Ch.3 Sites and Resources

3.1. Climates
3.2 Climates in climates
3.3. Buildings and sites
3.4 Analyzing the site
3.5 Site design strategies
3.6 Direct sun and daylight
3.7 Sound and airflow
3.8 Rain and groundwater
3.9 Plants
3.10 Case study – site and resource design

Why site analysis?

- To understand the character of a given site
- Includes utility availability, noise sources, zoning, views, solar access, traffic, pedestrian patterns, climate, and the like
- Questions
  - What resources are available for a design solution and vice versa (what resources can be potential problems)?: ex. solar radiation, wind, etc.

Climates

- Fig. 3.1 is a convenient means, but it can be misleading for designers.
  - Cold climates can have very hot, humid summer days.
  - Hot-arid climates have bitterly cold winter conditions.

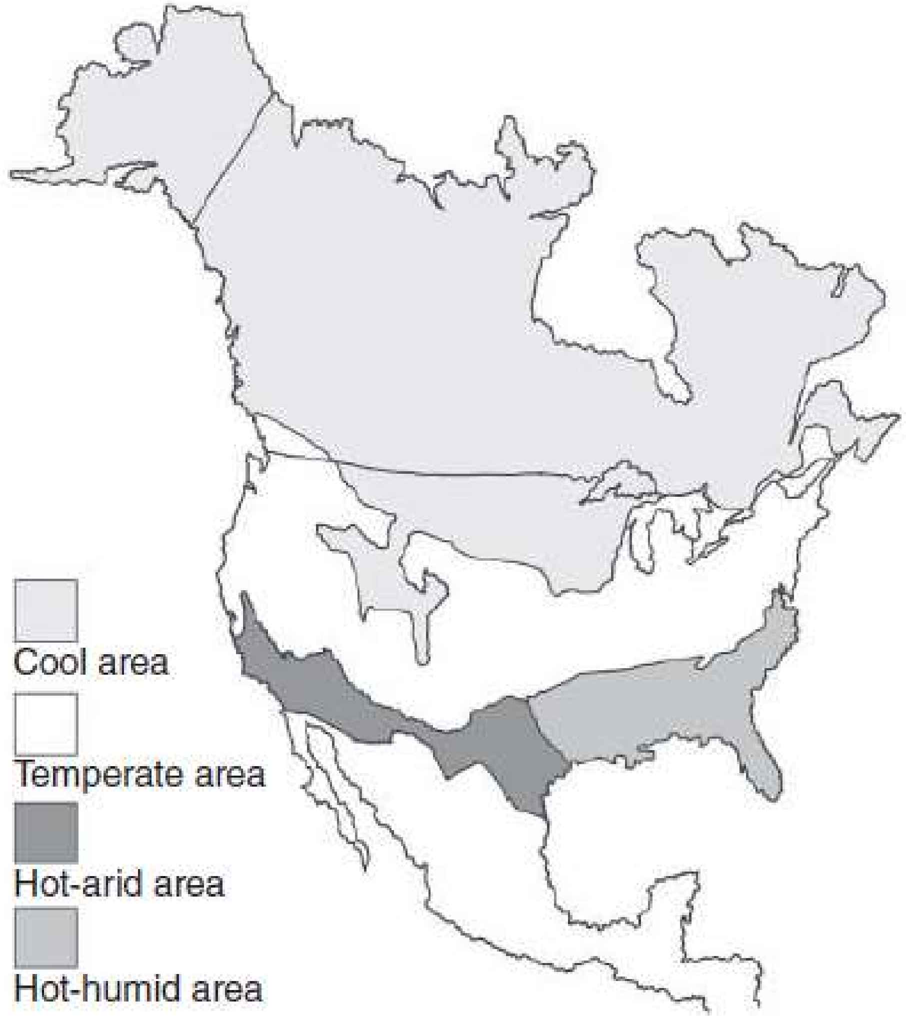
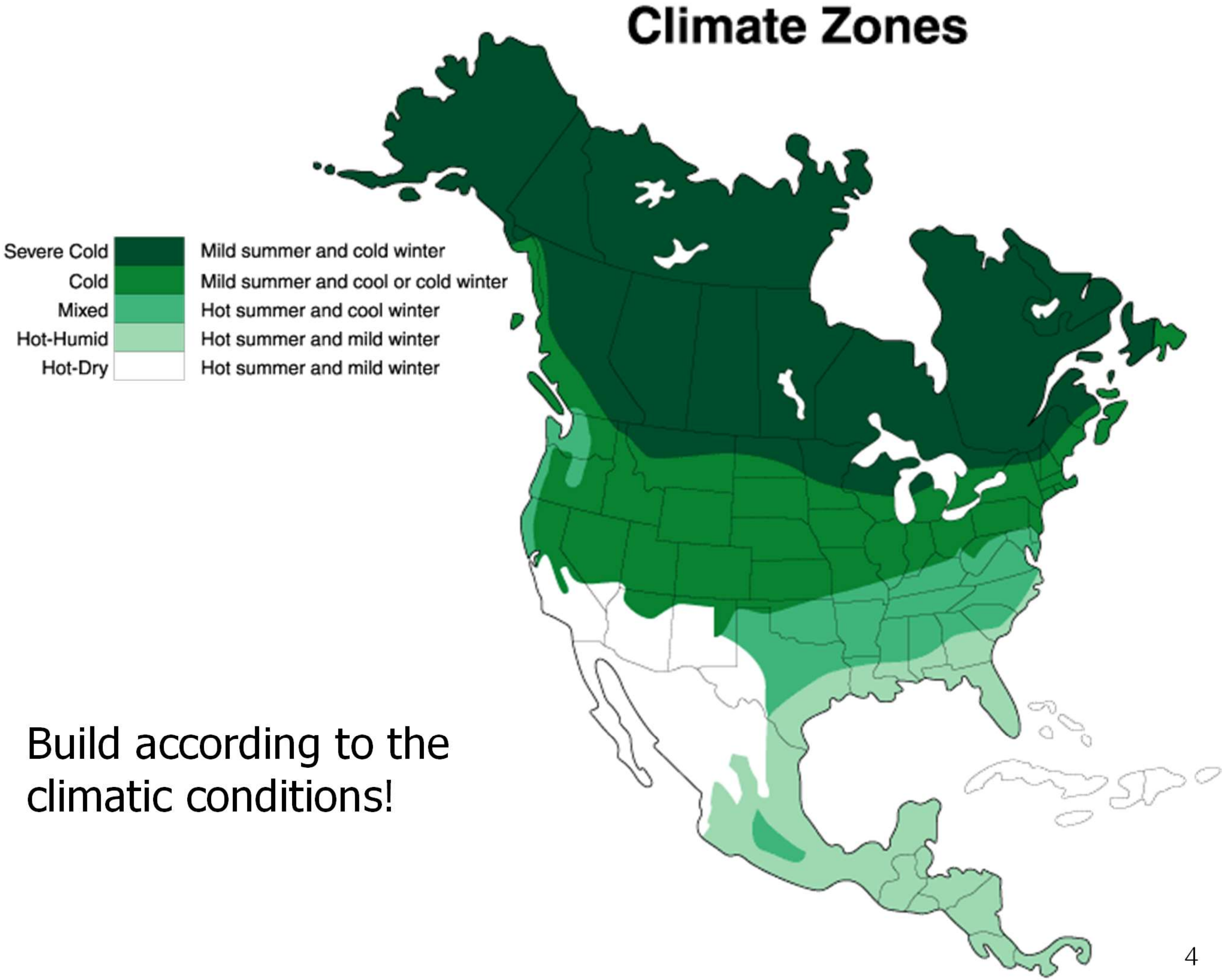


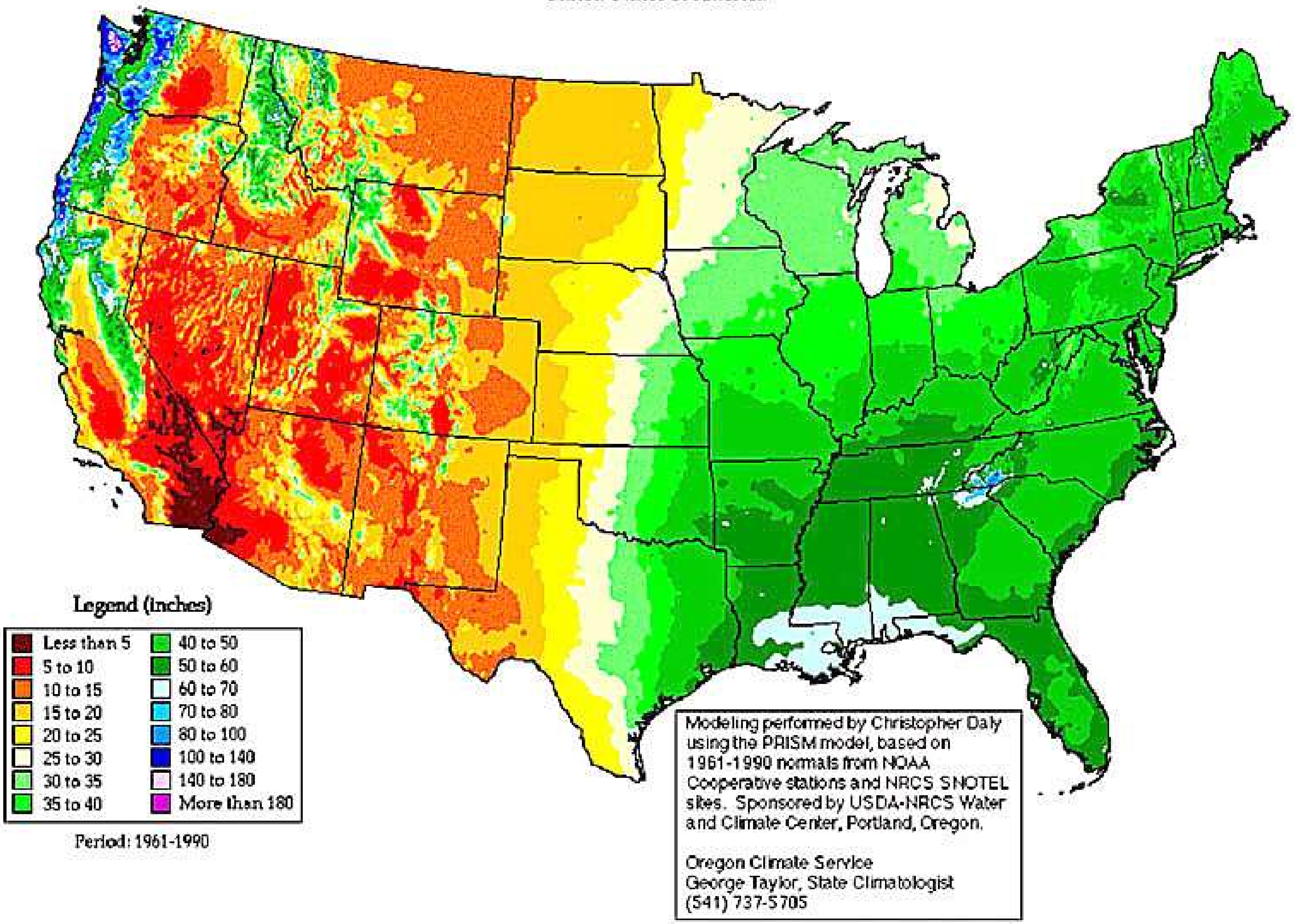
Fig. 3.1 *Regional climate zones of the North American continent. (Redrawn by Tyler Mavichien from Victor Olgyay,* Design with Climate: Bioclimatic Approach to Architectural Regionalism; *© 1963 by Princeton University Press. Reprinted by permission.)*



Build according to the climatic conditions!

Annual Average Precipitation

United States of America

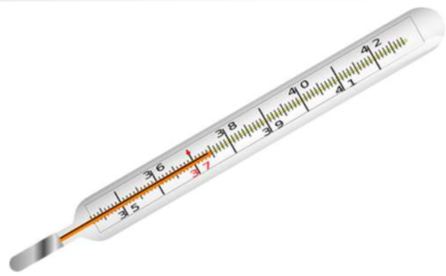


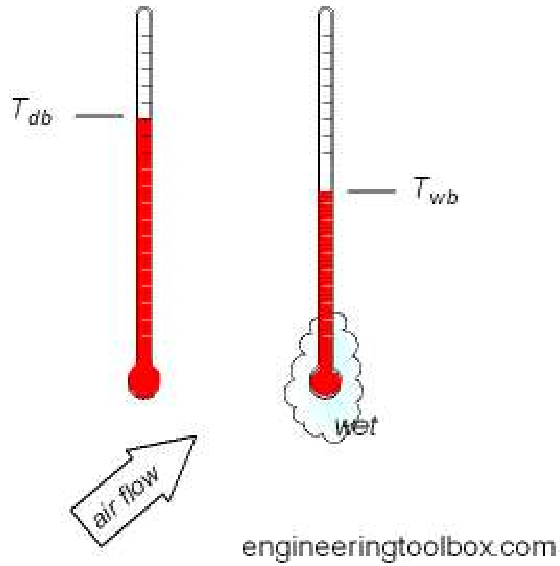
Dry air and moist air

- Dry air is a theoretical sample of air that has no water vapor.
- Moist air is a mixture of dry air and water vapor.

DB and WB temperatures

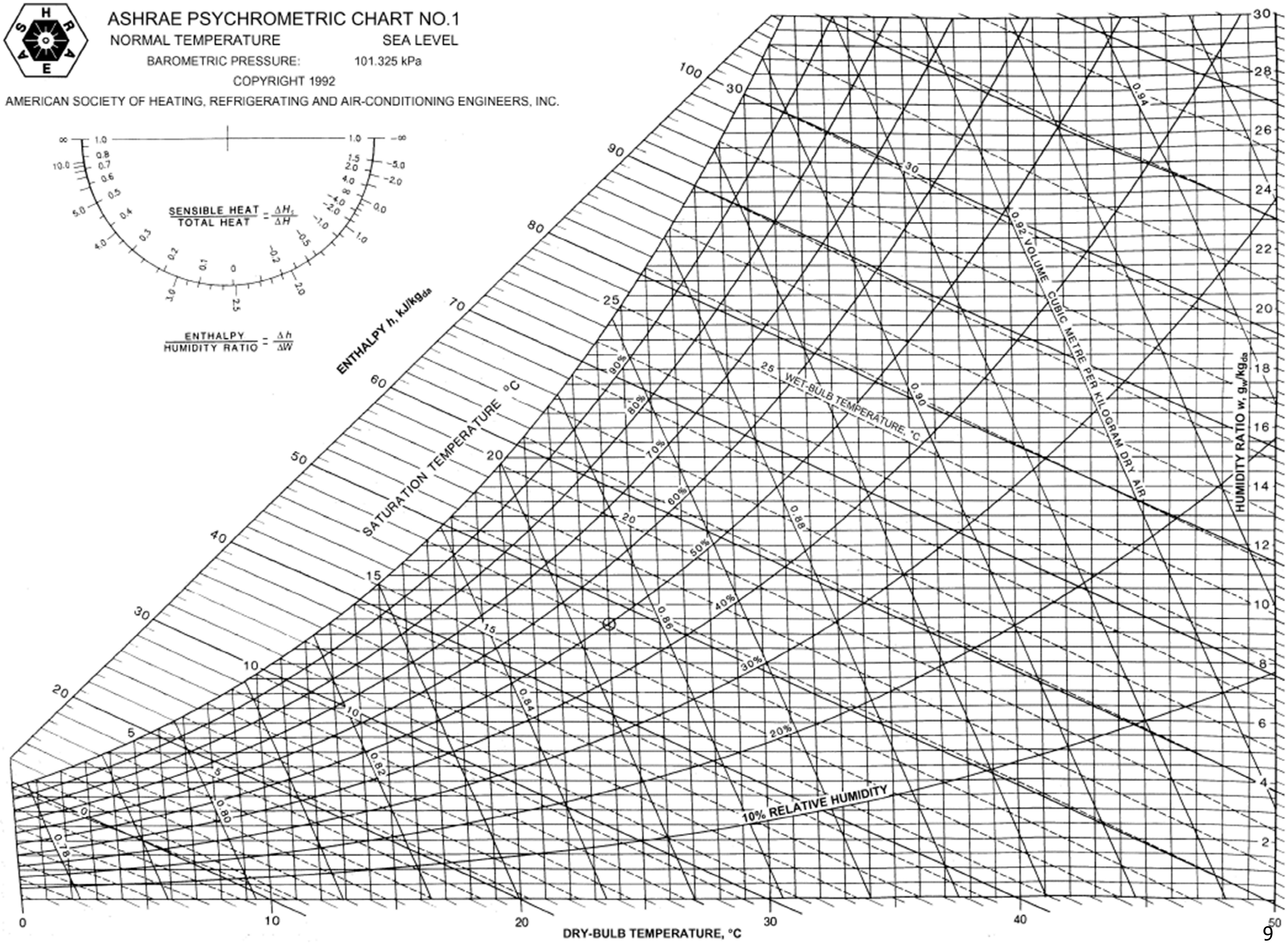
- Dry-Bulb temperature (DB)
- Wet-Bulb temperature (WB)





humidity ratio, relative humidity and enthalpy

- humidity ratio:
  - the moisture content of a given moist air sample. It is defined as the ratio of the mass of water vapor to the mass of dry air (kg/kg[DA])
- relative humidity:
  - the amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the same temperature (%)
- Enthalpy of moist air: kJ/kg, kcal/kg


ASHRAE PSYCHROMETRIC CHART NO.1
NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
COPYRIGHT 1992
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SENSIBLE HEAT / TOTAL HEAT = ΔHs / ΔH
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY h, kJ/kgda
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
10% RELATIVE HUMIDITY
HUMIDITY RATIO w, gw/kgda
DRY-BULB TEMPERATURE, °C

Psychrometry

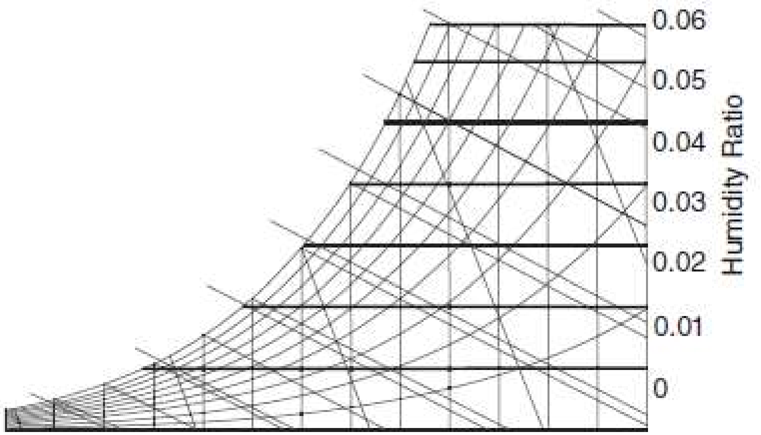


Fig. 4.6 Humidity ratio on the psychrometric chart: I-P units are lb moisture/lb of dry air; SI units are kg moisture/kg dry air. (Drawn by Sharon Alitema.)

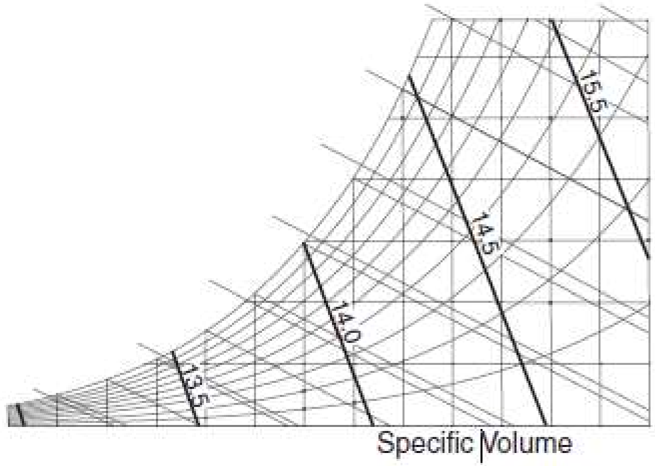


Fig. 4.7 Specific volume on the psychrometric chart: I-P units are ft^3/lb dry air; SI units are m^3/kg dry air. (Drawn by Sharon Alitema.)

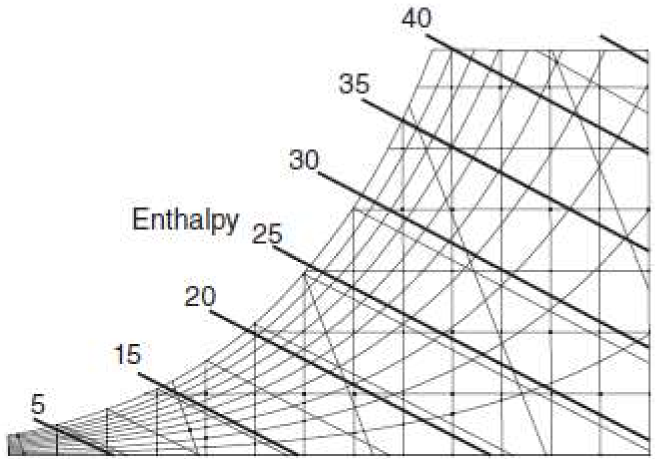


Fig. 4.8 Enthalpy on the psychrometric chart: I-P units are Btu/lb; SI units are kJ/kg. (Drawn by Sharon Alitema.)

Psychrometry

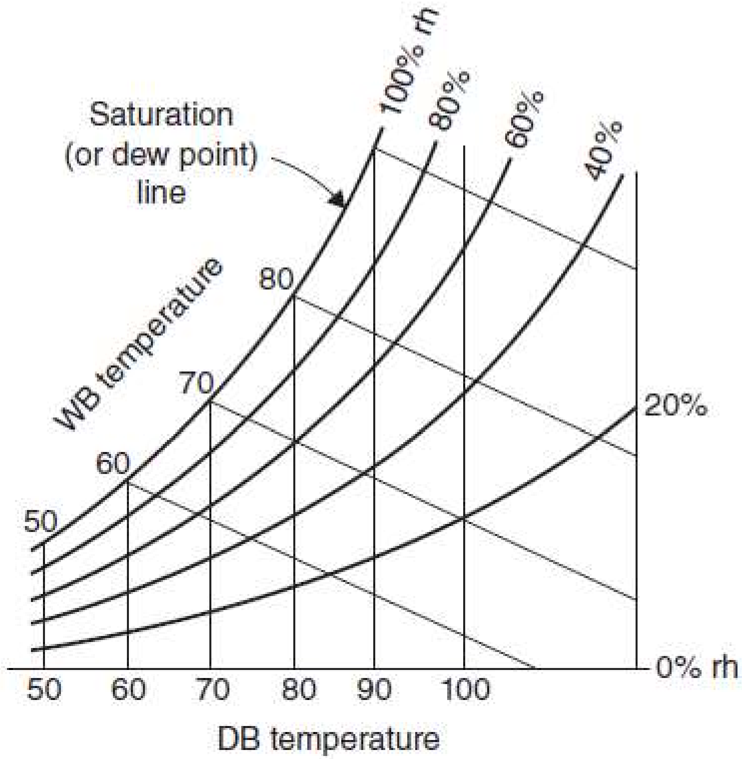


Fig. 4.4 Some basic components of the psychrometric chart: DB and WB temperatures and RH.

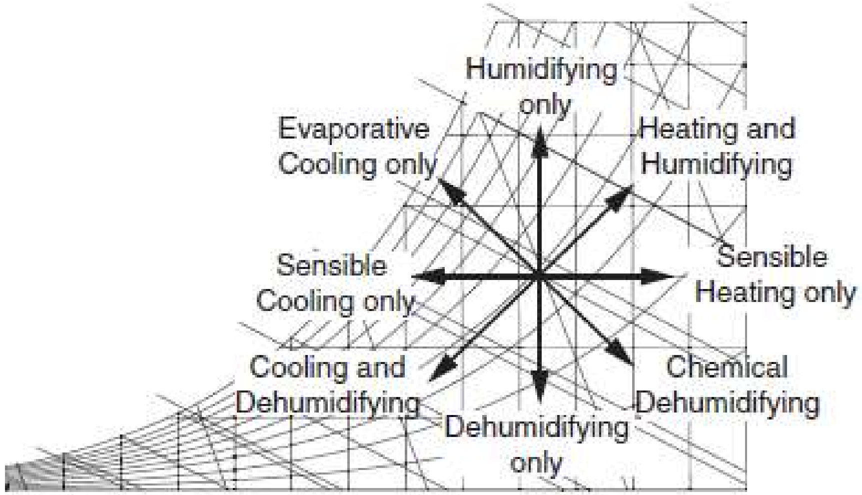


Fig. 4.5 Climatic-conditioning processes expressed on the psychrometric chart. (Adapted from "Architectural Design Based on Climate," by M. Milne and B. Givoni, in Watson (ed.), in Energy Conservation in Building Design. *Redrawn by Sharon Alitema.)*

Psychrometric chart

700 fpm = 3.5m/s
300 fpm = 1.5m/s
(fpm = foot per minute)

Solar radiation intensity

100 Btu/h.ft^2 = 315 W/m^2
200 Btu/h.ft^2 = 630 W/m^2

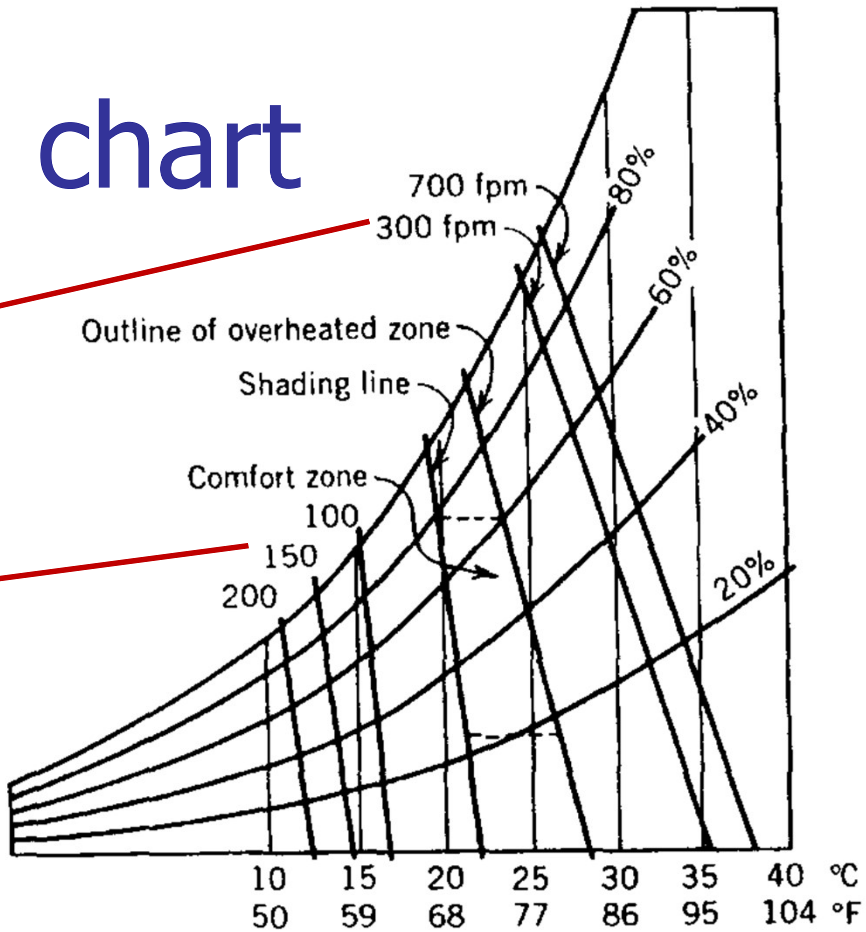
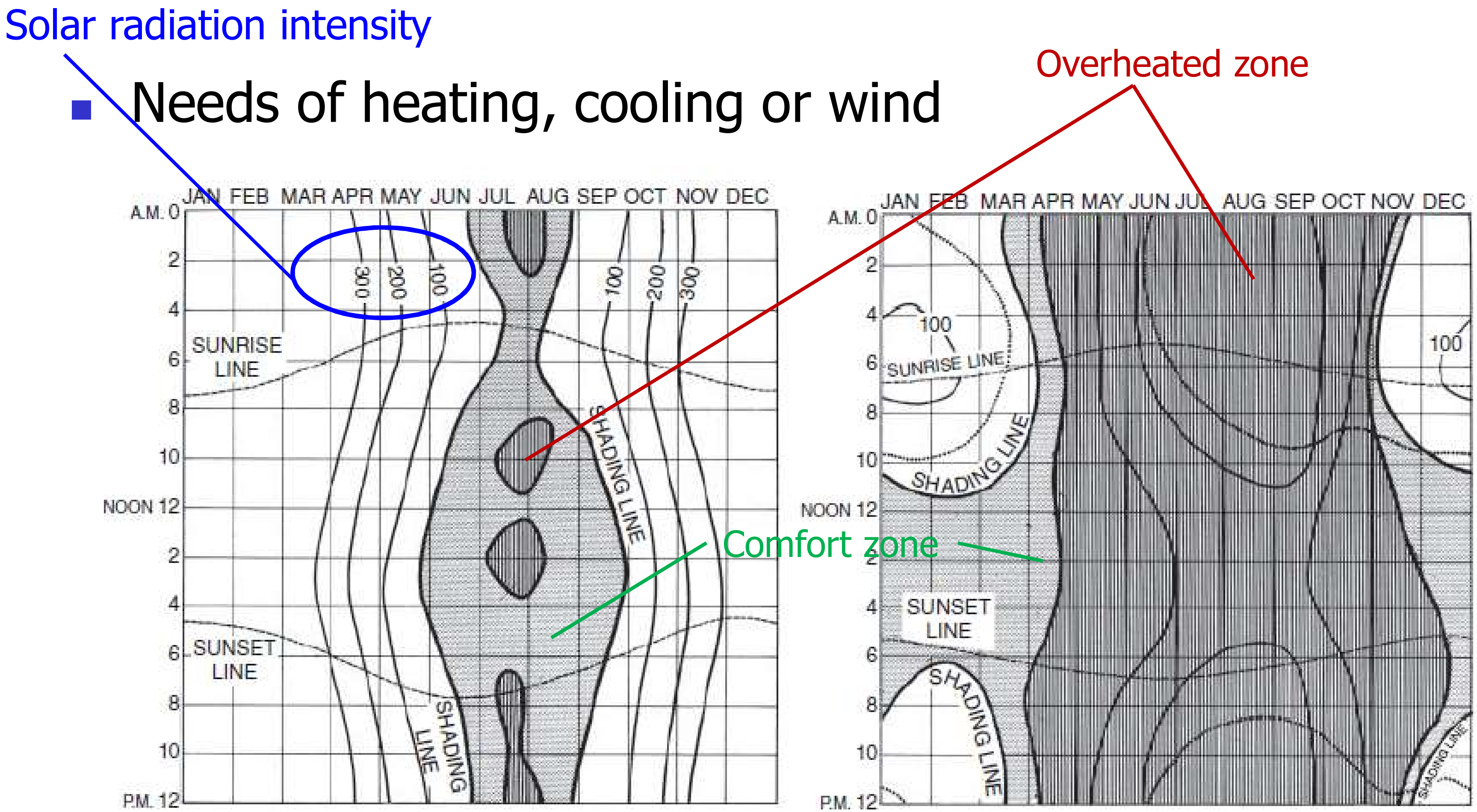


Fig. 3.2 *Relationship of isolines to the thermal comfort zone. Isolines are lines with a constant value of a given property, such as wind speed. Several isolines are plotted on the timetables of climatic needs (see Fig. 3.3).*

Source: MEEB book. 11th ed.

Timetables of climatic needs

- Needs of heating, cooling or wind



(a) New York (b) Miami

Fig. 3.2 Timetables of climatic needs for (a) New York City and (b) Miami, cities representative of two of Olgyay's North American regional climate zones. The shaded regions represent overheated zones; the isolines outside of the shaded areas represent solar radiation intensity needed to remain comfortable outdoors without wind. (From Victor Olgyay, Design with Climate: Bioclimatic Approach to Architectural Regionalism; *© 1963 by Princeton University Press. Reprinted by permission.) Hourly and monthly dry bulb temperature representations of the same cities (c) New York City and (d) Miami using Climate Consultant. The visual patterns and details help the user to characterize the climate more readily than with data tables. (© Climate Consultant 6.0, Regents of the University of California, Energy Design Tools Group, UCLA; used with permission.)*

Climates within climates

- A climate at a particular site can be quite different from the climate data that are published as being representative of an entire region.
- Local variations (surroundings [buildings, hills, lake, etc.]) constitute microclimates.
- The characteristics of a microclimate are influenced by the interaction of both the site and the macroclimate.
- Urban climate: 'heat island' (Table 3.1, Fig. 3.3)
  - Urban heat sources: air-conditioners, furnaces, electric lighting, cars

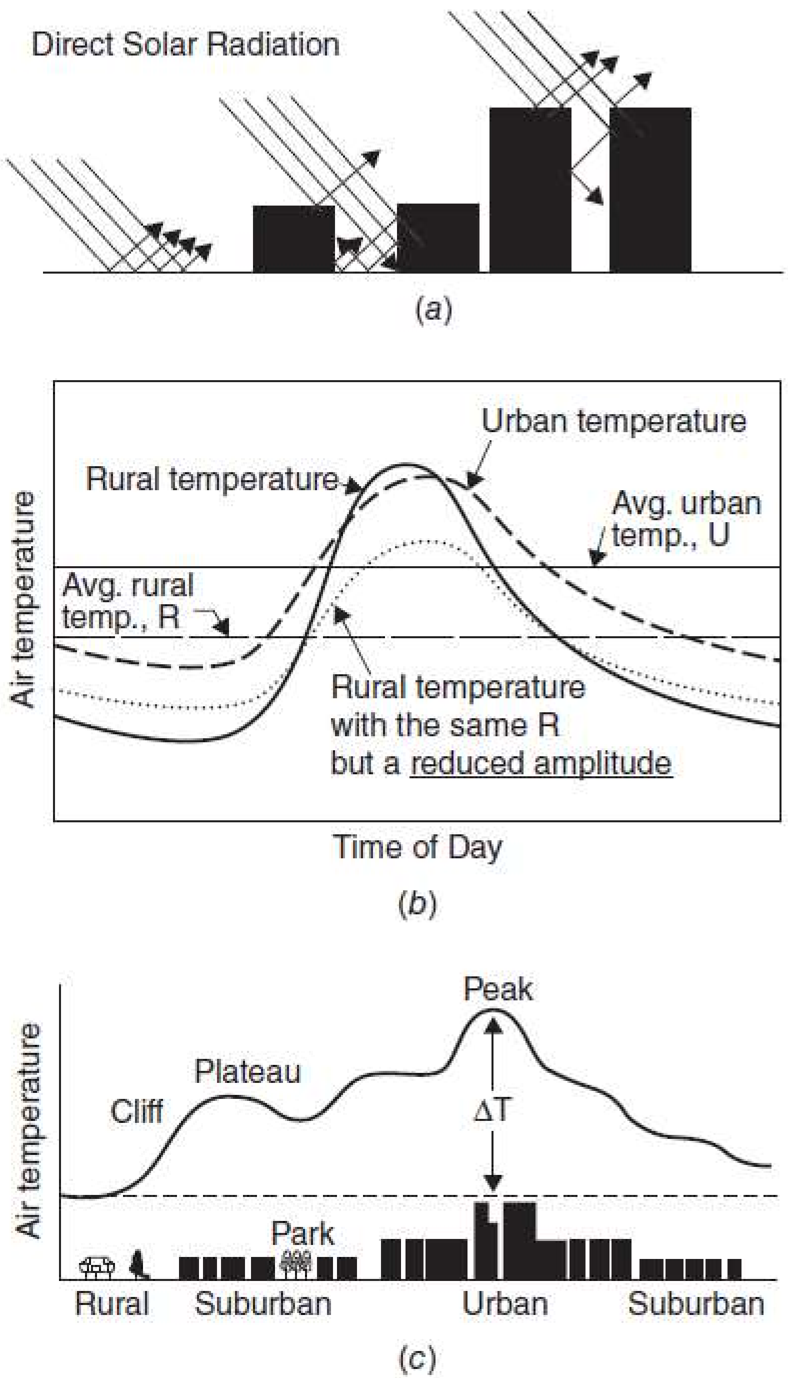
TABLE 3.1 Average Changes in Climate Effects Caused by Urbanization[a]

Effect	Comparison with Rural Environment
Contaminants	
Condensation nuclei and particulates	10 times more
Gaseous admixtures	5 to 25 times more
Cloudiness	
Cloud cover	5 to 10% more
Fog, winter	100% more
Fog, summer	30% more
Precipitation[b]	
Totals	5 to 10% more
Days with less than 2 in. (5 mm)	10% more
Snowfall	5% less
Relative humidity	
Winter	2% less
Summer	8% less
Solar radiation	
Global	15 to 20% less
Ultraviolet, winter	30% less
Ultraviolet, summer	5% less
Sunshine duration	5 to 15% less
Temperature	
Annual mean	0.9 to 1.8°F (0.5 to 1.0°C) higher
Winter minima (average)	1.8 to 2.6°F (1 to 2°C) higher
Heating degree days	10% fewer
Wind speed	
Annual mean	20 to 30% lower
Extreme gusts	10 to 20% lower
Calms	5 to 20% more

Source: Landsberg (1970).

[a]These effects vary from city to city and from day to day.

[b]Research since 1970 has shown that it is not at all certain that urbanization causes increases in precipitation amount within a city.



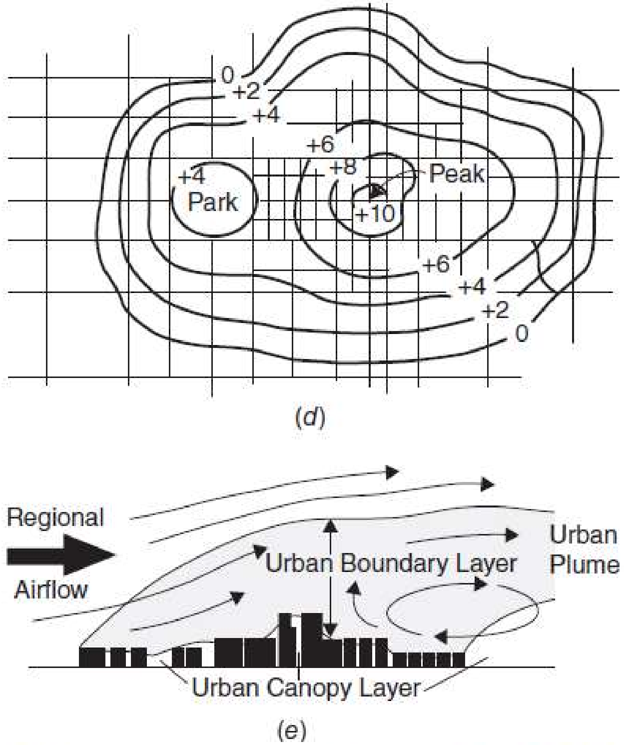


Fig. 3.3 *Urban heat island: a densely occupied area with a temperature distinctly higher than that of the surrounding rural area. (a) Direct solar radiation is likely to be reflected within the city, thereby increasing solar heat gain in urban areas. (b) Temperature records at a rural site (solid line) and in the center of a city (dashed line) during a typical night and day. The city's heat-conducting materials and thin cloud of polluted air acting alone would not change the average air temperature, but would reduce the day–night difference (the dotted line). In addition, the heat from increased solar gain and city-specific heat sources (cars, buildings) warms the air at all hours, producing the observed urban record (dashed line). (c) Idealized profile of the air temperature difference between urban and rural areas at times of peak differences—calm, clear nights. (d) Based upon (c), typical isotherms (lines of equal temperature) provide a "contour map" of the urban heat island. (e) An urban heat island can affect the "downstream" countryside. (Reprinted by permission from Lowry, 1988.)*

TABLE 3.2 Heat Generated within Cities

	City or Region[a]	Population (millions)	Area mile² (km²)	Population Density 10³/mile² (10³/km²)	Energy Use per Capita[b] (kW/capita)	Energy Use per Unit Area[b] (W/m²)
			CITIES AND INDUSTRIALIZED REGIONS			
3	Fairbanks[c]	0.045	30.8 (80)	1.6 (0.6)	10.91	6.55
11	Vancouver	0.6	42.8 (111)	14.0 (5.4)	3.55	19.2
12	Brussels	1.3	62.9 (163)	20.7 (8.0)	3.5	28.0
14	West Berlin	2.3	90.7 (235)	25.4 (9.8)	2.14	21.0
9	St. Louis	0.75	96.5 (250)	7.8 (3.0)	5.3	15.9
10	Munich	0.9	116 (300)	7.8 (3.0)	3.0	9.0
5	New Jersey suburbs of NYC	4.7	2355 (6100)	2.1 (0.8)	9.1	7.3
1	Los Angeles County	7.0	3860 (10,000)	0.2 (0.07)	10.5	0.74
4	Nordheim–Westfalen[d]	16.9	13,045 (33,800)	1.3 (0.5)	8.0	4.0
2	BosNyWash[e]	33.0	33,582 (87,000)	1.0 (0.38)	11.2	4.3
			COMMERCIAL/INDUSTRIAL CITIES			
15	Sheffield	0.5	18.5 (48)	26.9 (10.4)	1.83	19.0
17	Manhattan	1.7	22.8 (59)	74.6 (28.8)	5.52	159.0
16	Montreal	1.1	30.1 (78)	36.5 (14.1)	7.02	99.0
13	Budapest	1.3	43.6 (113)	29.8 (11.5)	3.74	43.0
8	Cincinnati (summer)	0.6	85.7 (222)	7.0 (2.7)	9.3	25.1
7	Hamburg	1.83	295 (763)	6.2 (2.4)	5.3	12.7
6	Chicago	3.5	711 (1842)	4.9 (1.9)	27.2	51.7
			TROPICAL			
18	Hong Kong	3.9	40.5 (105)	96.1 (37.1)	0.88	32.6
19	Singapore	2.1	54.0 (140)	38.9 (15.0)	0.81	12.2

Source: Lowry and Lowry (1995) by permission.

[a]Index numbers refer to Fig 3.4

[b]0.317 W/m² = 1 Btu/ft². These columns were not converted to I-P units. The units shown are as presented in the source, but technically energy should be expressed in kW-h while power is in W.

[c]Data for Fairbanks, Alaska, include a sparsely populated incorporated area surrounding the central business district.

[d]Nordheim-Westfalen is the heavily urbanized and industrialized region in the lower Rhine valley near Düsseldorf–Dortmund.

[e]BosNyWash is the term often used by urbanists to refer to the megalopolis that stretches from Boston through New York to Washington, DC.

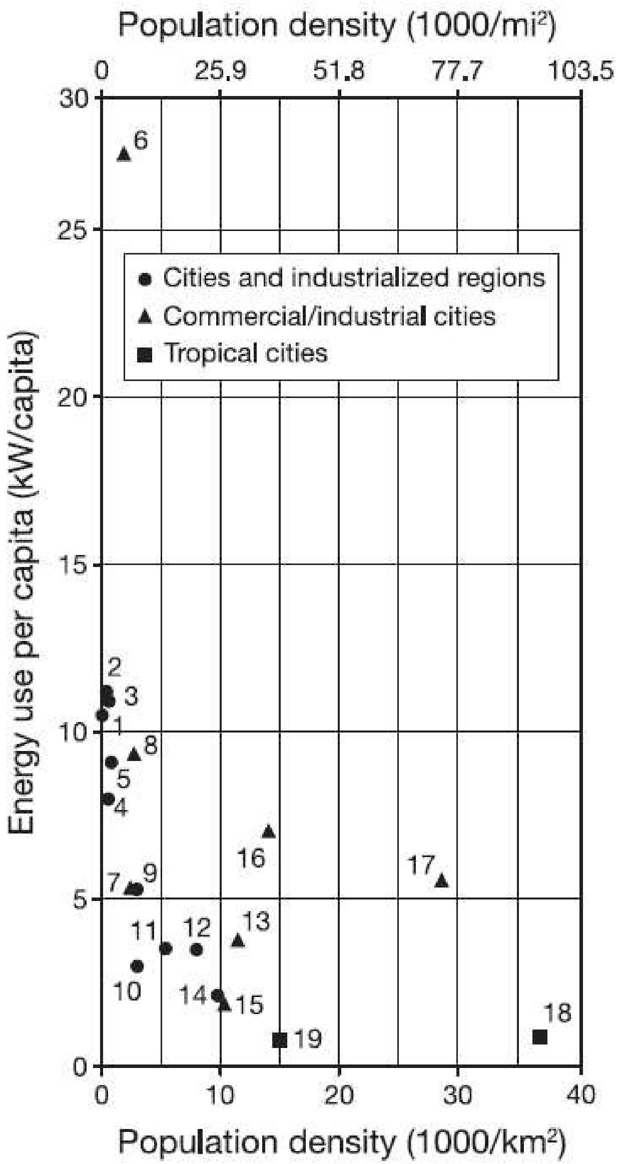


Fig. 3.4 Population density and energy use per capita for 19 cities and regions. Numbers refer to locations in Table 3.2. The heat island effect is influenced by both density and energy use. (Data with permission from Lowry and Lowry, 1995. Redrawn by Alisa Kwok.)

What urban does

- Reduce rainwater's evaporative cooling mechanism
- Changes the cooling action of wind
- Reduce radiative heat loss at night (Fig. 3.5)
- Influence a contaminated air

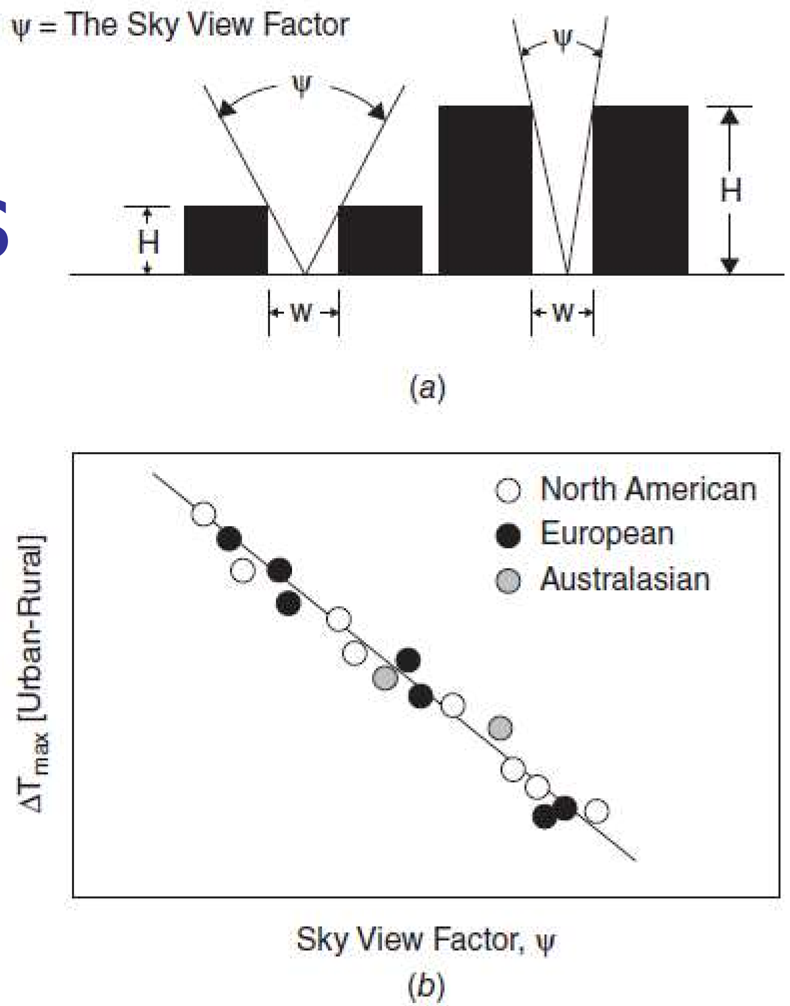


Fig. 3.5 *The urban heat island effect is particularly strong on calm, clear nights. (a) With a greatly reduced "sky view factor" (Ψ) to the cold night sky, the walls and floors of urban canyons (the right part of the sketch) cannot lose heat as readily as can the open countryside or less dense suburban areas (the left part of the sketch). (b) The narrower the Ψ, the more pronounced is the effect (ΔT) of the urban heat island in cities throughout the world. (Reprinted by permission from Lowry, 1988.)*

Microclimate in relation to vertical distance from the surface

• Privacy, accessibility, view, heat, light, and air motion change with vertical distance from the surface: Fig. 3.6(a)

• Vertical and horizontal site analyses: Fig. 3.6(b)

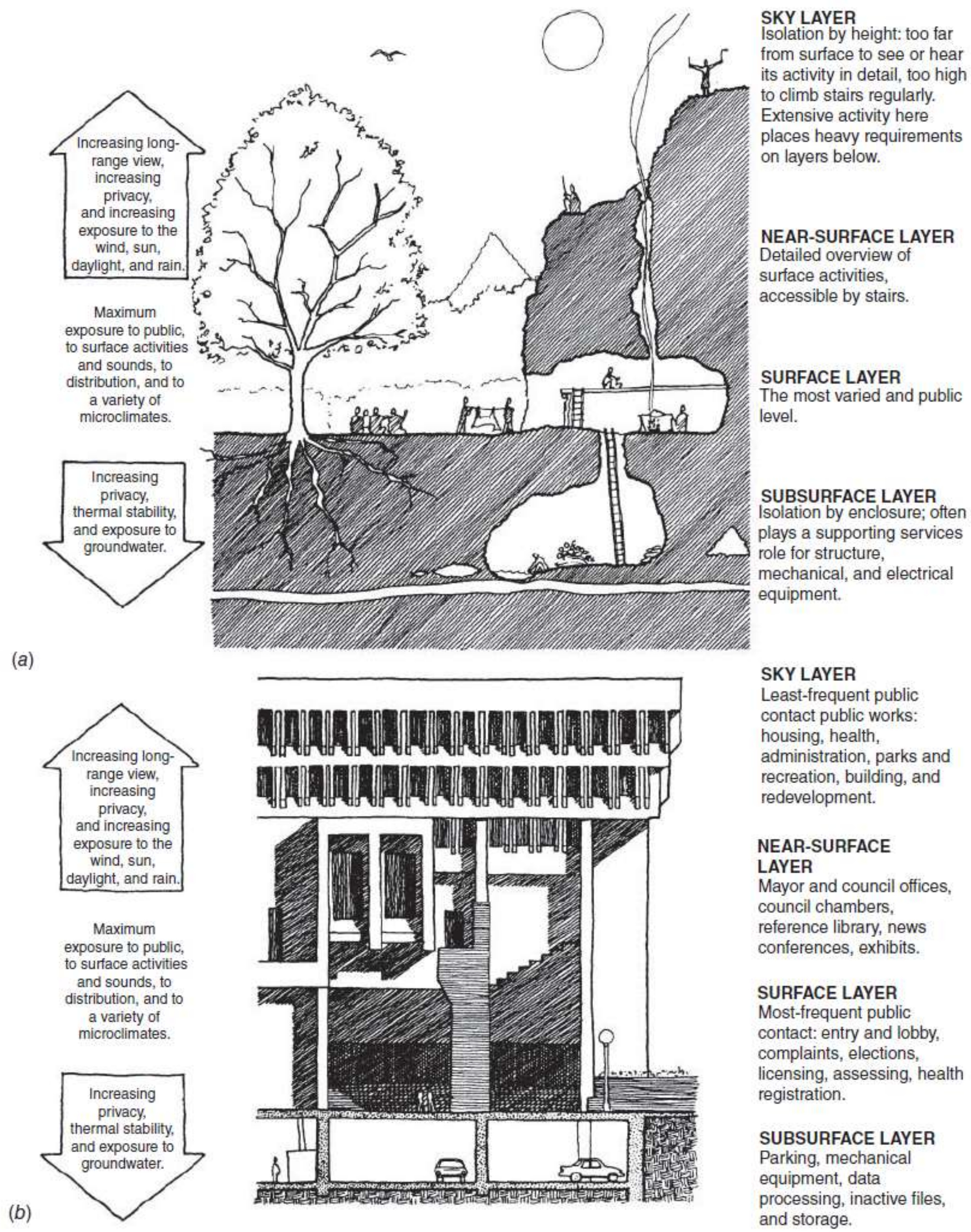


Fig. 3.6 (a) Characteristics of horizontal layers of a site. (b) Vertical layers and form: Boston City Hall, 1969. (Kallman, McKinnell and Knowles, Architects.)

Site design concept

Site can be utilized to assist in heating, lighting and cooling.

	Winter: Minimize Conductive Heat Flow	Winter: Minimize External Heat Flow	Winter: Promote Solar Gain	Winter: Minimize Infiltration	Summer: Delay Periodic Heat Flow	Summer: Promote Ventilation	Summer: Minimize Solar Gain	Summer: Promote Radiant Cooling	Summer: Promote Evaporative Cooling
Windbreaks		●		●					
Plants and water							●		●
Indoor/outdoor rooms			●			●			
복토건축 Earth sheltering	●	●		●	●		●		●
Solar walls and windows			●						
외피 단열 Thermal envelope	●			●	●			●	
Sun shading							●	●	
Natural ventilation						●			

Fig. 3.7 Generic bioclimatic site design concepts and building strategies. (Reprinted from Passive Cooling by permission of the publisher, American Solar Energy Society.)

Image source: https://www.hortweek.com/growers-best-use-windbreaks/ornamentals/article/1662887

Solar Hemicycle house (F.L. Wright)

This is a good example of how the information in Fig 3.7 can be skillfully applied in the planning of a building that works with its site.

- Location: Madison, WI (built in 1948)
- Winter heating is dominant in this area.
- The house is shorter in the north-south and longer in the east-west direction: good for passive solar heating.
- South-facing windows → passive solar heating in winter
- Protection from summer overheating is provided by an overhang.
- Earth was bermed against the curve north wall, almost to roof level.
- North wall made of stone: insulation & winter wind protection / narrow strip of second floor windows

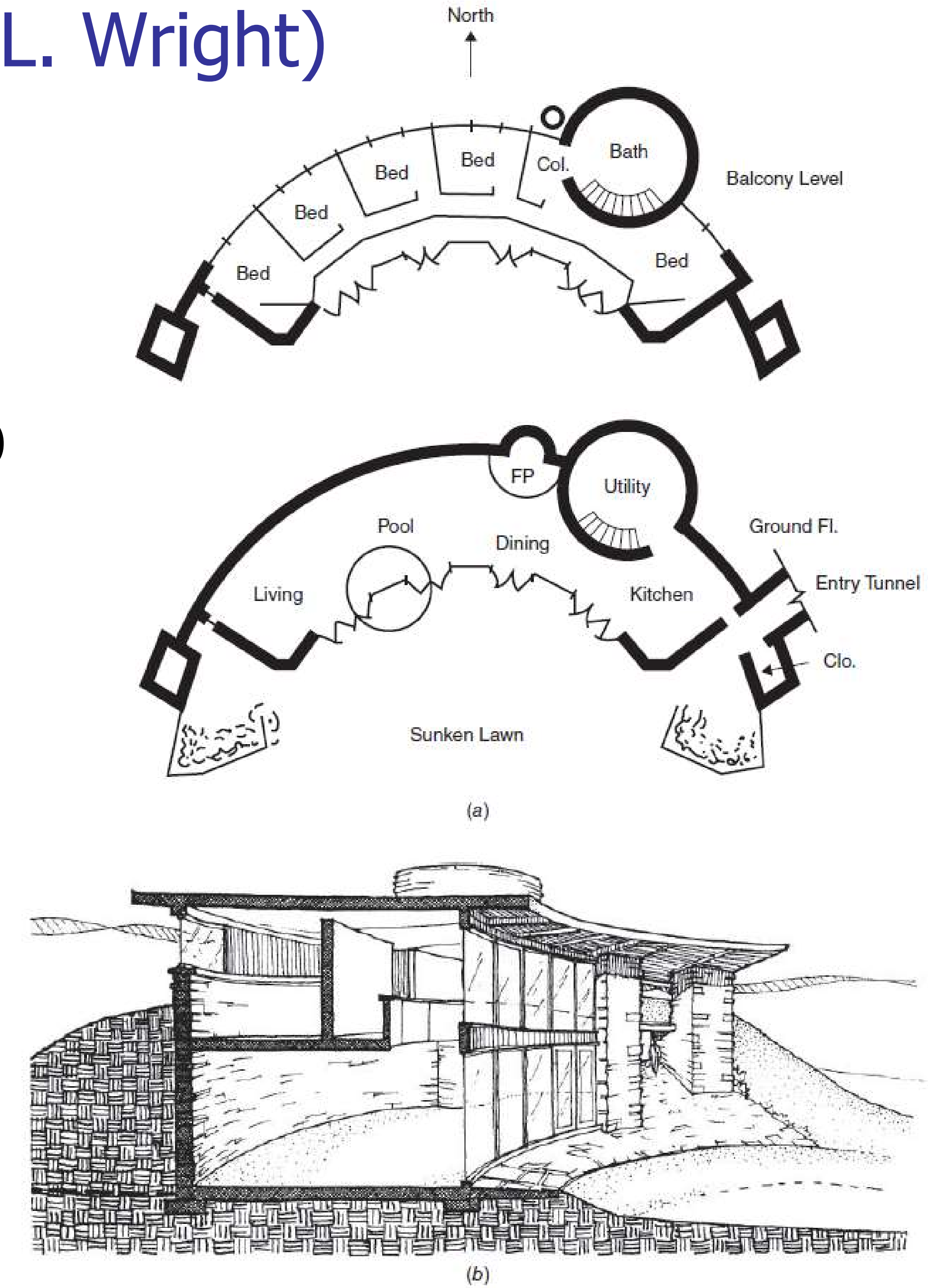
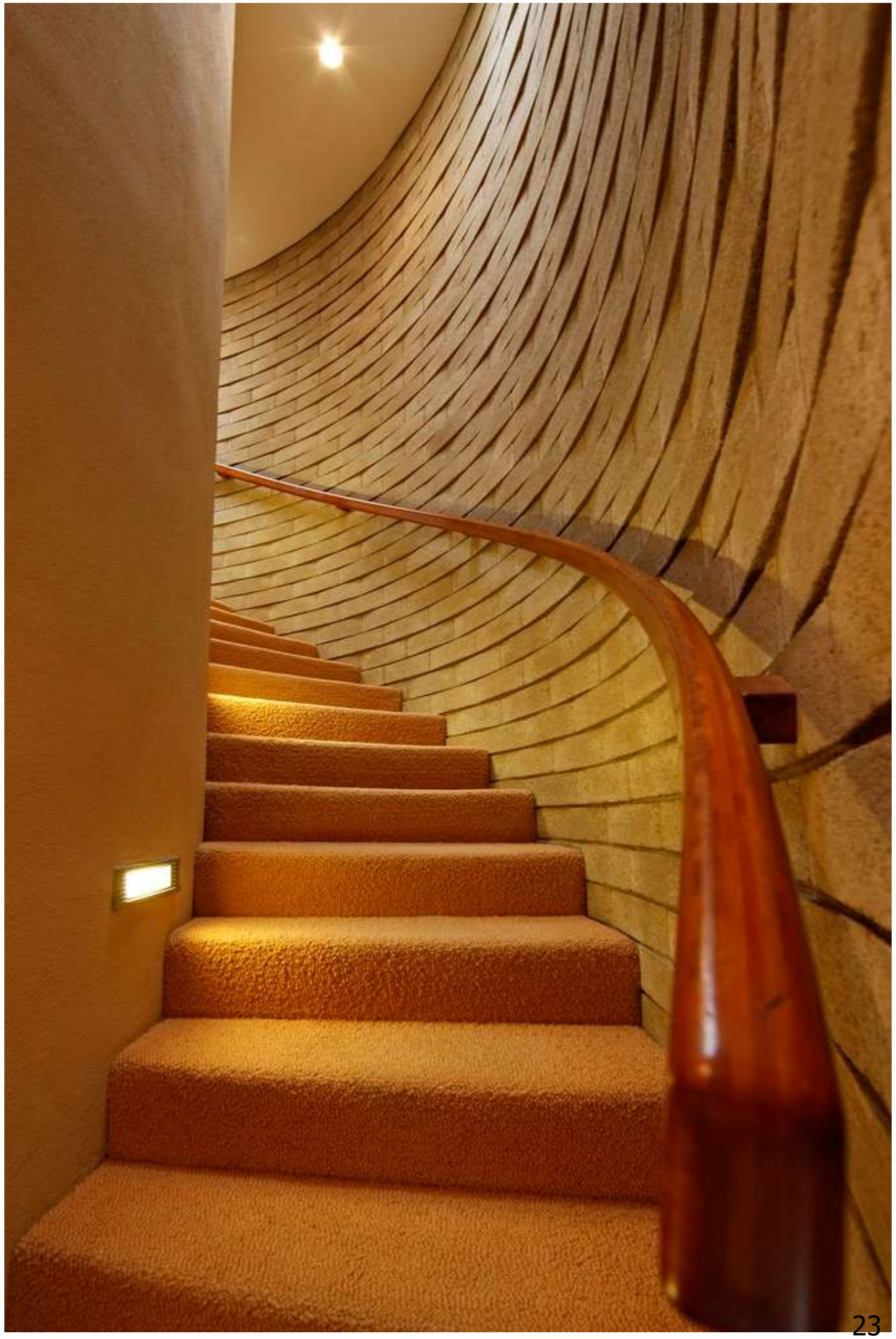
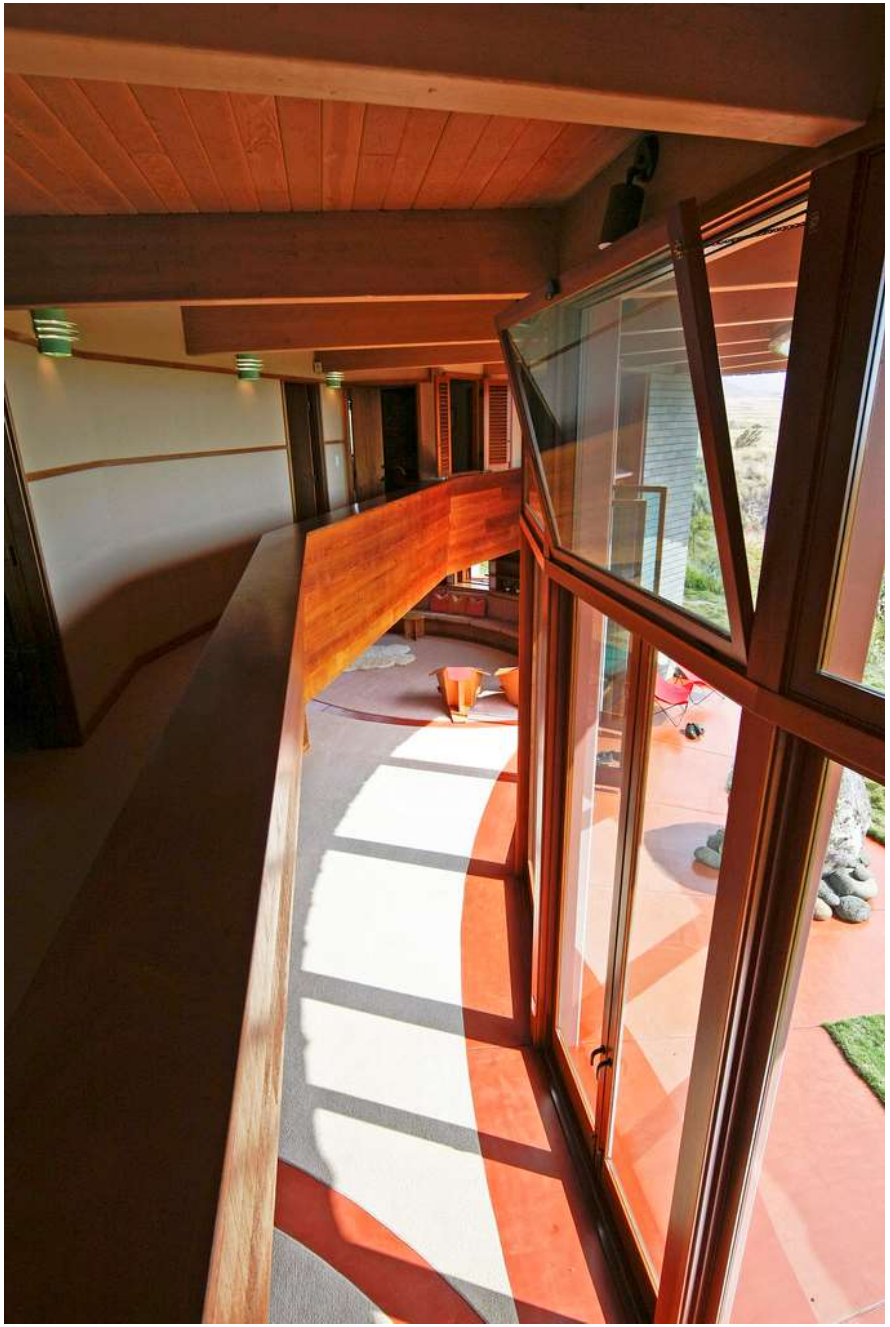
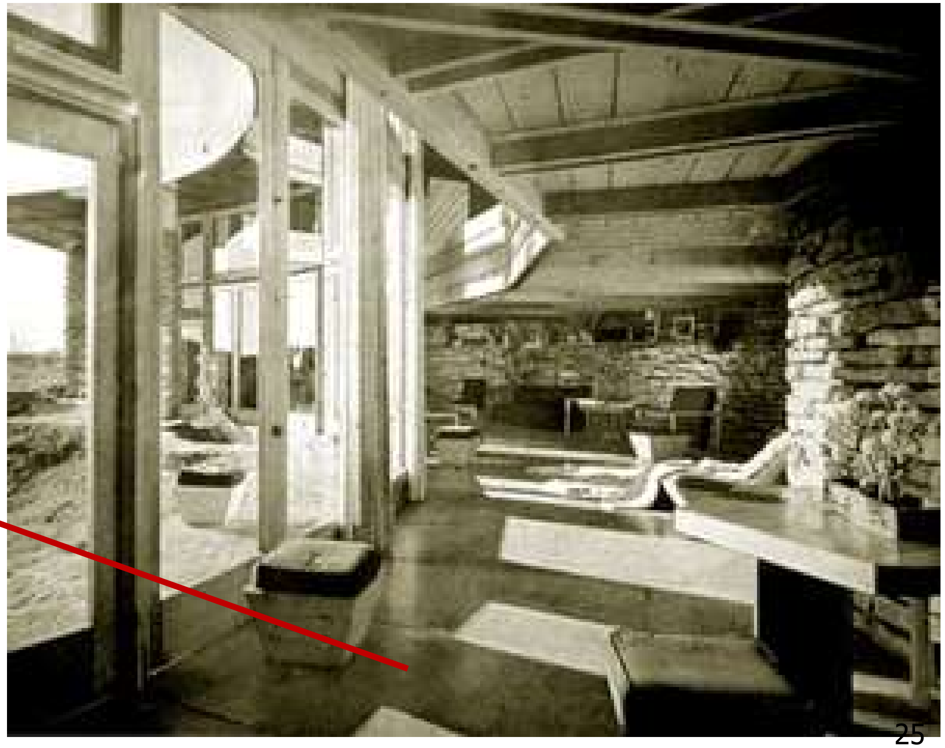


Fig. 3.8 An early passive solar-heated home, Frank Lloyd Wright's Solar Hemicycle (Jacobs House II) near Madison, Wisconsin. The house was designed in the early 1940s and built in 1948. (a) Floor plans. (b) Section-perspective, looking east toward the entry tunnel in the berm wall.

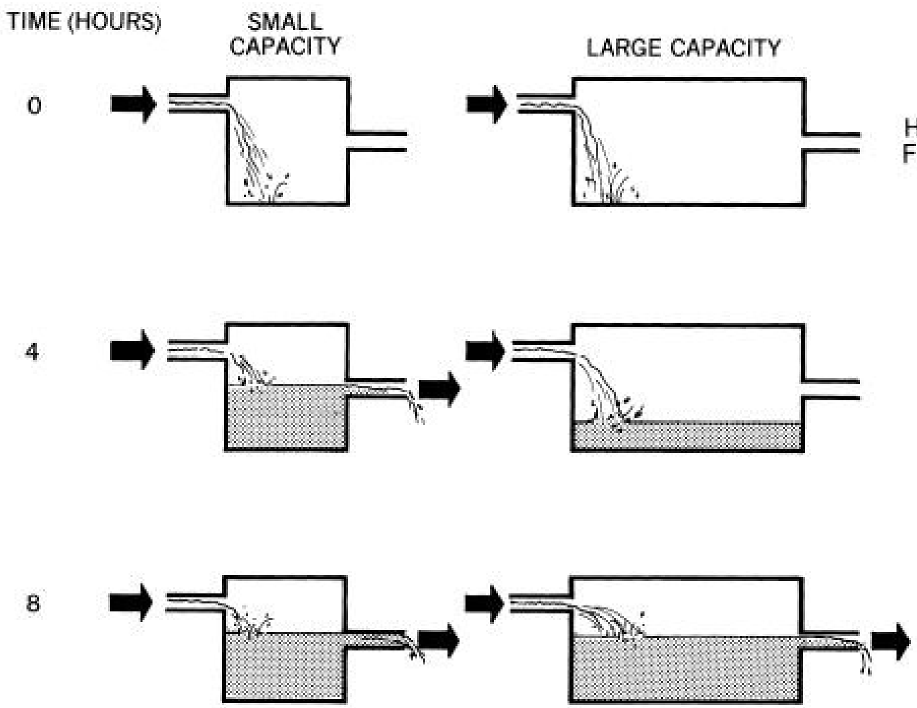


http://www.planetclaire.org/fllw/sh.html

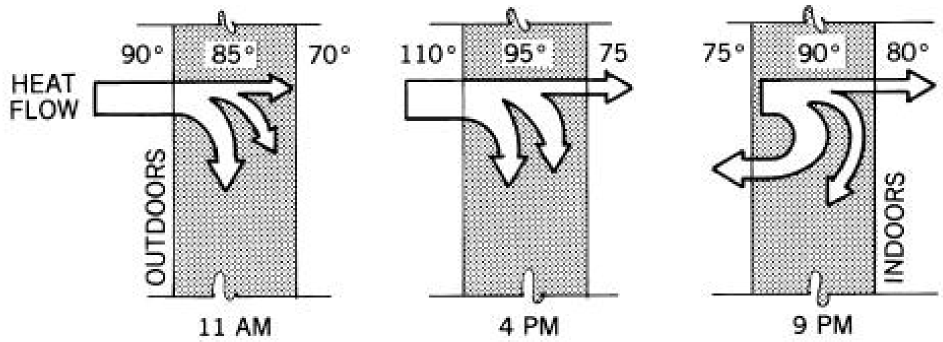


This concrete slab-on-grade first floor also stores solar heat in winter.

Time lag (thermal inertia)



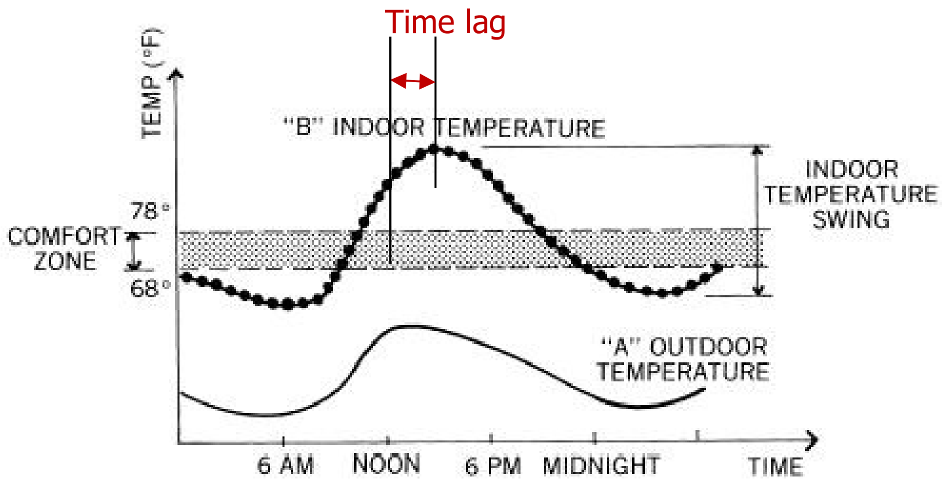
High capacity delays the passage of water



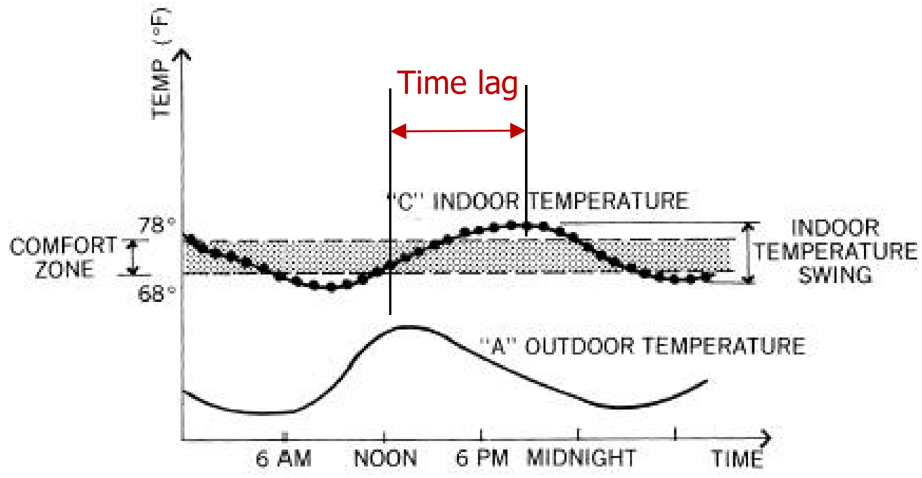
High thermal capacity delays the transmission of heat.

˚F	˚C (exact)	˚C(approximate)	△T		˚F	˚C (exact)	˚C(approximate)	△T
20	-6.7	-5.0	-1.7		62	16.7	16.0	0.7
22	-5.6	-4.0	-1.6		64	17.8	17.0	0.8
24	-4.4	-3.0	-1.4		66	18.9	18.0	0.9
26	-3.3	-2.0	-1.3		68	20.0	19.0	1.0
28	-2.2	-1.0	-1.2		70	21.1	20.0	1.1
30	-1.1	0.0	-1.1		72	22.2	21.0	1.2
32	0.0	1.0	-1.0		74	23.3	22.0	1.3
34	1.1	2.0	-0.9		76	24.4	23.0	1.4
36	2.2	3.0	-0.8		78	25.6	24.0	1.6
38	3.3	4.0	-0.7		80	26.7	25.0	1.7
40	4.4	5.0	-0.6		82	27.8	26.0	1.8
42	5.6	6.0	-0.4		84	28.9	27.0	1.9
44	6.7	7.0	-0.3		86	30.0	28.0	2.0
46	7.8	8.0	-0.2		88	31.1	29.0	2.1
48	8.9	9.0	-0.1		90	32.2	30.0	2.2
50	10.0	10.0	0.0		92	33.3	31.0	2.3
52	11.1	11.0	0.1		94	34.4	32.0	2.4
54	12.2	12.0	0.2		96	35.6	33.0	2.6
56	13.3	13.0	0.3		98	36.7	34.0	2.7
58	14.4	14.0	0.4		100	37.8	35.0	2.8
60	15.6	15.0	0.6					

Time lag



Low-mass passive solar

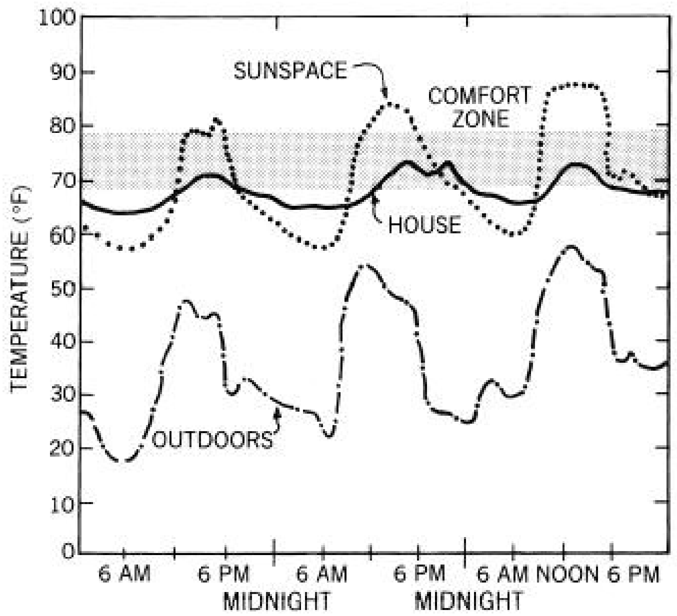


high-mass passive solar

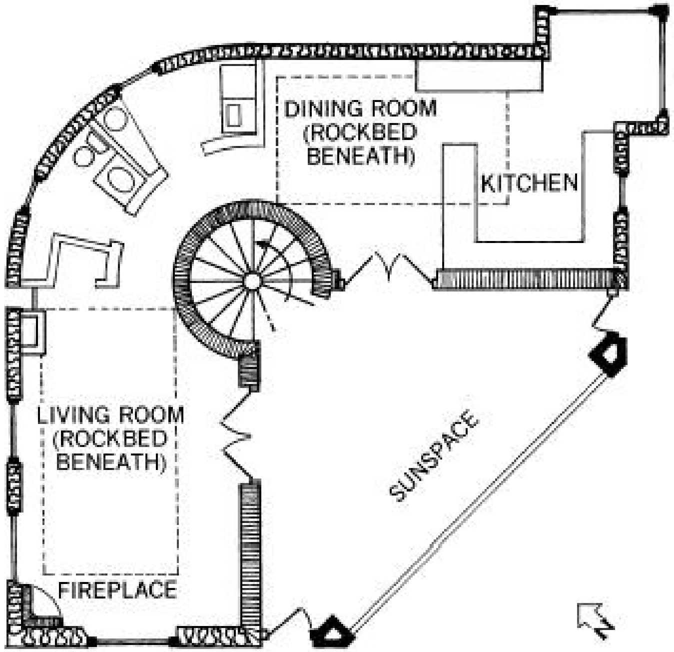
< Benefits >

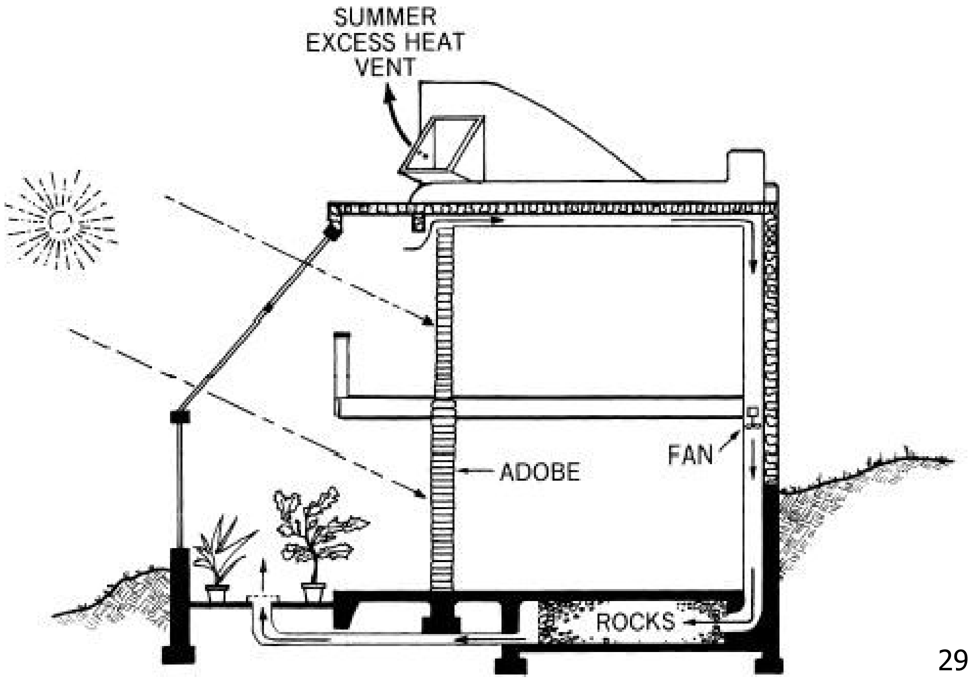
- Reduction of peak cooling and heating loads
- Reduction of equipment sizing

Balcomb house, New Mexico



< Three winter days >





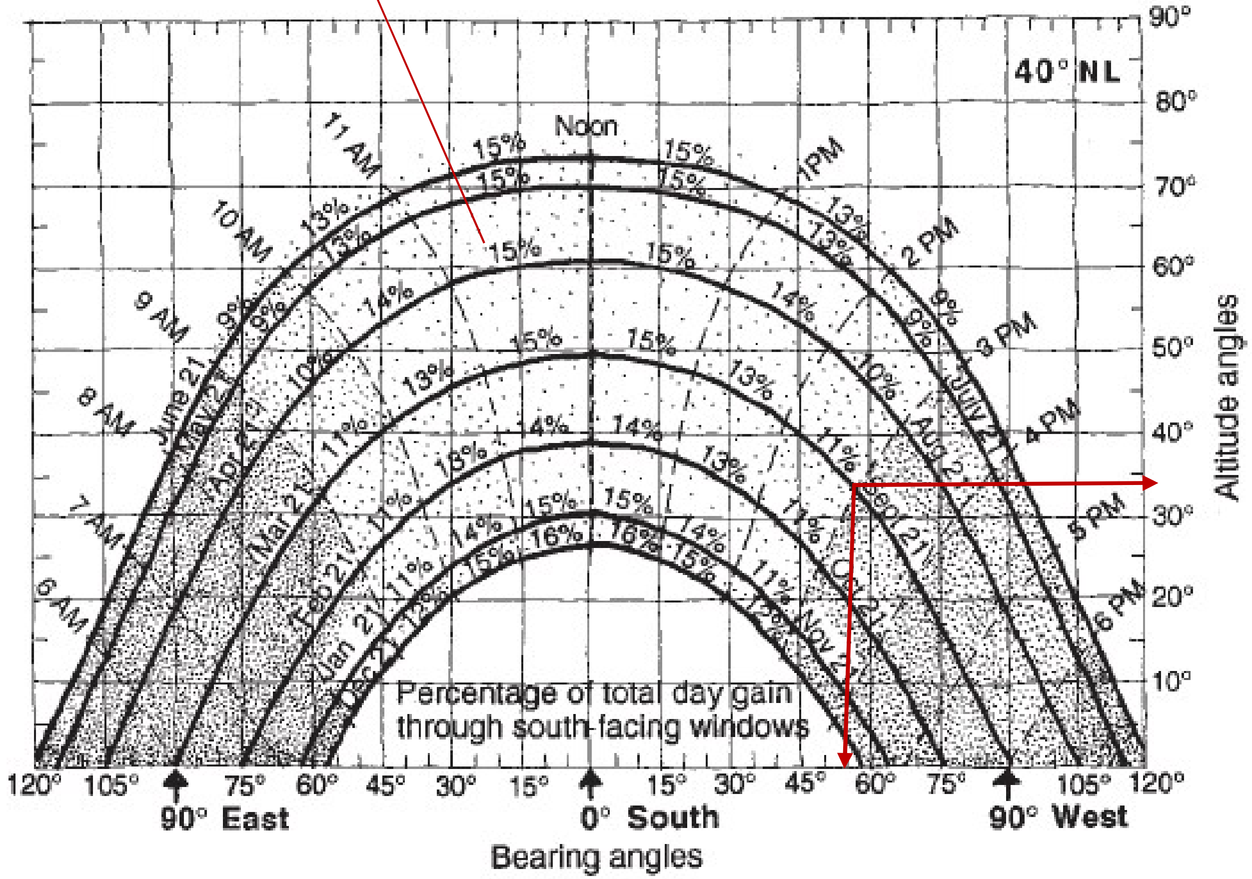
Sun chart

- Southern orientation: more sun in winter and less sun in summer than any other orientation

Solar irradiance: W/m² (instantaneous measurement)
Solar insolation: The solar irradiance integrated over time (ex.: kwh/m²)

For the 6 hours (from 9 AM to 3 PM., best solar collection hours) of greatest insolation, the percentage of clear-day insolation gained each hour by an unshaded south-facing vertical window

Dec.21 @solar noon: 800W/m²
Jun.21 @solar noon: 300W/m²



3 p.m., Mar 21: solar altitude and azimuth angles?
Surface solar azimuth angle?

Fig. 3.13 Sun chart for 40° N latitude showing the approximate percentage of clear-day insolation for south-facing windows for each of the 6 maximum hours of sun each month. (From Edward Mazria and David Winitsky. 1976. Solar Guide and Calculator. Center for Environmental Research, University of Oregon.)

A southern orientation receives more sun in winter and less sun in summer than any other orientation (textbook, p.73).

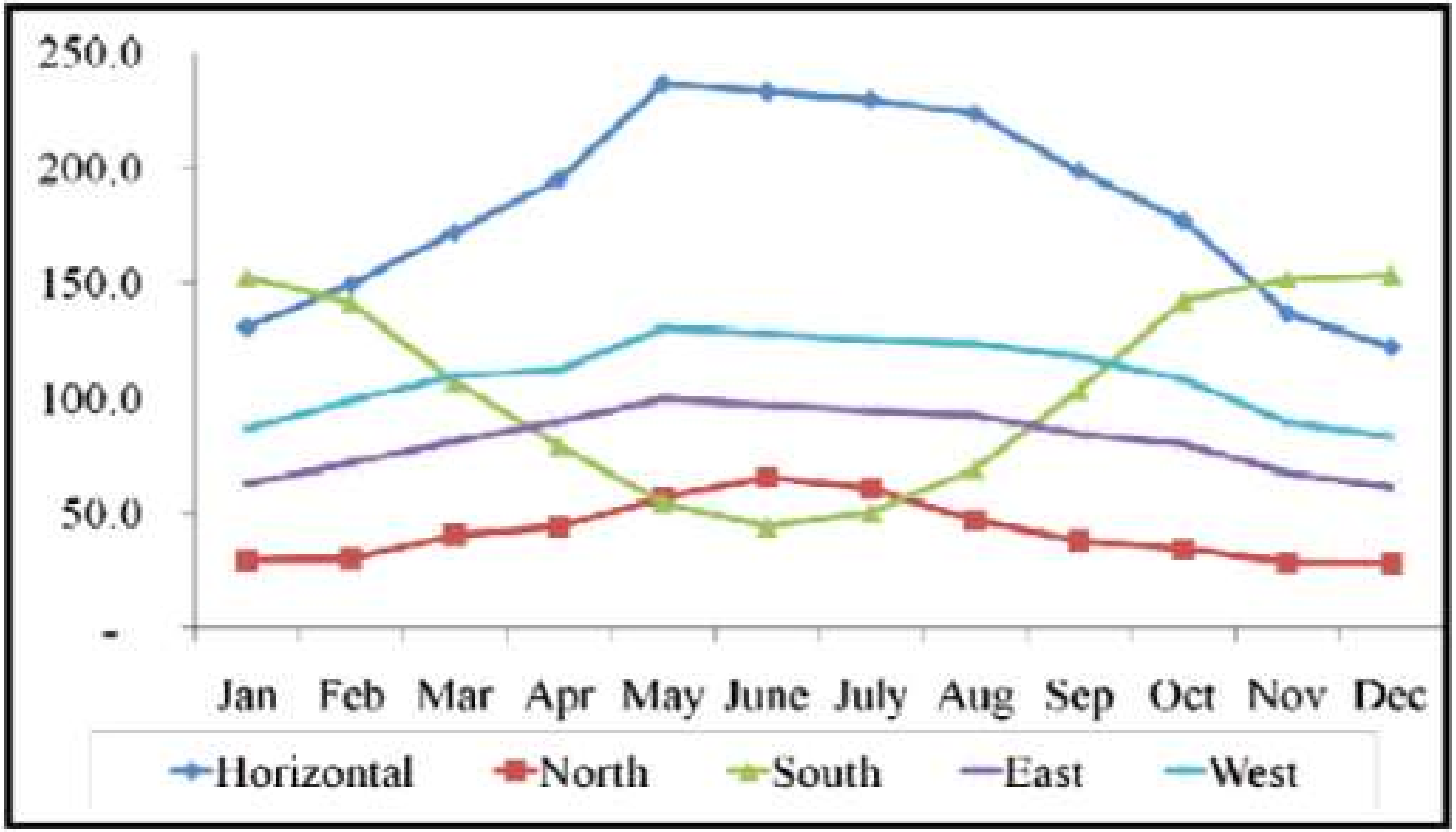


Figure 10. Global solar radiation per month in all orientations (kWh/m^2).

Image source: Approaches to reducing carbon dioxide emissions in the built environment: Low carbon cities, *International Journal of Sustainable Built Environment, Volume 3, Issue 2, December 2014, Pages 167-178*