Climate Consultant 4.0 Develops Design Guidelines for Each Unique Climate

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ABSTRACT:

Energy efficient design requires different types of buildings in each different climate. This makes it essential for architects, builders, contractors, and homeowners to understand the resources of their unique local climate and how it influences the performance of their buildings. Climate Consultant 4.0 has been created to achieve this. It adds a number of new features, including new graphic screens and an interactive tutorial to explain the psychrometric chart. It also automatically creates a list of Design Guidelines based on the attributes of each unique climate and it then displays a sketch illustrating how each Guideline applies. Thus, Climate Consultant 4.0 helps people who are designing, constructing, and maintaining buildings anywhere in the world understand the resources of their local climate and how it impacts their building's performance.

1.0 INTRODUCTION:

Buildings use over 40% of this nation's energy and produce a comparable amount of greenhouse gasses. About half of this energy is used in residential buildings, of which most is used for space heating and cooling. The energy consumption of the vast majority of these "envelope dominated" buildings is determined by how well they respond to the local climate.

Climate Consultant 4.0 is intended to support this vast constituency of small energy consumers who design, build, own, and maintain this huge stock of envelope-dominated buildings. The purpose is not simply to plot climate data, but rather to organize and represent this information in easy-to-understand ways that show the subtle attributes of the climate, and its impact on built form. The goal is to help users create more energy efficient, more sustainable buildings, each of which is uniquely suited to its particular spot on this planet.

2.0 CONTENT OF THE NEW CLIMATE CONSULTANT 4.0:

Climate Consultant 4.0 uses the annual 8760 hour EPW format climate data that is made available at no cost by the Department of Energy for thousands of stations around the world (available through a link on our web site). Climate Consultant 4.0 translates this raw climate data into dozens of meaningful graphic displays. Only a few of the more advanced features are described here.

2.1 Psychrometric Chart: On the psychrometric chart each dot represents the temperature and humidity of each of the 8760 hours per year (Fig.1). Different Design Strategies are represented by specific zones on this chart. The percentage of hours that fall into each of the 14 different Design Strategy Zones gives a relative idea of the most effective passive heating or passive cooling strategies[1]. Climate Consultant 4.0 analyzes the distribution of this psychrometric data in each Design Strategy zone in order to create the unique list of Design Guidelines.

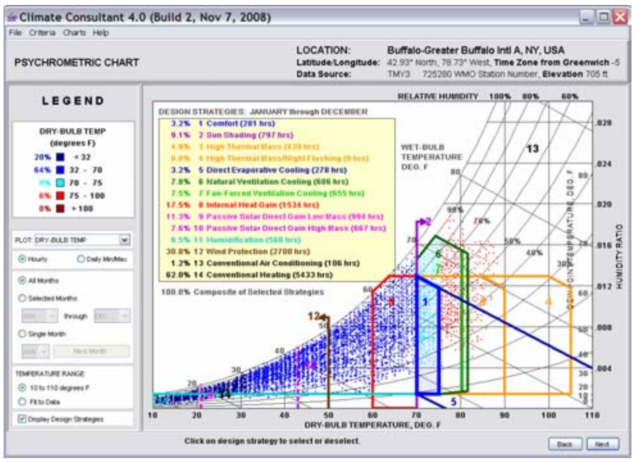

Fig.1: Psychrometric Chart: Each dot represents one of the 8760 hours per year. This example is for Buffalo New York

A new Fan-Forced Ventilation zone was added to the Psychrometric Chart in Climate Consultant 4.0 because it is an important cooling strategy in climates where wind speeds are low, or where local obstructions block the available wind (large buildings, trees).

Wind data in the EPW files is usually recorded at the top of a high building or in a large unobstructed area like an airfield. This means that in more dense urban settings wind velocities will be much lower. It can be argued that Fan-Forced Ventilation should be considered a passive cooling strategy, like Natural Ventilation, because it has such a high COP (Coefficient of Performance). This means that although it uses electricity for fan power, the energy used compared to the cooling effect produced is many times better than Air Conditioning. ASHRAE Standard 55 says that with air velocities of about 160 fpm, occupants will feel an effective temperature that is about 4.5ºF cooler than the recorded dry bulb temperature. This amount of air motion will just barely flutter a piece of paper.

In this example (Fig.2) for Buffalo, New York, the most effective passive cooling strategies are Sun Shading (9.1% of the hours) and Natural Ventilation, while the most effective passive heating strategies are Wind Protection and Passive Solar Direct Gain Low Mass.

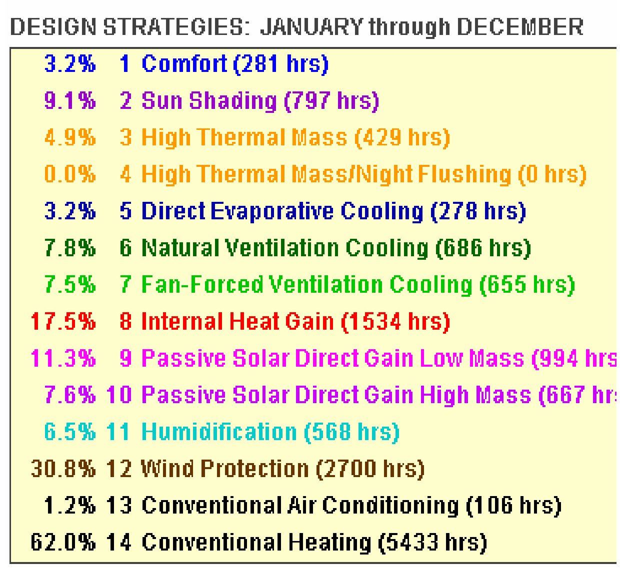

Fig.2: Design Strategies: This detail from the psychrometric chart shows the percentages and number of hours for Buffalo New York

Many of these 14 Strategies can be used concurrently, for example Sun Shading works with all cooling strategies. Other Strategies might conflict with each other, for example Natural Ventilation usually implies low mass construction with large openings during the day, while High Thermal Mass construction usually is closed up during the day to hold the "coolth" from the previous night in the high mass walls and floors. Thus it is usually better to incorporate in the building one cooling strategy or the other, using the one that has the highest percentage of hours and is most compatible with the winter passive heating design strategy that was selected.

[1] The definition of each of these zones on the psychrometric chart is outlined in Givoni 1981, Milne and Givoni 1979, Watson and Labs, 1993

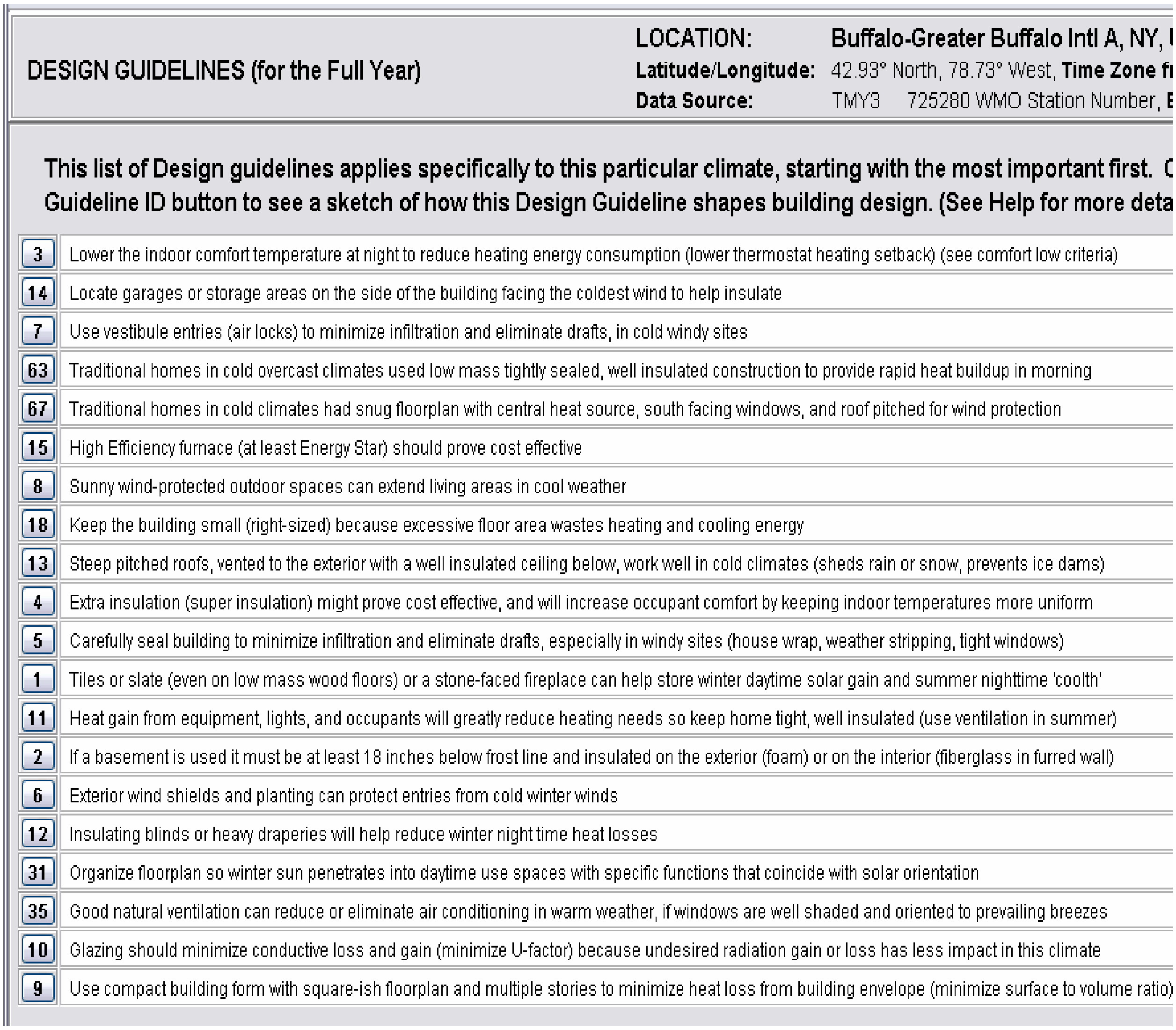

Fig.3 Design Guidelines: This list shows the top 20 Design Guidelines for Buffalo, New York.

2.2 Design Guidelines Based on Climate: One of the major new additions to the new Climate Consultant 4.0 is the calculation of the list of the Top 20 Design Guidelines for each climate (see Fig.3).

A master list of 68 Design Guidelines was created (see Table 1). For each of the 68 Design Guidelines a weight is assigned for each of the 14 Design Strategies on the psychrometric chart to represent the strength of their correlation. Negative weights represent cases where they conflict. It turns out that no two guidelines have the same pattern of weights. The percentage of hours in each of the 14 zones from the psychrometric chart is multiplied by these weights. The total represents how well each Design Guideline applies in that particular climate. The 20 highest weighted Design Guidelines are listed.

This list of Design Guidelines will be automatically revised whenever any of the Design Strategies are eliminated from the Psychrometric Chart. For example if the home is not going to use evaporative cooling, then click on the Evaporative Cooling Design Strategy line and it will be eliminated and a revised Top 20 list with different guidelines will be generated. Another way this list will change is if the user changes the definitions on the Criteria Screen of the boundaries of any of these 14 Design Strategies on the psychrometric chart.

Different climates will result in different sets of Design Guidelines. For example, in climates where more of the hours on the psychrometric chart fall in the zone when Natural Ventilation is the most effective cooling strategy, the Design Guidelines list might include:

38 Shape and orient floorplan to within+/- 45 degrees of prevailing breezes, provided that all windows are well shaded (deep roof overhangs)
36 Locate door and window openings on opposite sides of building to facilitate cross ventilation, with larger areas facing up-wind if possible
55 Low pitched roof with wide overhangs works well in temperate climates
62 Traditional homes in temperate climates used light weight construction with slab on grade and openable walls and shaded outdoor spaces

However, in climates where more of the hours fall in the zone of High Mass with Night Ventilation, then the Building Design Guidelines are almost the exact opposite:

24 Use high mass interior materials to store winter passive heat and summer night 'coolth' such as slab floors, high mass walls, stone fireplace
39 A whole-house fan or natural ventilation can store nighttime 'coolth' in high mass interior, thus reducing or eliminating the need for air conditioning
9 Use compact building form with square-ish floorplan and multiple stories to minimize heat loss from Building envelope (minimize surface to volume ratio)
61 Traditional homes in hot dry climates used high mass construction with small well shaded openings operable for night ventilation to cool the mass

Sometimes Design Guidelines will be in conflict with each other. It is the resolution of these conflicts that is the essence of the architect's design task. Clever designers can create innovative solutions that resolve these apparent conflicts. Thermally uncomfortable or energy-wasteful buildings are usually the ones that ignore the most important Building Design Guidelines.

Thus, because each list of Building Design Guidelines is different for each different climate, it answers the question of how this specific local climate implies a unique local architectural form.

2.3 Design Guideline Sketches: For each Guideline on the Master List, a sketch is available that is a graphic illustration of one of the many possible ways to translate that Guideline into built form (for one example see Fig.4). These sketches are certainly not the only way to interpret each guideline, but they serve to graphically communicate the issues.

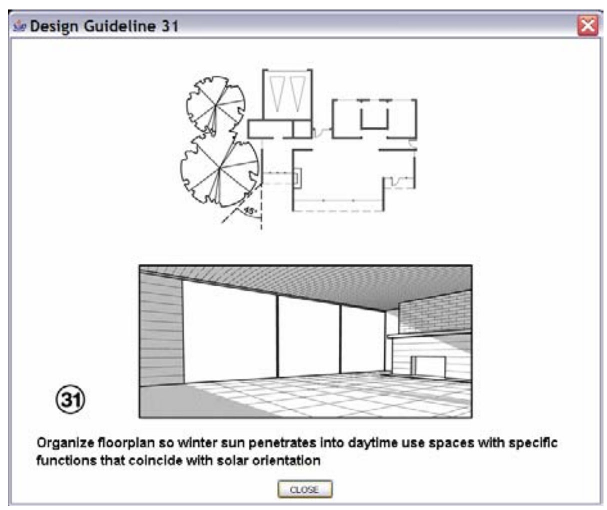

Fig.4: Typical Design Guideline Sketch: If you click on the ID number of any guideline in the Top 20 list you will get a Sketch showing one of the many possible ways it affects the architectural form of the building.

2.4 Monthly Diurnal Averages: One of the new screens that has been added to Climate Consultant 4.0 shows the Monthly Diurnal Averages. This new screen displays five variables simultaneously, showing the average values for each of the 24 hours plotted for all 12 months (see Fig.5): Dry Bulb Temperature, Wet Bulb Temperature, Global Horizontal Radiation, Direct Normal Radiation, and Diffuse Radiation. It is also possible to plot the full range of Dry Bulb Temperatures showing the distribution of maximum and minimum temperatures for every hour of the month. This gives an idea of the variability of temperatures that can be anticipated.

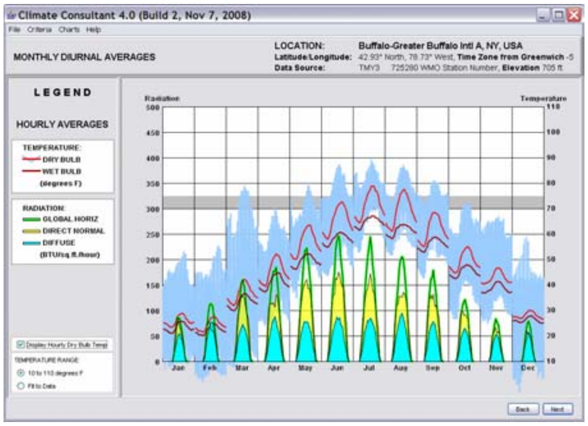

Fig.5: Monthly Diurnal Averages: This new chart shows for Buffalo each month's 24 hour average Dry Bulb and Wet Bulb Temperatures, and Global Horizontal, Direct Normal and Diffuse Solar Radiation. It also shows (in light blue) the peak hourly Dry Bulb temperatures for each hour of each month.

2.5 Psychrometric Chart Tutorial: Also posted on the web site is a graphic and audio tutorial to help users understand the Psychrometric Chart. It shows the relationship between dry bulb temperature and the various definitions of humidity. It also shows how human thermal comfort can be represented on the psychrometric chart, and how an HVAC system can change environmental conditions. This tutorial is written in Flash and can be downloaded from our web site (www.aud.ucla.edu/energy-design-tools).

2.6 Help: Climate Consultant 4.0 contains a vastly expanded set of Help options that will give the user definitions of each variable on the current screen and detailed discussions of how to apply this data to create energy efficient buildings. This option is intended to serve as the "Users Manual" for Climate Consultant 4.0.

3. SUMMARY:

Among the new capabilities have been added to Climate Consultant 4.0 is an expert system that automatically interprets each location's climate data to create a unique set of the Top 20 Building Design Guidelines. In addition, a number of other new graphic climate data analyses options have been added.

Energy Codes usually require slightly different types of buildings in each climate zone. This makes it essential for architects, builders, contractors, and homeowners to understand the resources of their unique local climate and how it influences the performance of their buildings.

Because each Top 20 list of Building Design Guidelines is different for each different climate, it answers the question of how each specific local climate implies a unique architectural form.

ACKNOWLEDGEMENTS:

This project would not have been possible without the support of the University of California Energy Institute (UCEI).

At UCLA the Principal Investigators were Murray Milne and Robin Liggett. The Design Sketches for each of the Design Guidelines were produced by Andrew Benson, based in part on work by Don Watson and Ken Labs, and by Vivian Loftness et al. The Psychrometric Chart Tutorial was written in Flash by Yasmin Bhattacharya. Technical advice was provided by Don Leeper and Carlos Gomez.

The list of Design Guidelines was developed based on a number of references, including in part Watson and Labs, as well as Loftness, et.al.. The description of Traditional Buildings was developed from many authors especially James Marston Fitch.

WEB SITE

Both Climate Consultant 4.0 and the new Psychrometric Chart Tutorial, along with the paper describing this and the prior version of Climate Consultant, are all available at no cost on the following web site: www.aud.ucla.edu/energy-design-tools

Table 1: Master List of Design Guidelines:

1. In this climate conventional heating will always be required, but can be greatly reduced by careful energy conserving design
2. A basement must be insulated on the exterior with foam (usually 18 inches below the frost line) or on the interior with fiberglass in furred wall
3. Lowering the indoor comfort temperature at night will reduce heating energy consumption (lower thermostat heating setback)
4. Extra insulation (super insulation) might prove cost effective
5. Carefully seal building to minimize infiltration and eliminate drafts, specially in windy sites (house wrap, weather stripping, good window construction)
6. Exterior wind shields and planting can protect entries from cold winter winds
7. Use vestibule entries (air locks) to minimize infiltration and eliminate drafts, in cold windy sites
8. Sunny wind protected outdoor spaces can extend living areas in cool weather
9. Use compact building form with square-ish floorplan and multiple stories to minimize heat loss from building envelope (minimize surface to volume ratio)
10. Glazing should minimize conductive loss and gain (minimize U-factor) because radiation gain or loss (Low-E) will have less impact in this climate
11. Equipment, lights, and occupants generate a significant amount of heat gain that can reduce winter Heating loads or increase summer cooling
12. Insulating blinds or heavy draperies will help reduce night time heat losses
13. Steep pitched roofs, vented with an insulated ceiling below, work well in cold climates to shed snow, and prevent ice dams
14. Locate garages or storage areas on the side of the building facing the coldest wind to help insulate
15. High Efficiency furnace (at least Energy Star) should prove cost effective
16. Trees (neither conifer nor deciduous) should not be planted in front of passive solar windows, but rather beyond 45 degrees from each corner
17. Use plant materials (ivy, bushes, trees) especially on the west to shade the structure
18. Keep building small (right-sized) because excessive floor area wastes heating and cooling energy
19. This is a good climate for passive solar heating so face the long side of the floorplan to the south to maximize glazing exposure to winter sun
20. Provide double pane high performance glazing (Low-E) on west, north, and east, but clear on south For maximum passive solar gain
21. Use raised floor, well insulated, because a slab on grade is of little benefit for thermal storage in cold climates or small day-to-night temperatures
22. Even wood floors with tile or slate, or a stone fireplace can help store winter daytime solar gain and summer nighttime 'coolth'
23. Small well-insulated skylights (less than 3% of floor area in temperate climates, 5% in overcast) reduce daytime lighting energy and cooling loads
24. Use high mass interior materials to store winter passive heat and summer night 'coolth' such as slab floors, high mass walls, stone fireplace
25. Steep pitched well ventilated roofs work well in wet climates to shed rain and protect outdoor porches and verandas
26. A radiant barrier (shiny foil) will help reduce radiated heat gain through the roof in hot climates
27. Raise buildings high above ground to minimize dampness and maximize natural ventilation
28. Windows can be unshaded and face in any direction because there is little benefit from passive solar heating and little danger of overheating
29. Humidify the air in enclosed outdoor spaces before it enters the building with spray-like fountains, Misters, wet pavement, or cooling towers
30. High performance glazing on all orientations should prove cost effective (Low-E with insulated frames) in hot

clear summers or cold winters

31 Organize floorplan so winter sun penetrates into daytime use spaces with specific functions that coincide with solar orientation

32 Minimize or eliminate west facing glazing to reduce afternoon heat gain

33 High performance glazing (Low-E) might NOT be needed in mild more overcast climates, or in Warmer climates if windows are fully shaded

34 Wind direction can be changed up to 45 degrees by exterior wingwalls, casement windows, L shaped floorplans, or plantings

35 Good natural ventilation can reduce or eliminate air conditioning, especially if windows are well shaded and oriented to prevailing breezes

36 Locate door and window openings on opposite sides of building to facilitate cross ventilation, with larger areas facing up-wind if possible

37 Air conditioning can be reduced or eliminated by carefully designing fixed overhangs or operable sunshades (extend in summer retract in winter)

38 Shape and orient floorplan to within +/- 45 degrees of prevailing breezes, provided that all windows are well shaded (deep roof overhangs)

39 A whole-house fan or natural ventilation can store nighttime 'coolth' in high mass interior, thus reducing or eliminating the need for air conditioning

40 High mass interior surfaces like stone, brick, tile, or slate, feel naturally cooler on hot days and reduce day-to-night temperature swings

41 The best high mass walls use exterior insulation (EIFS foam) and expose the mass on the interior or use plaster or direct contact drywall

42 Ceiling fans during the day can provide up to 4.5º F of added comfort cooling and thus can reduce or eliminate the need for air conditioning

44 Plant tall deciduous trees close to south façade at 45 degrees from the corners to shade the roof (in New England called husband and wife trees)

45 Flat roofs work well in hot dry climates (especially if light colored)

46 High Efficiency air conditioner (at least Energy Star) should prove cost effective

47 Use open plan interiors to promote natural cross ventilation, or use louvered doors or jump ducts if privacy is required

48 Raising indoor comfort temperature to 80° (thermostat setpoint) will reduce cooling energy, while added air motion will increase comfort

49 Provide vertical distance between air inlet and outlet to produce stack ventilation (open stairwells, two story spaces, roof monitors) when wind speeds are low

50 An Evaporative Cooler can provide all the required cooling capacity (thus eliminating the need for an air conditioner)

51 Slab on grade should provide enough thermal mass, but if air conditioning is still needed consider high-mass walls or better window shading

52 In very cold climates outdoor air is extremely dry, but a well sealed home generates more than enough moisture to make it comfortable

53 Shaded outdoor areas (porches, patios) oriented to the prevailing breezes can extend living spaces in warm or humid weather

55 Low pitched roof with wide overhangs works well in temperate climates

58 This is one of the more comfortable climates, so shade to prevent overheating open to breezes in summer, and use passive solar gain in winter

59 In this climate air conditioning might always be required, but can be greatly reduced if building is designed to minimize overheating

60 In very hot climates earth sheltering or occupied basements benefit from earth cooling in summer (it remains close to average annual temperature)

61 Traditional homes in hot dry climates used high mass construction with small well shaded openings operable for night ventilation to cool the mass

62 Traditional homes in temperate climates used light weight construction with slab on grade and openable walls and shaded outdoor spaces

63 Traditional homes in cold overcast climates used low mass well sealed, well insulated construction to provide rapid heat buildup in morning
64 Traditional homes in mixed hot humid and cold climates used low mass well ventilated second floor, and high mass sun tempered first floor
65 Traditional homes in hot humid and cool climates used high ceilings and high operable (French) windows protected by roof overhangs and verandas
66 Traditional homes in hot dry climates used enclosed well shaded courtyards, with a small fountain to provide wind-protected microclimates
67 Traditional homes in cold climates had snug floorplan with central heat source, south facing windows, and roof pitched for wind protection
68 Traditional homes in warm humid climates used light weight construction with openable walls and shaded outdoor porches, raised above ground

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