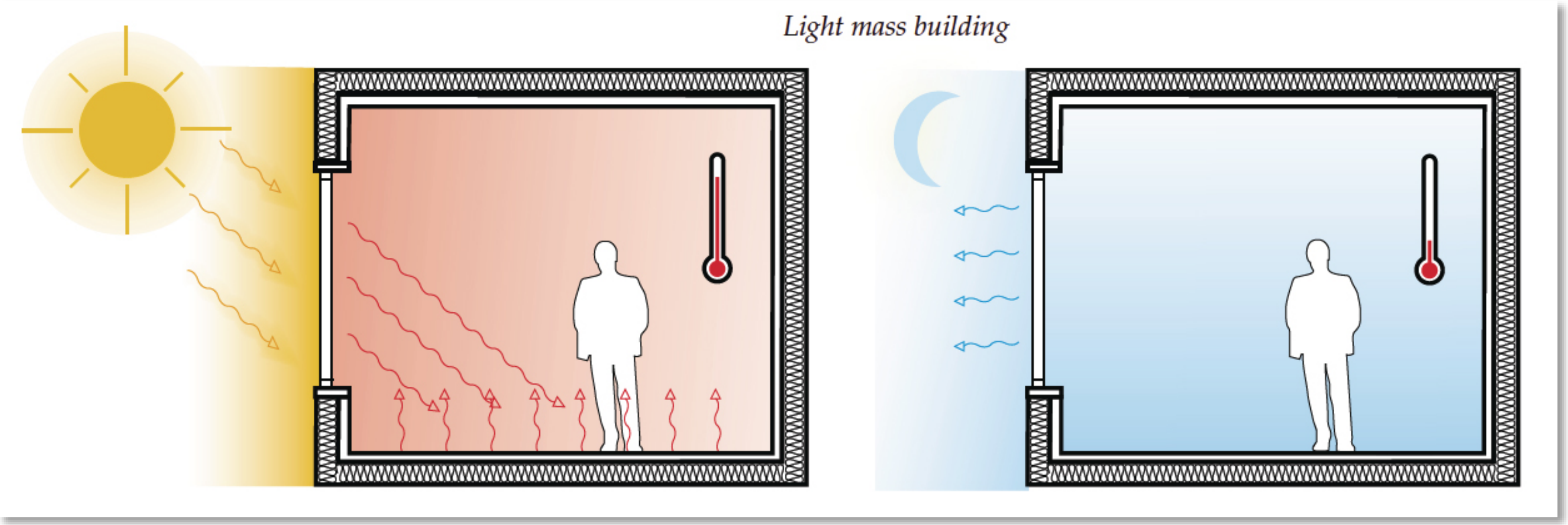
Just like water, free solar energy needs to be stored somewhere to be useful!

Problems with traditional placement of thermal mass

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

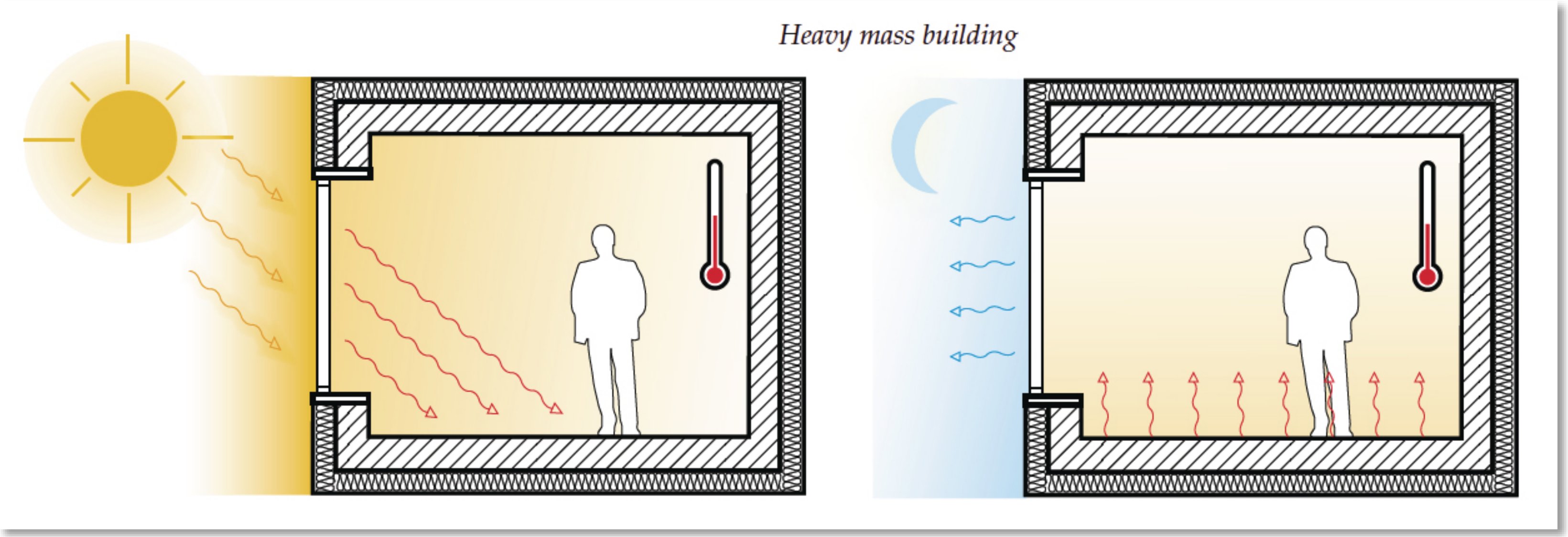
Thermal mass is needed on the INSIDE of the envelope – as floor and/or walls.

Light Mass Building Problems



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

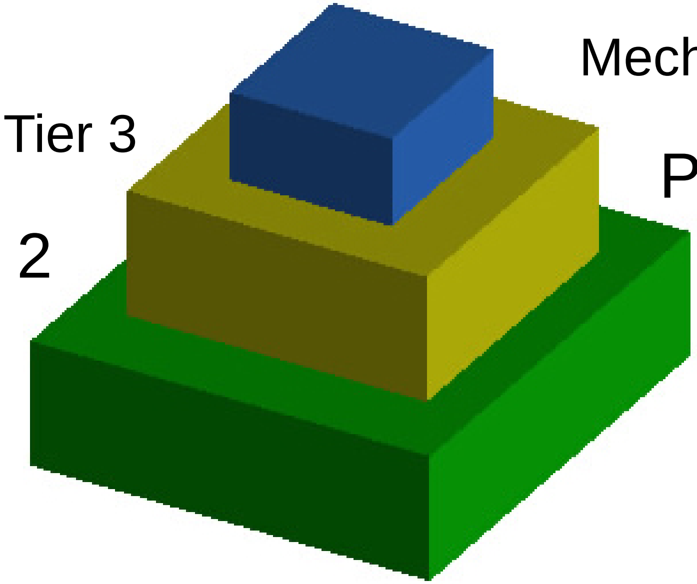
Heavy Mass Building Benefits



- 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:



Tier 3

Mechanical Cooling

Tier 2

Passive Cooling

Tier 1

Heat Avoidance

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

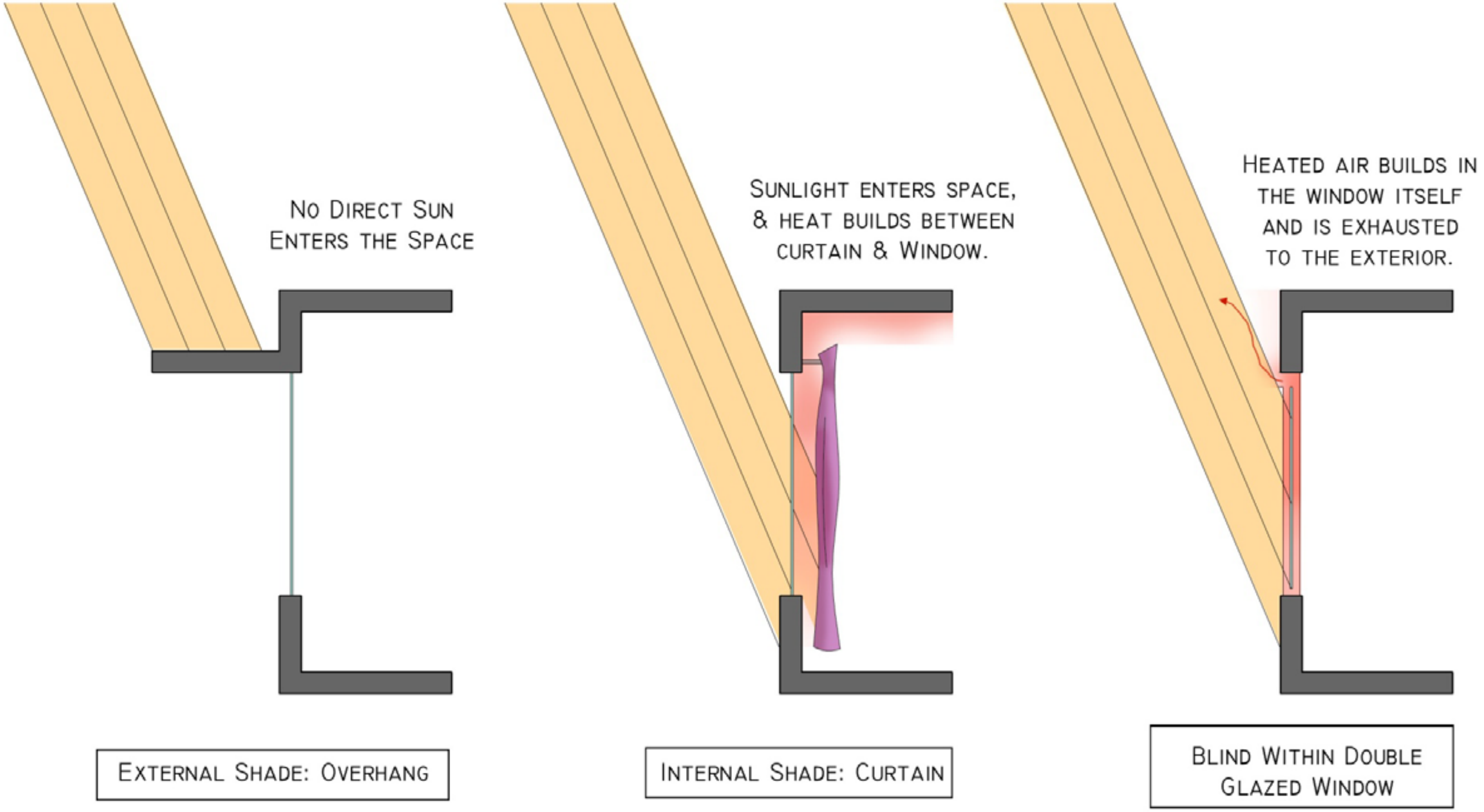
Source: Lechner. Heating, Cooling, Lighting.

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…..

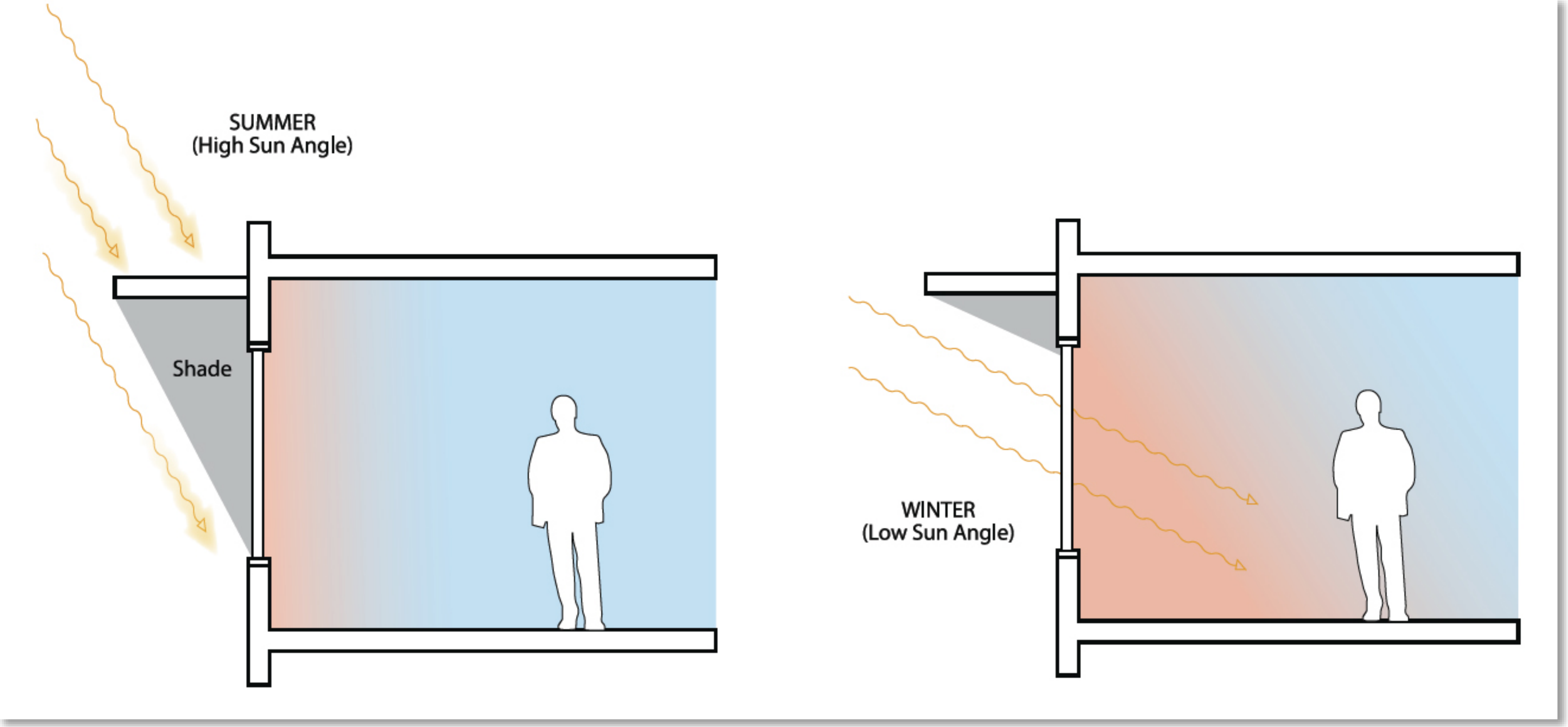
Interior vs Exterior Shades



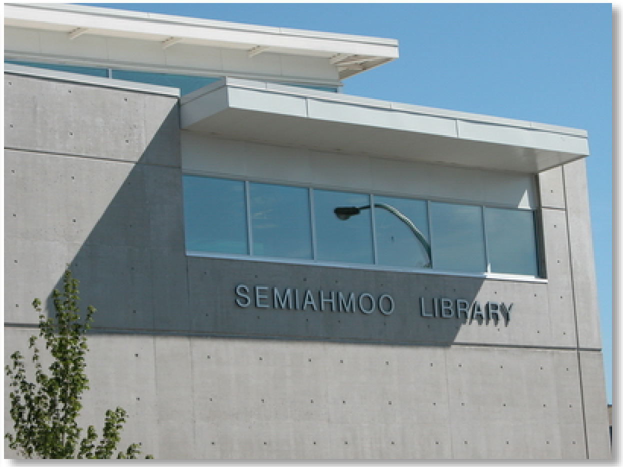
Once the heat is IN, it is IN!

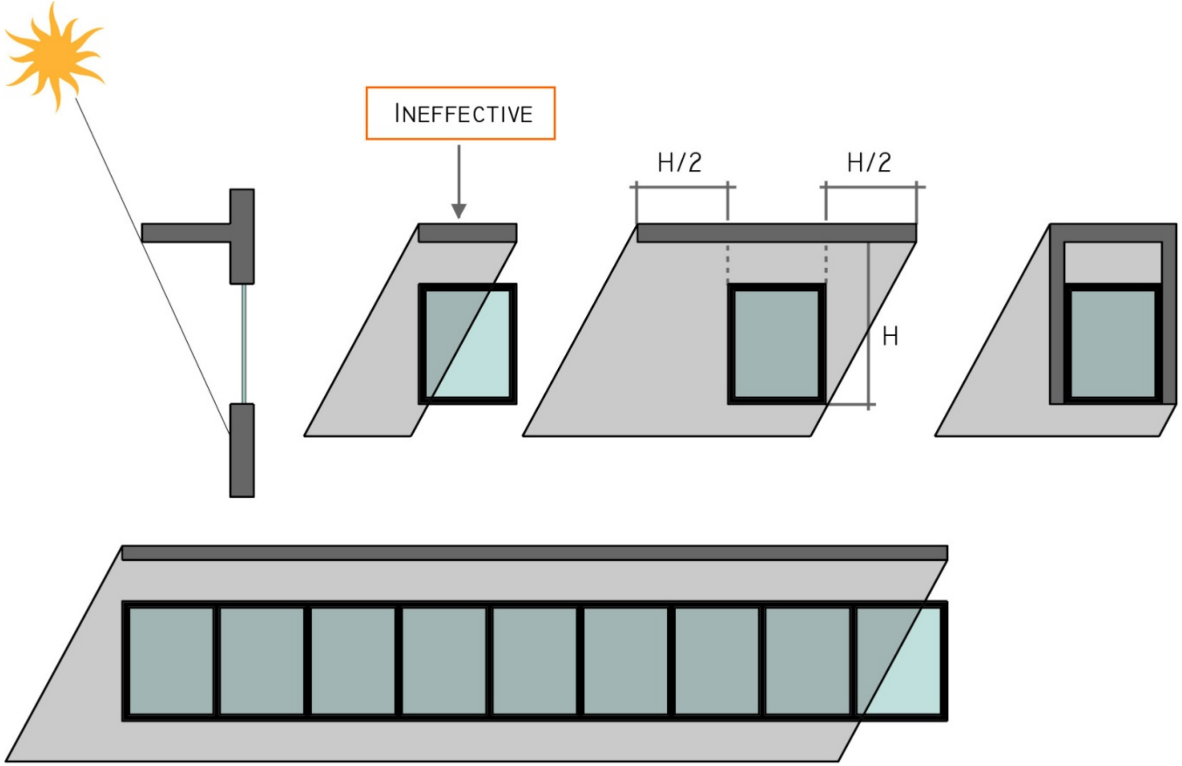
Internal blinds are good for glare, but not preventing solar gain.

South Façade Strategies



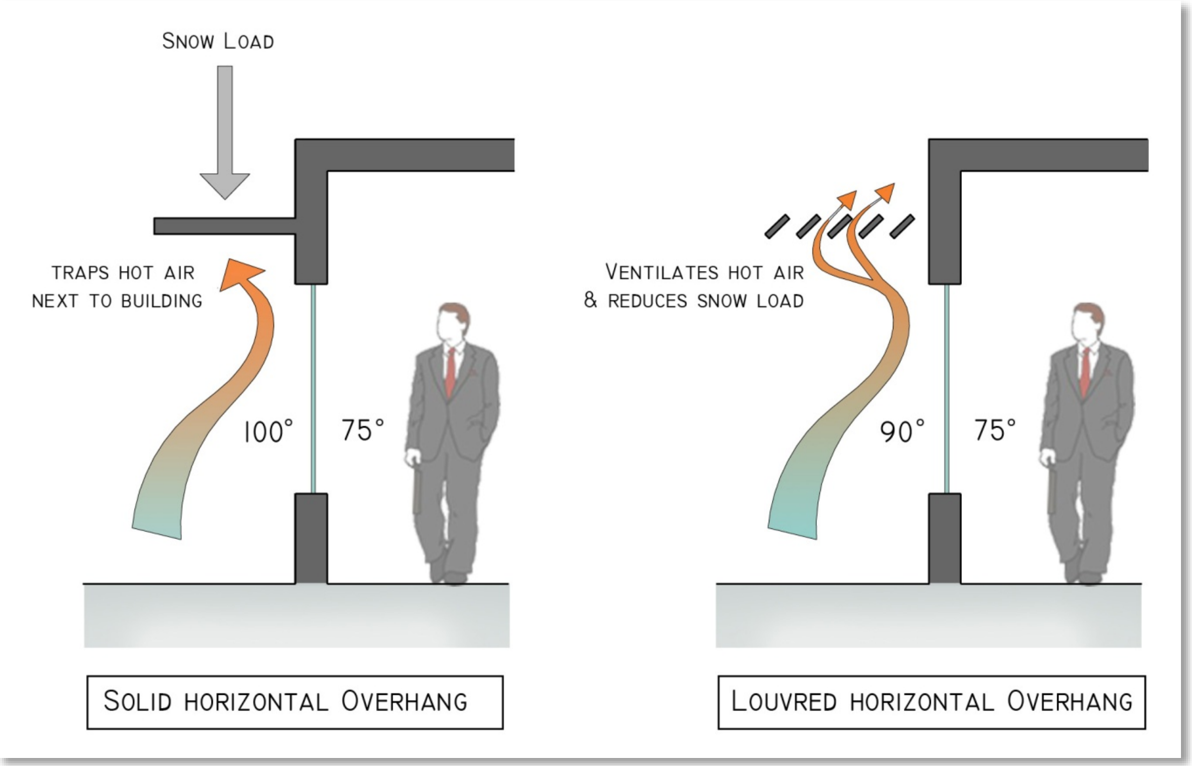
- South façade is the easiest to manage as simple overhangs can provide shade in the summer and permit entry in the winter.
- Need to design for August condition as June to August is normally a warm period.





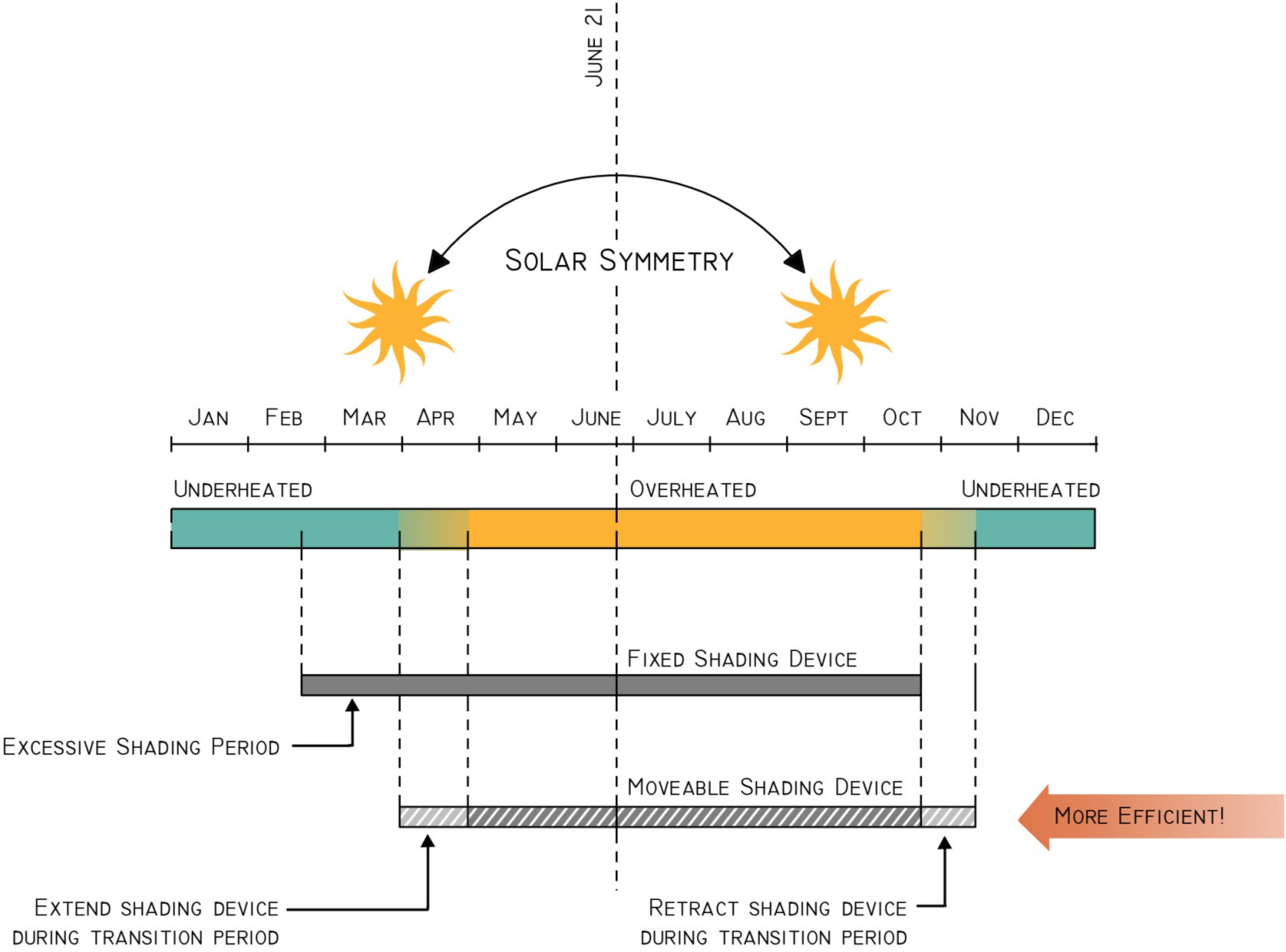
…extend device for full shading

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

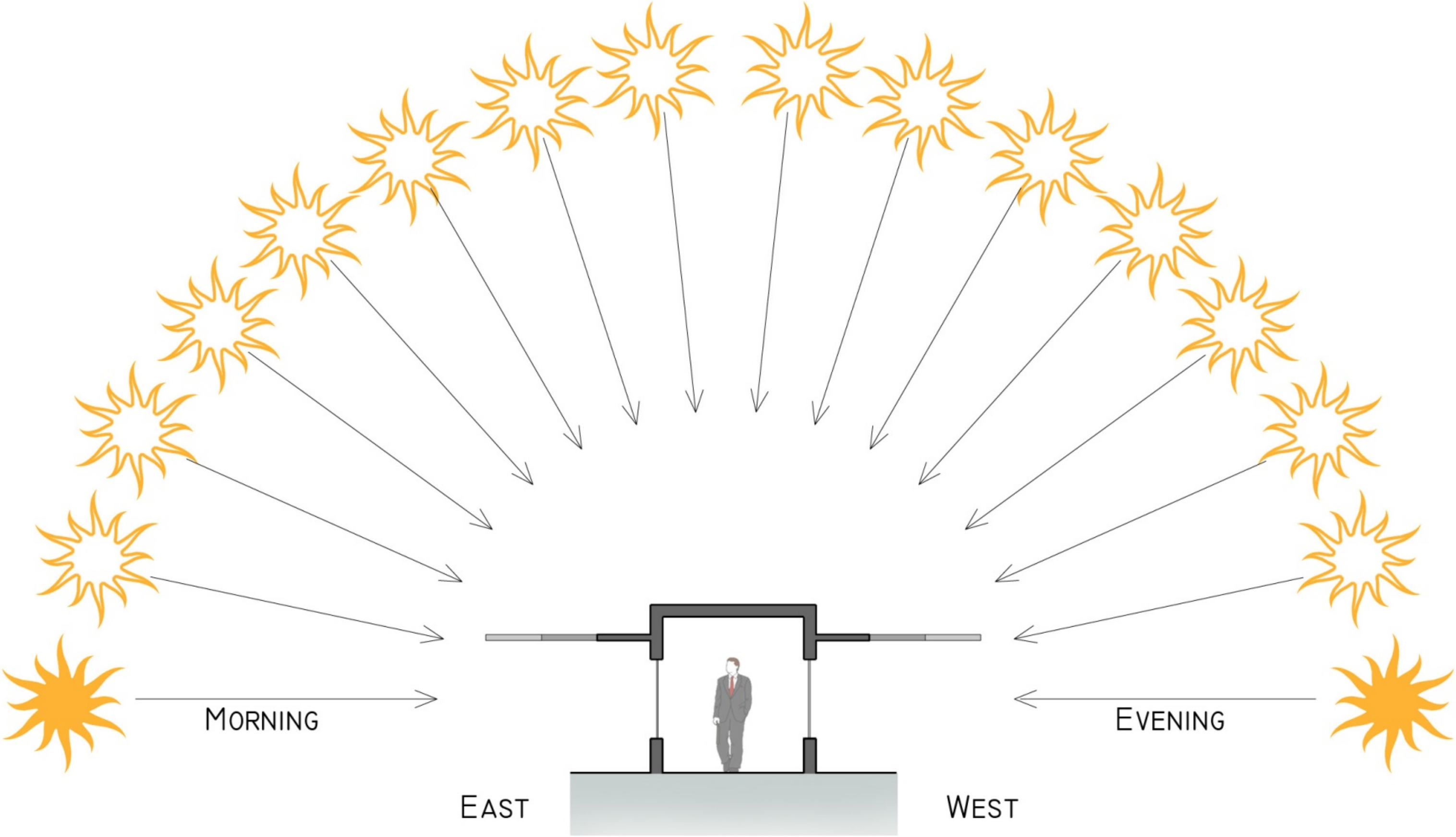


The above two use louvers or grates that will let snow, rain and wind through.

Preventing Overheating South Façade

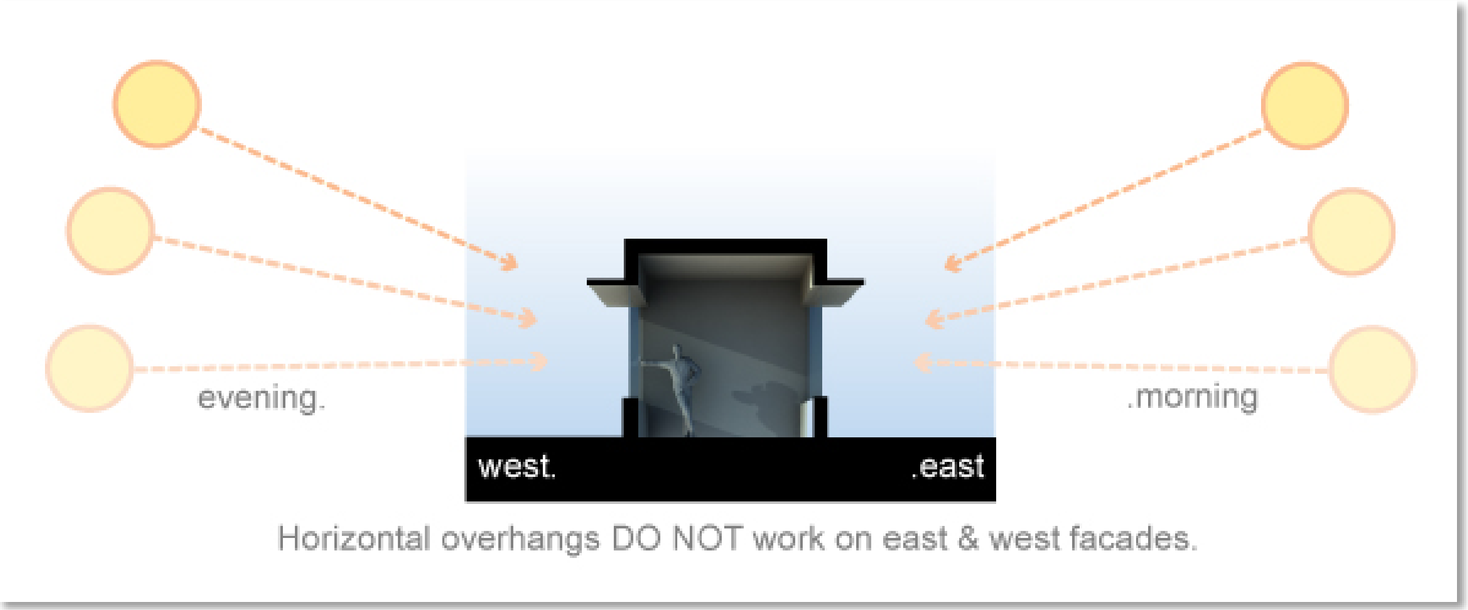


Shading Strategies for East and West Orientations



HORIZONTAL OVERHANGS DO NOT WORK ON EAST & WEST FACADES

East and West Façade Strategies



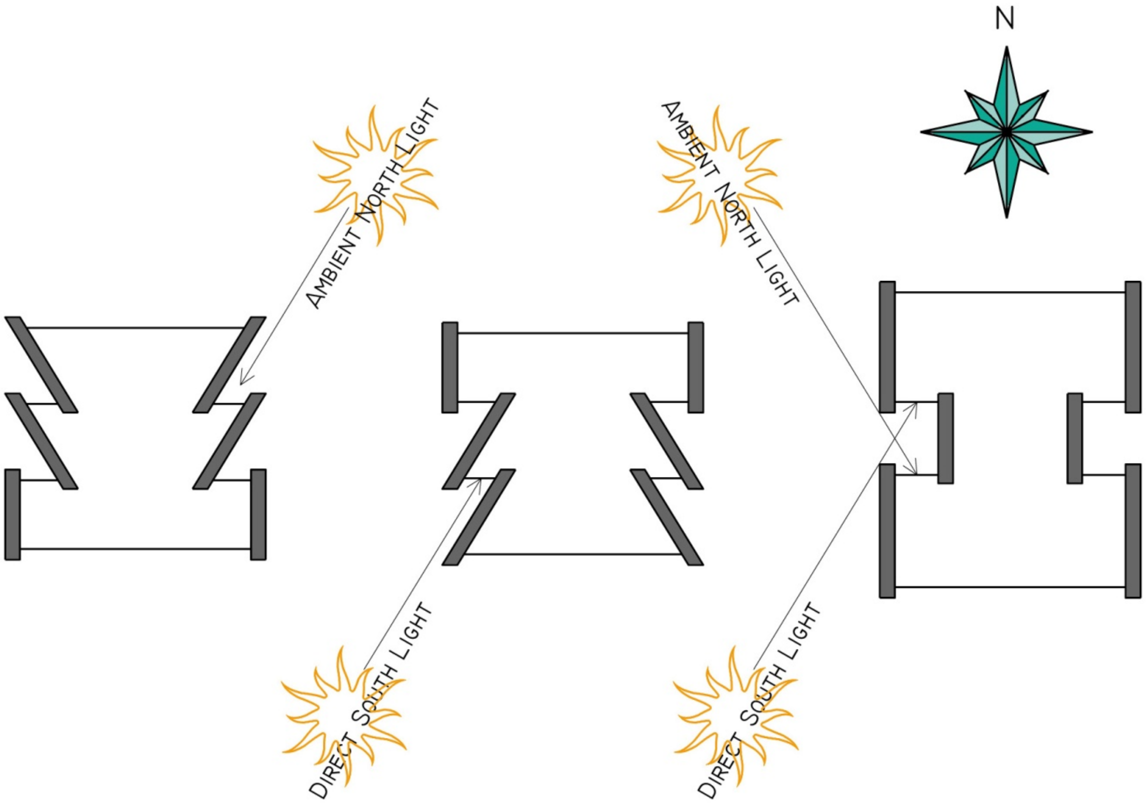
Horizontal overhangs DO NOT work on east & west facades.

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

Shading Strategies for East and West Elevations

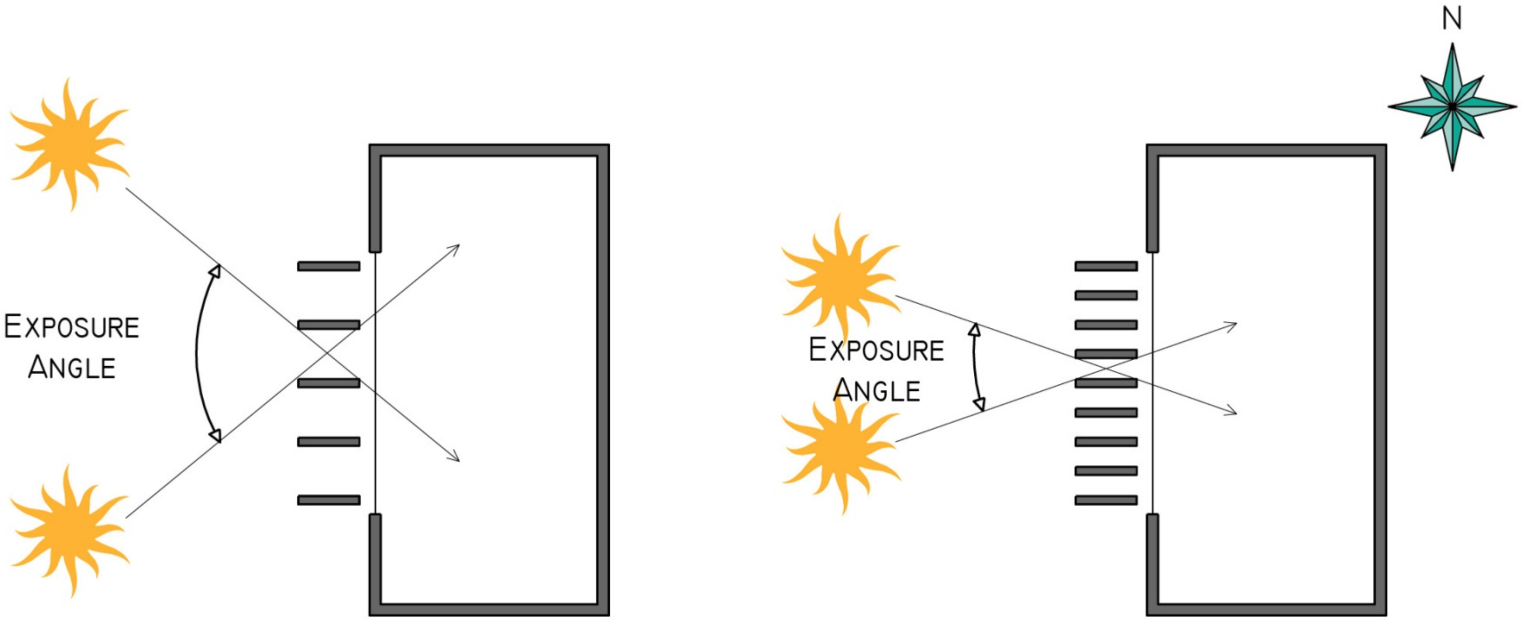
1. The best solution by far is to limit using east and especially west windows (as much as possible in hot climates)

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



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

Shading Strategies for East and West Elevations

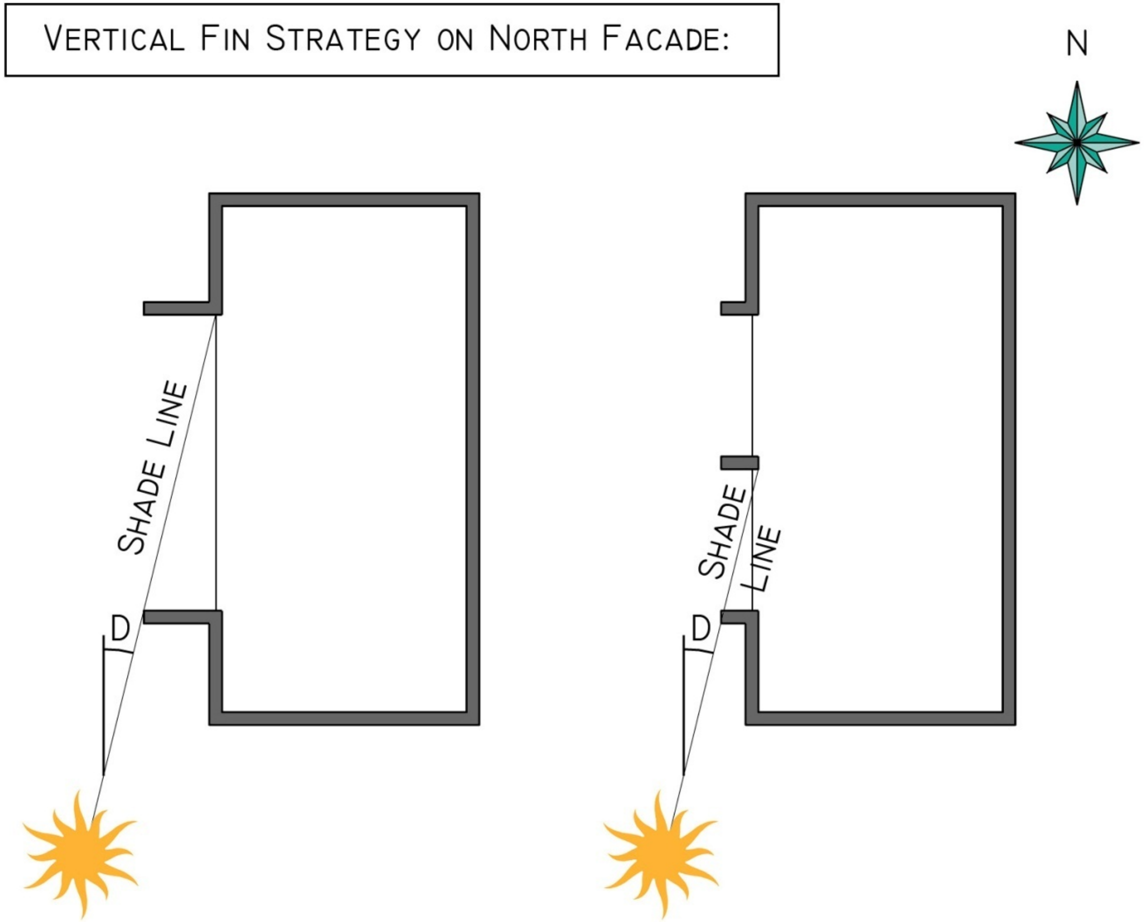


Solar Penetration is Reduced by Moving Fins Closer Together, Making Them Deeper, or Both.

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

VERTICAL FIN STRATEGY ON NORTH FACADE:

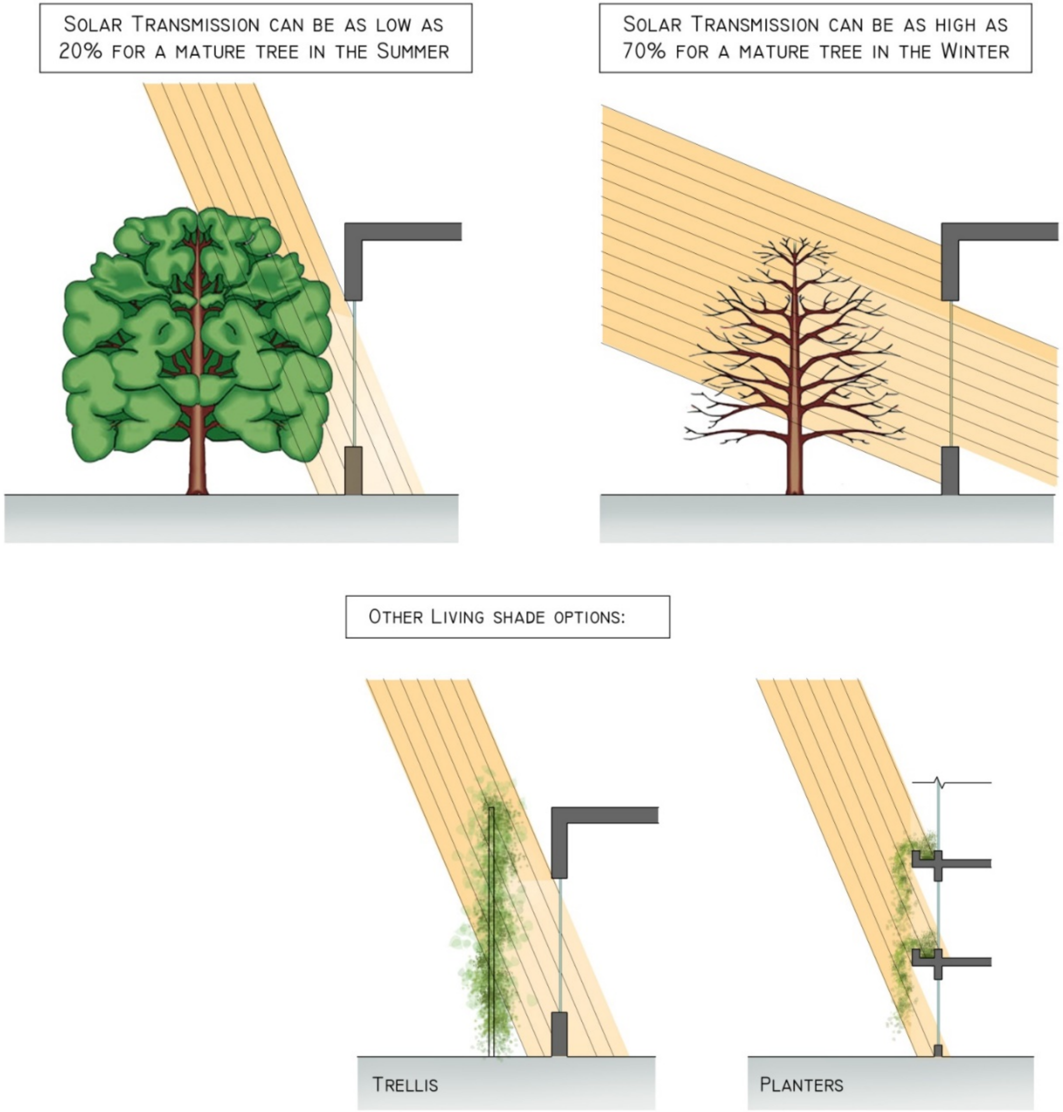


THE "SHADE LINE" AT ANGLE "D" DETERMINES FIN SPACING & DEPTH.

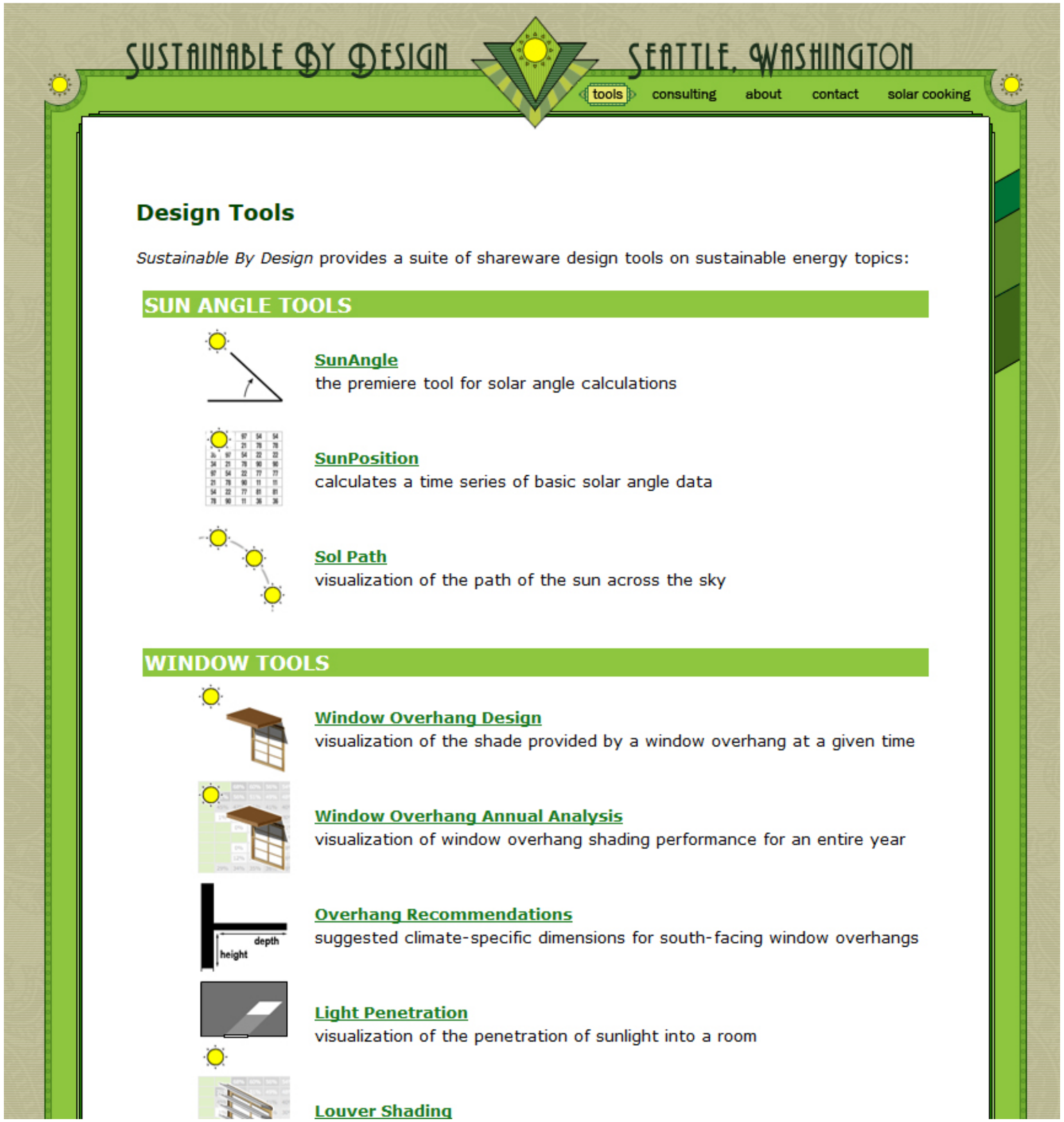
The sun also hits the façade from the north east and north west during the summer. Fins can be used to control this oblique light as well. It is a function of the latitude, window size and fin depth/frequency.

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



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

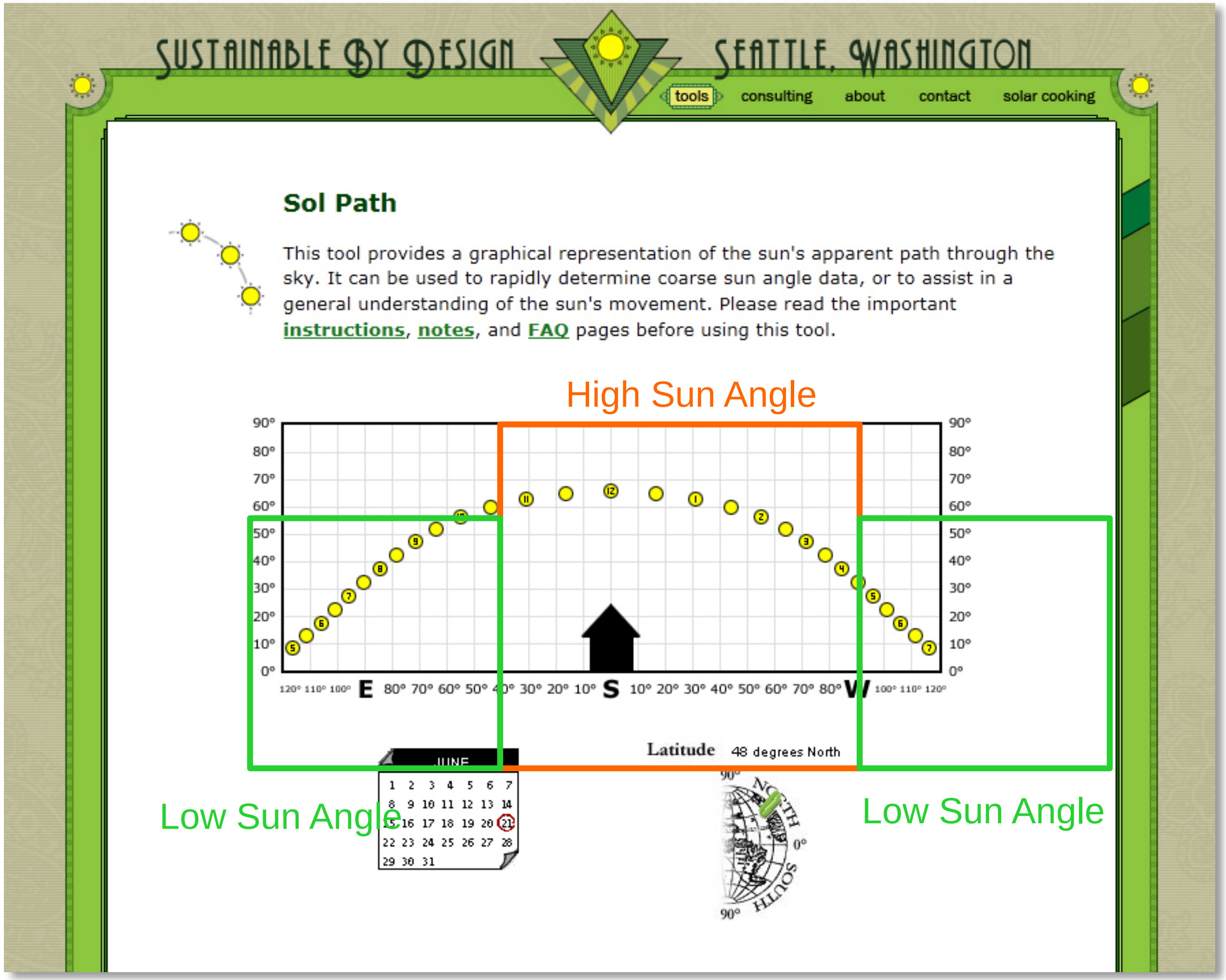
Overhang Recommendations
suggested climate-specific dimensions for south-facing window overhangs

Light Penetration
visualization of the penetration of sunlight into a room

Louver Shading

http://susdesign.com/tools.php

Differentiated Shading Strategies



Sol Path

This tool provides a graphical representation of the sun's apparent path through the sky. It can be used to rapidly determine coarse sun angle data, or to assist in a general understanding of the sun's movement. Please read the important **instructions**, **notes**, and **FAQ** pages before using this tool.

Latitude 48 degrees North

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

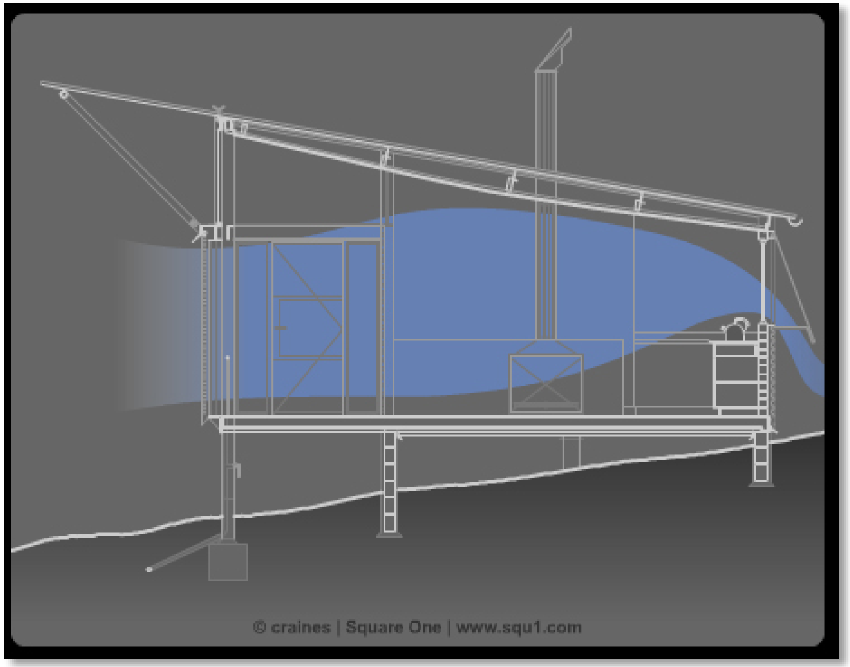
Passive Cooling Strategies:
Ventilation

- 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.



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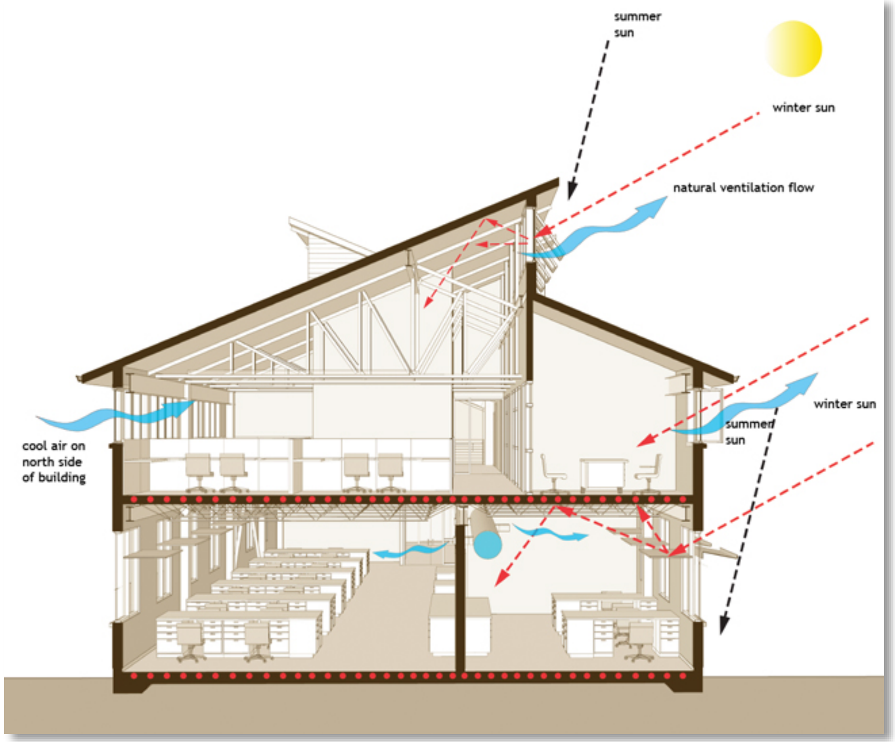
It will only work if the occupants are indeed comfortable. Otherwise they will install less efficient A/C systems to solve their comfort problems.

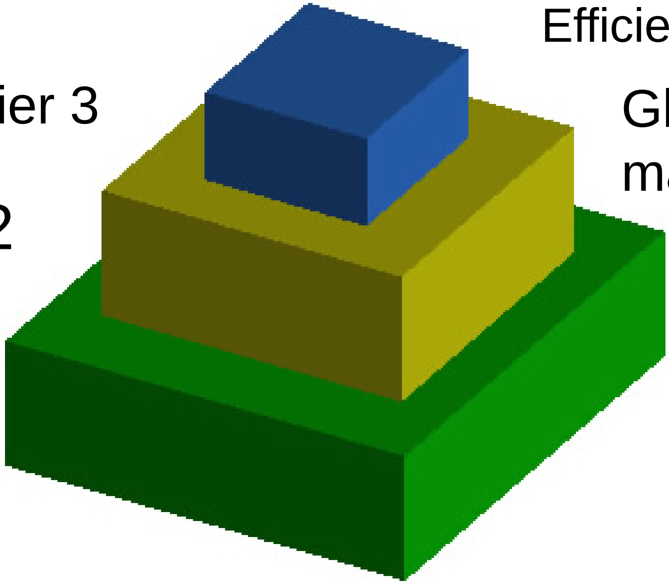
Passive Cooling Strategies:
Ventilation

- 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



Reduce loads: Daylighting

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



Tier 3

Efficient artificial Lighting w/ sensors

Tier 2

Glare, color, reflectivity and material concerns

Tier 1

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