THERMAL COMFORT IN GREEK REVIVAL HOUSES IN TEXAS: A Computerized Energy Simulation

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Introduction

The appeal of the Greek Revival style in America through the 19th century reflected the political spirit of the newly independent United States. It expressed the sentiment that America, with its democratic ideals, was a spiritual successor of ancient Greece. These strong feelings were evident not only in architecture, in naming of new towns, and in education, but were also part of the general culture of the period founded on classic myth, literature, and art. The archeological expeditions in Greece and their publications in American journals of antiquities (Hamlin 1964; Wiebenson 1969; Poppeliers et al. 1983; Kennedy 1989; Sutton 1992; Lane 1996) reinforced this cultural trend.

The Greek Revival style became one of the first in a succession of national styles that attempted to erase the regional boundaries previously marked by vernacular types. This attempt was reinforced by the many publications of popular carpentry/architectural books, such as, Lafever Minard's books (*Modern Builder's Guide,* 1833, and *The Beauties of Modern Architecture*, 1835) and Benjamin Asher's books (*The Practice of Architecture*, 1833, and *The Builder's Guide,* 1837). The pattern books guided builders how to build a Greek Revival house and revealed the aesthetics of this style in America. The books not only developed the domestic Greek Revival style, but also displayed a freedom in using the style's details.

The adaptation of the Greek temple front in United States houses during the 19th century usually employed a symmetrical white painted facade designed on the basis of one of the classical orders (i.e., Doric, Ionic, Corinthian) and included pediment gables, wide cornices with unadorned friezes, and horizontal transoms above entrances.[1]

However, since the interpretation of the recommended details was influenced by local political, economical, cultural and environmental conditions, the style was never, anywhere, 'pure'. As a result, the Parthenonic form lent its pediment front and portico to the architecture of the northern states, and its white columns and simplicity to the southern and western states (Kennedy 1989; Lane 1996). The style's plan and elevations were ideally suited to the traditional plan and gable-roofed houses in America. It became a logical continuation of the traditional Georgian style room layout in the northeast and of the simplified form of the dogtrot and early frame house in Texas. Very often the existing houses were modified to fit the style. A Greek colonnaded portico was added as an entrance, the windows were enlarged and symmetrical aligned, and the ceiling was heightened. Since the porch, the windows, and the high ceiling were already part of the traditional building pattern of Texas, built to accommodate the harsh summer conditions (Geva 1995a; 1995b), they were easily altered with Greek Revival details. (Hamlin 1964; Drury 1984; Sutton 1992).

While the literature acknowledges the Greek Revival style as a reflection of politics, socio-economic status, and fashion, the relationship of

[1] For additional review of the style see Hamlin (1964); Poppeliers et al (1983); McAlester (1991); Sutton (1992); Lane (1996).

this style and regional climatic conditions that determined the extent of comfort in these houses usually appears merely as an observational note that addresses the practical grounds of the style.

The objective of this paper is to fill the limited empirical basis offered by these observations and to examine how Greek Revival houses responded differently to regional climates. Specifically, the study posits that Greek Revival houses of the 19th century are more compatible with the hot-humid climate of southeast Texas than with the cooler climate of the northeast where this style originated.

In pursuing this objective the study analyzes two pairs of 19th century Greek Revival houses. Each pair consists of one house originally constructed in Texas and the other constructed in New York. The study tested the extent of the compatibility of the style with each specific climate utilizing a multi-method approach that incorporates two methods: a qualitative morphological analysis and a quantitative empirical methodology of computerized energy simulations.

The Sample Houses

The study analyzes two pairs of 19th century Greek Revival houses. Figure 1 shows the first pair of the Oliver Culver House (1818) built in Rochester, New York (top) and Matthew Cartwright House (1840) built in San Augustine, Texas (bottom). Figure 2 shows the second pair of Elihu Kirby house (1840) built in Henrietta, New York (top) and Governor Joseph D. Sayers House (1868) built in Bastrop, Texas (bottom).

Figures 1 and 2

The selection of the sample houses was based on the following four criteria:

(a) the houses within each pair are similar in their Greek Revival architectural features Similar Greek Revival architectural features both in plan and elevations.

(b) The construction period: 19th century when the style was originated and was popular all over the nation. In addition, this criterion eliminates buildings that were constructed with mechanical heating, ventilation, or electrical systems.

(c) The climatic regions: two of the houses are located in a cold region (up-state New York) and the other two are in a hot-humid region (east and south central Texas).

(d) Availability of Historic American Buildings Survey (HABS) drawings and pictures[2].

Procedure

The research proposition that the Greek Revival houses are more compatible with the hot-humid climate of Texas than with the cooler climate of New York is tested by two methods: a qualitative morphological analysis that evaluated the design of the houses along accepted architectural design guidelines for hot and cold climates; and a quantitative analysis in the form of computerized energy simulations. This proposition is formulated in the following two equations:

(1) For the houses of New York: $\mathbf{X_{(i)}V > X_{(i)}A}$

(2) For the houses of Texas: $\mathbf{X_{(i)}A > X_{(i)}V}$

The study tested each house in its actual site in Texas or New York (denoted as 'A' in the equations) and as if "transplanted" to the other location in Texas or New York -- the house's virtual (simulated) site (denoted as 'V'). The $X_{(i)}$ represents the two dependent variables in the study: $X_{(1)}$ the compatibility of the house with the regional morphological guidelines, and $X_{(2)}$ the energy performance of the house as calculated by the simulations.

Morphological Analysis of the Houses

Several design guidelines and architectural strategies were developed to accomplish thermal comfort in buildings constructed in different climate zones (Olgyay 1963; Brown 1985; Lechner 1991). These guidelines usually refer to site layout (i.e., orientation), building form and

[2] The analyses were performed only on the original 19th century houses.

geometry, construction and finish materials, and architectural details. Lechner (1991) suggests an explicit summary of the preferred conceptual design strategies for each climate zone. His design guidelines for the cold and hot-humid zones are used in this study.

The design guidelines for cold region (New York) include three major recommendations: keep the heat in, and cold temperatures out; protect the house from the cold winter winds which usually come from the West and Northwest; and use heavy masonry walls painted dark on the exterior to lengthen the time scale of heat transmission.

The design guidelines for hot-humid region (Texas) consist of three major recommendations: provide natural ventilation for cooling and removal of excess moisture; protect the house from sun and rain; and use lightweight construction materials (i.e., wood) painted white due to the small difference in temperature between night and day and to reflect the heat.

Each house of the study has been evaluated against the design recommendations for both climates using an ordinal ranking which seems appropriate for the qualitative nature of this analysis. A greater climatic comfort can be achieved in a house that fulfills most of the design strategies for the specific climate.

Figures 3 and 4 illustrate the floor plan of the two pairs respectively. All four houses are arranged around a main hall that opens to the rooms and to the front and back entrances. In addition, each room consists of maximum windows and doors for cross ventilation.

Figures 3 and 4

All four houses are wood frame buildings (lightweight materials) with white painted wood clapboard siding on the exterior walls. The bright paint reflects the sun.

All four buildings have horizontal and vertical transoms lighting at the entrance door, and rectangular windows with six lights in each of the double-hung sashes.

The Culver and Cartwright houses both are two story buildings with a small entry portico that does not extend the full height and width of the façade (see Figure 5). The porticoes include four or two Doric columns and have a front pediment. The houses are built with an end-low gable roof with wide trims.

Figures 5

The Kirby and Sayers houses are one-story buildings,[3] with an entry portico that extend the full height of the facade, but not the full width. (see Figure 6). The porticoes include four Doric columns and have a front pediment. These houses have a low hipped roof with wide bands of trim.

Figures 6

Table 1 and 2 summarize the extent of compatibility of each of the four houses with the design guidelines for cold climate (New York) and hot-humid climate (Texas), respectively. The buildings were rated as fulfilling a given criterion (√), partially fulfilling a specific criterion (0), or as failing to fulfill a given criterion (-). A greater climatic comfort can be achieved in a house that fulfills most of the design strategies for the specific climate.

Tables 1 and 2

As indicated before, all four houses were built with lightweight materials (wood) painted white on the exterior; low pitch gable or hipped roofs; covered porches and porticoes; and maximum windows and doors in each room for cross ventilation. These architectural features are consistent with the recommendations for

[3] The front facade of the Kirby house appears as one story, but actually includes an additional low-ceiling second floor

buildings in hot-humid climates. Moreover, these morphological features should be avoided in houses built in cold areas. As predicted in equation (1), the morphological compatibility of the houses of New York with the climate of the virtual location (Texas) is greater than their compatibility with the climate of their actual location (New York): $X_{(1)}V\{60\%, 70\%\} > X_{(1)}A$ $\{11\%, 11\%\}$[4]. As predicted in equation (2), the morphological compatibility of the houses of Texas with the climate of their actual location (Texas) is greater than their compatibility with the climate of the virtual location (New York): $X_{(1)}A\{100\%, 80\%\} > X_{(1)}V\{22\%, 0\%\}$.

In summary, all four buildings fulfill or partially fulfill most of the criteria of the design guidelines for hot-humid climate, while they fail to fulfill (or partially fulfill) most of the recommendations for cold climate. These findings demonstrate that the Greek Revival design of these houses, regardless of their actual locations (New York or Texas), is more compatible with the hot-humid climate of Texas than with the cold weather of up state New York.

Computerized Energy Simulations

ENER-WIN -- a computerized energy simulation program is used in this study (Degelman and Soebarto 1994, 1995). This software enables to evaluate the comfort level of buildings with and without mechanical systems (HVAC), and lighting. The program performs an hour-by-hour energy simulation based on given climatic conditions, building description and economic data. This software includes a weather database, an envelope materials catalogue, and numerous user profiles based on ASHREA energy efficiency standards.

Two modes of the ENER-WIN program are used in this study. First the *passive system* which applies mainly to structures without HVAC. In this mode, the simulations evaluate the comfort level of the passively heated and cooled buildings. The output of these simulations represents the deviation of the internal conditions of the building from the designated comfort conditions. In other words, to assess the comfort or discomfort of these internal conditions, the simulation provides a summary of total operative temperatures expressed by Discomfort Degree Hours (DDH) (Al-Homoud's 1994). This output implies an inverse relation between the DDH and the compatibility of the building to the local climate.

The second run, the *active system* assesses the energy performance of a building with an HVAC system in energy units and dollars. This run can simulate historic buildings as if they include an HVAC system to indicate how much energy would have been required to achieve a designated thermal comfort in the buildings. Results of the active system simulations show the building's source energy in thousand Btus per square feet (kBtu/sq.ft.)[5] , energy loads in million Btus (MBtus)[6], and energy cost analysis[7] . The more Btus required to maintain thermal comfort, the less compatible the building is to the climate.

Two input files were prepared for each house of the study. One describes the house (the architectural envelope and details, and users' profile) in its original/actual location (i.e., New York or Texas). The second describes the same buildings, but changes the weather data. (e.g. weather data of the New York houses were changed to weather data of Texas, while the weather data of the Texas houses were replaced with weather data of New York). The simulations have been performed twice on each pair of houses using these input files. Utilizing

[4] The percentages in the parentheses express the extent of compatibility of each house with the specific climatic guidelines.

[5] Source Energy: energy consumed by the power plant to produce the total energy used by the building.

[6] The building's cooling/heating loads: how much energy is required to cool or heat the building

[7] Cost's results are not relevant for this study

the simulation program to "transplant" buildings from their actual location to a virtual (simulated) different location, enables to show the extent of climatic compatibility of the houses in different regions (Geva 1994; 1995a; 1997; 1998).

Figure 7 illustrates the findings of the passive system simulation runs. As predicted by equation (1) the houses of New York exhibit a higher comfort level (lower DDH scores) in the climate of the virtual location (Texas) than in the climate of their actual location (New York): $X_{(2)}V\{134,100; 150,400\} > X_{(2)}A\ \{242,100; 217,500\}$. In correspondence to equation (2) the houses of Texas are more comfortable (lower DDH scores) in the climate of their actual location (Texas) than in the climate of the virtual location (New York): $X_{(2)}A\{128,300; 112,600\} >> X_{(2)}V\{205,000; 217,600\}$. All four houses exhibit lower DDH scores in the hot-humid climate of Texas than in the cold climate of New York. Thus, these Greek Revival houses are more comfortable in Texas than in New York.

Figures 7

Detailed analysis of the simulations suggests that the major contribution to the higher numbers of DDH in New York is the discomfort associated with cold temperatures. Naturally, the discomfort due to hot temperatures is higher in Texas. However, the increase in the DDH due to the heat in Texas is smaller than the increase in DDH due to cold in New York. The results show that the Greek Revival houses better accommodate the hot humid than the cold weather conditions.

Figure 8 portrays the results of the active system simulation runs in kBtu/sq.ft In correspondence to equation (1) the energy performance of the houses of New York is better (lower kBtu/sq.ft.) in the virtual location (Texas) than in their actual location (New York): $X_{(2)}V\{47.9; 45.2\} > X_{(2)}A\{120.3; 133\}$. As predicted in equation (2) the energy performance of the houses of Texas (lower kBtu/sq.ft.) is better in their actual location (Texas) than in the virtual location (New York): $X_{(2)}A\{111.4; 142.1\} > X_{(2)}V\{279.3; 381.3\}$. These results corroborate the previous findings of DDH, and show that all four Greek Revival houses are more compatible with the hot-humid climate of Texas than with the cold climate of New York.

Figures 8

Detailed analysis of these simulations also show that the heating was the major contributor to the energy use of all four houses in all locations. The results show that even in Texas the heating load was larger than the cooling load. These findings reinforce the proposition that the Greek Revival style house better accommodates hot-humid conditions than cold climate.

Conclusion

The findings support the research proposition and introduce an additional angle to the study of nineteenth century Greek Revival houses in the south of the United States. It shows that in the south, this style represented not only the influences of politics, status symbols, and fashion, but also became a rational response to regional climate. Since most of the vernacular domestic Greek Revival houses were constructed from wood the study examined the wooden structures. These findings of this paper suggest an additional explanation of the popularity of this style in the south, and support the proposition that the construction of residences in the south was sensitive to local environmental conditions (see more on this proposition in Geva 1994, 1995a, 1995b and anecdotal evidence to that respect in Lane 1996:131). Further investigation should analyze masonry Greek Revival houses in addition to the wooden Greek Revival houses to understand their contribution to the study of the thermal comfort in Greek revival houses in Texas.

Finally, this study highlights two methodological implications. The utility of a multi-method approach to enhance the validity of findings (Frankfort & Nachmias 1995). The rigor of computerized simulations provides quantitative means to test hypotheses and concepts of environmental theories in the context of history and place.

References

Al-Homoud, M. 1994. “Design optimization of energy conserving building envelopes” *Ph.D. dissertation*. College Station, TX: Texas A&M University.

Brown, G. Z. 1985. *Sun Wind and Light Architectural Design Strategies.* NY: John Wiley and Sons.

Degelman, L. Soebarto, V. 1994. “ENER-WIN: A visual interface model for hourly energy simulation in buildings,” Presented at *The E&R '94 Symposium* Prairie View: Prairie View University

Degelman, L. Soebarto, V. 1995. “Software Description for ENER-WIN: A Visual Interface Model For Hourly Energy Simulation in Buildings,” *Proceedings: Building Simulation '95. International Buildings Performance Simulation Association.* (August)

Drury , A. Webb, T. 1984. *Texas Homes of the Nineteenth Century,* 3rd ed. Austin, Texas: The University of Texas Press.

Frankfort -Nachmias, C. Nachmias D. 1995. *Research Methods in the Social Sciences,* 5th ed. New York: St. Martin's Press.

Geva, A. 1994."Computerized Energy Simulation: A Method for Testing Environmental Design Theory." *Proceedings of EDRA 94*

Geva, A. 1995a. "The Interaction of Climate, Culture, and Building Type on Built Form: A Computerized Simulation Study of Energy Performance of historic Buildings". *A Ph.D. Dissertation*. College Station, TX: Texas A&M University.

Geva, A. 1995b. "Whose Vernacular Architecture Is It? Vernacular Architecture of North European Immigrants in the US". Presented at the Annual Meeting of *the Society of Architectural Historians Southeast Chapter* (*SESAH)*), Birmingham, Alabama (November)

Geva, A. Soebarto, V. Degelman, L. 1997. "The Energy "Penalty" for Maintaining A National Image in Chain-Operated Buildings." *The ARCC (Architectural Research Centers Consortium) 1997 Spring Conference Book* .

Geva, A. 1998. “Energy Simulation of Historic Buildings: St. Louis Catholic Church, Castroville, Texas,” *APT Bulletin.* Vol. XXIX, No. 1

Hamlin, T. 1944 *Greek Revival Architecture in America*.. NY: Dover Publications(Reprint, 1964)

Kennedy, R.G. 1989. *Greek Revival America*. NY: Stewart, Tabori & Chang, Inc.

Lane, M. 1996. *Architecture of the Old South: Greek Revival and Romantic*. Savannah, Georgia: Beever Press.

Lechner, N. 1991. *Heating, Cooling, Lighting: Design Methods for Architects*. NY: John Wiley and Sons.

Olgyay, V. 1963. *Design with Climate* Princeton, NJ: Princeton University Press.

Poppeliers, J. Chambers Jr., A. Schwartz, N. 1983. *What STYLE Is It? A Guide to American Architecture.* Washington DC: The Preservation Press.

Sutton, R. 1992. *Americans Interpret the Parthenon: the progression of Greek revival architecture from the East Coast to Oregon, 1800- 1860.* Niwot, Co: University Press of Colorado.

Wiebenson, D. 1969. *Sources of Greek Revival Architecture.* University Park, PA: Pennsylvania State University Press.

Table 1. Summary of the Morphological Analysis for A Cold Region

Design guidelines	Specific criteria	**Culver house (NY)**	**Cartwright house (TX)**	**Kirby house (NY)**	**Sayers house (TX)**
Keep heat in, and cold out	orientation (S or SE)	–	√	–	–
	windows (minimum)	–	–	–	–
	windows (double glazing)	–	–	–	–
	compact design (two stories, basement)	√	0	√	_
Protect from cold winds	enclosed porches	–	–	–	–
	long sloping roofs	–	–	–	–
	tight construction	–	–	–	–
Construction materials	heavy masonry	–	–	–	–
	exterior walls pained dark	–	–	–	–

fulfill (√); partially fulfill (**0**); fail to fulfill (**-**)

Table 2. Summary of the Morphological Analysis for A Hot-Humid Region

Design guidelines	Specific criteria	**Culver house (NY)**	**Cartwright house (TX)**	**Kirby house (NY)**	**Sayers house (TX)**
Natural ventilation	orientation (S or SE)	–	√	–	–
	a crawl space under building	–	√	–	√
	windows, doors (maximum)	√	√	√	√
	ceiling (10' and higher)	–	0	0	√
	roof (low pitch gable or hipped)	√	√	√	√
Protect from sun and rain	plan (parts of building shade other parts)	–	√	–	√
	covered porches, porticoes	√	√	√	√
	shutters	0	√	√	–
	white color	√	√	√	√
Construction materials	lightweight materials (wood)	√	√	√	√

Figure 1. The Oliver Culver House, Rochester, New York (top)
The Matthew Cartwright House, San Augustine, Texas (bottom)

Figure 2. The Elihu Kirby House, Henrietta, New York (top)
Gov. Joseph D. Sayers House, Bastrop, Texas (bottom)

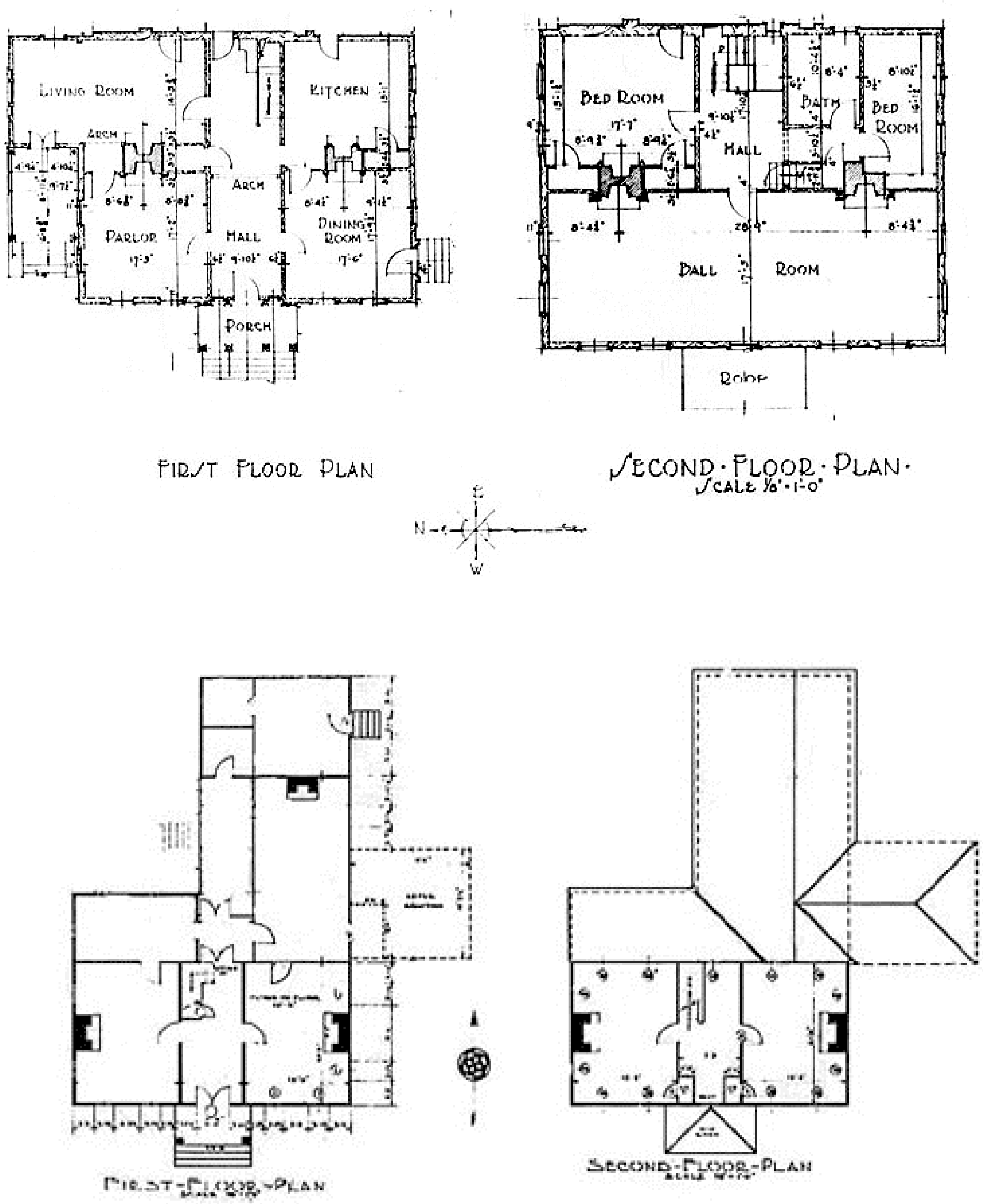


Figure 3. Floor Plan of Oliver Culver House, Rochester, New York (top)
and Matthew Cartwright House, San Augustine, Texas (bottom)

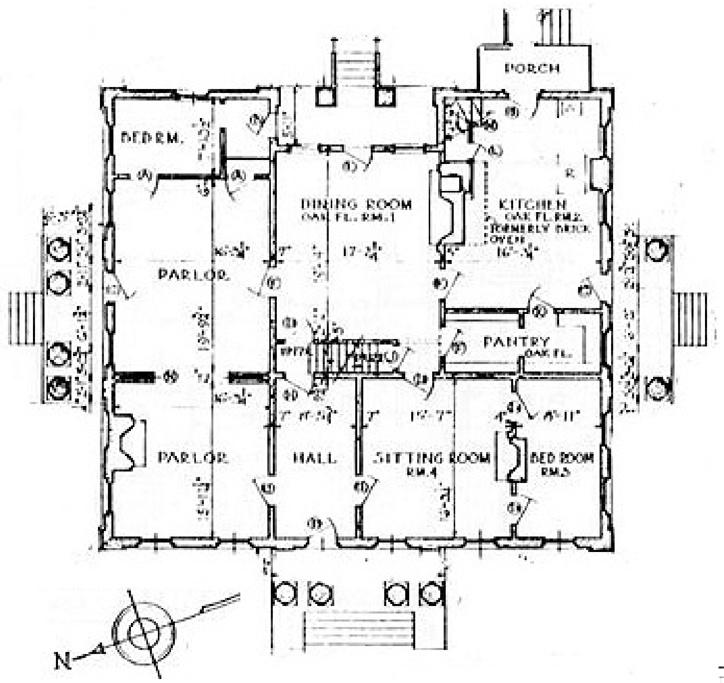
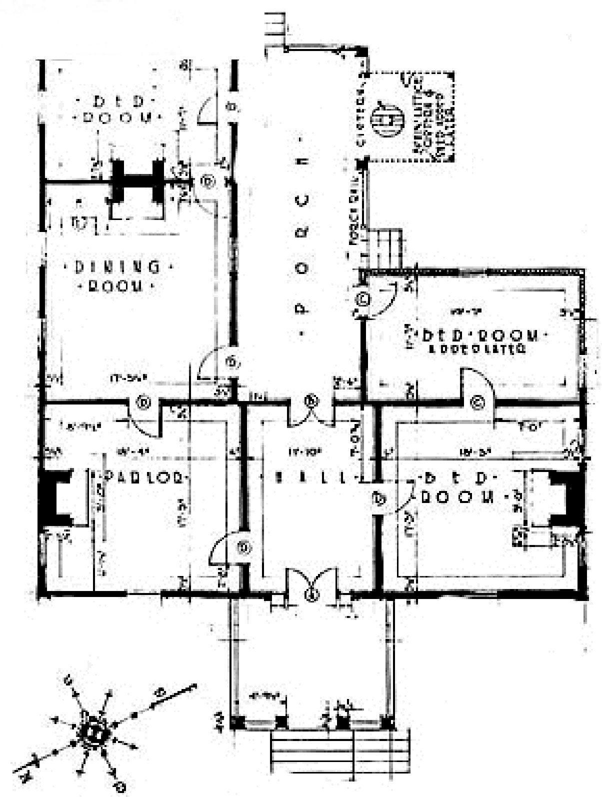


Figure 4. Floor Plan of The Elihu Kirby House, Henrietta, New York (top)
Gov. Joseph D. Sayers House, Bastrop, Texas (bottom)



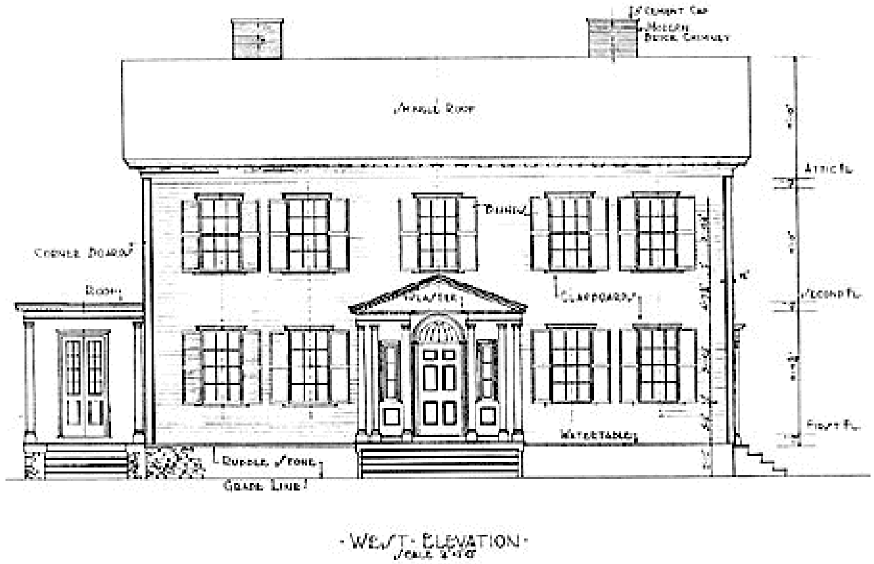
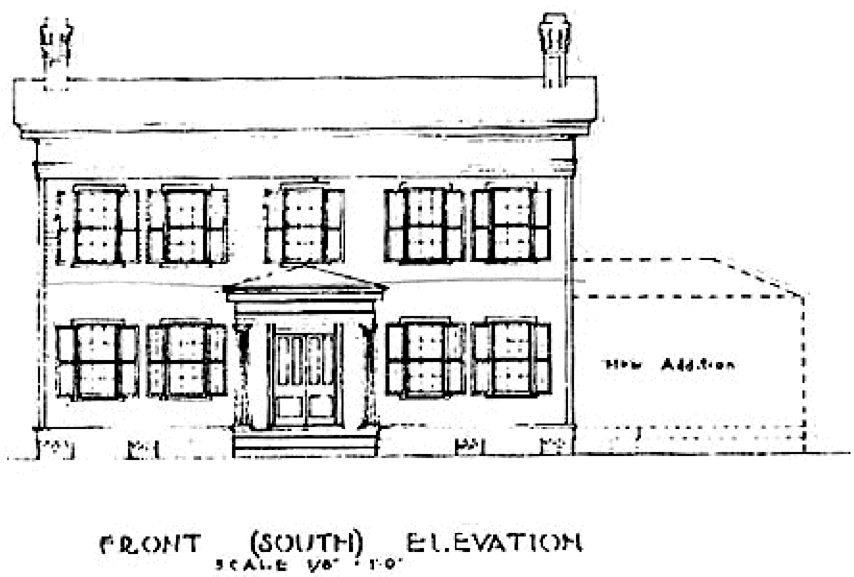
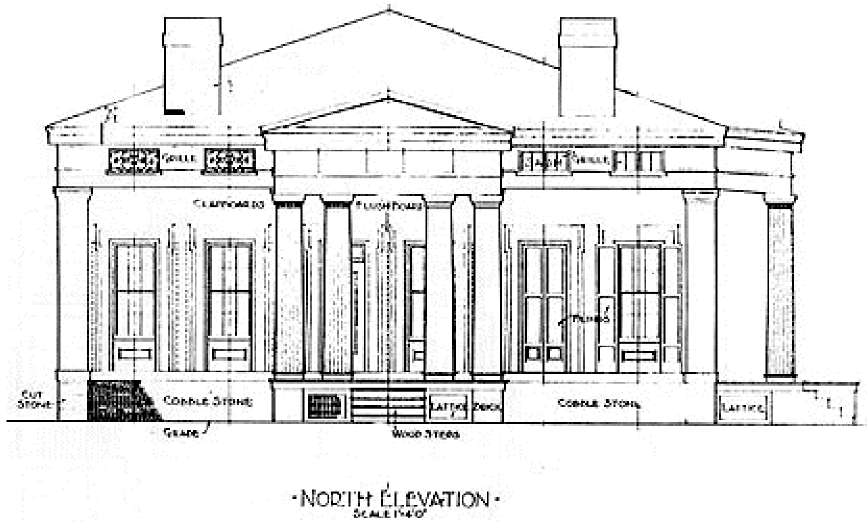


Figure 5.
Front Elevation of Oliver Culver House, Rochester, New York (top)
and
Matthew Cartwright House, San Augustine, Texas (bottom)





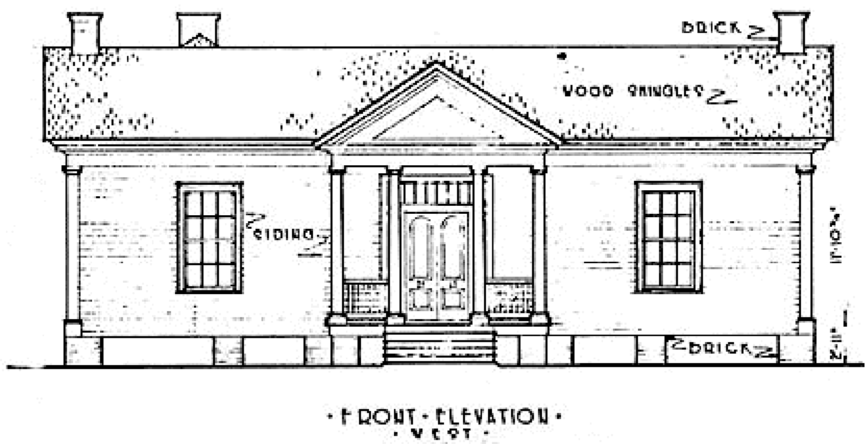


Figure 6. Front Elevation of The Elihu Kirby House, Henrietta, New York (top) The Gov. Joseph D. Sayers House, Bastrop, Texas (bottom)

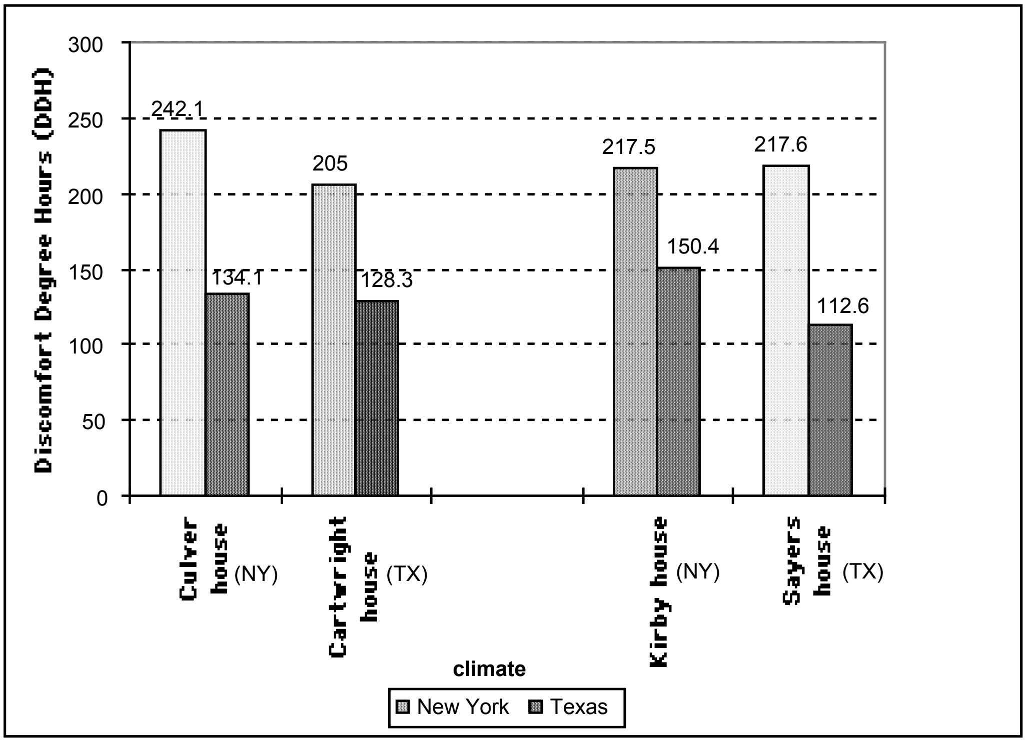


Figure 7. Results of the Passive System Simulation (DDH)

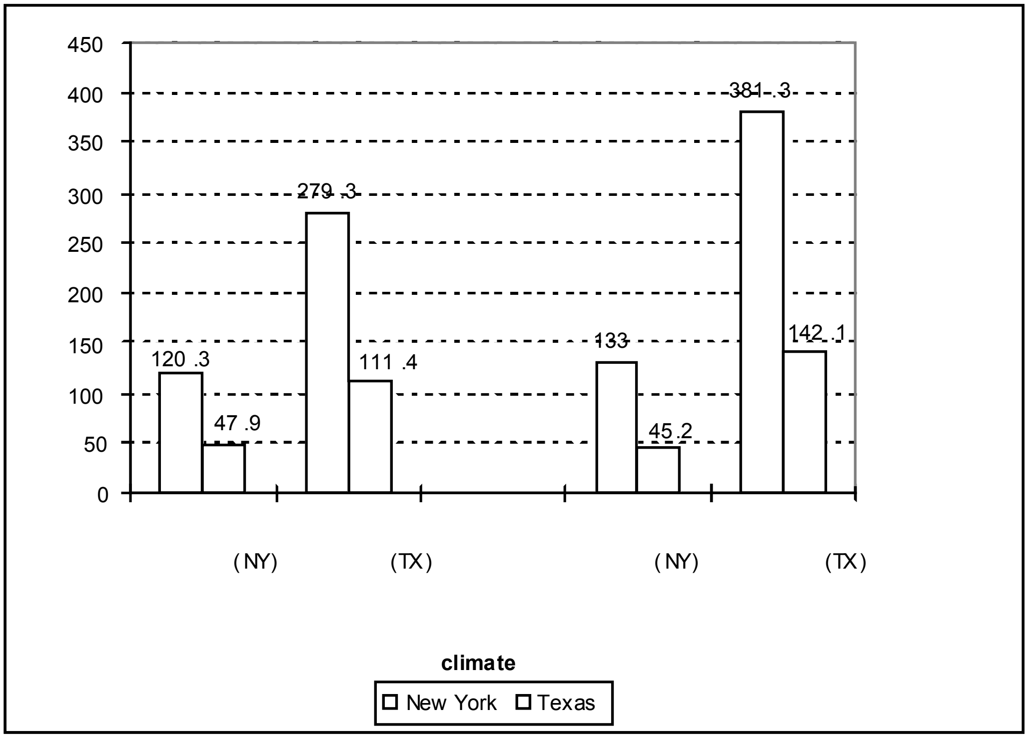


Figure 8. Results of the Active System Simulation (Source Energy in Kbtu/sq.ft.)