# The Successful Design, Construction and "Live-ability" of an Energy Efficient Home in a Hot and Humid Climate

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## ABSTRACT

This paper will present a case study of an energy efficient home completed in 2004 in the hot and humid climate near Houston, Texas. The presentation will include comparisons between this renewable energy home and several homes of typical construction. The paper will include the implementation of design construction and "live-ability" of an energy efficient home. The paper will include actual utility costs and costs of construction.

The house utilizes north/south orientation, south and west shading, double pane Low E windows, white metal reflective roof with radiant barrier and light exterior colors to prevent heat gain. Attic ventilation is provided by continuous soffit vents; full length ridge vents and skin vented walls resulting in an attic temperature no more that 10 degrees F hotter than the outside ambient. Green building materials including low VOC paint, engineered beams, no formaldehyde fiberglass insulation and cork flooring were utilized in this low environmental impact residence. The house meets the requirements for an Energy Star home with the extensive use of fluorescent lighting, ceiling fans and Energy Star appliances including a 14 SEER air conditioner.

In addition to the energy efficient construction, a hybrid 2 KW wind/solar PV (photovoltaic) system provides back up power and reduced energy consumption from the electric utility. A solar hot water heater provides preheated water to the gas fired hot water heater reducing gas consumption. A rainwater harvesting system provides landscaping irrigation and will collect 1200 gallons of water in a one inch rainfall.

In summary, this paper will present operating data for the two years since completion including energy consumption compared to typical homes in the area and effects of the overall system design on temperature and moisture control. The presentation demonstrates the effectiveness of renewable energy products and green building materials in an affordable home. It is an excellent example of the application of energy efficient principles in the real world.

## INTRODUCTION

The design of an energy efficient house includes many different aspects based on the type of construction, site selection, materials of construction and the homeowner's budget. A fixed budget means that compromises must be made in the overall design and particularly in the materials used. The guidelines used to design and build the home presented in this paper were based on the following:

- Comfortable home for two adults with no children
- Conventional stick built construction
- Availability of "Green" building materials
- Incorporation into the design for future Solar PV, Solar hot water, Wind power and Rainwater collection
- Finding an open minded builder willing to work with us

The energy efficient home is a system made up of many interrelating parts. You cannot optimize one part and ignore something of equal importance right next to it. Our advantage in building a new house from scratch is that we could incorporate everything we had learned about energy efficient design into the same "system". The compromise we made was to build a smaller house with the best materials we could fit within our budget.

## SITE SELECTION

It was important to find the best possible location to build the house. We had to find land in an area that would allow the solar and wind systems, be relatively close to work, had the characteristics suitable for the optimum operation of the systems we were to integrate into the house and it must be affordable.

Figure 1. Orientation of the house (West – left, East – left)

The site we found was a combination of an old hay field and thick woods. The open space where we placed the house is on the high point of land away from trees that would interfere with the solar and wind systems. The north/south orientation (Figure 1) also took advantage of the prevailing winds, which in our area come from the southeast most of the time.

**HOUSE DESIGN**

The house (Figure 2) is a 30' x 60' box on a concrete foundation. A breezeway and carport were attached to the west end of the construction. A full length porch across the south face and the breezeway/carport on the west shade the windows and walls from direct sun exposure in the summer. Energy Star double pane low-E vinyl frame windows were used though out. The exterior is Hardi Plank siding, resistant to the humid climate and provides a Class 1 fire rating and is painted a light color.

Figure 2. Completed house

Green building materials were utilized where possible (Chew, 2002). These included:

- Low VOC interior and exterior paint
- Engineered beams
- No formaldehyde fiberglass insulation
- Cork Flooring

All of these materials were available locally and did not require any special orders or handling. One of the compromises we made was the extent of cork flooring. Due to the expense we ended up with more tile and carpet than we originally wanted. The cork flooring was used in the master bedroom where we did not want to use carpet to decrease the accumulation of dust..

The framing is conventional stud (fir) construction. OSB sheathing covered with Tyvek house membrane covered the outside walls. One of the unique features of this house is the use of "Skin venting" (Figure 3).

Figure 3. “Skin Venting”

Treated 1”x 2” strips were added vertically to the exterior walls over the Tyvek. This provided a ¾” air space between the wall sheathing and the siding. This air space is open at the bottom and vented into the attic at the top. The opening at the bottom is covered with a stainless steel screen to prevent insects from entering the wall cavity. Cool air enters at the bottom and passes into the attic at the eaves. This skin vent design helps prevent heat gain through the walls and adds additional ventilation for the attic.

There has been much discussion about the advantages/disadvantages of sealed vs. ventilated attic space (Parker, 2005, Parker, 2003, Cushman, 1996). We chose the ventilated attic space for this house to take advantage of the skin vented walls and to actively maintain cooler attic temperatures and provide moisture removal. Our A/C system and ducts are located in the attic space so we needed to maintain as low an attic temperature as possible. R-19 insulation was used in the walls and R-30 insulation was used in the attic space.

To prevent as much heat gain as possible, polar white galvalume metal roofing was placed over plywood deck with aluminum radiant barrier. A continuous ridge vent and continuous soffit vents along with the contribution from the vented walls provide the attic ventilation. This roof and vent design combination results in less than a 10 Deg. F temperature rise above ambient (Figure 4). This can be compared to the attic temperatures in the previous house we lived in. That house had inadequate ridge vents and dark composition shingles (Figure 5).

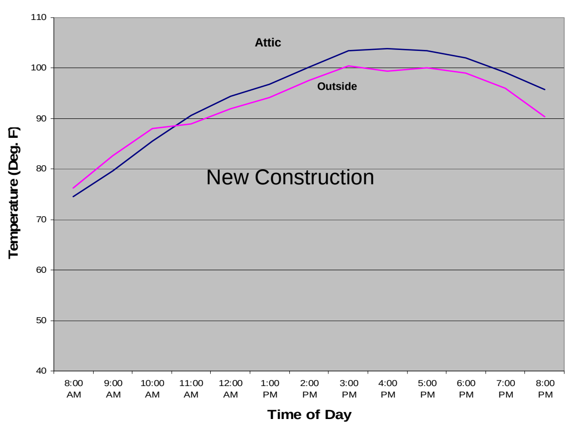



Figure 4. Attic temperature – new construction

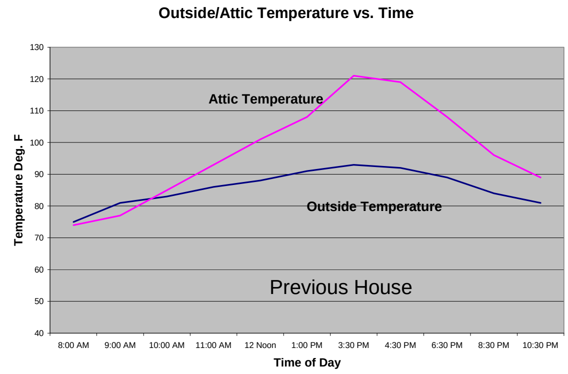



Figure 5. Attic construction – Previous house

To prevent air migration through the walls, all joints between the walls and slab, corners, wall penetrations from wiring and water pipes were sealed with foam sealant (Figure 6). A fresh air vent on the A/C system brings outside air into the house to provide positive pressure and help maintain good indoor air quality.

Figure 6. Sealed penetrations

**ENERGY EFFICIENT APPLIANCES**

A lot of effort was made to prevent heat gain into the structure and loss of cooling from the inside. A major load for the air conditioning system is heat and moisture generated inside the home. To minimize this load, energy efficient appliances were utilized. These included:

- Energy Star 14 SEER A/C unit with variable speed blower
- 80 AFUE gas fired furnace
- Energy Star dishwasher
- Energy Star front load clothes washer
- Energy Star Hunter ceiling fans
- 90% of the lighting is fluorescent
- Gas fired water heater with solar assist

For those ten really cold days in winter we have a wood burning stove with catalytic converter to supplement the gas furnace. The design for the house was submitted by the architect for Energy Star evaluation and the calculations showed we met the Energy Star rating, however we did not pursue this after the house was finished.

**RENEWABLE ENERGY SYSTEMS**

The house was designed and built to add renewable energy systems after the completion of the house. We installed a separate electrical distribution panel next to the utility panel. Wiring for the ceiling fans, refrigerator, stereo/TV, septic system, computer and a variety of lights are terminated in the separate panel. The 2 KW hybrid PV/wind system (Figure 7) provides power to this panel. A switch allows the utility power to power the separate distribution panel when required.

Figure 7. Hybrid PV/Wind system

The house was piped for the addition of a solar hot water system. A separate tank (Figure 8) was installed ahead of the standard gas fired water heater. The solar collector (Figure 9) preheats the water in the first tank before it enters the regular water heater. This allowed us to lower the thermostat on the water heater and still have plenty of hot water.

Figure 8. Solar heated tank

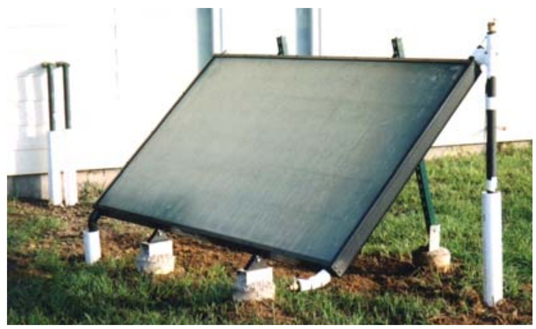


Figure 9. Hot water solar collector

Oversize gutters were installed on the house when it was build. I buried a rainwater collection manifold underground while the house was under construction (Figure 10).

Figure 10. Manifold for rainwater collection

The sealed down spouts take water from the metal roof, through the piping system to a 1500 gallon tank. We can fill the tank with a one inch rain fall. The collected rainwater is used to water the garden and flower beds.

## HOME PERFORMANCE

The design and construction of the energy efficient house is a system of parts working together. Like any complex system, it takes many interrelated parts to meet the final goal. From site selection to the details of construction, the final result is a house that is comfortable to live in and less expensive to operate than similar homes.

The basis for comparison is how much energy was consumed, i.e.: the electric and gas bills. By comparing the monthly KWH usage for the new house to the previous house, it was possible to relate the change in energy use based on our particular lifestyle. To compare the energy usage for the new house to typical houses in the area, the utility company provided three (3) years of electric bills for homes of the same size with a gas furnace and gas water heater. Since there is no way to know what the lifestyle for the other homes may be, a direct comparison is not possible. However, the comparisons show clearly that a well designed and built home can use less energy to provide a comfortable living environment than a "conventionally" built house.

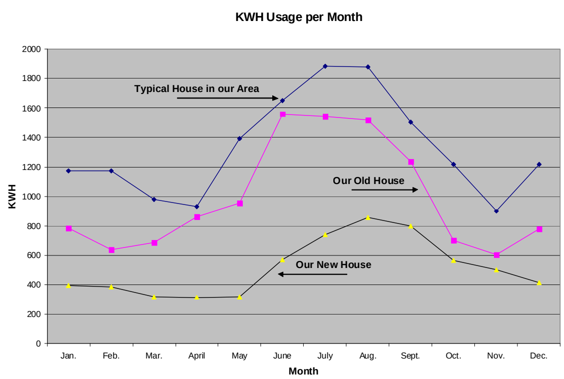



Figure 11. KWH usage comparison

Figure 11 compares the monthly KWH usage for the new house to the previous house we lived in and to the average of two (2) other houses in the area based on electric bills provided by the utility company. The previous house had 100 $ft^2$ more living space and suffered from a poorly ventilated attic and dark asphalt shingles. The house was surrounded by trees so the south and west walls were shaded most of the day. The difference in average KWH usage is obvious. The new house uses roughly 30% less electricity than the previous one. Another contributing factor, besides the ones mentioned above, was a 10 year old air conditioner.

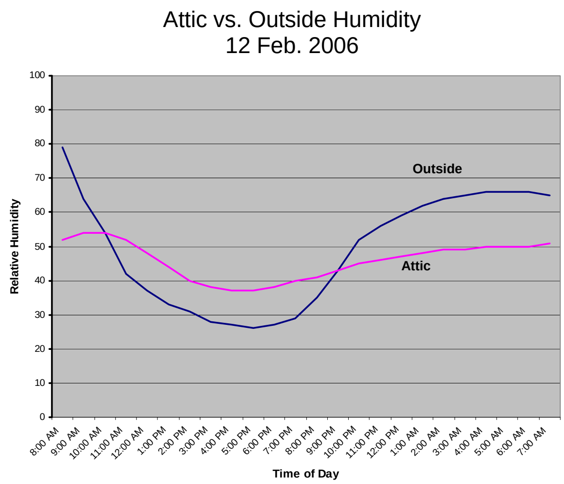
The comparison to the "similar" homes in the area is more difficult to quantify because the specifics such as the age of the house, number of inhabitants and type of construction are unknown. However the difference in average KWH usage is again obvious. The raw numbers show a 50% lower electric usage in our home than those to which it is compared.

Total reduction in KHW usage is a function of the energy efficient construction of the house and the contribution of the PV/Wind system. The average monthly KWH production from this system is 190 KWH. In the heating portion of the year (November to March) this represents about 35% of the total electrical requirements for the house. In the cooling months (April to October) this represents about 15% of the total electrical load. Thus, the PV/Wind system provides a 23% average contribution each month.

There has been a reduction in the use of propane since the installation of the solar hot water heater of 15%.

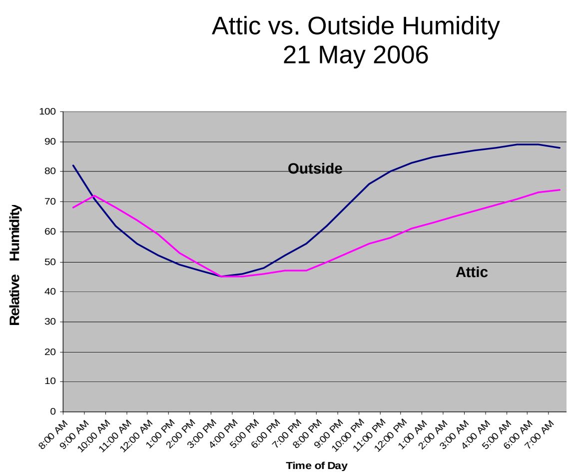
One question often asked is "What is the reduction in energy requirements based on the energy efficient construction vs. the reduction from the PV/Wind system?" This is not easy to quantify, however it can be said that 190 KWH would only represent 2% of the average monthly consumption from the "typical" home. Therefore, the vast majority of energy reduction would be from the construction and site orientation of the new home.

One of the concerns of the vented attic space is the introduction of moisture into this space. Structural degradation and growth of mold are serious problems that must be addressed in this high humid climate. To determine the extent of moisture accumulation in the attic space, measurements were made to compare the relative humidity outside to that in the attic. Figures 12 and 13 illustrate this at two different times of the year.




Temperature range = 24 – 62 Deg. F

Figure 12. Humidity Comparison (winter)




Temperature range = 69 – 90 Deg. F

Figure 13. Humidity Comparison (spring)

Figures 12 and 13 both represent sunny days with light wind. Figure 14 shows the result on a rainy day.

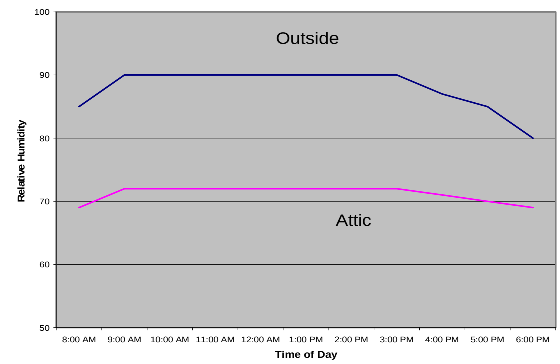



Figure 14 Humidity Comparison (Raining)

Moisture control is a major priority (Pfeiffer, 1997). The humidity levels rise and fall during the day in response to the outside levels. In the spring the moisture level in the attic is 15 – 20% less than outside during the afternoon. However, in the winter, the moisture level in the attic is less than the outside in the early morning. During consistent rain the moisture level in the attic is at least 20% less than the 90% humidity registered outside.

It is important to note the trends and not necessarily the actual numbers. An affordable energy efficient house can be built, using common, readily available materials and a good builder. To provide a reference for the cost of the house as it related to construction costs for other new homes in our area, the following costs are provided:

- Our new house was constructed for $64.00/ft$^2$. This does not include the added cost for the rainwater collection system, solar hot water heater or the hybrid solar/wind power system.
- The cost of adding these additional items to the house added $8.00/ft$^2$ for a total of $72.00/ft$^2$.
- The average cost for a new house in our area, based on forty five (45) homes picked at random from a realtor list was $86.00/ft$^2$.

## CONCLUSION

It can be seen that is possible to build an affordable energy efficient house that out performs the standard mass produced home. The addition of the hybrid/solar wind system, rainwater collection and solar hot water provided efficiencies beyond the house alone and at an affordable price. This combination of features resulted in a system that works harmoniously with each other and the environment, resulting in lower utility bills and a reduction in greenhouse gas emissions.

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**VITA**

John C. Gardner graduated from Texas A&I University with a BSEE and is a Professional Engineer in the State of Texas. He is a member of the American Solar Energy Society, American Wind Energy Association, the Houston Renewable Energy Group and a board member of the Texas Solar Energy Society. John has made several presentations on renewable energy including Speaker at the **Texas Renewables 2005** conference. The home was on the ASES, Houston Renewable Energy Group Chapter 2005 Solar Tour and has been the subject of articles in the Wall Street Journal and the local paper. John is employed by Appleton Electric Company, Division of EGS as the International Specifications Engineer. He is a senior member of IEEE and a member of the Industrial Applications Society and the ISA. He has authored four IEEE-PCIC papers.