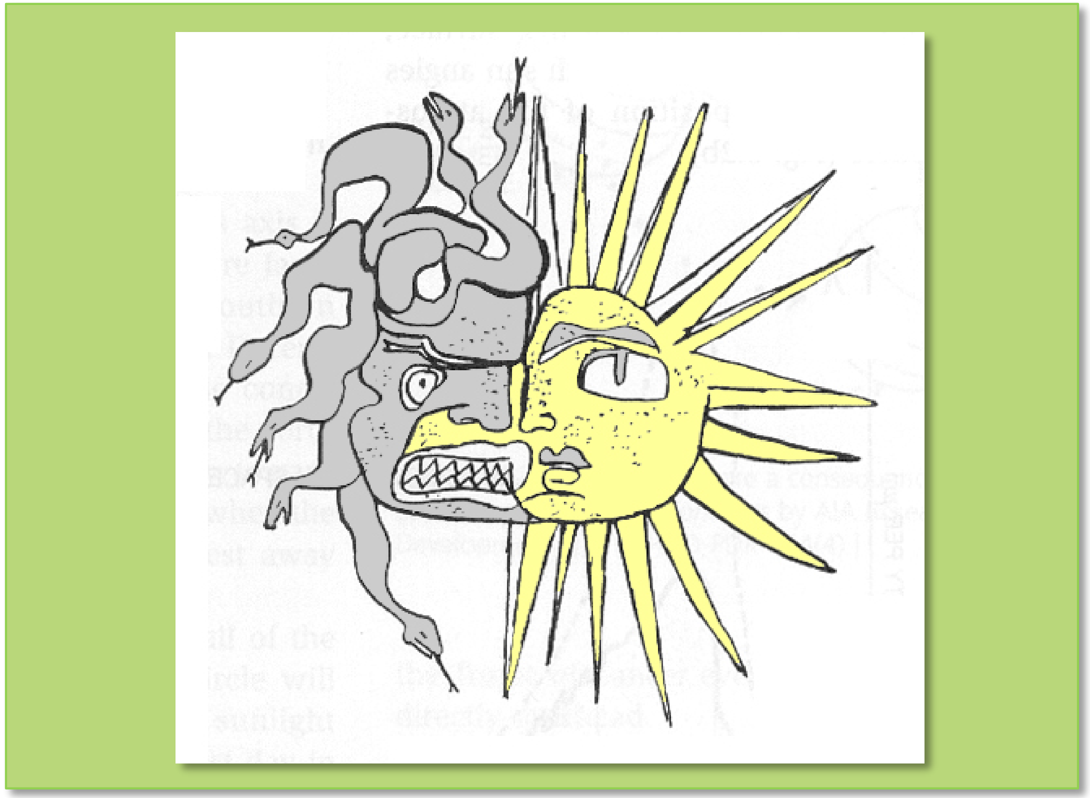
THE EVOLUTION TOWARDS CONTEMPORARY CLIMATE RESPONSIVE DESIGN



Drawing by LeCorbusier

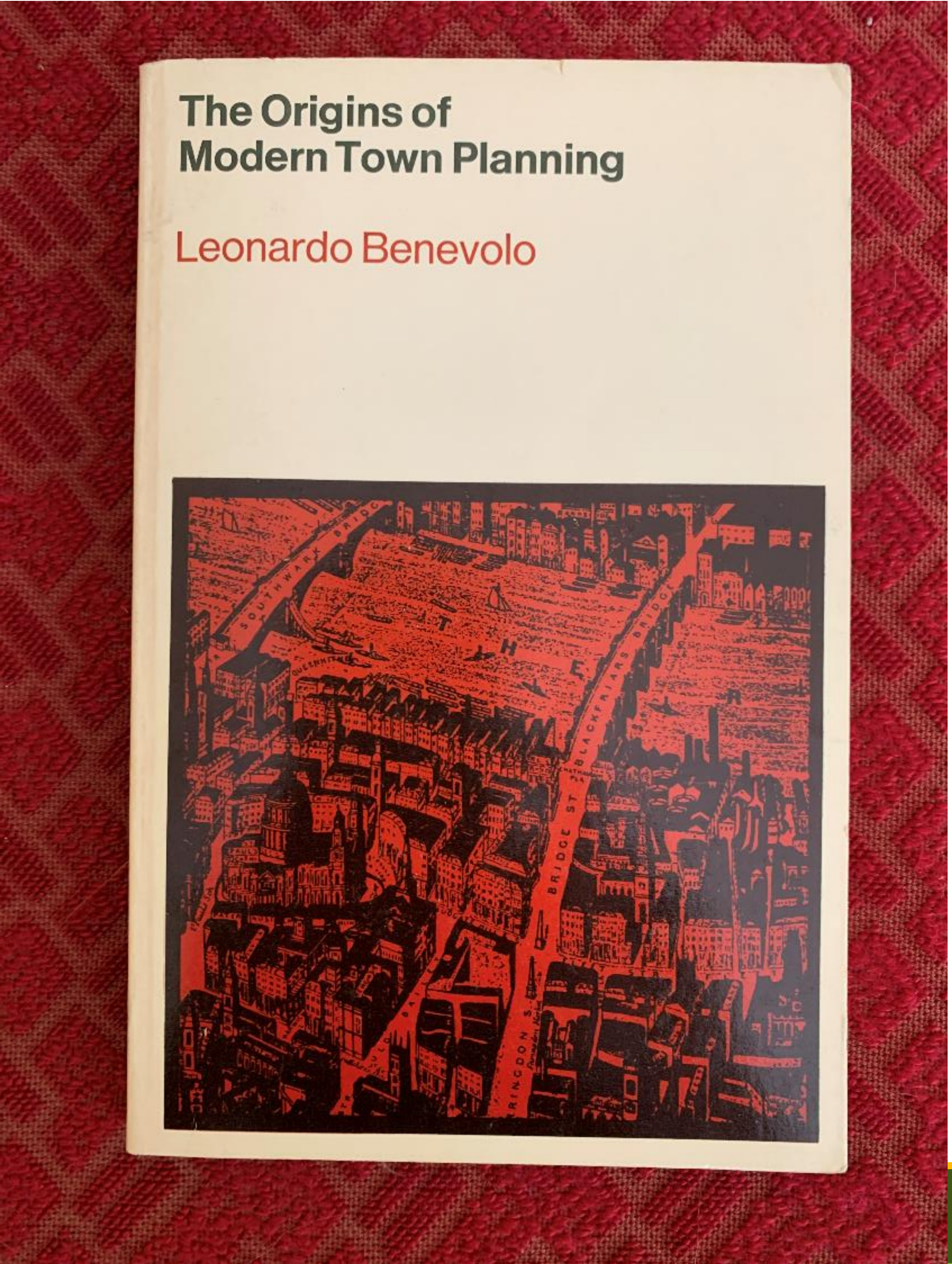
The Positive Potential of Learning From Bio-Climatic Practices

High Level Ideas:

- Did people do better with respect to **climate responsive design**
  - *Before* the interference of architects and engineers?
  - *Before* the invention of HVAC

- Was **colonialization** responsible for the eradication of successful **indigenous** building practices?

- Is **Globalization** currently responsible for taking the evolution of bad colonial practices that culminated in International Style architecture to even more places (that are climatically inappropriate)



Origins of our current climate problem

- Most of the development of North America was based on well intentioned European thinking
- Industrialized cities were generally not respectful of anything nature or climate based – there was a focus on formal layouts, organized streets, architectural styles
- Rivers were simultaneously a source of water for drinking (life), water to feed industrial processes, and the place to dump sewage
- Hard to believe but people didn’t understand the basics that when you dump feces into the river, and drink that water, you might get cholera and die

Technological advances have allowed us to build anything without concern for how it should be economically/environmentally heated and cooled.

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 Waterloo turn it the other.

Think Building Green.com


CONNECTICUT
Source: CTMLS, Inc.

ARIZONA
04 20 2012

NEW MEXICO
3785

314
BCAR 2010
FLORIDA

GLOBALIZATION

Chicago

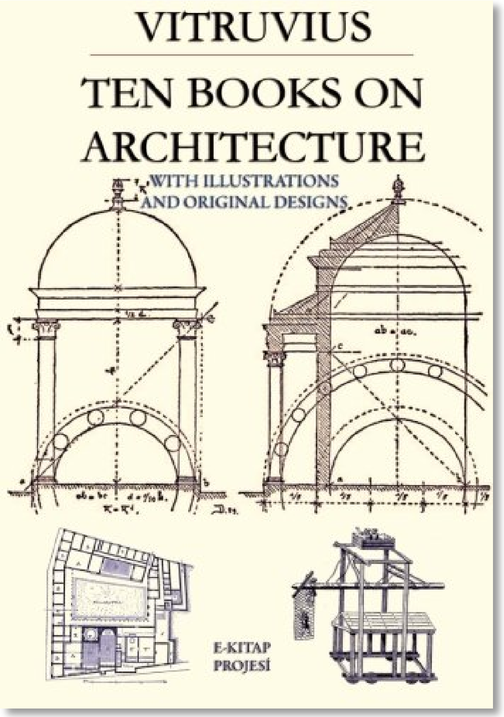
Shanghai

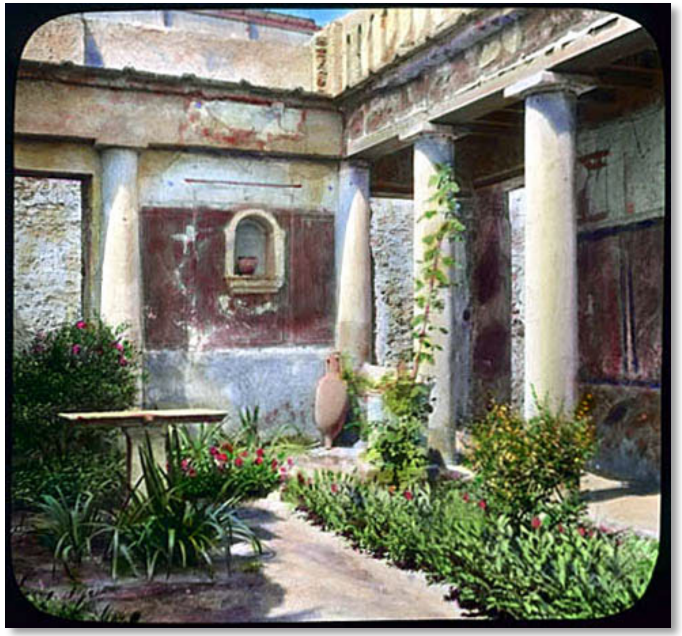
Dubai


COLD
HOT
HOTTER
GLOBALIZATION
Chicago
Shanghai
Dubai

Paris, Texas, Canada, Jamaica?? Can you tell which is which??

Climate Responsive Architecture




Pompeii: House of the Vettii


Tangier: inside a Medina House

"We must begin by taking note of the countries and climates in which homes are to be built if our designs for them are to be correct. One type of house seems appropriate for Egypt, another for Spain…one still different for Rome…It is obvious that design for homes ought to conform to diversities of climate."

Vitruvius, Architect 1st century BCE

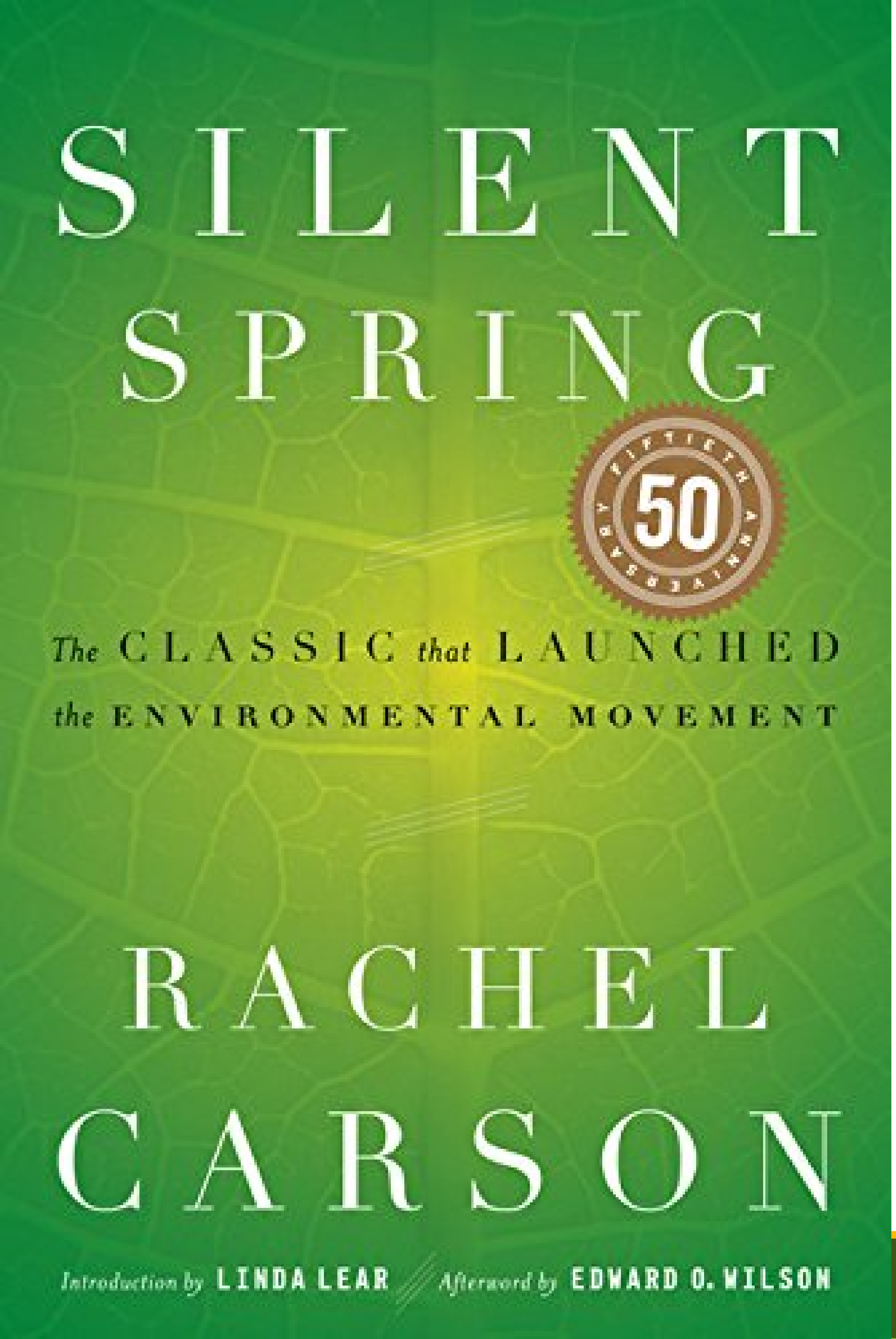
Primitive Architecture and Climate

1960

Despite meager resources, primitive people have designed dwellings that successfully meet the severest climate problems. These simple shelters often outperform the structures of present-day architects

by James Marston Fitch and Daniel P. Branch

This is the required reading that accompanies today's lecture.

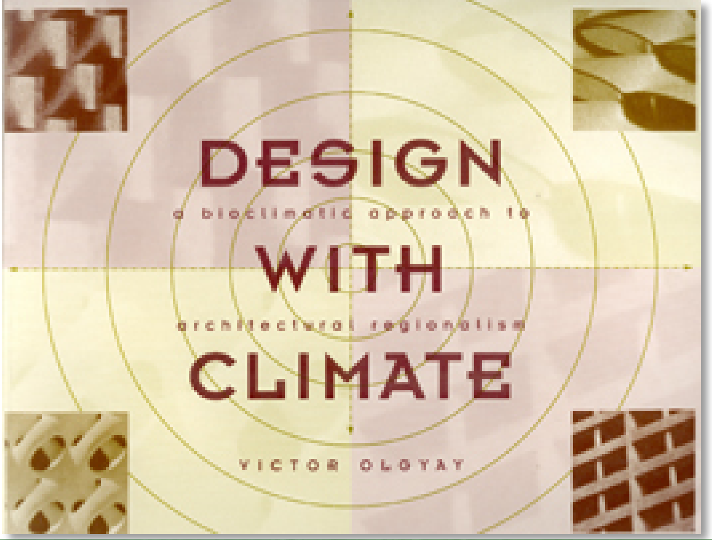


1962

This book launched environmental consciousness in the 20th century.

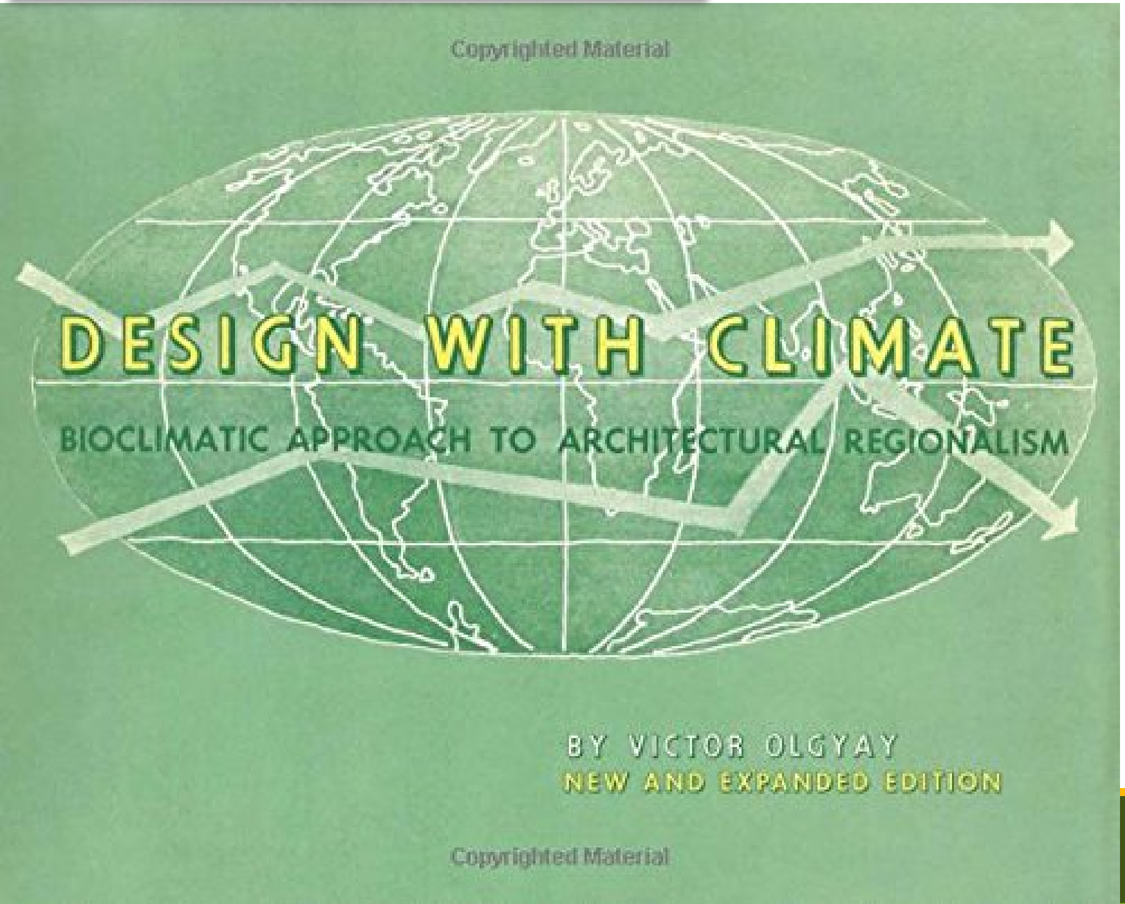
Rachel Carson connected the negative health impact of DDT (pesticide) on human health.

Surprisingly before that time people didn't appreciate that you sprayed it on plants, it rained, the rainwater entered the ground, ended up in ponds, cattle drank the water, and people ingested DDT.



1963

Victor Olgyay establishes the relationship between original indigenous practices, building form, climate (based on Fitch and Branch) and *human comfort*.



2015

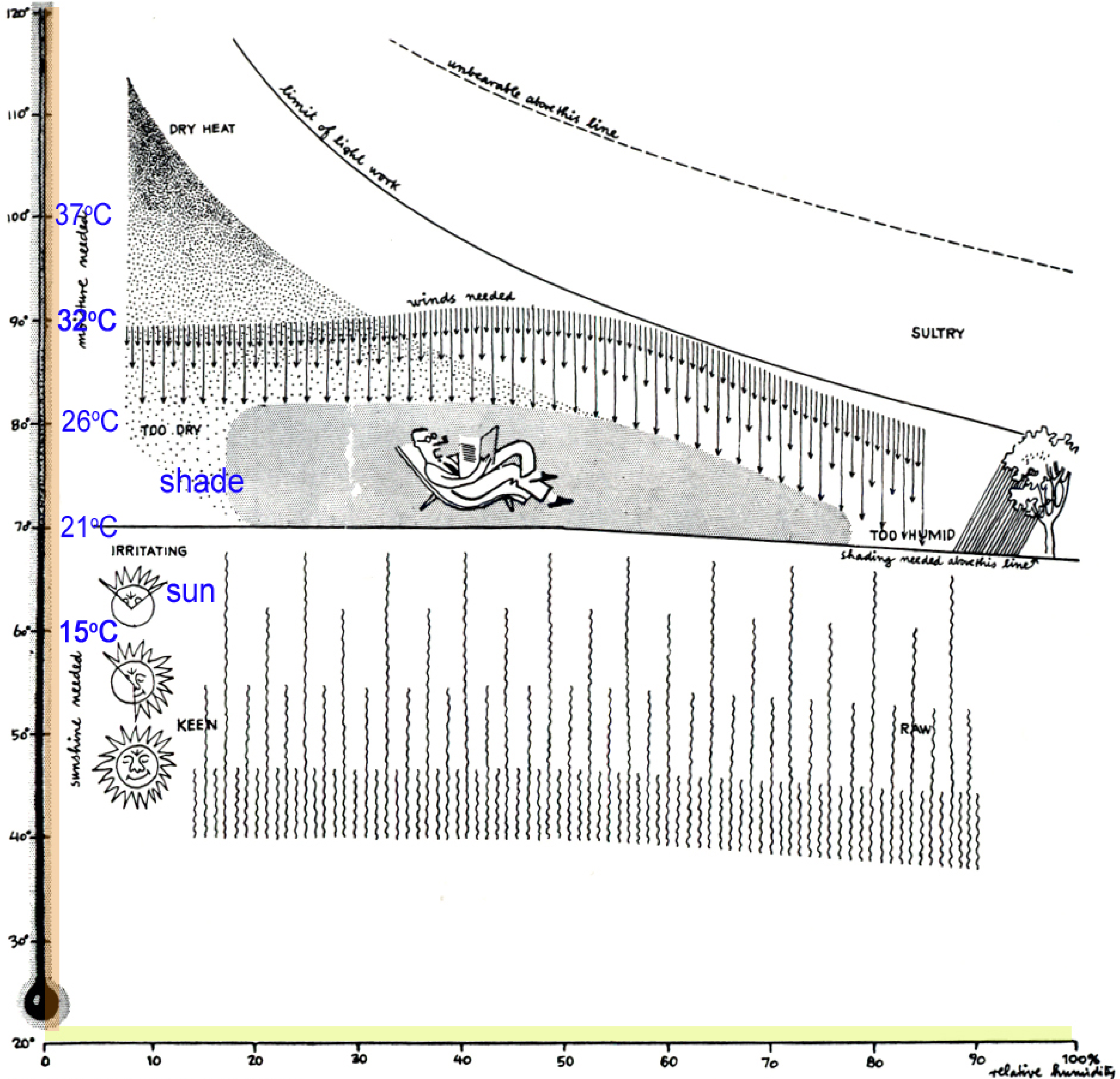
The second environmental movement demanded a reprint to the out of print original text.

Olgyay's basic ideas about climate and its relationship to **HUMAN COMFORT** were to become the basis for thinking in current sustainable design.

Victor Olgyay, 1963, introduced the concept of the **COMFORT ZONE**.

There is little point of saving energy if the building is not comfortable for the occupants.

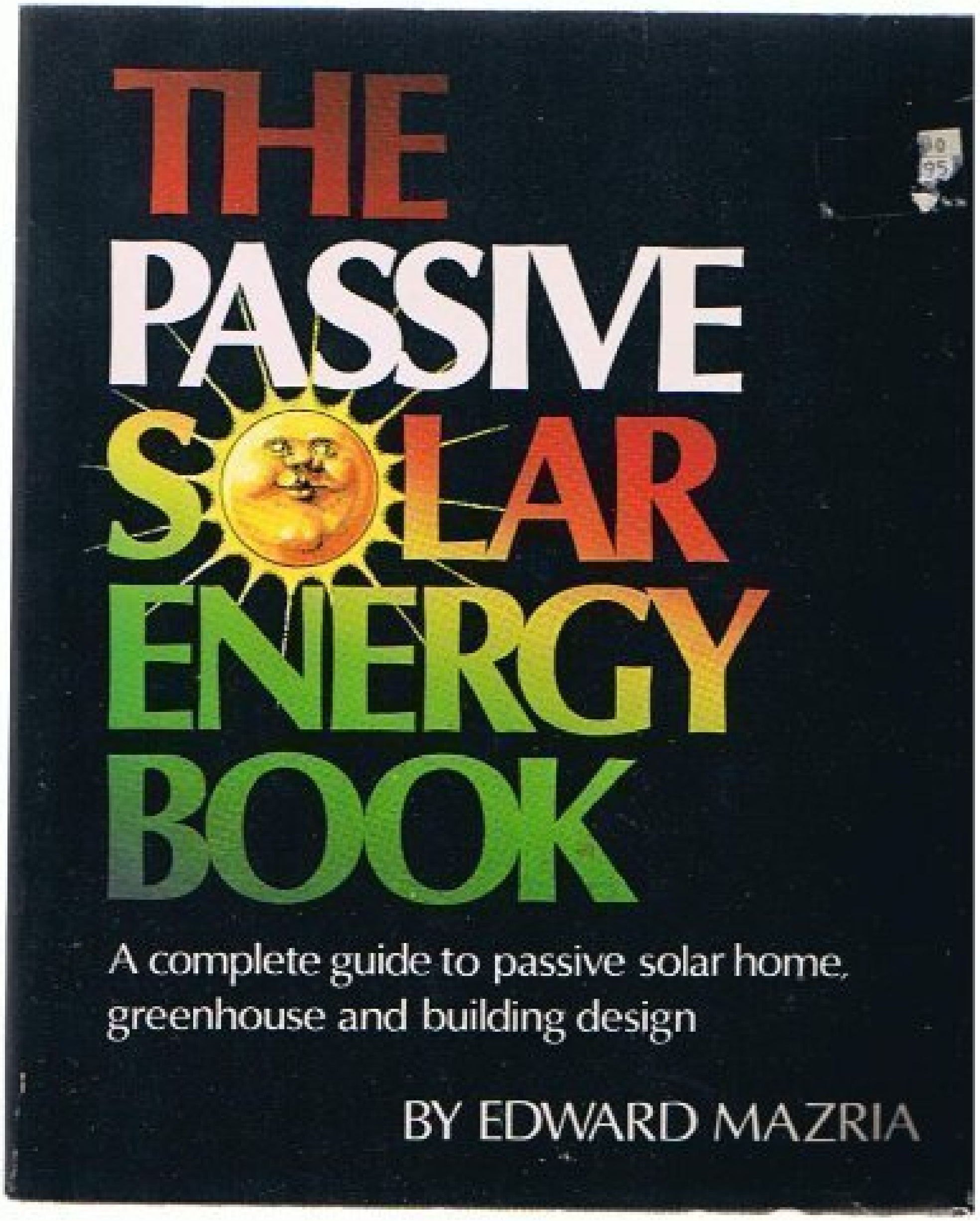
You can have reasonable comfort without heating or AC.



46. Schematic bioclimatic index.

Farnsworth House, 1945-51

Occupant thermal comfort was never a priority in highly formal projects like these. Mies didn't even want the owner to install drapery! The windows are all sealed. No natural ventilation. No built in shading. The majority of modern buildings were constructed sealed.



1979

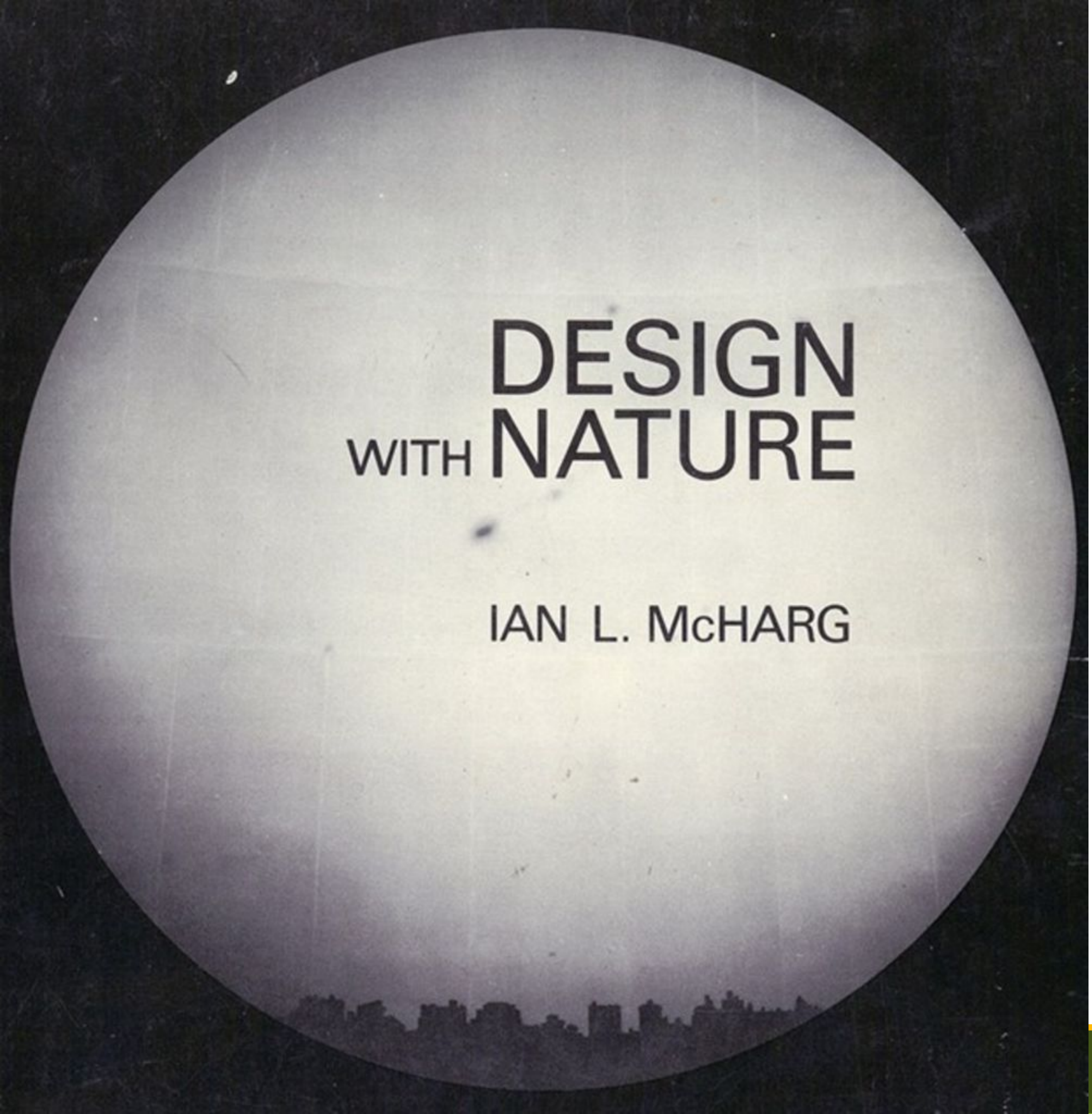
The 1970s saw a surge in interest in the design of solar responsive buildings. Edward Mazria' book became the basis of work in this area.

2009

Mazria founded architecture2030 and challenged all architects to design to zero carbon operating energy by the year 2030.

https://architecture2030.org/

architecture 2030



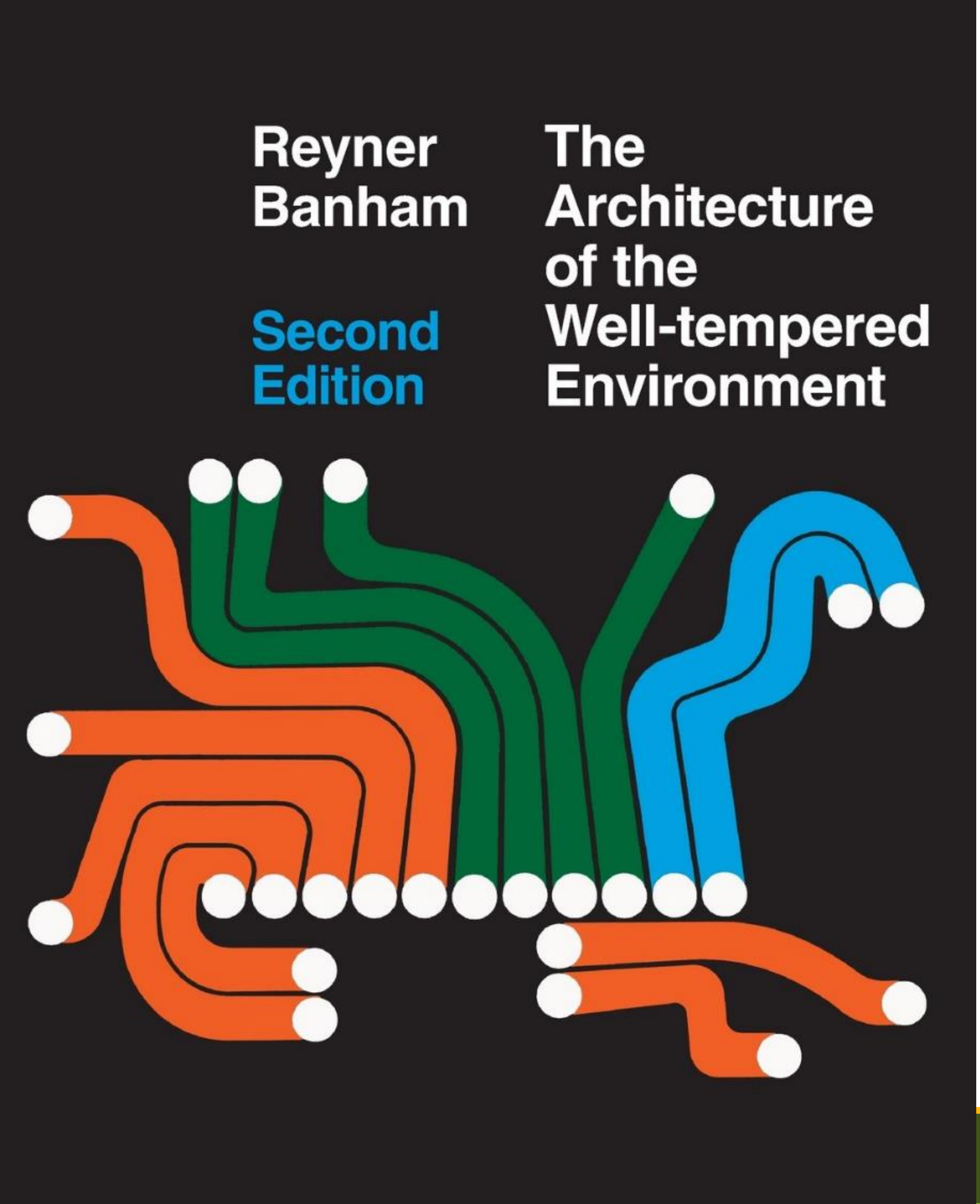
1969

Ian McHarg looks at the relationship of landforms to planning decisions.

Works against the modern notion of eradicating the landscape.

1995

The out of print book is resurrected as its ideas become the basis of current sustainable practices in development ideas.

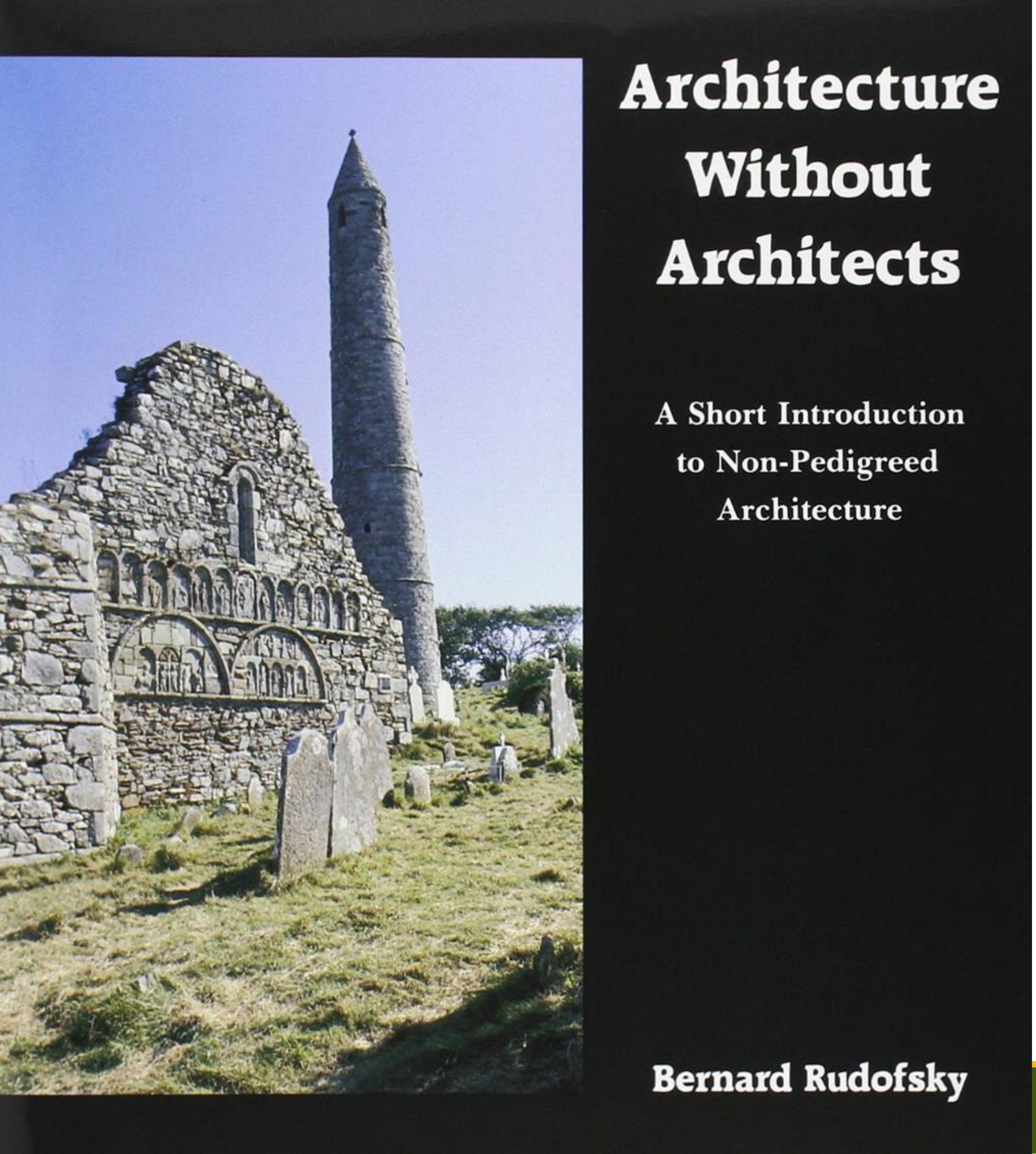


1984

This important text looked at the failure of Modern Architecture as it became reliant on mechanical heating and cooling systems.

The abandonment of good building practices that had environmental benefits.

Reyner Banham was a highly respected writer and so had a lot of influence.

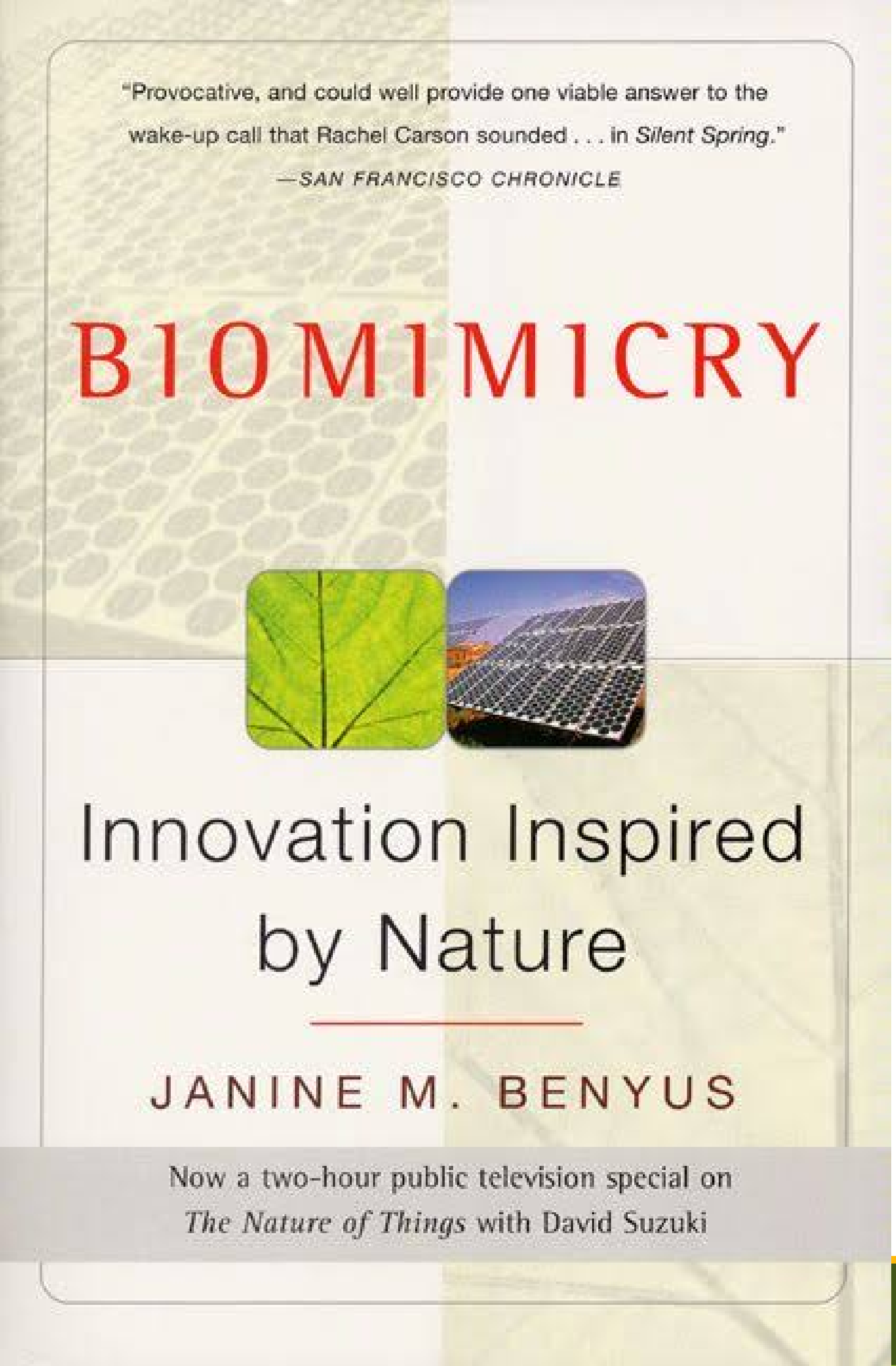


1987

This seminal text looked at historic architecture from around the world.

It didn’t have an environmental focus, necessarily, but was looking at building practices that were less formally driven.

Buildings that relied on local materials, ideas and skills.

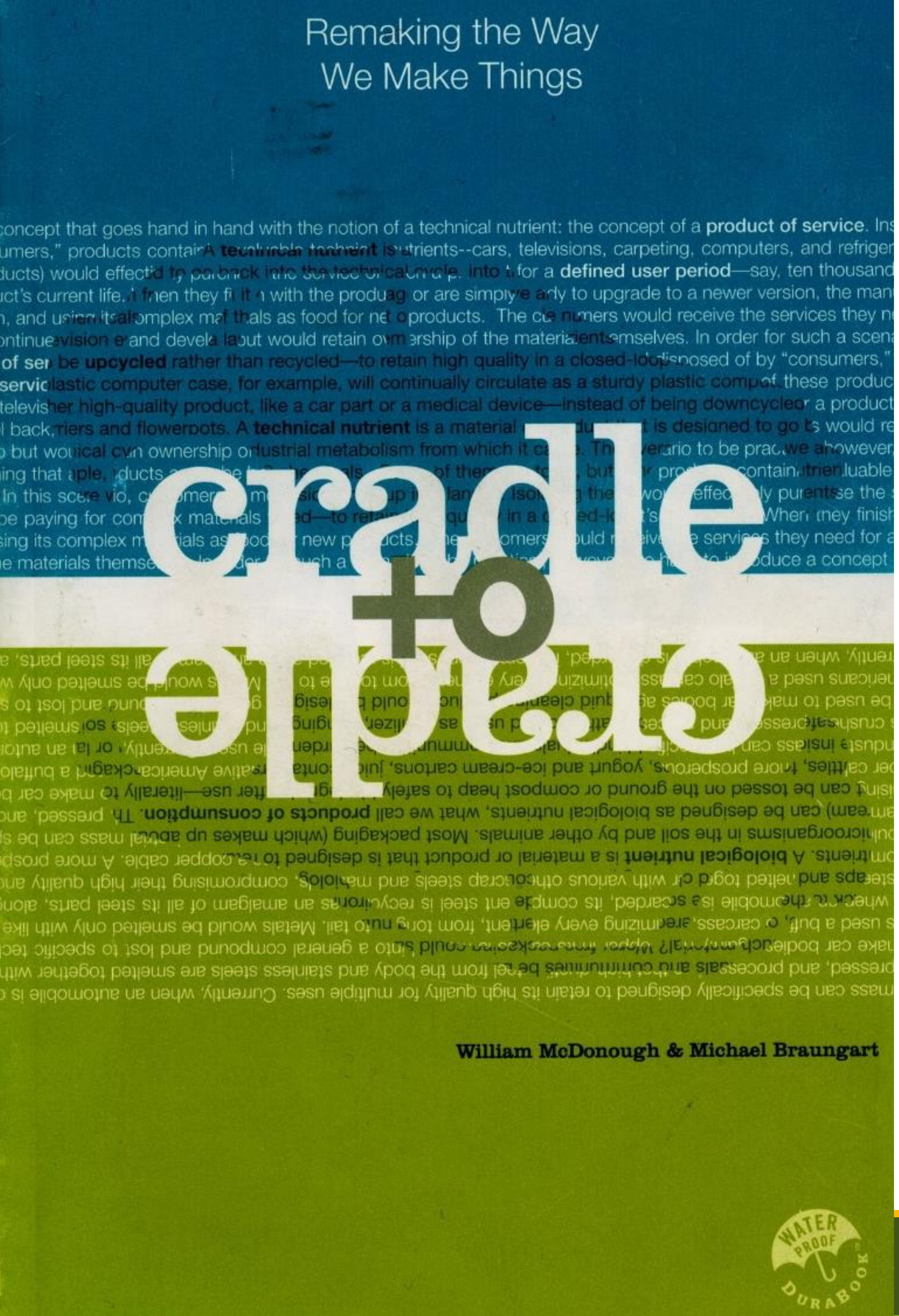


1997

Janine Benyus introduces the concept of Biomimicry.

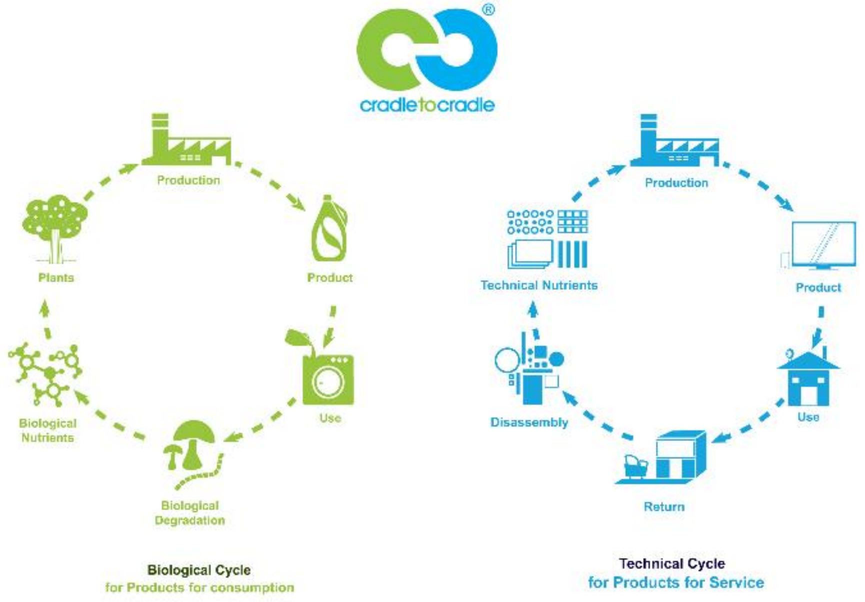
The larger idea is that nature has already solved so many problems that people/technology struggles to solve.

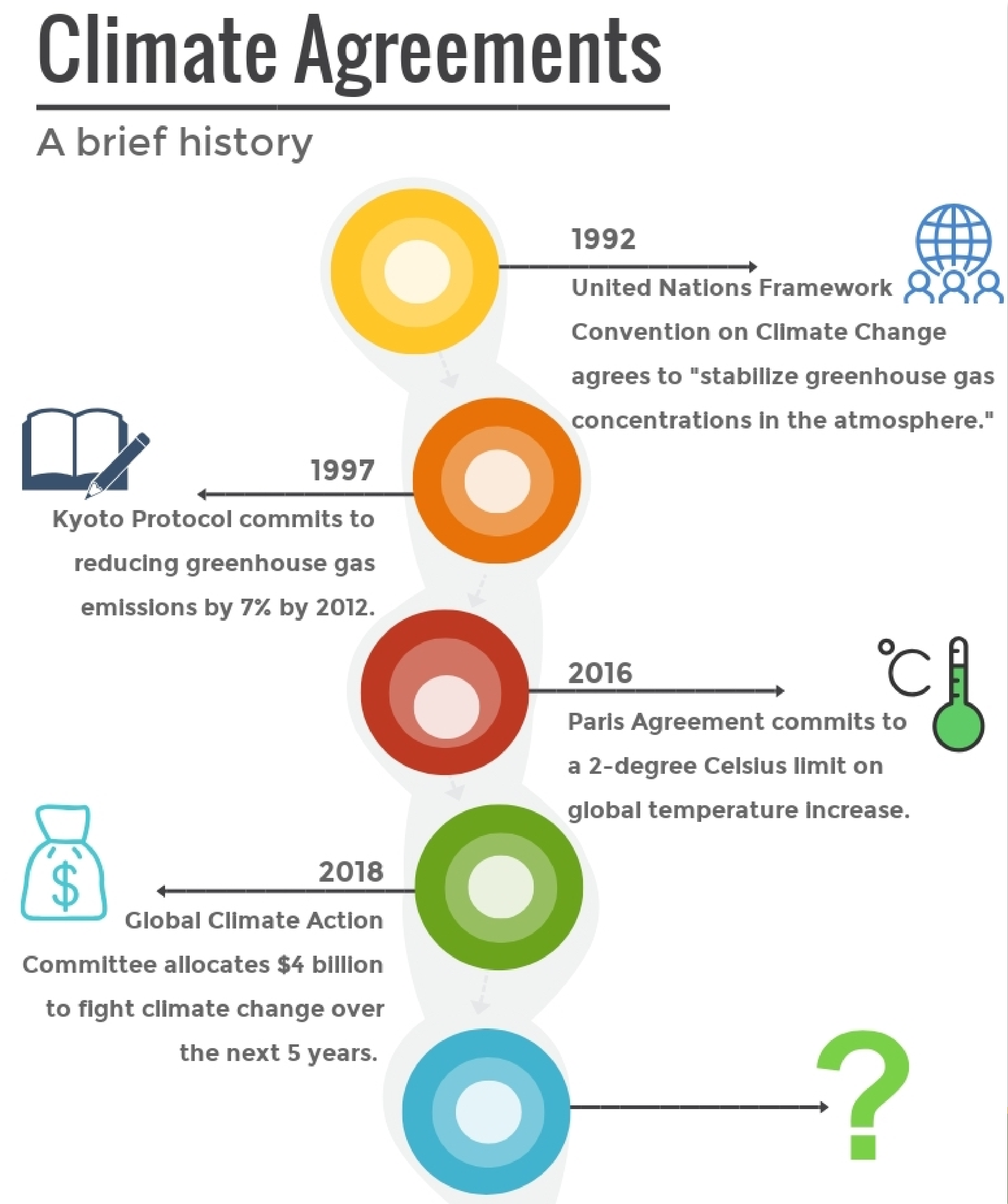
If we closely examine how nature does things, we can figure out how to adapt these functions to our own fabricated objects.



2002

William McDonough and Michael Braungart put for the idea that instead of objects being inevitable trashed, that we can change the way we make things to make use of waste to make new objects. All materials have value and all are limited in availability.



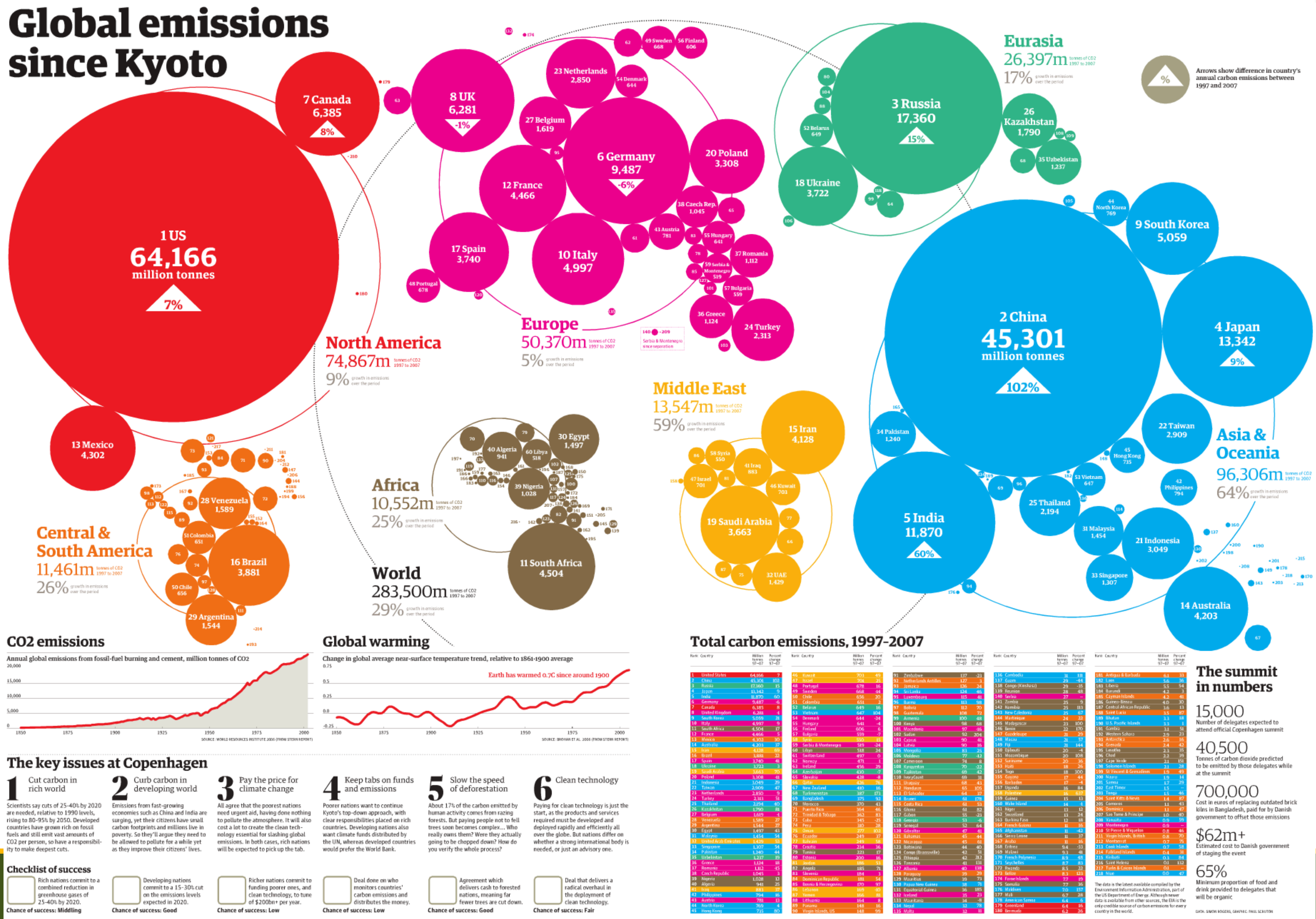


Many efforts have been made to get the countries of the world working to slow down climate change

None have been very effective

Much of the disagreement lies in disparity in population density, poor vs rich countries, developed vs developing countries

Developing countries do not think it fair to thwart their "progress" towards having lifestyles equal to developed countries.


Global emissions since Kyoto
Arrows show difference in country's annual carbon emissions between 1997 and 2007
%
1 US
64,166
million tonnes
7%
7 Canada
6,385
8%
13 Mexico
4,302
North America
74,867m tonnes of CO2 1997 to 2007
9% growth in emissions over the period
8 UK
6,281
-1%
23 Netherlands
2,850
54 Denmark
644
49 Sweden
668
56 Finland
606
27 Belgium
1,619
6 Germany
9,487
-6%
20 Poland
3,308
12 France
4,466
38 Czech Rep.
1,045
43 Austria
781
55 Hungary
641
37 Romania
1,112
59 Serbia & Montenegro
519
57 Bulgaria
559
17 Spain
3,740
10 Italy
4,997
48 Portugal
678
36 Greece
1,124
24 Turkey
2,313
Europe
50,370m tonnes of CO2 1997 to 2007
5% growth in emissions over the period
3 Russia
17,360
15%
52 Belarus
649
26 Kazakhstan
1,790
35 Uzbekistan
1,237
18 Ukraine
3,722
Eurasia
26,397m tonnes of CO2 1997 to 2007
17% growth in emissions over the period
28 Venezuela
1,589
51 Colombia
651
16 Brazil
3,881
50 Chile
656
29 Argentina
1,544
Central & South America
11,461m tonnes of CO2 1997 to 2007
26% growth in emissions over the period
30 Egypt
1,497
40 Algeria
941
60 Libya
518
39 Nigeria
1,028
11 South Africa
4,504
Africa
10,552m tonnes of CO2 1997 to 2007
25% growth in emissions over the period
World
283,500m tonnes of CO2 1997 to 2007
29% growth in emissions over the period
Middle East
13,547m tonnes of CO2 1997 to 2007
59% growth in emissions over the period
15 Iran
4,128
58 Syria
550
41 Iraq
883
47 Israel
701
46 Kuwait
703
19 Saudi Arabia
3,663
32 UAE
1,429
2 China
45,301
million tonnes
102%
34 Pakistan
1,240
5 India
11,870
60%
44 North Korea
769
9 South Korea
5,059
4 Japan
13,342
9%
22 Taiwan
2,909
45 Hong Kong
735
53 Vietnam
647
42 Philippines
794
25 Thailand
2,194
31 Malaysia
1,454
21 Indonesia
3,049
33 Singapore
1,307
14 Australia
4,203
Asia & Oceania
96,306m tonnes of CO2 1997 to 2007
64% growth in emissions over the period
CO2 emissions
Annual global emissions from fossil-fuel burning and cement, million tonnes of CO2
Global warming
Change in global average near-surface temperature trend, relative to 1861-1900 average
Earth has warmed 0.7C since around 1900
Total carbon emissions, 1997-2007
The key issues at Copenhagen
1 Cut carbon in rich world
2 Curb carbon in developing world
3 Pay the price for climate change
4 Keep tabs on funds and emissions
5 Slow the speed of deforestation
6 Clean technology
Checklist of success
Chance of success: Middling
Chance of success: Good
Chance of success: Low
Chance of success: Low
Chance of success: Good
Chance of success: Fair
The summit in numbers
15,000
Number of delegates expected to attend official Copenhagen summit
40,500
Tonnes of carbon dioxide predicted to be emitted by those delegates while at the summit
700,000
$62m+
Estimated cost to Danish government of staging the event
65%
Minimum proportion of food and drink provided to delegates that will be organic

The Global Warming Pie

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

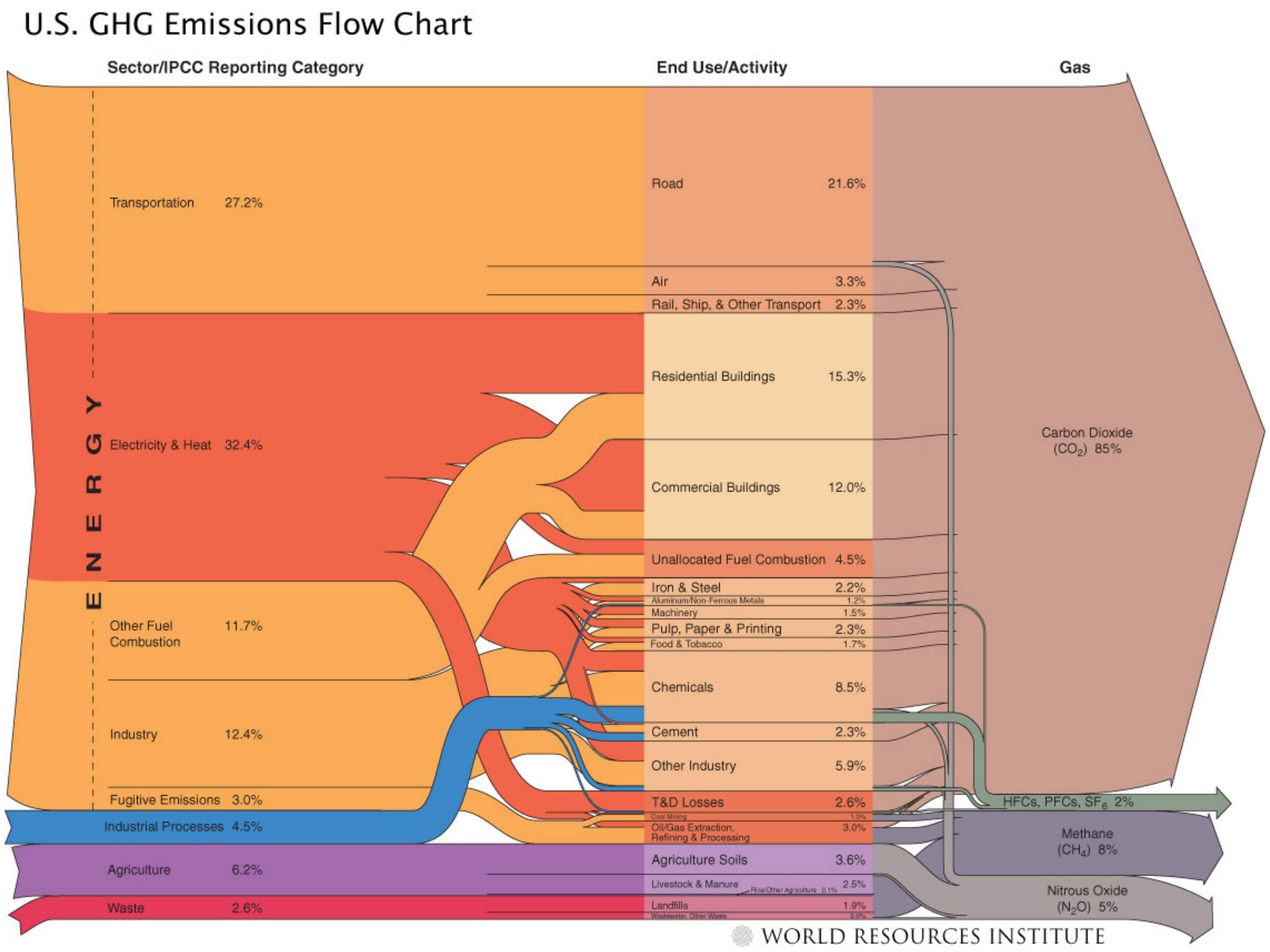
Buildings and the layout of our urban environments are responsible for climate change.

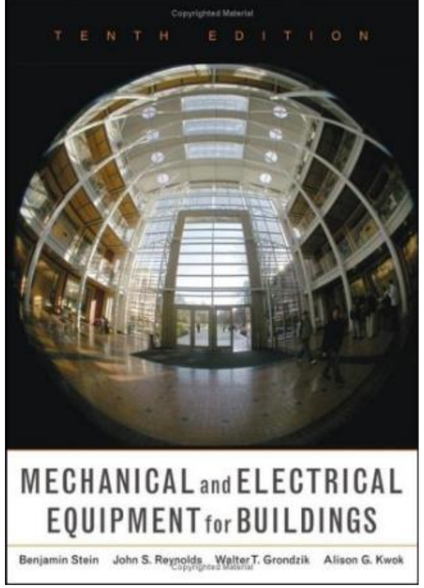
Engineers and architects are the professionals that must learn and apply better ways of designing buildings to reduce their greenhouse gas emissions

This means reducing their operating energy requirements and dependence on fossil fuels

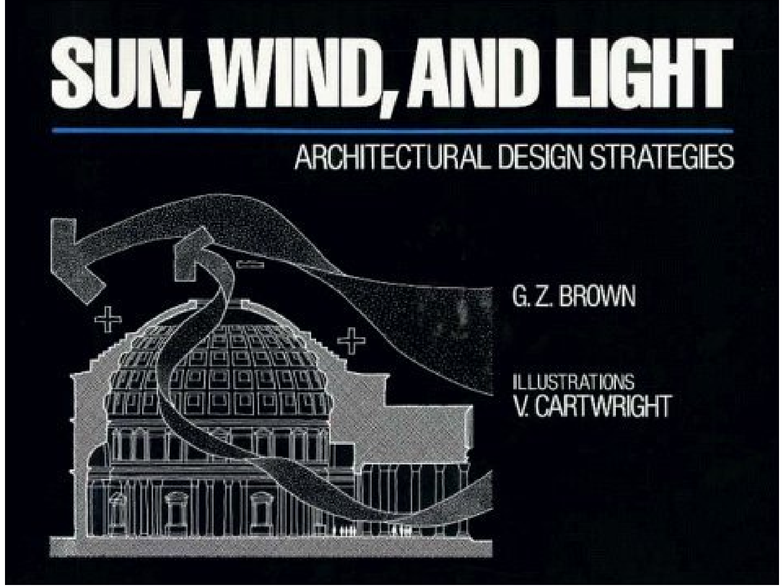
Ecological justice: it is the poor and marginalized that are the worst impacted by climate change. Desertification, floods, extreme weather events.

Emissions and their Sources

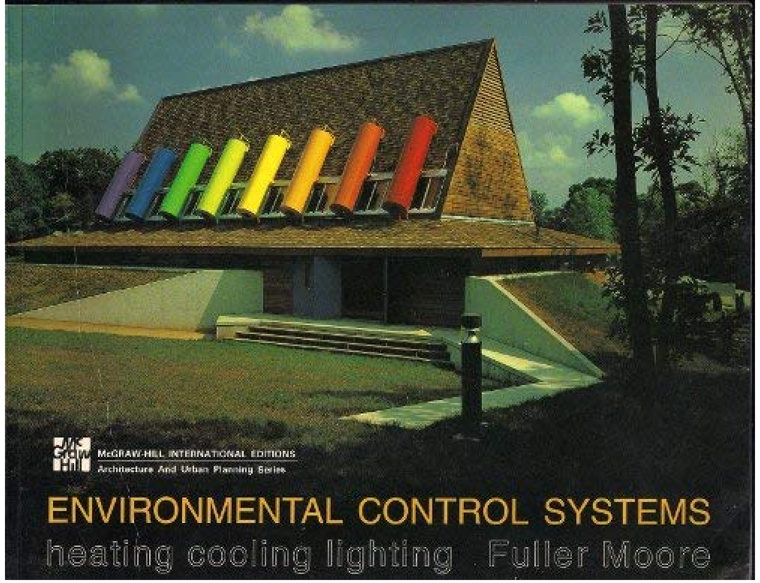




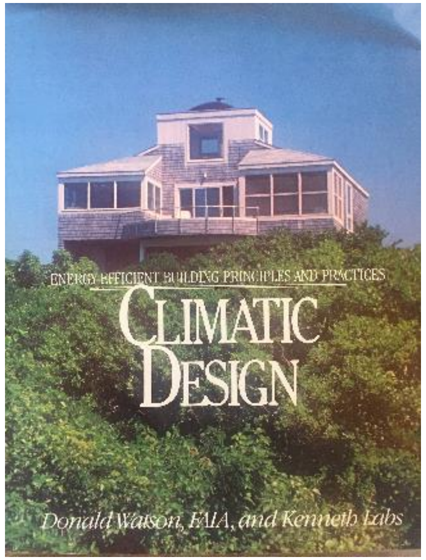
1980



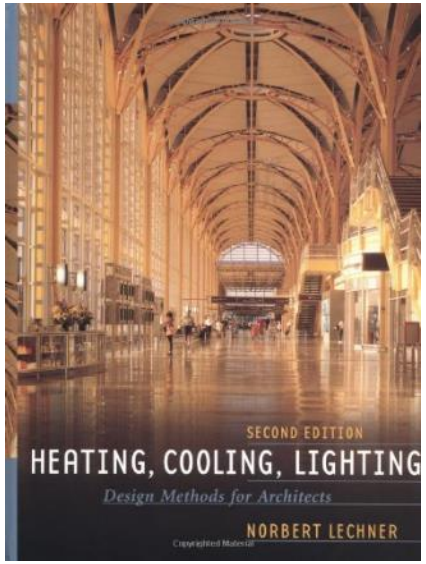
1985



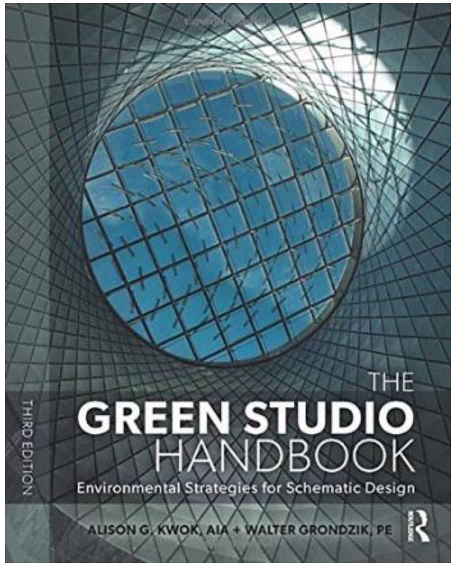
1993



1983



1991



2006

SOCIETY OF BUILDING SCIENCE EDUCATORS

All of these authors are colleagues.
They work at different universities.
I am friends with all of them through my work with SBSE.

Why do we build buildings, NOW???

Initially, it was for shelter from the outside weather, and thus, survival.

THEN, people desired a certain minimum level of COMFORT, but would modify clothing or expectations as a function of the weather.

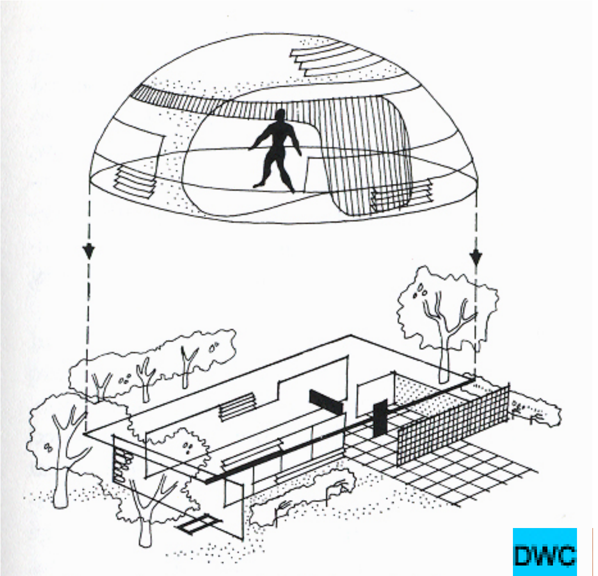
NOW, people (due to the invention of HVAC) expect to be held at a constant level of COMFORT, in spite of the weather or location (in the world).

Climate and Housing

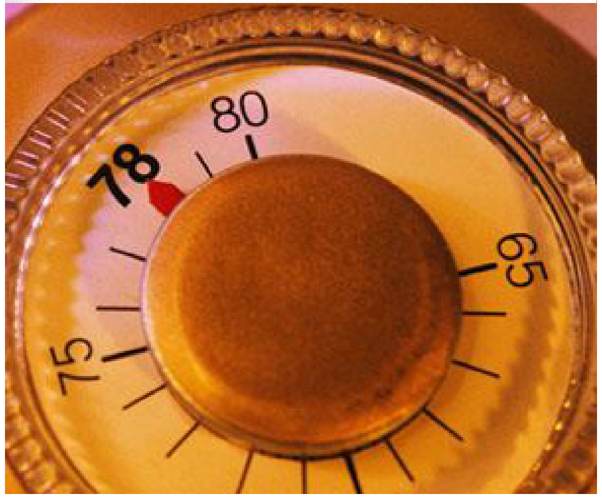
In its most fundamental form, housing is shelter – a system of components designed to mediate the existing environments (which is less than satisfactory in some way) into a comfortable and satisfactory environment. Historically, shelter has been built

- to reduce the range of local climatic variations;
- to avoid some of the heat of the sun in hot climates,
- to conserve heat in cold climates,
- to welcome the breezes when they can provide desired cooling,
- to avoid winds when they serve to compound the problems of an already cold environments,
- to admit light in sufficient amounts for task lighting and to keep out excessive or unnecessary light.

Shelter and Environment



35. Theoretical approach to balanced shelter.

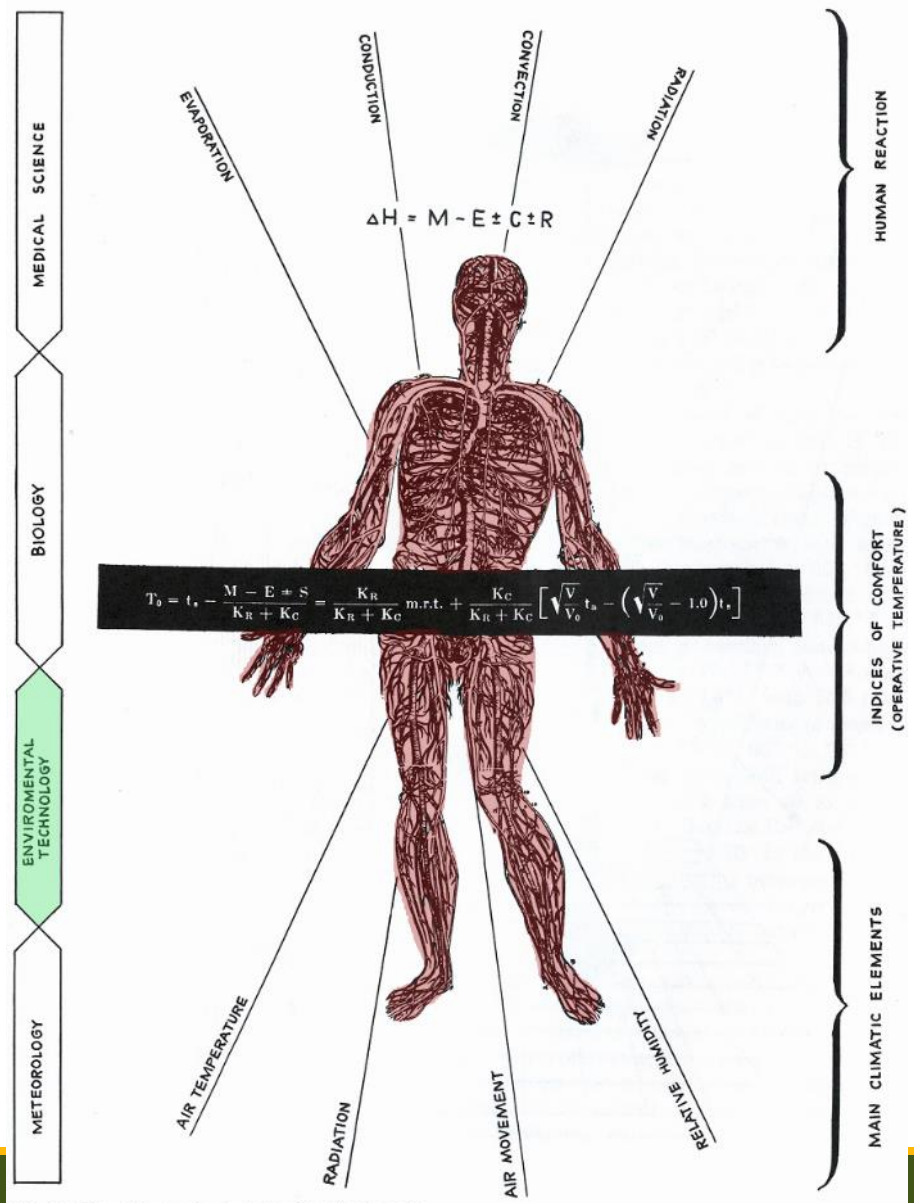


• Shelter is the main instrument for fulfilling the requirements of comfort. It modifies the natural environment to approach optimum conditions of livability.

• The architect and engineer's problem is to produce an environment that will not place undue stress upon the body's heat-compensation mechanism

• *It is NOW our task to make utmost use of* ***the natural means*** *available in order to produce a more healthful and livable building, and to achieve a saving in cost by keeping to a minimum the use of mechanical aids for climate control – thereby reducing demand for fossil fuels and lowering CO2 levels*

The Effects of Climate on People



36. Relation of human body to the climatic elements.

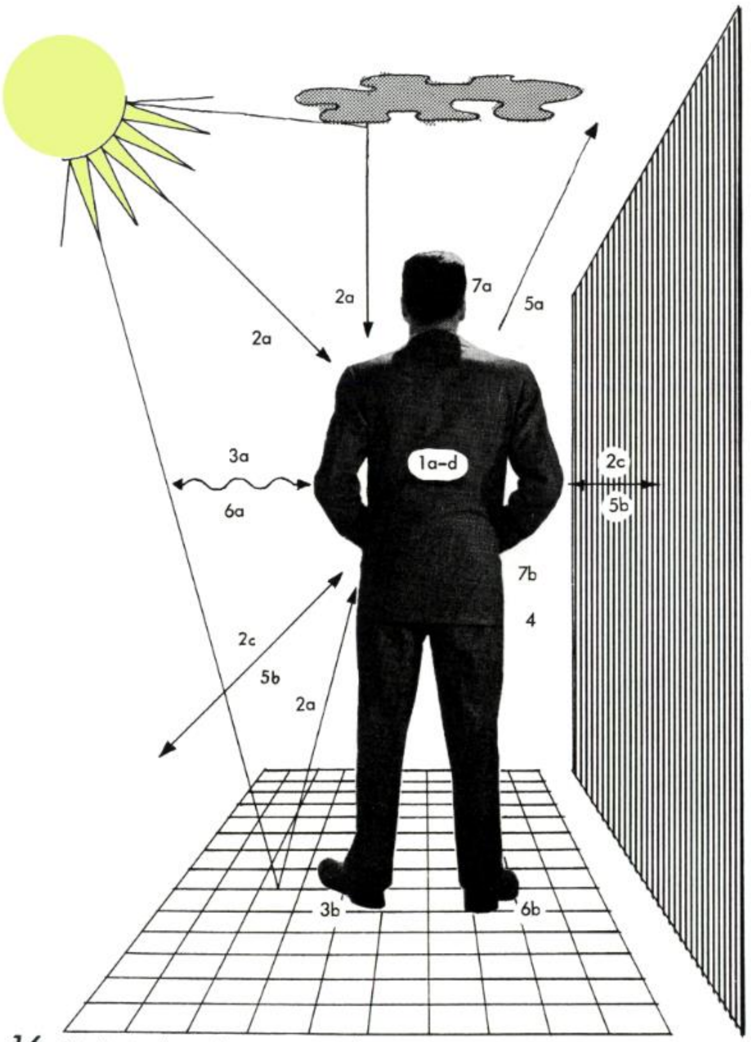
Major elements of climatic environment which affect human comfort are:

- Air temperature
- Radiation
- Air movement (Wind Speed)
- Humidity

"Thermal Comfort – that condition of mind which expresses satisfaction with the thermal environment."

ASHRAE Standard 55-66

Bodily Heat Transfer



16 37. Heat exchange between man and surroundings.

Heat Gains:
- Metabolism (conversion of food to activity and heat)
- Absorption of Radiant Energy
- Heat Conduction Toward Body

Heat Loss Through:
- Evaporation
- Conduction
- Convection (Wind Chill Factor)
- Radiation

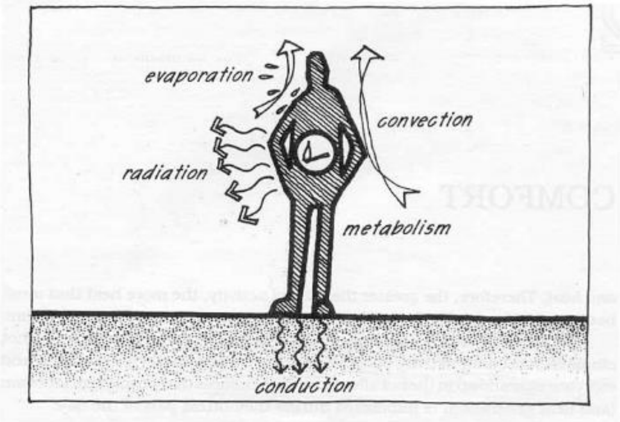
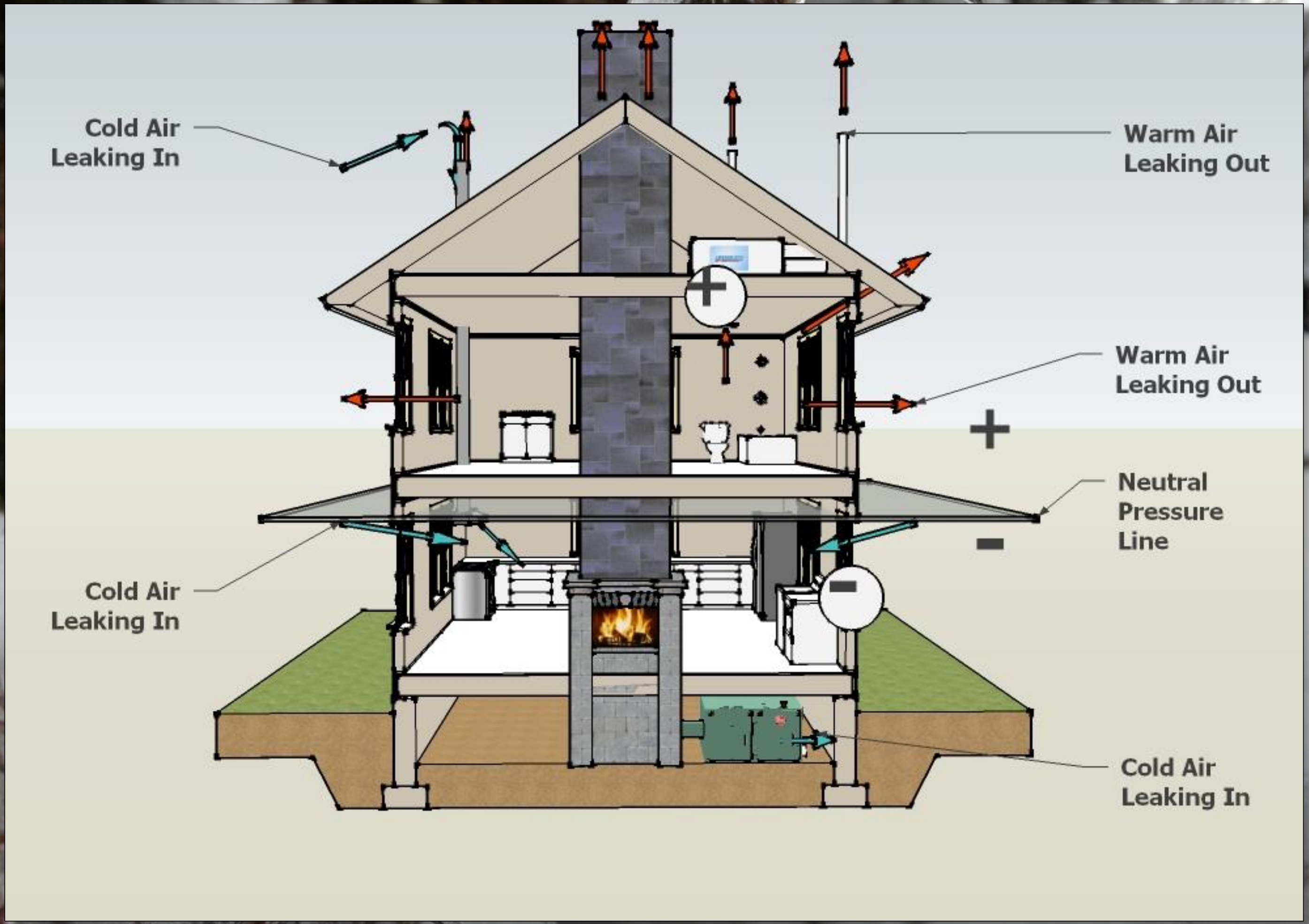


Figure 2.1: Maintaining the thermal balance by equalizing heat gain (due primarily to metabolic heat generation) and heat losses (by convection, radiation, conduction, and evaporation).

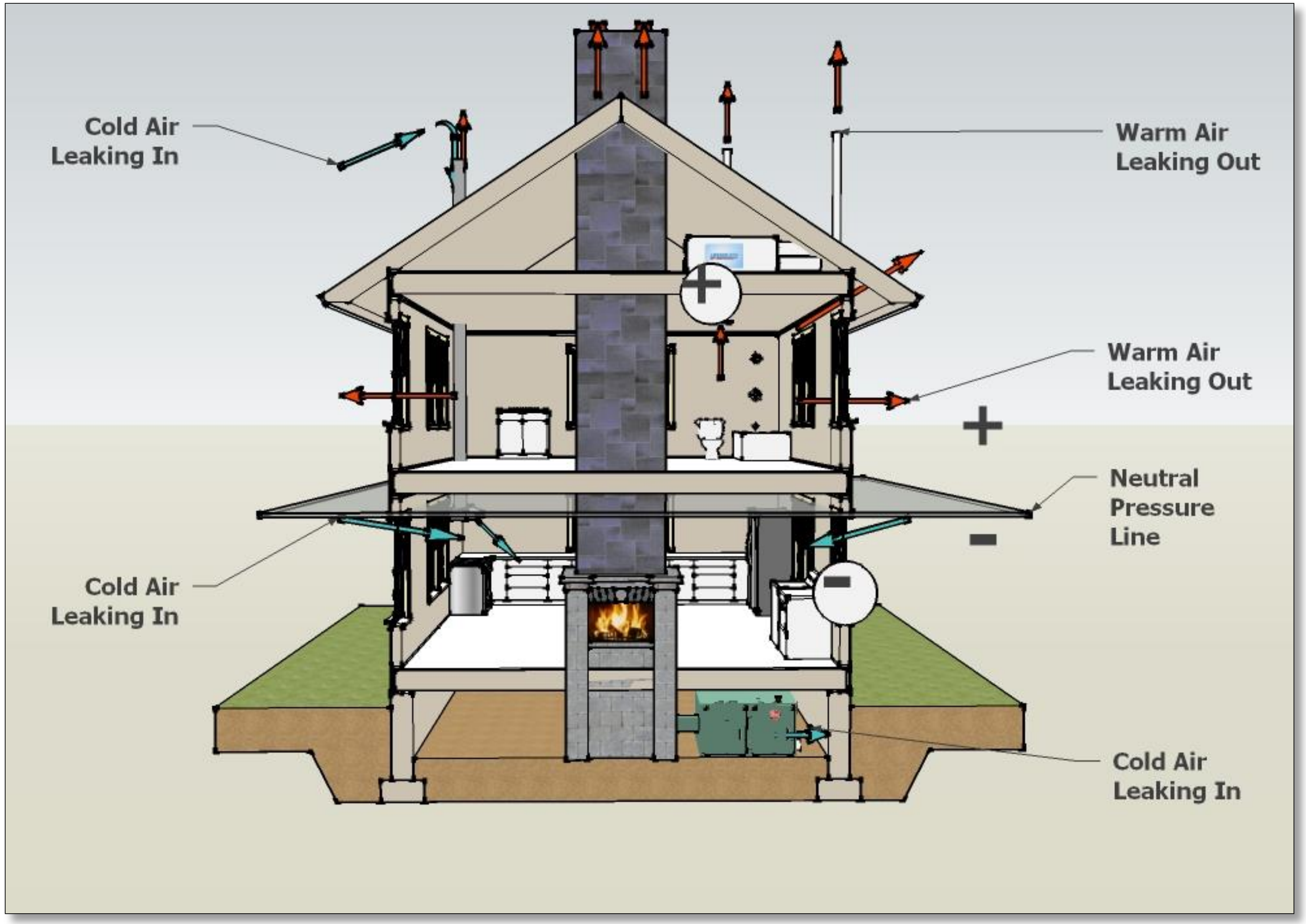
The First Skin

The Second Skin

The Third Skin



The Third Skin



The building envelope, aka third skin, must mediate between the environment and our second skin to make us comfortable.

The Third Skin is composed of:

#1 – opaque elements

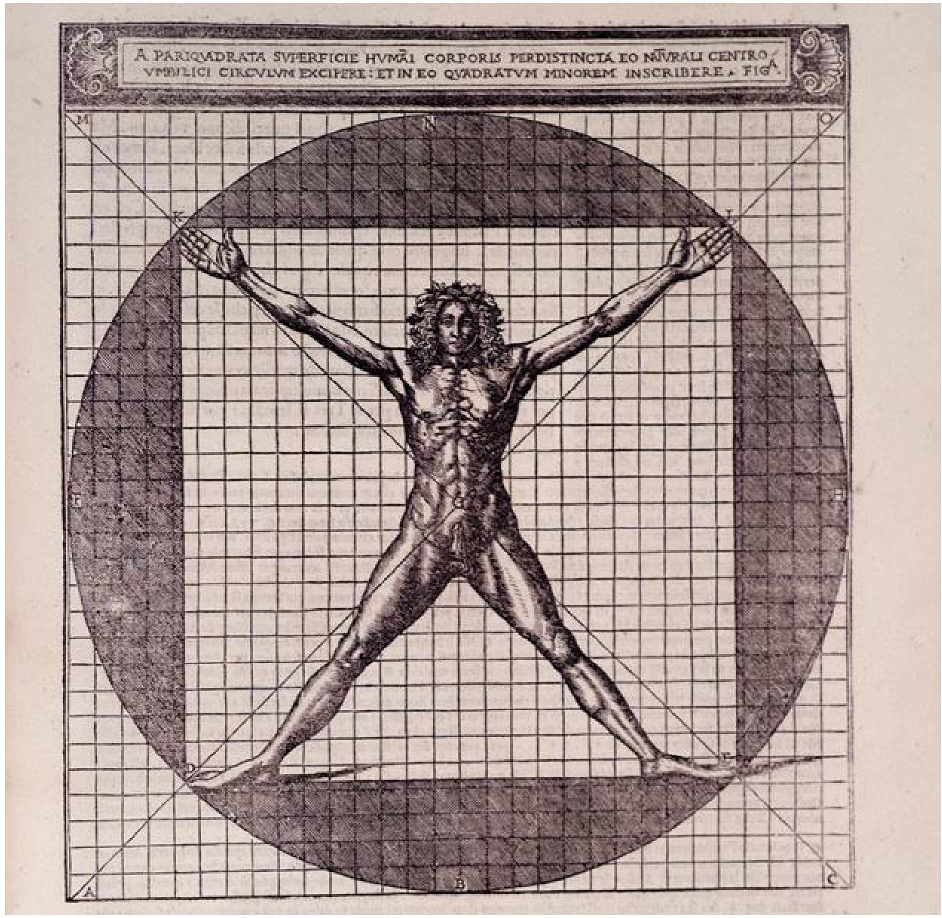
#2 – transparent elements

#3 – the details that join them

The Third Skin is supposed to:

#1 – Manage climate
(heat, cold, sun, light, breezes)
#2 – Be durable
#3 – Be sustainable
#4 – Be cost effective

#5 – Look good!



Vitruvius believed that an architect should focus on three central themes when preparing a design for a building: firmitas (strength), utilitas (functionality), and venustas (beauty).

Heat Transfer Mechanisms

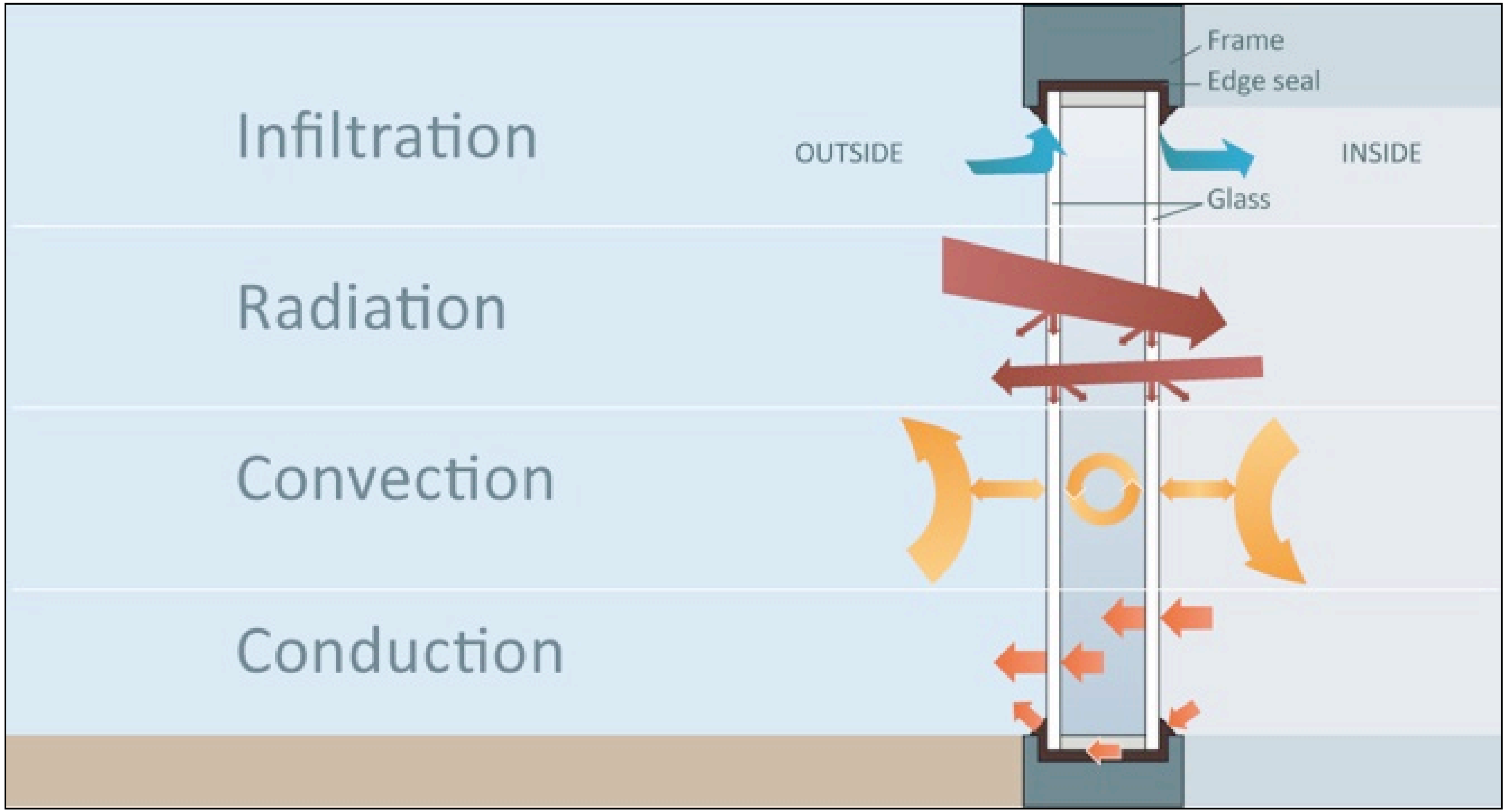
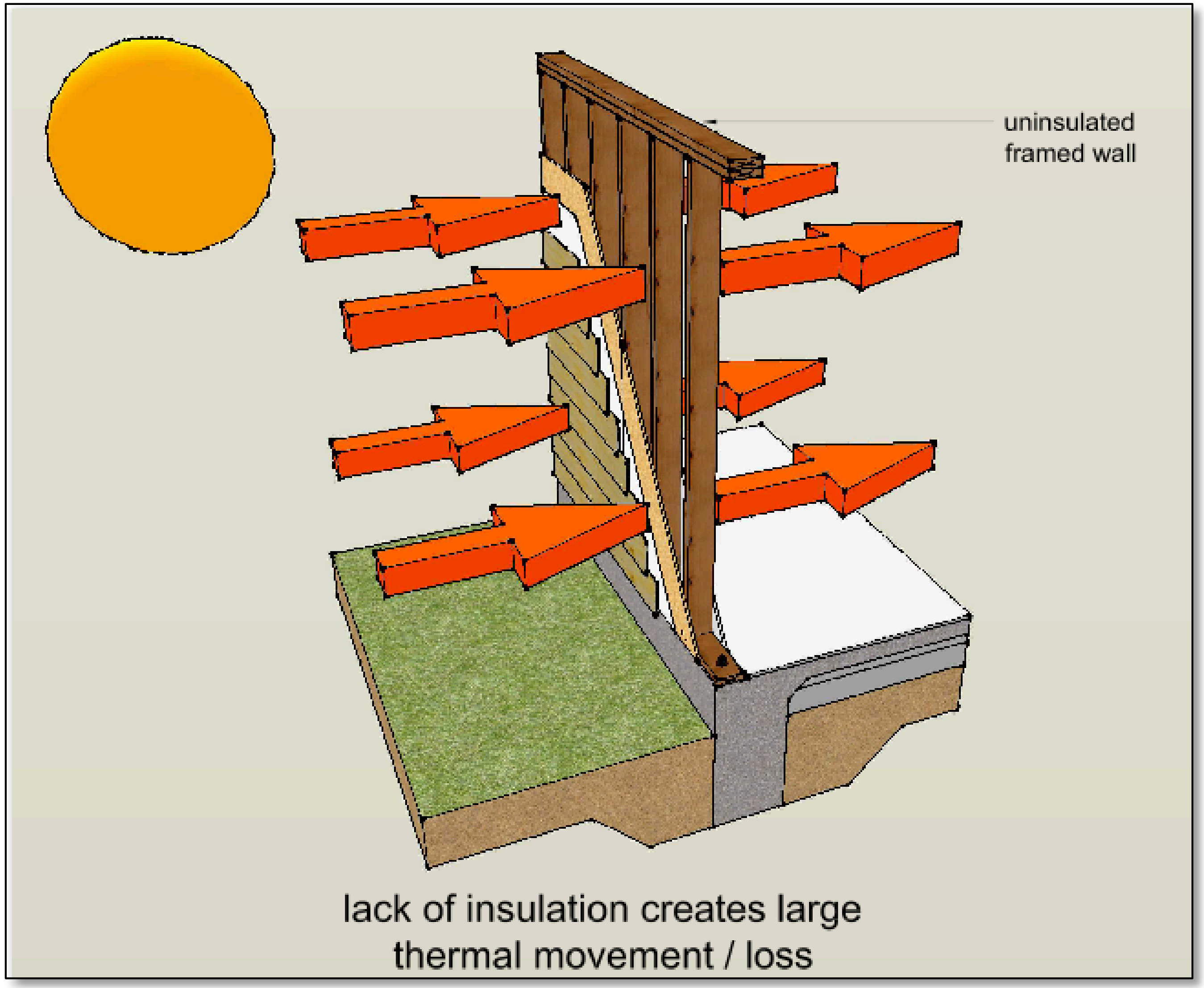


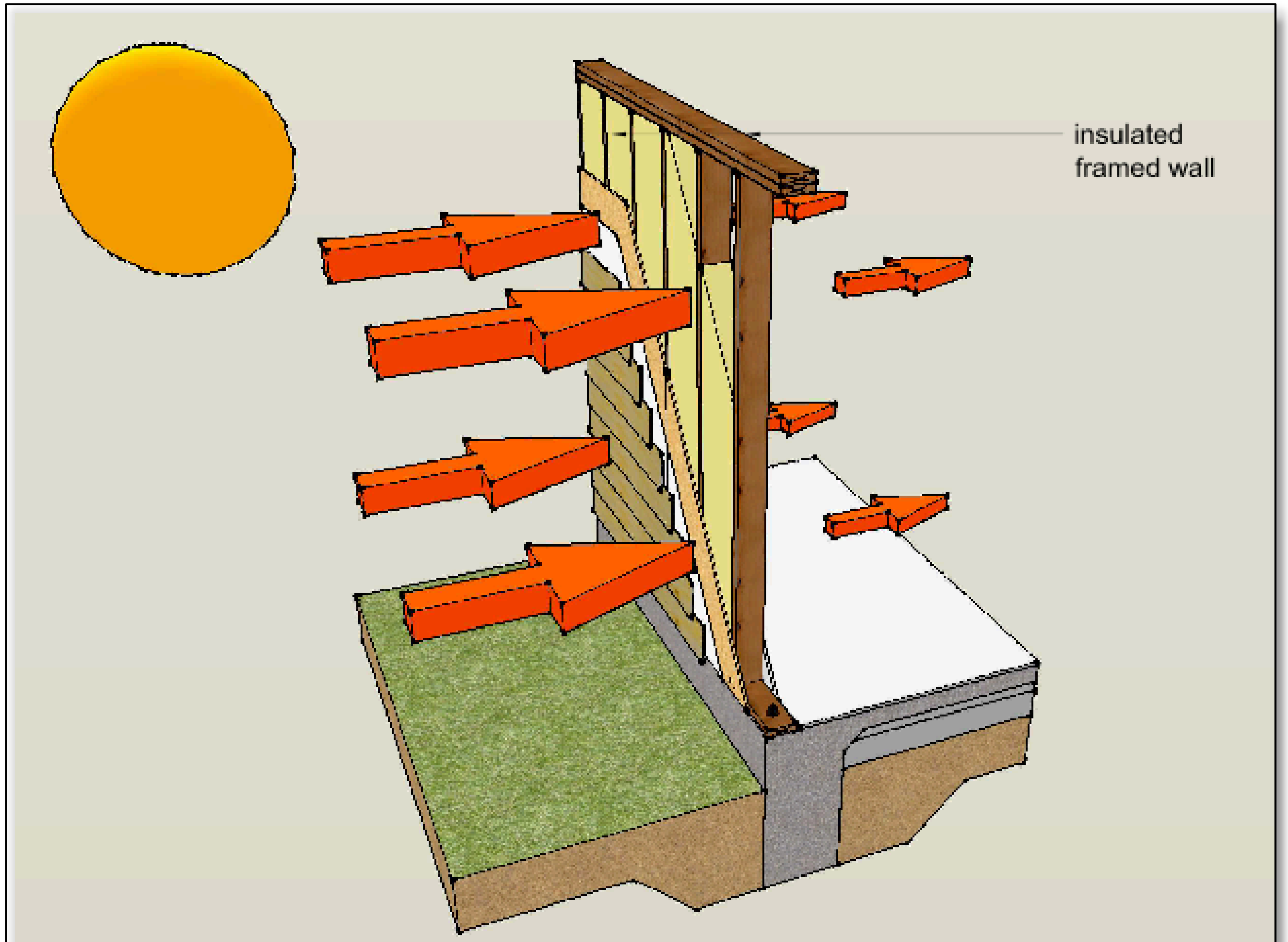
Image courtesy of Collette/Baker-Laporte

Insulation & Thermal Conductivity



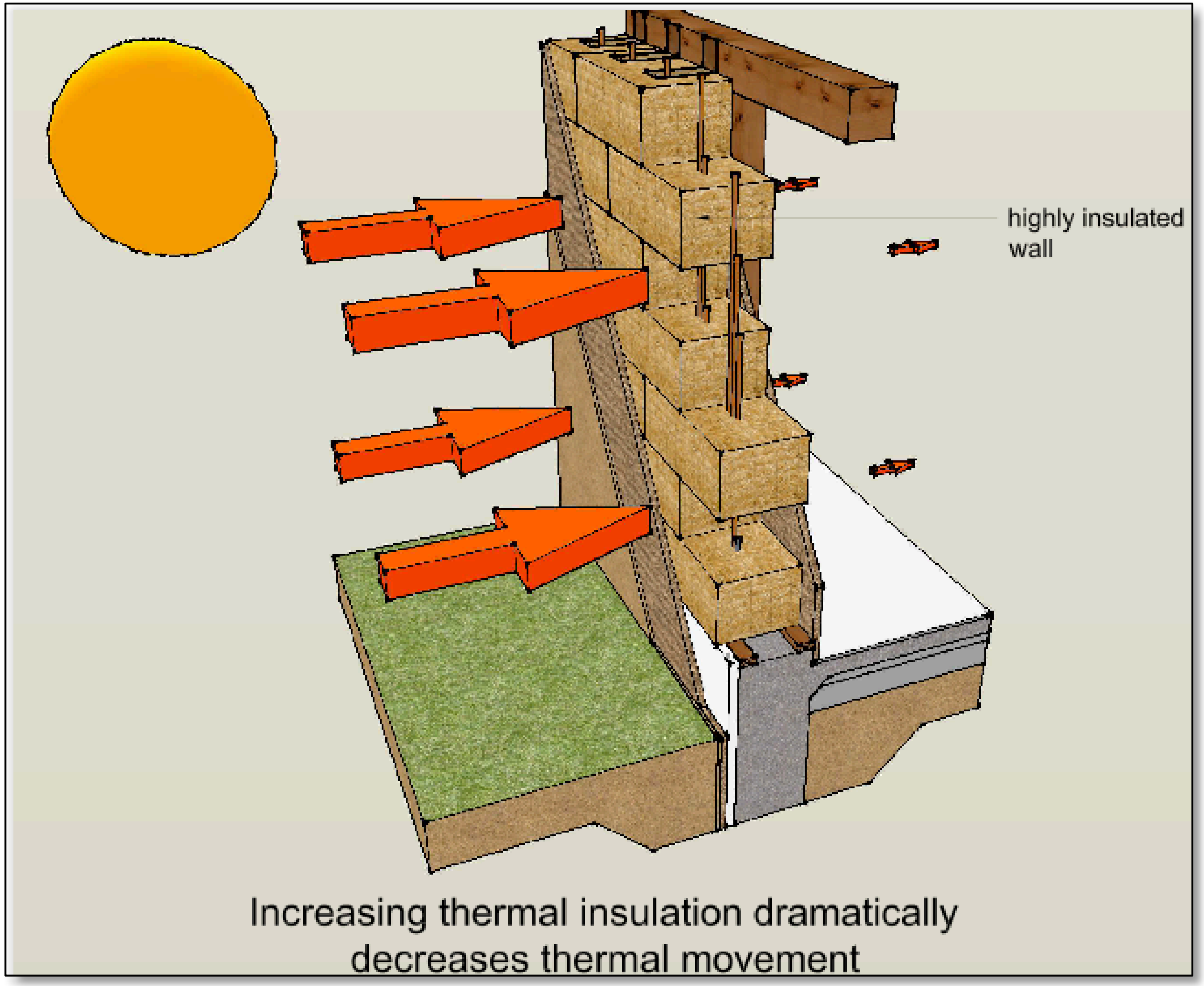
Cold climate design focuses greatly on insulating the building envelope and sealing up to prevent losses due to air leakage.

Insulation & Thermal Conductivity



Insulation works by trapping small pockets of air

Insulation & Thermal Conductivity



cellulose

fiberglass

polystyrene

Sheep's wool

Insulation is the only real way to keep the heat in. Some types are more environmentally friendly than others.

The Comfort Zone

The Comfort Zone refers to the range of temperature conditions of air movement, humidity and exposure to direct sunlight, under which a moderately clothed human feels “comfortable”.

This will be different for **Indoor** versus **Outdoor** conditions.

This will be different for different cultures and climate conditions - what are people used to??

We need our buildings to not only create comfortable indoor environments, but also pleasing and useful spaces outside of our buildings.

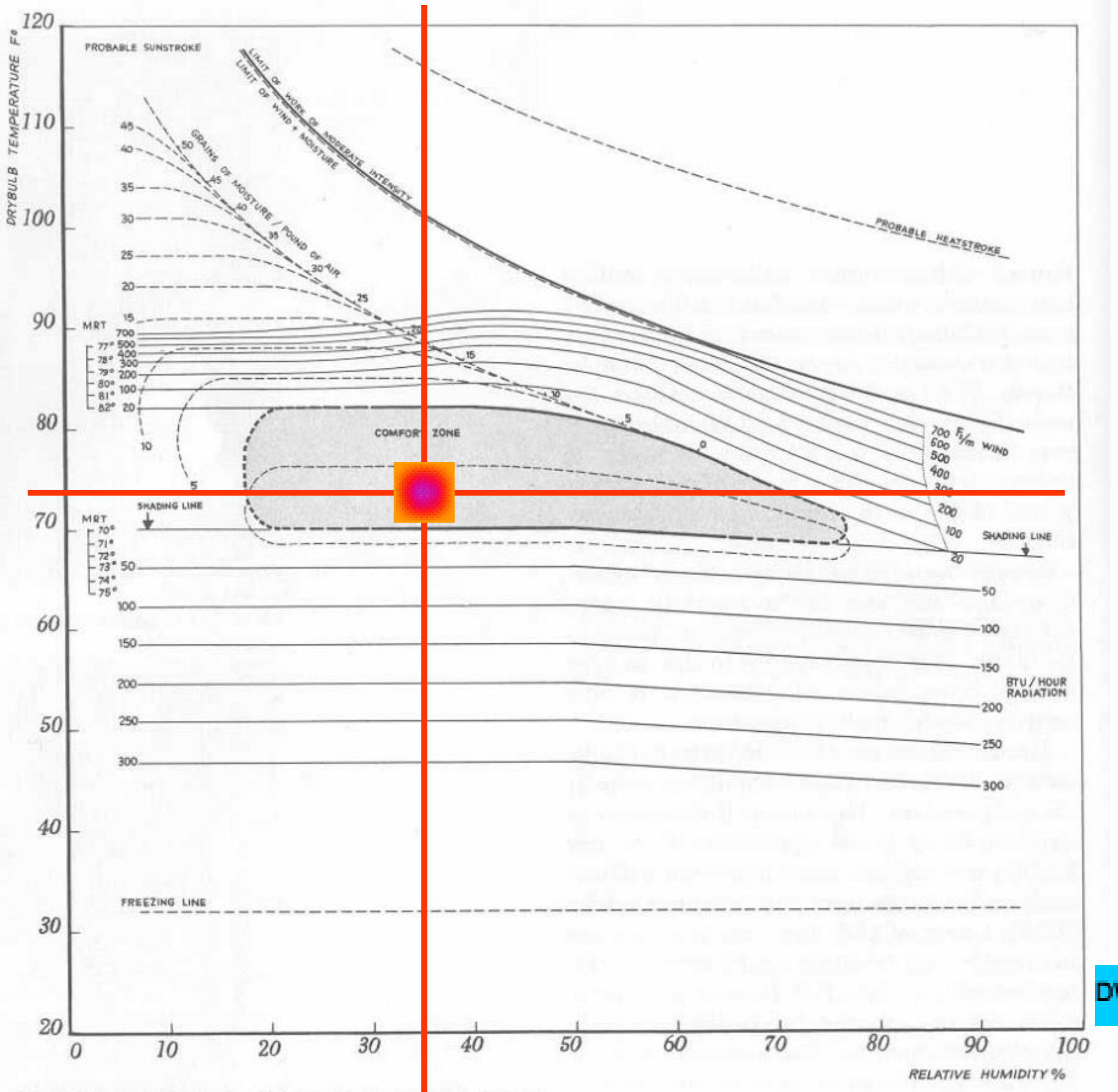
In a hot climate, where do people choose to sit?

Conversely when it is cold, people sit in the sun.

The Comfort Zone

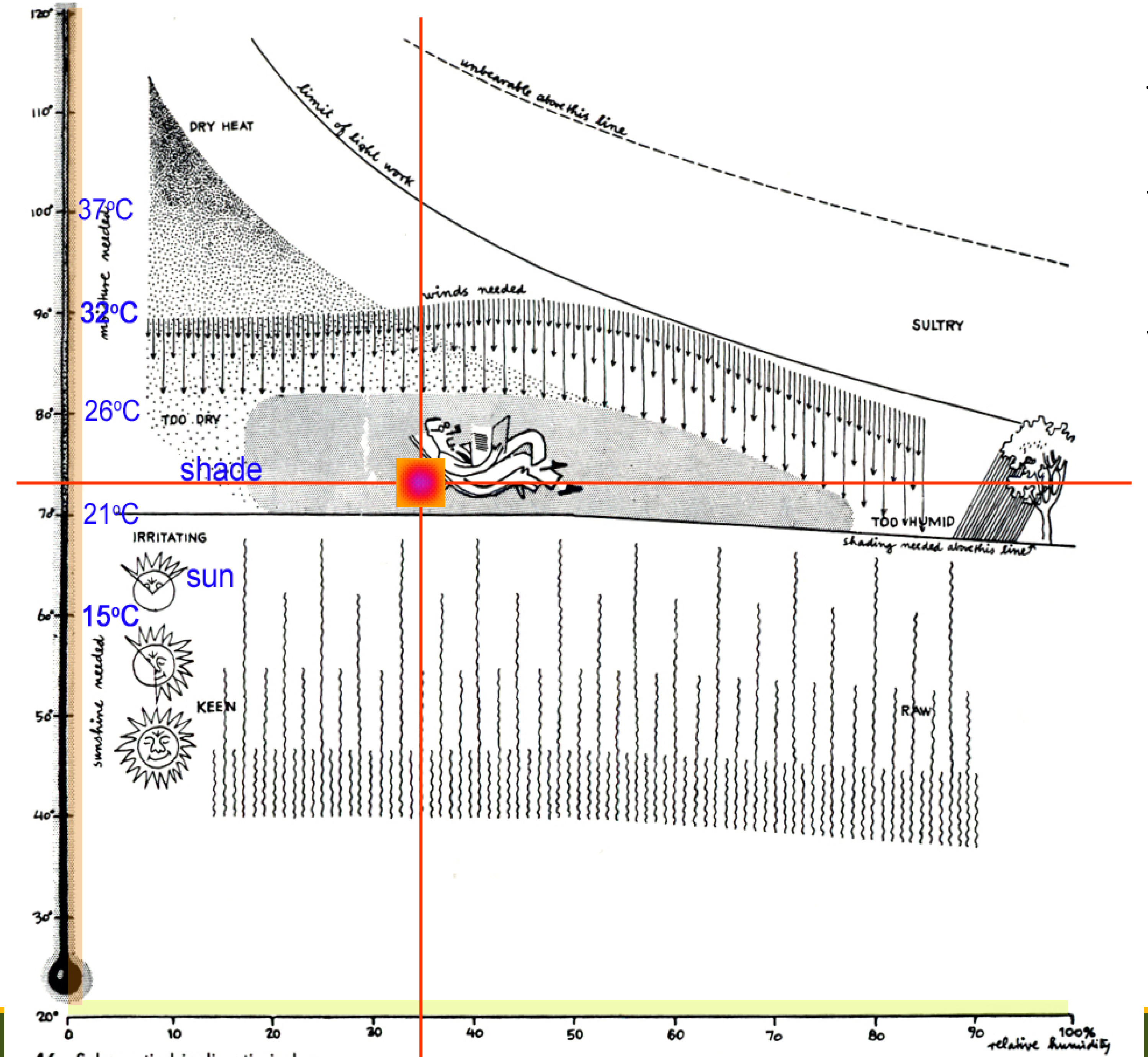
The comfort zone is the kidney shaped area that defines the range of conditions within which North Americans express no *great* objection.

However, the intersecting red lines show the temp and RH that we strive have been accustomed to striving for in our *interior* environments, winter, summer, Arctic, Florida!



45. Bioclimatic Chart, for U.S. moderate zone inhabitants.

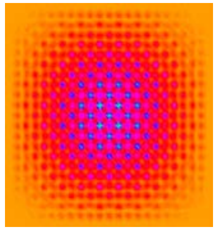
DWC



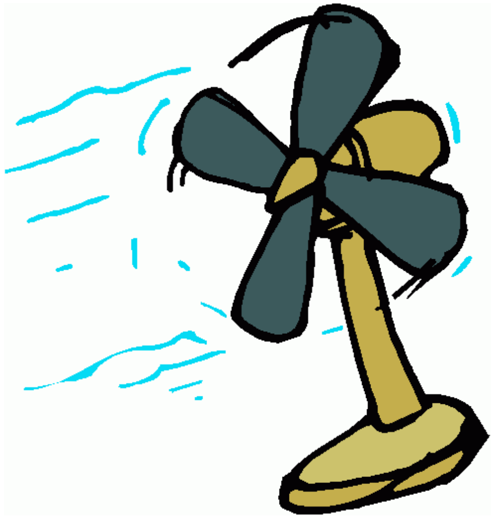
46. Schematic bioclimatic index.

This adaptation is from "Design with Climate" by Victor Olgyay, first published in 1963.

One of the biggest adjustments that must be made in trying to design buildings with less dependency on mechanical heating and cooling, is the *adaptation of human expectations* to have their environments held at a constant Temperature and Relative Humidity.



23C 35%RH



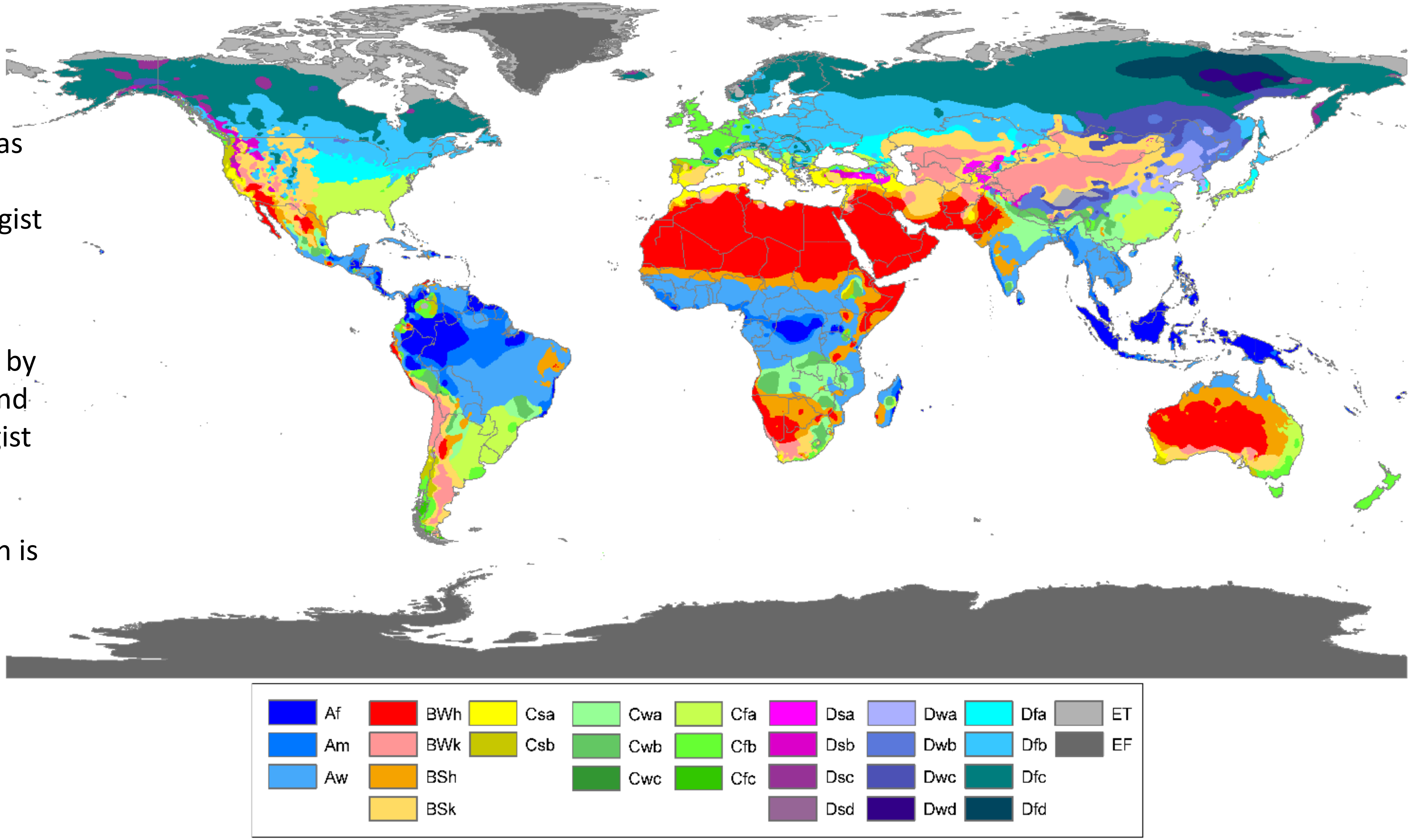
All indoor temp and RH that falls outside of 23C 35%RH normally has called for mechanical and electrical intervention!!

i.e. $$$ and fuel and CO2 emissions


Climate as the Starting Point
for a
Climate Responsive Design

Koeppen's Climate Classification

The Köppen climate classification is one of the most widely used climate classification systems. It was first published by the German-Russian climatologist Wladimir Köppen (1846–1940) in **1884**, with several later modifications by Köppen, notably in 1918 and 1936. Later, the climatologist Rudolf Geiger introduced some changes to the classification system, which is thus sometimes called the Köppen–Geiger climate classification system.



A Timeline of Air Conditioning

Ancient Egypt: Ancient Egyptians are vaguely credited as being the first to use evaporative cooling by hanging wet cloth or reeds in windows and doorways. As the wind blew across the wet materials, the air in the home would be cooled.

Ancient Rome: Aqueducts As Air Conduits

Wealthy citizens learn to route aqueducts through the walls of their homes. The circulating water has evaporative qualities that cool the air.

1758: Scientists Connect The Dots

Benjamin Franklin and John Hadley discover the science of evaporation.

1851: A Pioneer In Refrigeration Emerges

Dr. John Gorrie receives a U.S. patent for his invention that uses air blown over ice to cool hospital rooms. His idea was based on the theory that hot air in hospitals contained sickness, so cooling the air would create a healthier environment.

1902: The Advent Of The Commercial Air Conditioning System

Willis Carrier invents a machine in 1902 that blows air over cold coils to control air temperature and humidity. The goal is to de-humidify the air so that paper doesn't wrinkle and ink stays fresh. Carrier founds the Carrier Air Conditioning Company of America.

1914: The First Residential Air Conditioner Installed

The first in-home air conditioning unit is installed in a Minneapolis mansion. The machine is seven feet tall and twenty feet long.

1931: The Window Unit Invented

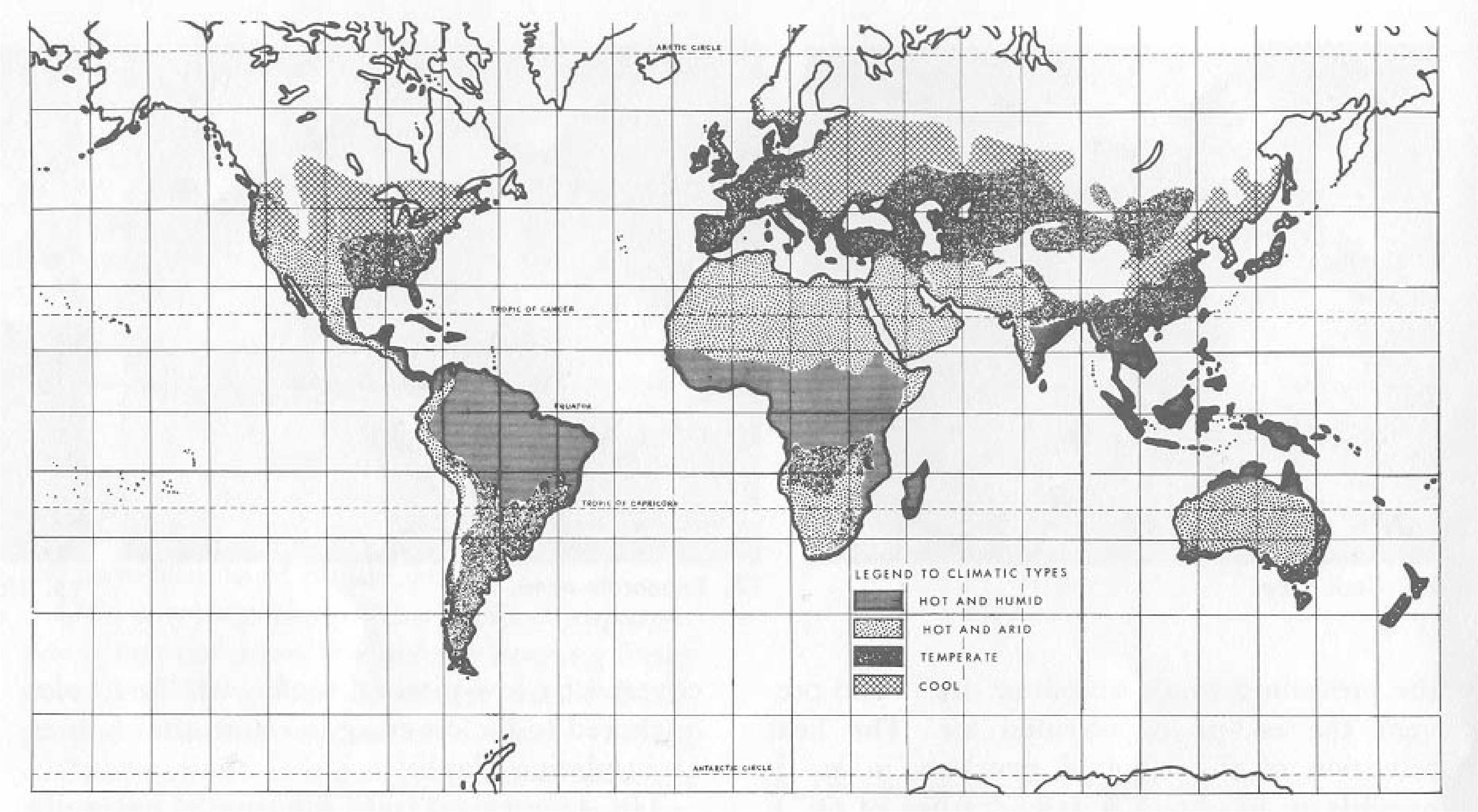
H.H Schultz and J.Q Sherman invent the first window unit air conditioner. The cost of a unit (in today's money) would be up to $600,000.

The 1950s: Home Air Conditioners Gain In Popularity

Residential air conditioners catch on in suburban homes.

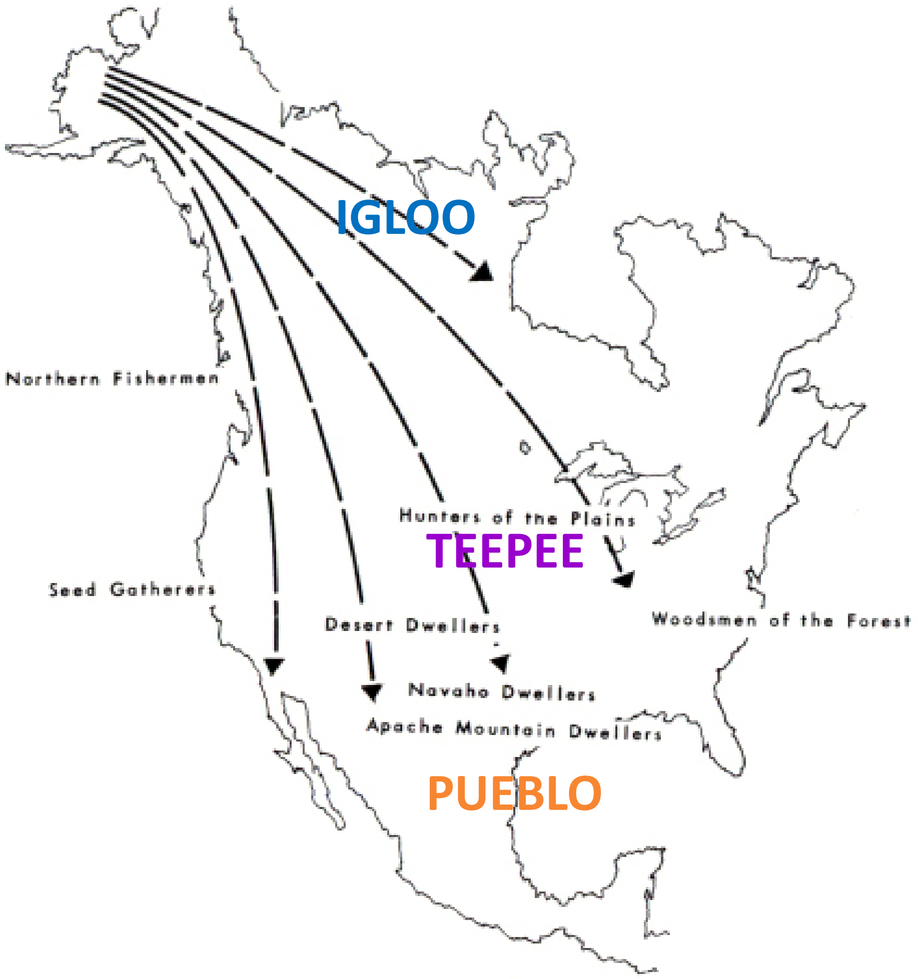
The 1970s: Central Air Becomes Standard

World Climate Regions



Introduced in modern times by Fitch and Branch in 1960. Reinforced by Olgyay in 1963.
Still the basis of current thinking, except for more subtle variations in the north.

Climatic Regions in North America



10. Diffusion of migrating groups.

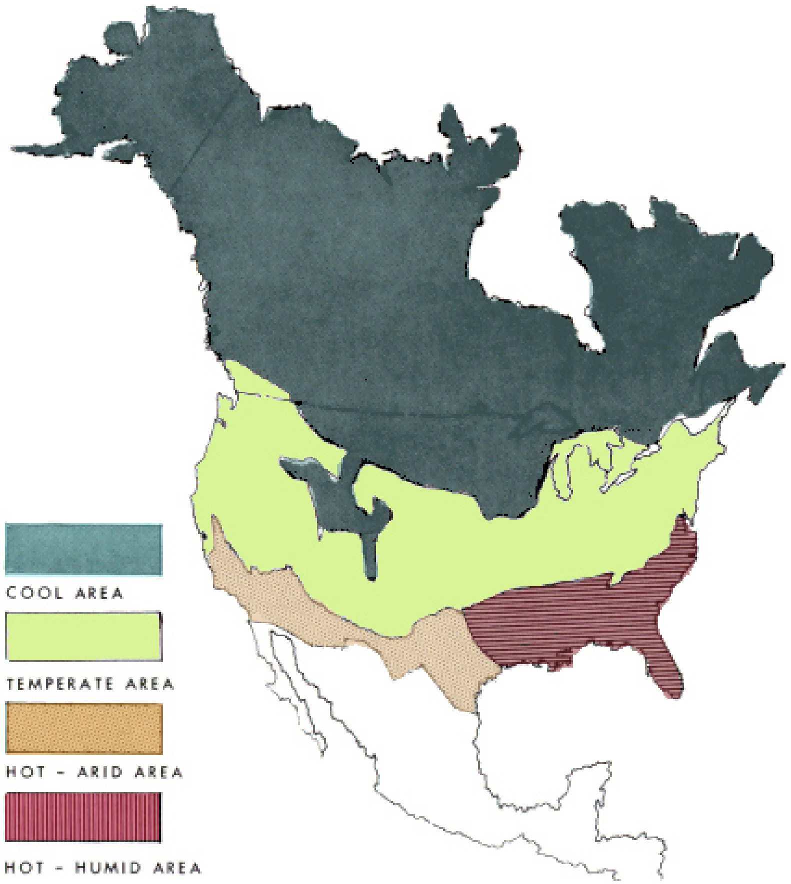
It is generally agreed that indigenous North Americans stemmed from Asia and that the waves of their migration across the Bering Strait established their populations from end to end of North and South America.

As they spread throughout North America, they entered into a broad variation of climatic environments.

These in turn impacted the type of dwellings that they created.

Dwellings also reflect nomadic vs. stable settlement.

Climatic Regions in North America



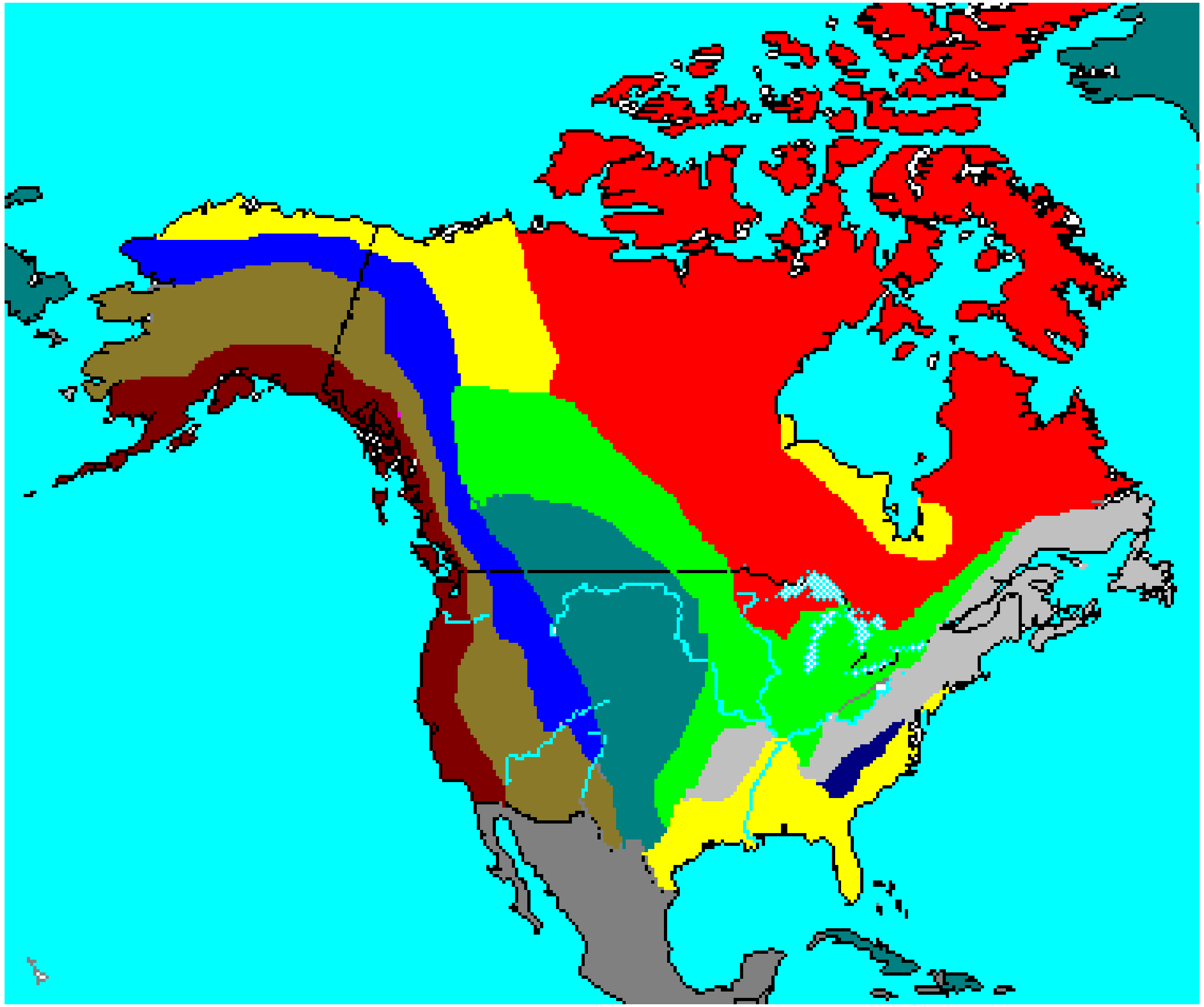
11. Regional climate zones of the North American continent.

Cold -where winter is the dominant season and concerns for conserving heat predominate all other concerns. (Eg: Minneapolis, Minnesota and Ottawa, Ontario)

Temperate – where approximately equally severe winter and summer conditions are separated by mild transitional seasons. (i.e.: New York, NY)

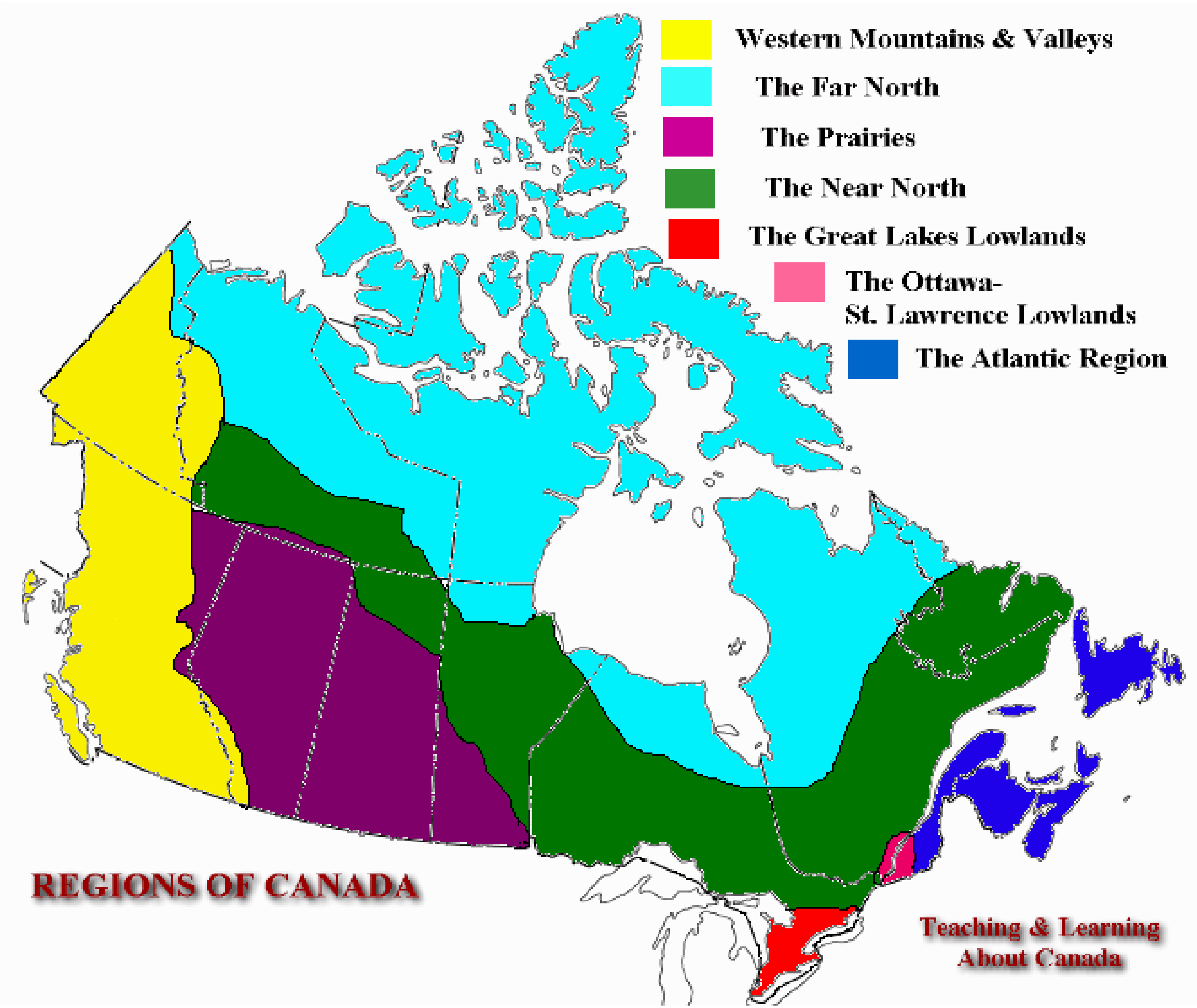
Hot-Arid – where very high summer temperatures with great fluctuation predominate with dry conditions throughout the year. (i.e.: Phoenix, Arizona)

Hot-Humid – where warm stable conditions predominate with high humidity throughout the year (i.e.: Miami, Florida)



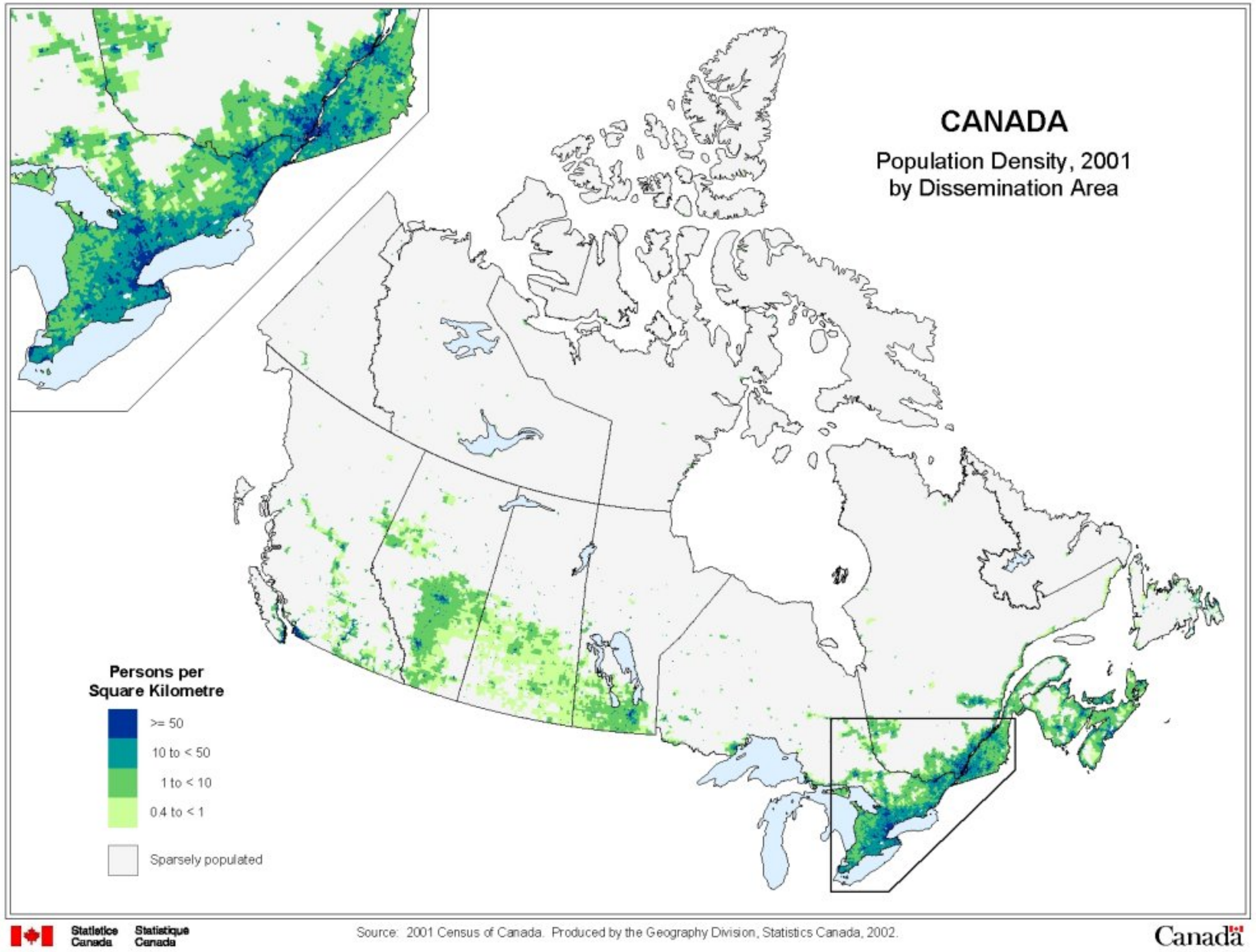
The climate regions closely align with the broad geographic regions of North America.

Early migration and settlement had much to do with the climate, landscape and available materials and food sources and the availability of water.



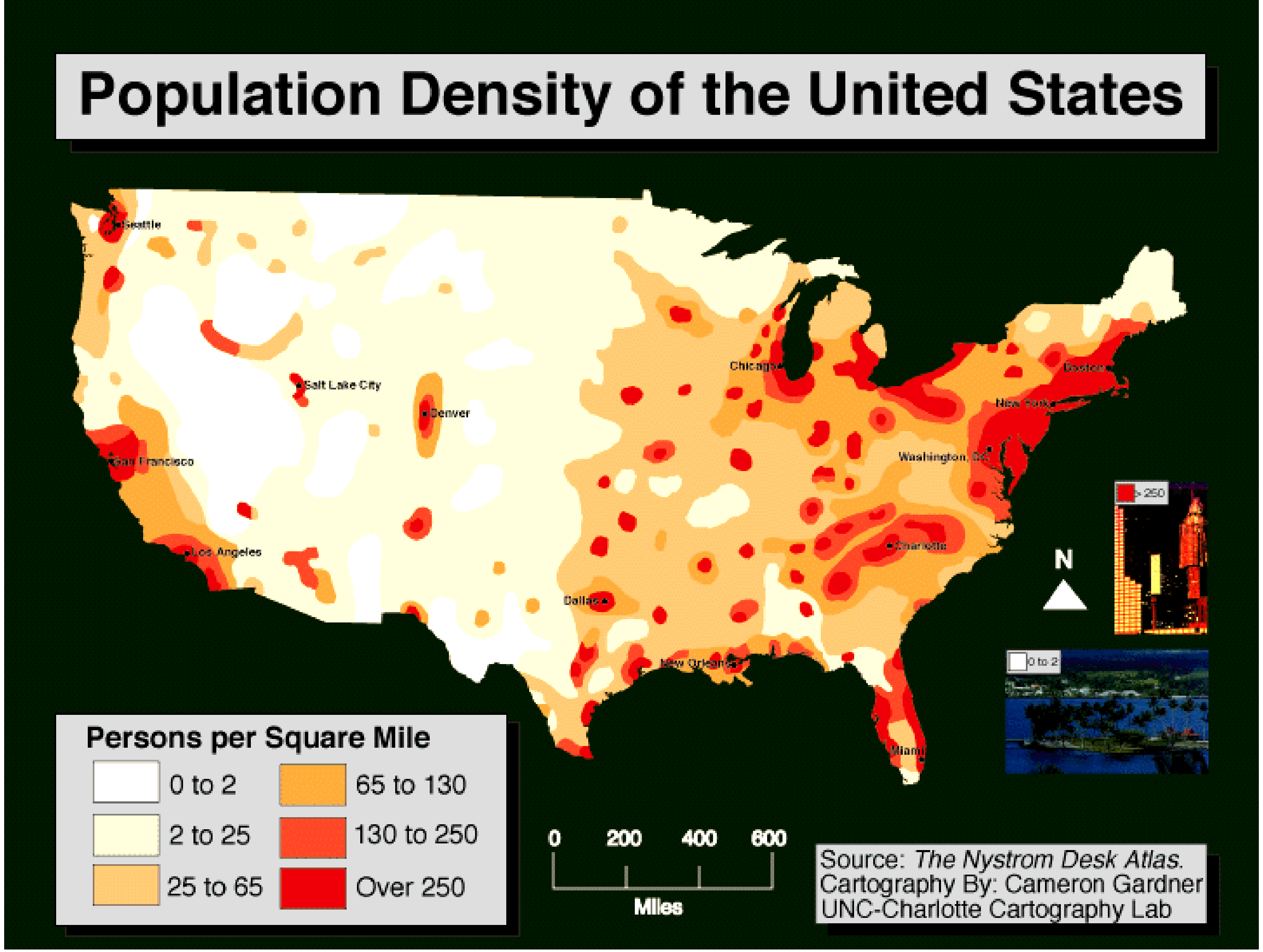
The geographic and climate regions also tend to support different cultures, ways of life, food, cooking, pace of living.

Eating fat helps if you live in a cold climate.

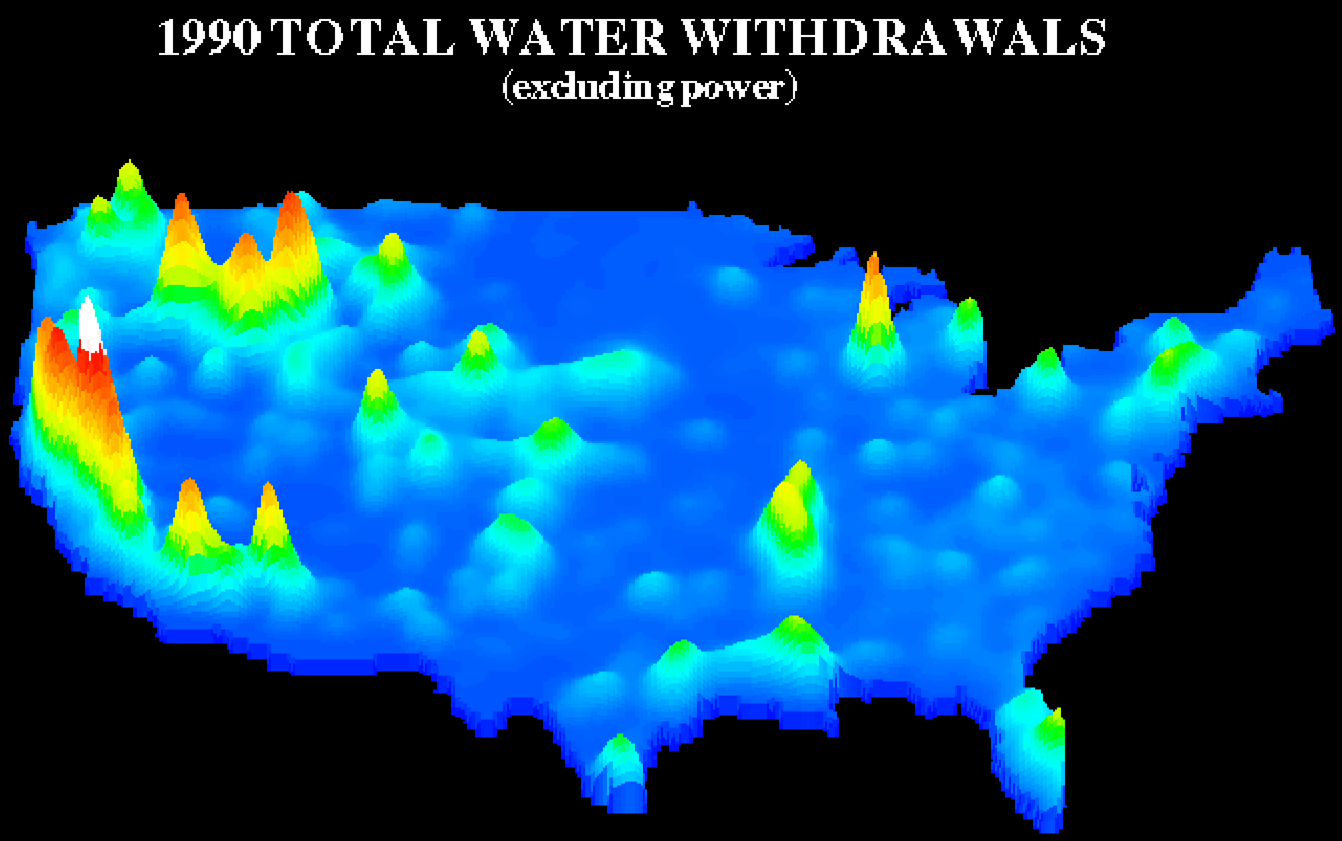


Population densities initially co-related to “good climate for life”, and have subsequently had less to do with this fact as modern systems and irrigation processes have been able to ignore these issues.

The availability of fresh water was also critical to these choices.



In the U.S. it is fairly easy to see geographic dependent patterns in settlement.



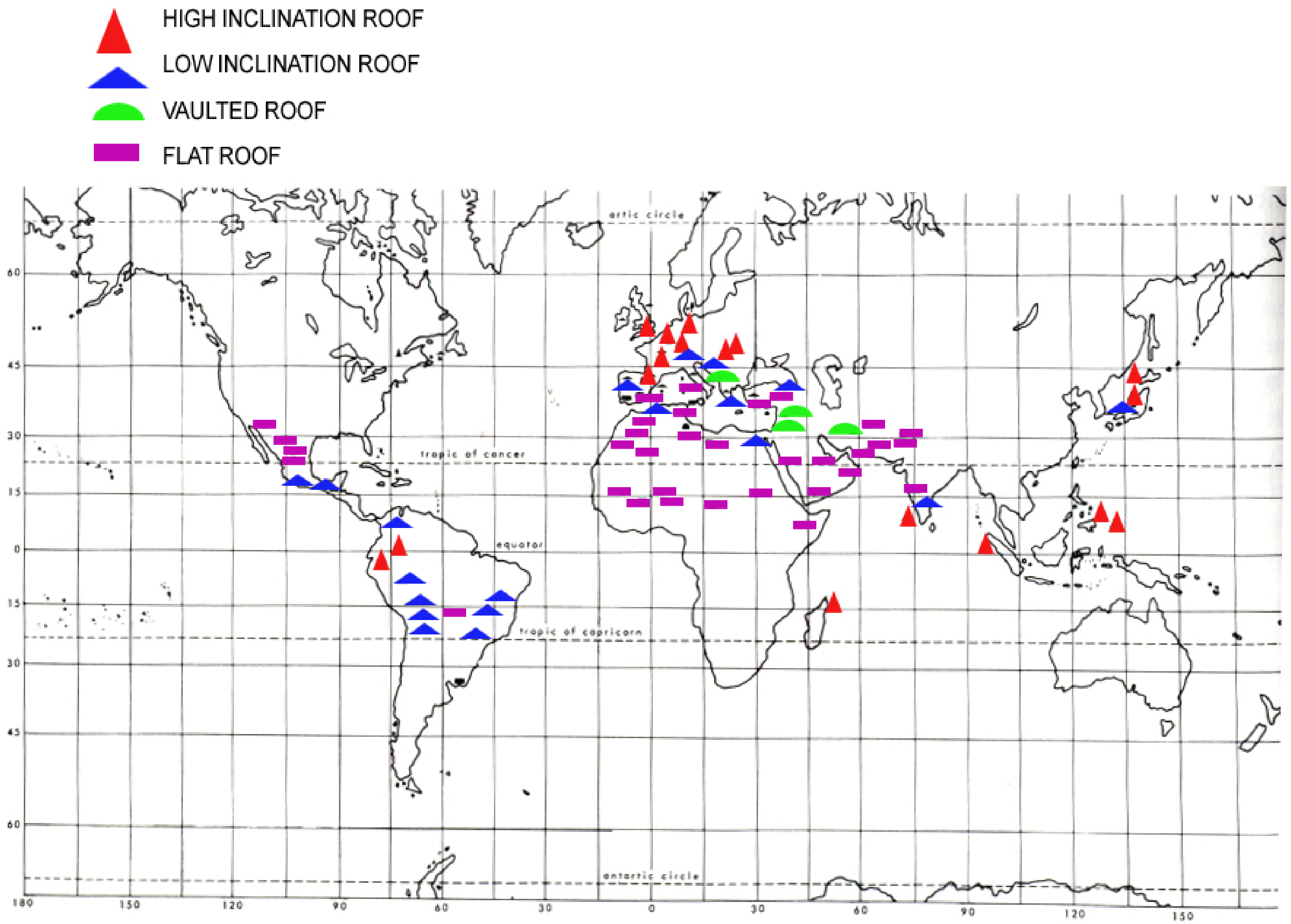
Settlement begins to conflict with geography when water consumption begins to exceed availability. This requires more thoughtful water use...

INDIGENOUS STRATEGIES

FOR RETHINKING ARCHITECTURAL DESIGN

Climate and Indigenous Housing

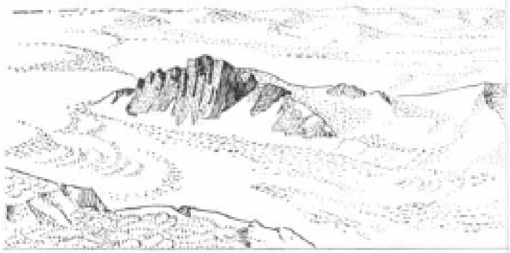
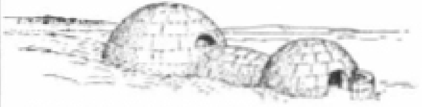
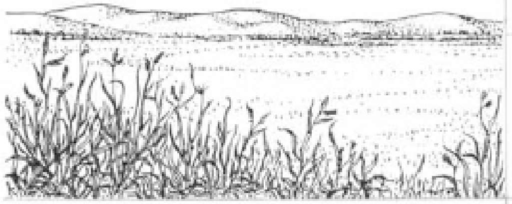
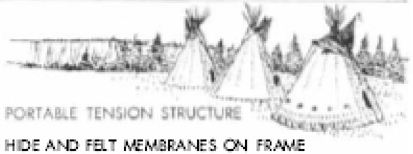
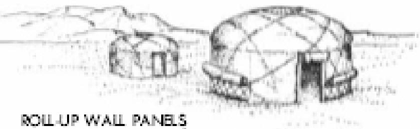
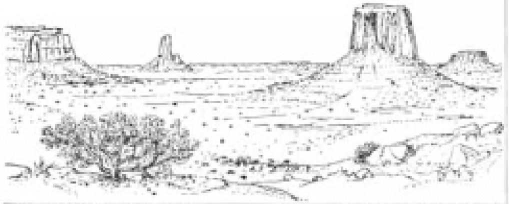
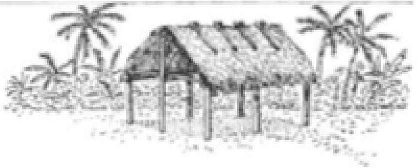
TYPICAL OCCURRENCE OF INDIGENOUS ROOF TYPES



Olgyay took the Fitch/Branch idea of climate and indigenous housing and analyzed roof types.

Roofs tell us a lot about housing.

- Flat roofs are to sleep on in hot climates.
- Pitched roofs shed rain.
- Low slope roofs hold snow.
- Vaulted roofs are lesser used and more style/material specific.

CLIMATE	THERMAL CHARACTERISTICS	REQUIRED ARCHITECTURAL RESPONSE	RAW MATERIALS AVAILABLE	TYPE OF TENANCY	STRUCTURAL SYSTEM EVOLVED
ARCTIC AND SUBARCTIC 	WINTER INTENSE, CONTINUOUS COLD LITTLE SOLAR LIGHT OR HEAT HIGH WINDS	LOW HEAT CAPACITY WALLS AND ROOF MINIMUM SURFACE, MAXIMUM STABILITY	SNOW	SEASONAL (HUNTING)	 SNOWDOME, ICE-AND FUR-LINED
	SUMMER MODERATE TEMPERATURES INTENSE SOLAR RADIATION	HIGH HEAT CAPACITY ROOF AND WALLS	TURF, EARTH, DRIFTWOOD	SEASONAL (HUNTING-FISHING)	 SOD-ROOFED DUGOUT
CONTINENTAL STEPPE 	WINTER INTENSE, CONTINUOUS COLD NEGLIGIBLE SOLAR HEAT HIGH WINDS	LOW HEAT CAPACITY WALLS AND ROOF MINIMUM EXPOSED SURFACE, MAXIMUM STABILITY	ANIMAL SKINS, HAIR SAPLINGS	NOMADIC (HERDING)	 PORTABLE TENSION STRUCTURE HIDE AND FELT MEMBRANES ON FRAME
	SUMMER LONG, WARM DAYS COLD NIGHTS	SHADE, VENTILATION LOW HEAT CAPACITY WALLS AND ROOF			 ROLL-UP WALL PANELS
DESERT 	LITTLE OR NO SEASONAL VARIATIC HOT DAYS-COLD NIGHTS INTENSE SOLAR LIGHT AND HEA VERY LOW HUMIDITY LITTLE RAIN	HIGH HEAT CAPACITY ROOF AND WALLS SHADE MINIMUM VENTILATION NONWATERPROOF	MUD, STONES REEDS, PALMS, SAPLINGS	PERMANENT (AGRICULTURE)	 SOLID, LOAD-BEARING MUD-MASONRY WALLS ROOFS: MUD CEMENT ON WATTLE; POLE OR PALM TRUNK RAFTERS
TROPICAL RAIN FOREST 	NO SEASONAL VARIATION HOT DAYS WARM NIGHTS INTENSE SOLAR RADIATION HIGH HUMIDITIES HEAVY RAINFALL	LOW HEAT CAPACITY WALLS AND ROOF MAXIMUM SHADE MAXIMUM VENTILATION	VINES, REEDS, BAMBOO, PALM-FRONDS, POLES	PERMANENT (AGRICULTURE, FISHING)	 SKELETAL FRAME, THATCHED ROOF, WALLS SLOPING PARASOL ROOF STILTED FLOORS

Climate Responsive Architecture

Indigenous structures are valuable subjects for study because of their ingenious use of available materials and technology to produce houses which provide a remarkably high degree of thermal comfort in sometimes hostile environments.

Vernacular architecture has grown out of simpler forms of indigenous building as done by earlier cultures, and usually includes the same set of climate responsive parameters and similar materials but using somewhat higher technology in the construction.

Typical "modern" 20th century architecture has characteristically thrown out all of the lessons of both indigenous and vernacular building BUT relied on mechanical heating and cooling to moderate the interior environment with complete disregard to climate.

Indigenous:

- Originating and living or occurring naturally in an area or environment.
- Intrinsic; innate.
- Bound to its geography.
- Using traditional, typically non-mechanized construction methods.
- Almost always pre-industrial

Vernacular:

• Being *derived from* an indigenous building style using local materials and traditional methods of construction and ornament.

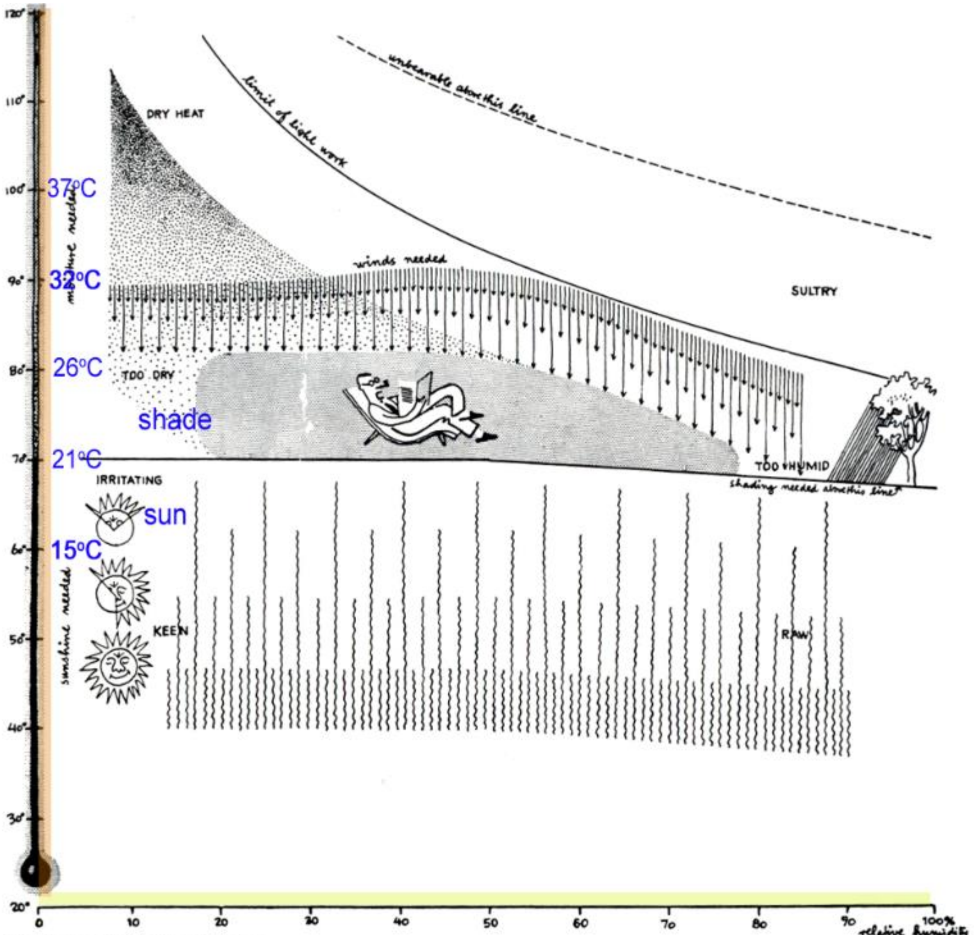
• Almost always post-industrial, using modern construction methods.
Ongoing cultural adaptation of a style (sometimes indigenous).

• *For example, Native American pueblos are indigenous and Mexican courtyard housing is vernacular.*

THERE IS A HUGE DIFFERENCE BETWEEN CLIMATE CONSCIOUS INDIGENOUS HOUSING AND “SHACKS” THAT ARE THE RESULT OF POVERTY.

…although there may remain remnants of climate effective indigenous strategies...

Poverty can result in a forced combination of old (appropriate) and new (inappropriate) materials.



46. Schematic bioclimatic index.

COMFORT IS THE GOAL

Comfort was possible before the invention of mechanical systems

Comfort can again be possible if we closely examine historic strategies and best practices and modify/apply them to contemporary buildings.

Climate Responsive Architecture

"…true regional character cannot be found throughout a sentimental or imitative approach by incorporating their old emblems or the newest local fashions which disappear as fast as they appear. But if you take…the basic difference imposed on architectural design by the climatic conditions…diversity of expression can result…if the architect will use utterly contrasting indoor-outdoor relations…as focus for design conception."

Walter Gropius

What we as architects/engineers are aiming for is to take the climate motivated, environmentally sustainable/valid ideas and practices, from both indigenous and vernacular building, and to incorporate them into a current architecture that clearly responds to issues of climate (and comfort) in the design of the building.

Cold Climate: Indigenous Housing

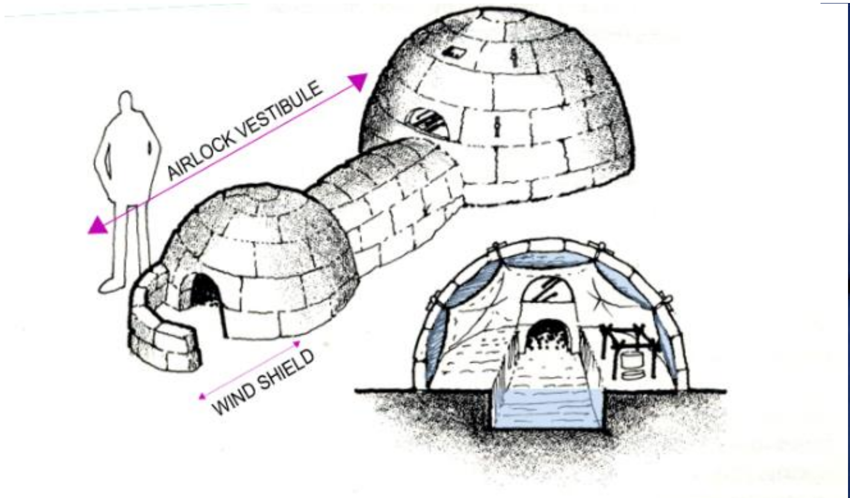


Figure 3.5: Eskimo igloo, with section showing draped animal skin insulation. *(Redrawn from "Primative architecture and climate," by Fitch and Branch. Copyright © 1960 by Scientific American, Inc. All rights reserved.)*

COLD

Cold: The severity of this climate suggests that cold temperature and wind conditions alone dictate the building sitting, form, organization and wall and window construction. Designing for all other conditions (sun, summer breezes, and humidity) are subordinated to the demands of the cold.

Also characteristic of indigenous housing is the tendency to use natural, renewable, low energy materials *(although if populations grow too quickly, materials such as wood may not be adequately replenished).* Such housing has a limited environmental impact.

COLD

This also affects the type of labour and tools that are used in construction, and typically meant inability to use “power” to assist in the building process.

COLD

Such housing does result in interior environments that would not be up to modern North American comfort standards. But perhaps we are aiming too high, making the gap between the environmental comfort level provided by indigenous solutions too far below our own expectations.

That said, don't expect to wear a tank top and shorts inside in the winter.

COLD

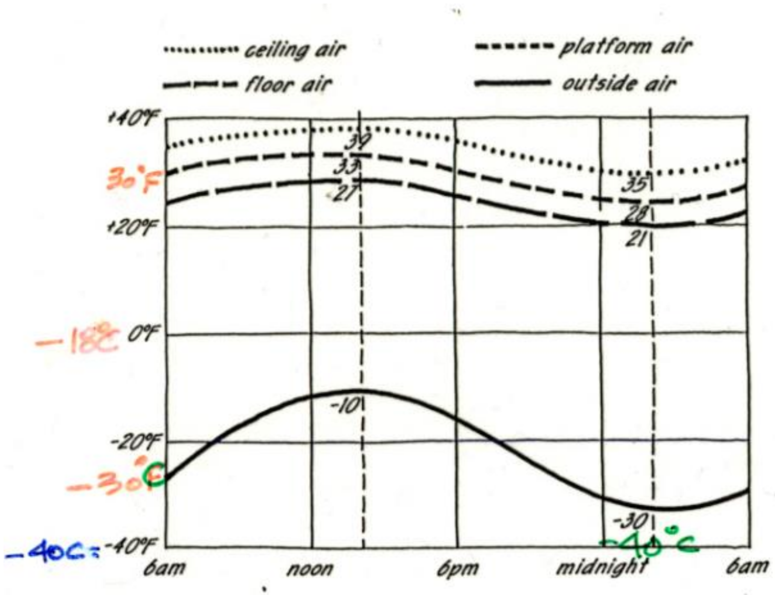


Figure 3.6: Igloo temperatures may run as much as 65°F higher than outside air temperatures using only a small oil lamp and occupant body heat. *(Redrawn from "Primative architecture and climate," by Fitch and Branch. Copyright © 1960 by Scientific American, Inc. All rights reserved.)*

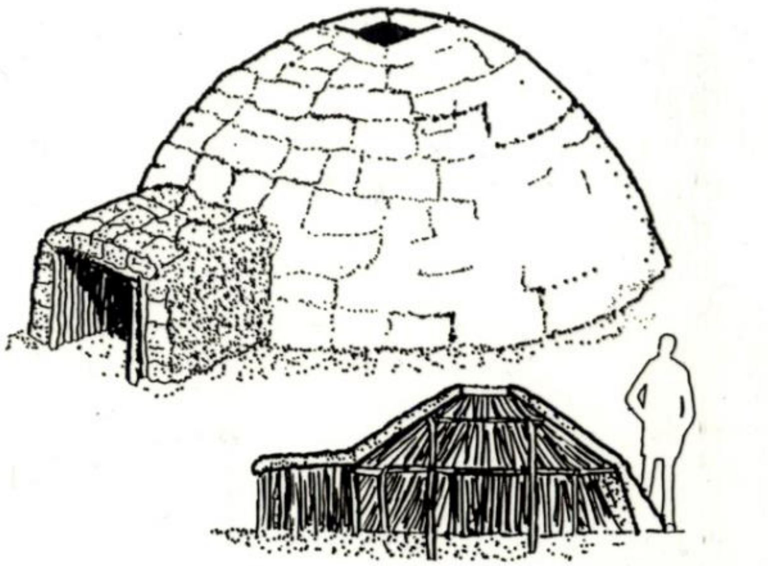


Figure 3.7: The summer house of the Nunamiut Eskimos follows the form of the igloo but is constructed using sticks covered with slabs of turf. *(Redrawn from "Primative architecture and climate," by Fitch and Branch. Copyright © 1960 by Scientific American, Inc. All rights reserved.)*

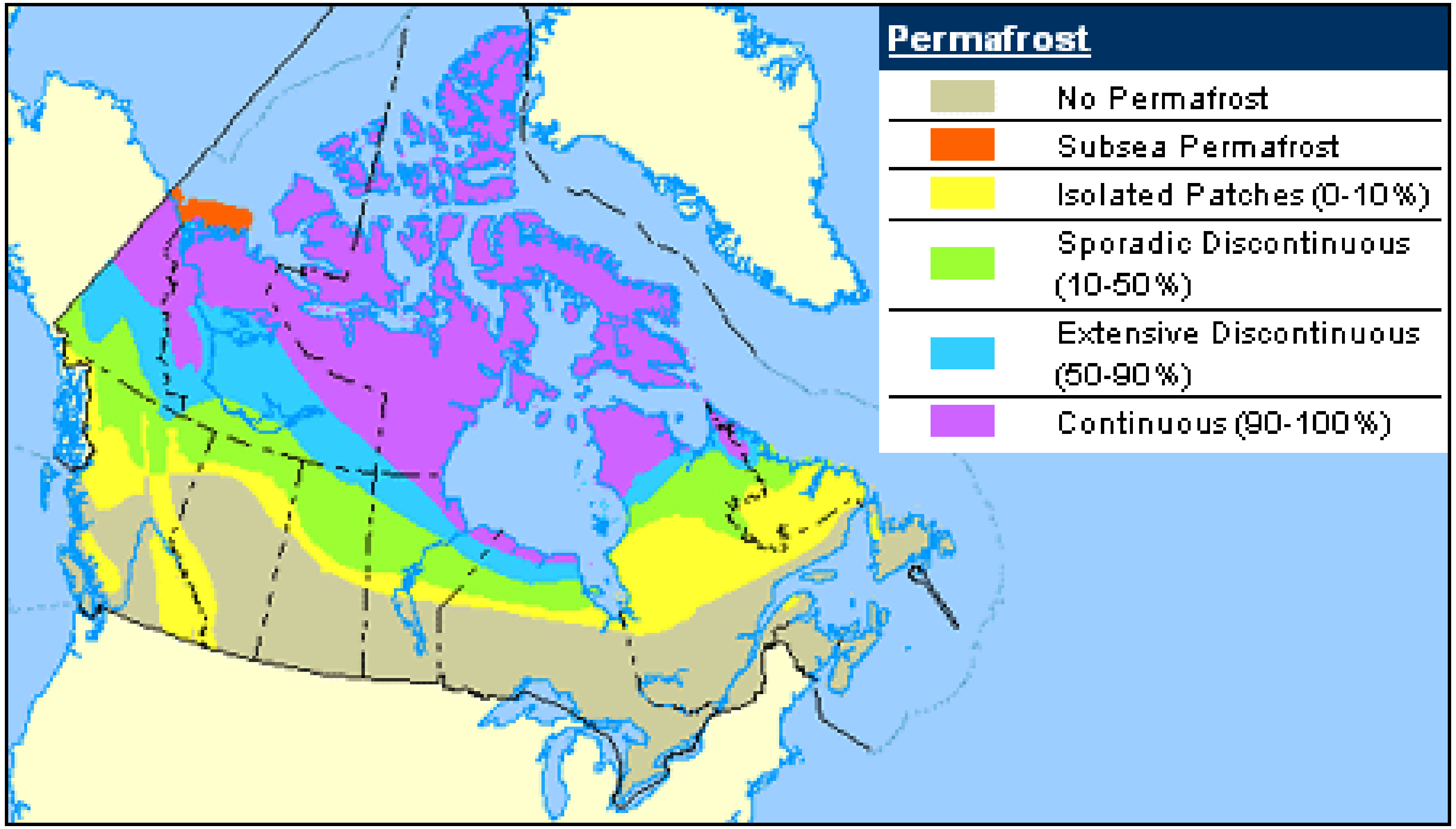
The igloo was able to keep the sleeping bench above freezing, with limited use of a lamp and the body heat of the occupants. Most modern houses are so large that occupants are quite incapable of altering the interior temperatures.

LESSON: *Warm air rises. People typically occupy the area close to the floor, the volume at the ceiling is warmer. Taller ceilings, more volume to heat.*

COLD

The tundra -- where are the natural building materials??

COLD



Extreme Northern building is also affected by Permafrost. Dwellings may not allow heat to escape into the ground as thawing will destroy the permanently frozen condition of the soil and the building will "sink" rather than "float" on top of the soil.

COLD

These ancient Irish buildings used a similar shape to the igloo, but in this case, stone was plentiful - so these became permanent habitations.

COLD

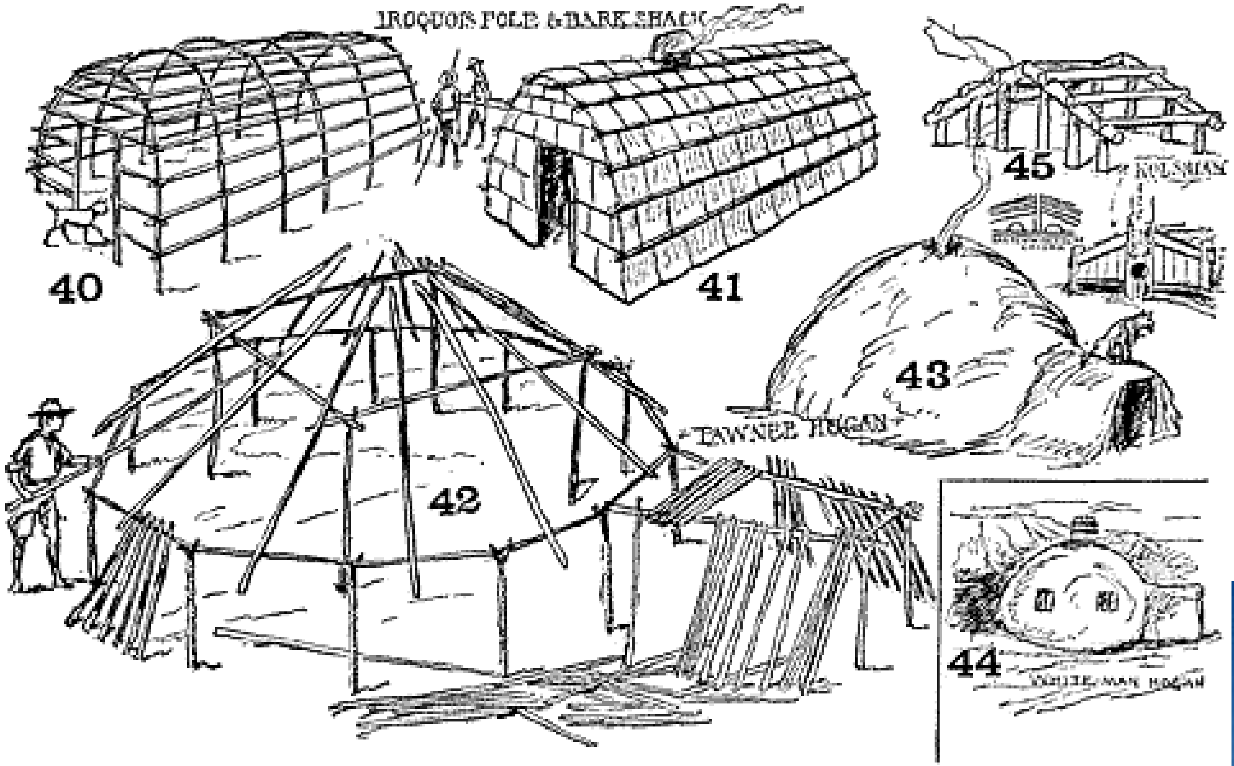
- Early settlers made houses out of solid hewn logs, with mortar or mud in the cracks to keep out the wind.
- They whitewashed the interiors to reflect light better as they only had coal lamps and candles.
- Later buildings used brick and enlarged windows as glass became available.
- Taller ceilings – so hot air rises.
- No insulation as the walls were load bearing.

Temperate: Indigenous Housing

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.

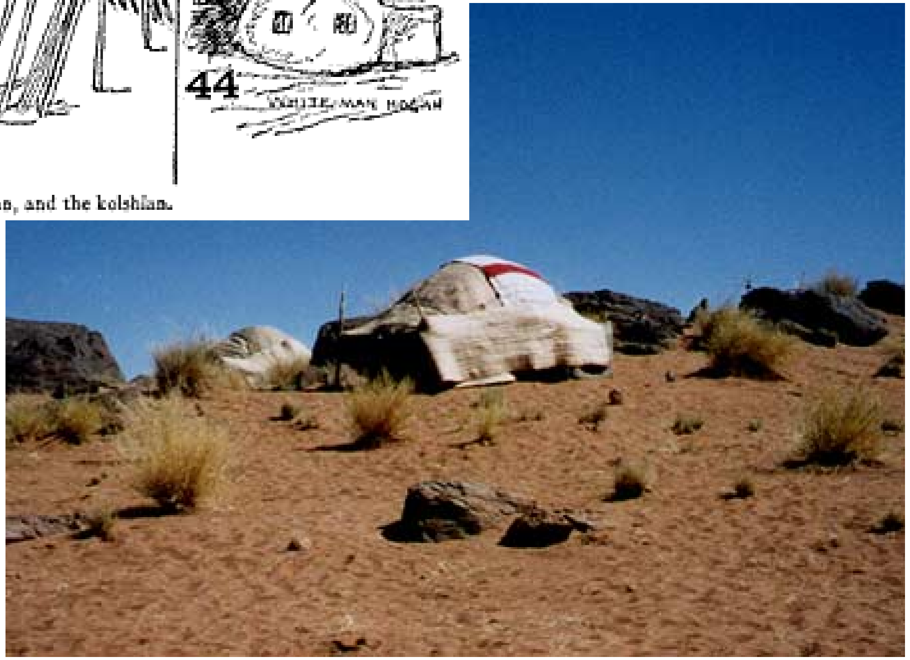
This housing maximizes flexibility in its design in order to be able to modify the envelope for varying climatic conditions.

TEMPERATE



The Iroquois, the Pawnee hogan, the white man's hogan, and the kolshlan.

Similar techniques are seen in temperate buildings worldwide.



TEMPERATE

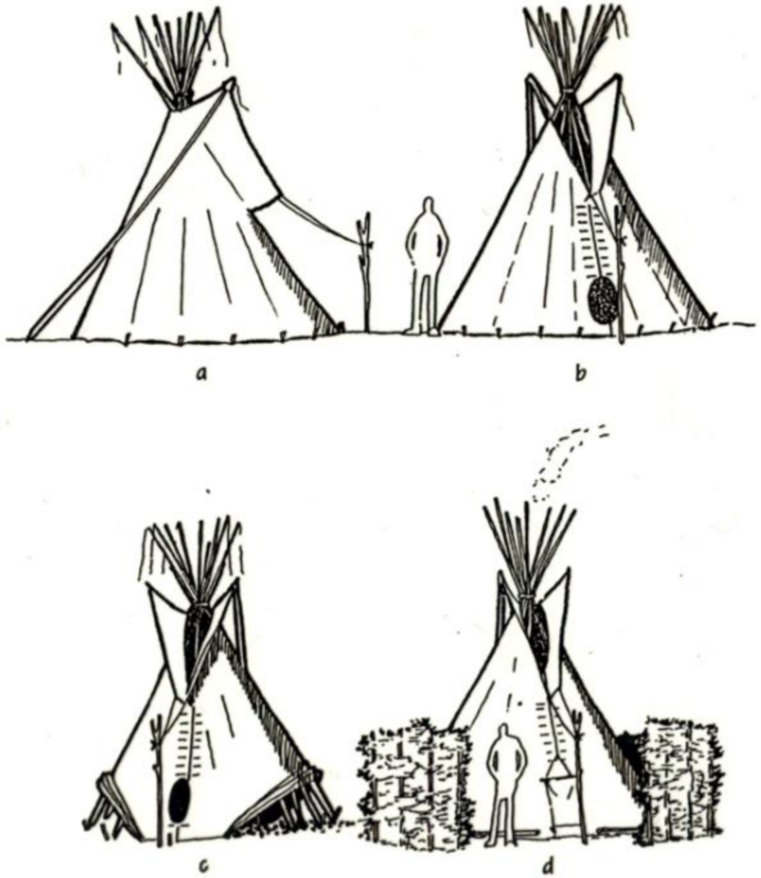
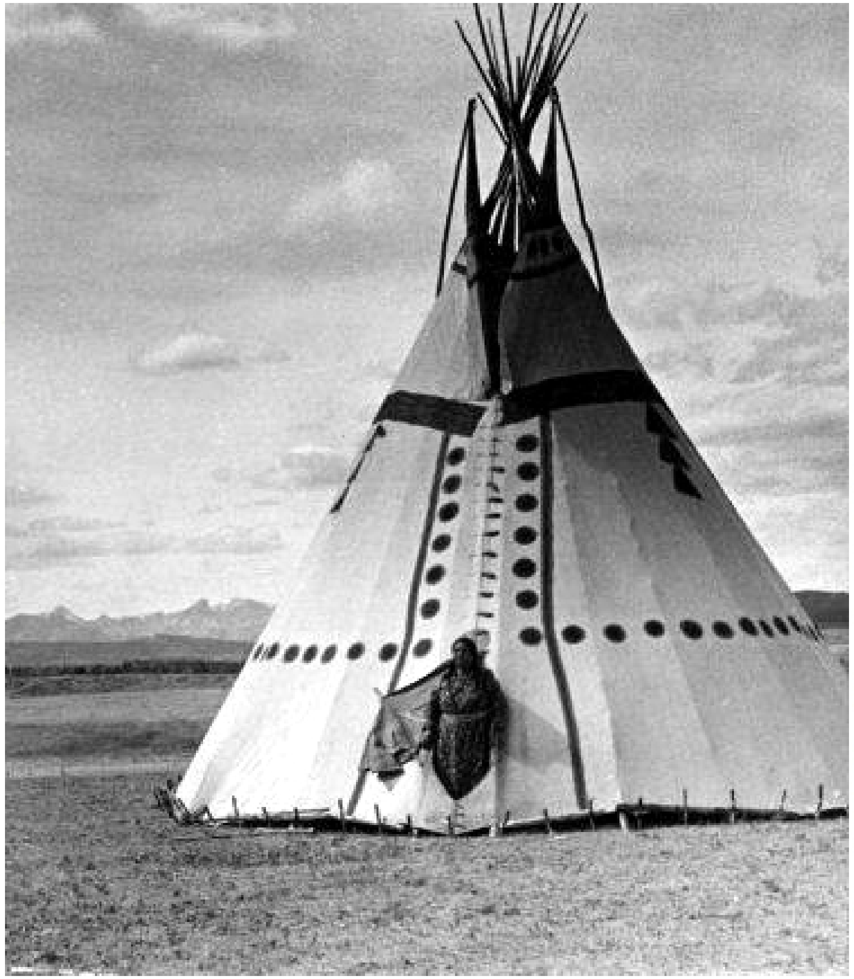
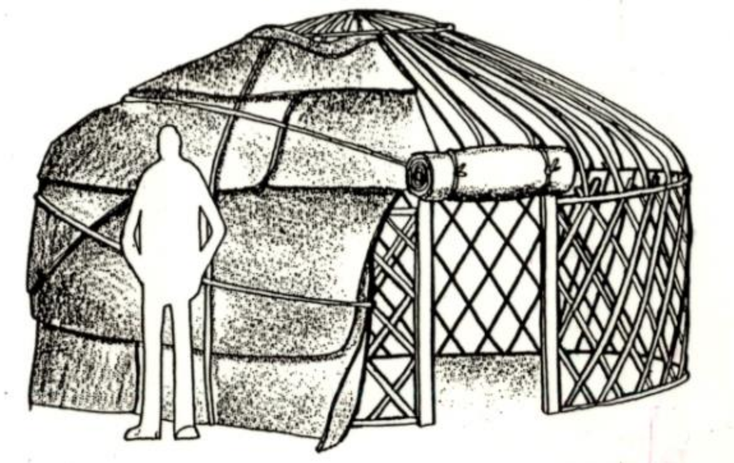


Figure 3.10: North American Indian tipi (a) side, and (b) front view; configured for (c) hot weather, and (d) cold weather. *(After Laubin and Laubin, 1977.)*



TEMPERATE



TEMPERATE

Mongolian YURT with collapsible “pantograph”side walls, and felt mat covering.

TEMPERATE

MAJOR LESSON FROM TEMPERATE:

- Design the envelope to allow seasonal changes
- Natural ventilation in the summer
- Close it down in the winter
- Contemporary equivalent would be operable windows and a level of solar control that changes throughout the year.

Hot-Arid: Indigenous Housing

Figure 3.17: Acoma pueblo, New Mexico, looking northeast. *(Reproduced fron Knowles, 1974, by permission.)*

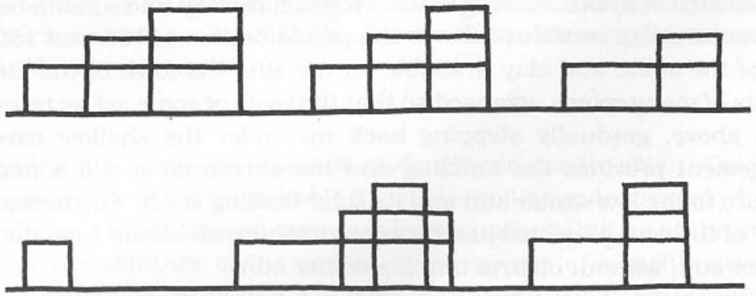


Figure 3.18: Acoma Pueblo, New Mexico. Typical sections show the critical spacin between rows of three- and two-story houses to ensure solar access. *(Redrawn fron Knowles, 1974, by permission.)*

Hot-Arid: Located in the desert region that spans California, Arizona and Nevada, the climate is characterized by extremely hot summers and moderately cold winters. The cold season lasts from November until March or April, with January temperature between 0 and 15 degrees C. A small amount of precipitation occurs during the winter. The summers are extremely hot and dry, with great temperature variations between day and night. *This "diurnal" temperature swing is used to moderate the interior building temperatures.*

HOT-ARID

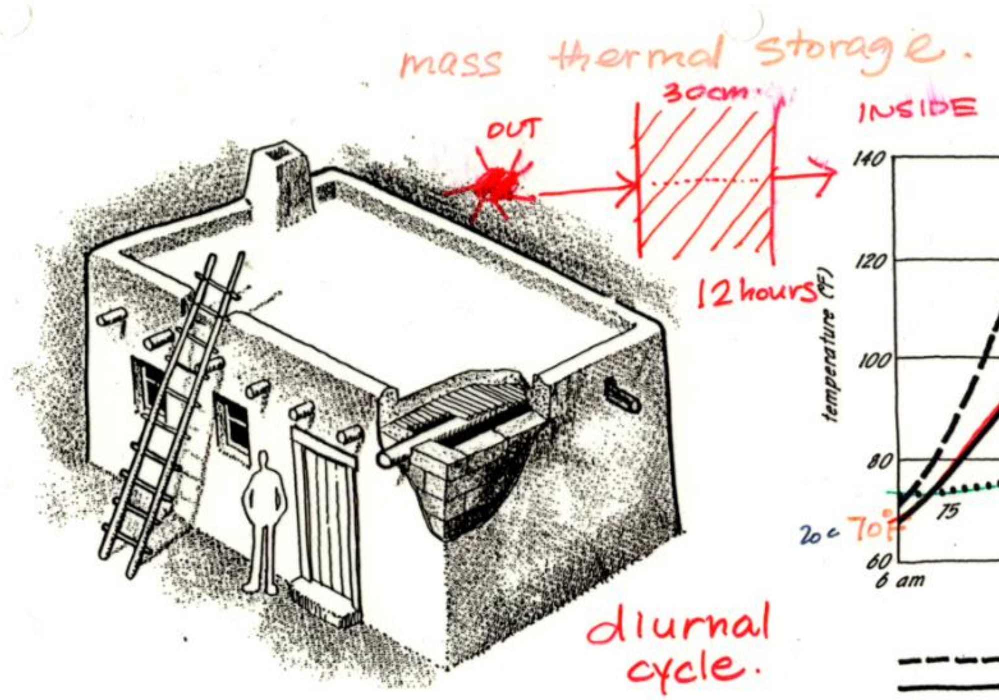


Figure 3.19: Cutaway drawing showing construction of adobe Pueblo dwelling. *(Redrawn from "Primative architecture and climate," by Fitch and Branch.*

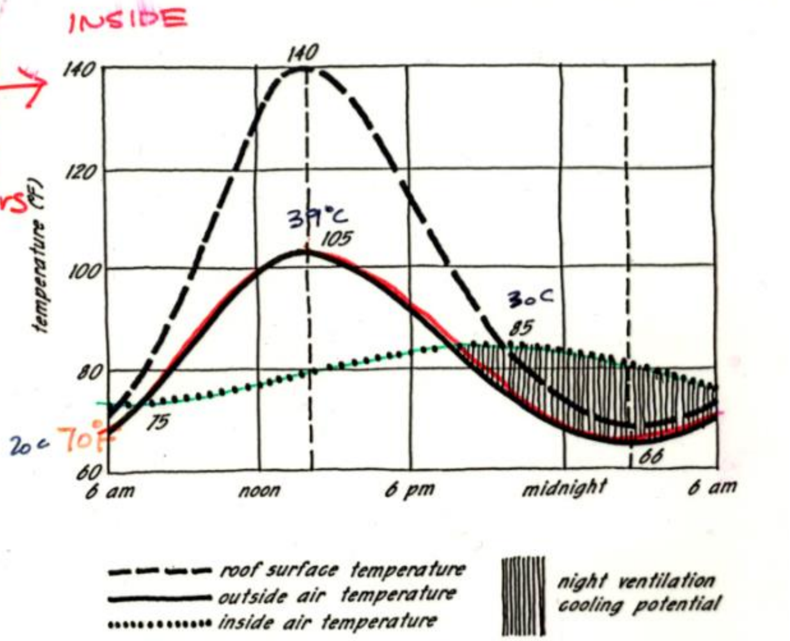
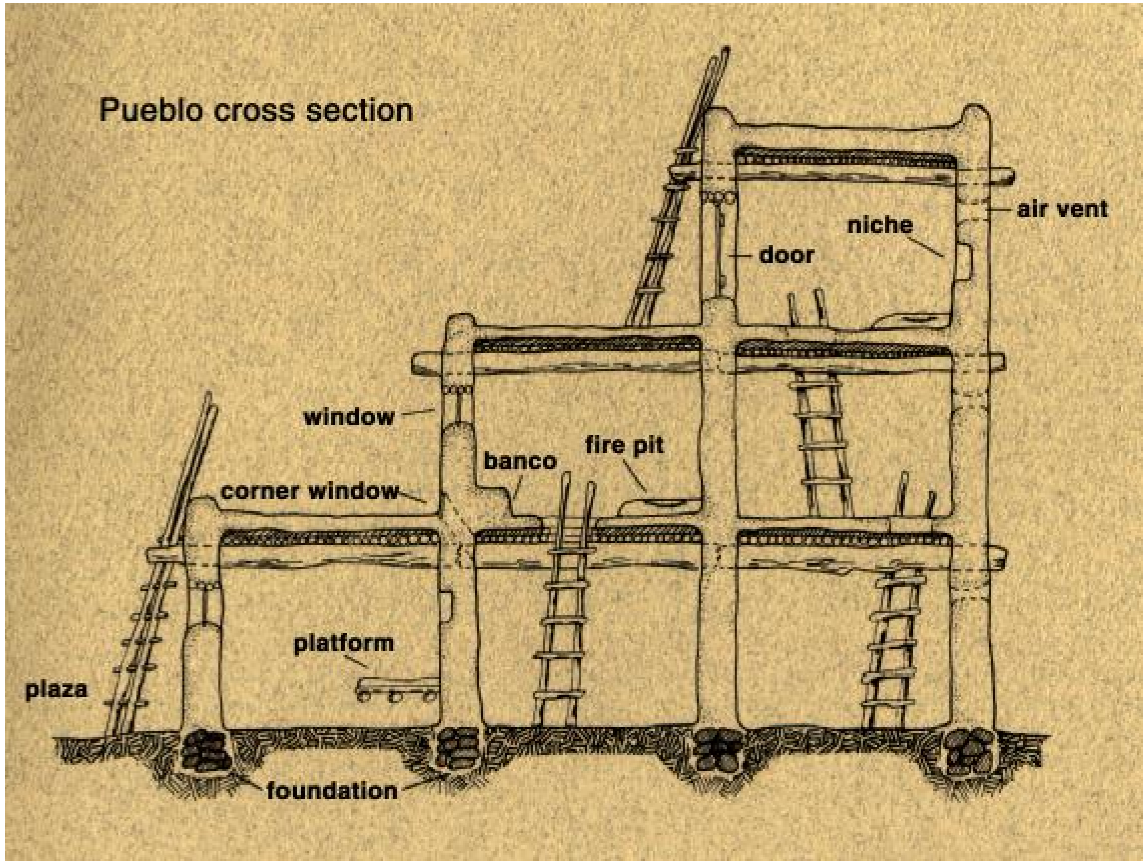
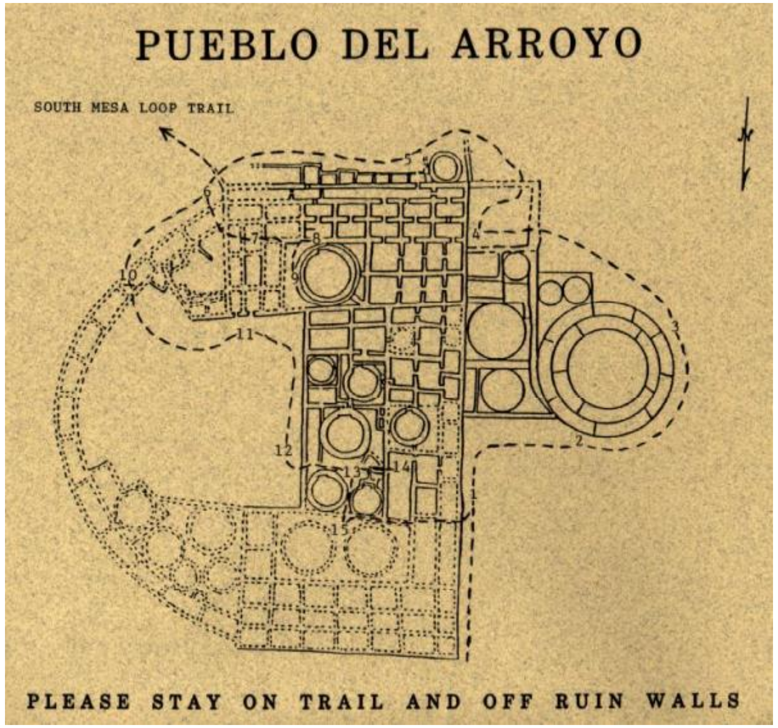


Figure 3.20: Temperatures in and around an adobe dwelling. Notice that while the average inside and outside temperature are about equal, the maximum interior temperature occurs about 10 p.m. — about eight hours after the outside peak. By this time the outside temperature has actually dropped below the inside and the window can be opened for ventilative cooling. Notice that the outside temperature swing is about 40°F wile the interior is only about 10°F. Finally, the shaded area shows the cooling effect of night ventilation. The thermal qualities of this primitive construction system are impressive indeed. *(Redrawn from "Primative architecture and climate," by Fitch and Branch.*

Hot arid buildings use the mass of the building to moderate the heat flow through the envelope. Occupants move out to the roof to sleep if it remains too hot indoors in the night.

HOT-ARID



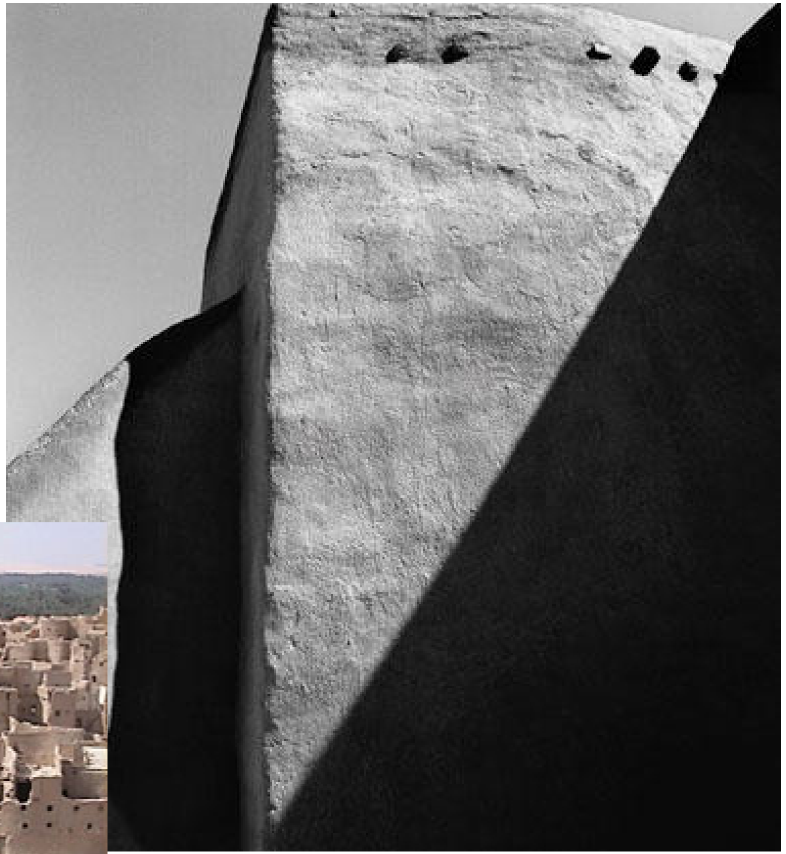


Historic pueblo type building in Chaco Canyon, New Mexico c. 1075 CE

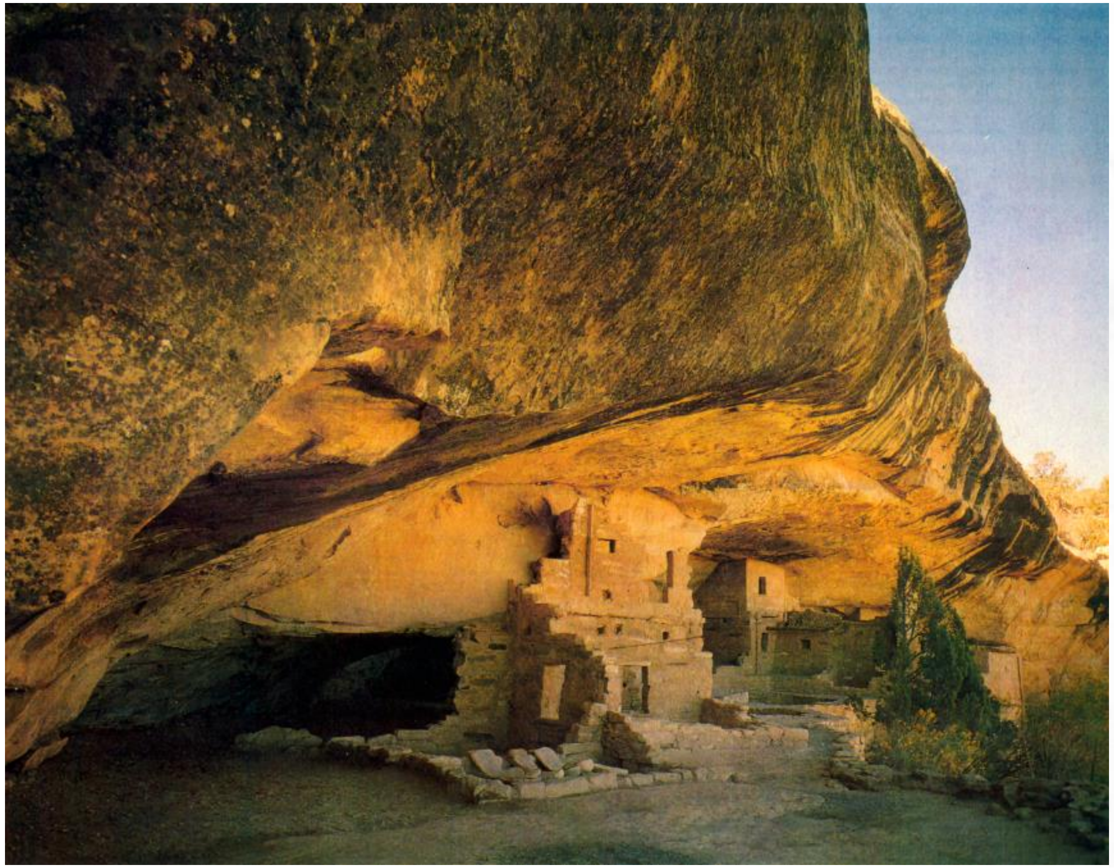
HOT-ARID

Taos pueblos, some dating back to the 17th century and are still in use today.

HOT-ARID



These buildings do not employ “insulation” and have very **limited window openings** so that the sun cannot enter. They use **reflective colours** to keep what little light is let in. Small windows also exclude ventilation as they wish to exclude the hot daytime air from entering the building.



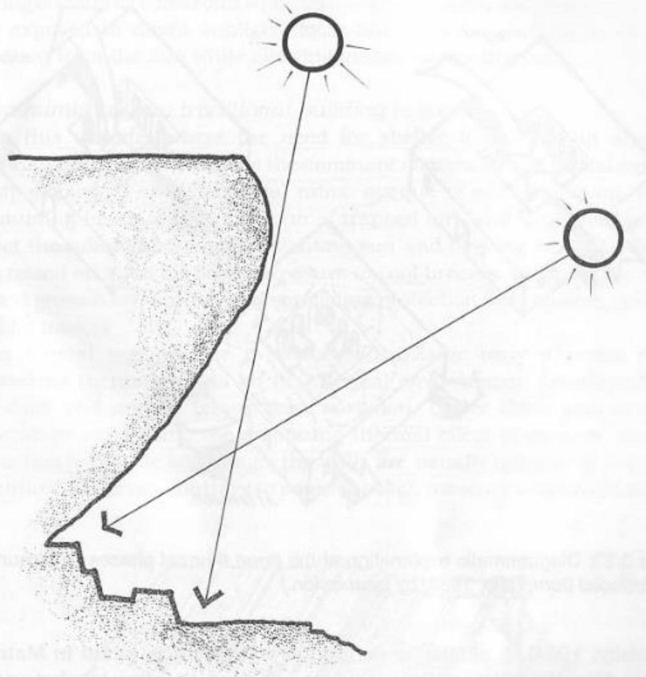


Figure 3.22: Longhouse Pueblo. Buildings were placed inside the cave in such a way that their vertical stone walls and horizontal terraces received great benefit from the low winter sun while being protected during the summer by shadow cast from the upper edge of the cave opening and by the high summer altitude of the sun. *(Reproduced from Knowles, 1974, by permission.)*

HOT-ARID

Mesa Verde used the natural landscape to take advantage of the winter and summer sun. Winter sun penetration heated up the masonry and kept the buildings warm. The cliff shaded from the summer sun, keeping things cooler.

HOT-ARID

Desert housing makes use of dense materials (stone/adobe) to store heat. It does get quite cold at night.

Not all hot-arid buildings are made from stone or adobe. Other accommodations are required when there is no stone, nor water with which to make mud bricks. Water is too scarce to be wasted in making a building… in this case, shade is optimized.

HOT-ARID

Hot-Humid: Indigenous Housing

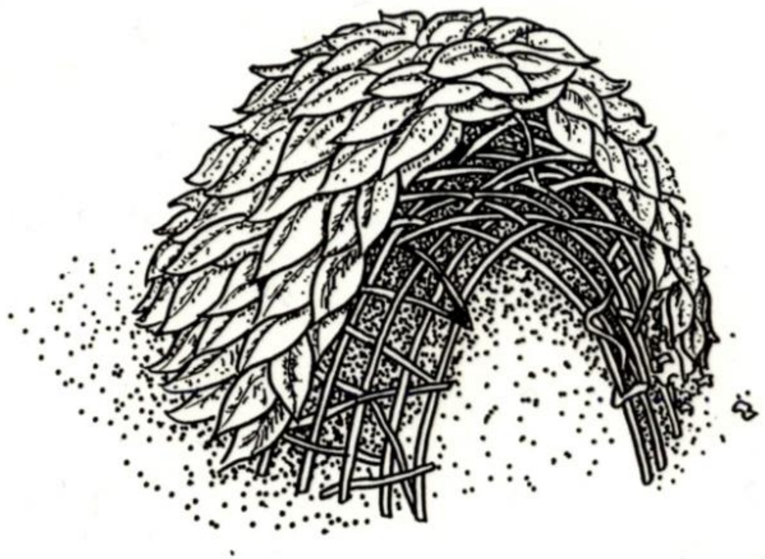


Figure 3.27: Simple dome hut of Banbuti Pygmies is a woven frame of twigs covered with large leaves. *(Redrawn from "Primative architecture and climate," by Fitch and Branch. Copyright © 1960 by Scientific American, Inc. All rights reserved.)*

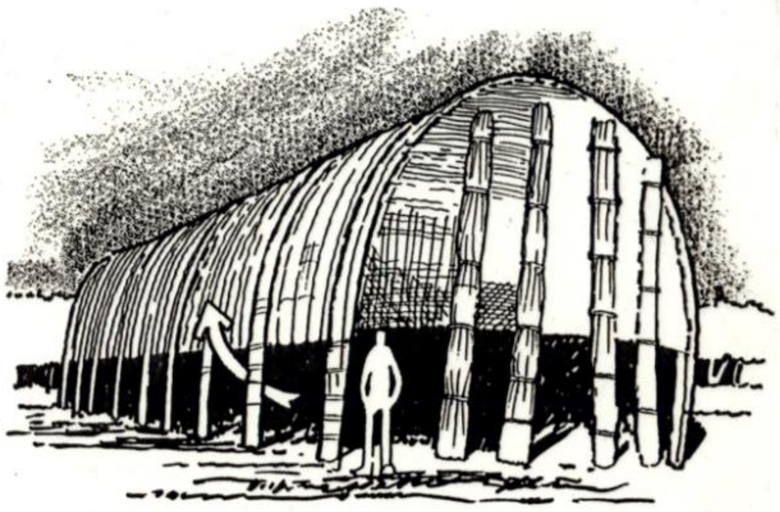


Figure 3.28: The design of this Ma'dan house (Iraq), built of 20 ft tall local reeds, has remained unchanged for 6,000 years. The sides can be raised to maximize ventilation. *(After Grundfeld, 1975.)*

Hot-Humid: is characterized by high humidity and warm summer temperatures. Day to night temperature swings during the summer are insignificant because of the extensive humidity and cloud cover which prevents surfaces from re-radiation to the night sky. Very mild winters make for a short heating season. Sunshine available all year. Often a lack of breeze.

HOT-HUMID

Hot-Humid: Indigenous Housing

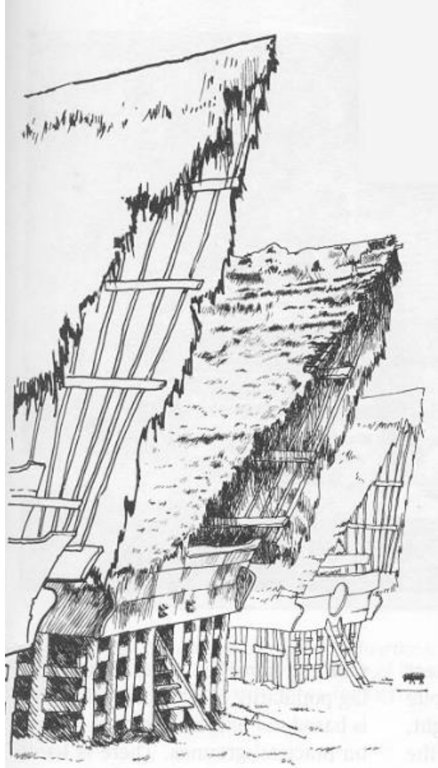
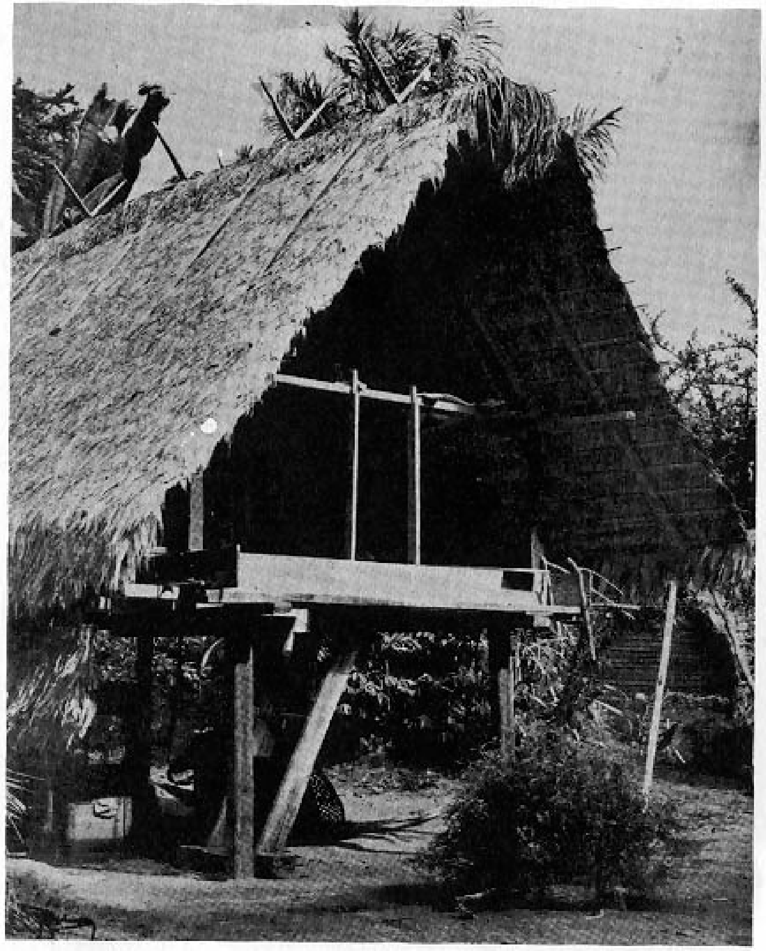


FIGURE 1.2b In hot and humid climates, natural ventilation from shaded windows is the key to thermal comfort. This Charleston, SC, house uses covered porches and balconies to shade the windows, as well as to create cool outdoor living spaces. The white color and roof monitor are also important in minimizing summer overheating.



26. Elegance in regional expression at the Hot-Humid island climates.

HOT-HUMID

Hot-Humid: Indigenous Housing

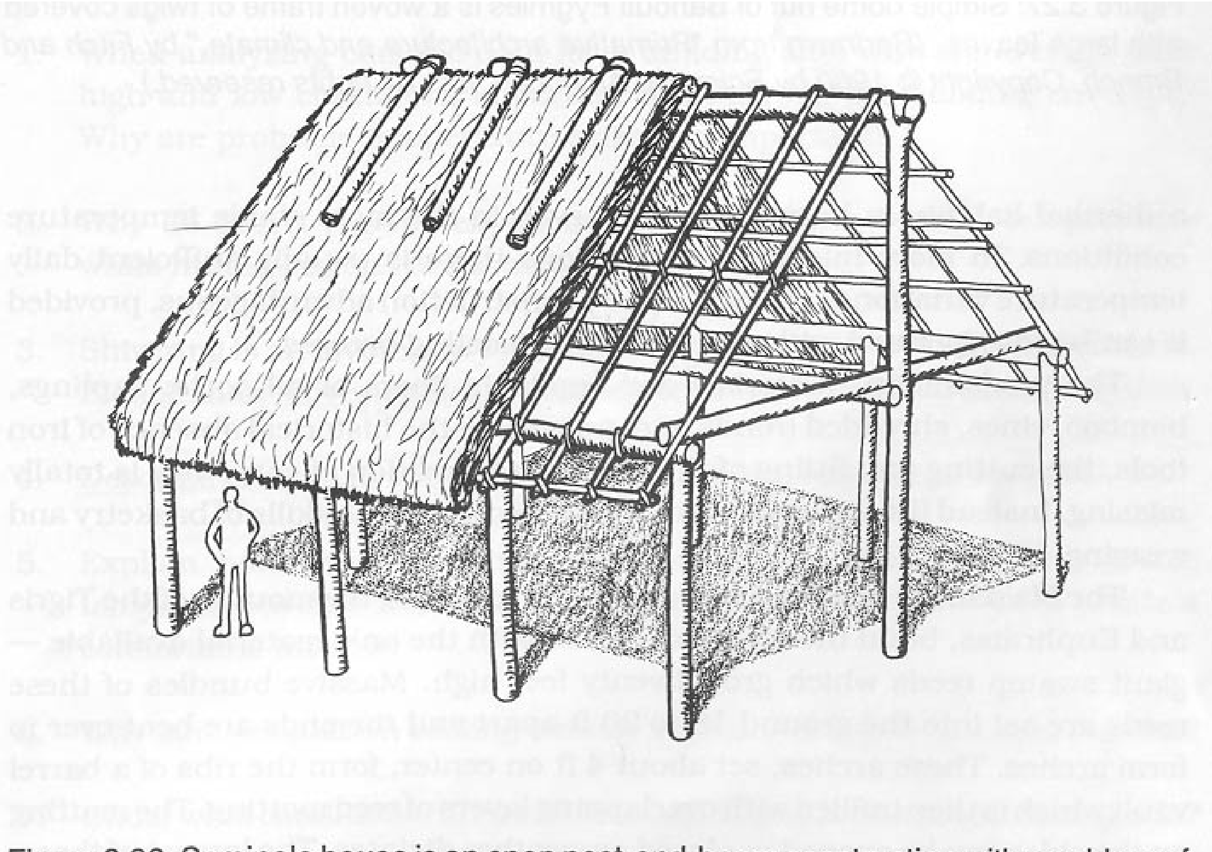
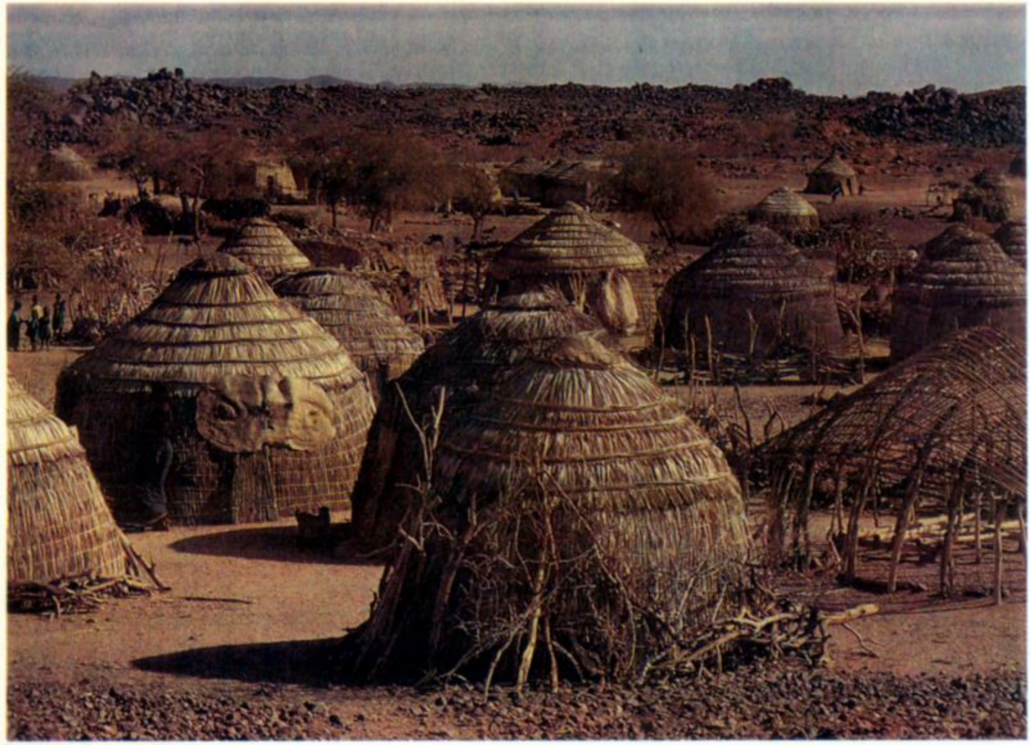


Figure 3.26: Seminole house is an open post-and-beam construction with a gable roof of thatch. *(Redrawn from "Primative architecture and climate," by Fitch and Branch.*

HOT-HUMID

HOT-HUMID



George Holton from Photo Researchers

bones and covered with animal hides—quite possibly kangaroo hides.

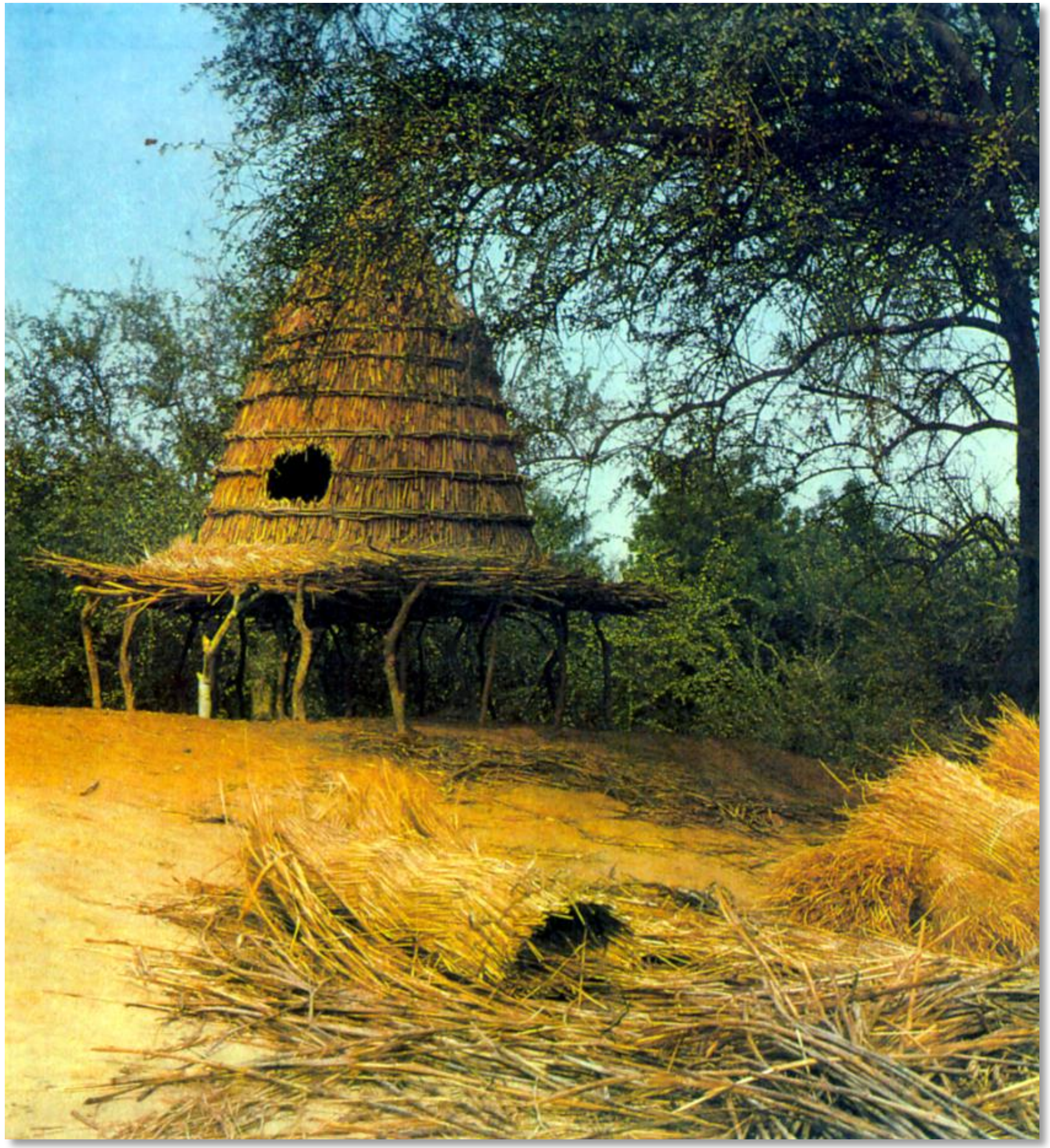
The Sakai of Malaysia still build some of their houses in trees. In the absence of lifts and cranes, building materials must be light enough to climb with. Flooring consists of bamboo bound with rattan. Walls are rattan, and the roof is made of attap leaves, which have a life expectancy of from four to ten years. Since the attap grows leaves up to ten feet long and four feet wide, one leaf sometimes does the entire roofing job.

Carl Frank from Photo Researchers

HOT-HUMID

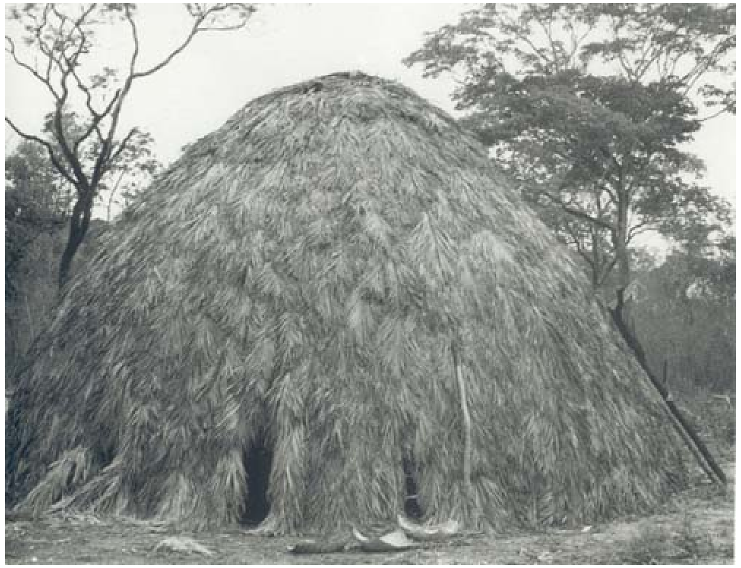
Conical thatched grass roofs top circular dwellings built with interlaced fiber siding , Village in New Guinea

HOT-HUMID



Buildings are also elevated to protect their occupants from animal predators.

HOT-HUMID



HOT-HUMID

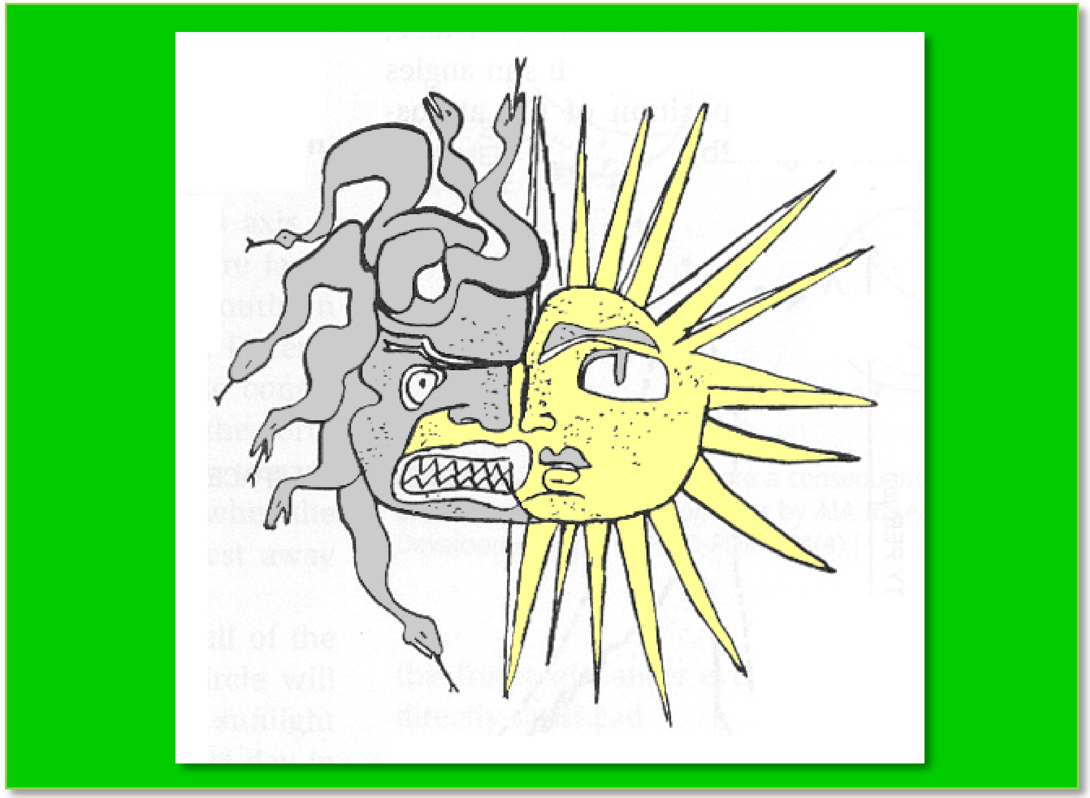
Plentiful materials are compromised in urban areas, as shown in the construction of these “favelas” in Brazil, which use found, cheap, modern materials - sometimes what the rich throw away. Density does not permit air circulation.

THESE ARE BOTH BAD EXAMPLES!

Kandy shacks - Sri Lanka
A combination of natural and salvaged materials.

HOT-HUMID

THE EVOLUTION TOWARDS CONTEMPORARY CLIMATE RESPONSIVE DESIGN: Part Two



Drawing by LeCorbusier

Applying Vernacular Strategies to Passive Design

CLIMATE BASED STRATEGIES

FOR RETHINKING CONTEMPORARY ARCHITECTURAL DESIGN

PASSIVE – BIO CLIMATIC DESIGN

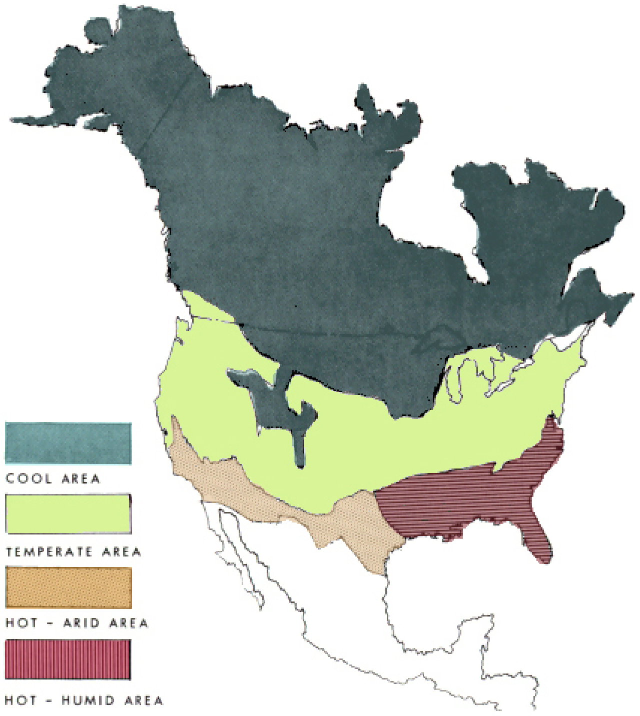
Design must first acknowledge regional, local and microclimate impacts on the building and site.

COLD

TEMPERATE

HOT-ARID

HOT-HUMID



11. Regional climate zones of the North American continent.

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

What is Passive Design?

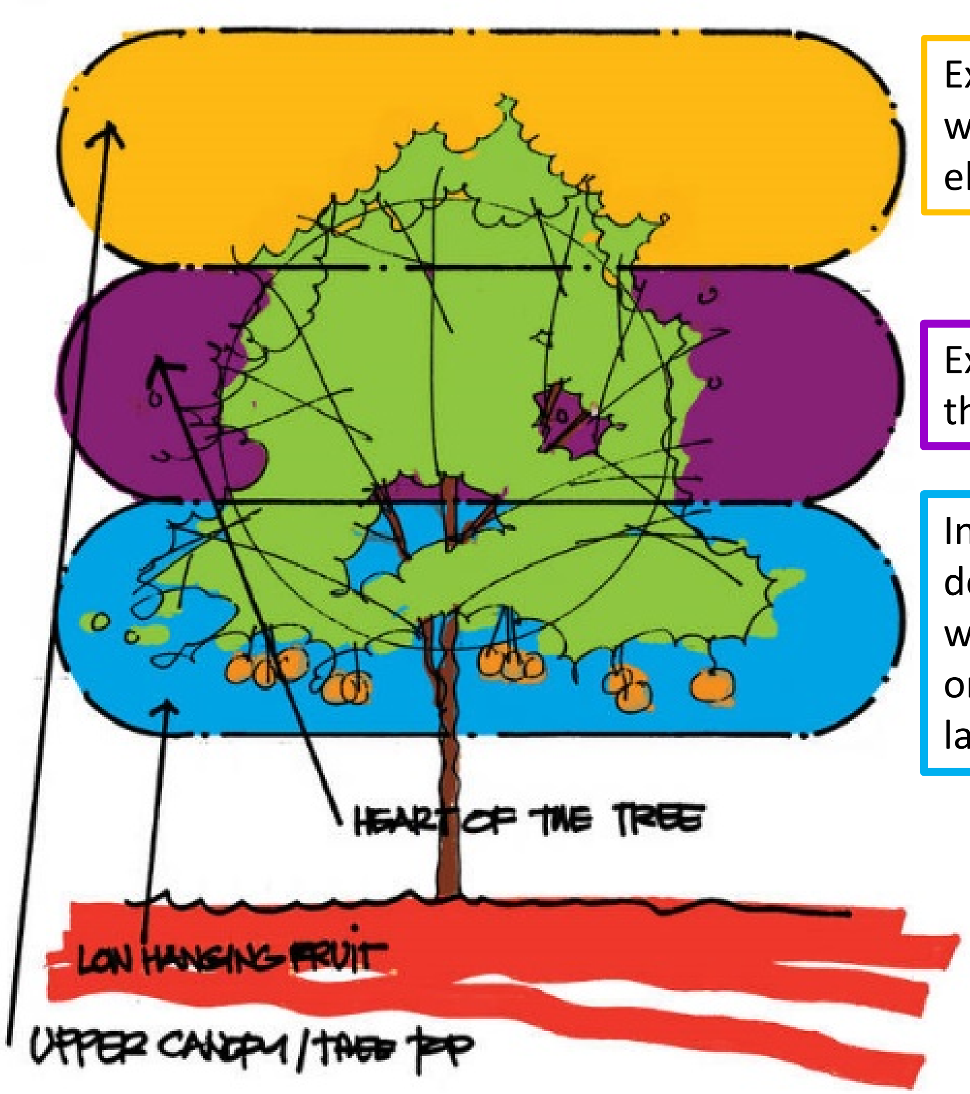
Start by seriously acknowledging the climate – sun, wind, light, temperature and relative humidity range

Design the building to:

- Let the sun in when it needs heat, without having to modify anything
- Prevent the sun from entering when it is unwanted and you need cooler interior temperatures
- Light the building from available daylight and avoid turning on the electric lights
- Allow natural breezes to flow through the building to cool it and bring fresh air/oxygen
- Design the walls to (in cold climates) avoid heat flow through them (by insulation)
- Design your roof to naturally shed water/snow – even include overhangs for shading

Important to locate the sun and orient the building properly

Low Hanging Fruit



www.amdgarchitects.com

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, orientation, adjacencies, massing, landscaping

If the ultimate goal is to be able to use renewable energy to reduce dependence on fossil fuels, then the load has to be light.

Imagine expecting to run a Hummer with photovoltaics?

Bio-climatic Design: COLD

Where **WINTER** is the dominant season and concerns for conserving heat predominate

RULES:

- **First INSULATE**
- *exceed* CODE requirements
-build tight to reduce air changes
- **Then INSOLATE** (let the sun shine in for free heating energy)
- roof sloped to shed rain and snow
- roof overhangs for shade during summer

YMCA Environmental Learning Centre, Paradise Lake, Ontario

COLD

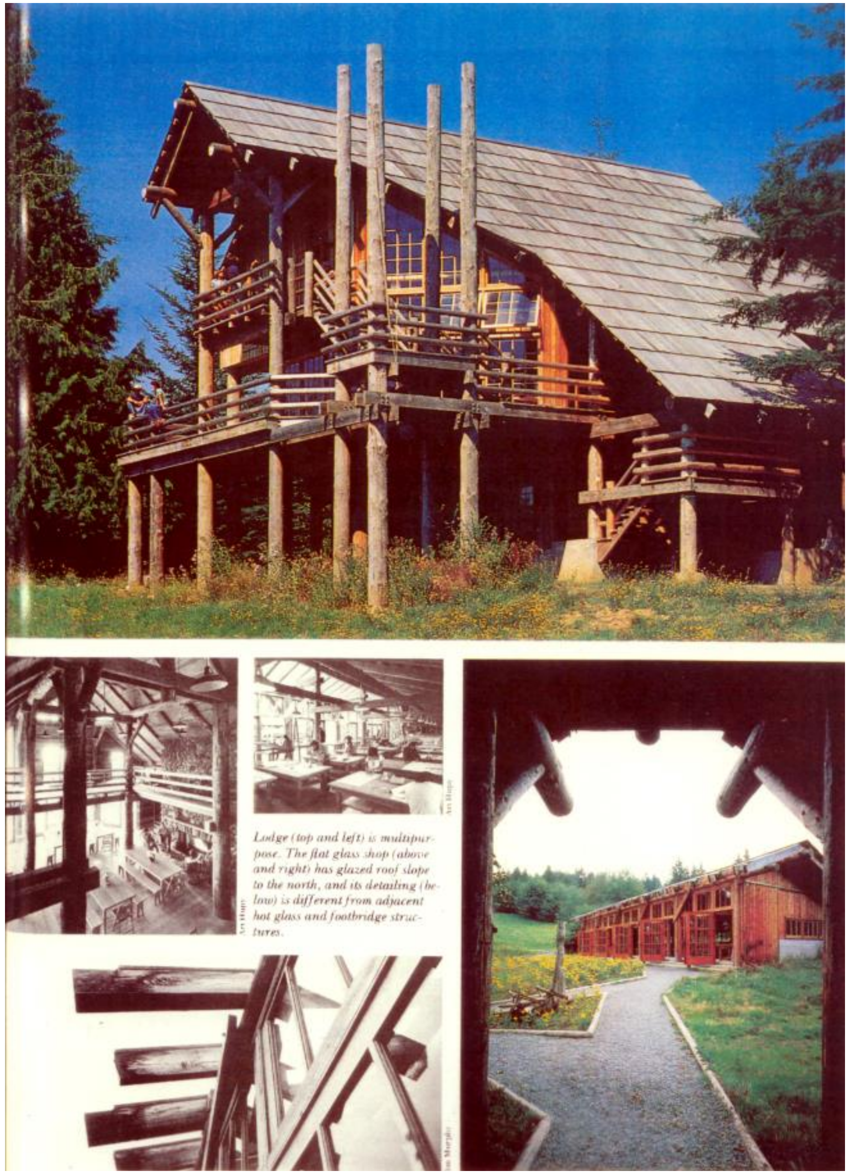
Cold climate is the most challenging in terms of preventing potential building envelope damage due to snow and moisture.

COLD

COLD

If spans are short enough, sloped roofs provide the best solution to prevent excessive snow accumulation that could cause a collapse.

Sloped roofs are also the best for shedding rainwater.



Cold climate houses can take varying attitudes towards their roofs. In some cases “stops” are put on the roof to hold the snow in place (so it does not slide off) and the snow is used as extra insulation. The roof must be stronger to prevent structural collapse due to this extra weight.

COLD


Traditional methods of holding snow on roofs are now required by building code to prevent slides onto the public.

COLD



Bio-climatic Design: HOT-ARID

Where **very high summer temperatures** with great fluctuation predominate with **dry conditions** throughout the year.

RULES:

- Solar avoidance : keep DIRECT SOLAR GAIN out of the building

-respect the DIURNAL CYCLE

- use heavy mass for walls

- keep windows small

- keep colours light and reflective

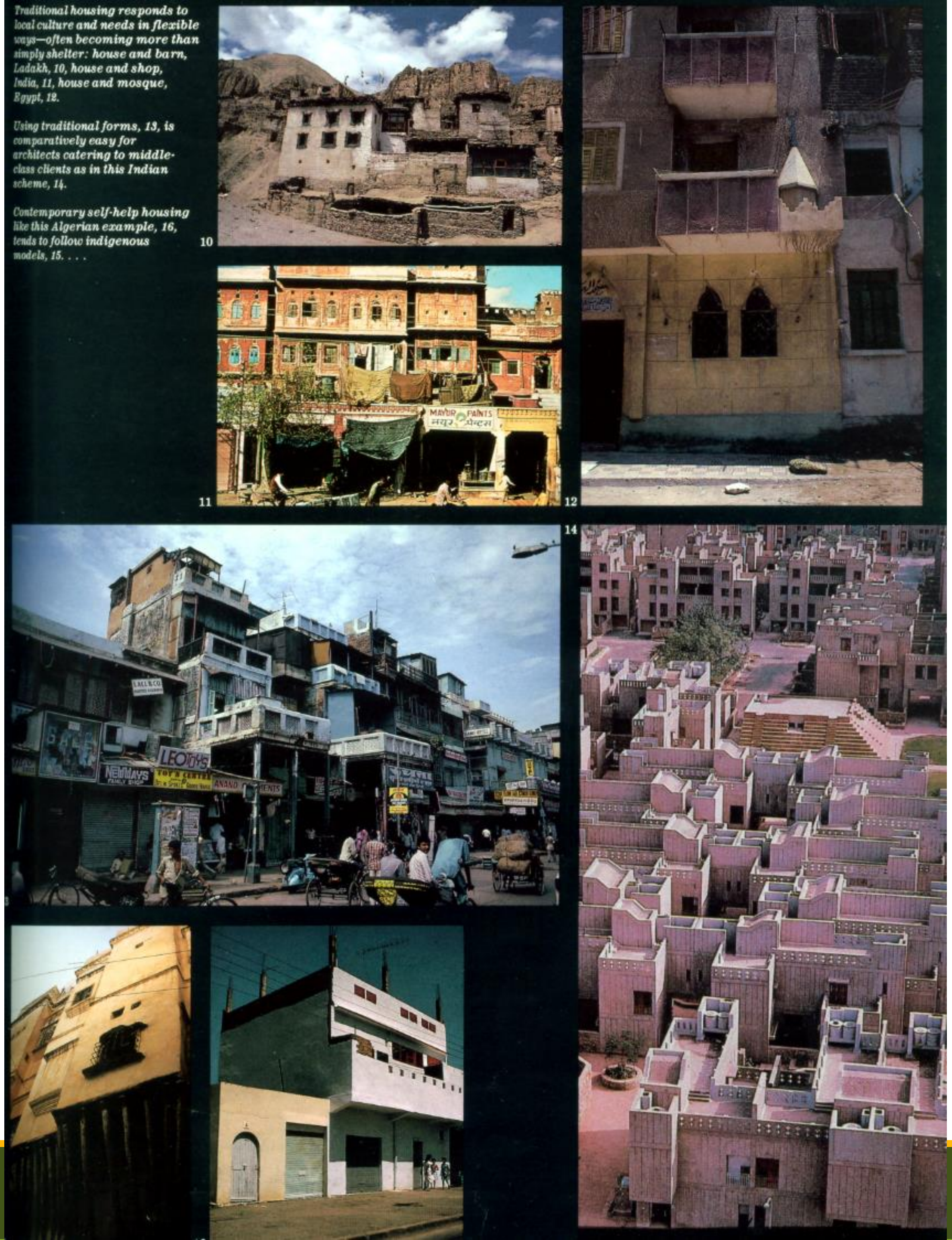
- roof can be flat as nothing to shed

Traditional House in Egypt

In hot dry (arid) climates windows are kept to a minimum to prevent the sun from entering the building.

Bright stucco finishes are used to reflect light and keep the environment bright.

Sperlonga, Italy

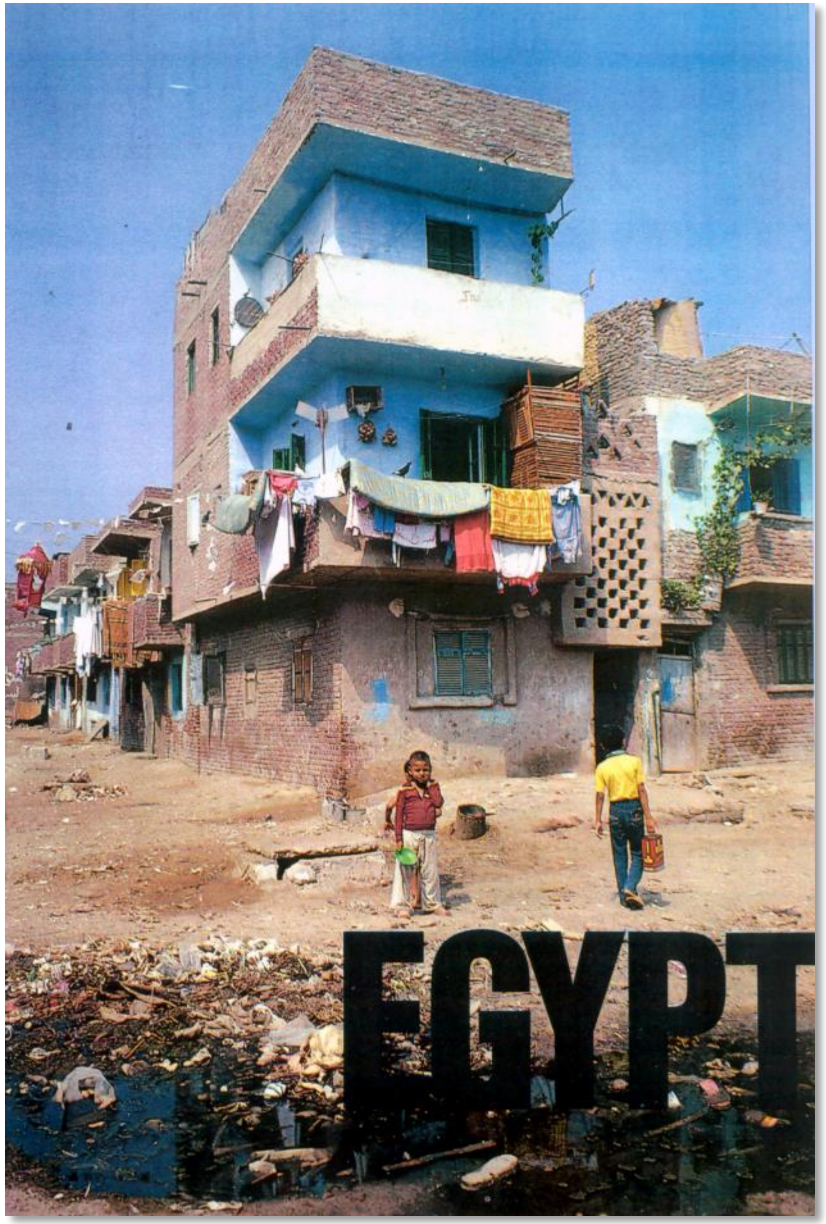


In some cases urban pressures have compromised valid climate based design strategies.

The “pink” town makes good use of courtyards and building shading to create a cooler place.

The stacked buildings on the left retain the small windows but expose more of themselves to the sun.

HOT-ARID



Vernacular architecture tends then to be building that grows out of indigenous practice and is adapted to somewhat more 20th century building.

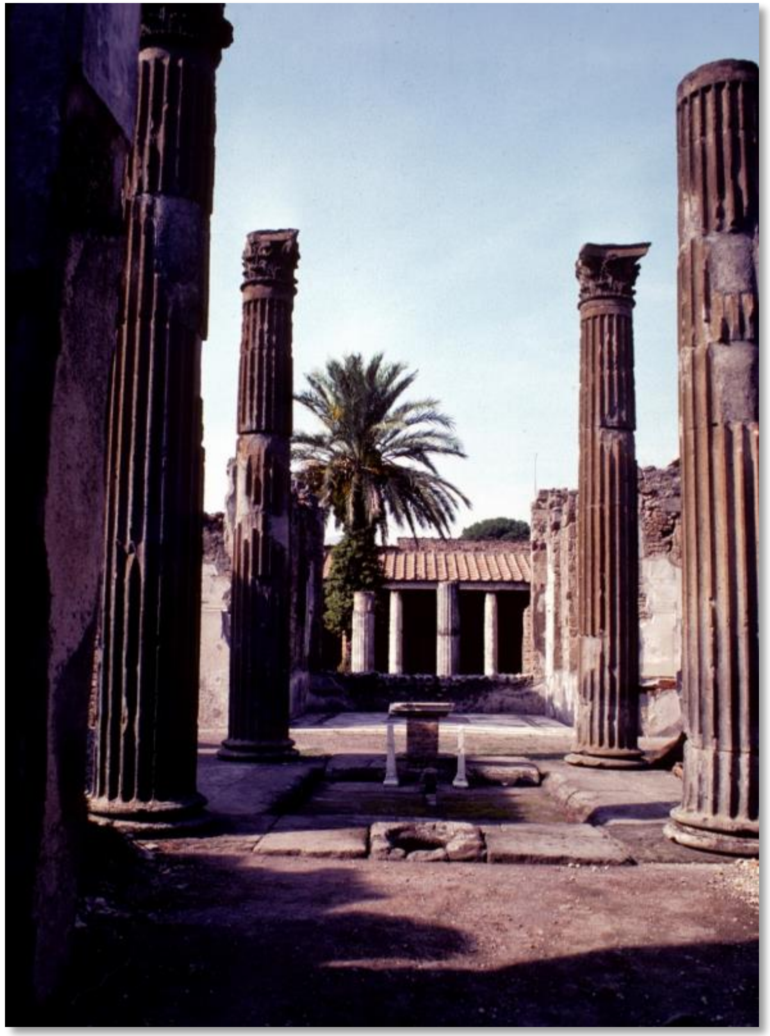
HOT-ARID

Cairo, Egypt

- Standard construction is a reinforced concrete frame
- same column size bottom to top
- Brick or tile infill
- Add floors as you have money
- See the rebar sticking out the top of the frame

- Exterior finishes applied as you can afford them
- Air conditioners added as you can afford them
- This is one of the least efficient ways to cool buildings as it is very high in energy costs and the AC units themselves produce heat as a waste by-product, making the city warmer

Courtyard buildings:

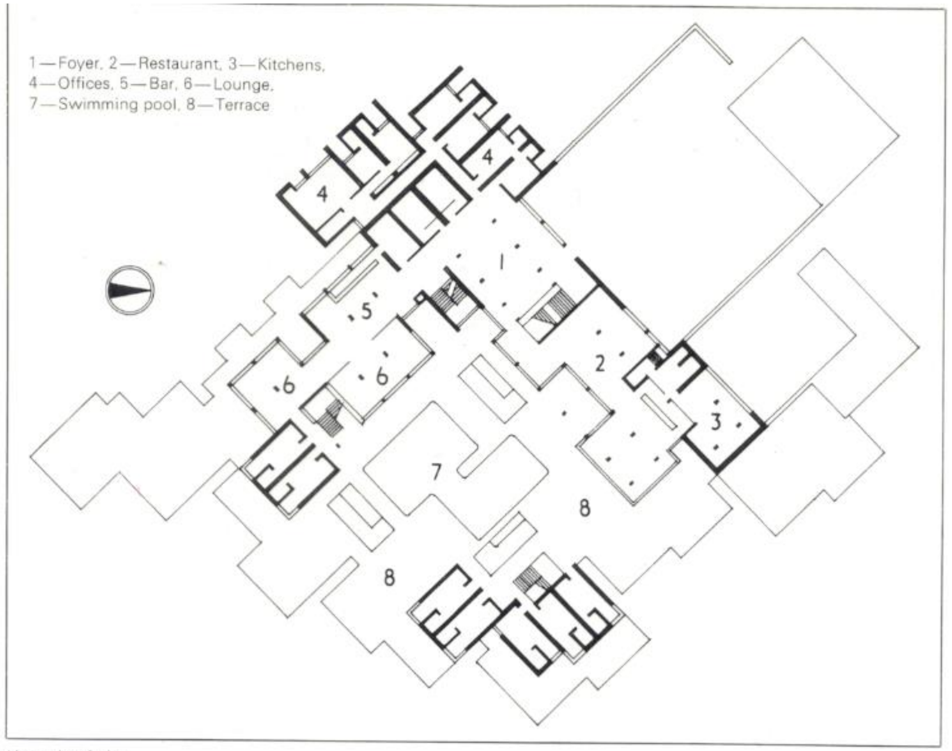


Courtyards are used in hot arid climates and work well because sun can warm these spaces in cooler months.

Courtyards do NOT work well in cold climates because of low winter sun angles.

HOT-ARID

This modern building makes use of the hot-arid method that employs small windows and creates an “airy” interior by opening up courtyards and spaces on the inside of the building, that are constantly shaded.



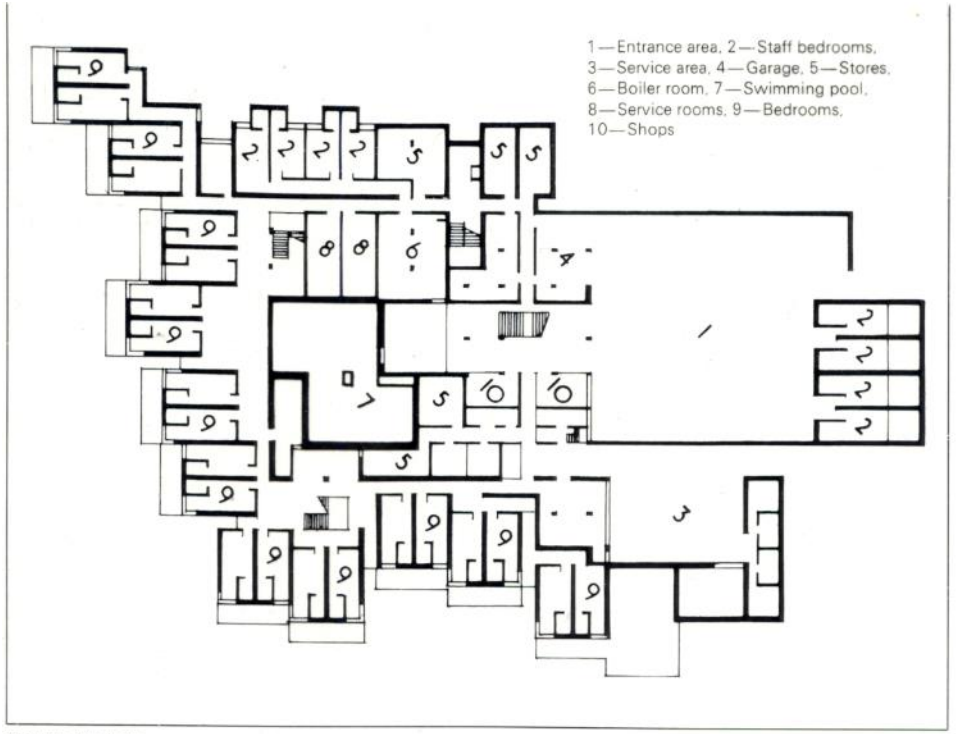
Upper level plan

General view

In various climatic designs, thermal mass (stone, concrete, brick, adobe) can be used as a "thermal sink". ie. The materials have a high capacity to hold heat and so the heat that comes to the interior of the space gets absorbed by the *building materials* and NOT the people.

People are 80% water, which also has a high thermal capacity.

Wood is an insulator so does not absorb heat.



Entrance level plan

Interior view with the dining room beyond

110 THERMAL MASS - HEAT SINK.

HOT-ARID

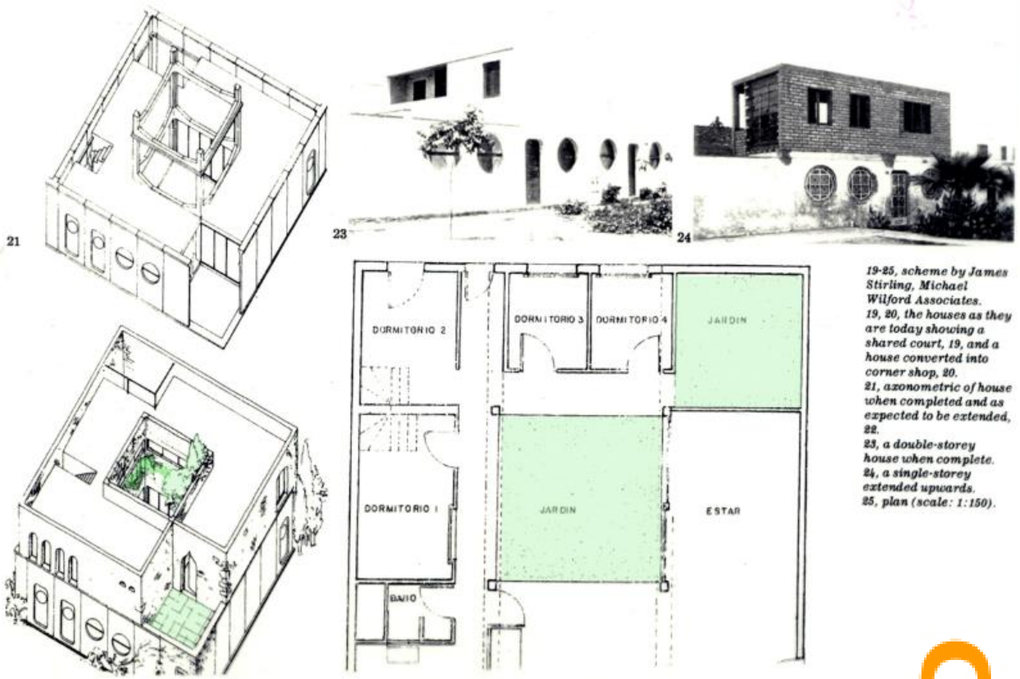
Modern building being marketed as a “pueblo” - “modern climate conscious adaptation”

Note light colours to reflect the light and heat.

Limited window openings to prevent excessive solar heat gain.

Use of masonry as it can work with a diurnal (hot day/cool night) cycle.

HOT-ARID



19-25, scheme by James Stirling, Michael Wilford Associates.
19, 20, the houses as they are today showing a shared court, 19, and a house converted into corner shop, 20.
21, axonometric of house when completed and as expected to be extended, 22.
23, a double-storey house when complete.
24, a single-storey extended upwards.
25, plan (scale: 1:150).

These more contemporary city based hot arid houses make use of courtyards to cool the house environment. The plants not only provide physical cooling, but also "mental" cooling. This becomes highly important in architectural design.

HOT-ARID

Aldo van Eyck's cluster

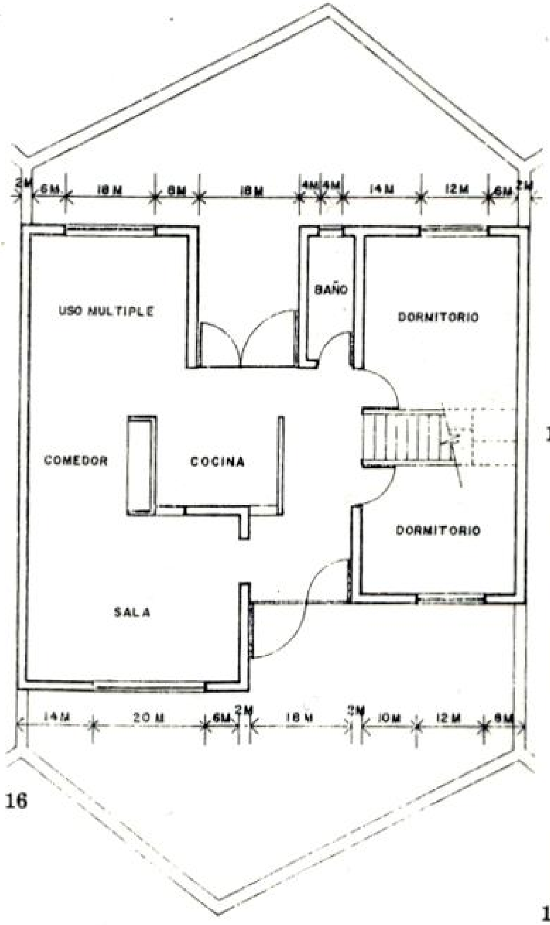
Many of the projects were conceived in pre-cast concrete, with Western floor plans. Some schemes, such as the Danish or Polish ones, had no separation between living and dining areas. Others, like Aldo van Eyck's, had the dining room as part of the living room, but tucked to one side. Van Eyck, maintained that what the dwellers may want now could change in the future: 'The question of existing norms and forms and the ways these will change confronts the architect with an apparent choice which it should not be his concern to make'.

The Dutch scheme, sharing a courtyard with Alexander's row, is easily recognisable by its hexagonal plan. The house within the walls is a more conventional shape, roughly a square. The hexagon shape, intended to discourage additions outwards, appears to work. About 35 per cent of the residents made an exterior addition such as adding one or more rooms, yet few appeared to push out against the surrounding wall or garden space. The design helped, or some might say coerced, the resident to build up instead of out.

The surrounding wall, though, did not remain untouched. Its one-storey height was perceived to be too low, and over half the homeowners extended it, a few adding broken glass as a crown.

Stirling's courts

Under the colonial style add-ons, the decorative roofs, diagonal trim, second-storey additions or colourful awnings can just barely be discerned the large round windows of Stirling's original design. Round windows worked in Runcorn New Town housing (1967), so why not Peru? Whether inspired by the



16

17

18

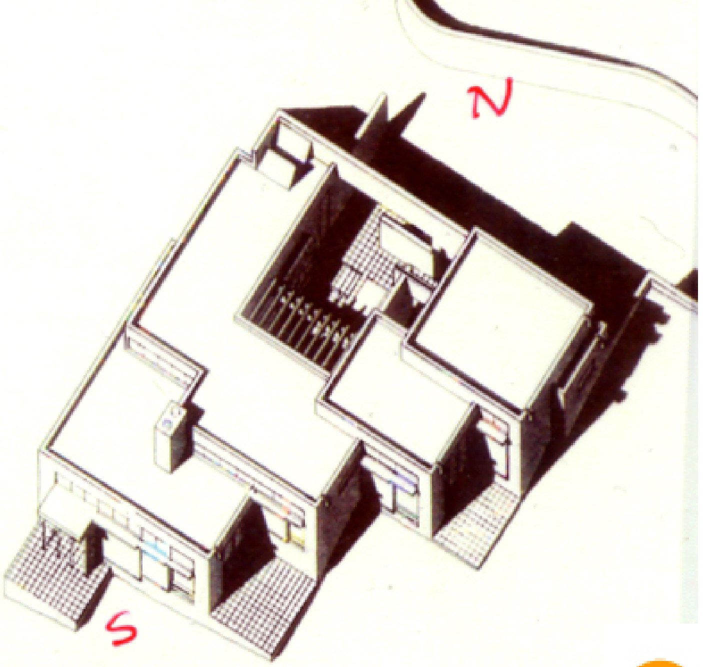
14-18, Aldo van Eyck's scheme:
14, the houses as they are today; the hexagonal garden walls were thought to be too low for security.
15, a modern kitchen in van Eyck's scheme: generally the residents are of a higher income group than was planned.
16, ground floor plan (scale: 1:150)
17, houses when completed.
18, as they are now.

In this case the courtyards are more to the exterior of the building and also provides spatial separation and "privacy".

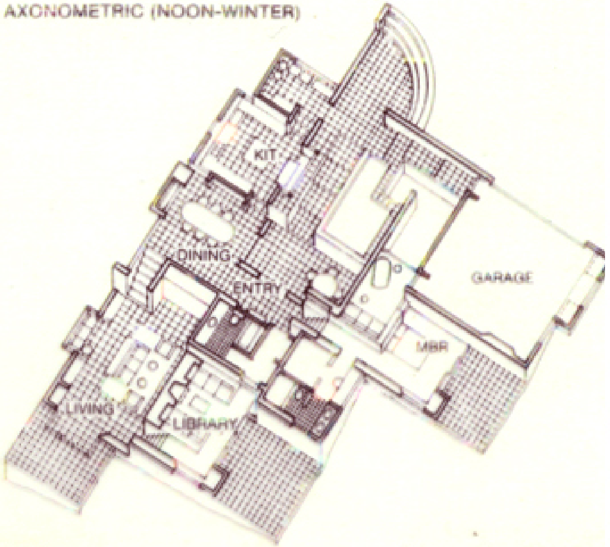
A view of the residence from the southwest (below). The non-vented trombe walls are visible on the south façade. The low winter sun strikes the trombe walls full strength (opposite).

the tradition of New Mexican architecture while adopting both a new energy strategy and the inspiration of a Mexican master in Luis Barragán. Its architects are themselves transplants, Ervin Addy arriving in Albuquerque from Texas and Robert Peters coming from Minneapolis via Chicago. The firm name, Alianza Arquitectos, symbolizes, however, the firm's intent to live and work within the Southwestern heritage and seek a vocabulary appropriate to it.

When Peters came to Albuquerque from SOM, Chicago (and work on the Sears Tower

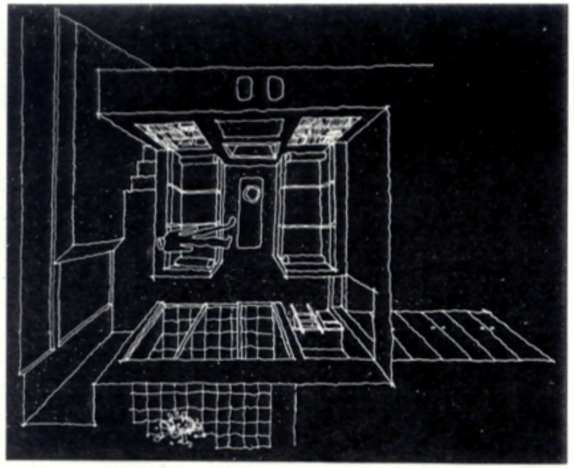


AXONOMETRIC (NOON-WINTER)

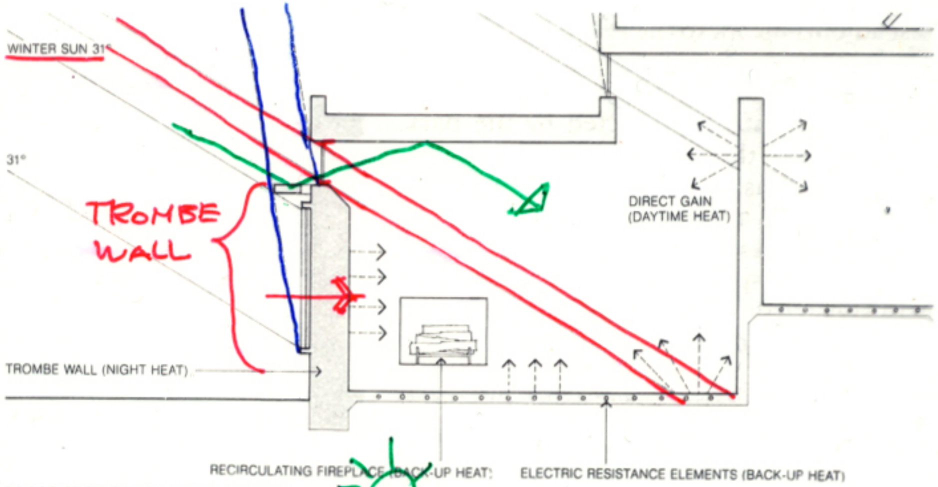


PLAN

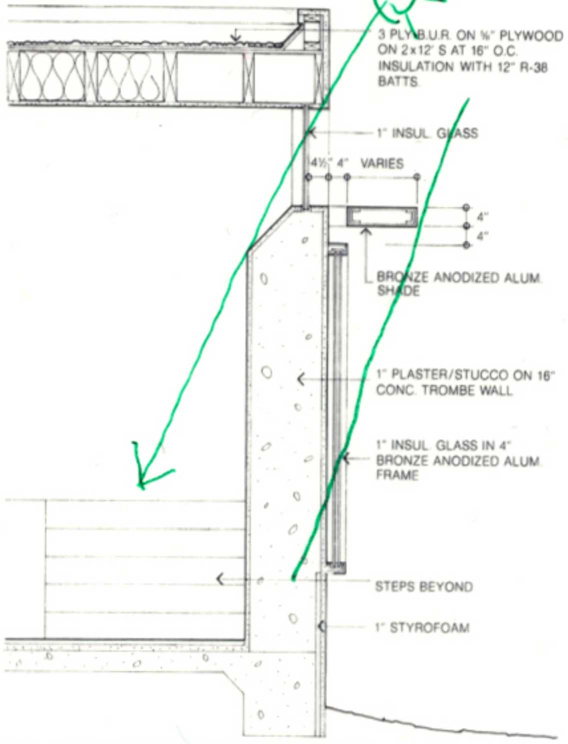
HOT-ARID



LOOKING DOWN INTO THE GUESTROOM/LIBRARY



CROSS SECTION: SOLAR STRATEGY



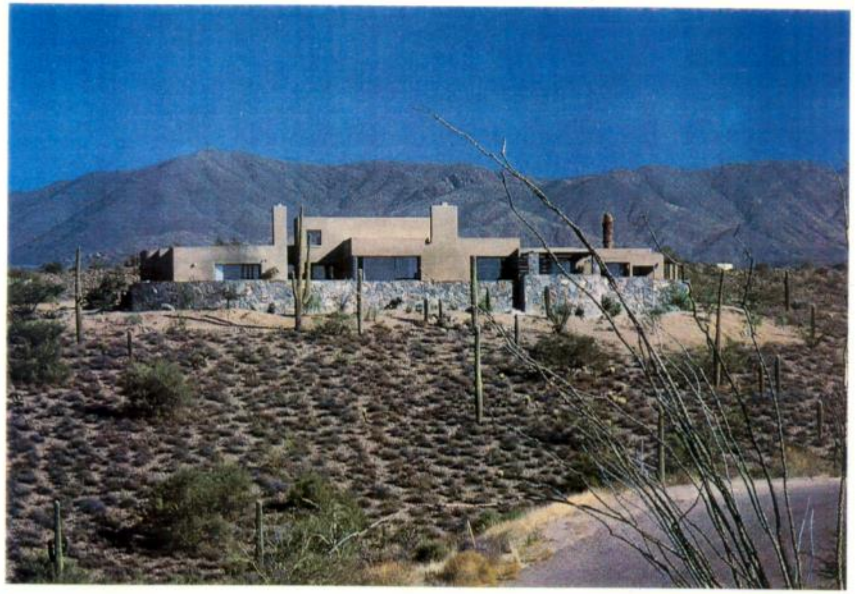
WALL SECTION AT TROMBE AND CLERESTORY

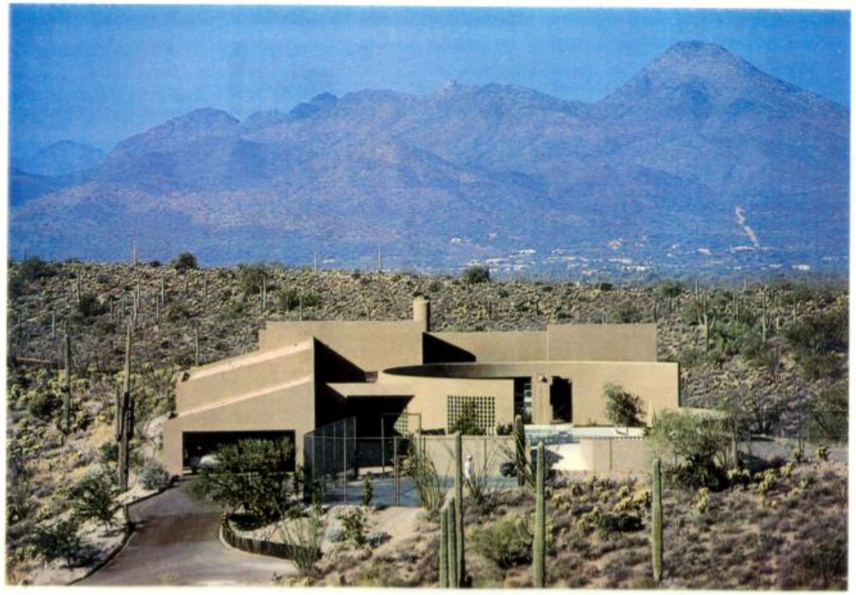
The aesthetic and technical solutions of the nonvented trombe wall (both exterior and interior are illustrated here.

Data

Project: *Kress residence.*
Architects: *Alianza Arquitect... An Architects Alliance. Ervin ... Addy, partner in charge; Robe... W. Peters and Jerry W. Geurts design team.*
Site: *1.75 acres in the foothills ... the Sandia Mountains. Vegetation is typical of New Mexico's high desert country.*
Program: *a one-bedroom residence with guest room/library to serve the retirement needs of the couple who travel extensively.*
Structure: *structural concrete slab on grade beams and piers with structural wood frame wal...*

HOT-ARID

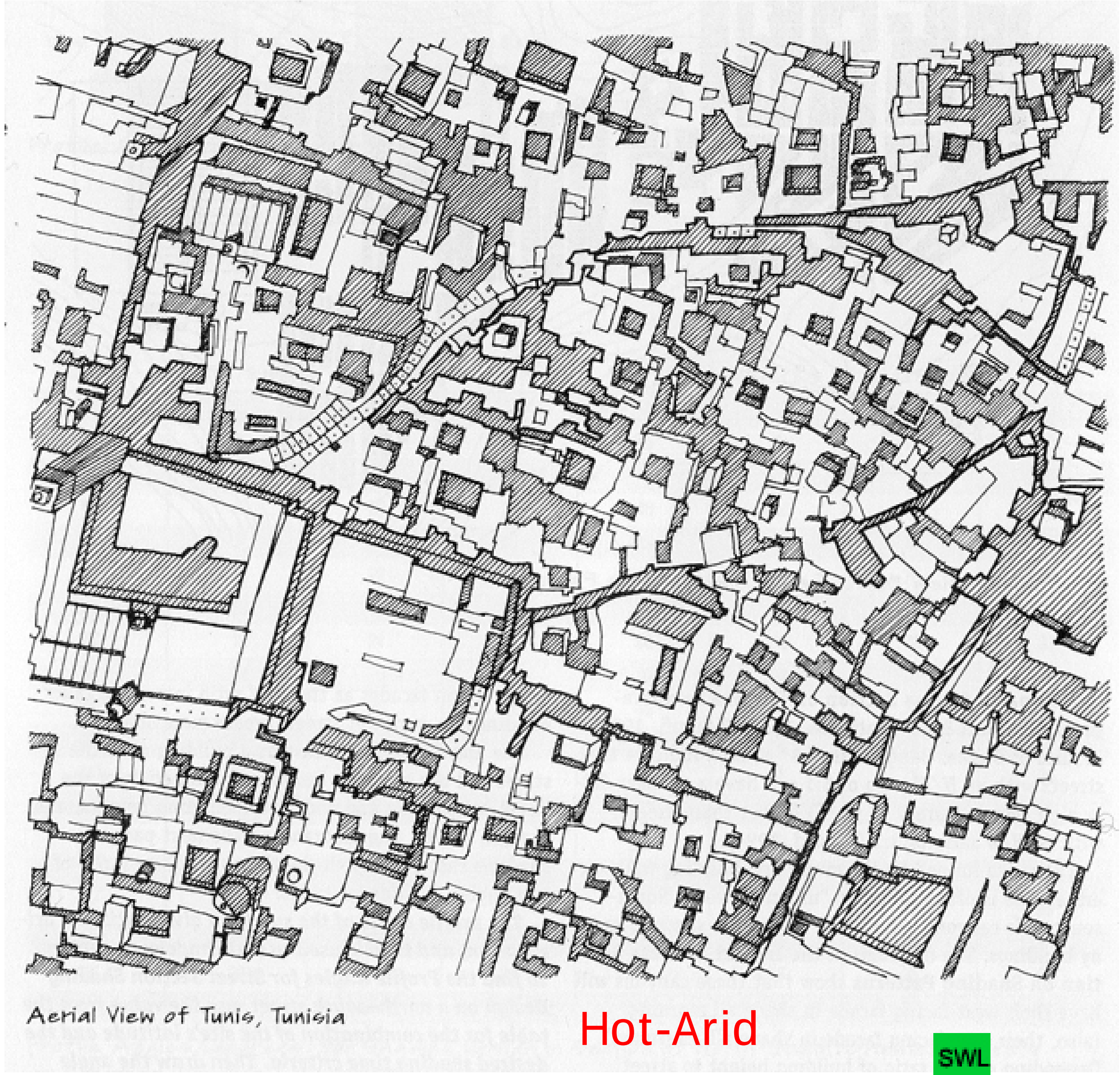





Street Layouts

In hot arid climates where wind/ventilation is *not desired*, city layouts are very dense and work with overshadowing to create coolth.

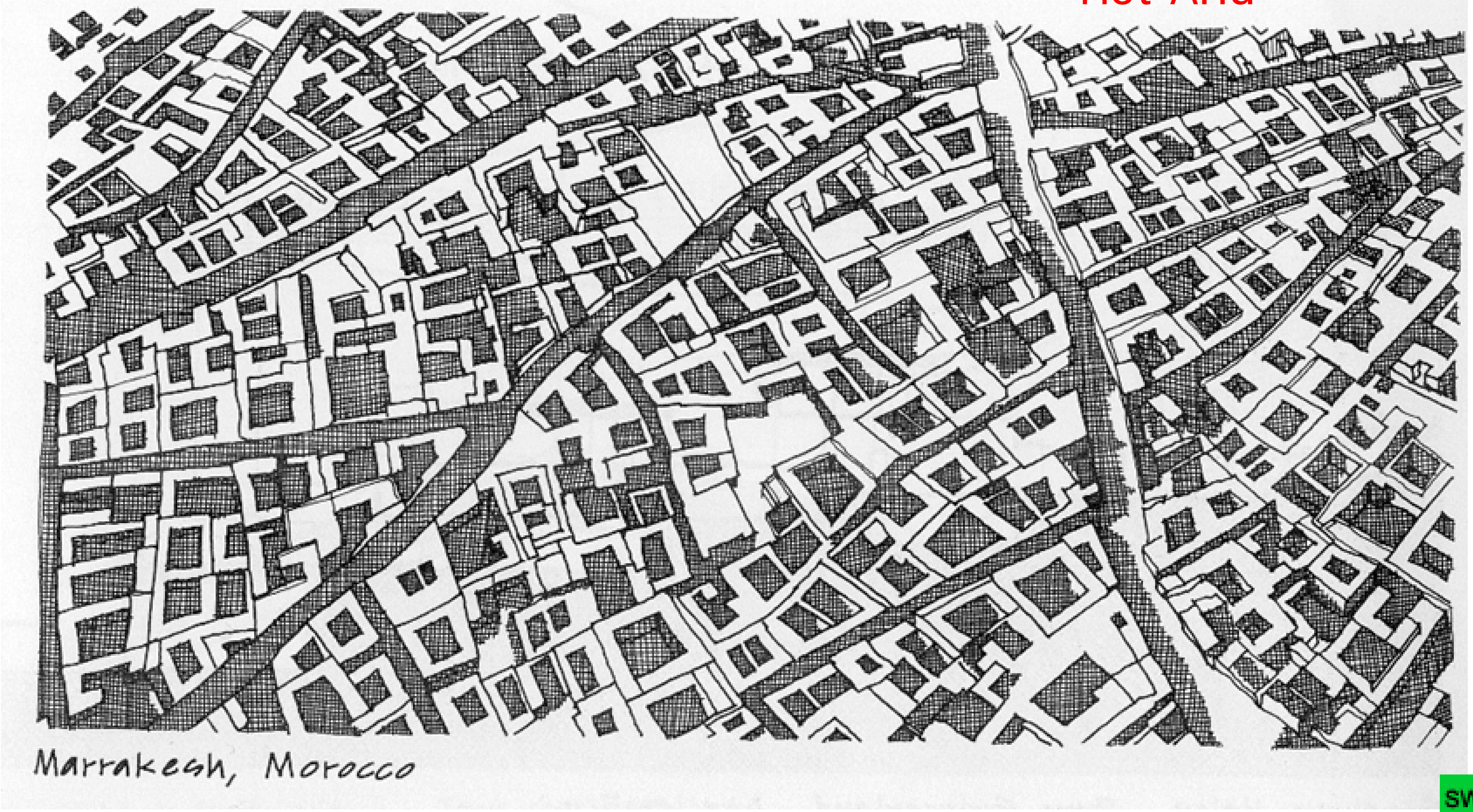
Narrow shaded streets.



Hot-Arid

SWL

Hot-Arid



SWL

Kasbah, Tangier, Morocco

Bio-climatic Design: HOT-HUMID

Where **warm to hot** stable conditions predominate with **high humidity** throughout the year.

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

House in Seaside, Florida

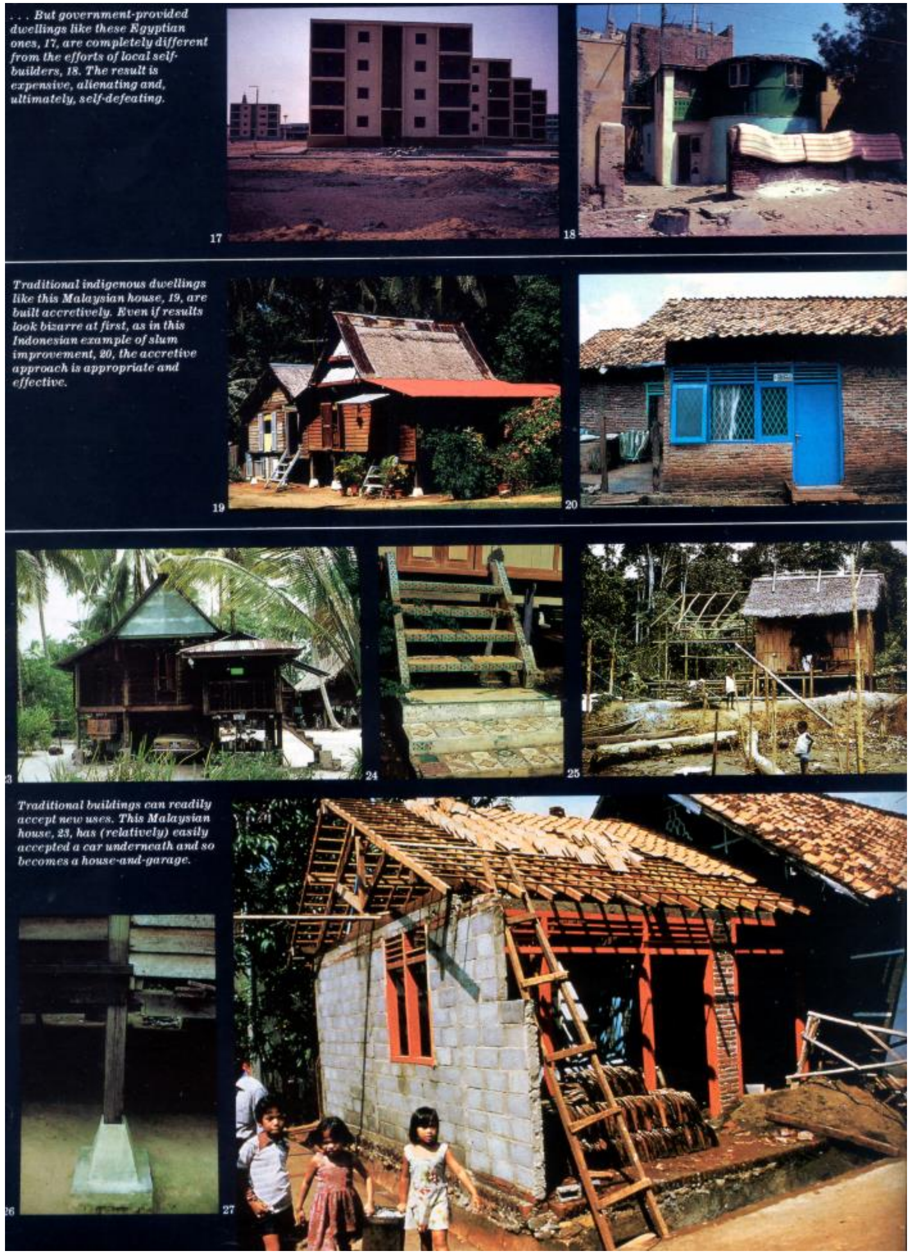
Loren A. McIntyre from Woodfin Camp & Associates

Master Plan: Transportation, Refuse Disposal, and Food Supplies

Few planners would care to lump these categories together, but consider the *de facto* master plan of pole-hut villages built over water. These began in the Late Stone Age and still exist in the marshes of Cambodia and New Guinea and the inner reaches of the Amazon. Transportation is by water. Garbage disposal is into water. And a good part of the food supply comes out of the water. Nor do residents have far to paddle for hunting and fishing: the refuse they throw into the water attracts marsh fowl and fish to the village.

Marc & Evelyne Bernheim from Woodfin Camp & Associates

HOT-HUMID


. . . But government-provided dwellings like these Egyptian ones, 17, are completely different from the efforts of local self-builders, 18. The result is expensive, alienating and, ultimately, self-defeating.

17 18

Traditional indigenous dwellings like this Malaysian house, 19, are built accretively. Even if results look bizarre at first, as in this Indonesian example of slum improvement, 20, the accretive approach is appropriate and effective.

19 20

24 25

Traditional buildings can readily accept new uses. This Malaysian house, 23, has (relatively) easily accepted a car underneath and so becomes a house-and-garage.

26 27

sultry

still

little air movement

or

very

windy

stormy

HOT-HUMID

HOT-HUMID



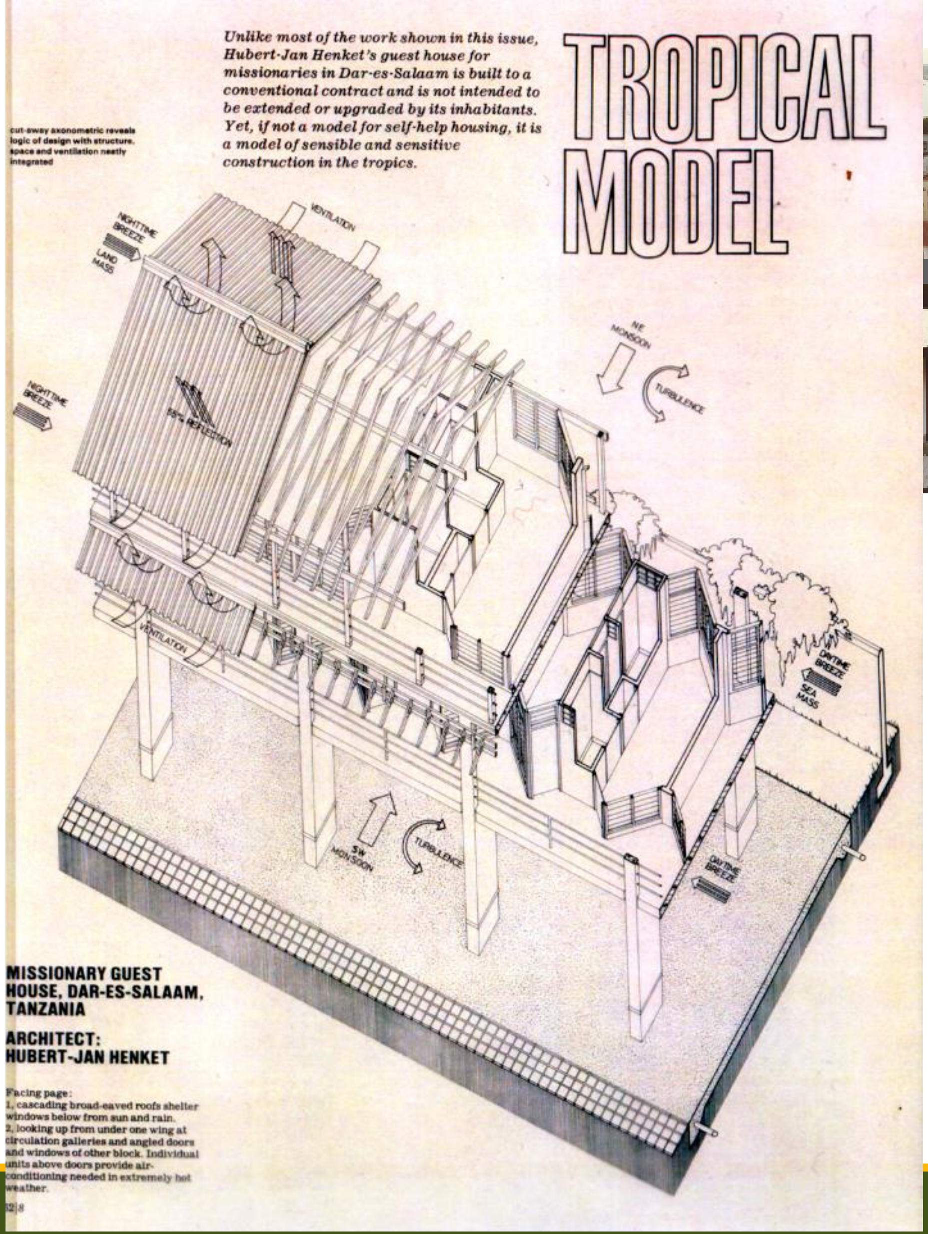



What can we learn from local traditions? Bamboo is one of the fastest growing, renewable natural materials...

HOT-HUMID

HOT-HUMID

Missionary guest house, Dar-Es-Salam, Tanzania



TROPICAL MODEL

Unlike most of the work shown in this issue, Hubert-Jan Henket's guest house for missionaries in Dar-es-Salaam is built to a conventional contract and is not intended to be extended or upgraded by its inhabitants. Yet, if not a model for self-help housing, it is a model of sensible and sensitive construction in the tropics.

cut-away axonometric reveals logic of design with structure, space and ventilation neatly integrated

MISSIONARY GUEST HOUSE, DAR-ES-SALAAM, TANZANIA

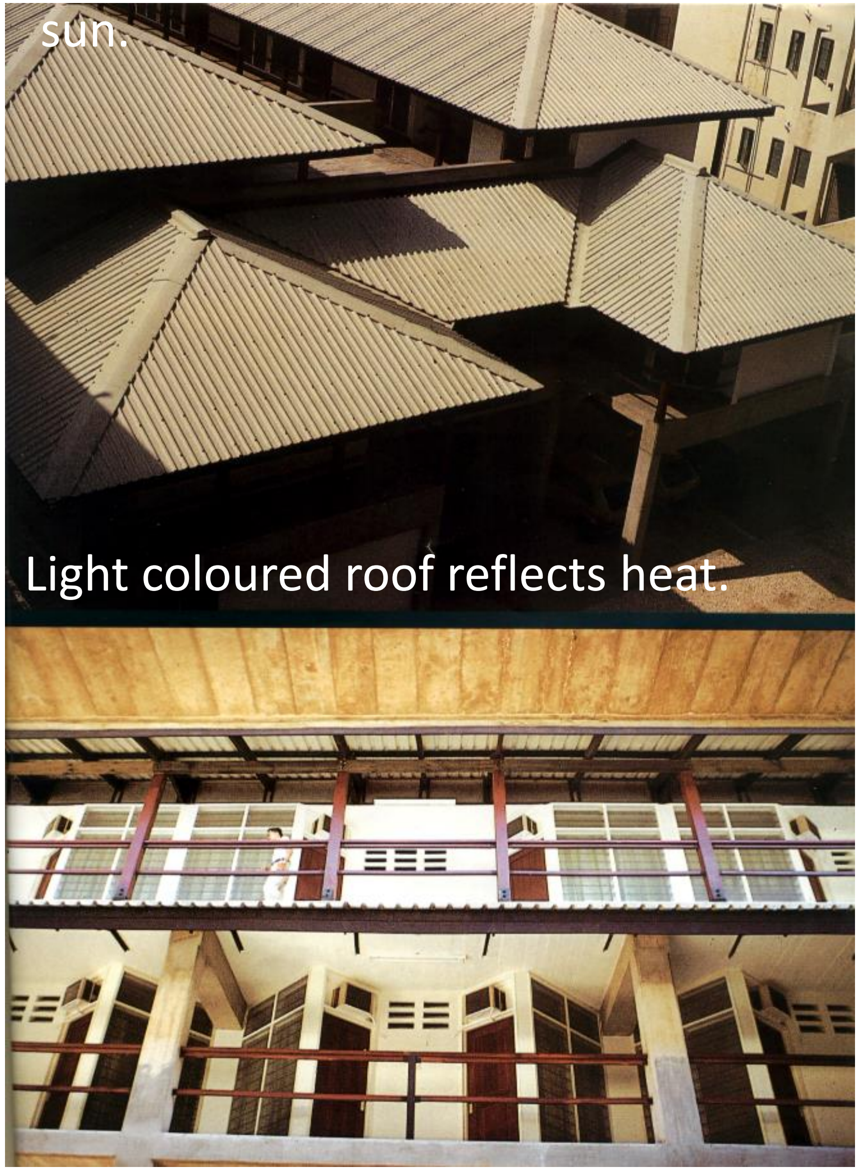
ARCHITECT: HUBERT-JAN HENKET

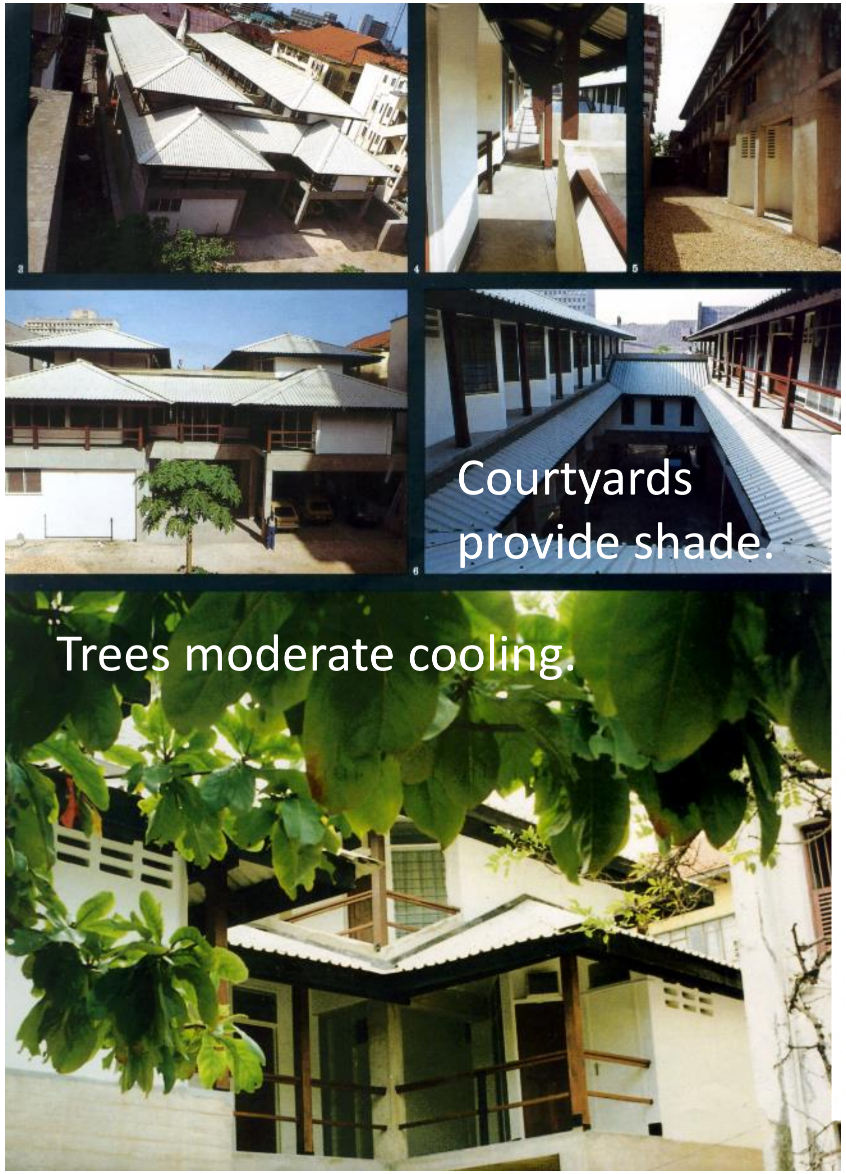
Facing page:
1, cascading broad-eaved roofs shelter windows below from sun and rain.
2, looking up from under one wing at circulation galleries and angled doors and windows of other block. Individual units above doors provide air-conditioning needed in extremely hot weather.

32|8

A contemporary building that is conscious of the wind and rain and uses modern materials to replicate some effective indigenous traditions.

HOT-HUMID


sun.
Light coloured roof reflects heat.


Courtyards provide shade.
Trees moderate cooling.

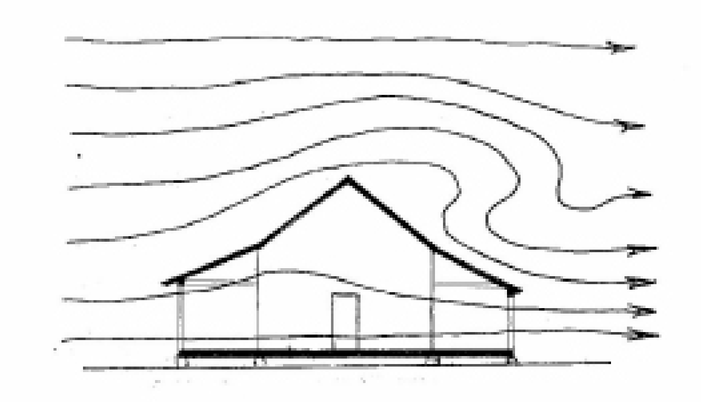
HOT-HUMID

Louisiana houses of both rich and poor(er) use shutters on the windows to allow air flow while maintaining security.

Shot-gun houses

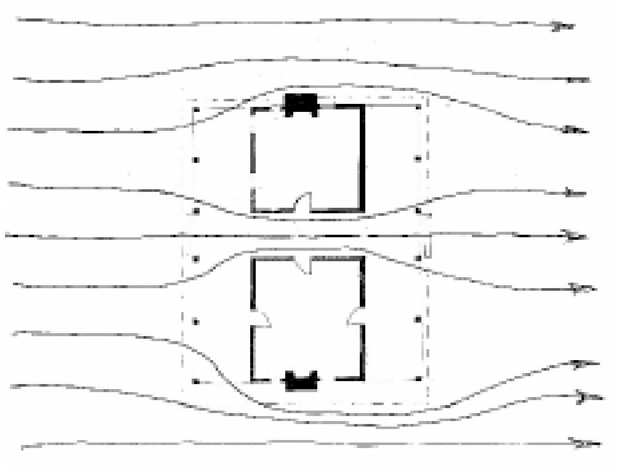
HOT-HUMID

The traditional dog trot house is characterized by two log houses with a central connecting passageway, a porch at either side, and a chimney at each end. Developed in response to its environment, the dog trot house is successful in providing cool shaded space in the Southeast's hot, humid climate. This is accomplished primarily through its successful passive ventilation strategy.



air flow diagram showing section through the central breezeway.

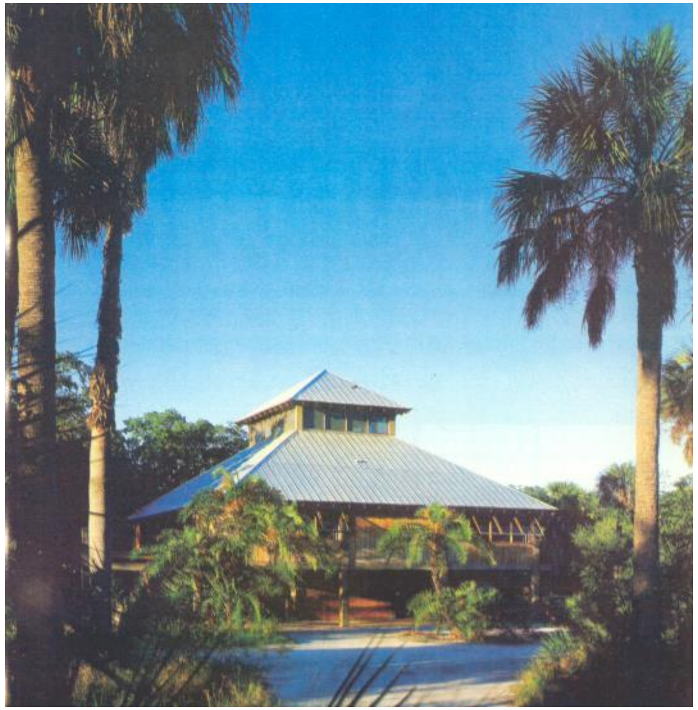
The image above shows air above ground mainly flows above and on the east or west side of the dogtrot. A smaller volume of air travels through the breezeway but at a greater velocity.



air flow diagram showing plan view of dog trot house.

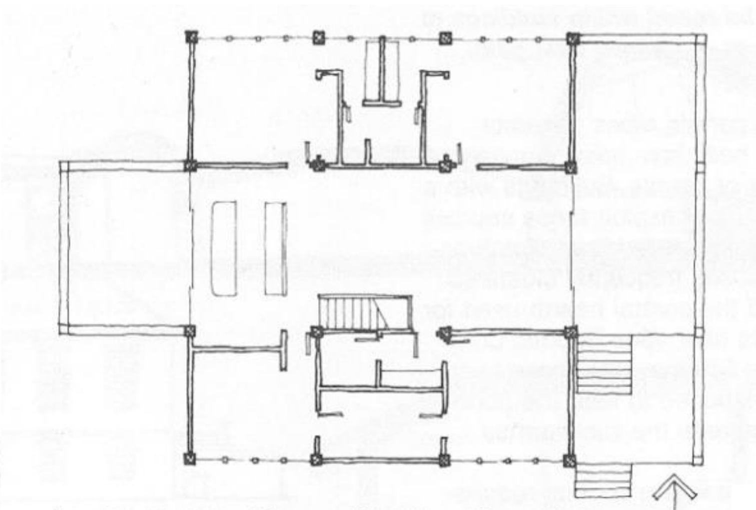
By studying more historic vernacular types that worked well, we can re-learn the principles that made these buildings effective.

Logan House, Tampa, FL



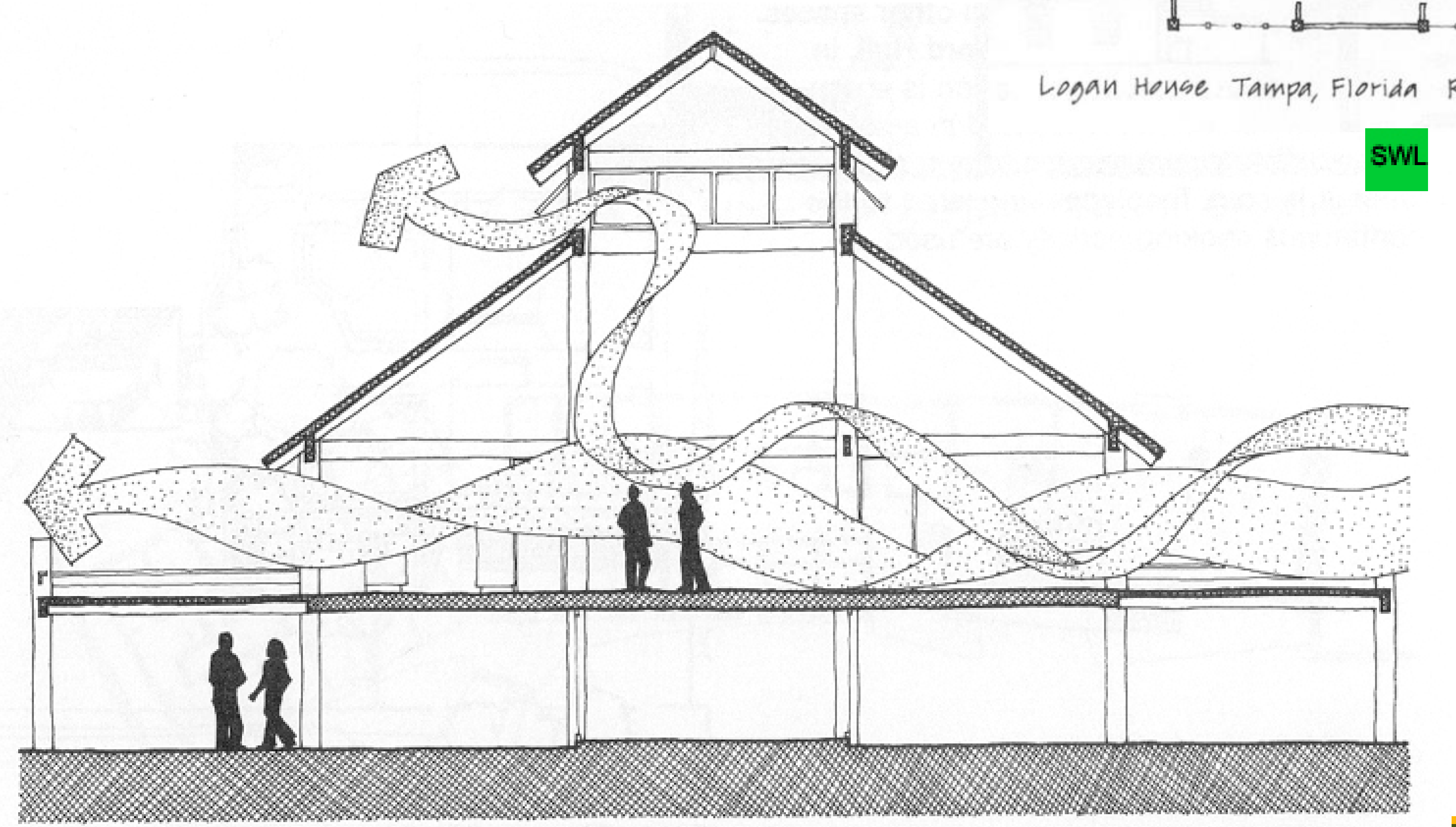
HOT-HUMID

This relatively modern building has become a model for a new kind of vernacular based upon ventilation strategies for hot-humid climates - that were derived from indigenous hot-humid buildings.



Logan House Tampa, Florida Rowe Holmes Assoc.

SWL



Logan House Tampa, Florida Rowe Holmes Assoc.

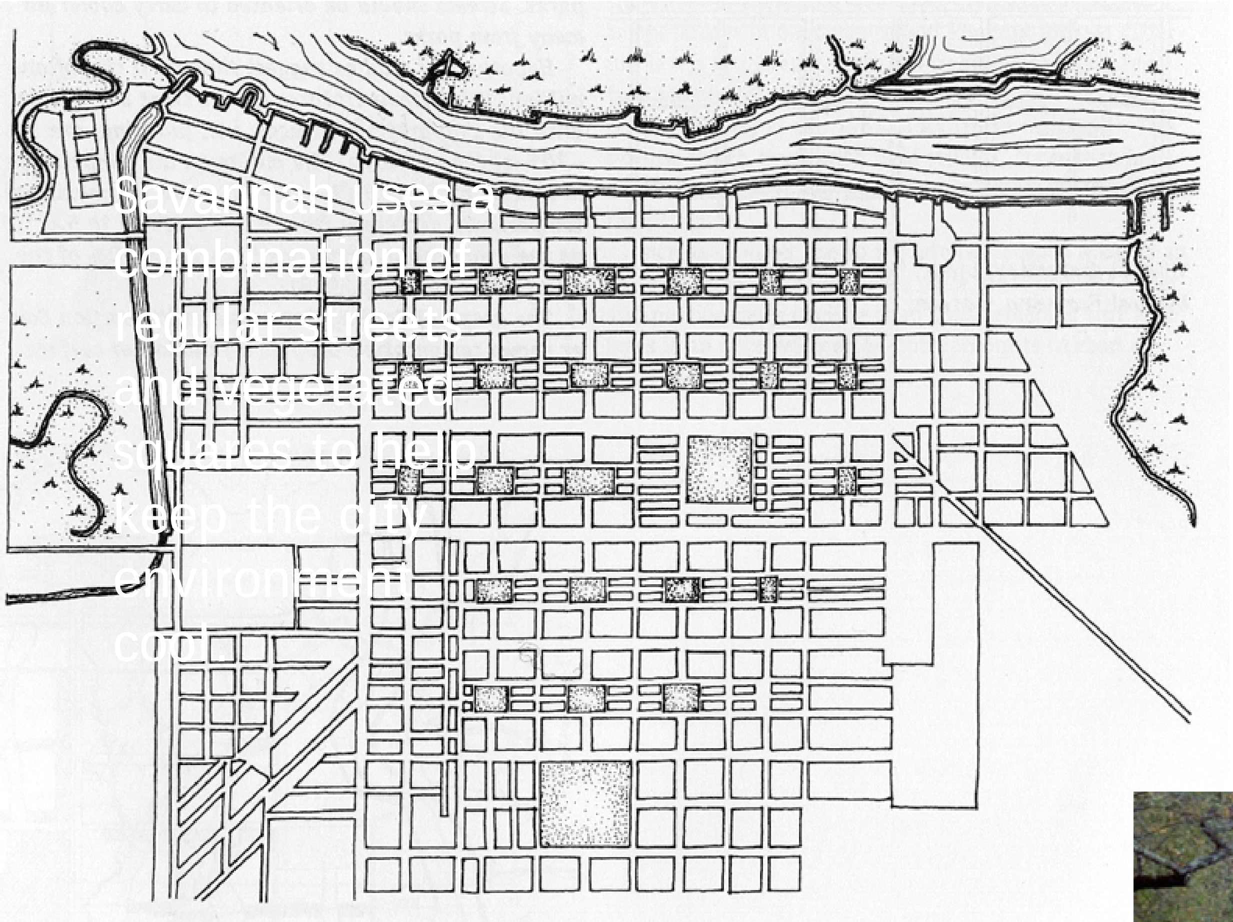
HOT-HUMID

Street Layouts

In hot humid climates a very dispersed layout is desired to maximize the ability of any available breezes to cool the town and its buildings at all times.

Hot-Humid

Savannah uses a combination of regular streets and vegetated squares to help keep the city environment cool



Plan of Savannah, Georgia, 1856, James Oglethorpe

The plan of Savannah, Georgia uses large green spaces and squares to disperse the buildings.

Intense plantings create a cooler micro climate through shade and the action of vegetation.

Hot-Humid

SWL




Savannah, Georgia

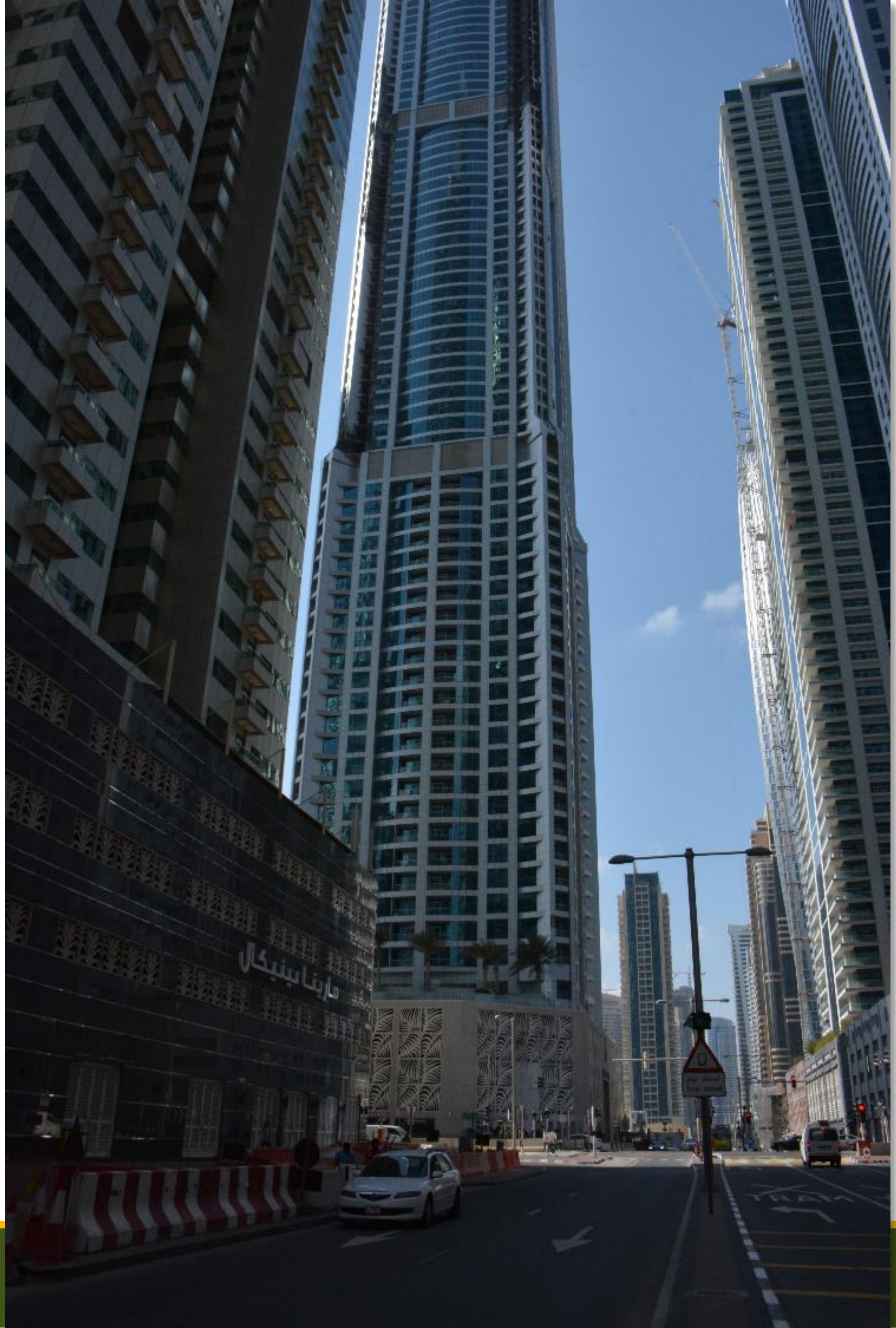
Large homes in the southern USA adopted a strategy of large covered porches to escape the interior heat.
Shaded courtyards for private interior spaces.
No corridors as people went outside to move from room to room, allowing flow through ventilation in all of the rooms.

The imported European style architecture that arrived in New England was eventually modified in the south.

HOT-HUMID

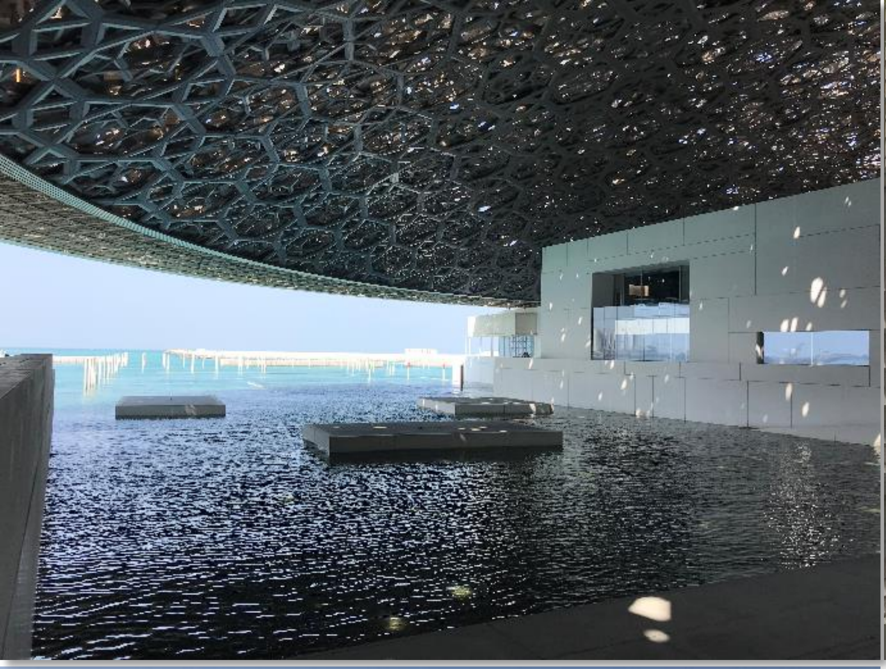
Southern plantation houses with large shaded porches.

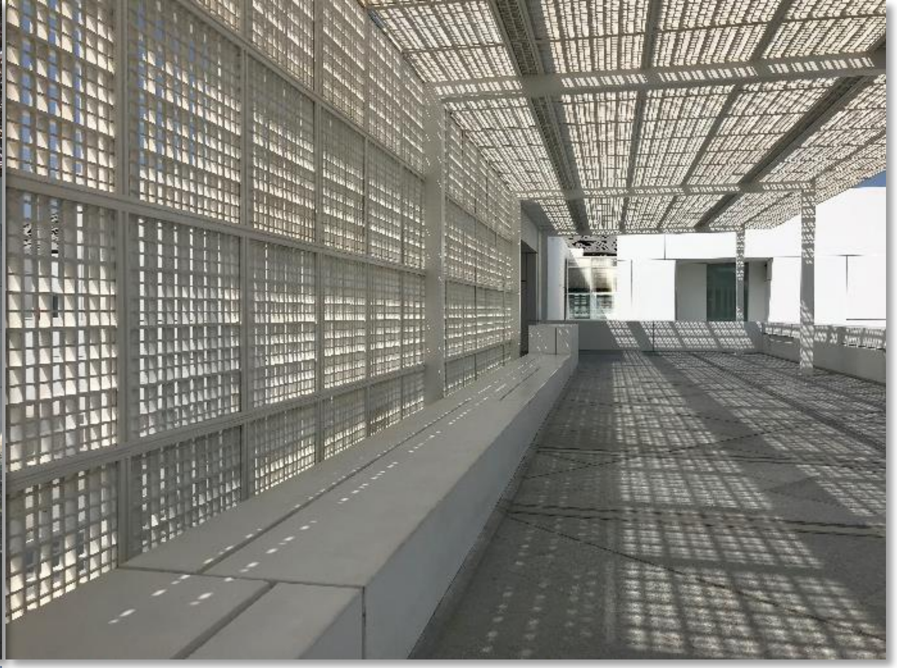
View from the freeway, Marina Bay, Dubai

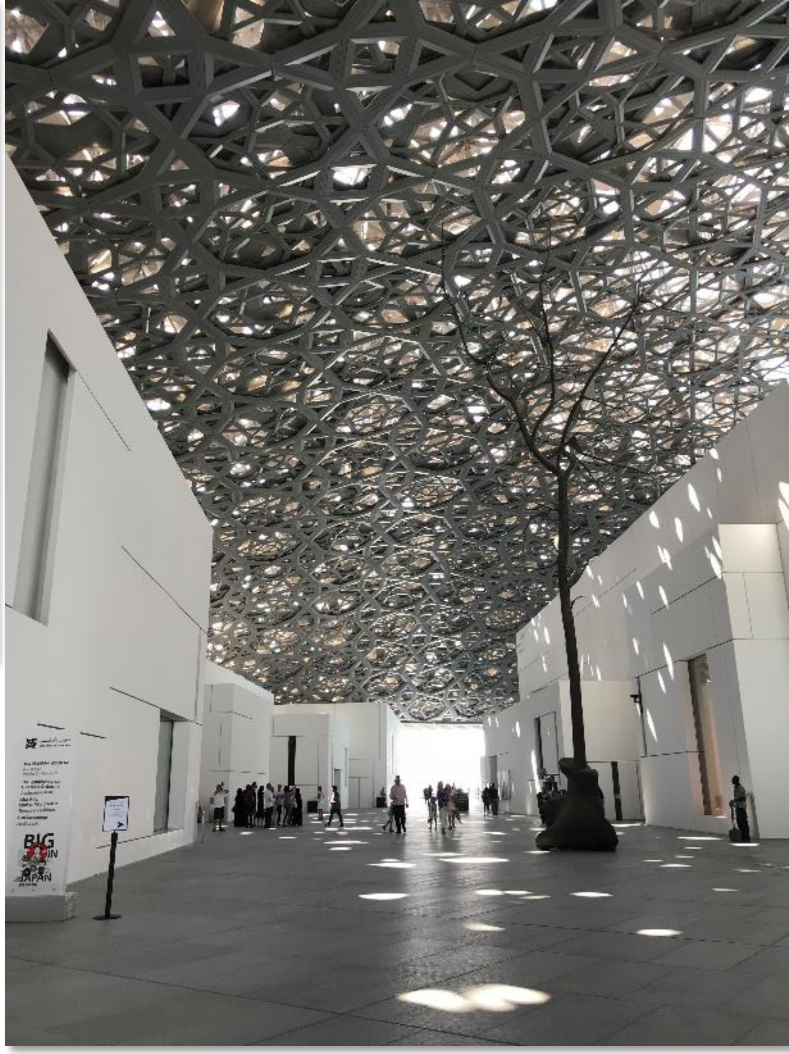


Whether intentional, or accidental, the dense layout of the skyscrapers in Marina Bay results in shade at ground level and a much cooler street environment than a more dispersed layout would have achieved.


View from the Burj Khalifa, Dubai







The Louvre in Abu Dhabi by Jean Nouvel uses massive shading devices to protect the outdoor spaces from the sun. Natural breezes flow through. The actual museum rooms are housed in fully conditioned spaces as the artifacts demand this control.

Bio-climatic Design: TEMPERATE

The summers are hot and humid, and the winters are cold.

The four seasons are almost equally long.

RULES:

- BALANCE strategies between COLD and HOT-HUMID

- maximize FLEXIBILITY in order to be able to modify the envelope

- sloped roofs for rain

- overhangs for shade

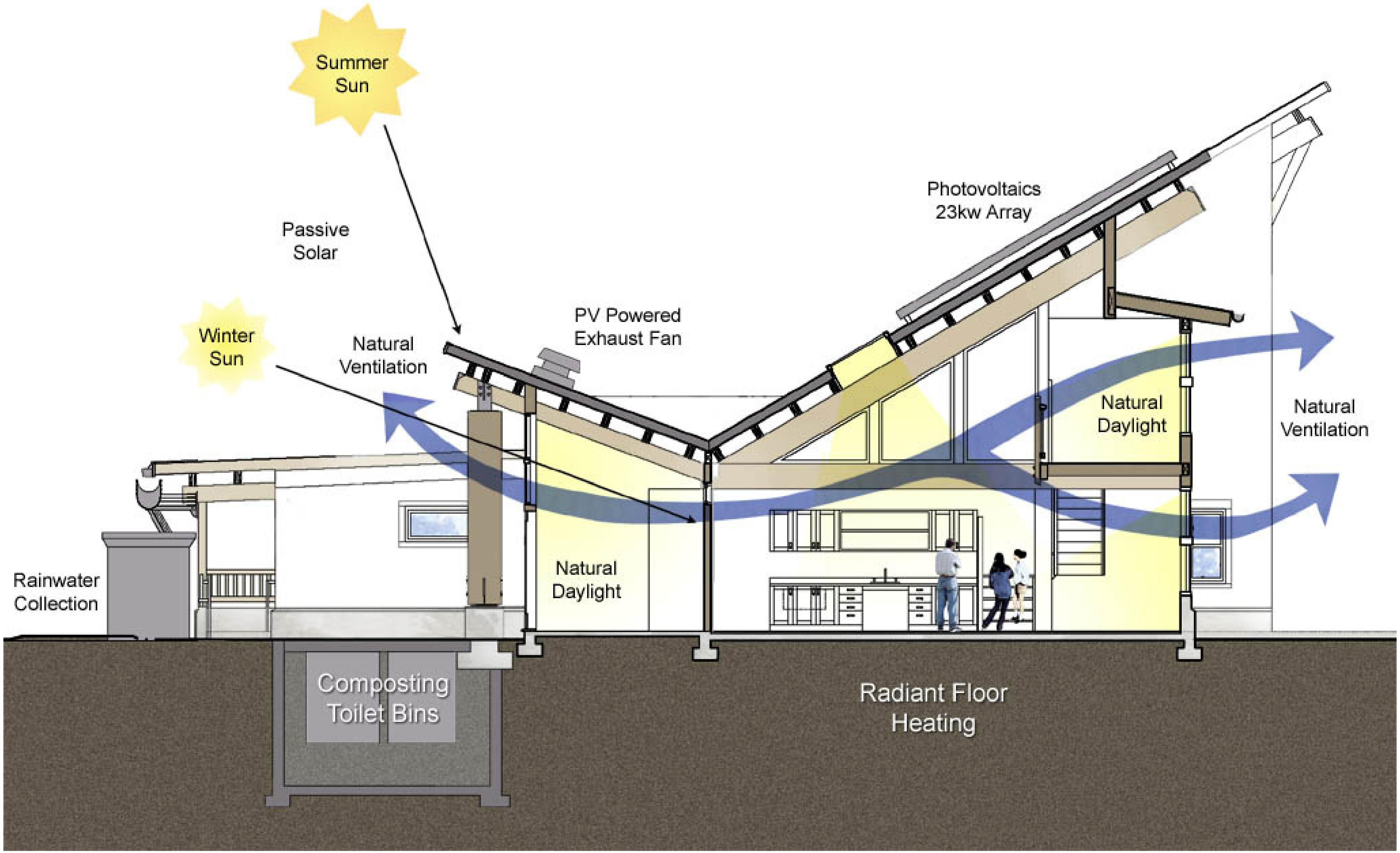
- operable windows for ventilation

IslandWood Residence, Seattle

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

Carbon Reduction: The Passive Approach

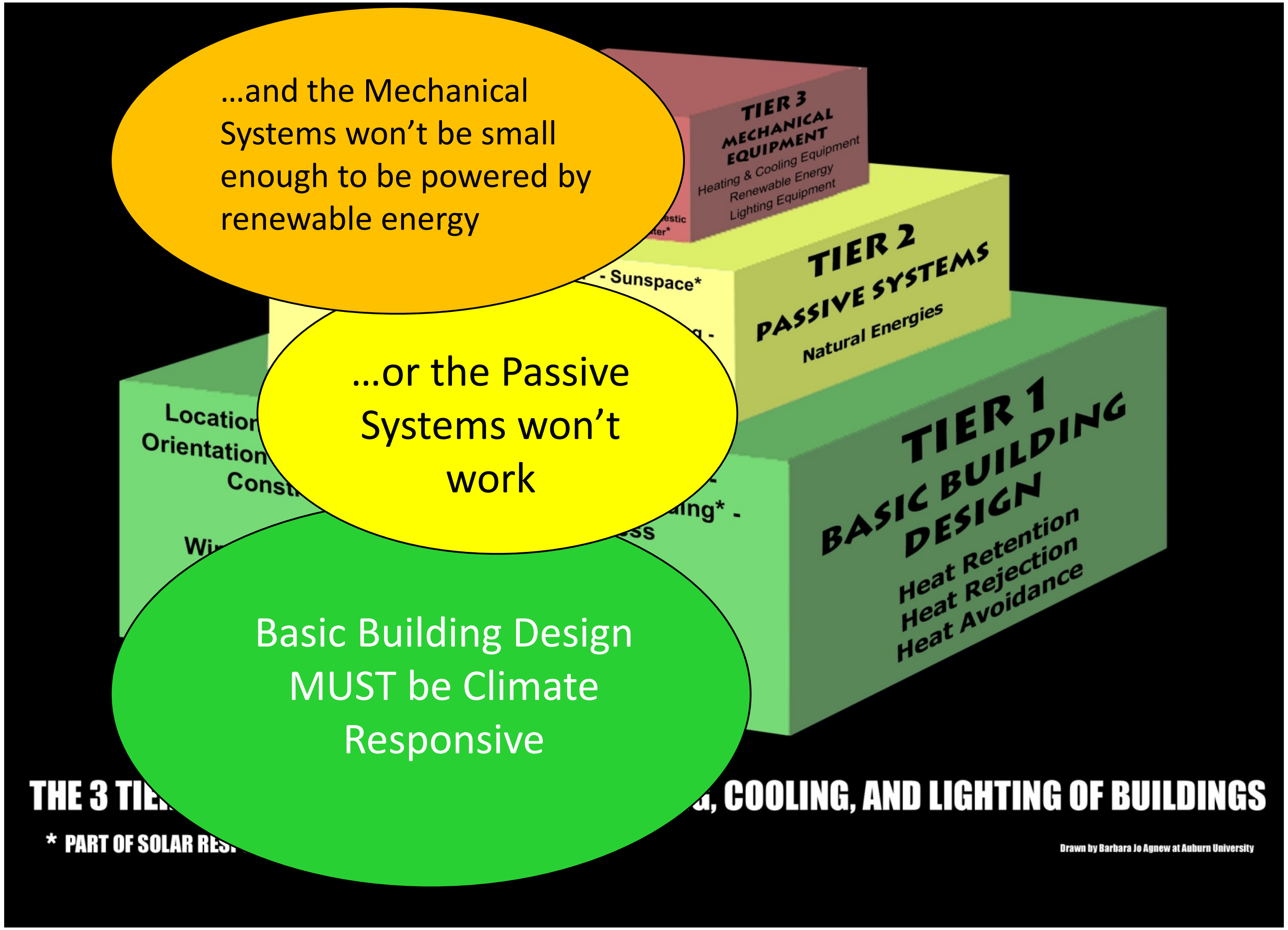
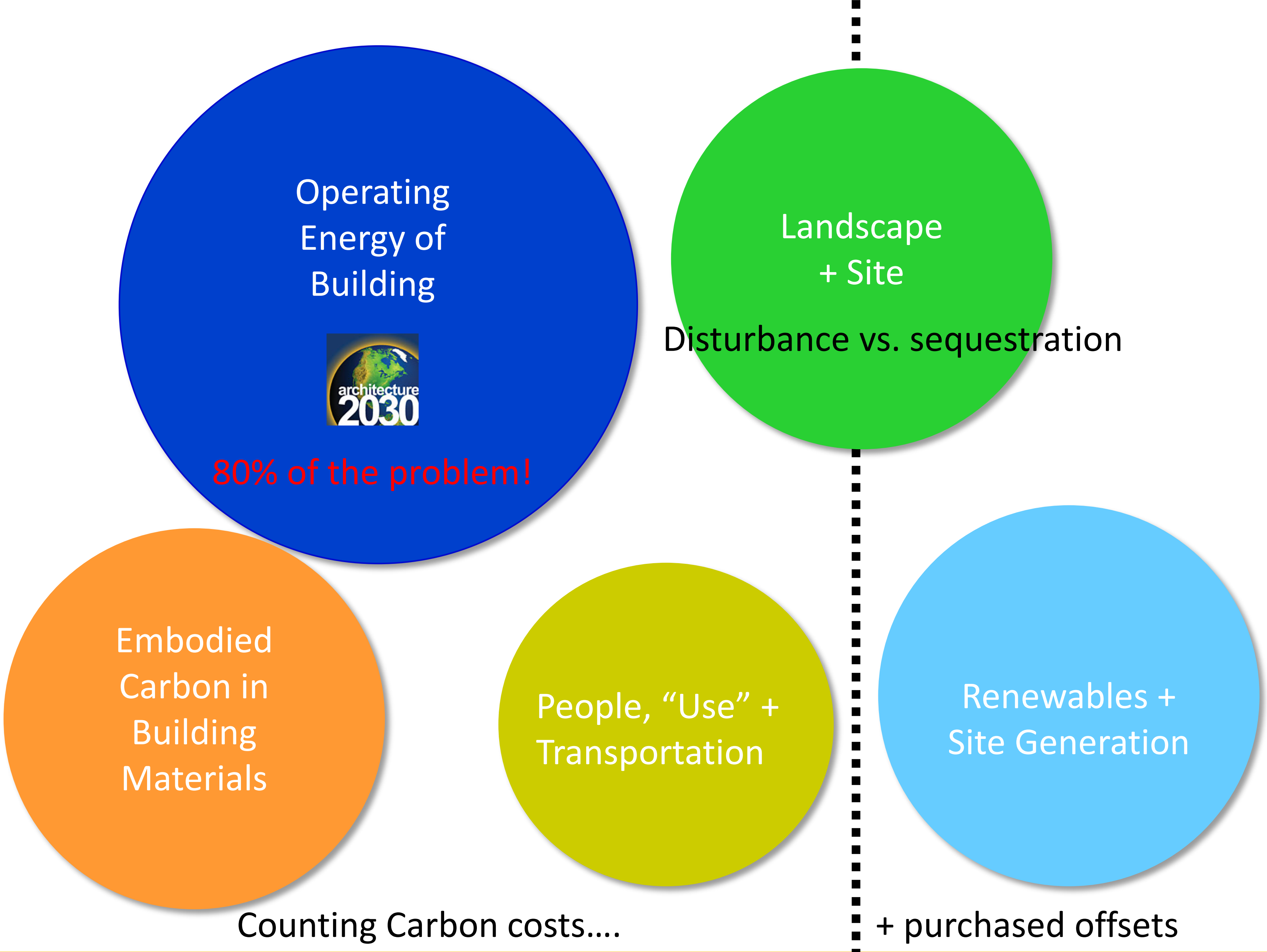
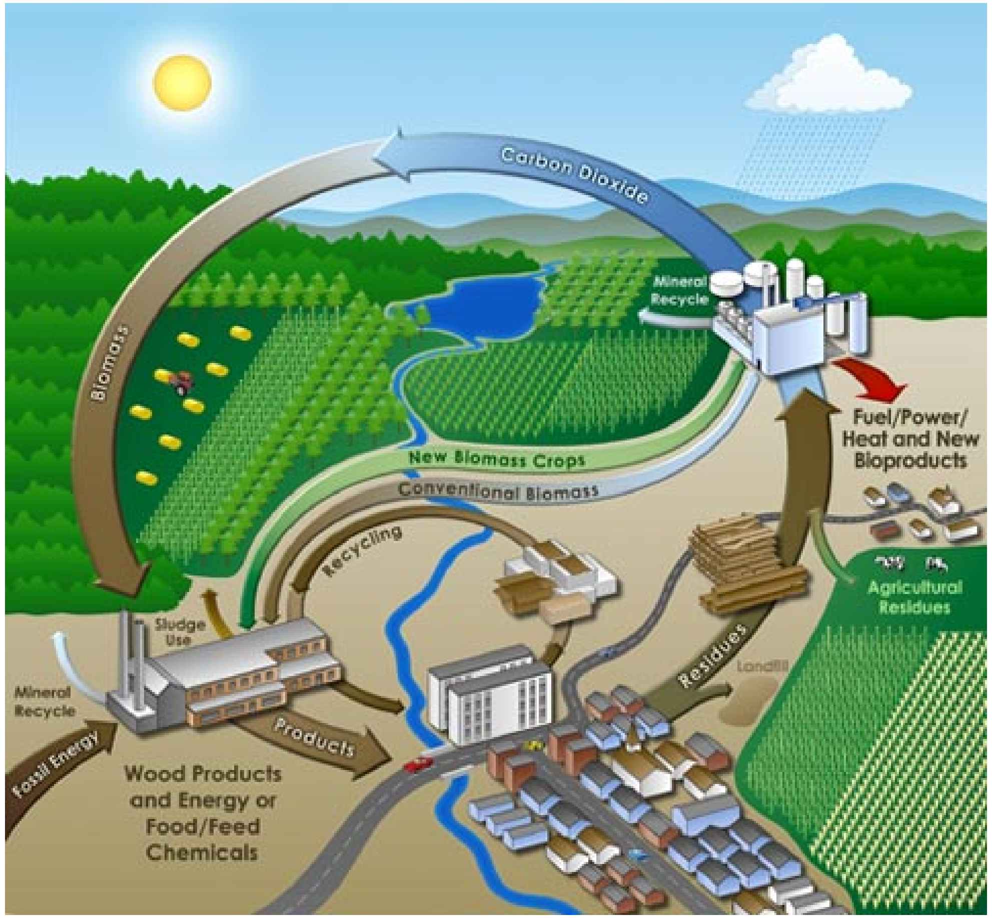


Image: Norbert Lechner, "Heating, Cooling, Lighting"


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

Buildings / Processes and the Carbon Cycle:



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

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

Energy vs Greenhouse Gas Emissions

In BUILDINGS, for the sake of argument

ENERGY CONSUMPTION = GHG EMISSIONS

BUILDING ENERGY IS COMPRISED OF

EMBODIED ENERGY

+

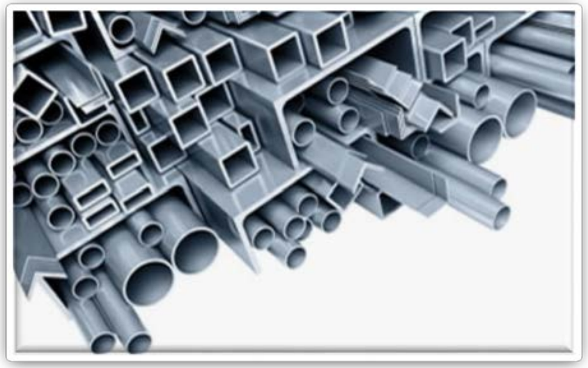
OPERATING ENERGY

Energy Use in Buildings

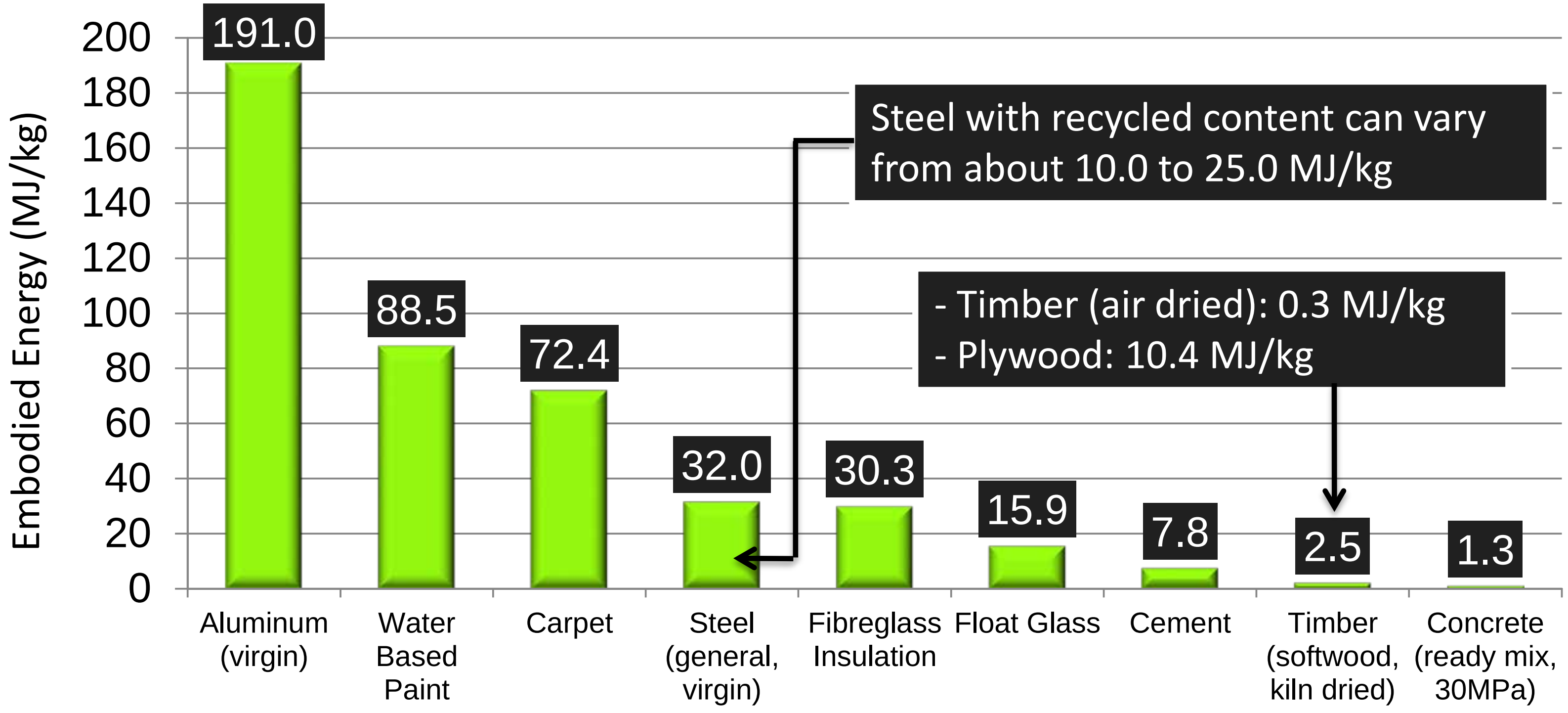
Embodied Energy

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

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

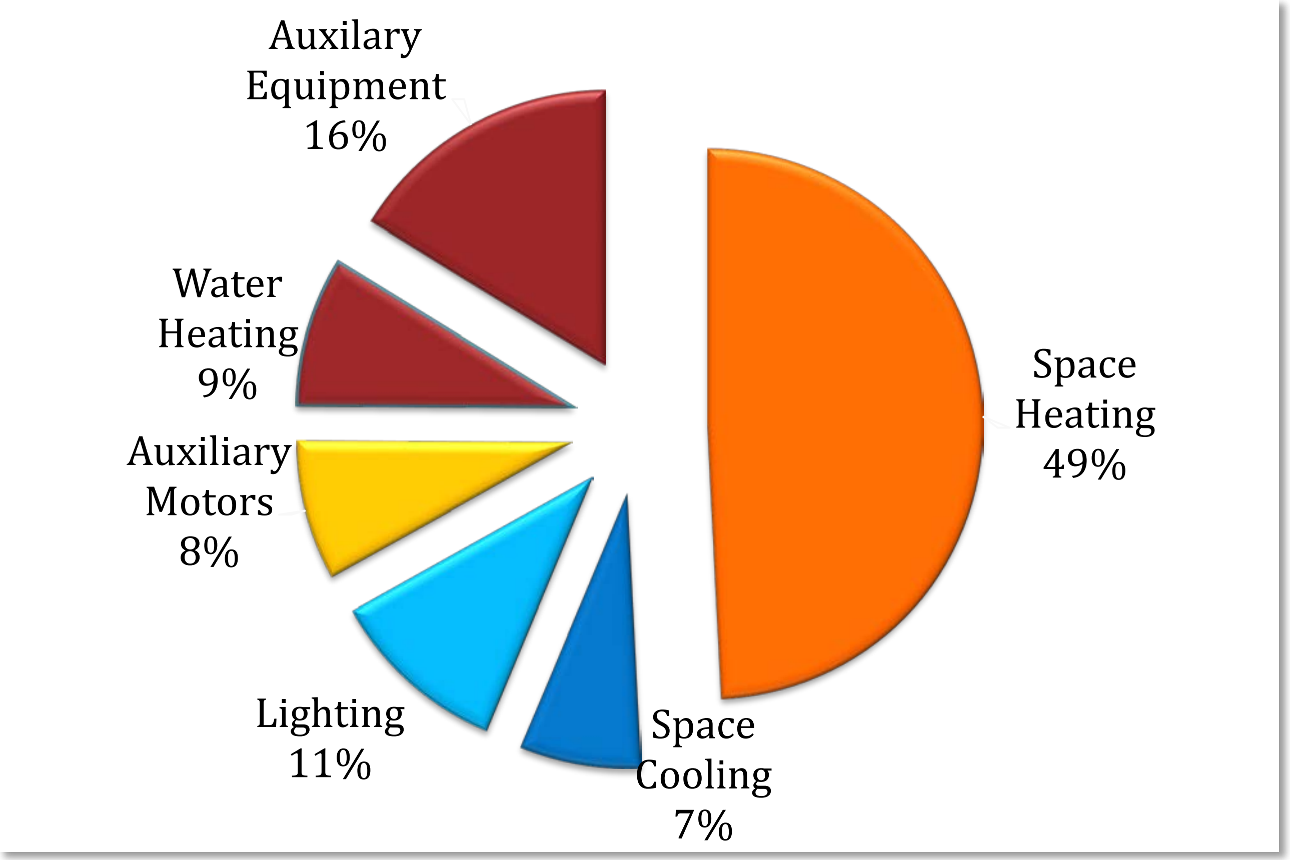
Initial Embodied Energy of Building Materials Per Unit Mass



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

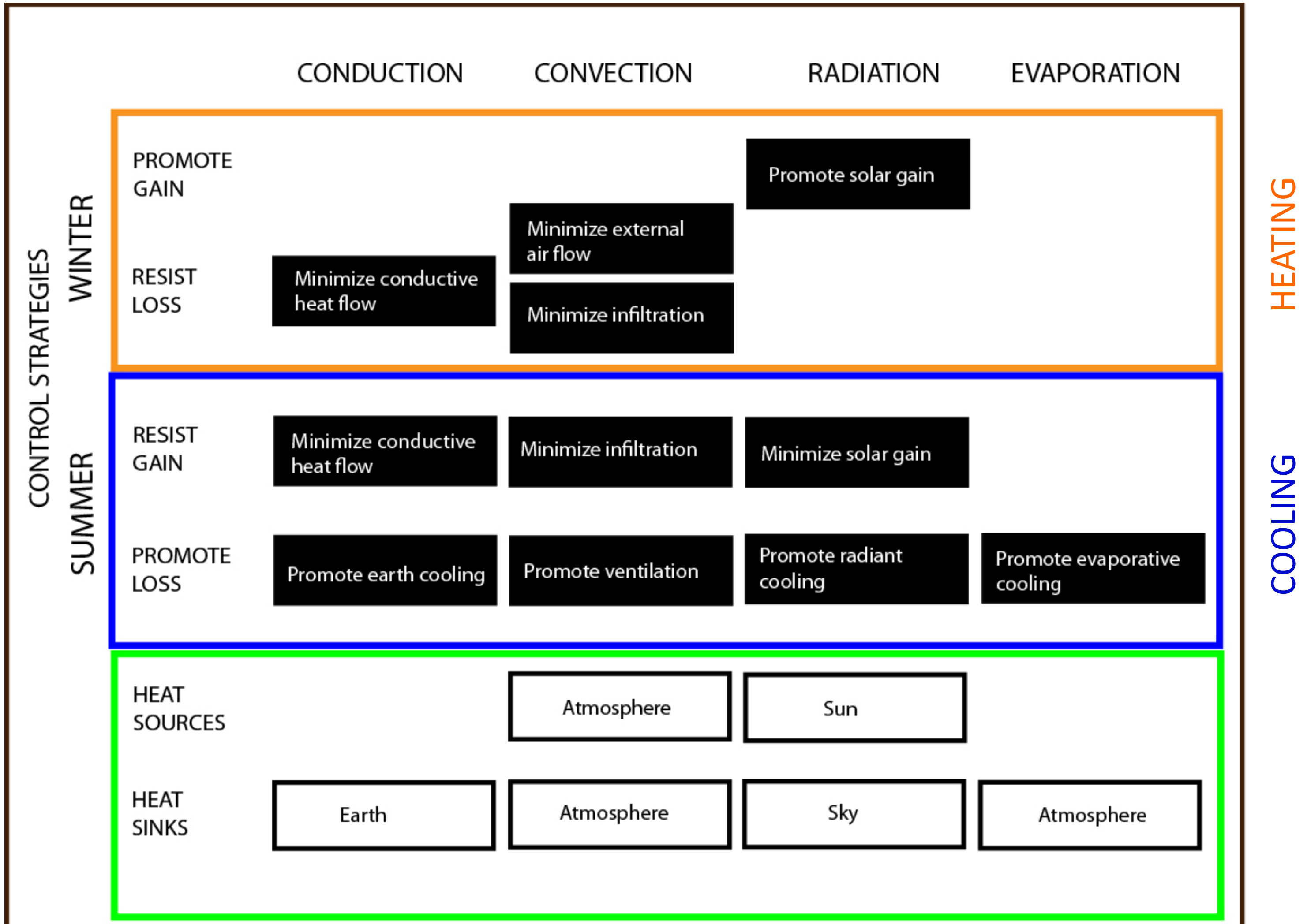
(conservation, passive design, daylighting, shading, orientation, etc.)

#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

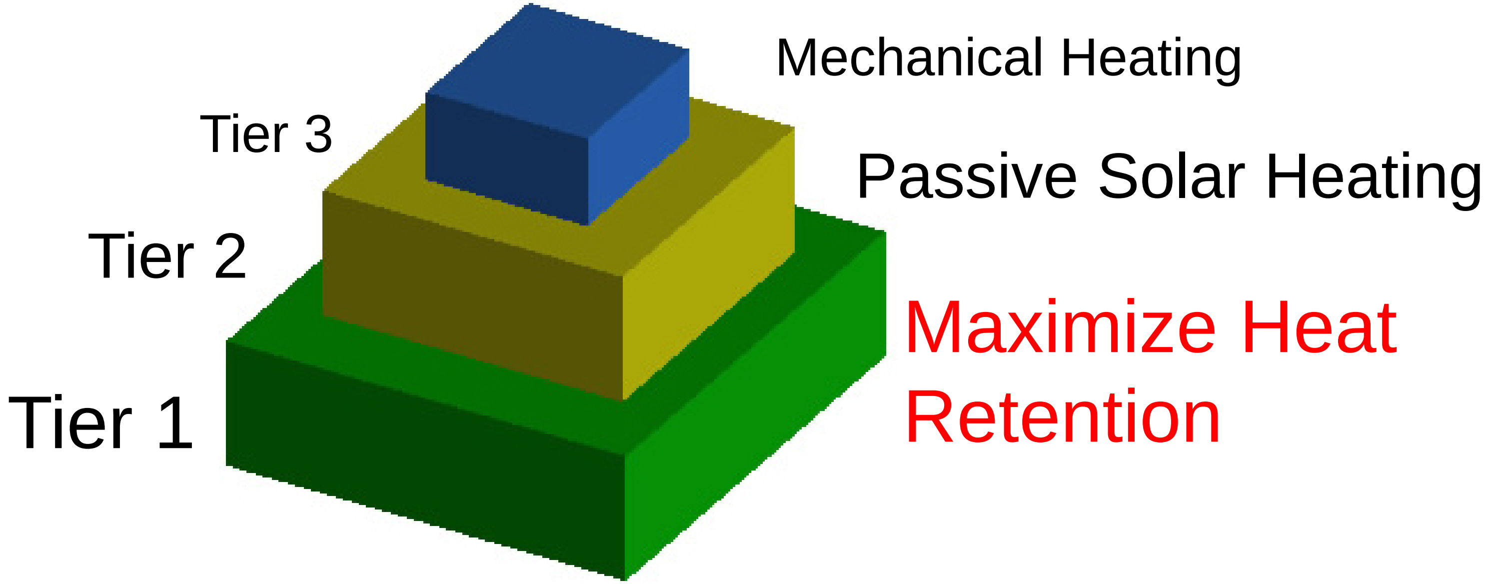
COOLING ↔ WIND

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)

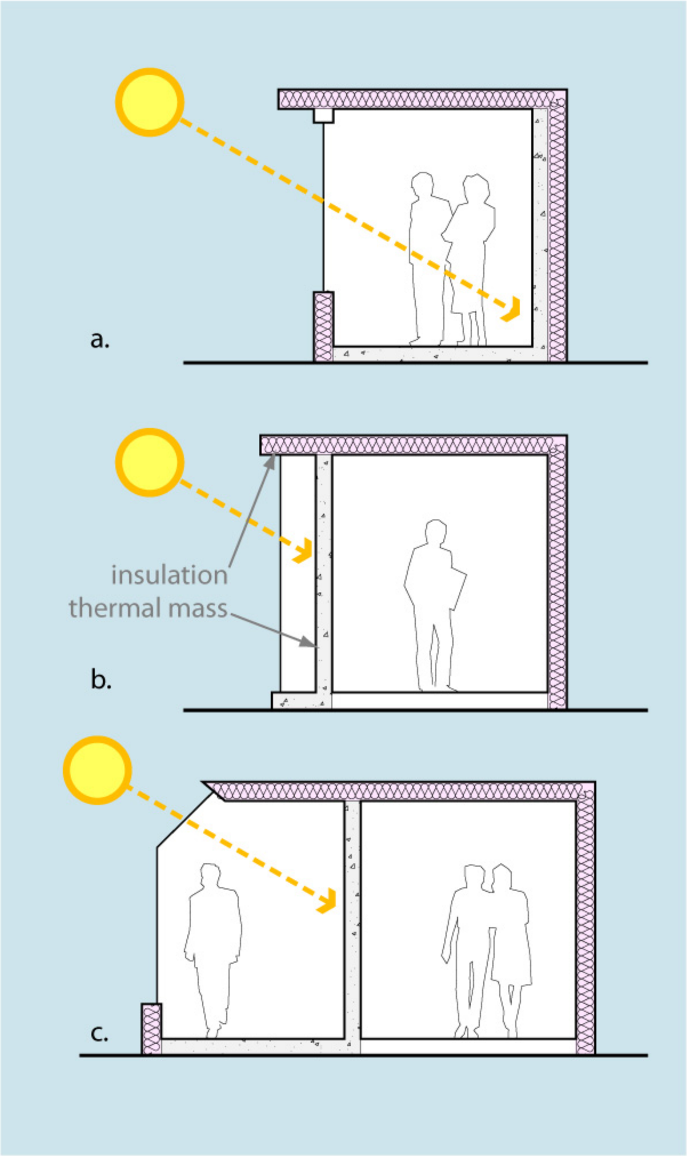
3 MAIN STRATEGIES:

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.

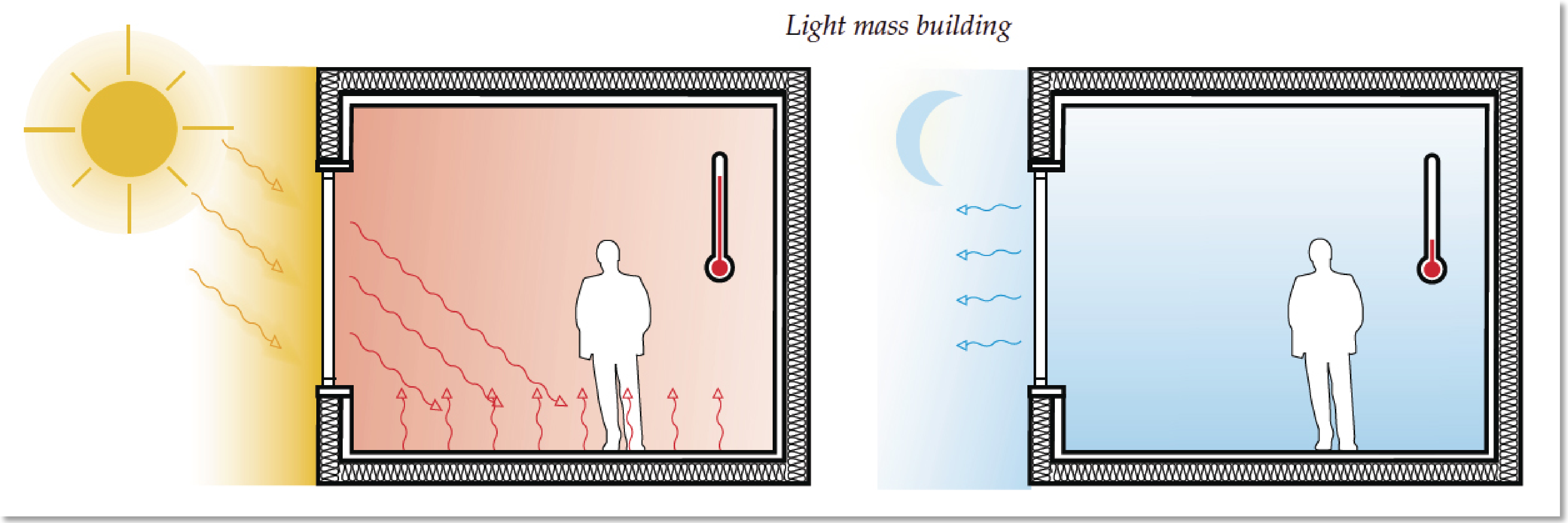
Just like water, free solar energy needs to be stored somewhere to be useful!

Problems with traditional placement of thermal mass

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

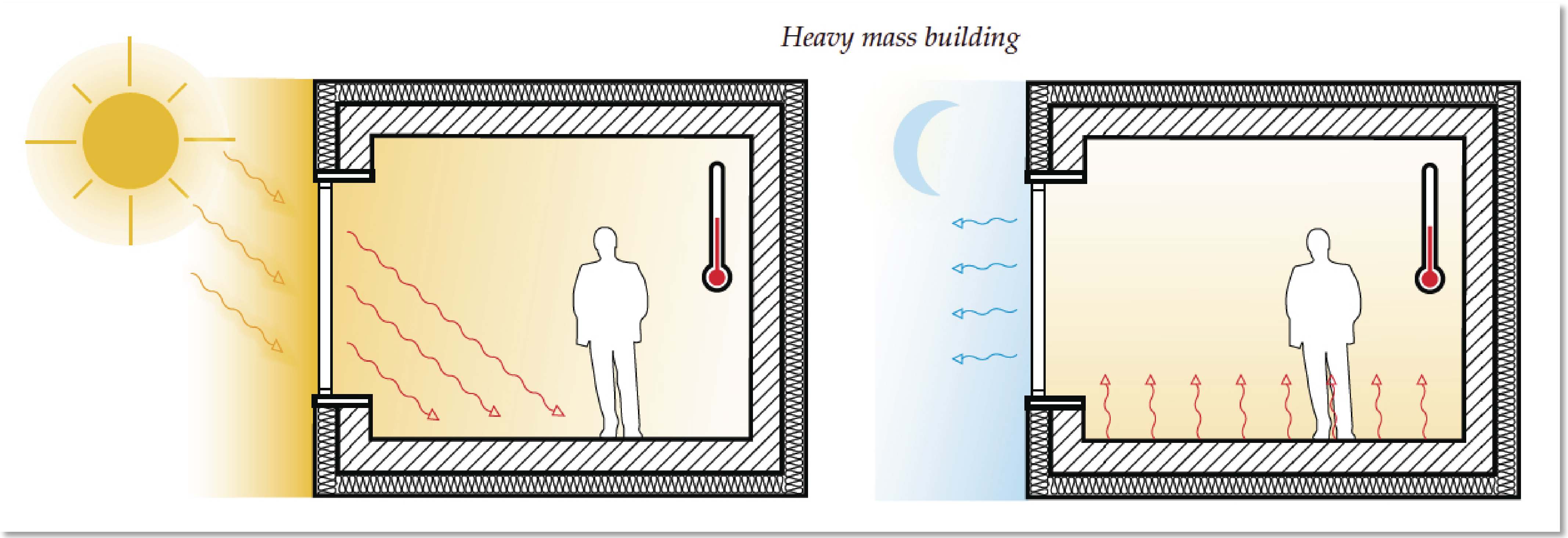
Proper thermal mass placement runs counter to the standard method of residential construction in Canada.

Light Mass Building Problems



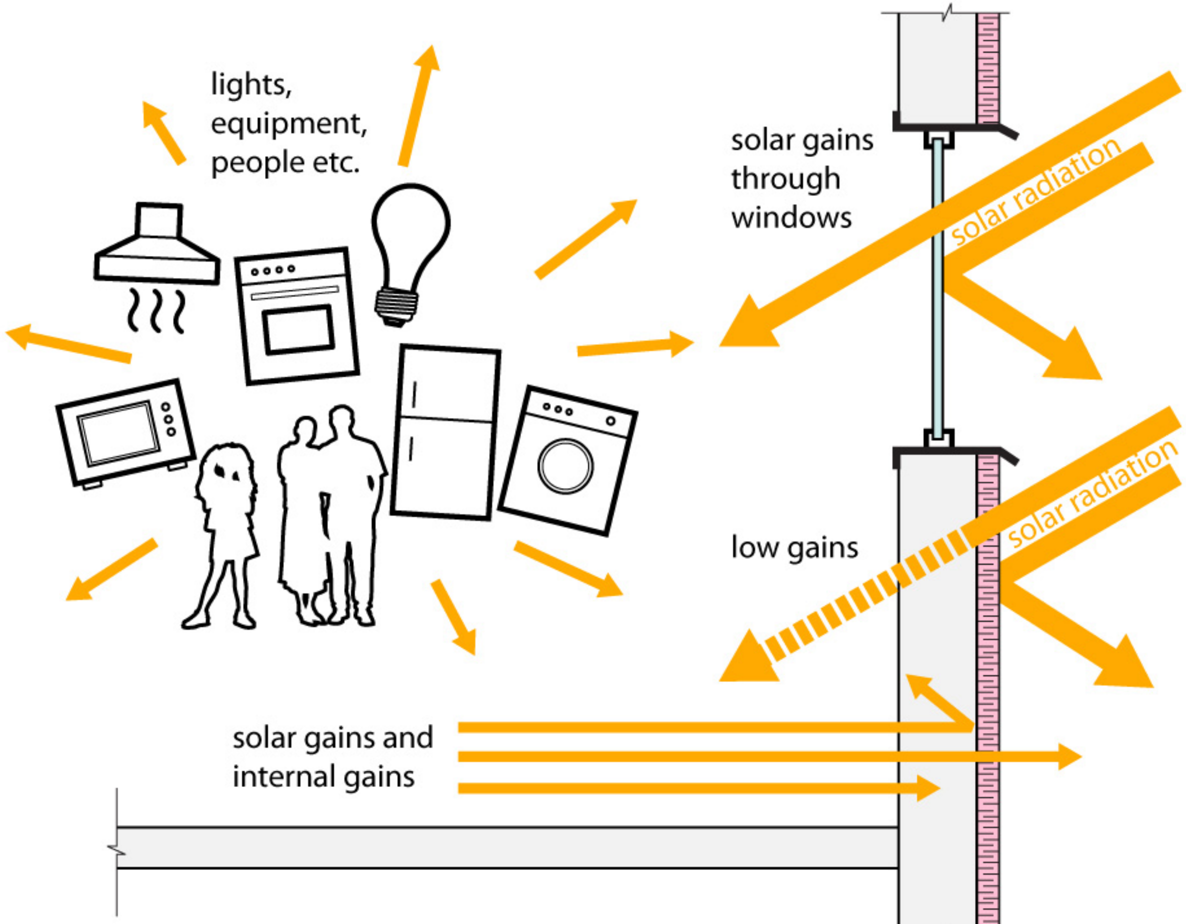
- Wide swings of temperature from day to night
- Excess heat absorbed by human occupants
- Uncomfortably cold at night

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

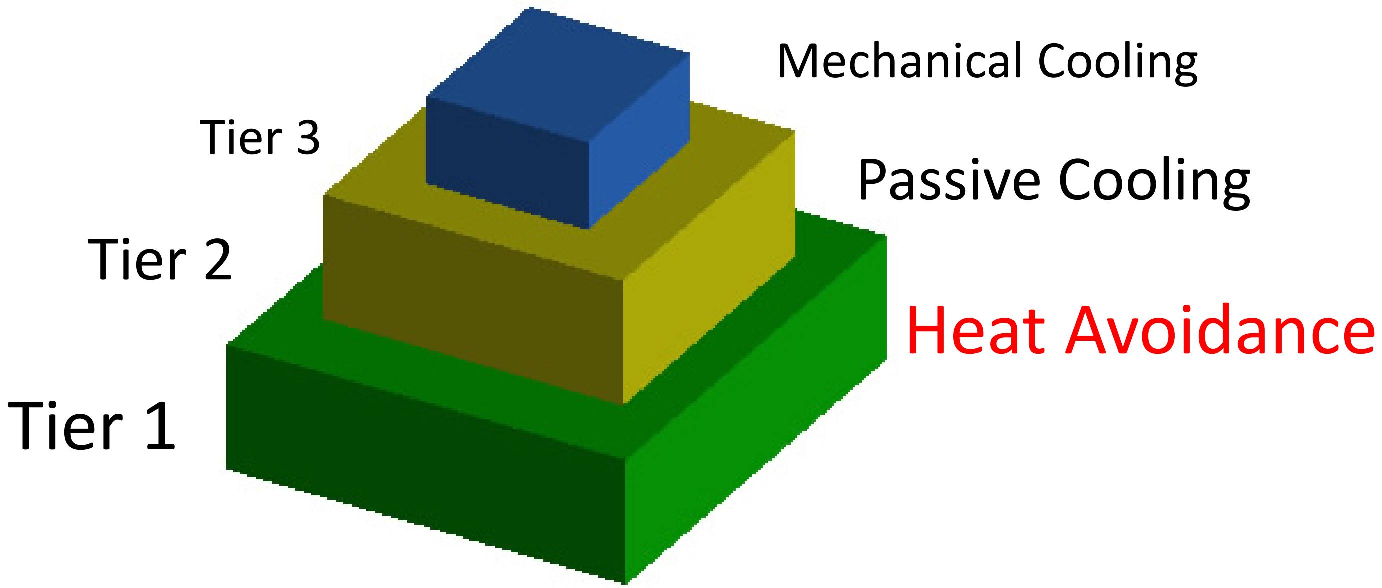


If the insulation is on the OUTSIDE of the building envelope (and thermal mass element), the heat that gets in STAYS in.

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:

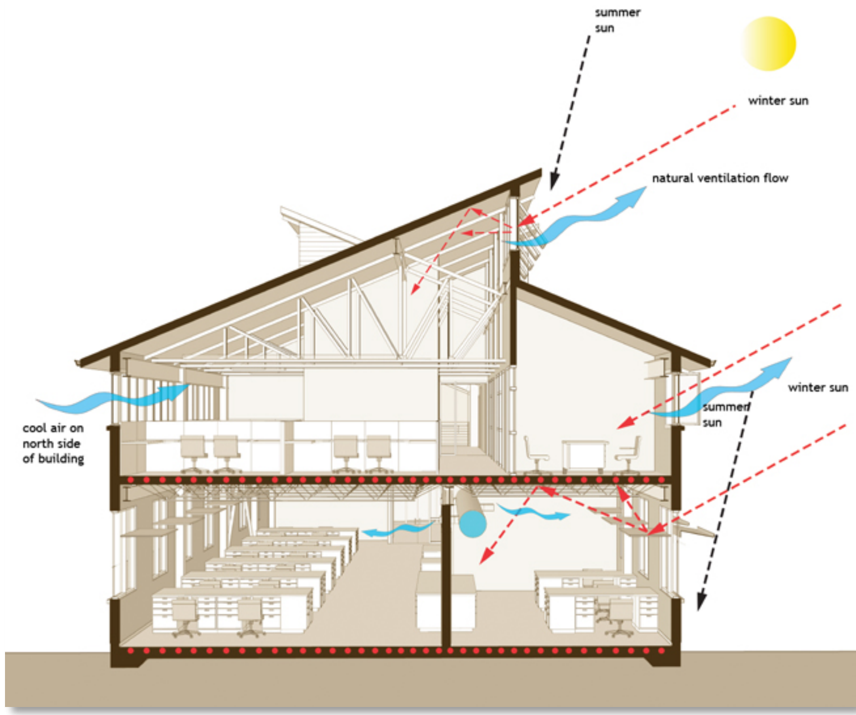


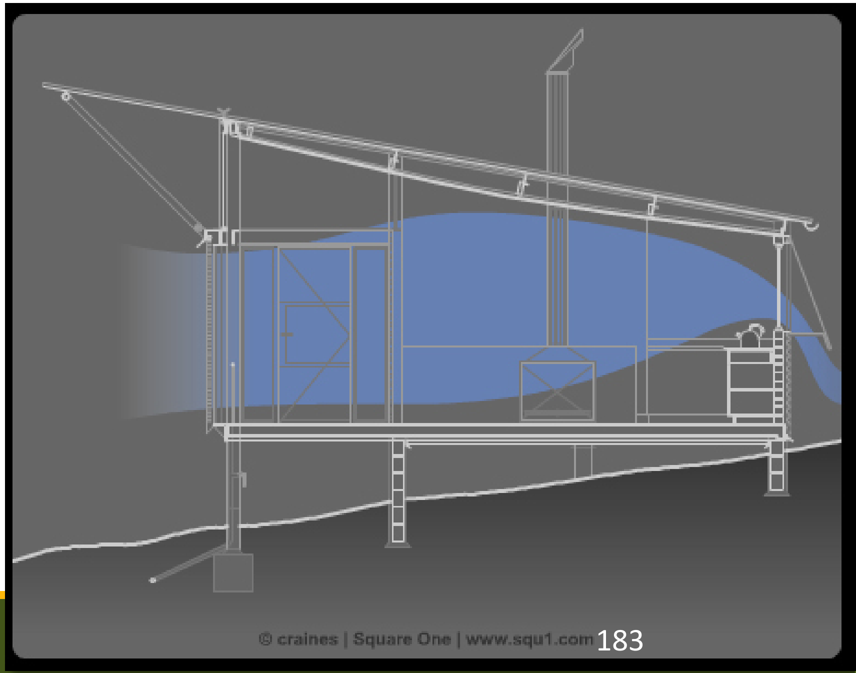
Maximize the amount of energy required for mechanical cooling that comes from renewable sources.

Source: Lechner. Heating, Cooling, Lighting.

Passive Cooling Strategies:
Passive Cooling

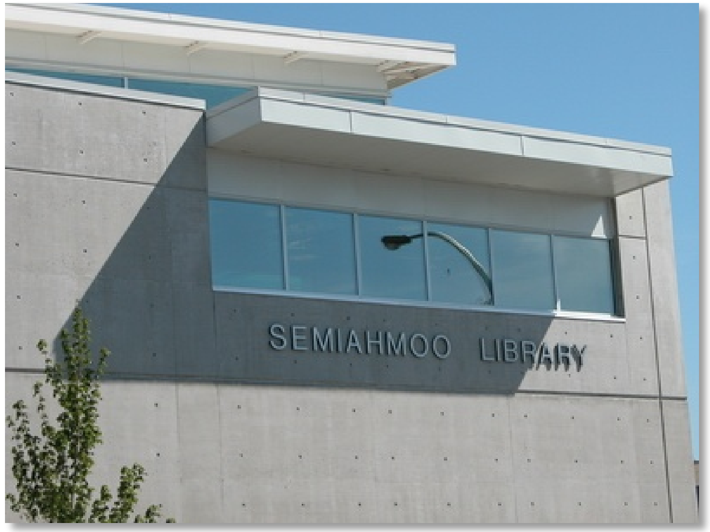
1. design for maximum ventilation
2. design plans as open as possible for unrestricted air flow
3. use easily operable windows at low levels with high level clerestory windows to induce stack effect cooling





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.

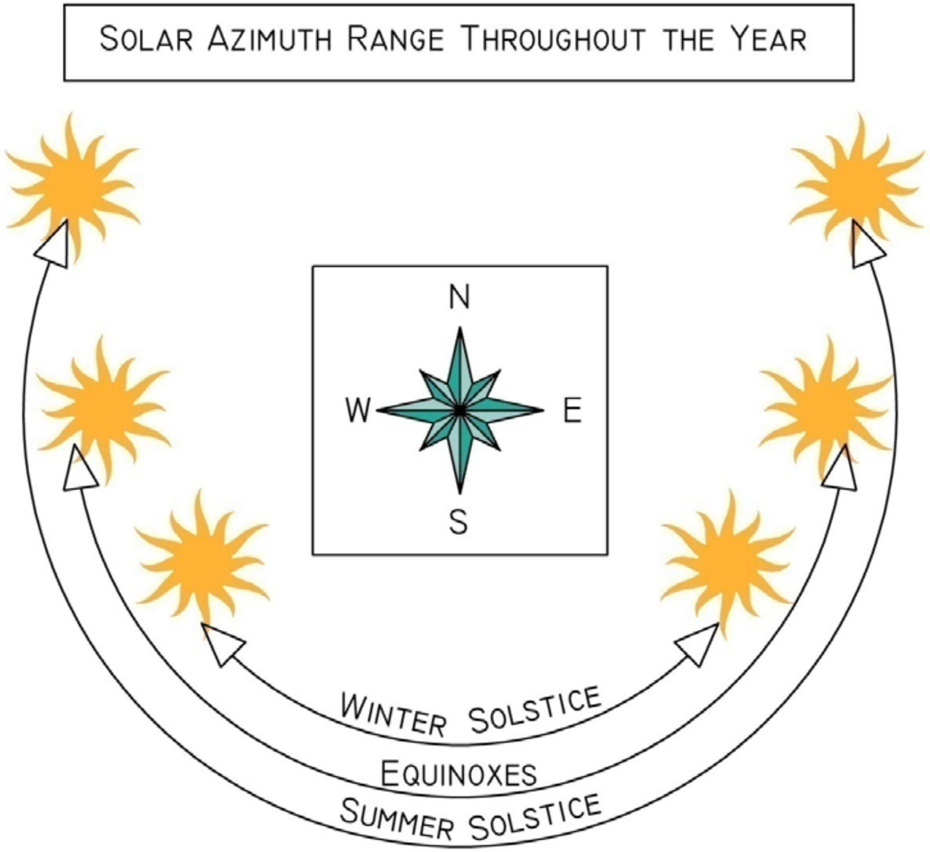
Atrium buildings have long had issues with solar gain, so some of the glass is opaque to give the appearance of "sky" without the solar gain.

Toronto, Eaton Centre – Zeidler Partnership


Salt Lake City Library, Moshe Safdie

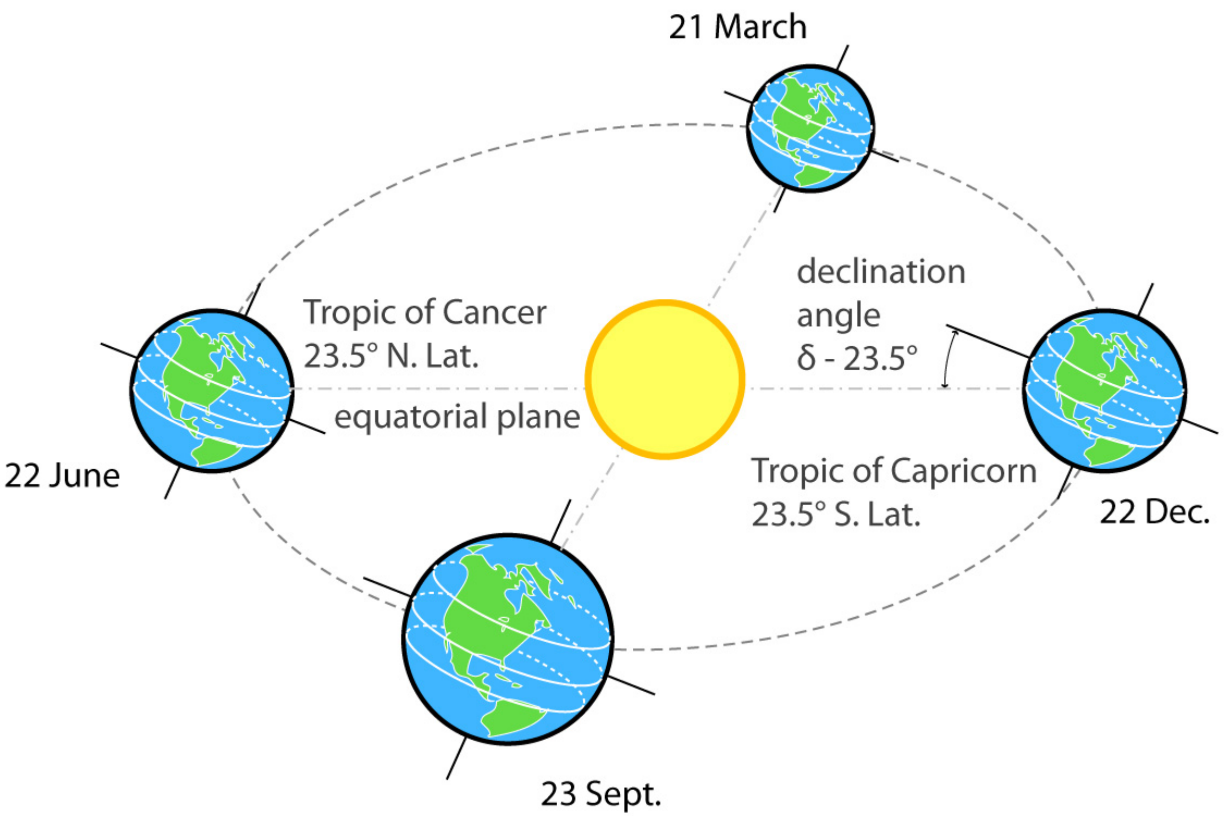
Blinds must be manually drawn by the librarian every sunny day to avoid baking the children in the lower library area!

#1 Starting Point ORIENTATION – Locate the SUN



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

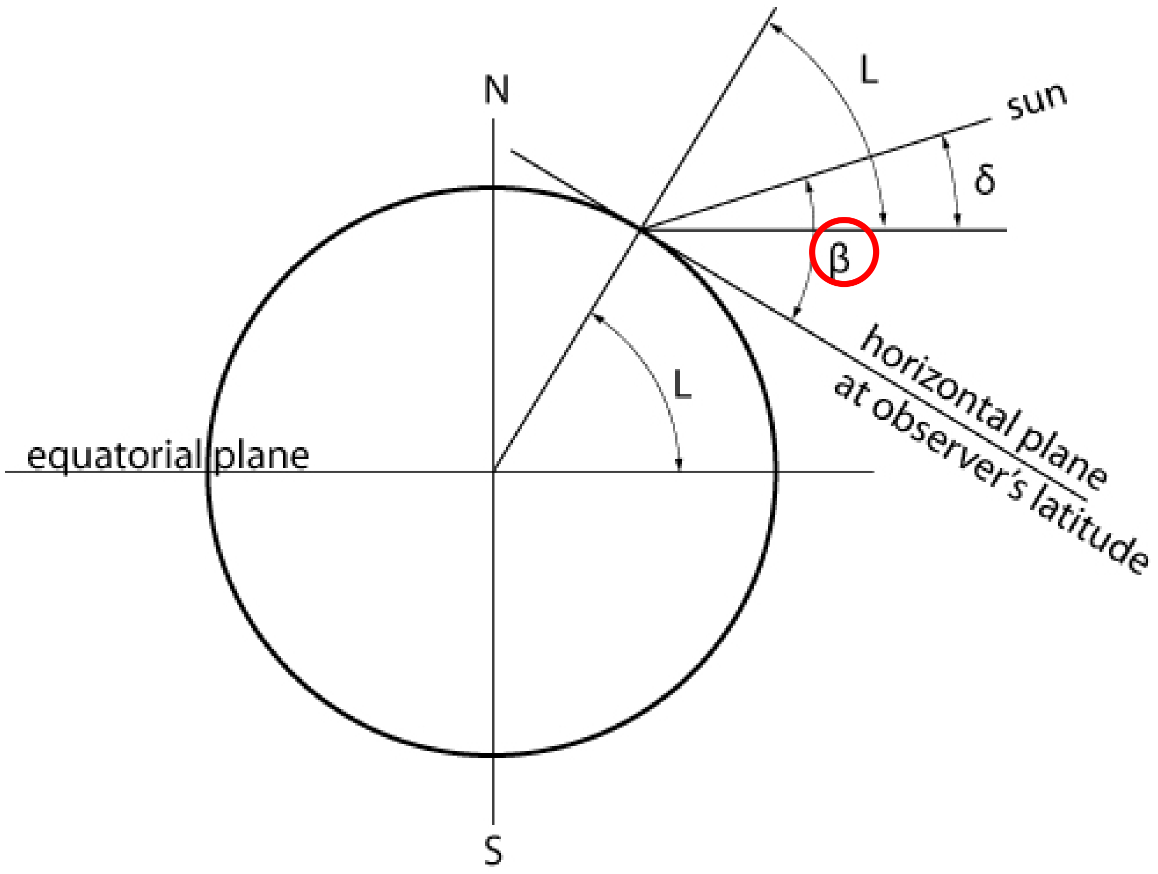
Solar Geometry



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

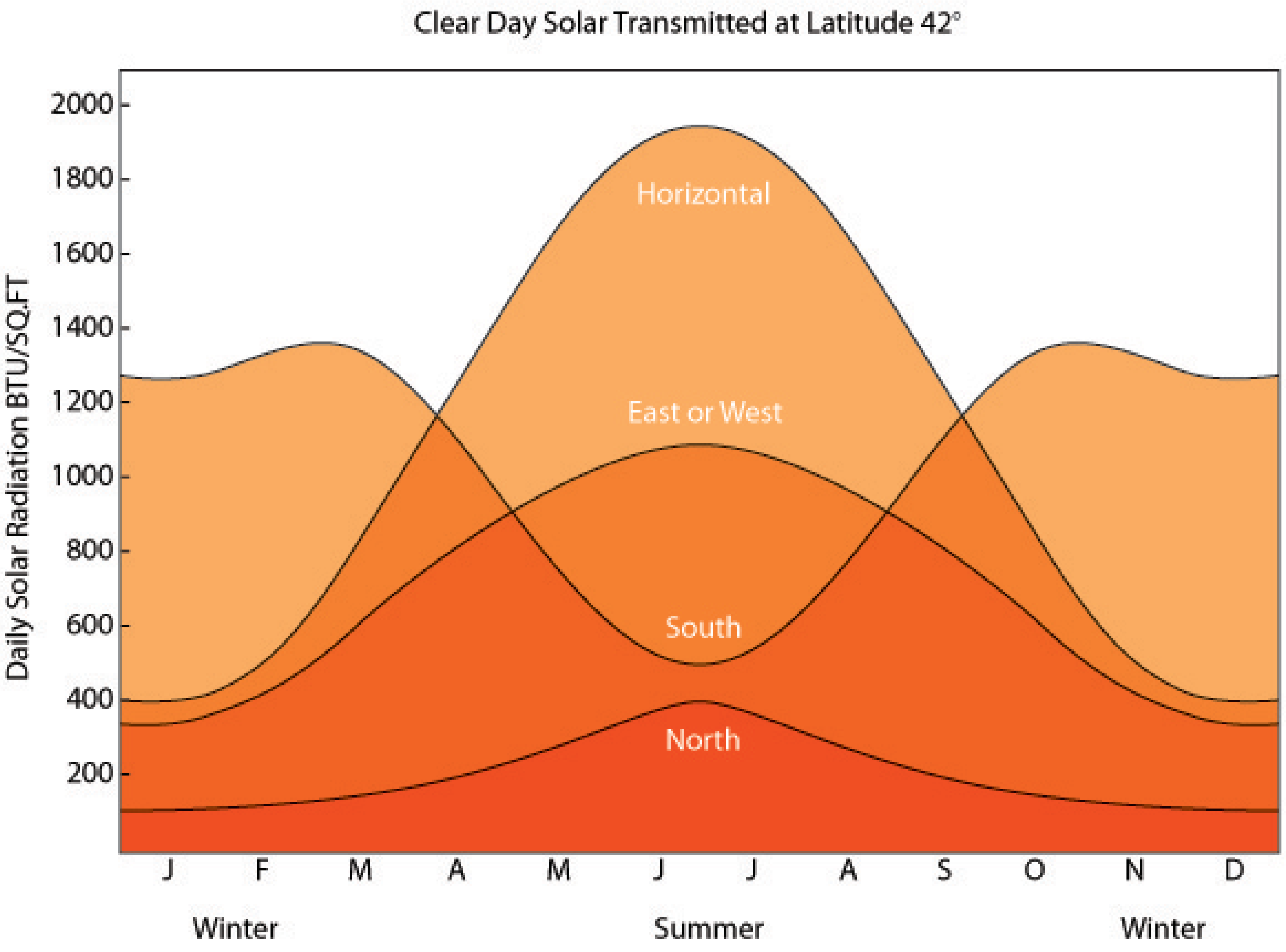
In studying Solar Geometry we are going to figure out how to use the sun's natural path in summer vs. winter to provide FREE heat in the Winter, and to reduce required COOLING in the summer.

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.

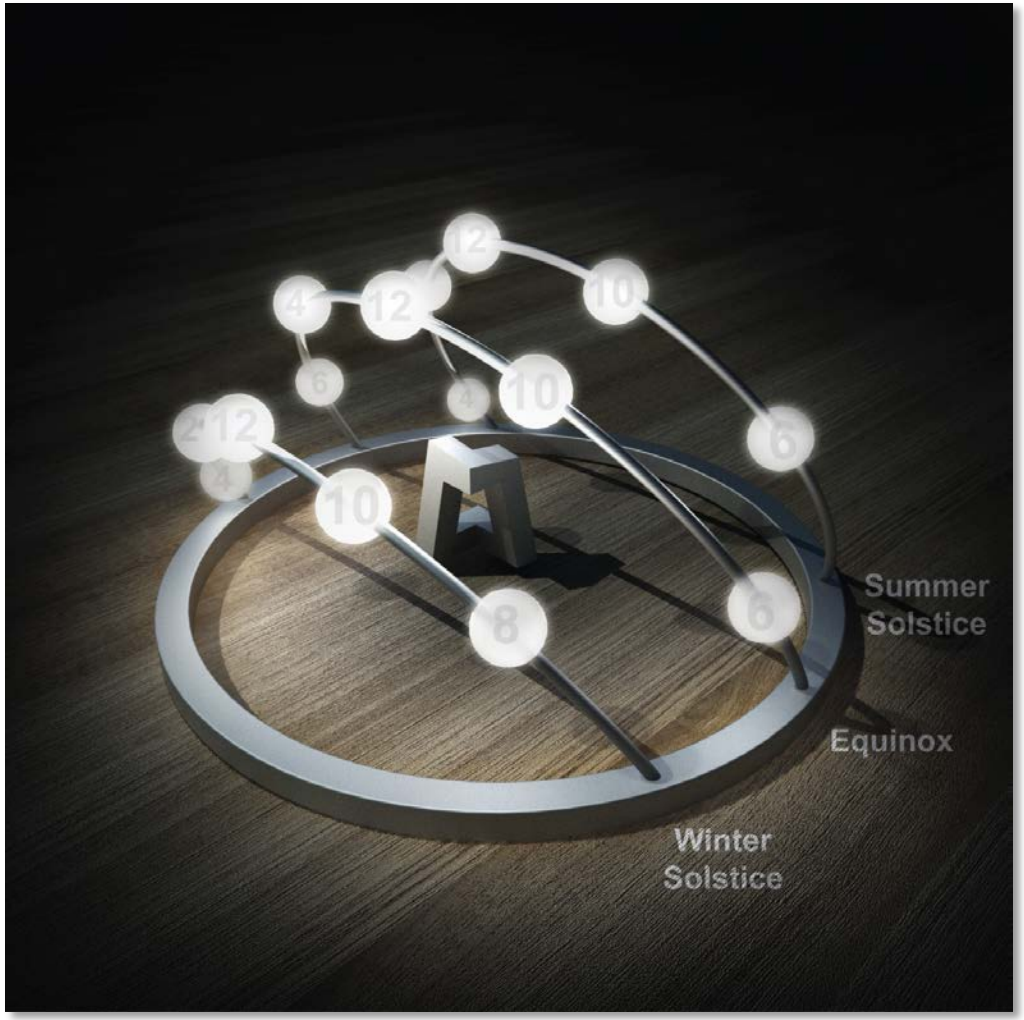
East and West glazing collects almost 3 times the solar radiation of south window.



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.

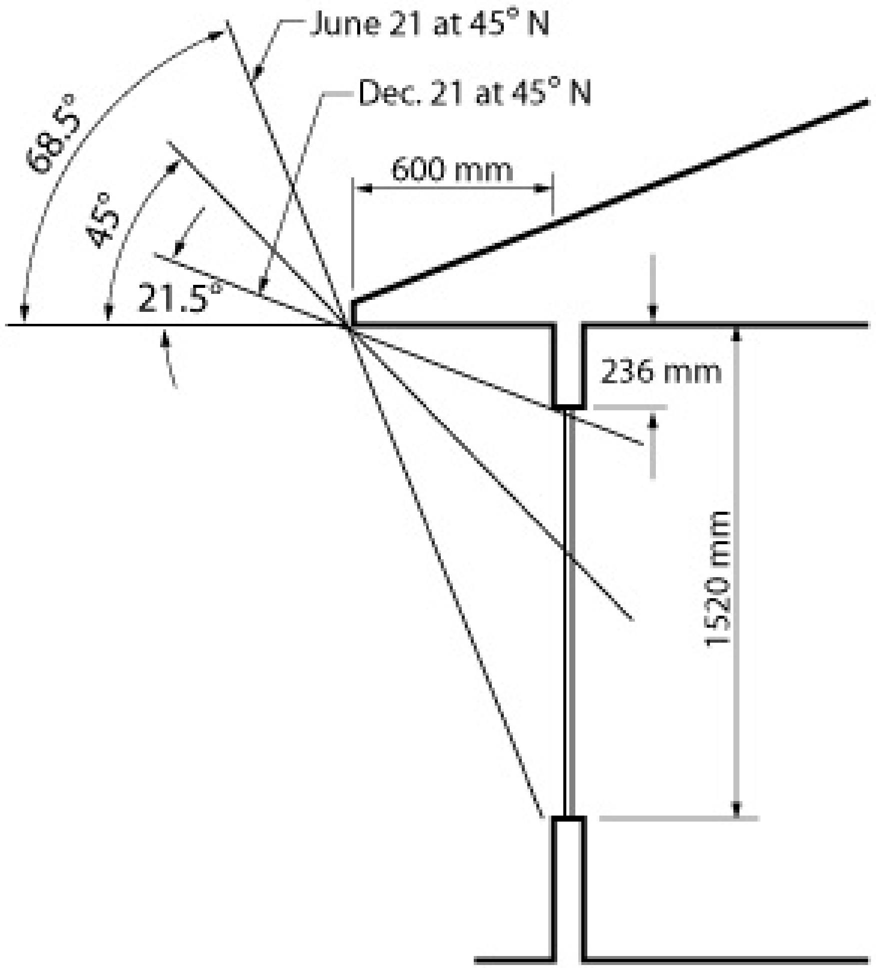
†Transmittance of insulating and laminated glass varies widely depending on whether or not one or more surfaces are treated with reflective films.

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

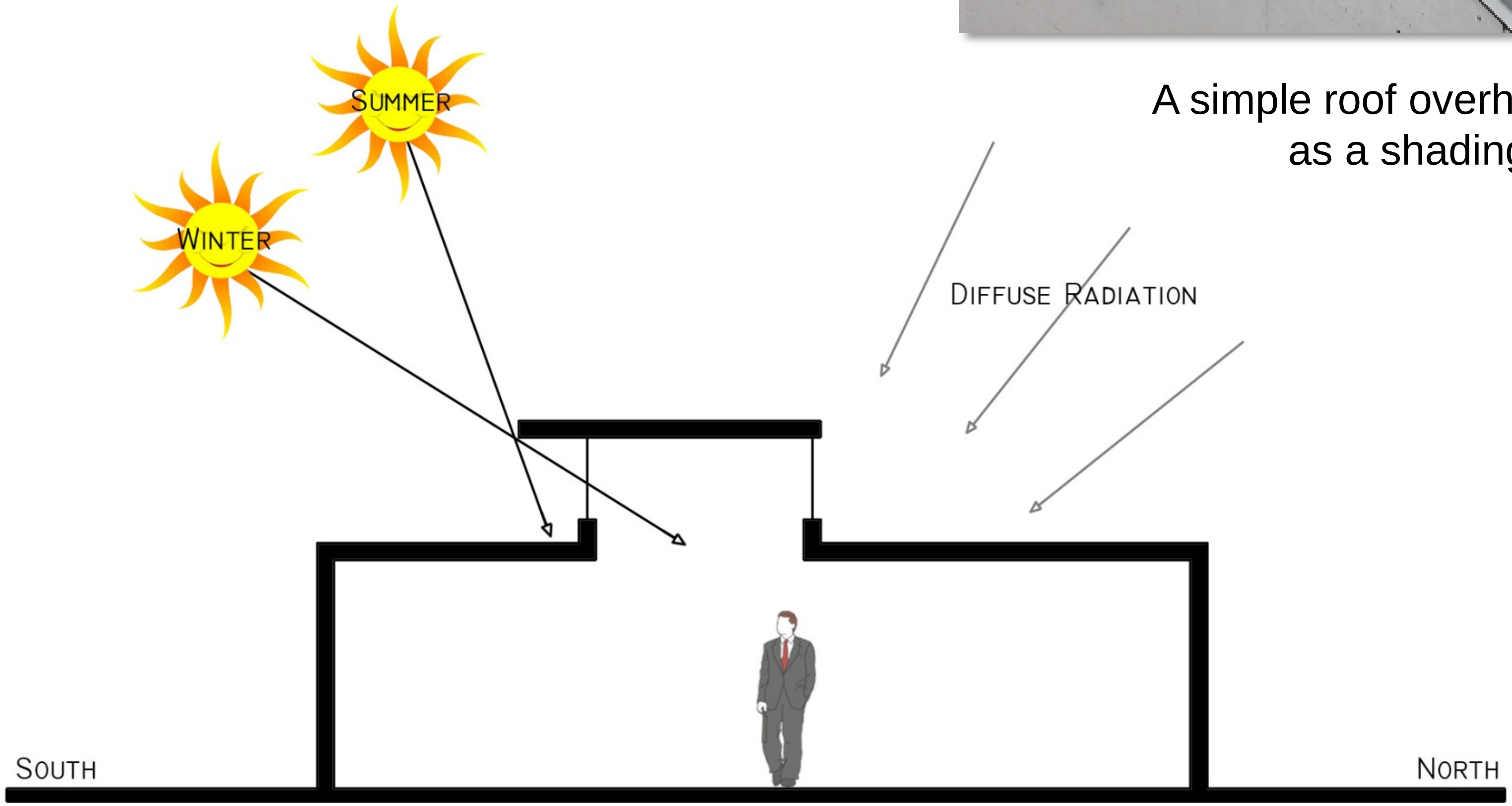
South facing windows are the EASIEST for control of sun penetration.

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.

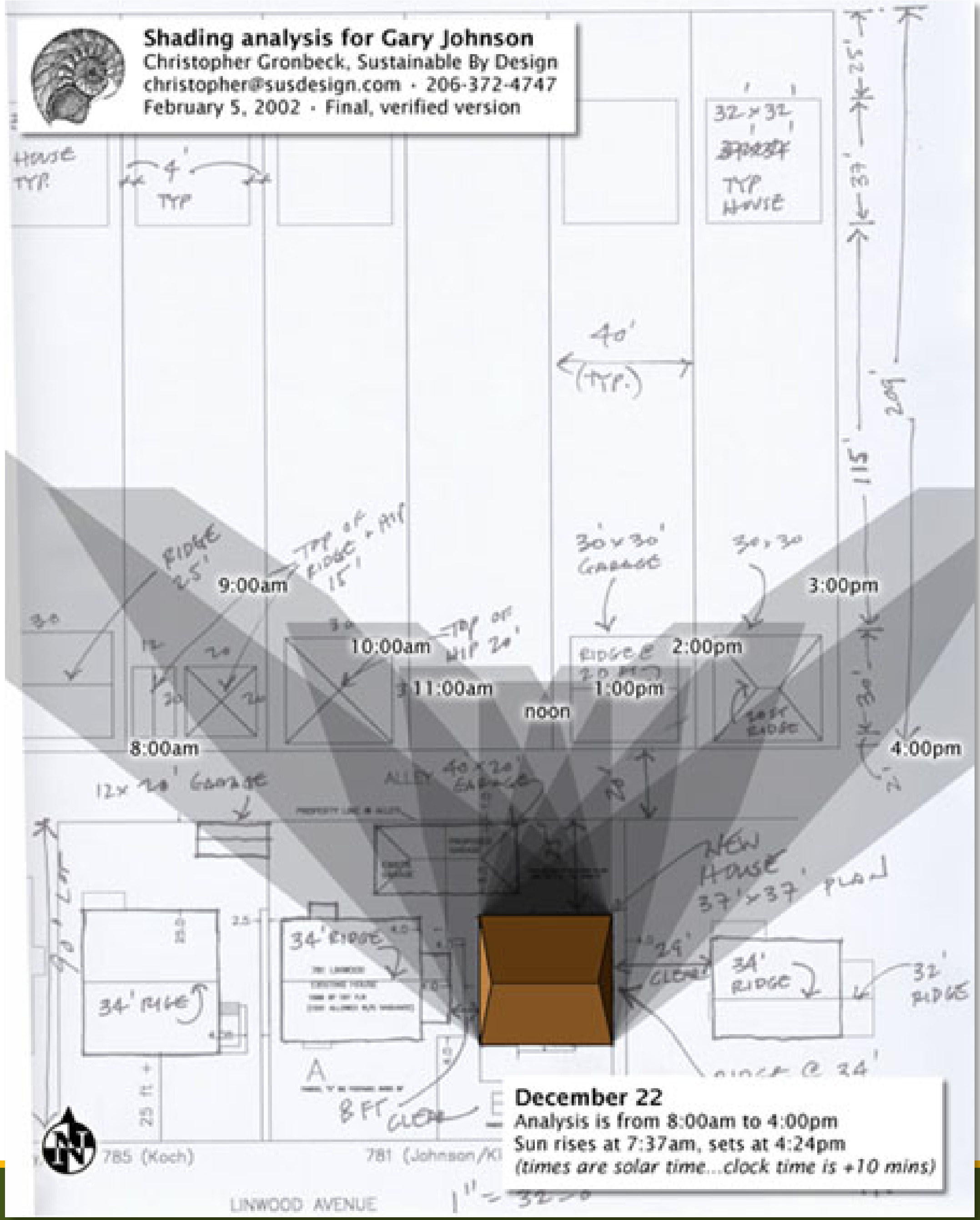
A simple roof overhang acts as a shading device.



CLERESTORY WINDOW

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.

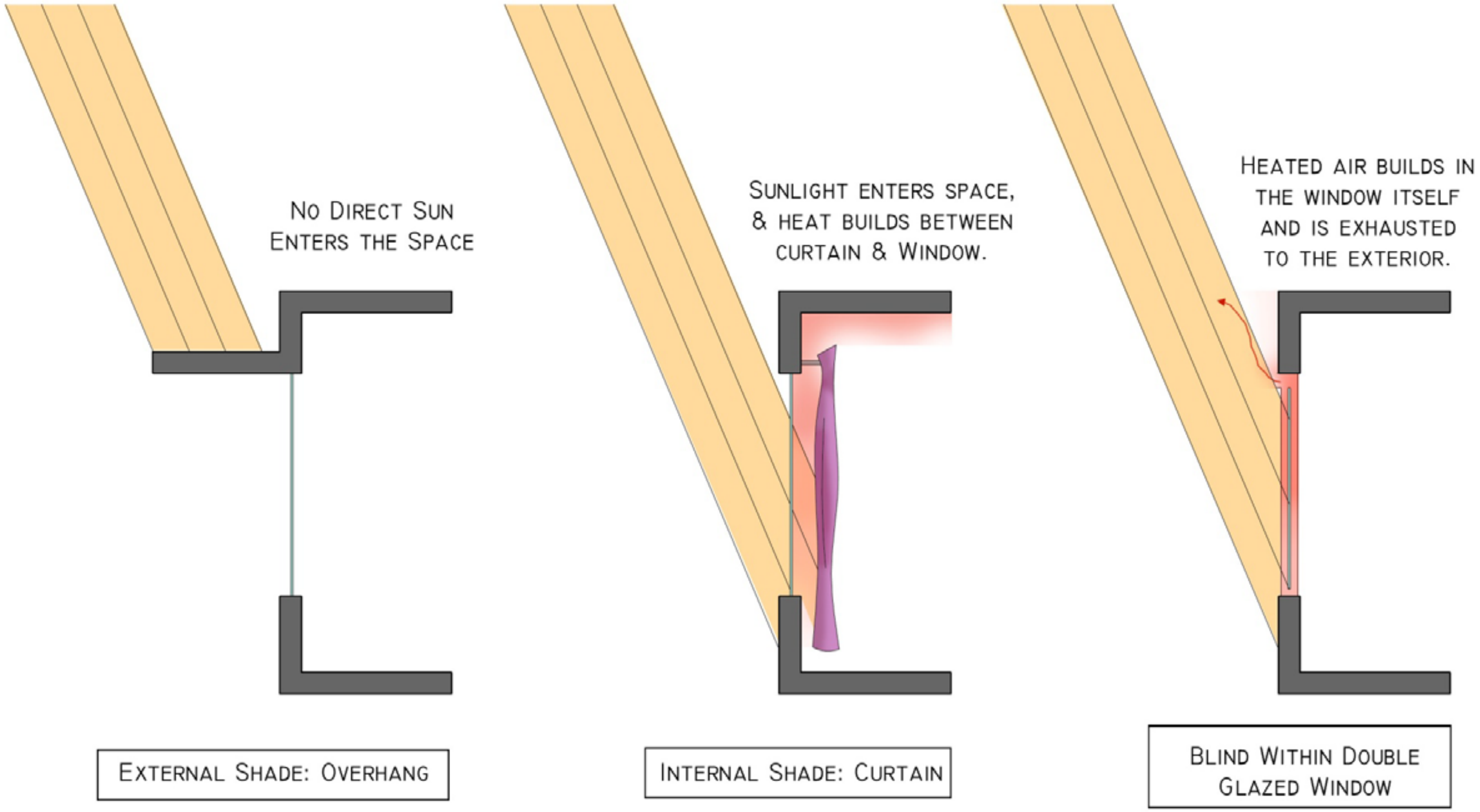
When we design our elevations to be solar responsive, this will mean having different facade treatments to respond to sun angles and the degree of exposure of the facade.



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.

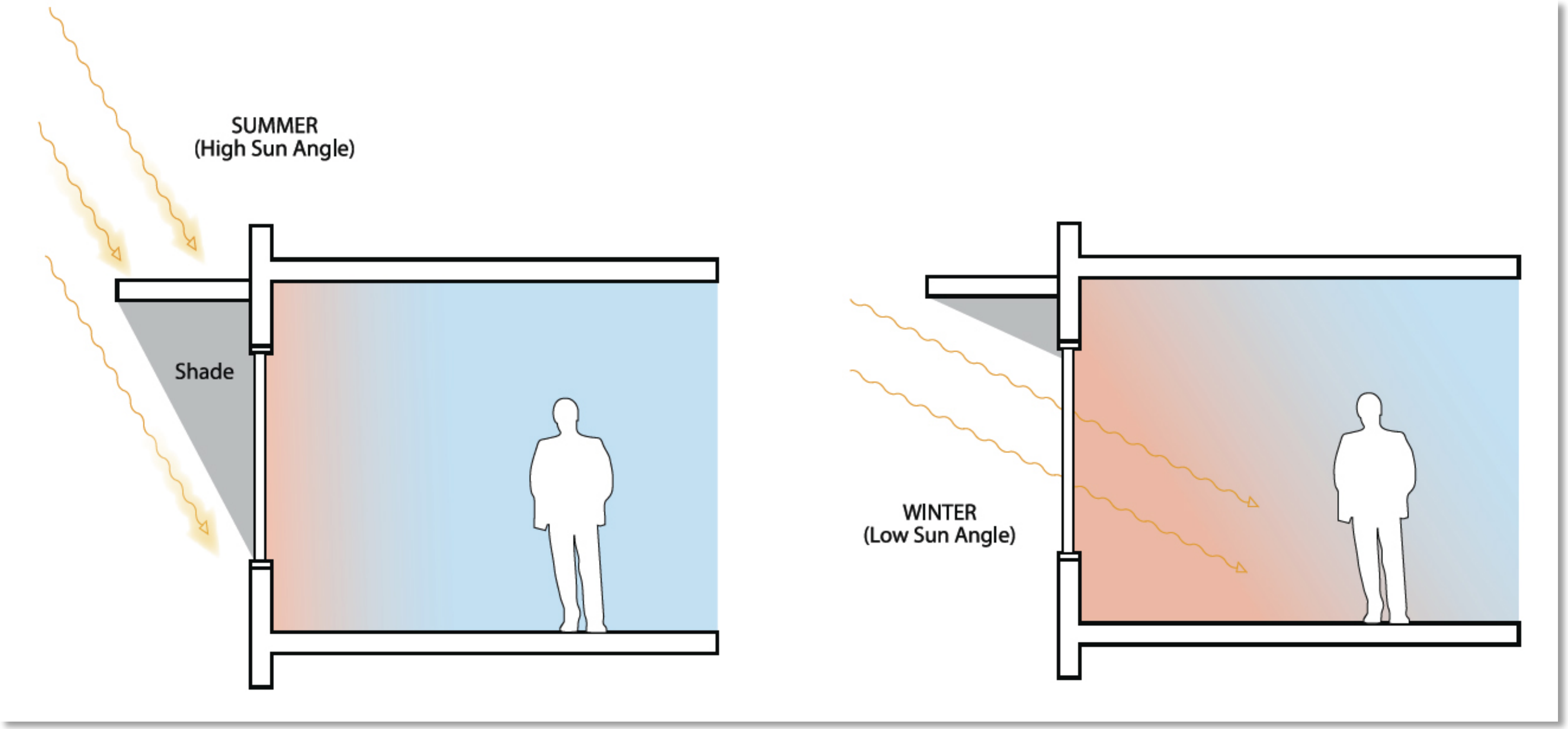
Interior vs Exterior Shades



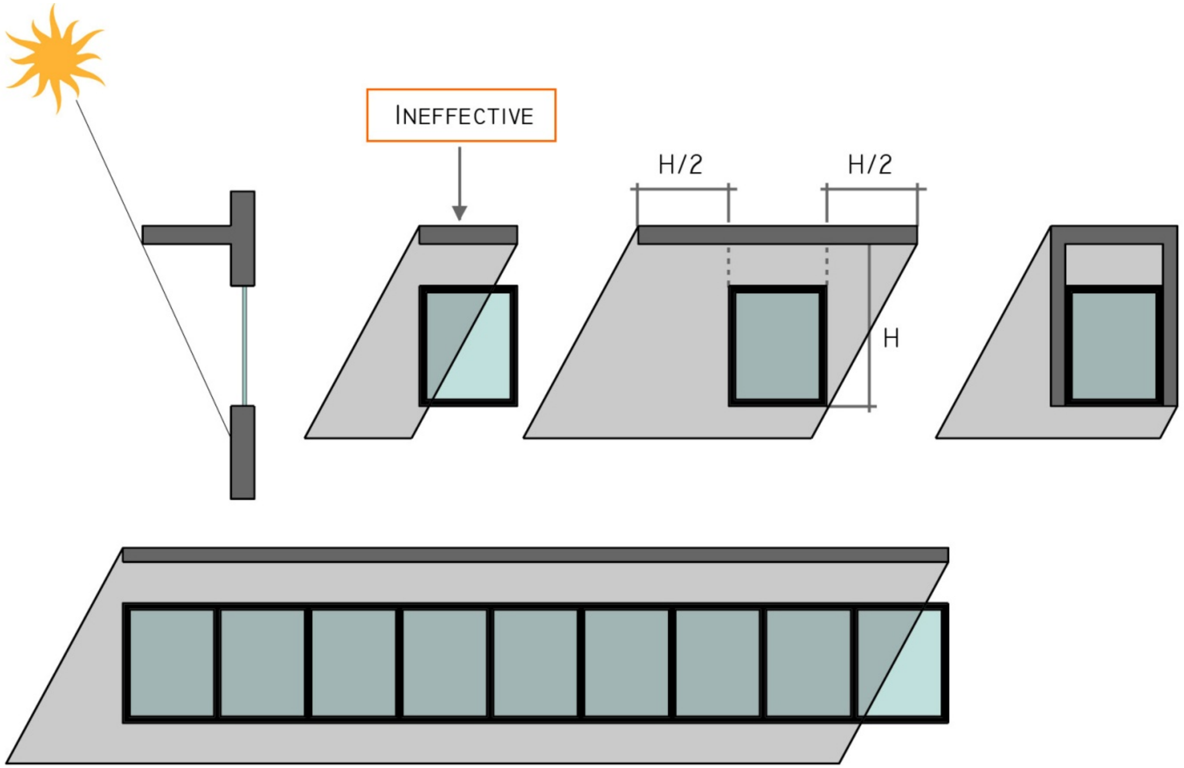
Once the heat is IN, it is IN!

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

South Façade Strategies

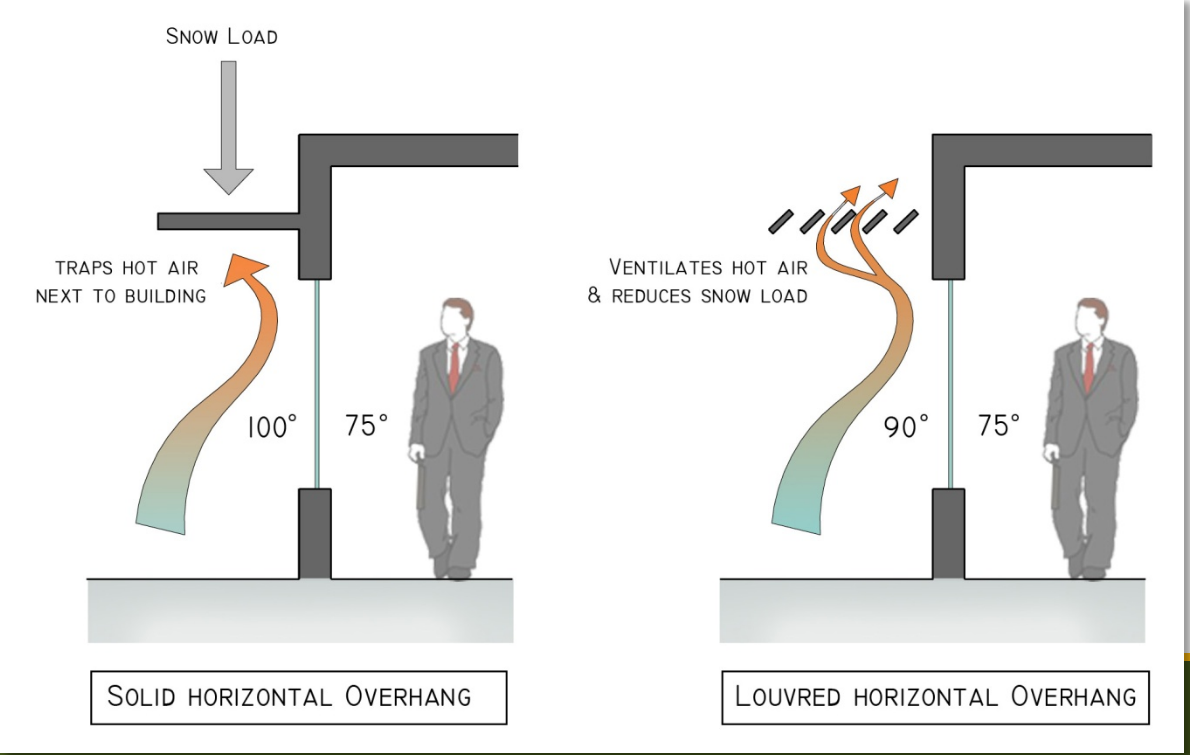


- South façade is the easiest to manage as simple overhangs can provide shade in the summer and permit entry in the winter.
- Need to design for August condition as June to August is normally a warm period.



…extend device for full shading

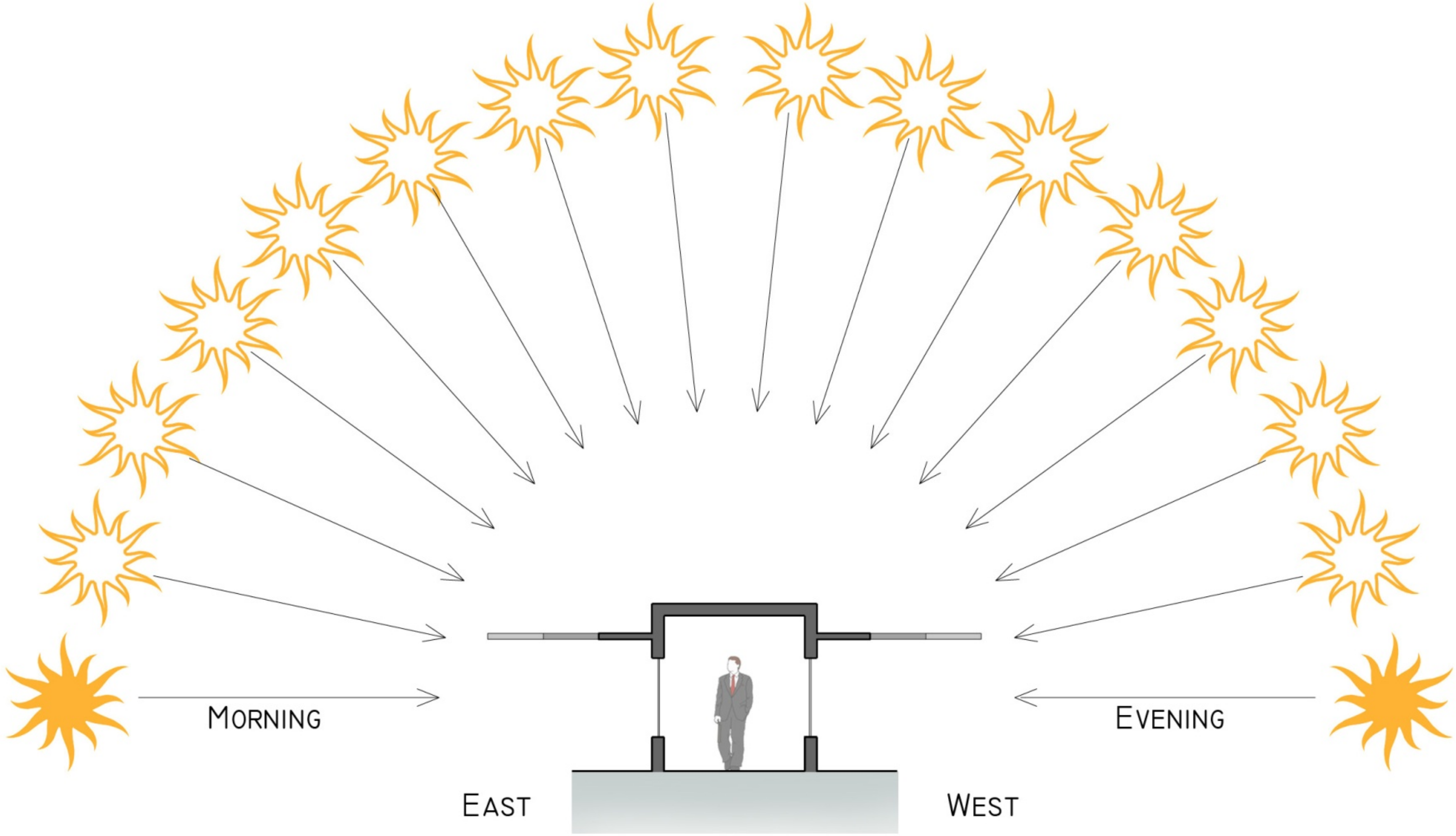
This one uses ceramic fritted glass that is sloped, to allow some light but shed rain and wet snow.



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.

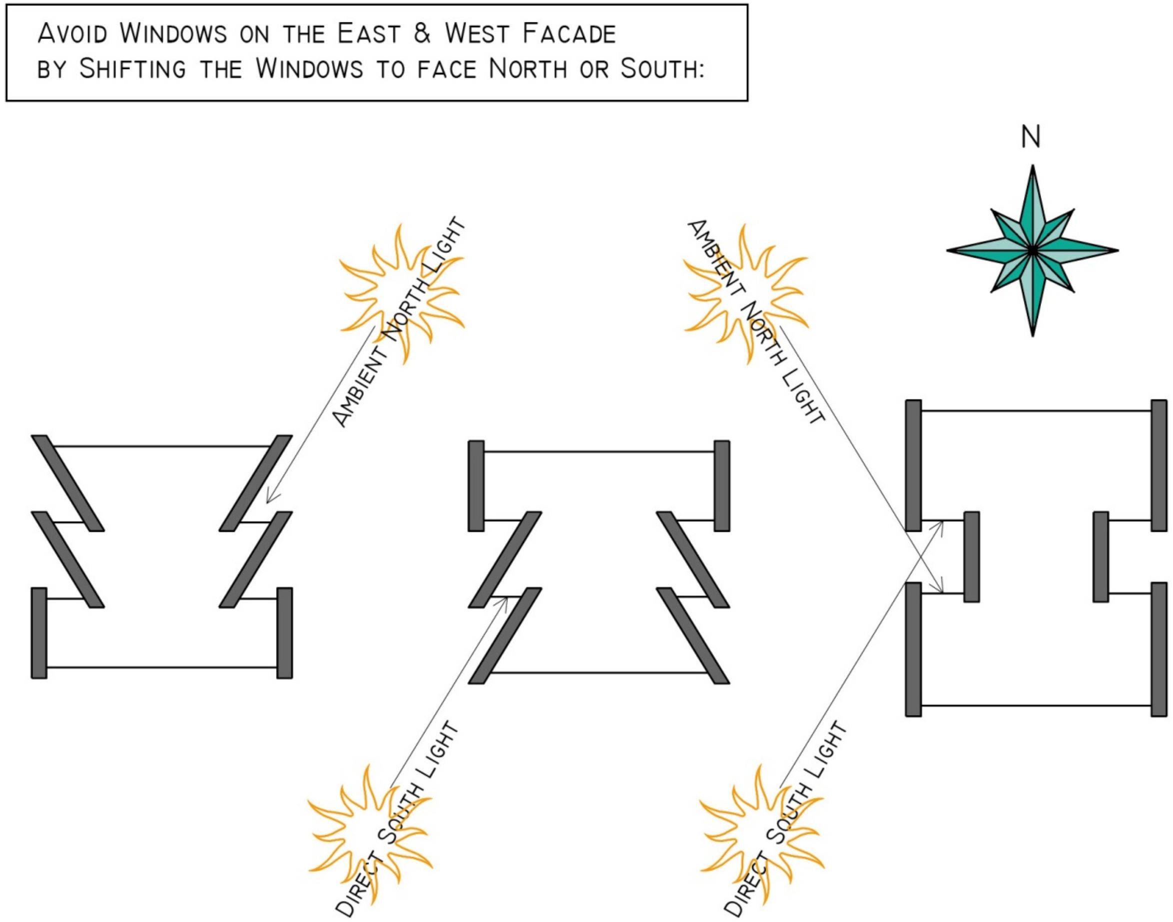
Shading Strategies for East and West Orientations



Horizontal Overhangs do NOT work on East & West Facades

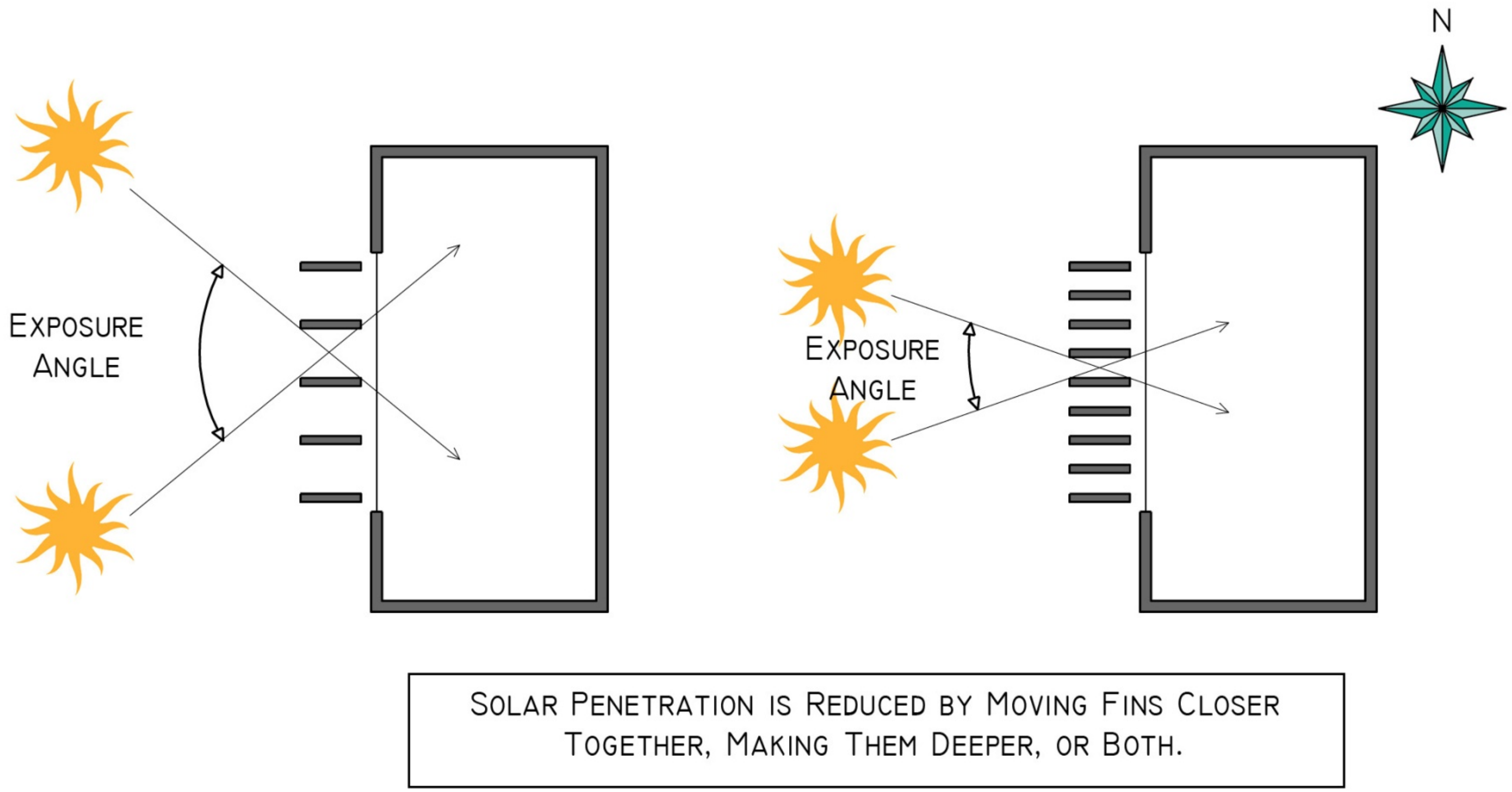
Shading Strategies for East and West Elevations

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



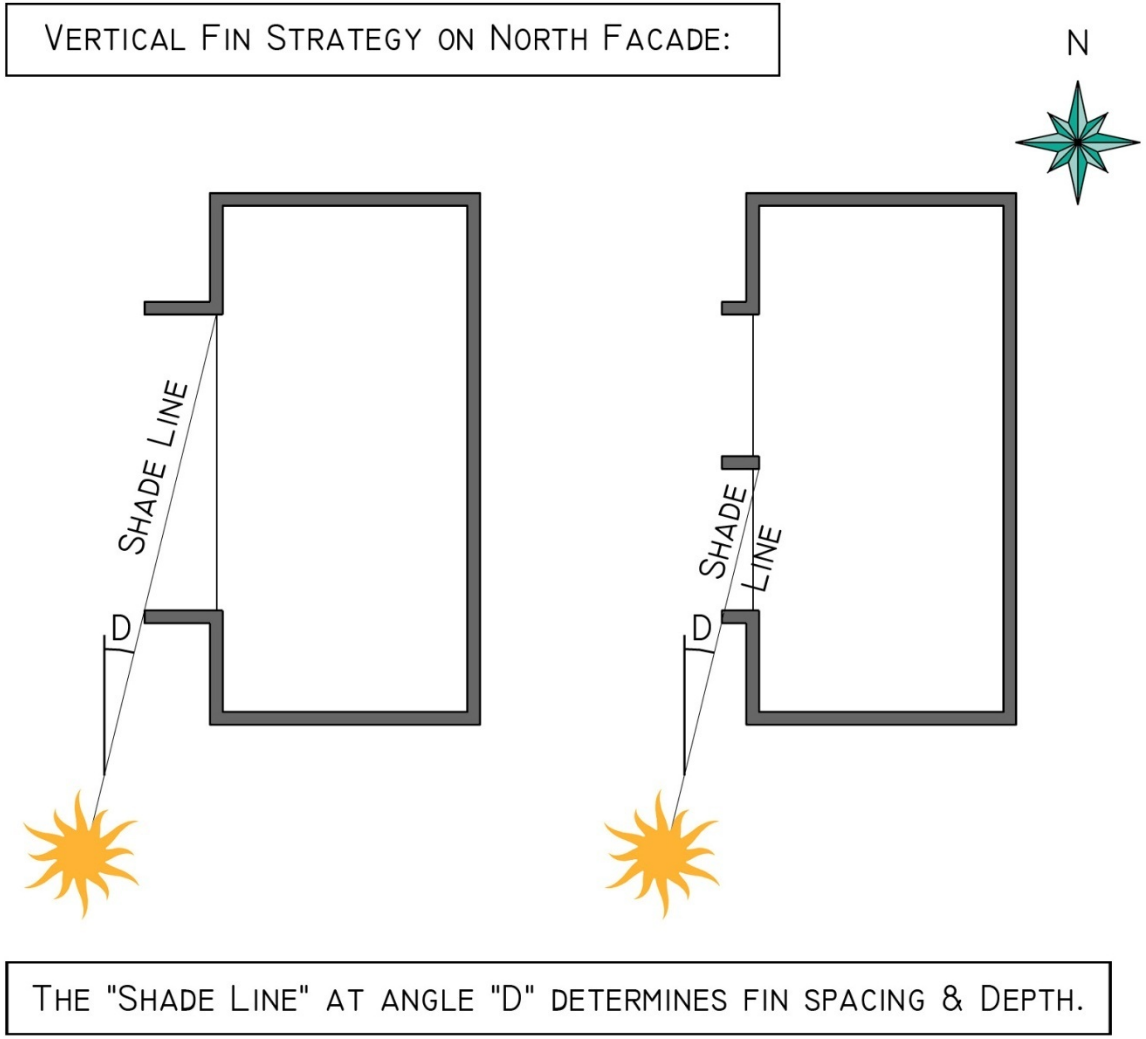
2. Next best solution is to have windows on the east and west façades face north or south

Shading Strategies for East and West Elevations



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

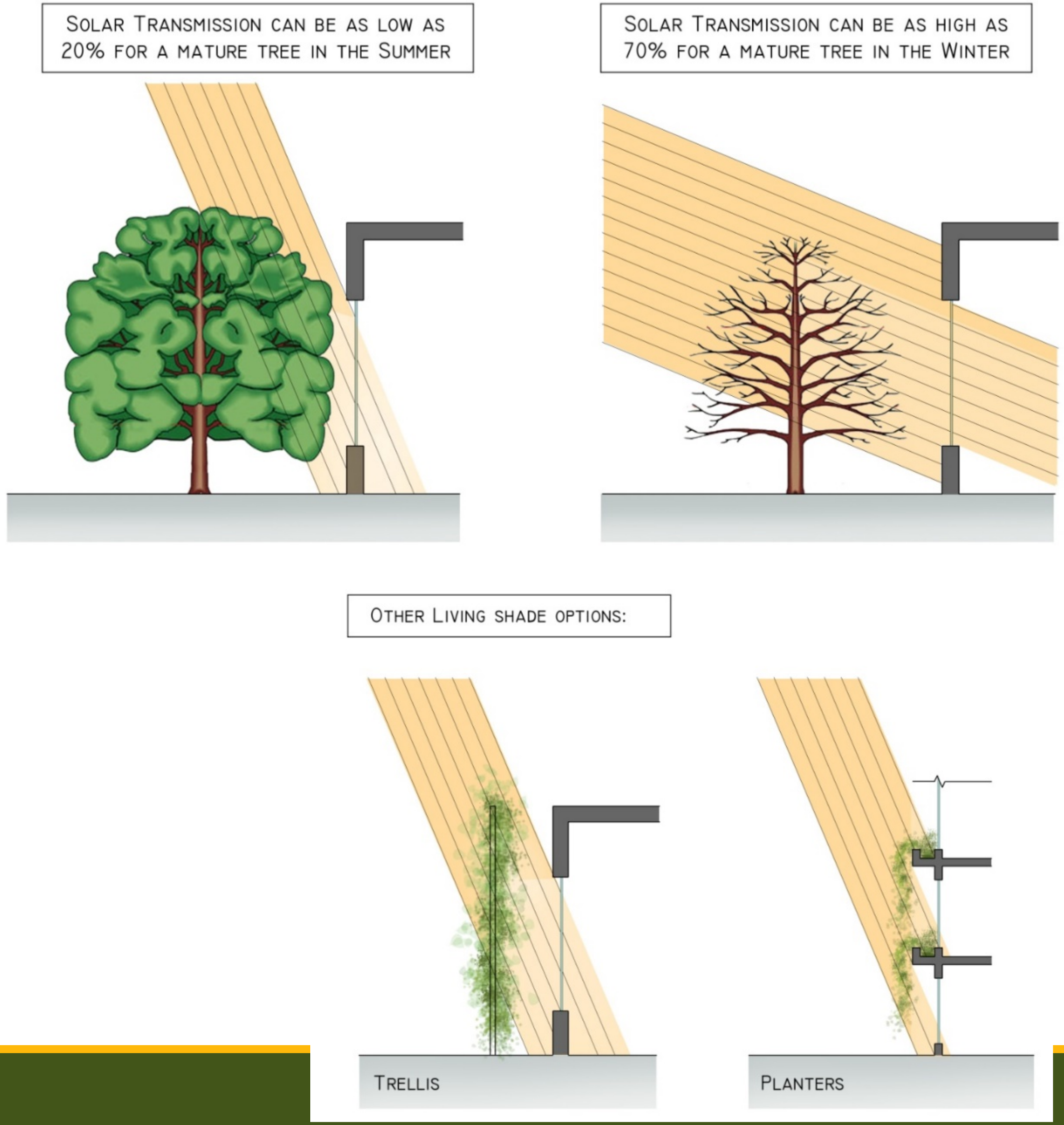
Shading Strategies for the North Elevation



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

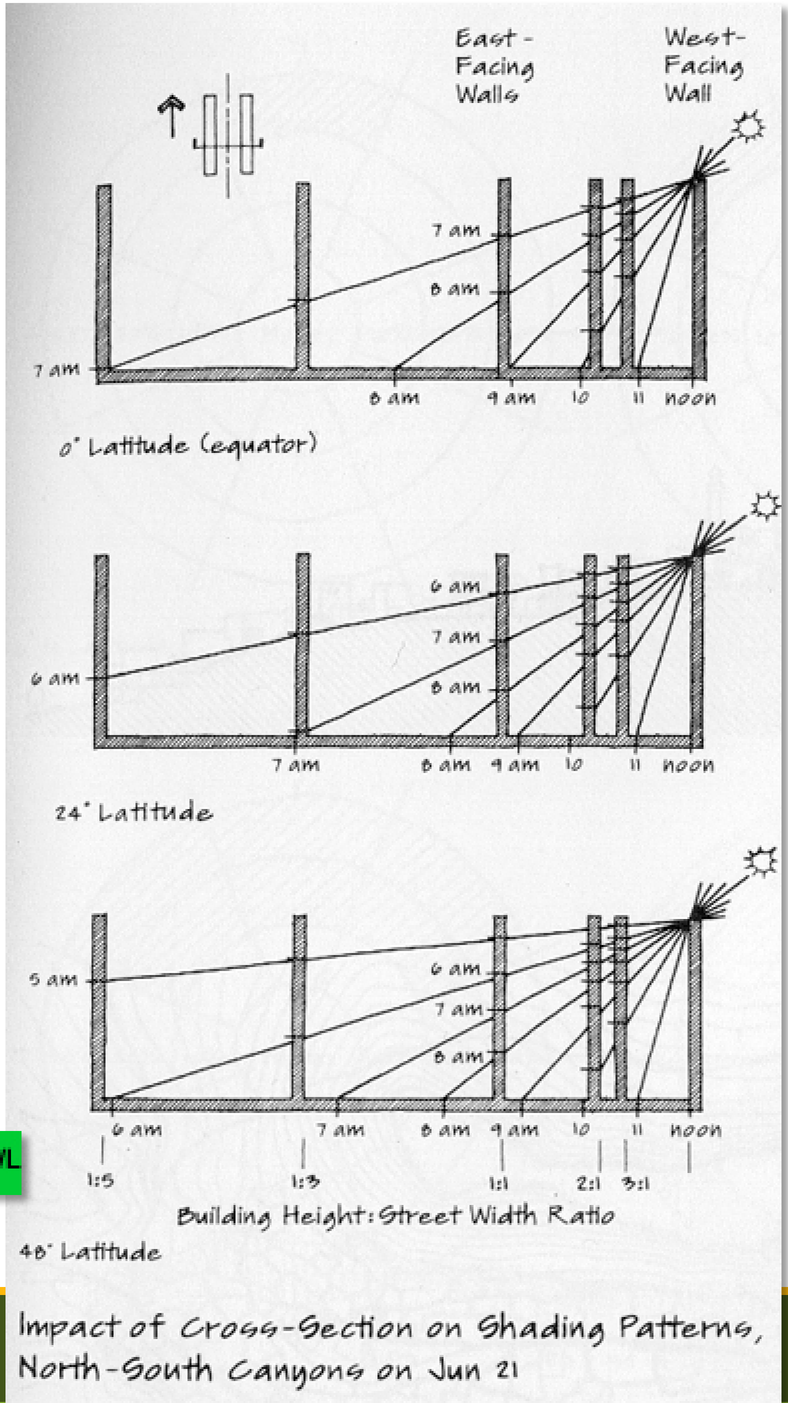
Living Awnings

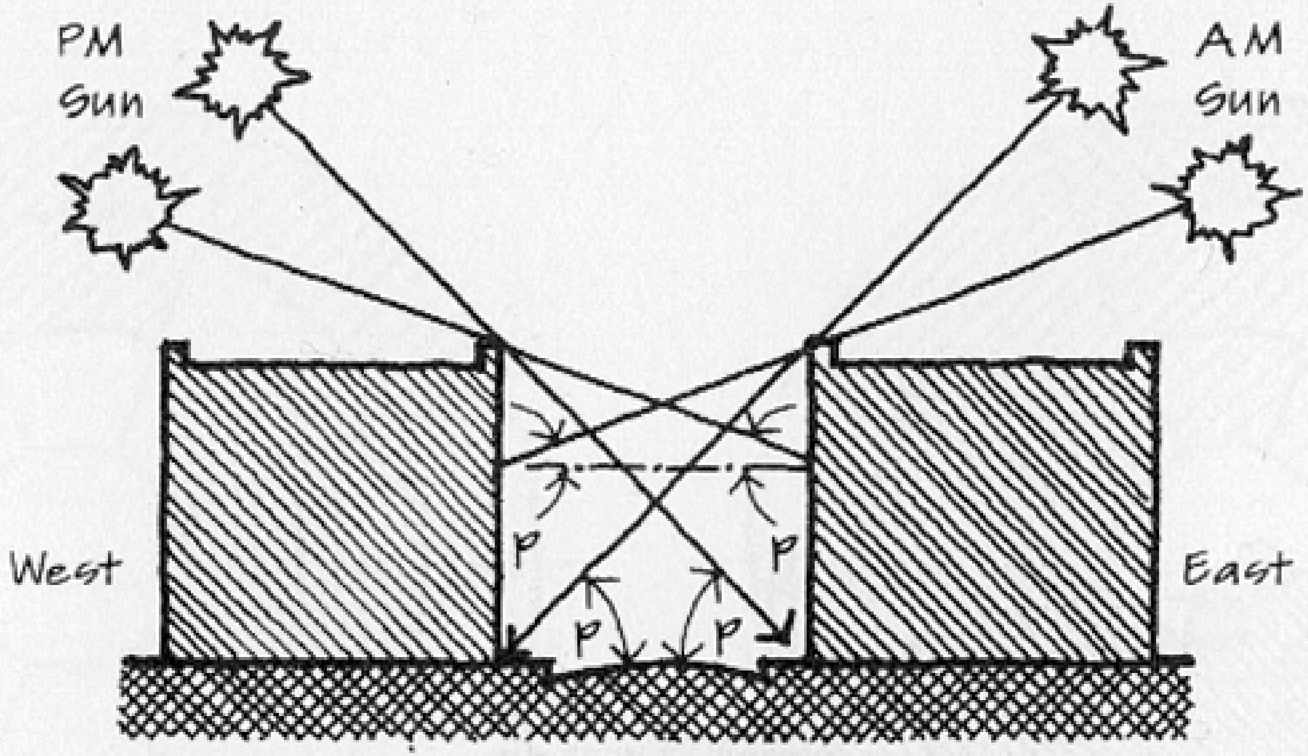
Living Awnings such as deciduous trees and trellises with deciduous vines are very good shading devices. They are in phase with the thermal year – gain and lose leaves in response to temperature changes.



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

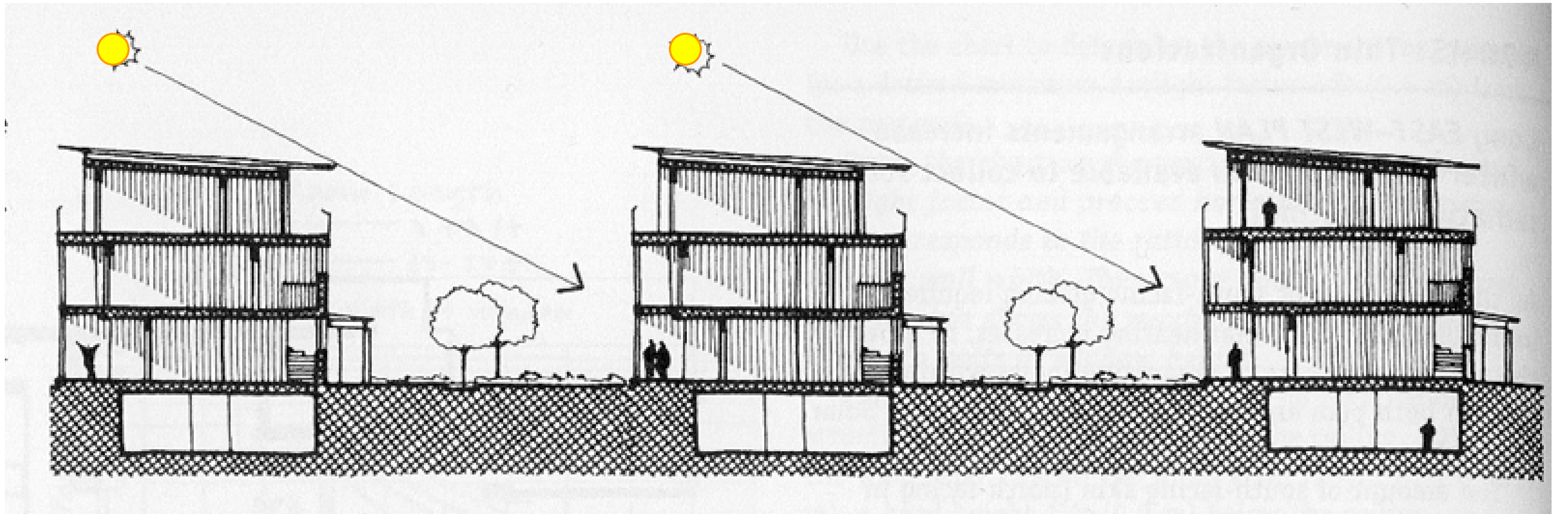




Profile Angle for North-South Canyons

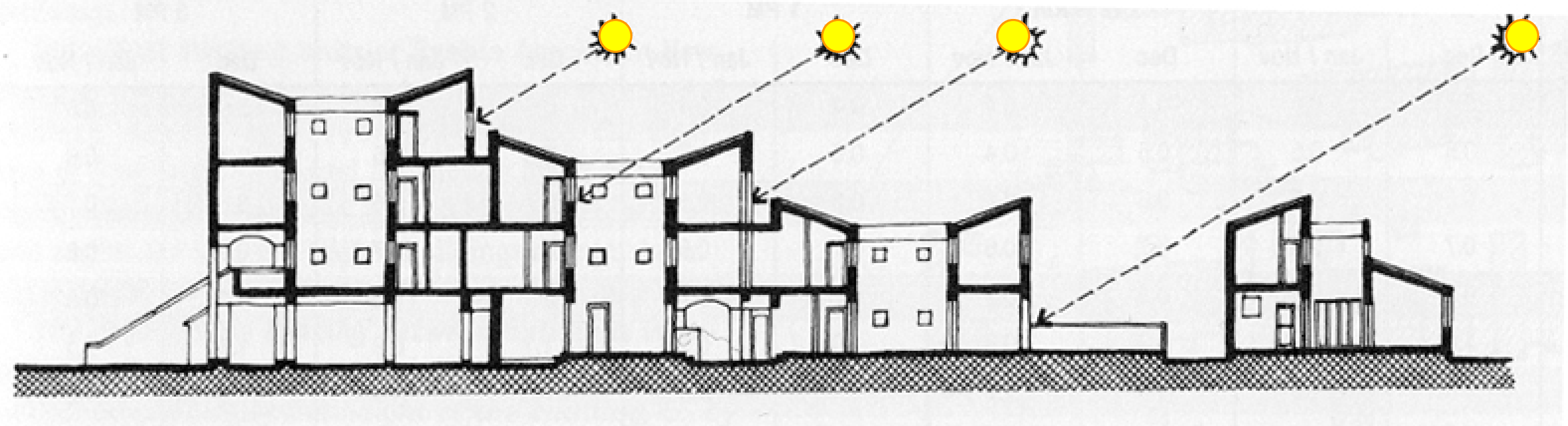
SWL

Solar Access



Housing Development Brunnerstrasse-Empergasse, Typical North-South Section

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).



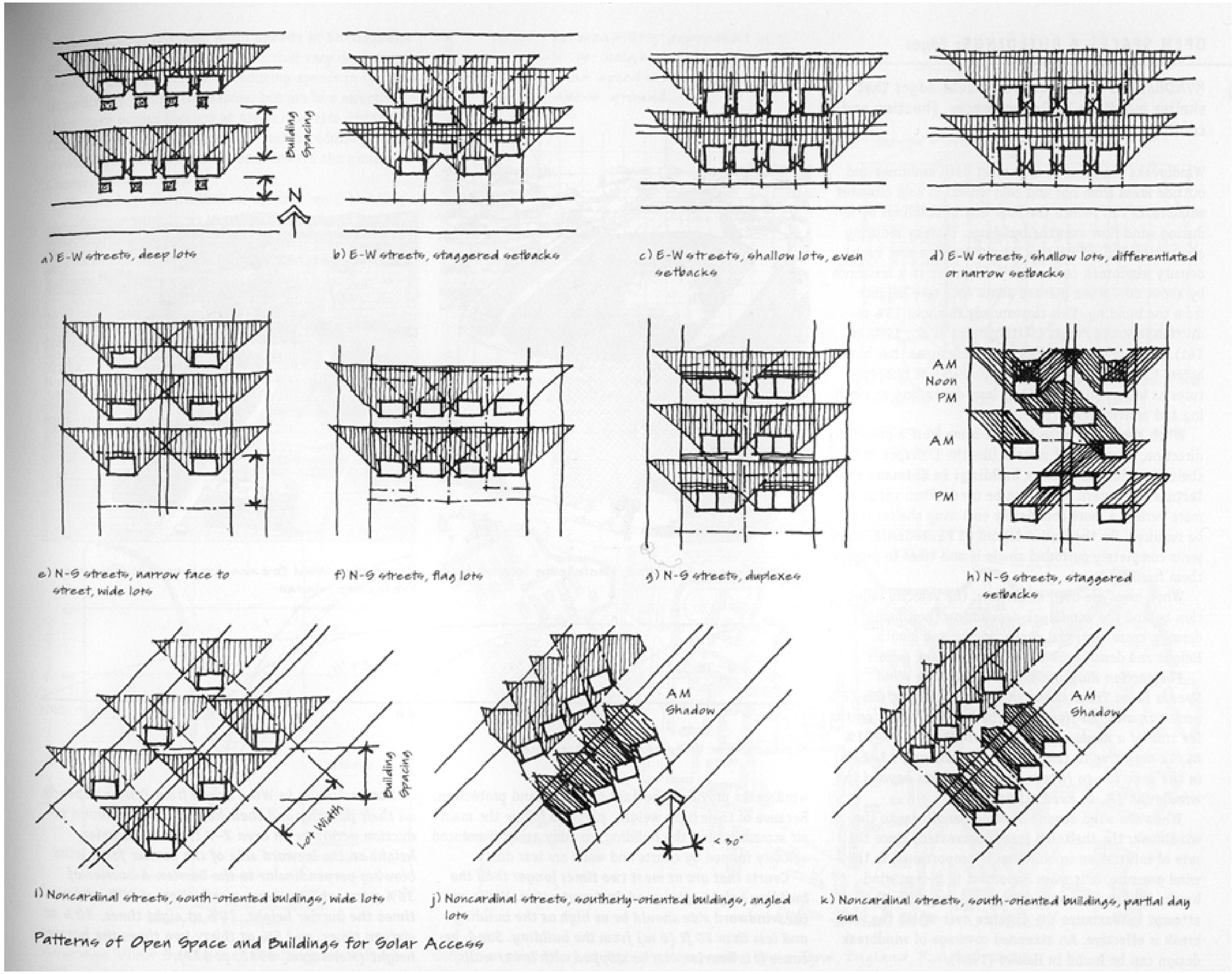
North-South Section, Public Housing Estate, Giudecca Island, Venice, Italy, Gino Valle

SWL

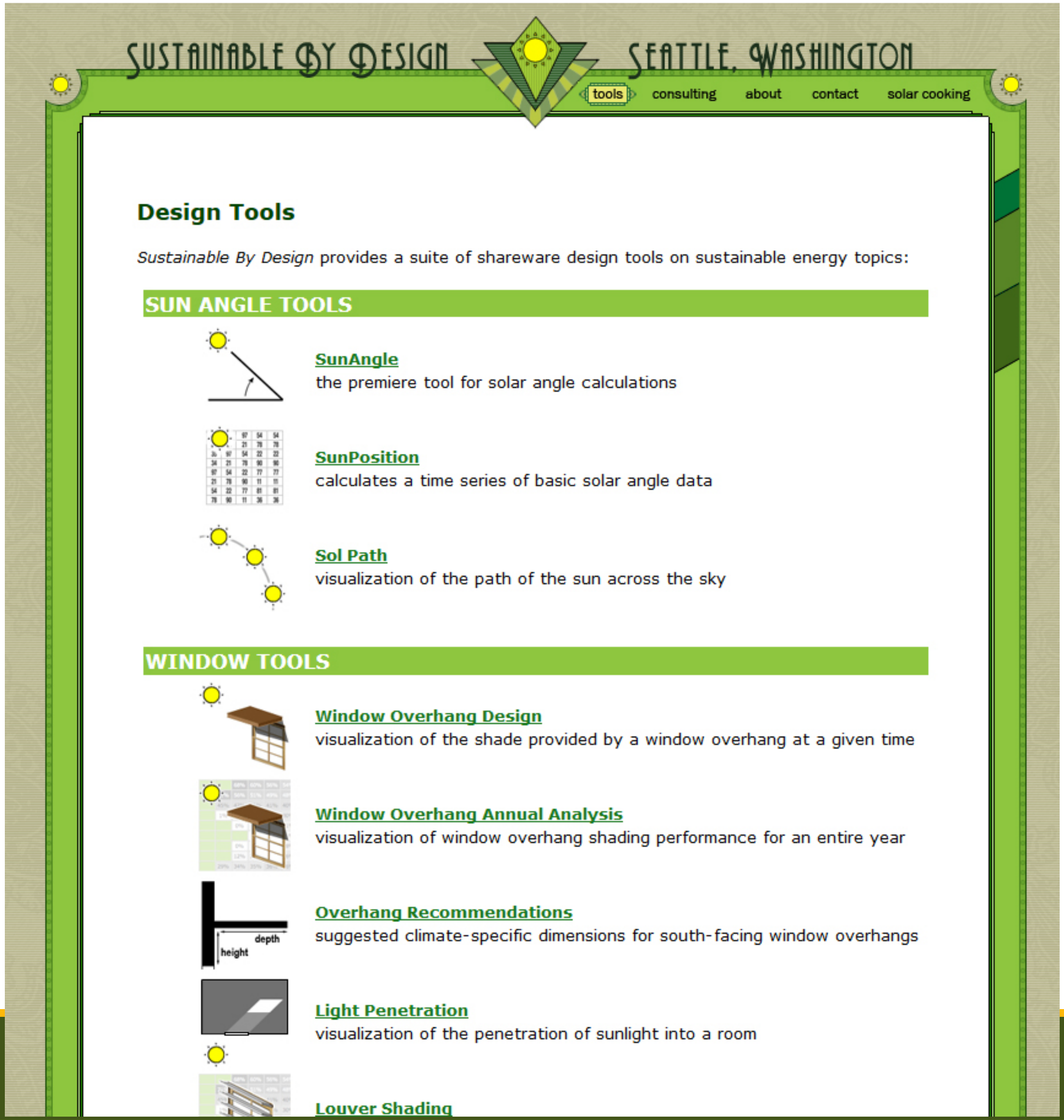
For more complicated sections, the building height and section is adjusted to allow south light to penetrate into various exposures of the building -- in this case through courtyards and clerestory windows.

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.

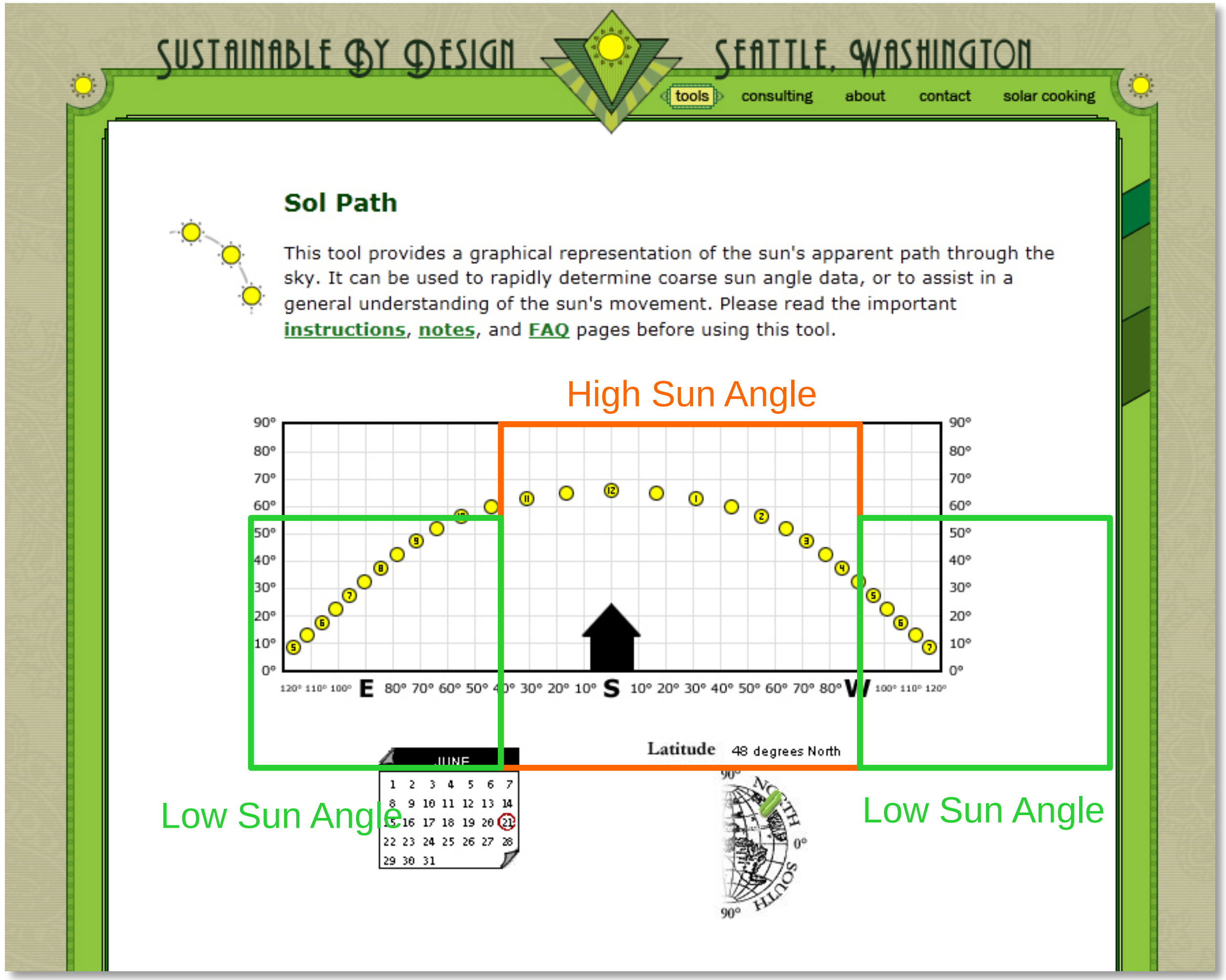


Helpful online tools



http://susdesign.com/tools.php

Differentiated Shading Strategies



http://susdesign.com/tools.php

Differentiated façade treatment

Different envelope construction on north, east/west and south

Terasan Gas, Surrey, BC

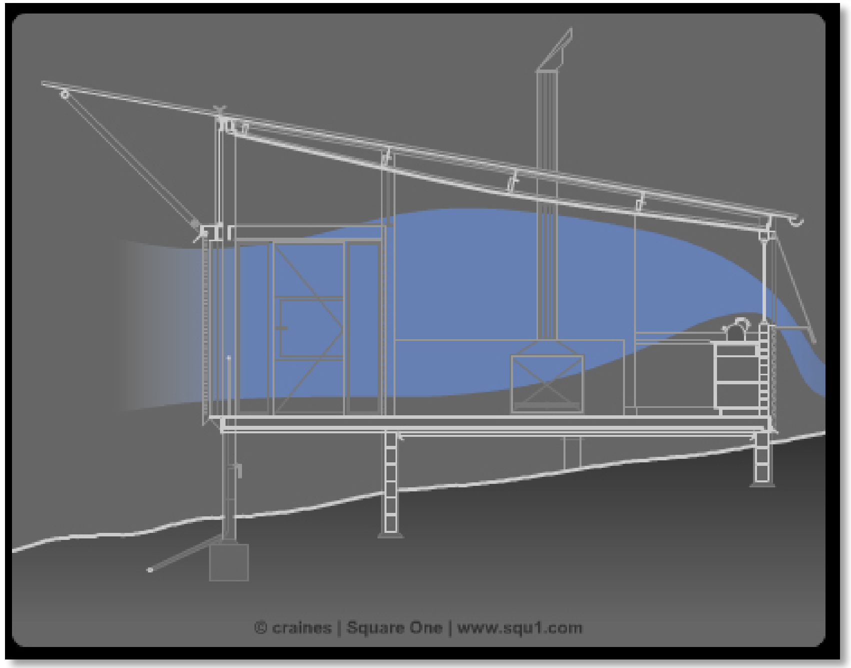
Passive Cooling Strategies:
Ventilation

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

Passive Cooling Strategies:
Ventilation

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

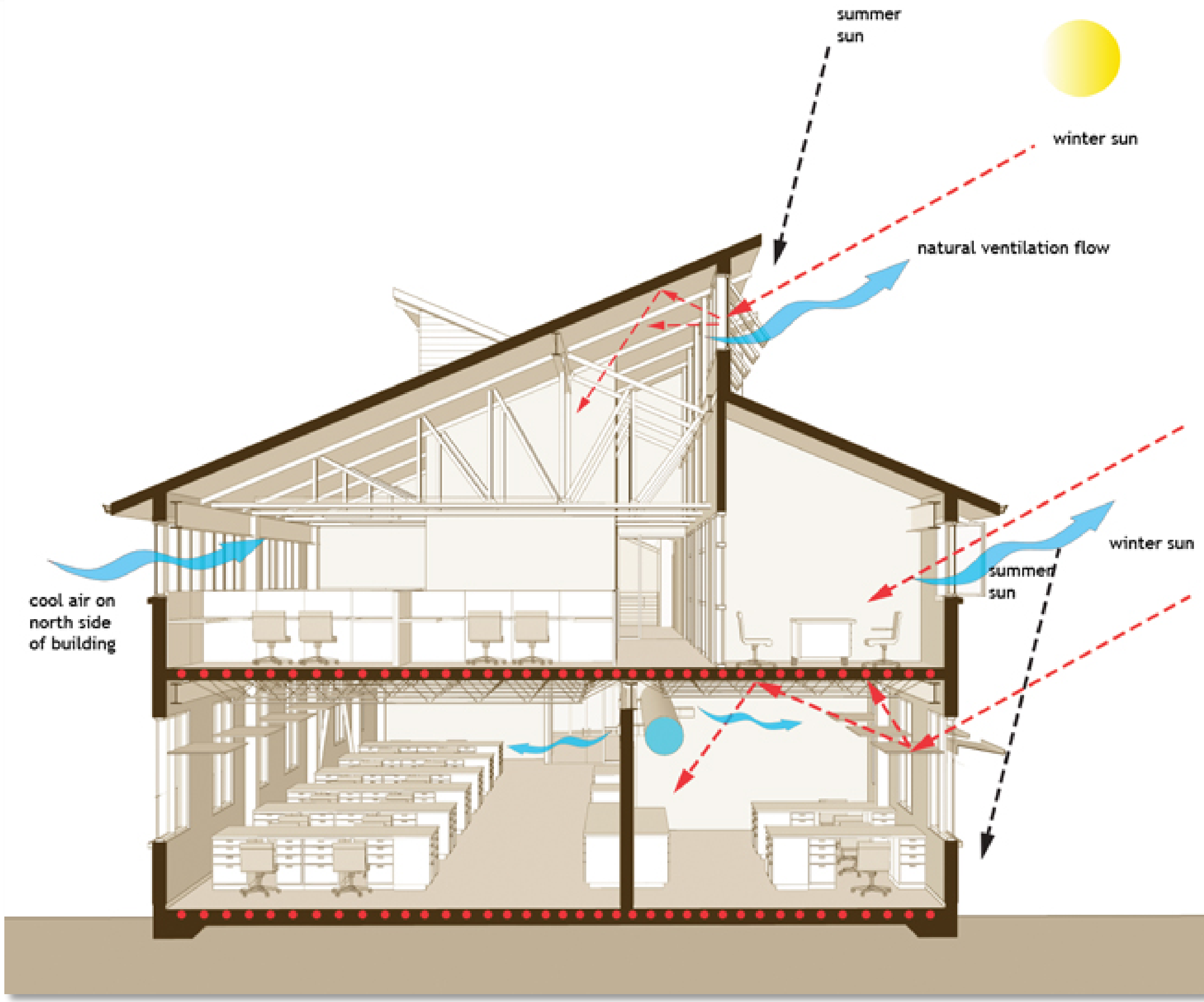
The elimination of A/C is one of the most effective ways to reduce operating energy.



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

Passive Cooling Strategies:
Ventilation

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



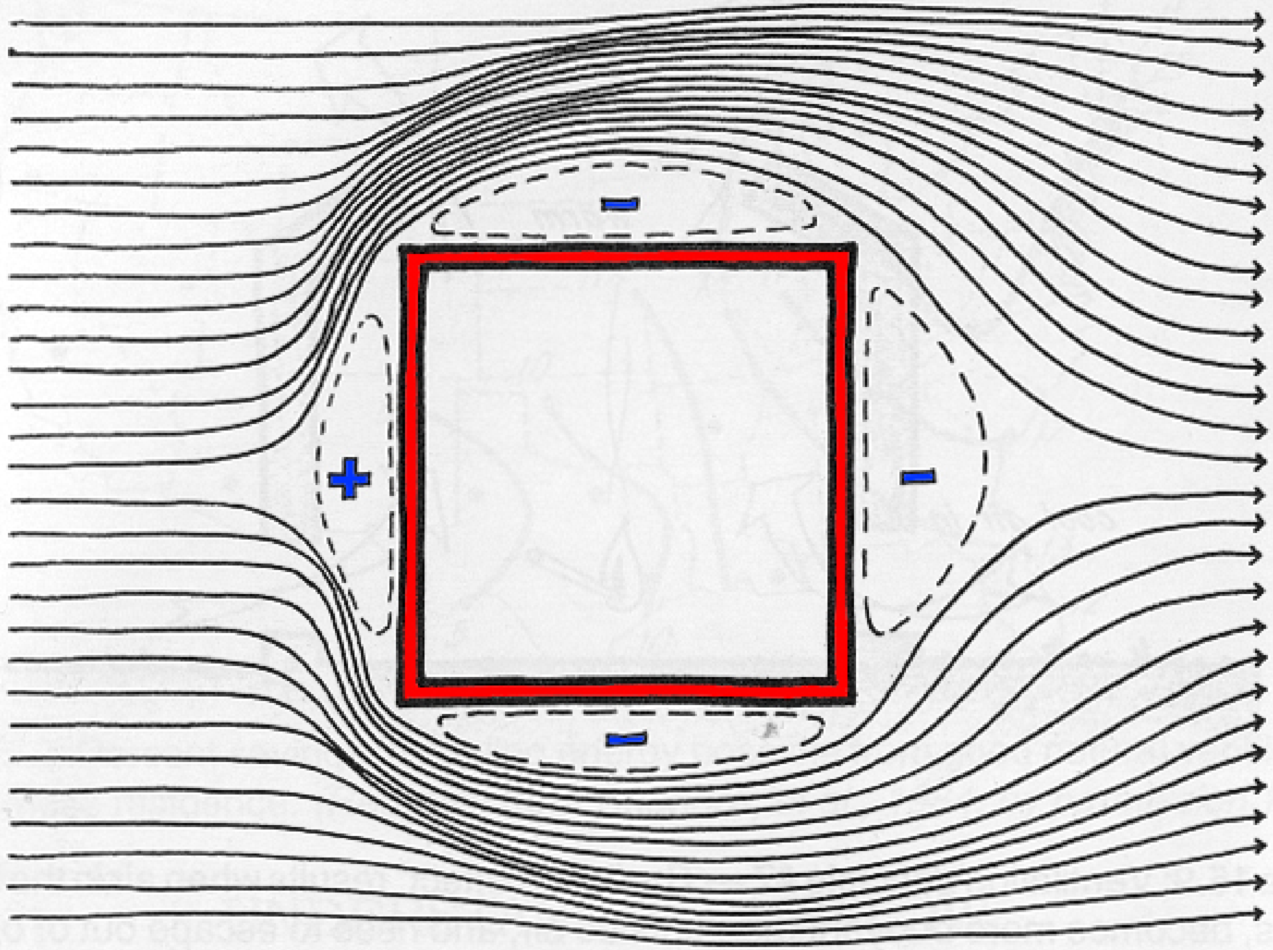


Figure 15.11: Low-pressure zones occur along the sides parallel to the wind and on the leeward side of the building. *(After Bowen, 1981.)*

HCL

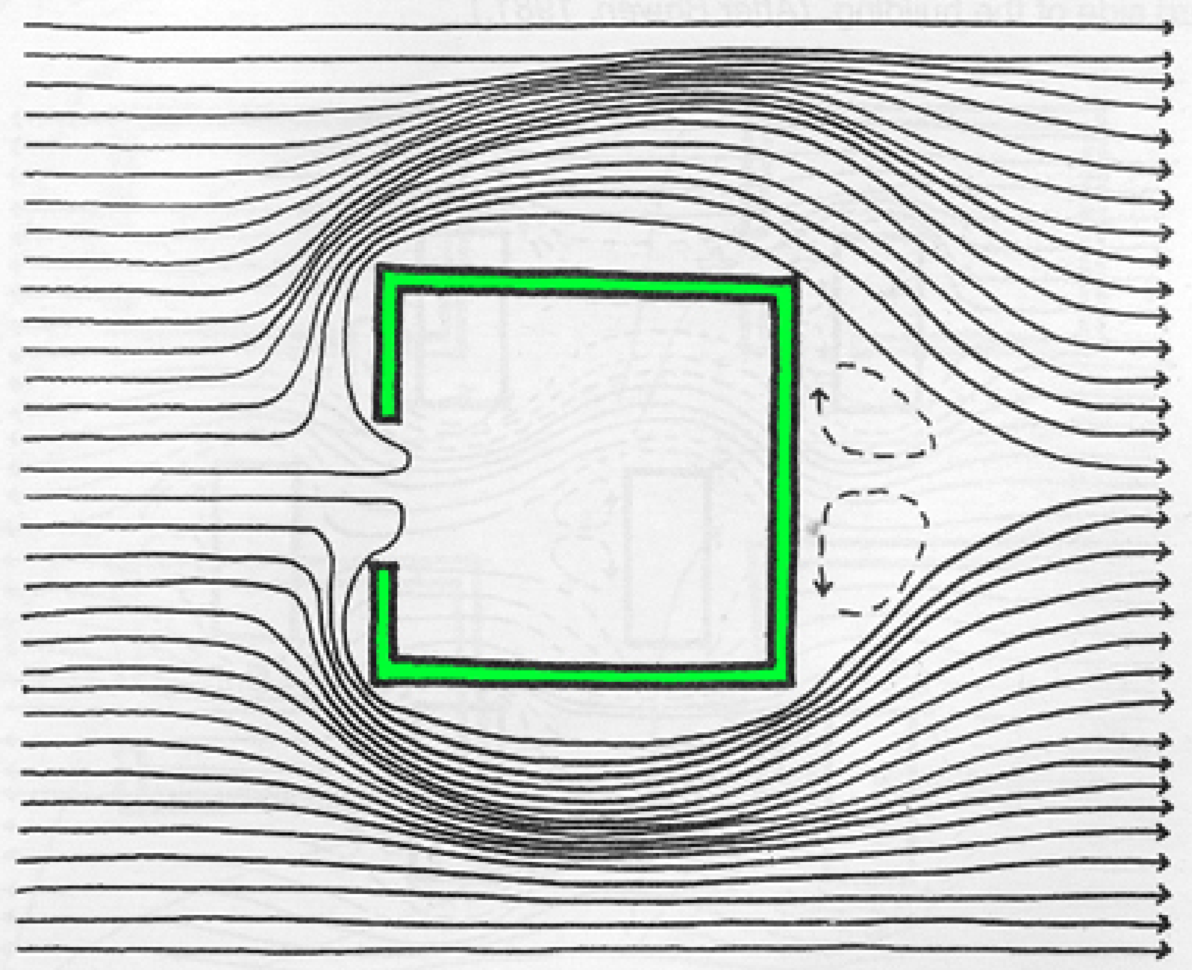


Figure 15.10: Ventilation principle #8 — Cross-ventilation requires an outlet as well as an inlet. (Analogy: water cannot be put into a bottle that is already full unless some old water is removed first — through a hole in the opposite end of the bottle, for example.)

HCL

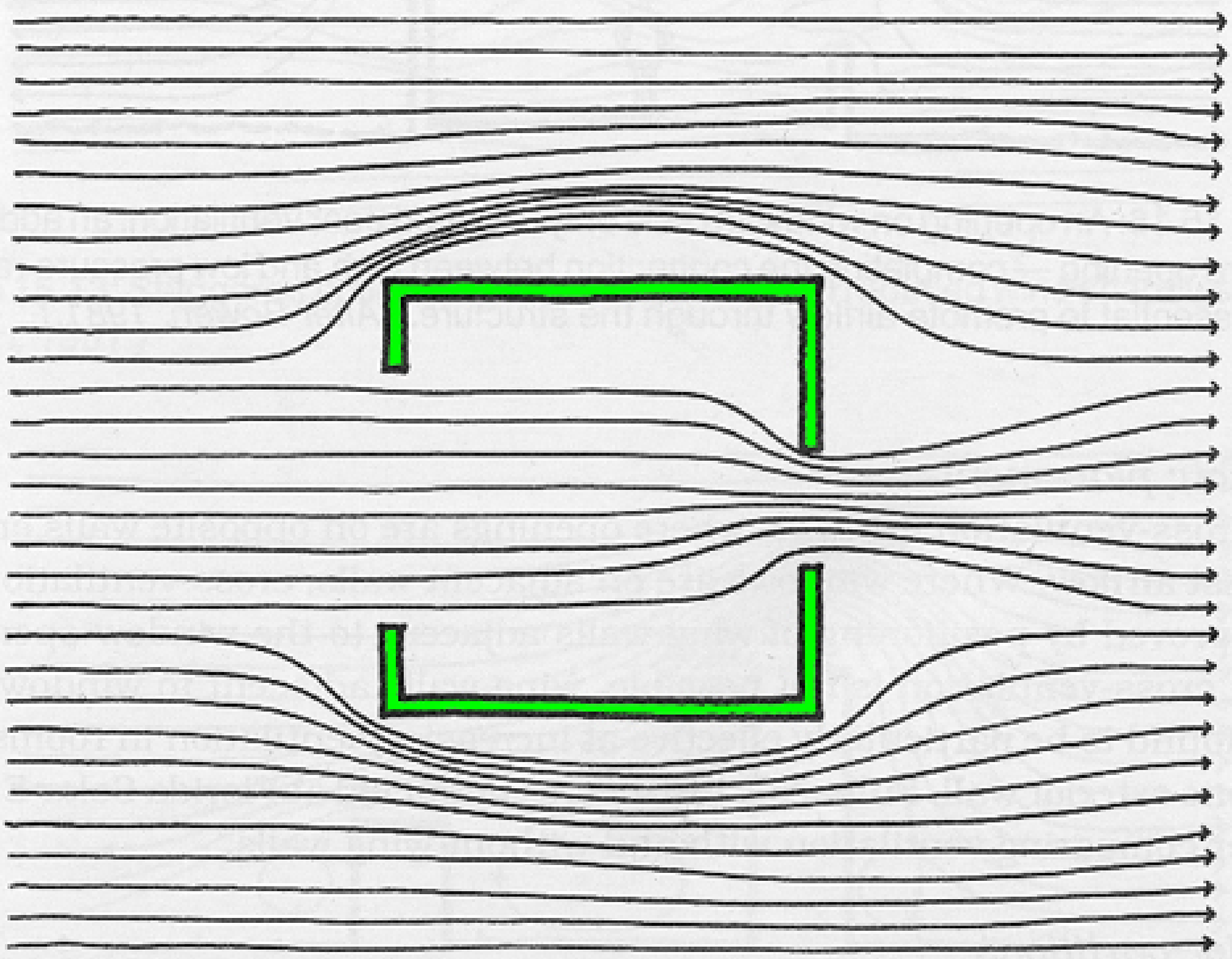


Figure 15.21: If the inlet is larger than the outlet, velocity in the room is reduced (although velocity outside just to leeward of the outlet is increased). This has potential for cooling a localized exterior area such as a patio. *(After Bowen, 1981.)*

HCL

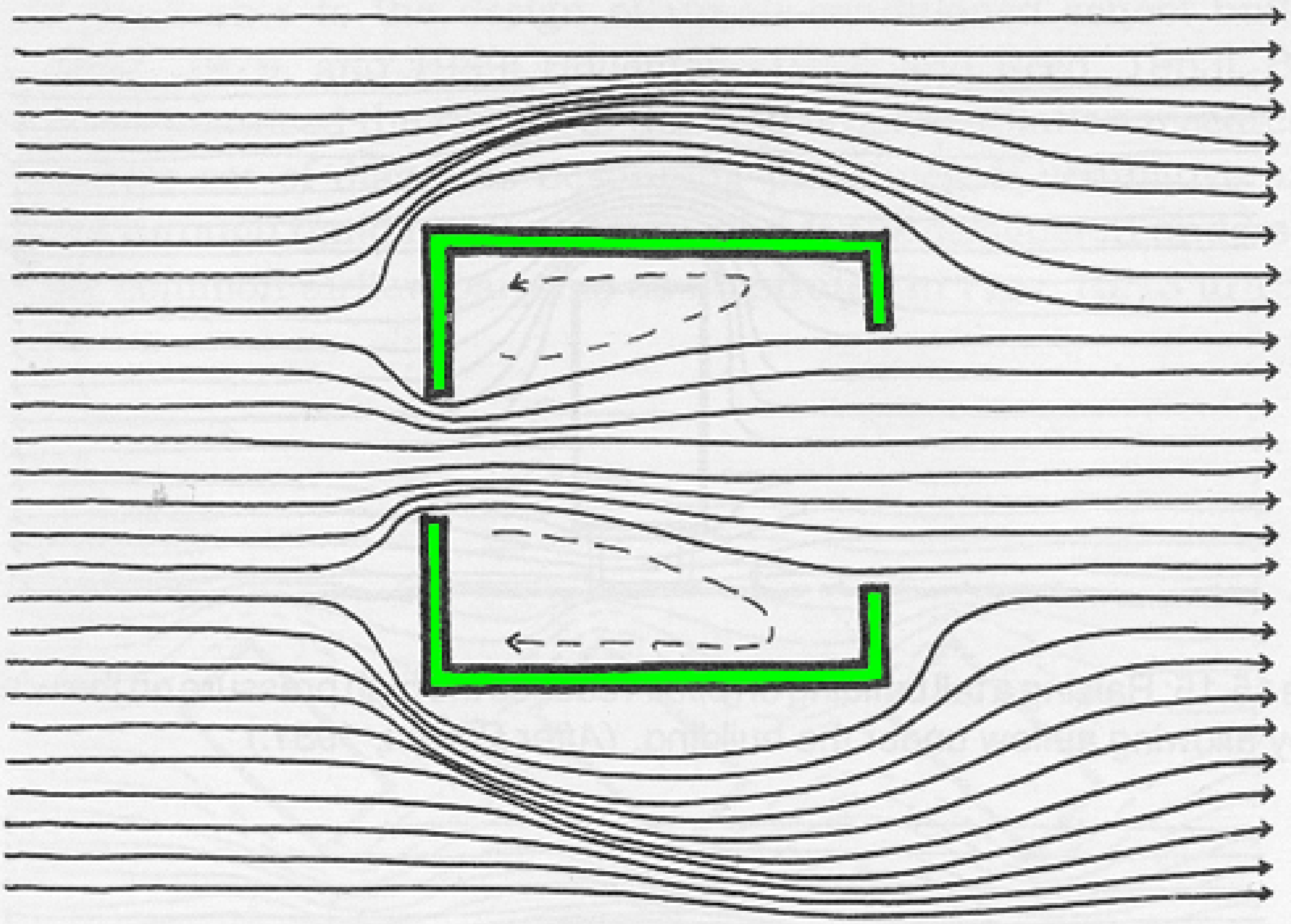


Figure 15.20: Maximum *interior airspeed* is created when the inlet is smaller than the outlet, making this the optimum configuration when *people* cooling is the goal. *(After Bowen, 1981.)*

HCL

IMPORTANT!

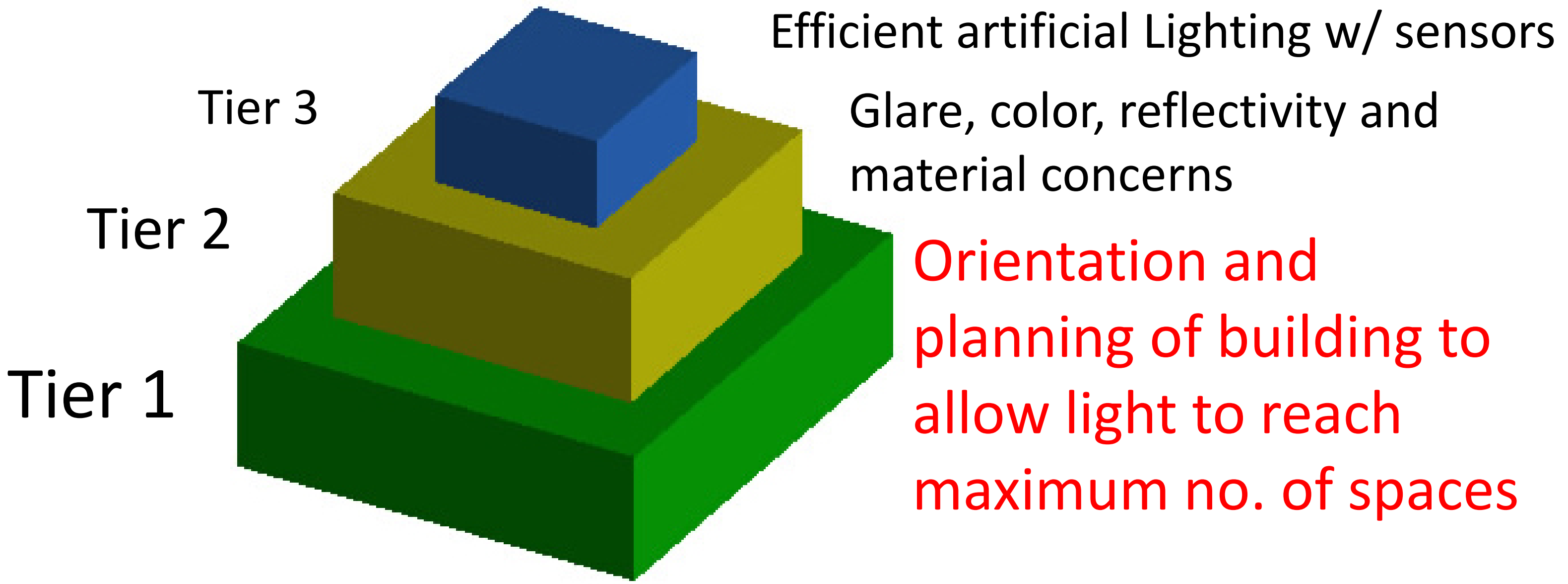
For natural ventilation to work you need:

OPERABLE WINDOWS – the more the better in our climate

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

Reduce loads: Daylighting

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



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.

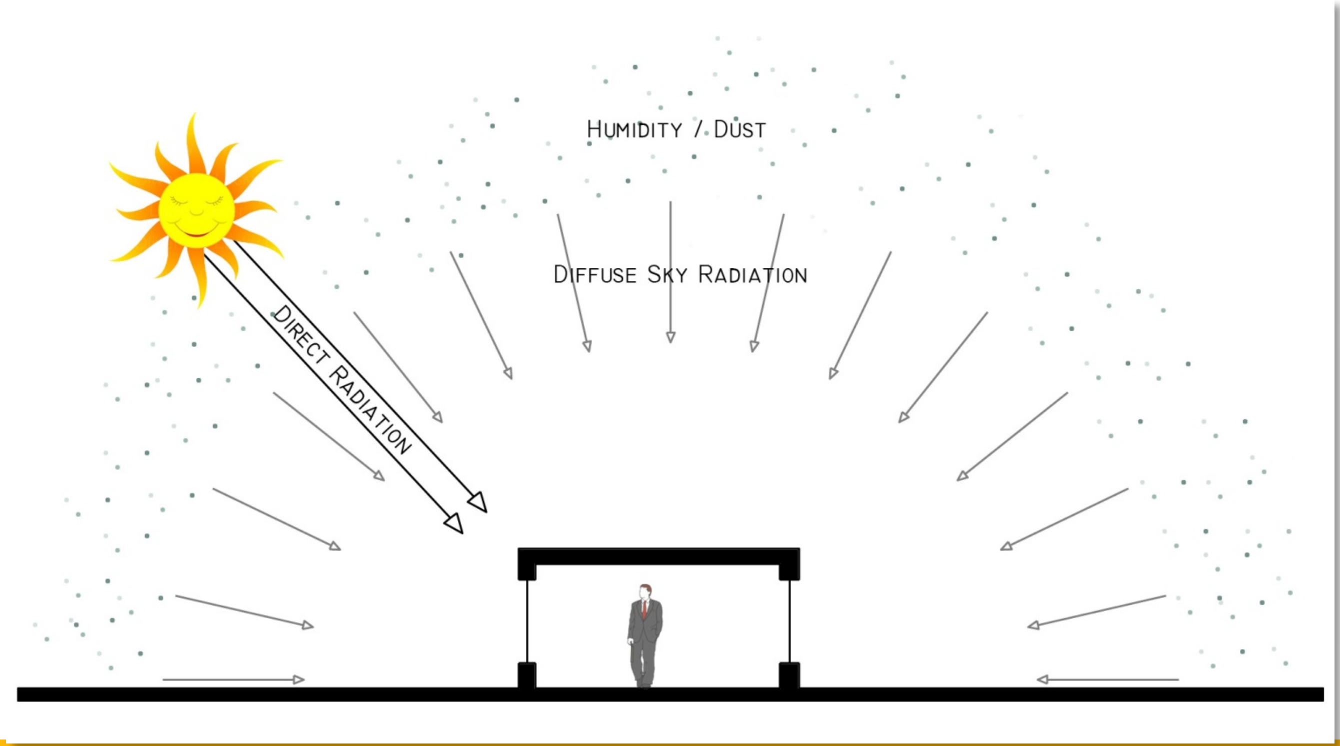
DIRECT SUNLIGHT is about **FREE HEAT.** 

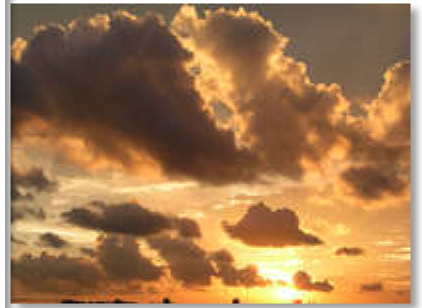
DAYLIGHT (diffuse light) is about **FREE LIGHT.** 

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 ***combined with light level sensors***
- aim to only have lights switch on only when daylight is insufficient
- provide electricity via renewable means: wind, PV, Combined Heat and Power plants

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

Environmental advantages of daylighting

Daylighting is **environmentally advantageous** because it:

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

TABLE 12.5 COMMONLY EXPERIENCED BRIGHTNESS LEVELS

	Brightness (cd/sq. ft.)*	
Sidewalk on a dark night	0.0003	
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

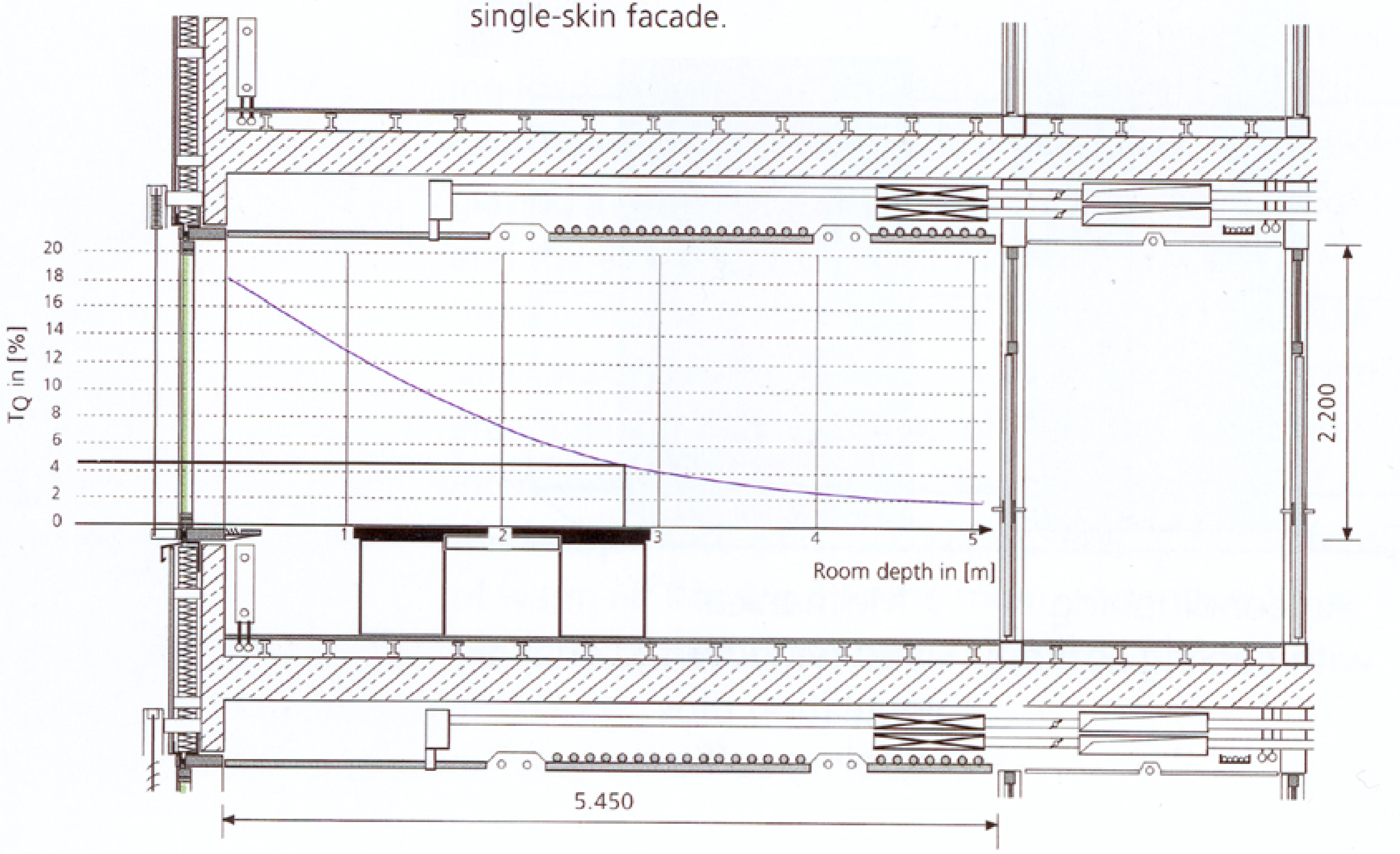
5% average daylight factor

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

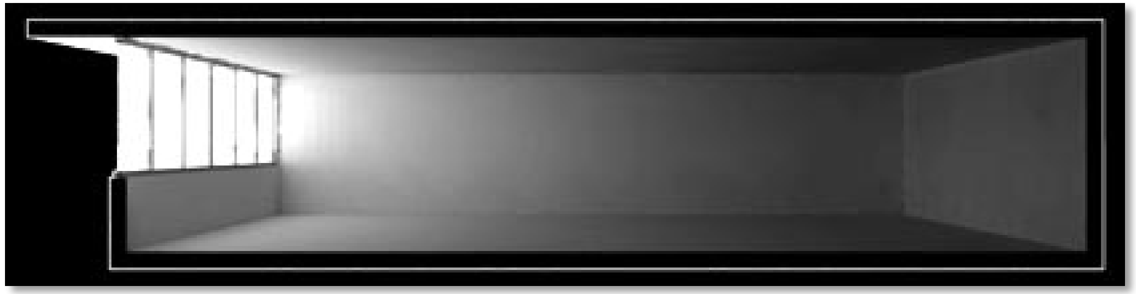
Solar Reflectance of Finishes

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

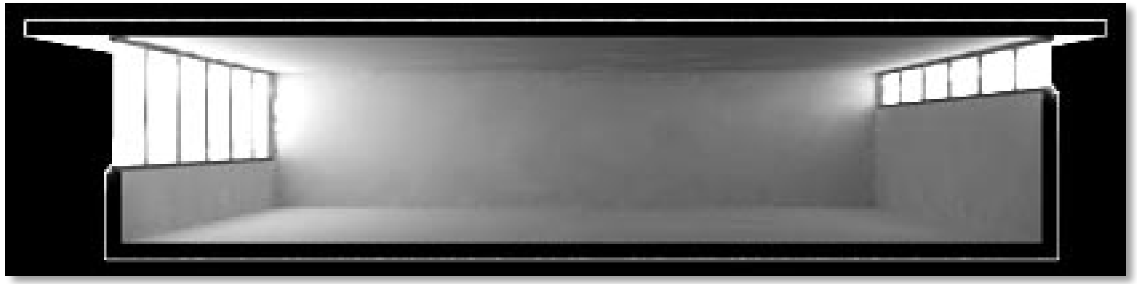
SWL

Window Types + Light Distribution

Window



Windows both sides



Lightshelf

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

Images from squ1.com

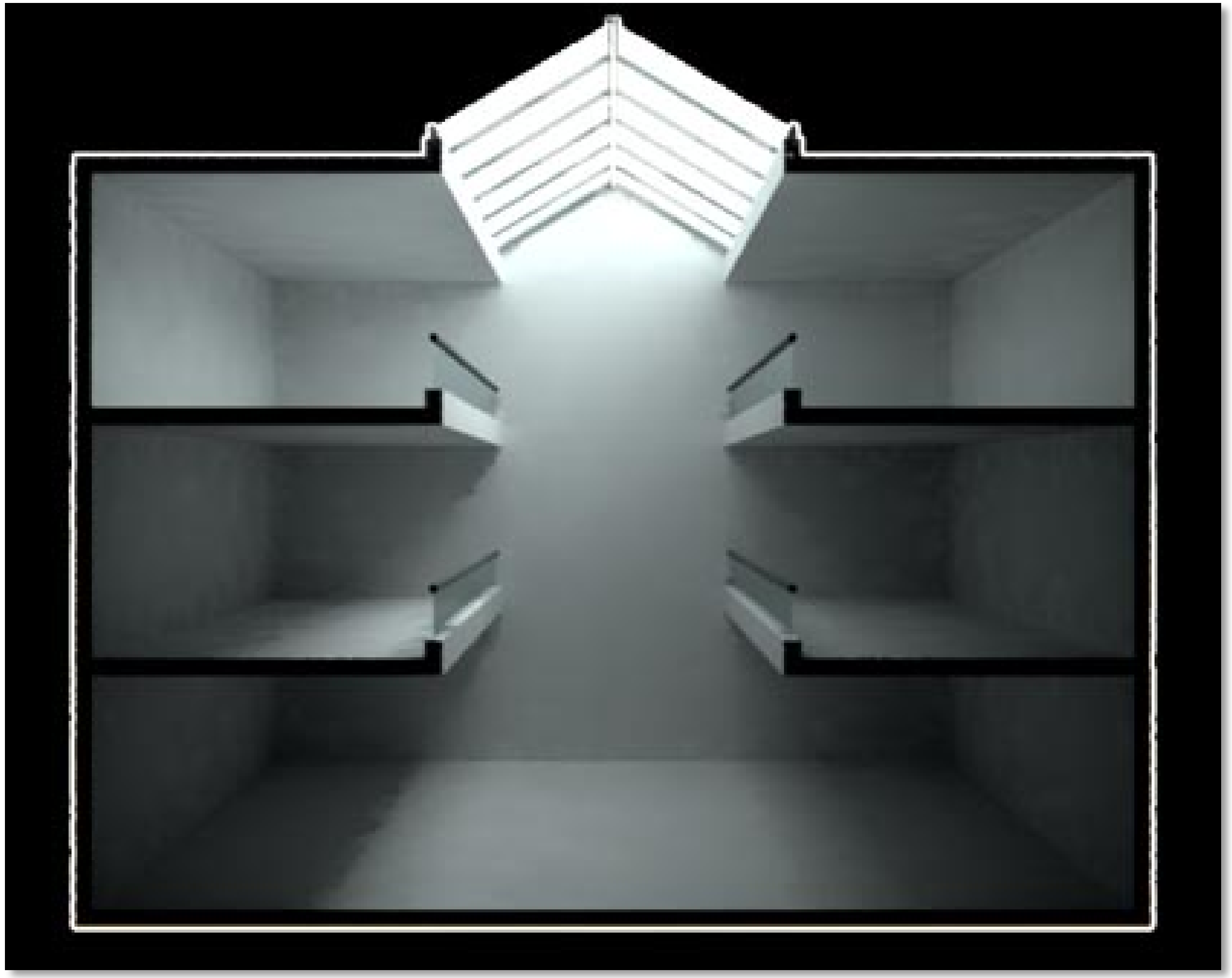
Skylight

Roof monitor

Sawtooth

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

Images from squ1.com



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

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

Images from squ1.com

Lightwell – provides more light directed to the lower floors

You might not remember August 14, 2003?

Radical Wake Up Call

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

Radical GREEN THINKING

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

You might remember December 21, 2013?

ICE STORM = NO POWER = NO HEAT

Radical PROBLEM!

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

SEALED BUILDINGS CANNOT BREATHE

ELEVATORS AND LIGHTS NEED POWER

Radical AWAKENING!

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

Radical THOUGHT!??

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

Start with a basic UNPLUGGED building

Radical Steps!

#1 - *start* by UNPLUGGING the building

Then…

#2 – heat only with the sun

#3 – cool only with the wind and shade

#4 – light only with daylight

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

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

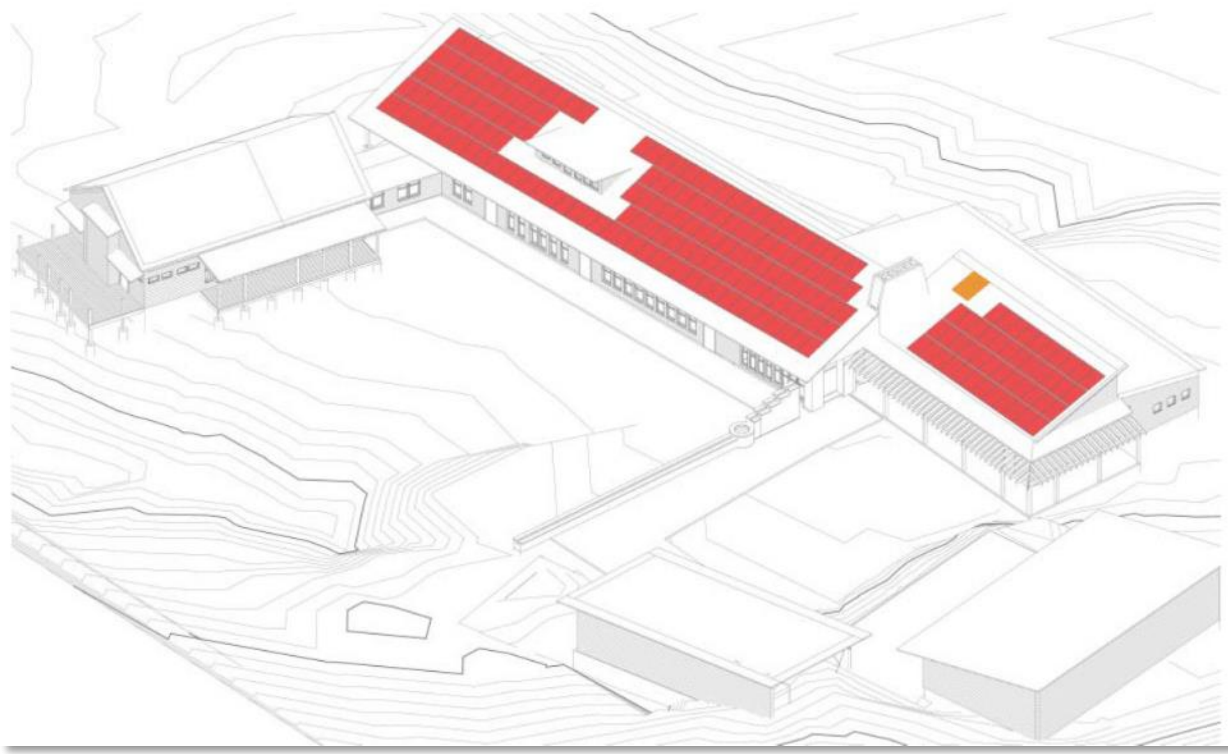
Radical IS Passive…

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

ARCHITECTURALLY

Aldo Leopold Legacy Center
Baraboo, Wisconsin

The Kubala Washatko Architects
LEED^{TM} Platinum 2007

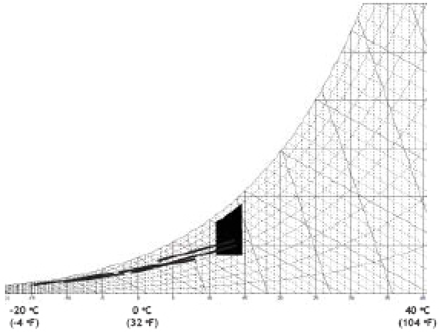


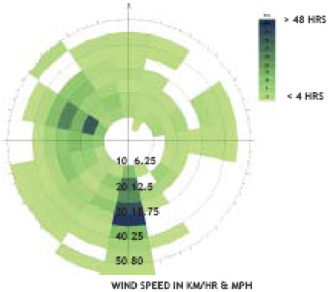
SOLAR PV DENSITY
(conditioned s.f.)
4.66 Watt / SF

SOLAR THERMAL DENSITY
(conditioned s.f.)
.012 SF / SF

- 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.





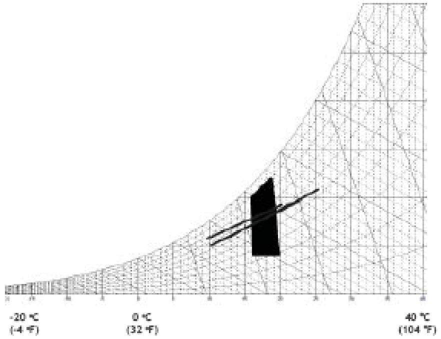
Climate Narrative

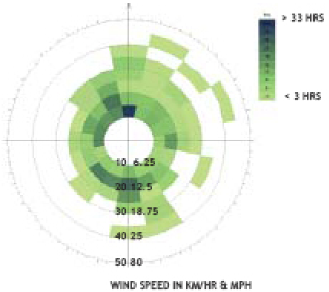
Source: NOAA Weather Data Files

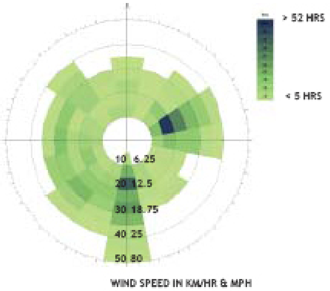
The climate is typical of the continental interior of North America with a large annual temperature range and with frequent short period temperature changes. The range of extreme temperatures is from about 43 to -40 degrees Celsius (110 to -40 degrees Fahrenheit). Winter temperatures (December-February) average near -7 °C (20 °F) and the summer average (June-August) is around 20 °C (in the upper 60s °F). Daily temperatures average below 0 °C (32 °F) about 120 days and above 4 °C (40 °F) for about 210 days of the year.

HEATING SEASON: OCT. - APR.

HEATING SEASON MONTH: JANUARY



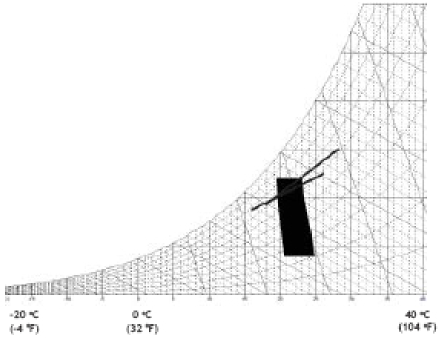


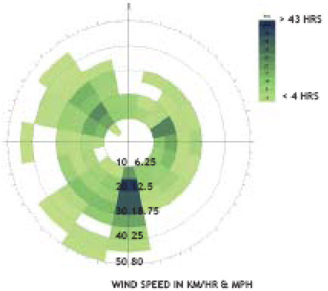


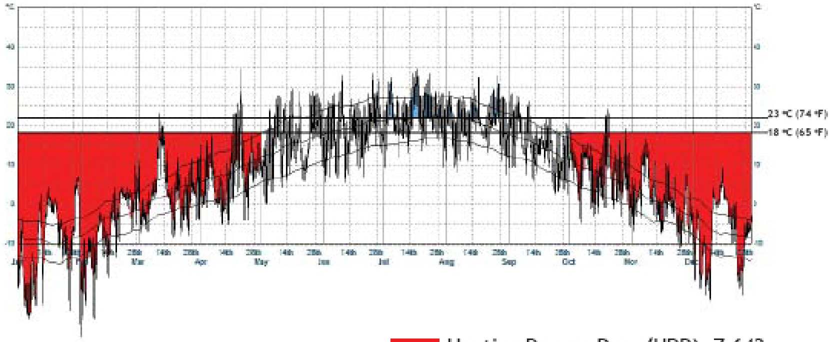
SWING SEASONS: MAY - JUN., SEP.

SWING MONTH: SEPTEMBER

SWING MONTH: MAY







Heating Degree Days (HDD): 7,643

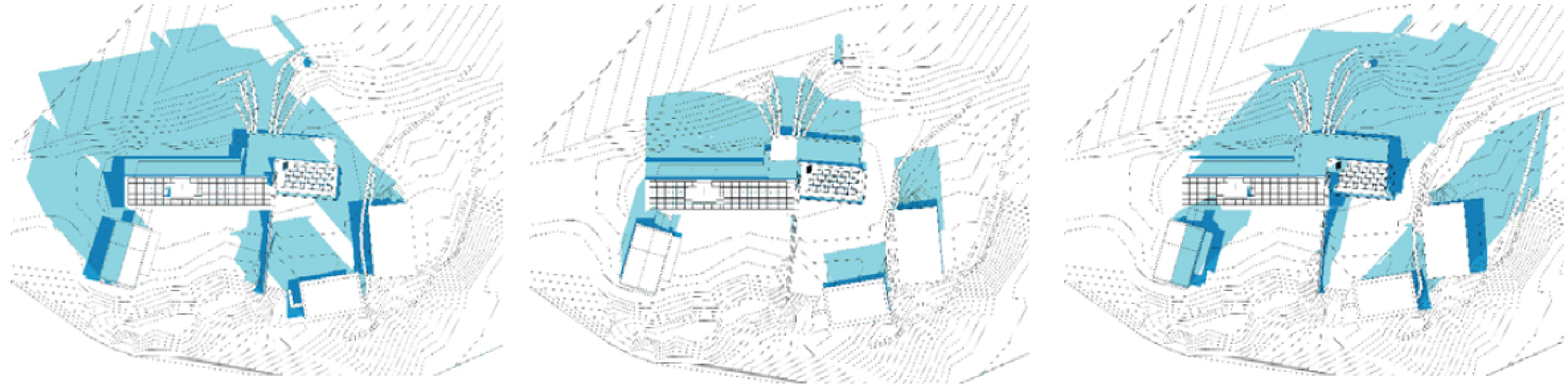
Cooling Degree Days (CDD): 139

COOLING SEASON: JUL. - AUG.

COOLING SEASON MONTH: JULY

DAILY TEMPERATURE

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



9:00 am

Noon

3:00 pm

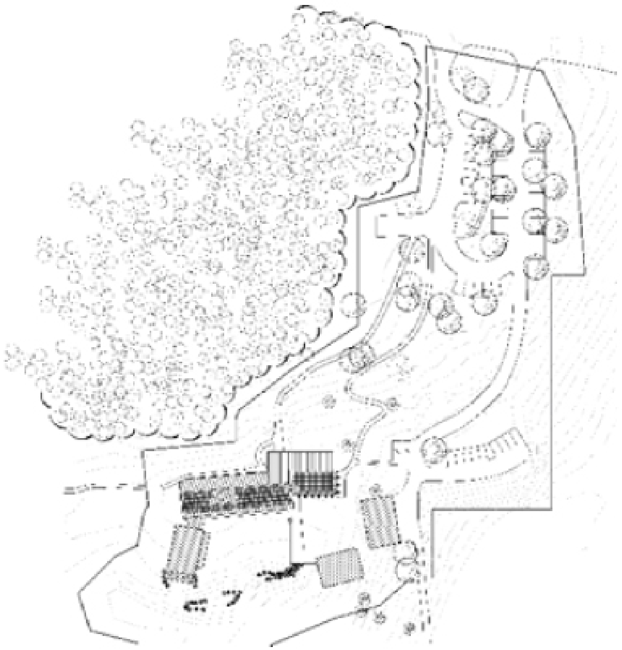
Site Shading Study

June 21

December 21

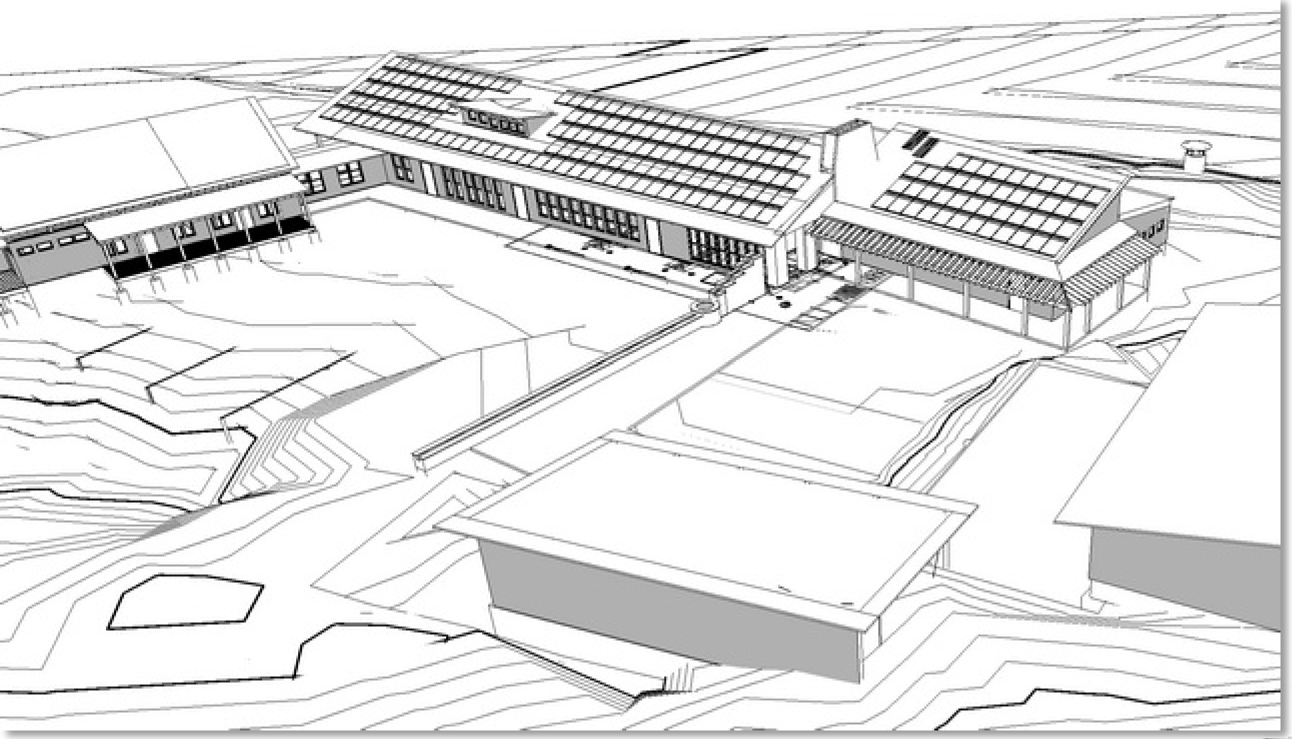
Ariel Image from South

Source: ____________



N

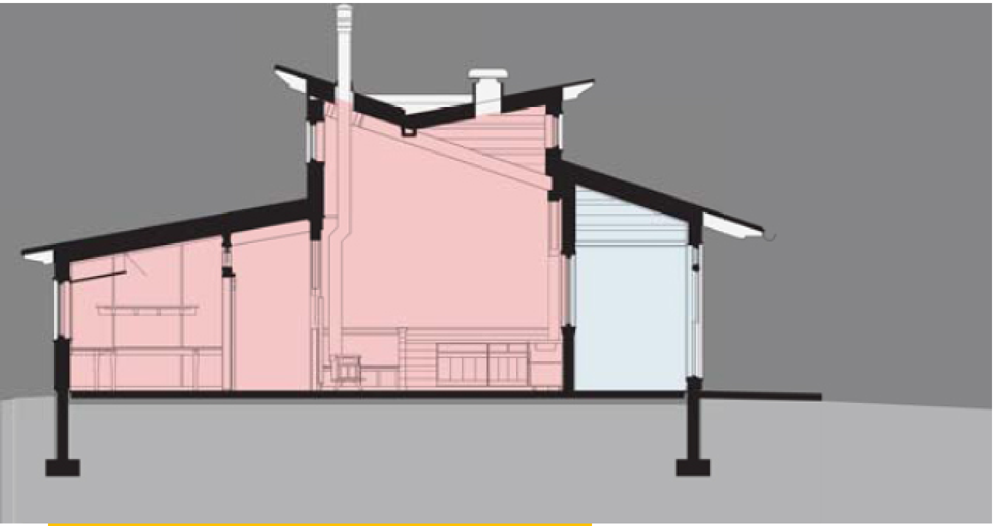
A solar analysis and ongoing solar analyses were conducted to ensure that the sun use for heating and solar avoidance were being maximized.



The South elevation is designed to capture energy.

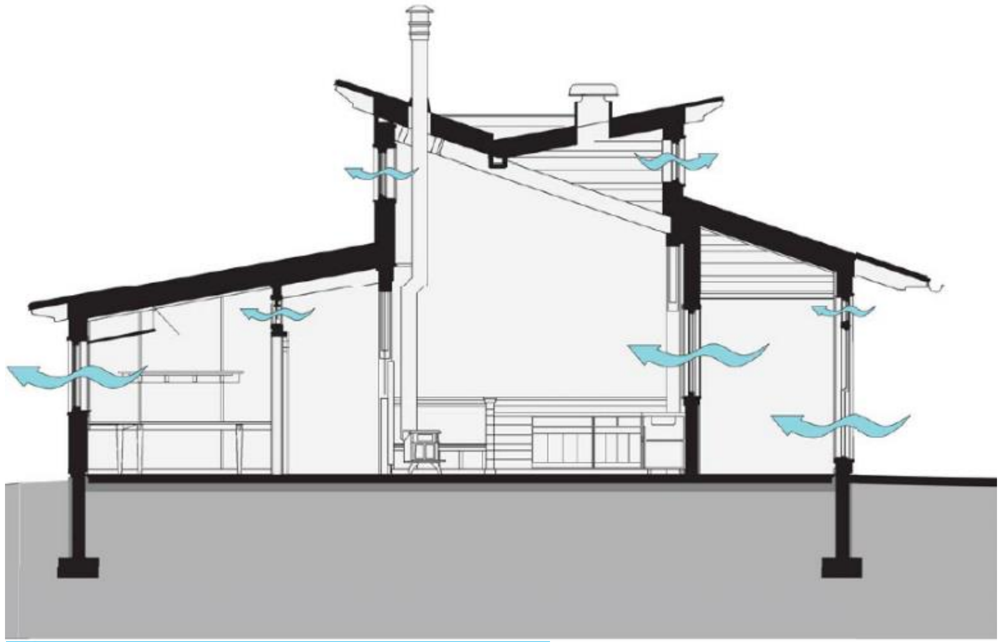
The North elevation is designed for thermal resistance, daylighting and ventilation.

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

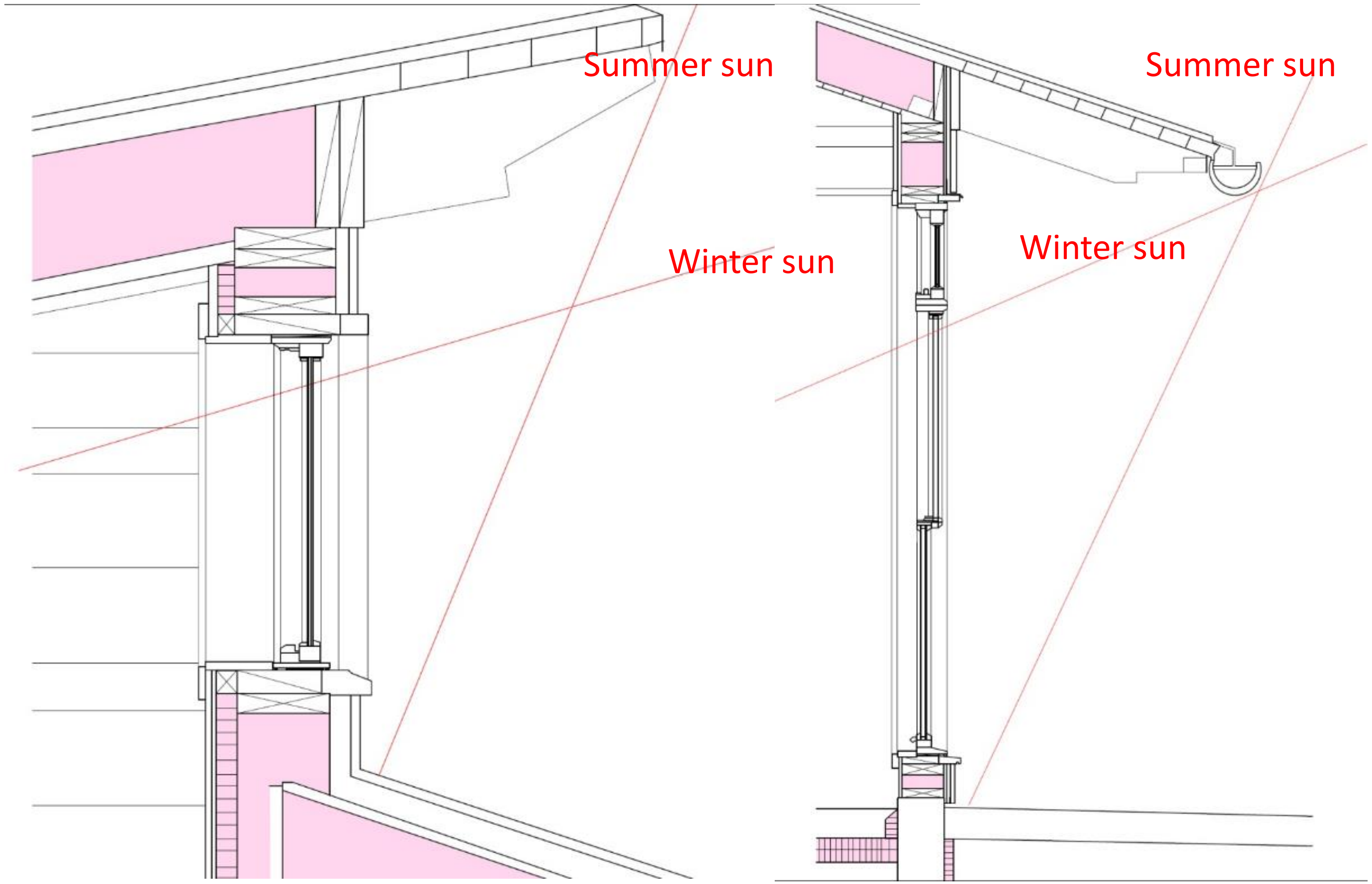


Passive Heating

- 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

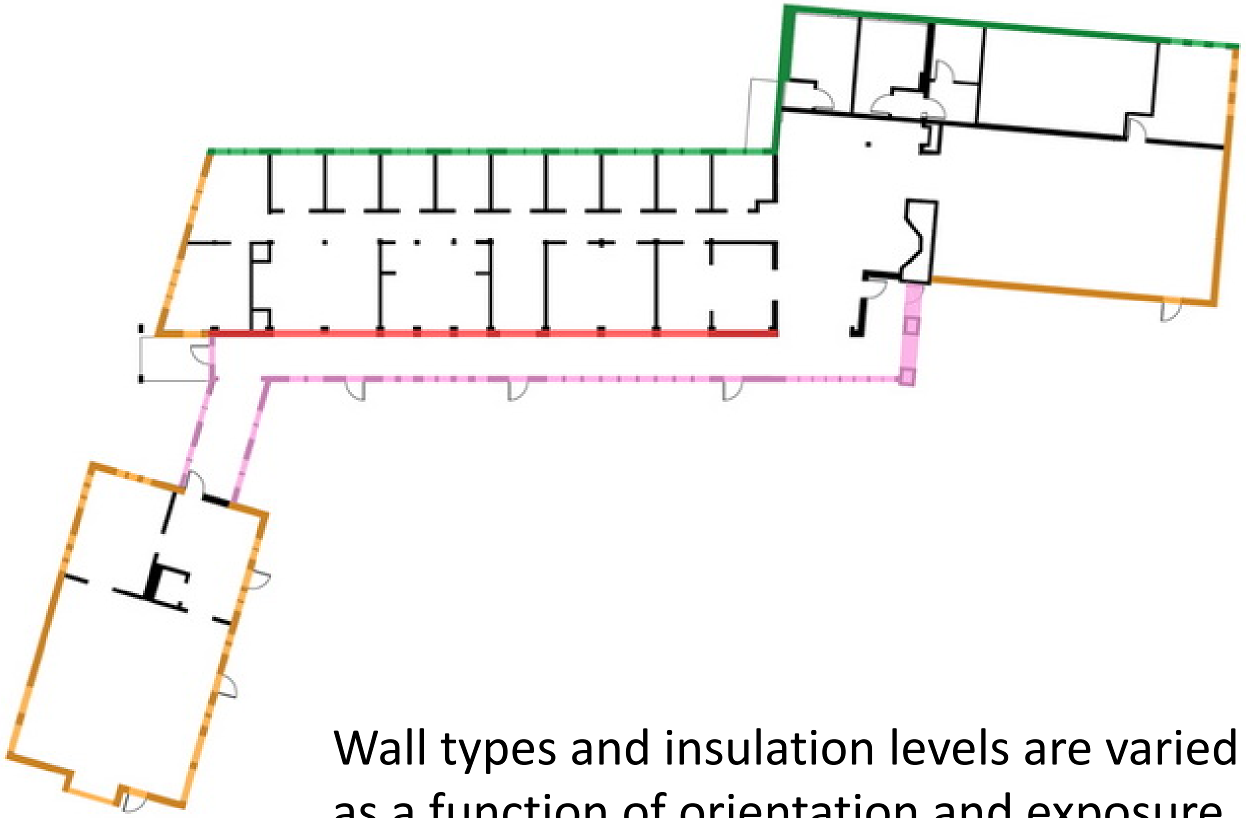


Passive Cooling



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.

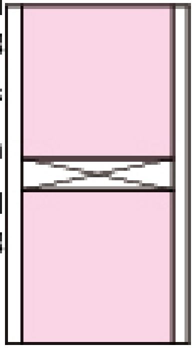


Wall types and insulation levels are varied as a function of orientation and exposure

Wall Type A

Interior to Exterior

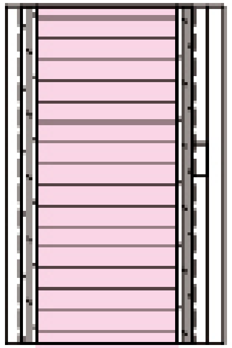
- -1x Interior Wood Siding
- -2x8 Wood Studs
- -Sprayed Insulation
- -1x Interior Wood Siding



Wall Type B

Interior to Exterior

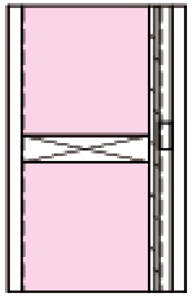
- -1x Interior Wood Siding
- -Vapor Barrier
- -8 1/4" Structural Insulated Panel
- - Air Barrier
- -Air Space w/ Vertical Furring Strip
- -1x Flatboard Exterior Wood Siding



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