GR24_HW02: Vernacular and Climate Sensitive Architecture;Fort Knox

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[1]Building Energy Modeling and Envelope Design

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1_Introduction

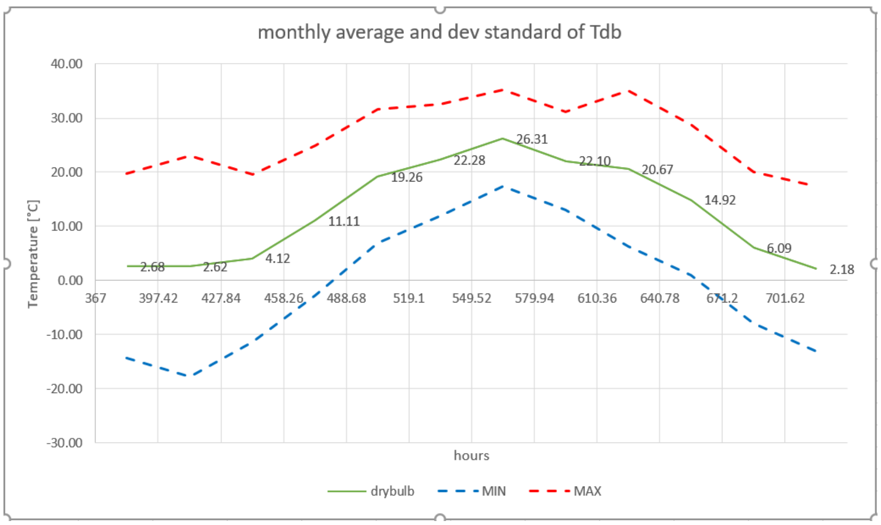
1a_The Site

Fort Knox is a United States Army post in Kentucky south of Louisville and north of Elizabeth town. It is also the site of the United States Bullion Depository, which is used to house a large portion of the United States' official gold reserves. reserves.

Figure 1: Fort Knox

1b_Climate

Fort Knox has a humid subtropical climate (Köppen *Cfa*) with four distinct seasons and is located in USDA hardiness zones 6b and 7a. Spring-like conditions typically begin in mid-to-late March, summer from mid-to-late-May to late September, with fall in the October–November period. Seasonal extremes in both temperature and precipitation are not uncommon during early spring and late fall; severe weather is not uncommon, with occasional tornado outbreaks in the region. Winter typically brings a mix of rain, sleet, and snow, with occasional heavy snowfall and icing. Fort Knox averages 5.8 days with low temperatures dipping to 10 °F (-12 degC), while readings of 0 degF (-18 degC) or below occur on average every several years, the last occurrence being January 7, 2014; the average window for freezing temperatures is October 31 thru April 6, allowing a growing season of 207 days. Summer is typically hazy, hot, and humid with long periods of 90–100 degF (32–38 degC) temperatures and drought conditions at times. Louisville averages 35 days a year with high temperatures at or above 90 degF (32 degC), and the average window for such temperatures on average fall on June 7 and September 10, respectively. The mean annual temperature is 58.2 degF (14.6 degC), with an average seasonal snowfall of 12.5 in (32 cm) and an average annual rainfall of 44.9 inches (1,140 mm). The first and last measurable ([?]0.1 in or 0.25 cm) snowfalls of the season on average fall on December 8 and March 12, respectively. The greatest amount of precipitation in 24 hours was 10.48 inches (266.2 mm) on March 1, 1997 and the heaviest 24-hour snowfall total was 15.5 in (39.4 cm), occurring only two days before the all-time record low.



The wettest seasons are spring and summer, although rainfall is fairly constant year round. During the winter, particularly in January and February, several days of snow can be expected. January is the coldest month, with a mean temperature of 34.9 °F (1.6 °C). July is the average hottest month with a mean of 79.3 °F (26.3 °C).The highest recorded temperature was 107 °F (42 °C), which last occurred on July 14, 1936, and the lowest recorded temperature was -22 degF (-30 degC) on January 19, 1994. The record high daily minimum was 84 degF (29 degC) on August 19, 1936, while the record low daily maximum was -2 degF (-19 degC) on January 12, 1918; the only other sub-0 degF (-18 degC) daily maximum occurred on January 5, 1884. In 2012, Louisville had the fourth-hottest summer on record, with the temperature rising up to 106 degF (41 degC) in July and the June all-time monthly record-high temperature being broken on two consecutive days.

As the city exemplifies the urban heat island effect, temperatures in commercial areas and in the industrialized areas along interstates are often higher than in the suburbs, often as much as 5 °F (2.8 °C).

Louisville's lowest solar noon is 28.4 degrees with the shortest day-length being 9 hours and 30 seconds, both occurring from December 17–26. The city's highest solar noon is 75.2 degrees with the longest day-length being 14 hours and 39 seconds, both occurring from June 17–25. The city's March and September equinox

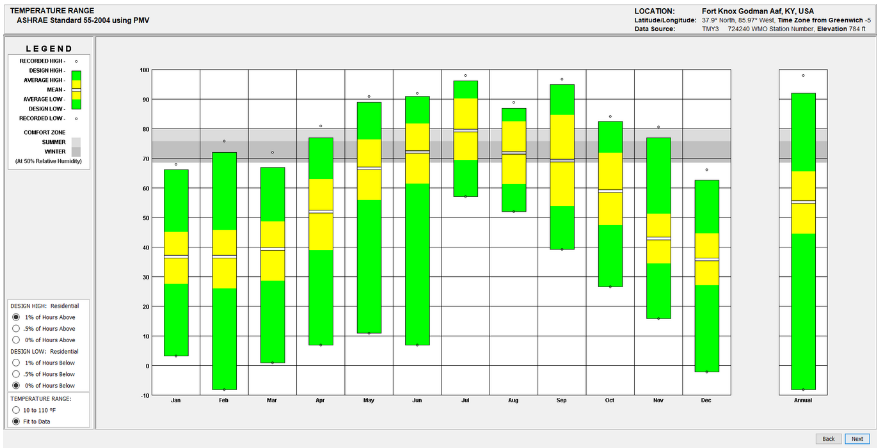


Figure 2: CC Temperature Range

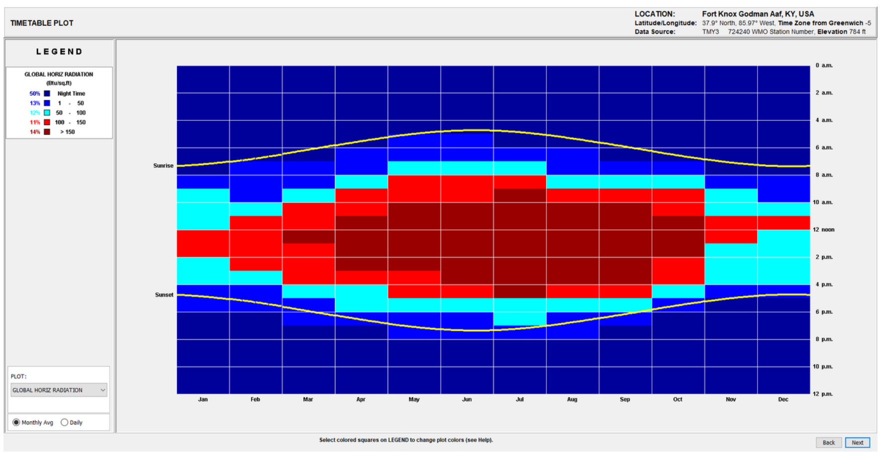


Figure 3: CC Timetable Plot

occurs at 50.5 degrees.

_____ *Heat Island Effect*

A 2012 study by the Urban Climate Lab at Georgia Tech shows that Louisville has the highest index of the heat island effect in America. According to Brian Stone of the Urban Climate Lab and author of *The City and the Coming Climate*,

> "The average increase in the temperature difference between urban and rural environments in the Louisville area has been 1.67 degrees Fahrenheit every decade between 1961 and 2010. That's nearly double the rate of the next city on the list, Phoenix, which saw an average change of .96 degrees in the same period."

Stone said that part of Louisville's problem stems from the unfortunate meteorological conditions of the Ohio River Valley, which is prone to stagnant air conditions but also that the lack of tree cover in the urban core contributes as well. Stone states that

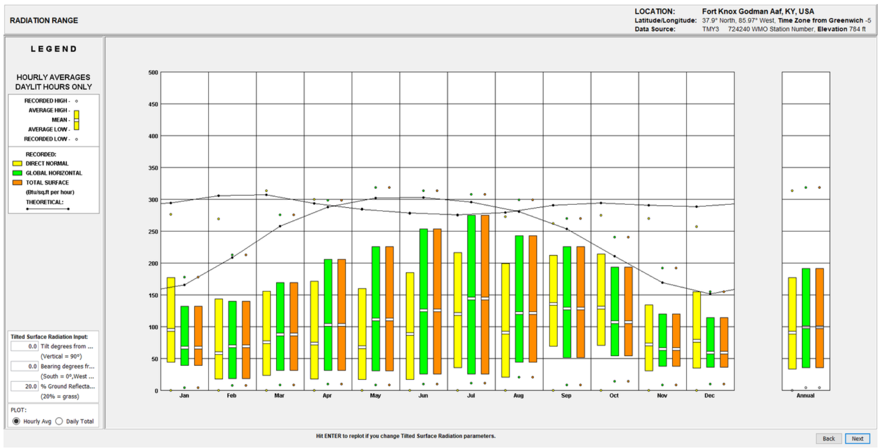


Figure 4: CC Radiation Range

> “The tree canopy downtown is one of the sparsest of any city I have seen in the country.”

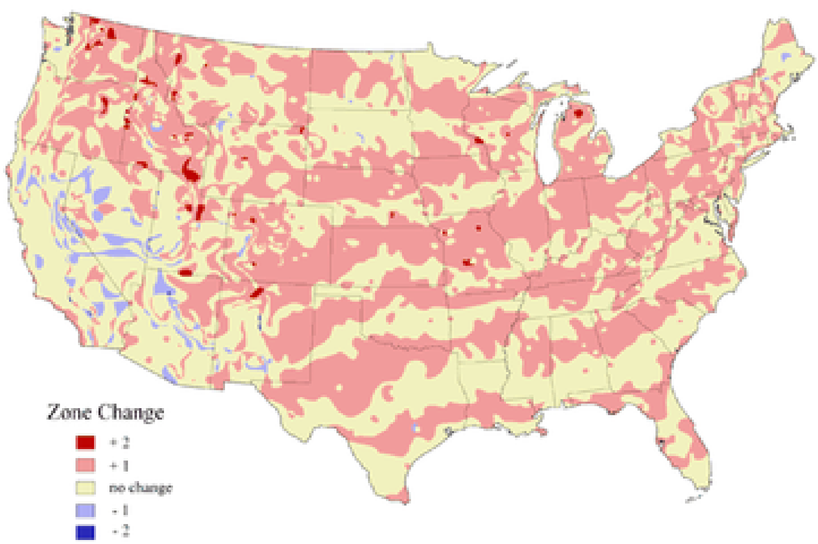


Figure 5: Differences between 1990 USDA hardiness zones and 2006 arborday.org hardiness zones reflect warmer climate

The tree cover in Louisville’s larger metro area is around 30 percent, according to Stone’s research, with the urban core at just 10 percent. That compares to about 45 percent in the city of Atlanta.

Air pollution is trapped in Louisville’s Ohio River Valley location. The city is ranked by Environmental Defense as America’s 38th-worst city for air quality.

2_Vernacular Architecture

American colonial architecture includes several building design styles associated with the colonial period of the United States, including First Period English (late-medieval), French Colonial, Spanish Colonial, Dutch Colonial, and Georgian. These styles are associated with the houses, churches and government buildings of the period from about 1600 through the 19th century.

2a_Origins and Survival of Netherlandic Building Traditions in North America

In 1621, the Dutch West India Company (WIC) received its charter from the States General for parts of West Africa, South America, the Caribbean, and a section of North America, to interfere with Spanish interests .

In 1624, the WIC did make its first serious attempts to settle its North American territory, known as New Netherland, to establish the permanent fur trade with the American Indians of the region .

The forty years of Dutch rule of New Netherland ended with the surrender of the colony to the English on September 8, 1664. Regardless of the fact that the English took control of the territory, signs of Netherlandic culture lasted well into the eighteenth century. Its most visible manifestation is the so-called Dutch Colonial architecture.

Figure 6: Four examples of Dutch Colonial Architecture. Top left to bottom right: Zabriskie, Van Alen, Van Schaick, and Wyckoff houses (Image in lower left corner courtesy Historic American Building Survey)

Fig. 6 shows just four examples of buildings associated with the Dutch Colonial style. The variety of building types labeled Dutch Colonial in North America is extensive. Builders utilized, brick, stone, and frame as building materials, and both gable and gambrel roofs as roof types—both roof types come with or without so-called flared eaves.

Unfortunately, there are no known surviving buildings from the initial period of settlement (circa 1624-1664), but we can learn a great deal about the architecture from the surviving colonial manuscripts.

The contracts specified in those manuscripts the construction of both dwelling houses and housebarns. The housebarn was a common multipurpose agricultural building in the Netherlands, providing shelter for the farmer and his family, his farmhands, and his livestock, and storage room for his crops.

Figure 7: The Hansford B. Ferguson House

Figure 8: A detail of the intricate balustrade and frieze on the porch.

Creek beds are the original roadways of many rural Kentucky communities, and this frame T-plan house was constructed facing the creek, which served as the main path in and out.

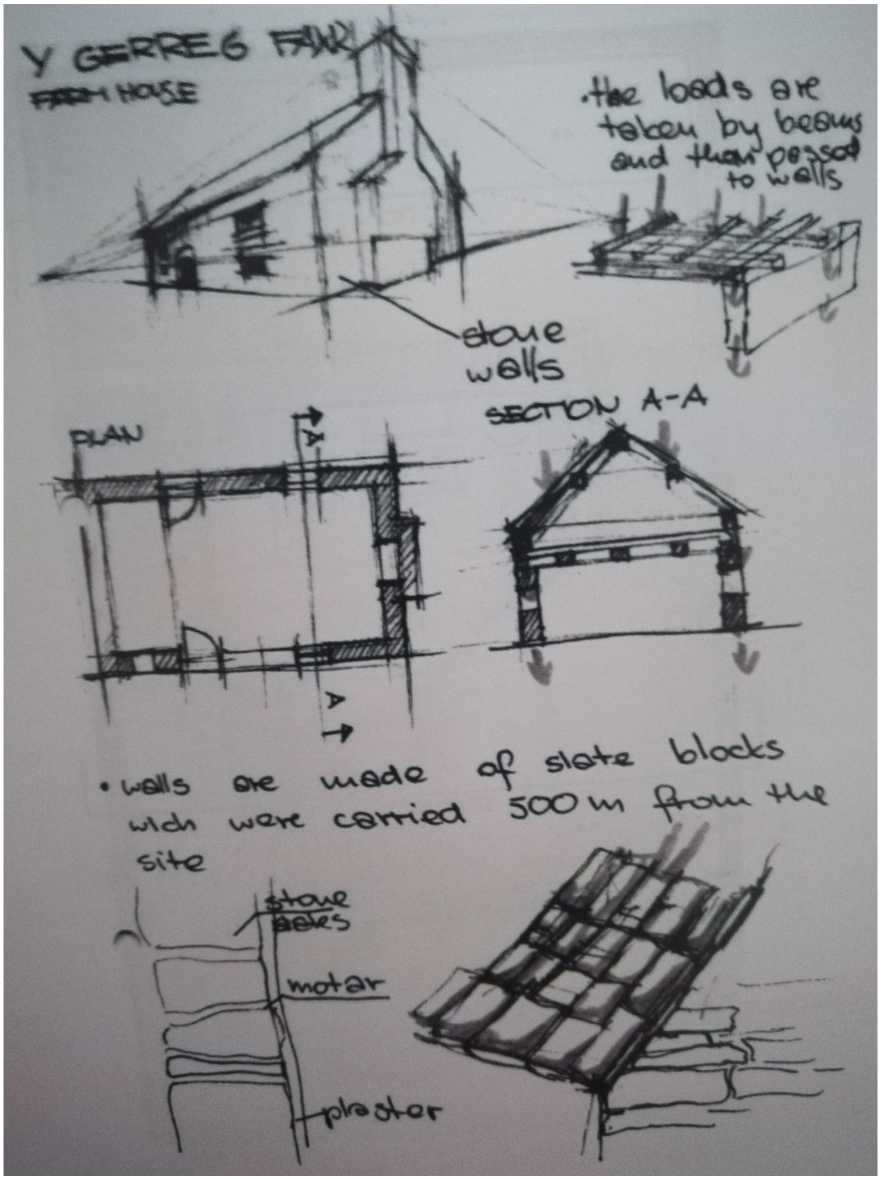


Figure 9: Materials and Typology of Construction

Is a T-plan a house. Although T-plan is the name we use in Kentucky, terminology depends on geographic location – some folks call this type a "gable and wing." It is essentially a central passage plan with one room flanking the central hall moved forward, resulting in the plane of the facade being broken, or uneven. It gained the house another room without changing what had become a favorite house type (the central passage) in rural Kentucky.

A log house occupied this creek side site originally, but between 1913 and 1917, Hansford B. Ferguson had this two-story house built, with porches on the front and along the back.

It was a substantial house, with plenty of room for the Ferguson family – in 1920, Hansford, a farmer, and

Figure 10: Hansford B. Ferguson built this house on Cindas Creek. He is standing in front of the original facade. Photograph courtesy of Timothy Ferguson.

his wife, Junie, had five children. The house had a two-story porch on the front, with lovely spindlework, a holdover from the late-19th century.

Hansford's home, as it stands above the creek, is a poignant reminder of so many similar Kentucky houses and families over the years.

2b_Vernacular Architecture as a 'Laboratory'

They are comprehensible due to their often simple forms and resourceful use of materials and technology. Vernacular architecture tends to respond to climatic condition using passive, low-energy strategies to provide for human comfort- strategies are integral to the form, orientation and materiality of the buildings. This architecture also demonstrates an economical use of local building resources and is, therefore, an ideal resource for teaching sustainable design.

Some principles of passive solar design remain the same in every climate. An important aspect of good passive solar design is that it takes advantage of the opportunities at the specific site. So, many fundamental aspects of passive solar design will depend on the conditions in a small local area, and even on the features of the building site. Considering Fort Knox, we have:

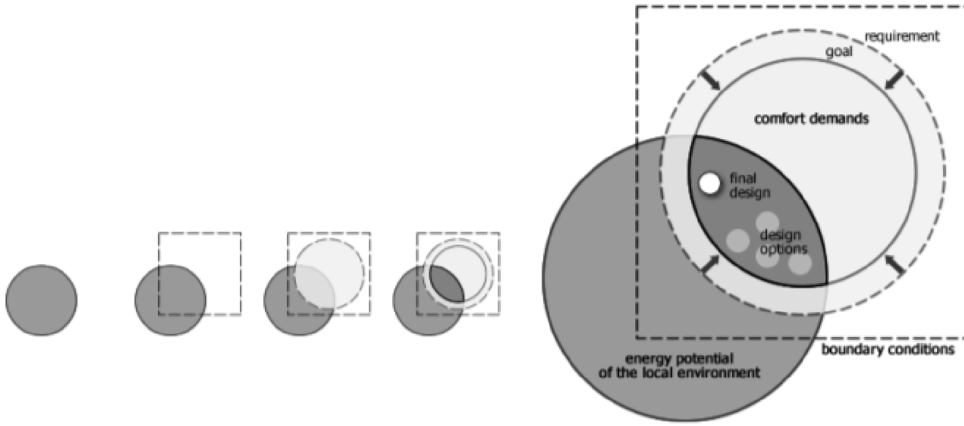


Figure 11: Design Through Environment

	contextual		architectural			technical
	site planning	building form and layout	building structure	building skin	building finish	(integrated) building services
passive solar heating			thermal storage wall	direct solar gain sun space		warm air collector
solar shading	shading from on-site vegetation		structural shading device	smart glazing* external solar shading light shelf*	printing	
solar driven ventilation				solar chimney		
natural illumination				smart glazing* translucent insulation* transparent openings		light pipes optical fibres
solar hot water						solar thermal collector
solar power						photovoltaic cell
night-sky cooling						
natural air cooling	cooling from shaded areas cooling from water bodies					
wind driven ventilation				wind catcher		
wind power						urban wind turbine
earth-coupling	earth shelter*		direct earth-coupling energy piles	earth shelter*		deep-layer earth coupling* ground-coupled ventilation

- *Energy Conservation*:

insulation levels, control of air infiltration, glazing type and location. mechanical equipment and energy efficient appliances.

The most important measures for improving the house's basic ability to conserve the heat generated either by the sun or by the house's conventional heating system are in the following areas:

* Insulation * Air lnfiltratlon * Non-solar glazing

geothermal hot water						**deep-layer earth coupling***
evaporative cooling				**roof pond**		
thermal conservation		**air lock compact design thermal zoning**		**adaptable insulation airtightness thermal shutter translucent insulation* wind screening**		
thermal buffering			**thermal mass thermo-activation***		**phase change material**	
thermal distribution			**hollow core ventilation thermo-activation***	**cavity wall heating**		
daylight distribution				**Light-redirecting glazing** [prismatic elements, laser cut panels, holographic films, holographic optical elements] **light shelf***		**optical fibres**
transmission heat recovery				**boundary wall heat recovery dynamic insulation**		
ventilation heat recovery						**breathing window**
grey water heat recovery						
thermal energy storage						
hot water storage						

- *Suntempering*:

a limited use of solar techniques; modestly increasing south-facing window area, usually by relocating windows from other sides of the house. but without adding thermal mass.

North windows should be used with care. Sometimes views or the diffuse northern light are desirable, but in general north-facing windows should not be large. Very large north -facing windows should have high insulation value, or R-value. Since north windows receive relatively little direct sun in summer, they do not present much of a shading problem. So if the choice were between an average-sized north-facing window and an east or west facing window. north would actually be a better choice, considering both summer and winter performance.

East windows catch the morning sun. Not enough to provide significant energy, but, unfortunately, usually enough to cause potential overheating problems in summer. If the views or other elements in the house's design dictate east windows, shading should be done with particular care.

West windows may be the most problematic, and there are few shading systems that will be effective enough to offset the potential for overheating from a large west-facing window. Glass with a low shading coefficient may be one effective approach for example, tinted glass or some types of low-e glass which provide some shading while allowing almost clear views. The cost of properly shading both east and west windows should be balanced against the benefits. As many windows as possible should be kept operable for easy natural ventilation in summer.

- *Solar Architecture*:

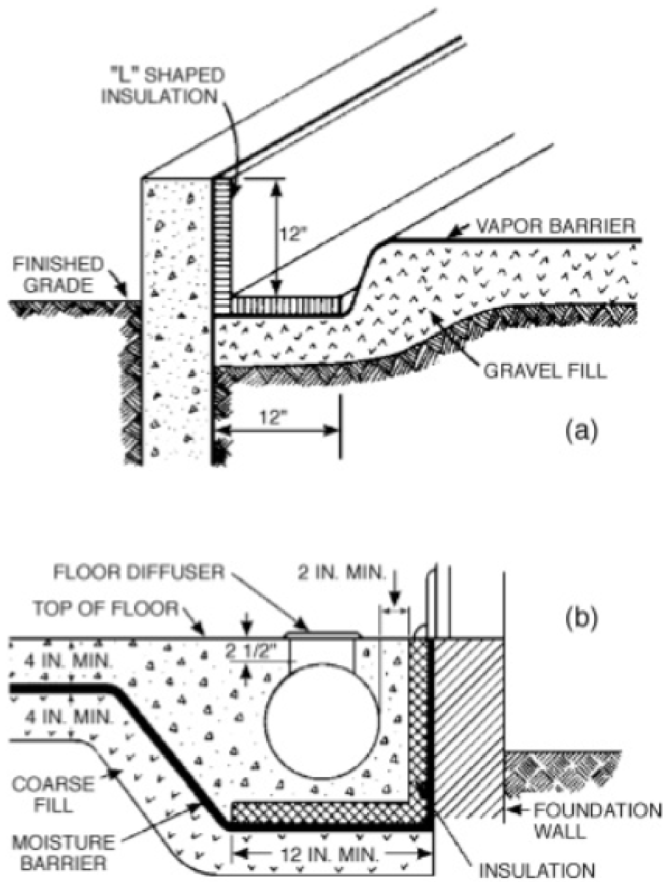


Fig. 3. Details at perimeter for below floor air distribution

Figure 12: Insulation Basement

going beyond conservation and suntempering to a complete System of collection, storage and use of solar energy: using more south glass, adding appropriate thermal mass, and taking steps to control and distribute heat energy throughout the house.

The ideal orientation for solar glazing is within 5 degrees of true south. This orientation will provide maximum performance. Glazing oriented to within 15 degrees of true south will perform almost as well, and orientations up to 30 degrees off - although less effective - will still provide a substantial level of solar contribution. In Louisville, magnetic north as indicated on the compass is actually one degree east of true north, and this should be corrected for when planning for orientation of south glazing.

- Natural Cooling:

using design and the environment to cool the house and increase comfort, by increasing air movement and employing shading strategies.

The essential elements in a passive solar house are south facing glass and thermal mass. In the simplest terms, a passive solar system collects solar energy through south facing glass and stores solar energy in thermal mass - materials with a high capacity for storing heat (e.g., brick, concrete masonry, concrete slab,

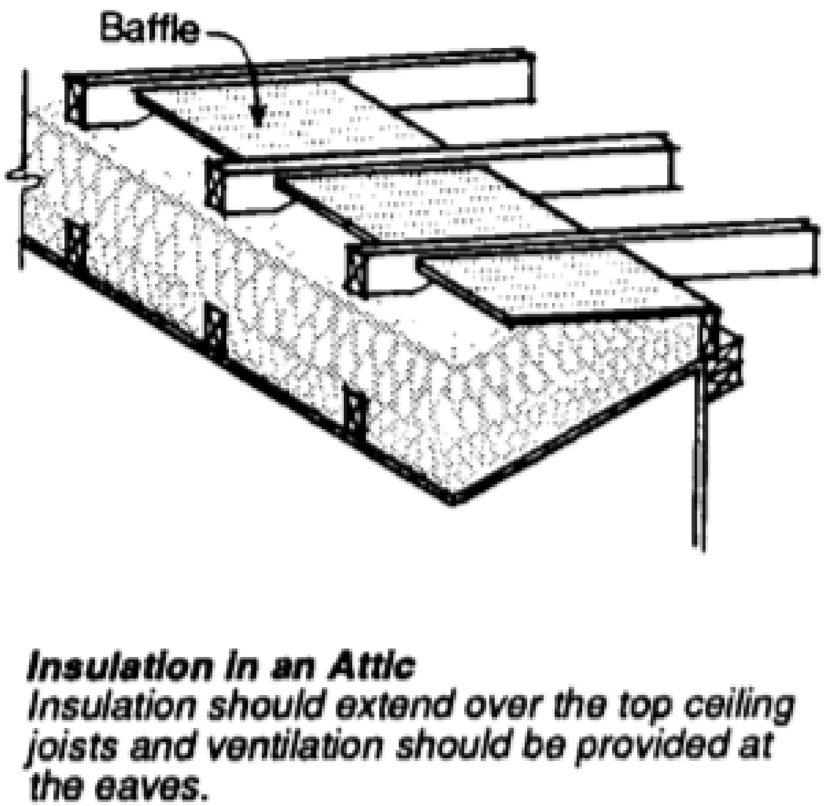


Figure 13: Insulation Roof

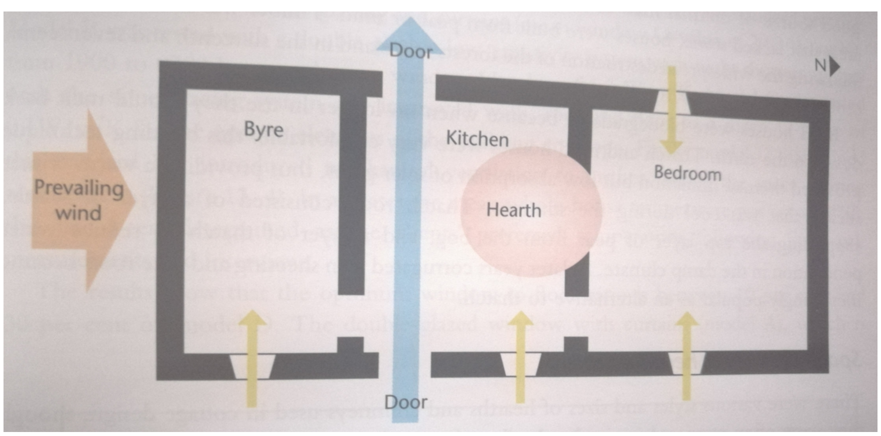


Figure 14: Design Scheme

tile, water). The more south facing glass is used in the house. the more thermal mass must be provided, or the house will overheat and the solar system will not perform as expected.

Thermal Mass Some heat storage capacity, or thermal mass, is present in all houses, in the framing, gypsum

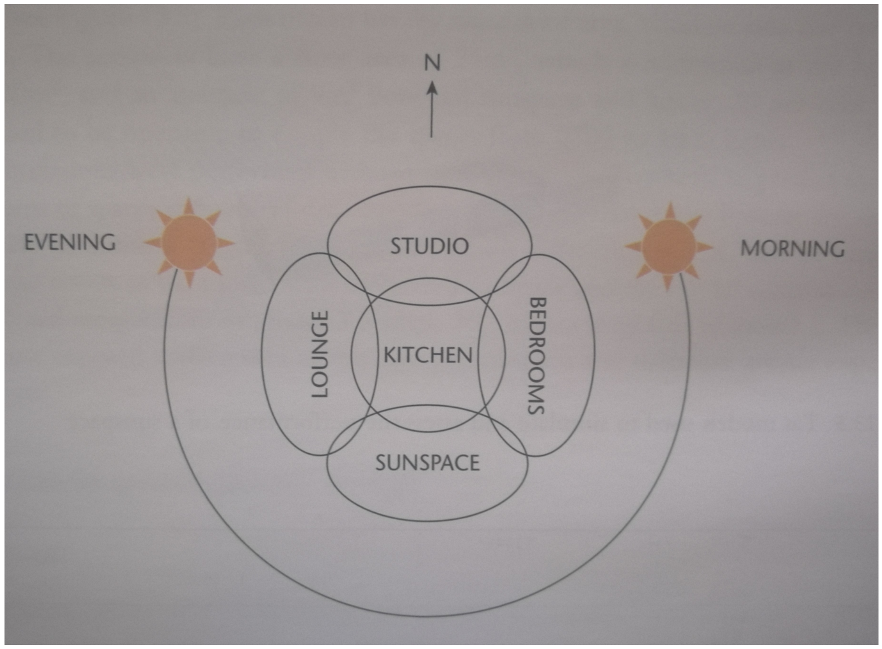


Figure 15: Solar Architecture

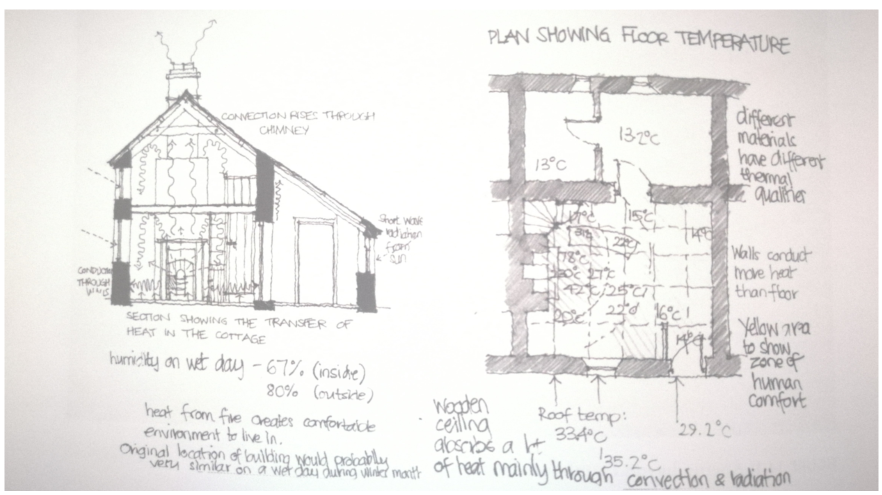


Figure 16: This is a caption

wallboard, typical furnishings and floor coverings. In suntempered houses, this modest amount of mass is sufficient for the modest amount of south-facing glass. But more thermal mass is required in passive solar houses, and the question is not only how much, but what kind and where it should be located.

2c_Design Strategies and the Psychrometric Chart

Psychrometric chart used to define what sustainable design strategies can be best used to improve occupant comfort.

When data points fall to the right of the comfort zone, you will want to reduce the air temperature. An example strategy to achieve this would be to increase air flow with natural ventilation. When data points fall to the left of the comfort zone, you will want to increase the air temperature. A common strategy to do this passively is to incorporate solar heat gains with high thermal mass materials. When relative humidity is too low it can be increased with evaporative cooling. And when it is too high it can be decreased with the use of desiccants. An example of how this sort of analysis could be done is demonstrated below. Climate Consultant was used to generate all the charts.

3_Climate Responsive Architectures

3a_The Green Building / (fer) studio

The Green Building in Louisville, Kentucky, was home to a dry-goods store for decades starting in the 1890s. In its adaptive reuse, the building is now designed to outperform Kentucky energy codes by up to 65 percent. A semi-enclosed outdoor courtyard is partially shaded by a canopy of 81 solar panels.

> - The masonry shell was sealed with inert recycled insulating materials.
> - The original window openings, that had been filled in with cinder blocks, were restored with low-e insulated glass.
> - Geothermal heating and cooling system; an 1,100-gallon (4,200-liter) ice storage cooling system; an energy-recovery unit;
> - Vegetated roof;
> - Rainwater collection for irrigation;
> - Daylighting and views in 95 percent of regularly inhabited spaces;
> - Exterior louvers on the south side for sun mitigation;
> - Use of recycled-content materials;
> - Reuse of bricks;
> - Reuse of existing old-growth wood members for framing, flooring, and furniture.

Located in the city's distressed East Market district, The Green Building has helped revitalize the area with a gallery, event space, offices, conference room, and cafe.

Designed by Los Angeles-based (fer) Studio and developed and owned by Gill Holland and his wife Augusta, The Green Building has not only spawned the redevelopment of the run-down East Market area of Louisville into a "locally grown" strolling arts district, but it has also resulted in a new name for the district—NuLu—"New Louisville."

Holland purchased the 115-year-old former dry goods store in 2006 intending to upgrade it for mixed use. His green aspirations were stimulated

> "when visiting Iceland which runs off geothermal and seeing the grass-covered Viking-type houses in the Norwegian countryside,"he remarks.

A longstanding friendship with (fer) Studio's Douglas Pierson, AIA, led Holland to bring the firm on as architects. Pierson and his partner Christopher Mercier, AIA, had met at Frank Gehry Associates and subsequently founded their own firm.

On the ground floor of the building, a long circulation corridor extends front-to-back, drawing visitors inward to a dramatic three-story atrium lobby at the center of the building, which provides access to the upstairs, an art gallery, and an indoor/outdoor gathering space at the back.

> “Design-wise the lobby is very democratic—anyone can see it and access it,” says Pierson.

Also three stories high, the circulation spine brings light and views inside with floor-to-ceiling glazed volumes, revealing the rough underpinnings of the original structure.

The building was substantially gutted and renovated, but the main masonry structural shell, “once covered up for a century” says Pierson, remains intact.

Much of the original wood was removed and corn-blasted (pulverized corn was put into sand-blasting equipment and the joists were pummeled).

> “The corn blasting was as effective as sand blasting and the look was better,” commented Peters. Holland was amazed at the rustic joists and joked that “George Washington was around when that tree started growing.”

The architects juxtaposed the old with a new modern core such that “the contemporary nature of the interventions is revealed as a procession,” explains Mercier. This journey through time is completed with clerestory windows at the top, “becoming the opposite of the historic facade at the front,” he continues. Bifurcating the existing roof into two planes sloped in opposing directions created a scissor-shape. “The existing roof slopes down and the new roof sloping up creates a new rear facade curtain wall that cascades down to a green roof,” says Mercier.

The lobby was set in the middle of the building to provide for the street-side restaurant. But because it occupies the core of the building, it could double as a heat sink—energy performance occurred as a result of design. Once that codependent pattern was established, other strategies fell into place. “The lobby became the nerve center for collection and distribution of the energy systems. Its integral mechanical room directly below became the convergence of energy storage, geothermal, energy recovery, and radiant heat,” Pierson explains.

Green interventions are plentiful and include natural lighting and ventilation, eco-friendly materials, 81 PV panels, an ice storage system, and 12 geothermal wells. Shaded by PV panels, the indoor/outdoor space features a green wall. The project has had enough points approved to achieve LEED Platinum but final certification awaits resolution on six additional points.

Development, including a green farmer’s market, continues in NuLu. Holland owns or is part owner of 16 existing buildings, which are either being renovated or will be. For him, the building is a long-term investment.

> “The geothermal will pay off in 5 to 6 years and the solar has a 14-year payback. I’m all about the economics of green,” he says. With the owners planning to occupy the building for the rest of their lives, that logic works.

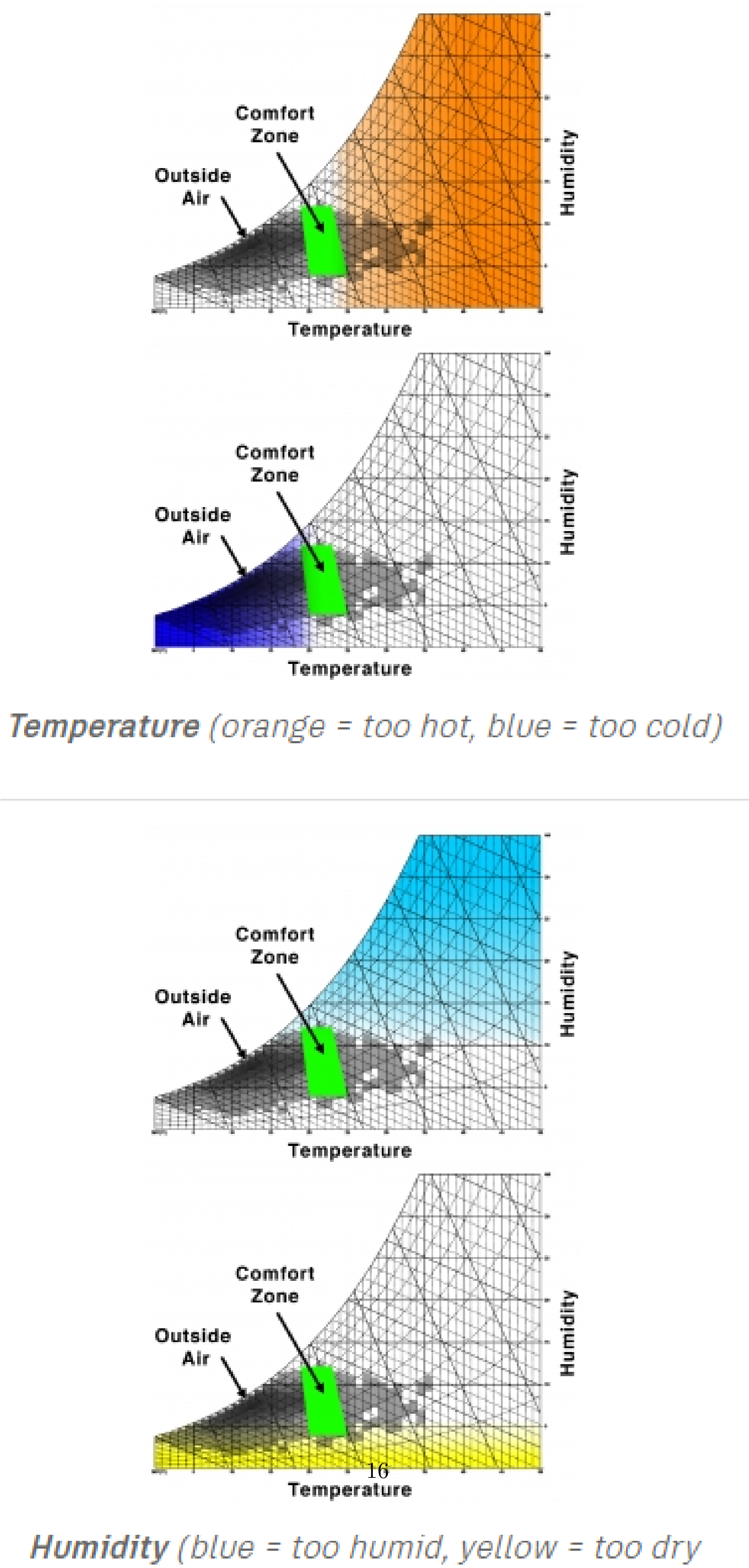


Figure 17: This is a caption

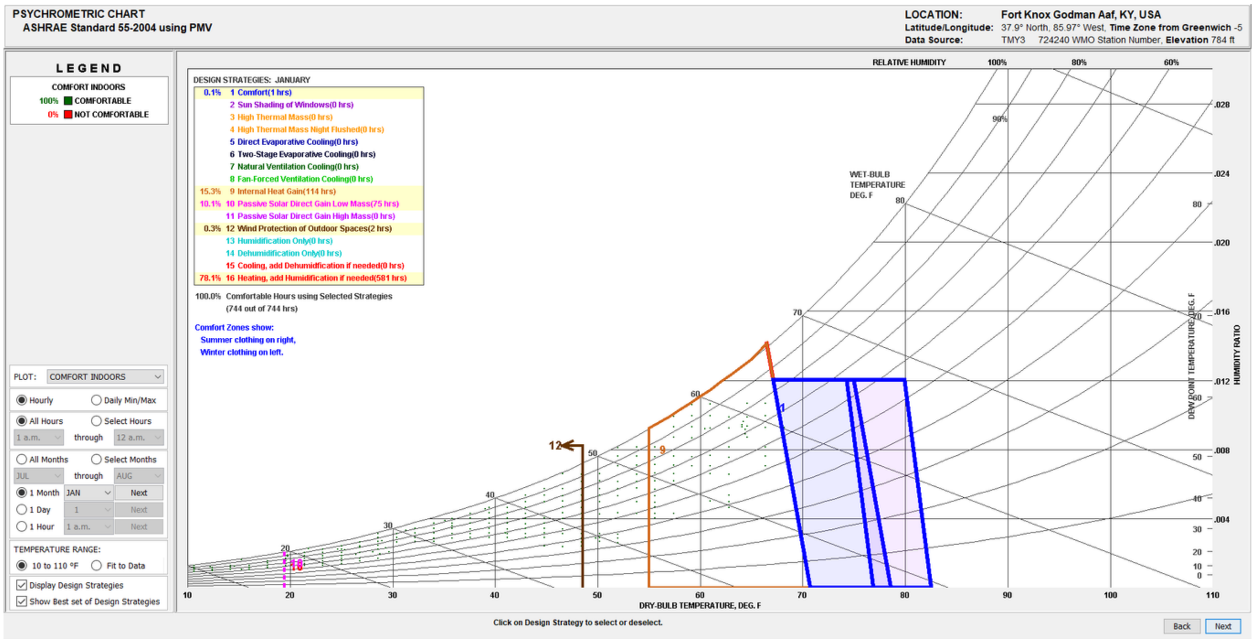


Figure 18: Psy. for January

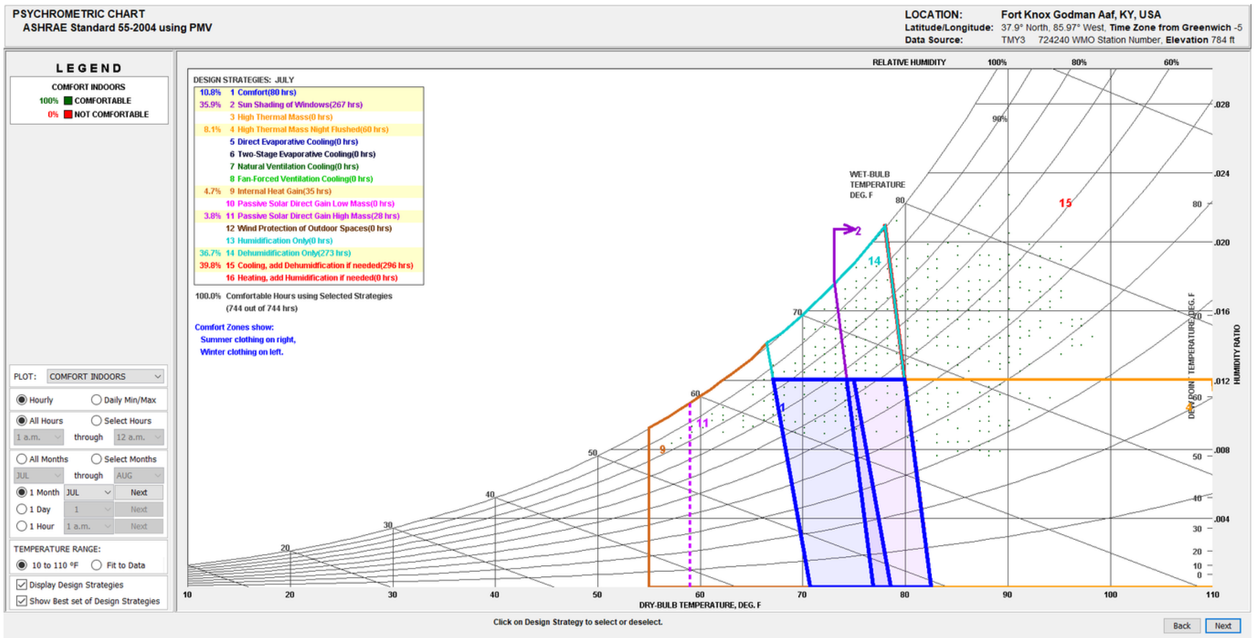


Figure 19: Psy. for July

Figure 20: The Green Building : Innovative Re-Use Design

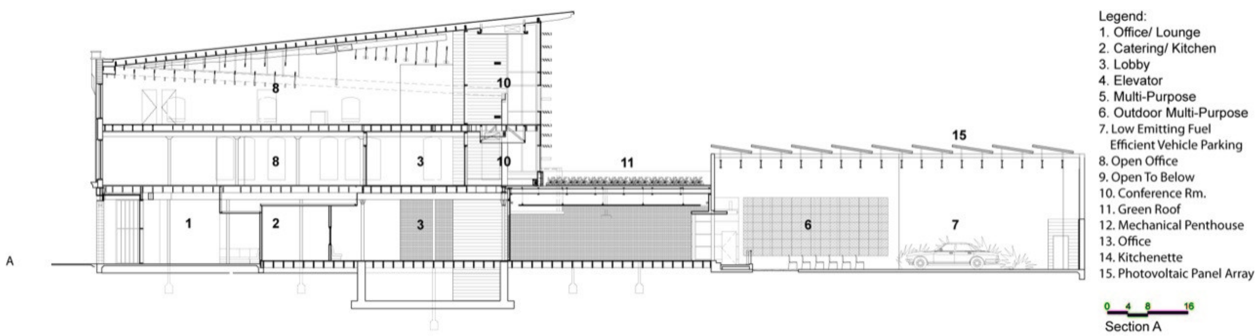


Figure 21: Longitudinal Section

Figure 22: Shading System

Figure 23: Structural Scheleton