Energy Efficient and Culturally Relevant Housing Concepts for Modern Native American Settlements

David N. Benjamin, Ph.D., MNAL, LEED A.P., NCI

Environmental Design Partners, Inc., Gates Mills, USA

In addition to a long history of cultural marginalization, Native American settlements presently experience both natural and economic challenges, such as drought, floods, climatic extremes, increasing energy costs, lack of capital, and expansive soils, yet have abundant solar and wind energy resources. The Intertribal Council on Utility Policy (ICOUP), has asked the author to provide a model conceptual house design for nine reservations in South Dakota, North Dakota, and Nebraska that introduces best practices energy efficient envelope and equipment design, affordability, and the use of renewable energy to reduce the total energy demand for the reservation and to allow for the system wide utilization of commercial scale wind generation.

The model concept will be a demonstration of how such design can be integrated with the historical traditions of Native American Great Plains Architecture and the present economic and social context of the nine reservations. The author will present the design process with photographs and drawings, using stakeholder involvement, expert knowledge, energy modeling, and historical research, together with the completed model. Further, I will raise some of the issues having to do with how novel technologies and design ideas can be introduced to indigenous cultures and how they are assimilated.

Keywords: Affordability, housing, energy efficiency, cultural relevance

1. INTRODUCTION

1.1 The Geographical Focus of the study

The Plains are both a culture area and a geographical region in the American west, defined by long term indigenous people's occupation and the boundaries of the Rio Grande River to the South, the Rocky Mountains to the west, the Saskatchewan River to the north, and the Mississippi River to the east, or the 96° west Longitude line as the eastern border [1,2].

1.2 Challenges to sustainable design

The design of housing for Native Americans in this region faces certain specific challenges from the climate as a background to all environmental design problems. These challenges include drought west of 100° longitude, flooding east of this line, a climate with large diurnal and annual temperature swings, ranging from 3,445 heating C°-days near the Nebraska Omaha reservation to 5,445 heating C°-days for the North Dakota Ft. Berthold and Fort Totten reservations , summertime high humidity, high interior humidity levels from constant cooking, expansive clay soils, prevalent subsurface radon gas, ice storms which cause power line failures, up to 120 KPH winds, migrations of new pests, bacteria, and molds, global climate change, imperatives for cultural and socio-economic change from within the tribes and from the wider United States, rising steel and concrete prices, increasing fuel costs, and a housing stock with high energy consumption. On the other hand, the Plains reservations have abundant renewable energy resources in the form of solar energy and the above mentioned winds, and relatively low-cost indigenous construction labor. Many of the above challenges will likely only become worse with time. It therefore seems prudent that designers and planners begin to include the future anticipated climate and other conditions into the design program now, lest the sustainable buildings of today become obsolete in 50 years.

Architects Dru Meadows and Dagmar Epsten, engineer Terry Brennan, and builder David Eisenberg have all contributed to this building design and participated in at least one of the charrettes, while engineer Rob Del Mar has also performed all the energy modeling.

2. THE DESIGN RESPONSE

2.1 The Building Program

To deal with these challenges and to help with the large scale introduction of renewable power production to the electric grid, the Intertribal Council on Utility Policy wants to provide models of energy efficient, sustainable building design to the regional Native American market. The first focus of this program is the production of an energy efficient, affordable house design concept and building code recommendations for the housing authorities and other government owned house builders.

The housing authorities require several versions of this house concept while their program constitutes a significant list of criteria and goals. The versions should include a 4 bedroom version of 125,000 USD or less, a HIP program version for Housing and Urban Development of not more than 72,000 USD, and a Veteran's Administration version of not more 80,000 USD, where one of these should be designed with strawbale walls. Further, the houses should be: generally affordable, energy efficient, have the ability to accept renewable energy technologies, culturally appropriate, flexible to relate to different site, family, or standards conditions, expandable and internally flexible, sustainable in the use of materials and construction methods, durable, with methods to avoid indoor air quality problems, created with the active participation of stakeholders in programming and design, based on the history of Native American architecture of the region, accessible for the disabled, and where the site planning allows for the *t'iyospaye* to comfortably reside on the lot. The t'iyospaye is an informant defined category for a group of co-located extended family members living in nuclear family units in separate homes, sharing economic and social tasks and goals. [3,4]

2.2 Description of the Design Process

This process is made up of five main components to access knowledge and process it into a design: Stakeholder involvement, expert knowledge of technical and architectural subjects, energy modeling, research on the history of architecture, and conventional architectural design iterations and research.

An initial literature research of the archaeology of Great Plains architecture was begun in early 2005 at the National Museum of the American Indian to establish a background understanding for basic plan forms, materials use, and construction methods.

The author then traveled to each of the nine reservations to survey the existing housing stock and interview the housing authorities. This on-site observation allowed the author to understand the general landscape of the reservations, the state of repair of the housing and the general style and build quality of the construction.

Design charrettes were then chosen as the main participation method to produce the major components of the design concept [5,6]. At the same time, Dru Meadows analyzed the prevalent building code in use for how sustainable design might best be integrated into the language and Rob Del Mar modeled the envelope and equipment loads of a 1,040, sq. ft., 96.61 m^2, three bedroom, two bath Fort Totten reservation house for an energy baseline.

The first charrette at the Standing Rock reservation in North Dakota identified the design program vision, goals, and site planning ideas. Two months later, the second charrette in Rapid City, S.D. went on to producing concepts for a floor plan, section, and materials and HVAC equipment type selections. At this stage, the author began to integrate knowledge from the charrettes and the archaeological-historical research with iterations of house plans, sections, framing options, and elevations.

By the end of 2005, the reservation governments requested a third charrette for Rapid City to review the design where new program elements were added, such as the HIP and VA program houses. For this, the author built a model based on the floor plan developed from charrette 2 to encourage participation in the details of the plan and section design.

2.3 Results of the Programming and Design Process

Charrette 1 produced a common vision of the site/house program (for a summary, see above in 2.1 Building Program), site planning concepts and lot sizes, a bedroom inhabitation schedule, an architectural program of the rooms with sizes, and the final maximum build cost for the house.

The minimum lot size to accommodate the t'iyospaye was defined as a 38.1 to 45.72 m wide street frontage by a 48.77 m depth, with a 1.52 m wide easement for a back alley access at the rear of each back-to-back property.

The bedrooms should accommodate either a couple or a maximum of 3 people, parents or children, while for bedrooms with children older than five, gender has to be separated. In general, designing bedrooms of various sizes is to be preferred, while the heads of the beds should never be in the east.

The housing authorities want a minimum four bedroom house, with the ability to expand to six, as any new house becomes an immediate attractor to a family relative. The kitchen should be the most prominent element of a woman centered, open living space, allowing for an overview of house activities from one spot, flexible enough to accommodate meals, Christmas/ceremonies, and more conventional living such as TV viewing. Along with this open space, avoiding hallways will also reduce the cost by reducing the number of doors and ventilation transfer grilles. The yard east of the house should be used for social occasions, while the western part of the property can be used for the parking pad, driveway, and an optional garage. Finally, the house should also be Uniform Federal Accessibility Standard compliant for the disabled and finally an entry vestibule should be added to reduce infiltration losses.

Initial construction cost estimates from the housing authorities were 732.02 USD/m^2. The charrette decided to use 807.38 USD/m^2, as a cushion and to take up the future price increases of materials. At this cost, the 156.42 m^2 final program from charrette 1 would be too expensive and some size reductions had to be found. The size would have to be below 154.94 m^2 and built on one floor.

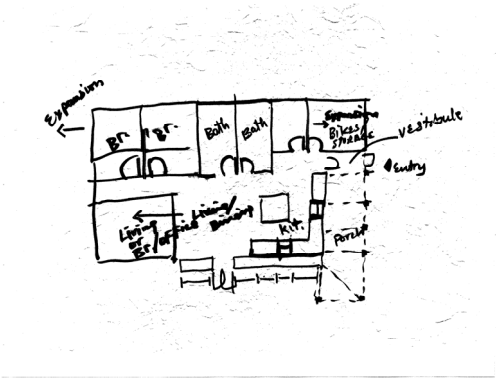

Figure 1: Initial house plan from charrette 2.

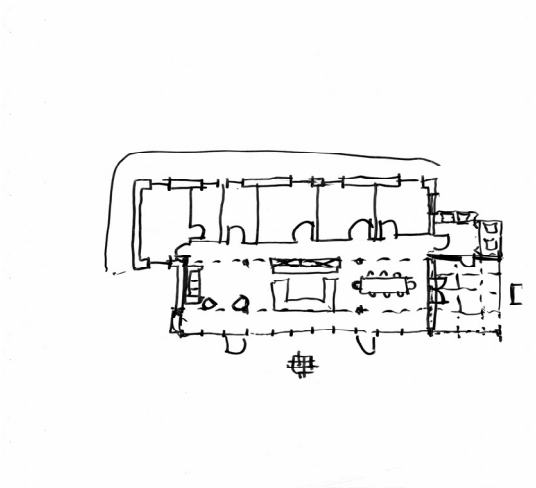

Figure 2: Second iteration house plan

To accommodate the above criteria, the author suggested as an overall organizing scheme an east-west oriented row of bedrooms and bathrooms to the north and a corresponding row of living room-kitchen-dining room to the south. The living spaces are open and the northern part of this space forms a passage and access to the bedrooms, obviating the need for a corridor. Furthermore, the ends of these rows are orthogonal and thus pack with expansion rooms or other house units to make duplexes, while the master bedroom can be shortened and a corridor pushed through (in line with the passage space between the living area and the bedrooms), toward the west to access a fifth, new master bedroom. Finally, the open living space toward the south collects passive solar gain and distributes it throughout the house, blocked only by the small (possibly masonry), core structures near the middle of the building's length,(Fig 1 and 2).

.

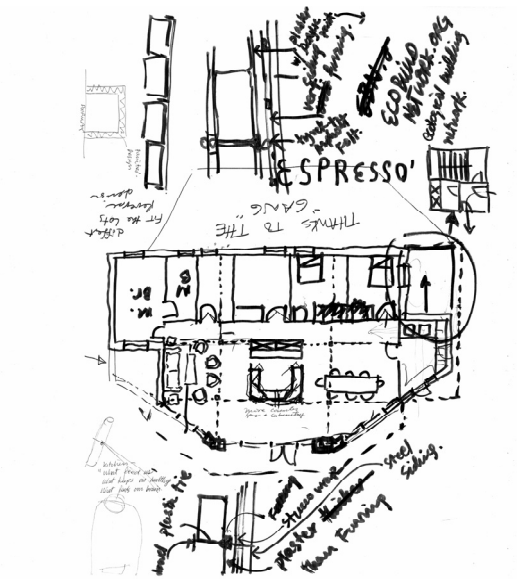

Figure 3: Final charrette 2 plan concept.

This organizing scheme was acceptable to the housing authorities but the shape of the space needed to be modified as it too much resembled a trailer, a negative connotation for the Native Americans. Different new geometries were suggested, some reminiscent of the polygonal 'earthodges' of the transition period from the pre-columbian to Spanish colonization era of the Great Plains. A final 4 bedroom, 2 bath plan and section were agreed upon by the end of charrette, forming the basis for the development of a schematic design (Fig. 3).

Rob Del Mar reported at the charrette that with several easy modifications, the baseline Fort Totten house could be made about 39% more energy efficient, mostly due to improving the envelope. The total annual per sq. meter heating demand for the furnace and fans would thus go from 407.72 kwh/m^2-yr to 249.50 kwh/m^2-yr , saving a total of 15,286 kwh every year. This figure is still 1,663% above what the passivhauses are able to achieve in northern climates, exemplified by Katrin Klingenberg's recent houses in Illinois [7,8]. The three versions of the ICOUP houses should be able to improve on the upgraded Fort Totten house by at least 33%, or bring the envelop energy demand down to about 164 kwh/m^2-yr.

Charrette 3 found the basic elements and plan shape of the scheme from charrette 2 acceptable. Here, the two main suggestions were that a separate children's play room would be useful and the interior should have the flexibility to build the kitchen either in the middle of the living space, or adjacent to the west or east facades. Further, the following additions were made to the program: The accommodation of the disabled through the Uniform Federal Accessibility Standards, the 72,000 USD and 80,000 USD house versions, an investigation of panelization, placement of a wood burning stove, and the accommodation of a walk-out basement.

Based on discussions with Terry Brennan concerning construction and Rob Del Mar concerning passive solar design, three versions of the house

concept were completed: a 4 bedroom, 1,664 sq. ft., 154.75 m^2 house, (Fig. 4), a 1 bedroom 956.5 sq. ft., 88.95 m^2 house for the HIP program at HUD, (Fig.5), and a 2 bedroom 1,050 sq. ft., 97.65 m^2 house for the VA, (Fig. 6).

It also became apparent that the basic concept of how to put bedrooms and living space together might afford other site planning possibilities, by disconnecting the bedroom row from the living space row, and re-assembling them in alternative geometries, although there is not space here to delve into this.

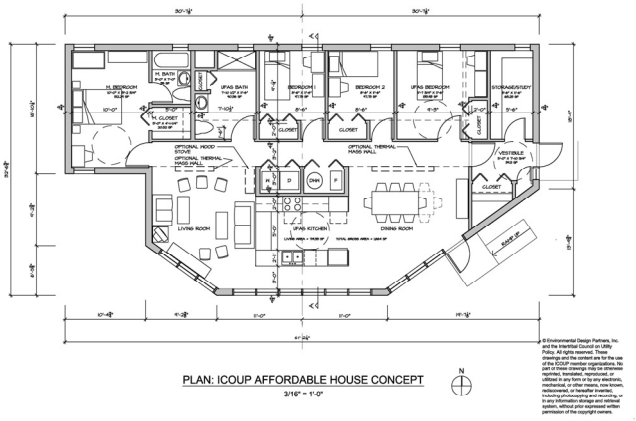

Figure 4: Four Bedroom House Plan.

The four bedroom house and the two bedroom HIP house are both designed with 2 x 6 (actual 38 x 89 mm), lumber walls and truss or rafter framing, insulated with cellulose. Following the recommendations of the U.S. Dept. of Energy Houses that Work Program [9], using methods of reducing the number of studs by using 61 cm. centers, insulated headers over doorways and windows, cellulose insulation, insulating the sheathing, sealing all joints, and allowing the wall/roof assembly to breathe to the inside and outside, these designs are an incremental improvement over conventional construction methods. They would however likely achieve some envelope heating demand savings beyond the Fort Totten improved base case due to the sun tempering of the added south facing glass, less infiltration, and added exterior extruded polystyrene in the wall and roof sections.

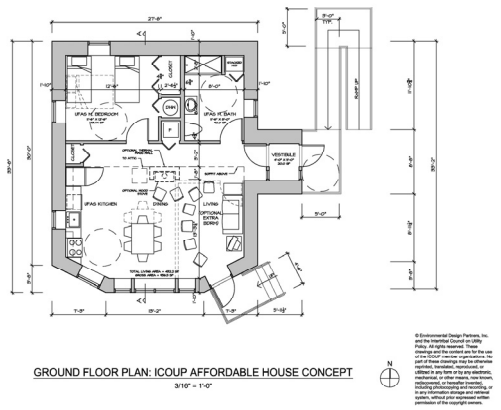

Figure 5: One Bedroom, Straw HIP Program house plan.

The more unconventional HIP program house is designed with 18" (46 cm), strawbale walls, lowering the U value to the range of between 0.2 to 0.15 W/m^2 K. [10] This, coupled with improved insulation in the roof, and below crawl-space floor insulation U value of 0.25 would be an even further improvement on the base case heating demand from the envelope. Strawbales enclosed within plaster also achieve a 1 hour fire rating from building officials, while conventional wood stud construction has no fire rating [11].

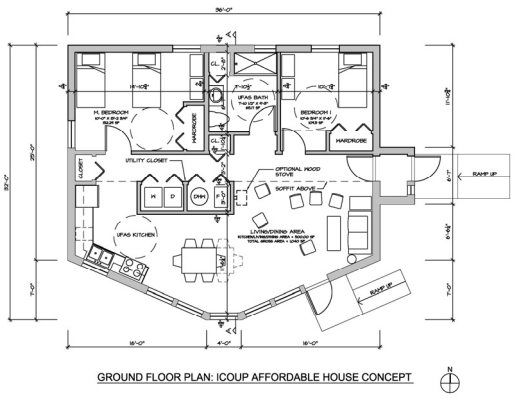

Figure 6: Two Bedroom VA House Plan.

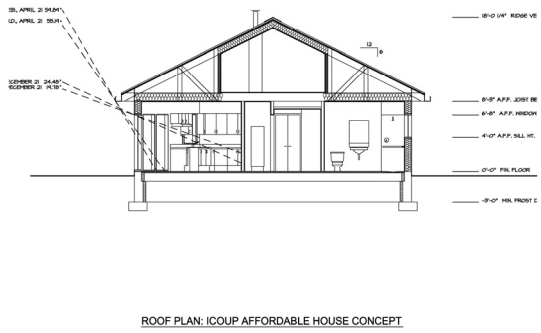

Figure 6: Strawblale HIP Program Cross Section

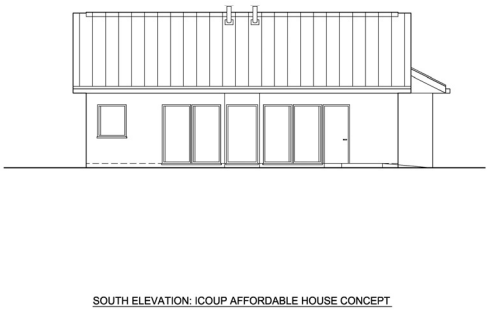

Figure 7: Strawbale HIP Program South Elevation

3. CULTURE AND TECHNOLOGY

3.1 Integrating Cultural Relevance and Technological Innovation

Two of the major themes from the Native American culture of the Great Plains evident in this design process are:

1. the desire to construct a woman centered house, focused on the kitchen
2. to shape the plan form in relation to their architectural history so the present inhabitants do not perceive it with negative connotations.

From the initial plan from the charrettes to the final design concepts, all present an open space with a prominent kitchen that provides an overview of the rest of the living space and the entry: The woman in the kitchen can be seen and can see almost everything else. This space, adjacent to the open passage south of the bedroom row, further afforded a simple circulation scheme that reduced the number of doors and transfer grilles, while it also defined an east-west line along which more rooms could be added, or another entire house, on either side.

Secondly, the convex bulge of the south wall made the center of the living space the most prominent area. Here, because of the open flexibility of the space, the kitchen can also be placed along either the west or east walls, perhaps reducing it's importance. The east or west placement of the kitchen however allows for a larger open space for Christmas/ceremonies/large dinner parties in the center of the space and next to the core and the wood burning stove.

The open plan and the convex bulge on the south wall also seem to increase the potential for gathering more solar gain and transporting it throughout the house, more so than a simple rectangular house with a corridor. By being next to the wood stove, this mass will also help to save and distribute stove produced heat.

The masonry core will allow for more glass to be used, increasing the passive solar heating component. The amount of masonry to glass ratio should be about 8.3:1 for back-wall mass, above the 7% of glass in a normal house. This masonry surface does not always have to be in the line of sight of the sun's rays, only in view of reflected light. With this added mass, significant savings on the heating demand from the furnace can be achieved [12].

Technological innovations from the latest DOE [9] or Passivhaus [8] recommendations are certainly helpful in saving on purchased energy and reducing wood use, but they seem to produce a polystyrene-wood hybrid, filled with mastic, caulk, and tape against infiltration. These innovations are important but they do remind the inhabitants of their lack of knowledge and ability: They do not know how, nor are they likely capable of producing these products, while many of them are either toxic or at least toxic in their manufacture [13]. Furthermore, as Glassie remarks, there is no evident memory of natural origins in most of these materials, no evident relationship with the local or regional landscape.

The alternative strawbale wall construction is a different kind of technological innovation: It does have a very local relationship on the Great Plains and has been on the American Plains for over 100 years. Such strawbales have been produced in many areas for many years and can now be compressed for greater stability, strength, and fire resistance [11]. They also provide a much lower effective U value [10], and are strong enough to be load bearing, although the ICOUP design uses wood studs at 91.5 cm O.C. and wood sill plates and headers. By using such local materials, total materials costs will also likely be reduced, heating costs will be reduced, many of the conventional toxics will be removed from the wall, and finally, the wall will dry to the inside and outside better with interior and exterior plaster finishes, making for a house that will likely feel more comfortable and free of mold issues.

It seems from this summary of a high performance house design, that future innovation in passive, sustainable construction will likely come from critical assessments of

1. the history of architecture
2. energy modeling
3. life cycle assessments
4. new ideas from innovations in sustainable materials and building methods

REFERENCES

[1] R. DeMallie, Introduction, in R. DeMallie (ed.), Plains Vol. 13, Part 1 of 2, Smithsonian Institution, Washington, D.C, (2001).
[2] W. Wedel and G. Frison, Environment and Subsistence, in R. DeMallie (ed.), Plains Vol. 13, Part 1 of 2, Smithsonian Institution, Washington, D.C., (2001).
[3] Personal Communication with Monica Larvie, Terry Pearman, and Orville Fox at Charrette 2.
[4] R. DeMallie, Sioux Until 1850, in R. DeMallie (ed.), Plains Vol. 13, Part 1 of 2, Smithsonian Institution, Washington, D.C., (2001).
[5] G. Lindsey, J.A. Todd, and S.J. Hayter, A Handbook for Planning and Conducting Charrettes for High-Performance Projects, National Renewable Energy Laboratory, Golden, CO., (2003). The book is also available at http://www.osti.gov/bridge.
[6] National Charrette Institute, NCI Public Meeting Facilitation: Professional Skills and Techniques, National Charrette Institute, Portland, OR. (2005).
[7] See the houses at www.e-colab.org
[8] Passivhaus Institut at http://www.passiv.de/
[9] Recommendations at http://buildingscience.com
[10] G. Minke and F. Mahlke, Building with Straw Design and Technology of a Sustainable Architecture, Birkhauser, Basel, (2005).
[11] B. Theis, Strawbale Safety, 2003, at http://www.thelaststraw.org/sban/tour/tour.html

[12] D.G. Balcomb, Buildings of the Land Energy Efficiency Design Guide for Indian Housing, National Renewable Energy Laboratory, Dept. of Energy, Golden, CO., (1994).
[13] H. Glassie, Vernacular Architecture, Indiana University Press, Bloomington, IA., (2000), 42