In cooperation with

Application of Energy Principles, Products and Information Dissemination for a Zero Energy Building in Southern Nevada

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Bimonthly Report
Zero Energy House Project
June 1, 2005

The following describes the work completed for the Zero Energy House and for the baseline house. In the main part of the report, discussions and pictures of the construction and instrumentation are discussed. An appendix gives additional details about the latter, including layout diagrams. Two other appendices discuss some simulation issues related to elements of the ZEH.

Zero Energy House

Thermocouple assemblies were fabricated using a piece of PVC pipe which held four thermocouples at depths of 1/2 inch below finished slab surface, just below the slab, one foot and three feet below the slab. The ends of the thermocouples were coated with RTV silicon to protect them from the concrete.

Figure 1. Placement of the floor sensors in the zero energy house before the concrete slab was poured. The thermocouples were mounted outside a small PVC pipe to maintain the depth below ground. This pipe was placed in a larger pipe which kept the hole from backfilling. After the sensors were placed, the hole was filled with sand, compacted, and the larger pipe was removed.

Holes were dug for the assemblies near the living room south exterior wall, in the middle of the living room, and in the pantry closet. A large piece of PVC pipe was used to line the hole until the assembly could be installed. After the assemblies were placed in the holes, the holes were back filled with sand and compacted (see Figure 1). As each hole was being filled the large pieces of pipe were carefully removed. The grade was checked during the installation to keep the thermocouples located at the proper heights. Care was taken during the concrete pour and finish to not allow the assemblies to be displaced (see Figure 2). The leads for the thermocouples were run in PVC pipe to adjacent interior walls where a junction box will be placed to allow connection during the wiring phase of construction. The installation was carefully documented to note the locations of the sensors after the concrete was poured.

Figure 2. Concrete slab pour for the baseline and zero energy house. The slab and undergound thermocouple leads can be seen in the center of the photo. The connections will be made in a j-box located in an interior wall.

During the assembly of the forms for the T-Mass walls at Precast Technologies, conduits and a junction box were placed in the forms at each of the four predetermined wall locations for the four exterior wall directions. Thermocouples were placed through the conduit and one was secured with a wire tie to the reinforcement mesh installed in the interior 4-inches of the wall. Figure 3 shows the conduits with the thermocouples in place. After the interior concrete was poured the second thermocouple was run through the interior wall foam insulation as it was installed. It was then secured and cast into the exterior layer of concrete. Care was again taken to not allow the thermocouples to be damaged during the concrete pour and finish. A second conduit was placed in the same locations to allow the installation of the interior heat flux sensors after the walls are installed and the interiors are finished. Figure 4 shows Precast Technologies detail for the wall sensor installation.

Installation of the conduit and wiring for the zero energy house will begin after plumbing, mechanical, electrical, and alarm rough installation is complete and coordination with the other trades is ongoing.

Secure metal boxes for the data loggers and peripheral equipment have been fabricated and equipment layout is underway.

Figure 3. T-Mass wall assembly at the Precast yard. Thermocouples for the interior and exterior concrete of the T-Mass wall were placed in a PVC coduit which was cast into the concrete. An additional conduit was run to the interior of the wall for the installation of the wall heat flux sensor which will be run after the interior of the wall is finished. A junction box for the conduit was placed at the top of the wall to allow connections to the sensors.

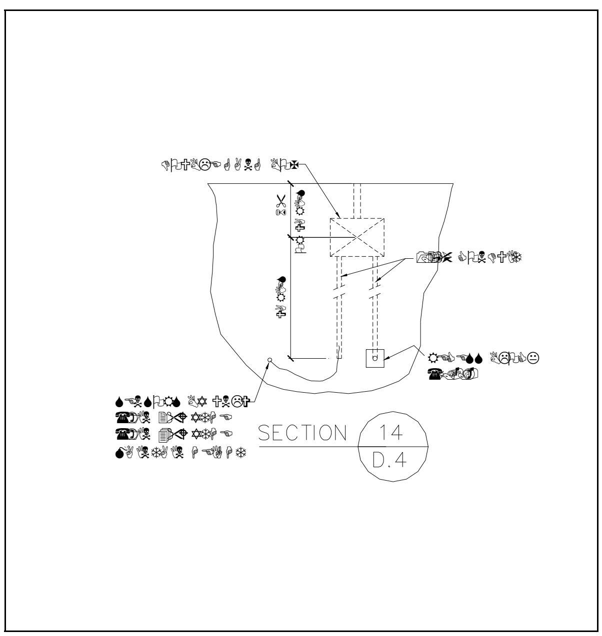


Figure 4. Sensor placement detail by Precast Technologies showing the conduits, j-box, and thermocouple placement in the T-Mass walls.

Figure 5. After the T-Mass walls were poured there were stood in the Precast yard to allow the concrete time to cure.

Figure 6. The erection of the T-Mass walls for the Zero Energy House.

Baseline House

For the baseline house, non-metallic conduits (nmc) were run to the four exterior wall locations. These conduits were run to allow the careful pulling of the sensor wire and to protect the wiring during construction. Penetrations through the structure for the conduit were sealed with expanding foam for fire and draft protection (see Figure 7).

Figure 7. Blue non-metalic conduit (nmc) was run to the sensor locations in the walls of the baseline house. This aided in the pulling of the sensor wires and helps to protect the wires during construction. The conduit was run to the air conditioning attic access area. Penetrations through fire blocking and top plates were sealed with foam.

A junction box was placed in the wall above the sensor locations to allow for connections. The conduits were run to a central location in the air conditioning access area for easy future access. A short piece of nmc was run from the junction box to a location 5 feet above the finished slab to allow installation of the interior heat flux sensors after the interior walls are finished.

Thermocouples were run from the j-box to two locations 5 feet above finished slab. An exterior thermocouple, for each of the four locations, was run through the exterior foam insulation and secured with a nylon wire tie to the plaster lathe wire. Again the end of the thermocouple was coated with RTV silicone to protect it from the plaster. A second thermocouple at each location was run to an adjacent interior location and pinned through the interior fiberglass insulation. During the installation of the sheetrock, this thermocouple was carefully placed in a seam of the sheetrock, and taped with wall mud to embed it into the interior of the wall near the surface.

Junction boxes were installed at three floor sensor locations that correspond to the floor sensor locations of the zero energy house. A slot was cut into the concrete at these locations and a thermocouple was placed into the slot 1/2-inch below finished floor. The slot was then grouted with dry pack concrete.

A junction box was installed at the water heater location for temperature and water flow. Sensor wiring was run after the rough installation by the other trades and terminated in the j-boxes for each sensor location. Continuous wires were pulled from each j-box location to the attic access area and then to the data logger location adjacent to the house power panel located in the garage. The wires were carefully labeled for future identification. The wires were run inside the garage exterior wall where two wall mud rings were installed. The wires will run through the mud rings into the back of the data logger enclosure after the interior walls are finished.

Wires were also run to thermocouple locations at two supply air locations. One location is at the end of the longest supply-air duct that runs to the dining room. The second location is in the bathroom of the master bedroom which is the shortest duct run. The thermocouples will be placed on mounts located at the duct opening into the ceiling can behind the supply diffusers. A thermocouple wire was run to two attic locations. The first location is above the middle-west bedroom. This is in a low section of the attic below a west facing section of the roof. The connection for this thermocouple is located in the ceiling can for this room and will be behind the diffuser. The wire for a heat flux sensor was also run to this location. The sensor will be placed on the interior surface of the ceiling with the connection also made behind the diffuser. The second attic location is at the peak of the roof above the attic access. The thermocouple is mounted at the bottom of the top chord of a roof truss with the connection accessible from the attic access. Wiring for a heat flux sensor was run to this location and will be placed on the interior ceiling surface after painting.

Figure 8. Front exterior view of the baseline house (left) and Zero Energy House (right) during construction.

A wire was run to the inside of the return air can to allow for the measurement of the room temperature in the high section of the vaulted ceiling. A second wire was run to behind the thermostat to allow for measurement of the room air temperature 5 feet above finished floor.

Additional wiring was run to the main gas meter, water heater gas location, and air handler gas location for future installation of gas flow meters. The main house water meter runs with the gas meter wiring. Wiring was also run from the main phone junction box to the data logger location for phone access to the data logger.

Interior surfaces are currently being finished, painted, and interior trims are being installed. After completion of the finishes the remaining sensors and data logger equipment will be installed for the baseline house.

Appendix A

List of Instrumentation and Diagrams Showing Locations

The ZEH and Baseline Houses are mirror images.

TABLE A-1
Key to Instrumentation Notation

Sensor Schedule	
△1	Interior wall thermocouples
△2	Exterior wall thermocouples
△3	Floor surface thermocouples
△4	Low attic thermocouple
△5	High attic thermocouple
△6	Shortest run from AC thermocouple
△7	Longest run from AC thermocouple
△8	Air temperature thermocouple located at thermostat
△9	Air temperature thermocouple located in return air can
△10	Water heater thermocouple located in inlet pipe
△11	Water heater thermocouple located in outlet pipe
□1	Wall mounted heat flux sensor
□2	Low ceiling heat flux sensor
□3	High ceiling heat flux sensor
⬠1	AC power meter located at AC fan coil
○1	Water heater flow meter
⬡1	Water heater gas meter
⬡2	Gas meter

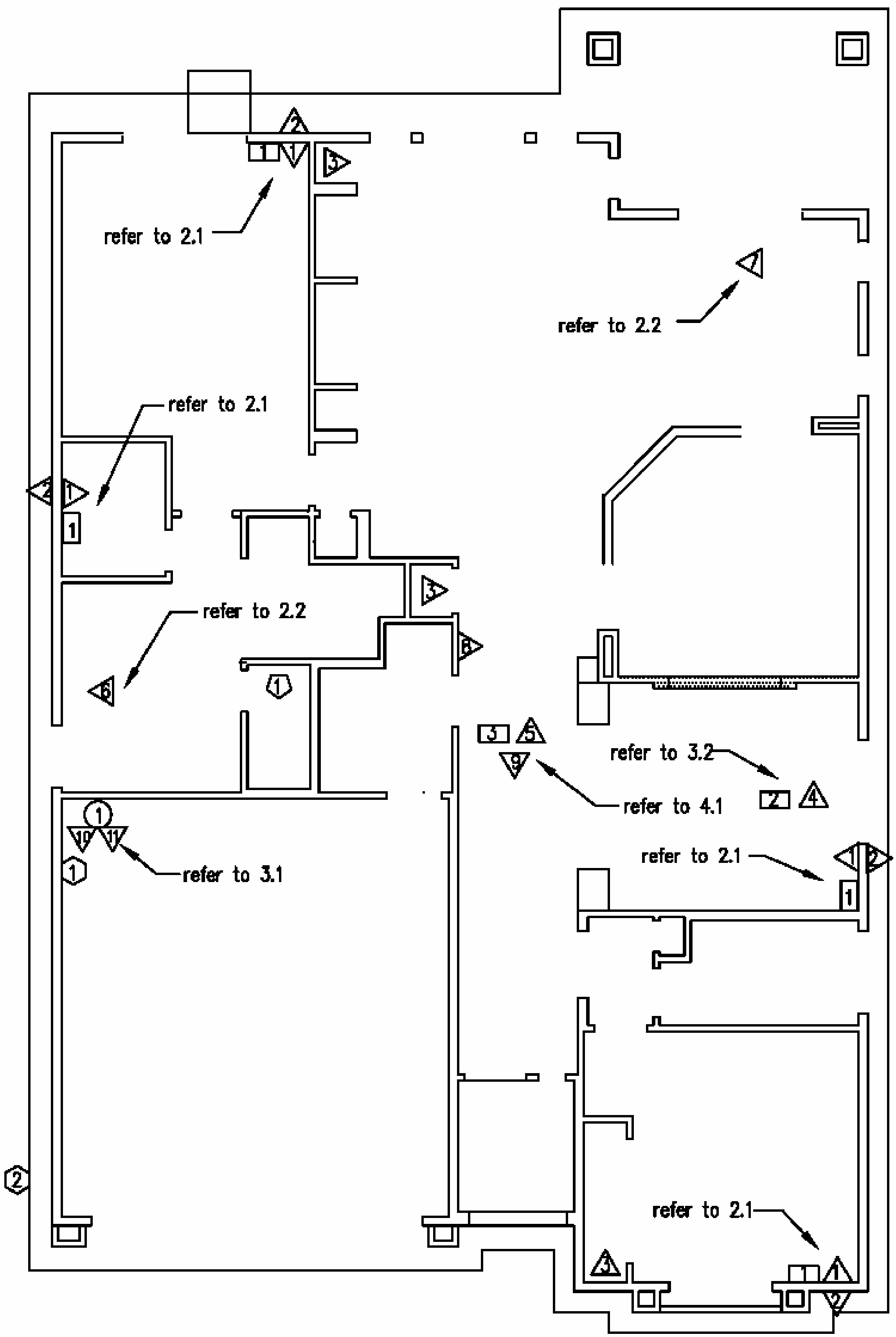
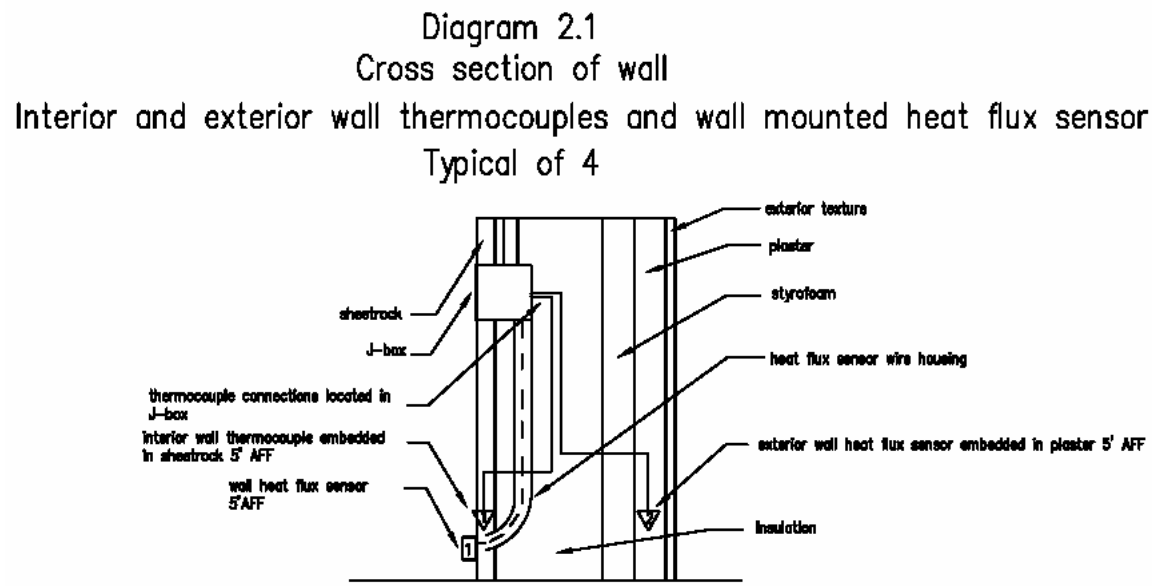


Figure A-1. The plan view of the baseline house is shown. The ZEH is the mirror image of this. Details are shown in the following figures.



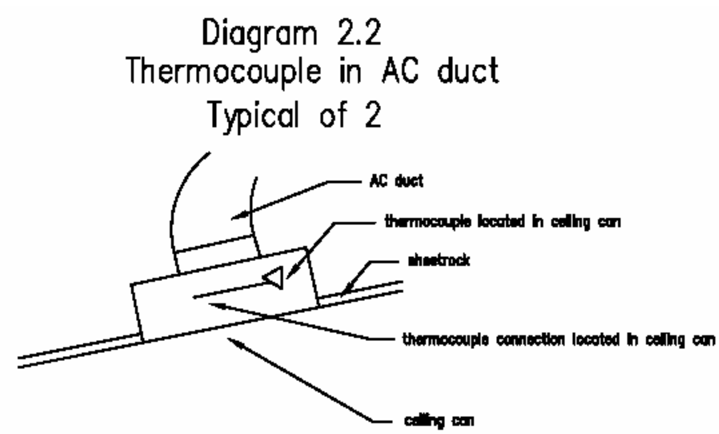
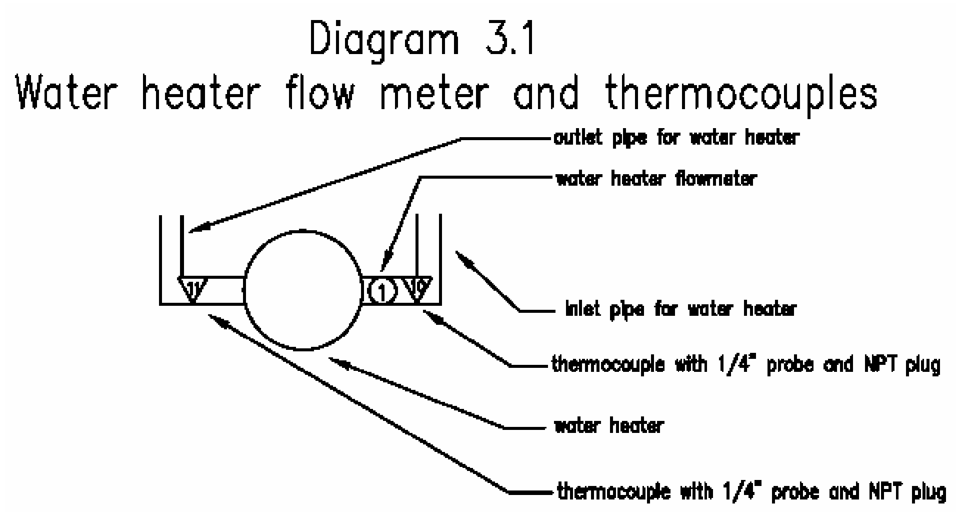


Figure A-2. Details of thermocouple and heat flux sensor installations in walls and ducts.



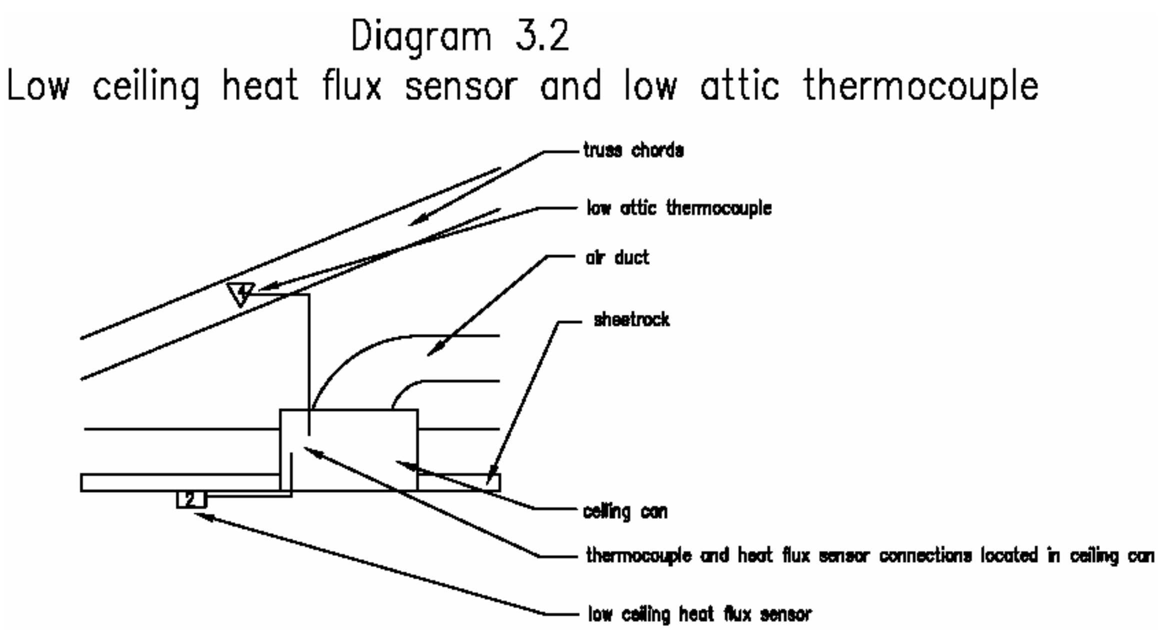


Figure A-3. Details of thermocouple and heat flux sensor installations in the water heater line and low ceiling/attic.

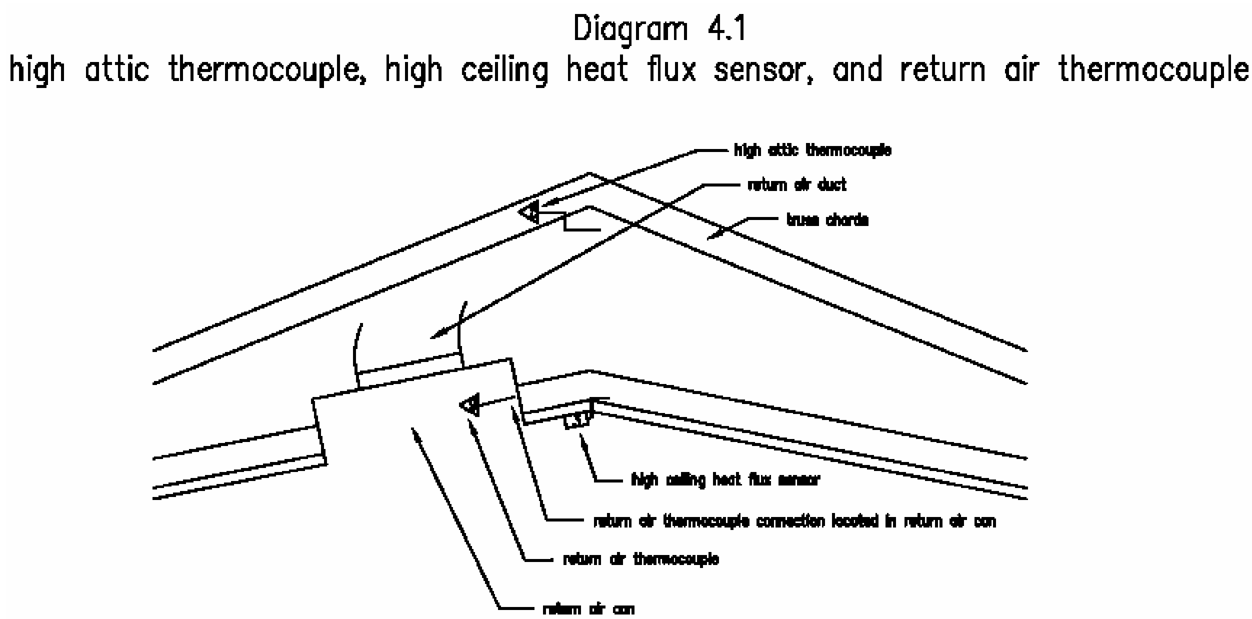


Figure A-4. Details of thermocouple and heat flux sensor installations in the high ceiling/attic.

Appendix B

Load Determination for the Zero Energy House

Introduction

In the Las Vegas area air conditioning costs represent a majority of the overall energy costs in a residential home. As such the Zero energy home is being designed to try and reduce those air conditioning costs by reducing the overall cooling load on the house. One such load reducing strategy chosen is to replace the standard frame wall with a more massive Dow T-mass concrete wall The Dow T-mass wall is characterized by Styrofoam insulation sandwiched between two layers of concrete. To simulate how effective the T-mass wall is in reducing the load in the house Trace-700 and Carrier HAP programs were used to compare the T-mass wall to a normal frame wall.

T-Mass Wall construction

The main feature of the T-mass wall is its ability to effectively use the Thermal Mass effect of concrete to offset the cooling loads to off peak hours when power rates are lower. The large mass of the concrete allows the wall to absorb and store more heat than a frame wall and then radiate it back to the outside when the ambient temperature has dropped during later hours of the day. The Styrofoam insulation shown in figure B-1 in between the two layers of concrete help to stop the flow of heat to the inside of the home.

Figure B-1 Styrofoam insulation

The Styrofoam is connected to the concrete with connectors made up c of 76% glass fibers and 24% vinyl ester polymer, The connectors have a low thermal conductivity and do not cause thermal bridges or energy/vapor leaks, and are effective in eliminating thermal loss through the wall. The T-mass wall is designed to work well In an area such as Las Vegas where there are large temperature swings between night and day. This can in lead to a substantially larger equivalent performance R-value when compared to the actual R-value based upon the material properties.

Figure B-2 shows a cross section of the wall with the insulation between the two layers of concrete.

Figure B-2 T-Mass Wall cross-section

The concrete used in this wall is taken to have a density of 130 lb/ft^3 and a conductivity of 1.04 Btu/hr-ft^2-F per inch. The specific heat is taken to be 0.22 Btu/lb*F. The outer wall has 2inches of concrete while the inner wall is composed of 4 inches of concrete. The interior insulation is composed of 2 inches of STYROFOAM extruded polystyrene and polyisocyanurate rigid board insulations. The insulation is rated to have an R-value of 5 hr-ft^2-F/BTU per inch, and a specific heat of 0.27 Btu/lb*F. The wall was also modeled to have standard 0.5 inch dry wall on the interior and 1 inch of stucco on the exterior. Including interior and exterior film coefficients the overall R-value of the T-Mass Wall was found to be 12.15 hr-ft^2-F/Btu. The overall weight of this wall was found to be 77 lb/ft^2.

Standard Wall

To compare the T-mass wall to how a standard wall is constructed in the Las Vegas are a normal framed wall was simulated. This wall The standard wall construction is based upon frame construction, 2 X 4ft 12 in on center. The insulation installed between the framing is R-13 Blanket and Batt insulation. As with the T-mass wall the exterior is covered by stucco and the interior by dry wall. With the same interior and exterior film coefficients as well and taking into account the loss due to the effect of framing the R-value for this normal wall was found to be 12.22 hr-ft^2-F/BTU. The overall weight of this wall is found to be 14.6 lb/ft^2.

Miscellaneous Construction

In order to focus on how the two walls compare to each other factors such as roof construction, window construction and interior loads were kept the same between the two simulations. The orientation and size of the home were also kept the same. The roof was taken to have above average insulation, and with the effect of framing taken into account the overall R-value of the roof was 25 hr-ft^2-F/Btu, and has a weight of 10.8 lb/ft^2 The windows were based on a low e design with an average U-value of the windows is 0.33 Btu/hr-ft^2-F, and an average shading coefficient is 0.35.

Results and Discussion

The two types of walls as well as other construction parameters were both put into the Trace and Carrier Programs and compared. In total between the two programs 6 different methods of cooling load calculations were performed, on the two houses with the two different walls. Figure B-3 shows the amount of load from the walls based on each cooling methodology. All the methodologies show that there is a significant reduction in the amount of heat that is transferred through the walls of the T-mass house when compared to the house with a normal wall construction.

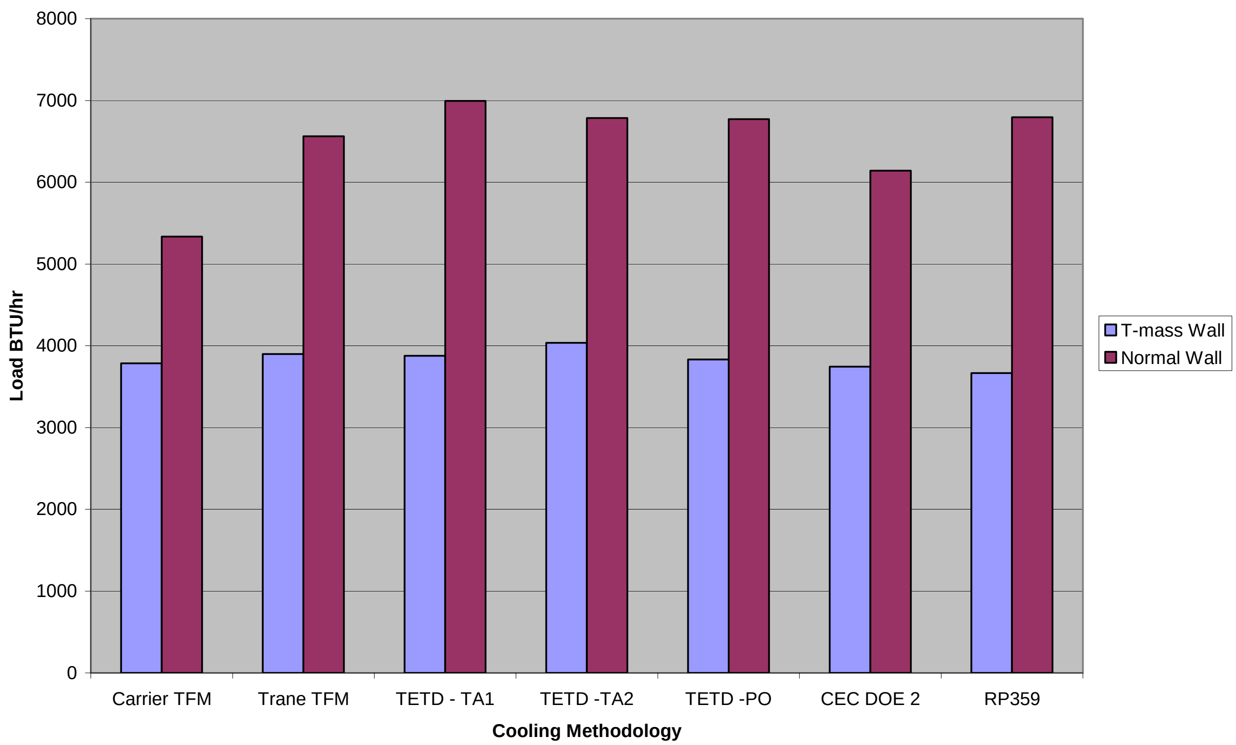


Figure B-3 Wall Loads vs Cooling Methodology

Figure B-4 shows the average of the wall loads calculated by each cooling methodology.

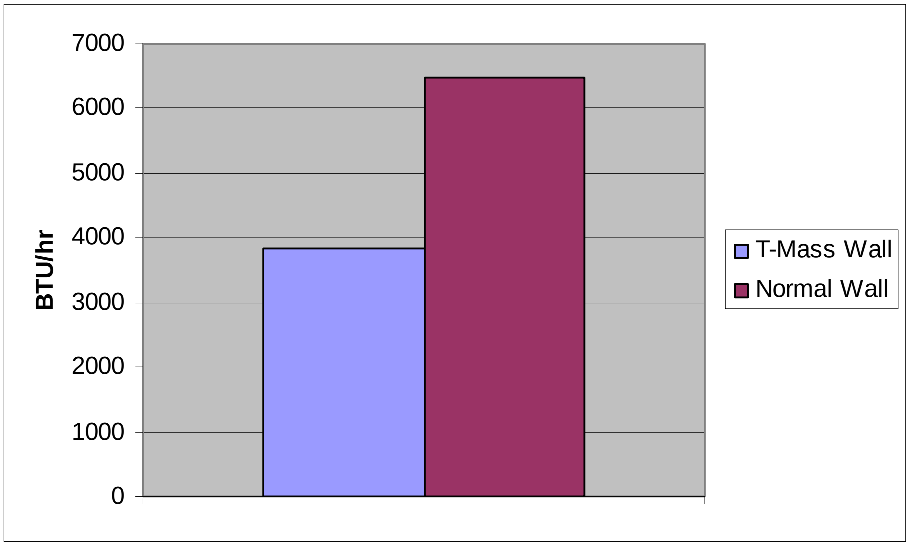


Figure B-4 Average Wall Loads

This shows that there is an average reduction in the load from the walls of around 40%, even though the actual R-value of the two walls are almost the same at R-12. This shows that the mass of the wall does in fact helps to reduce the heat transferred to the inside of the home. For a normal stick frame home to accomplish this, the overall R-value of the home would have to be around R-18. This overall R-value includes both the framing, insulation and inner and outer layer of the wall. Since framing reduces the effectiveness of the insulation that is placed in between it the R-value of the insulation would have to be significantly higher. To achieve that overall value of R-18 the insulation, assuming it is blanket and batt, would have to be rated as an R-30 to 35. It could also be accomplished by placing a foam board insulation on the exterior in conjunction with blanket and batt insulation. Examining the total peak load in the house, which includes all loads due to roofs, windows, etc, which is shown in Figure B-3, there is a reduction of 10% between the house with the normal walls and the T-mass house.

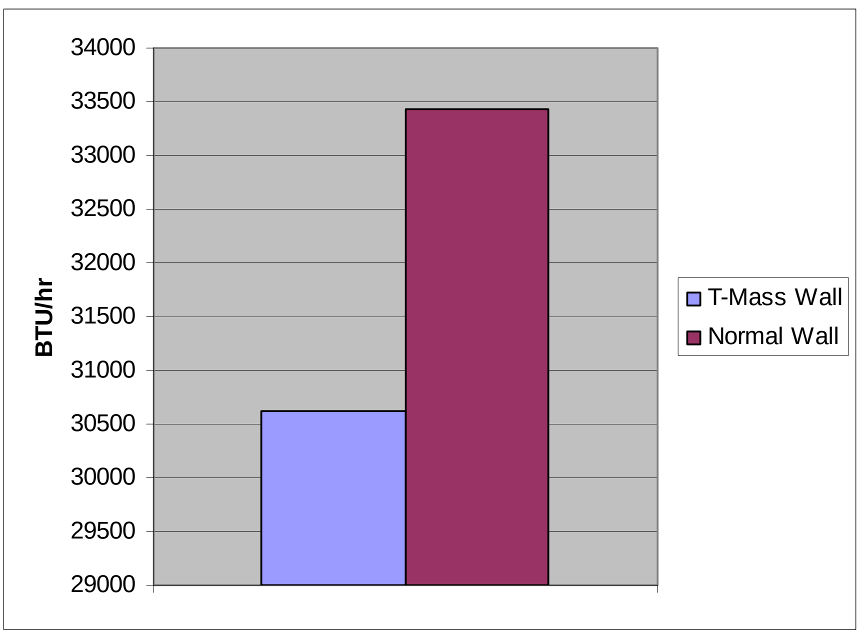


Figure B-5 Total Peak Loads

This reduction can lead to potential upfront savings from the fact that the home with the T-Mass walls could be conditioned with a unit that is 0.5 tons smaller than the normal home. The T-Mass home is also able to shift the peak loads to later times in the day. Most of the cooling load methodologies show that the T-Mass home loads peak at 5 or 6 pm while the normal home peaks at 3 or 4 pm. Depending on how much utility companies charge for electricity usage during on peak hours this shift in peak loads has the ability to lead to substantial savings, in addition to the reduction of overall air conditioning usage. One other benefit that the T-Mass wall could possibly have over a normal stick frame wall is that the interior of the home would not be as affected by large temperature swings of outdoor air temperature. In theory the temperature of the indoor wall should remain almost constant no matter how much the temperature on the outside of the wall changes during the day. The constant temperature of the interior of the wall will help to keep the actual indoor ambient temperature more stable and more comfortable.

Appendix C

Energy Usage Prediction in the ZEH

ZEH Energy Usage

Introduction

The Zero Energy Home with its concrete T-Mass walls has the ability to shift the peak cooling loads to later time during the day when electricity costs are reduced. In order to determine how well the zero energy home does in shifting the loads an energy simulation was done using Trace-700. The Transfer Function Method was chosen as the cooling methodology as it is most accurate in predicting peak load time in concrete structures. In addition power rates were applied to see how much the zero energy home can save in terms of cooling cost.

Power Rates

The Zero Energy Home will be under the jurisdiction of Nevada Power and is subject to its rate structure. For Single Family homes Nevada Power offers two types of Rate structures. The Normal Residential Single Family Rate is shown below

Table C-1 Normal Residential Rate

Customer Charge, per KWH	$0.08763
Deferred Energy Accounting Adjustment All KWH, per KWH	$0.00578
Customer Charge, per meter (per month)	$6.00

The Normal Single Family Rate if chosen would be in effect all year. Nevada Power also offers a Time of Use Rates, which are shown in Table C-2

Table C-2 Time Rate of Use Residential Rate

Summer On Peak, per KWH	$0.16030
Summer off Peak, per KWH	$0.06617
Winter all periods	$0.07139
Deferred Energy Accounting Adjustment All KWH, per KWH	$0.00578
Customer Charge, per meter (per month)	$7.30

The summer rates are in effect from June through August. The on Peak hours are 1pm to 7pm. This rate structure is designed for those who are not home during the day as the use of electrical devices including the HVAC system will be significantly reduced. However it would be of use to see how well the Zero energy home can offset these loads when compared to the baseline home. It would also be interesting to see how the two rate structures will end up comparing.

Simulation Parameters

For simplicity the energy simulations were done only on the cooling system, in particular the compressor and condenser fan. Both the baseline and the Zero Energy home were simulated to have a SEER 13 system. Both home constructions were kept the same except for the T-Mass walls which the Zero Energy Home is built with. The Baseline home has standard R-13 stick and frame wall construction.

Results & Discussion

As Nevada power only charges for Peak kWh in the summer, the Peak kWh were only calculated from June-August. Figure 1 shows the Peak and Non Peak kWh for both the Zero Energy Home and the Baseline home.

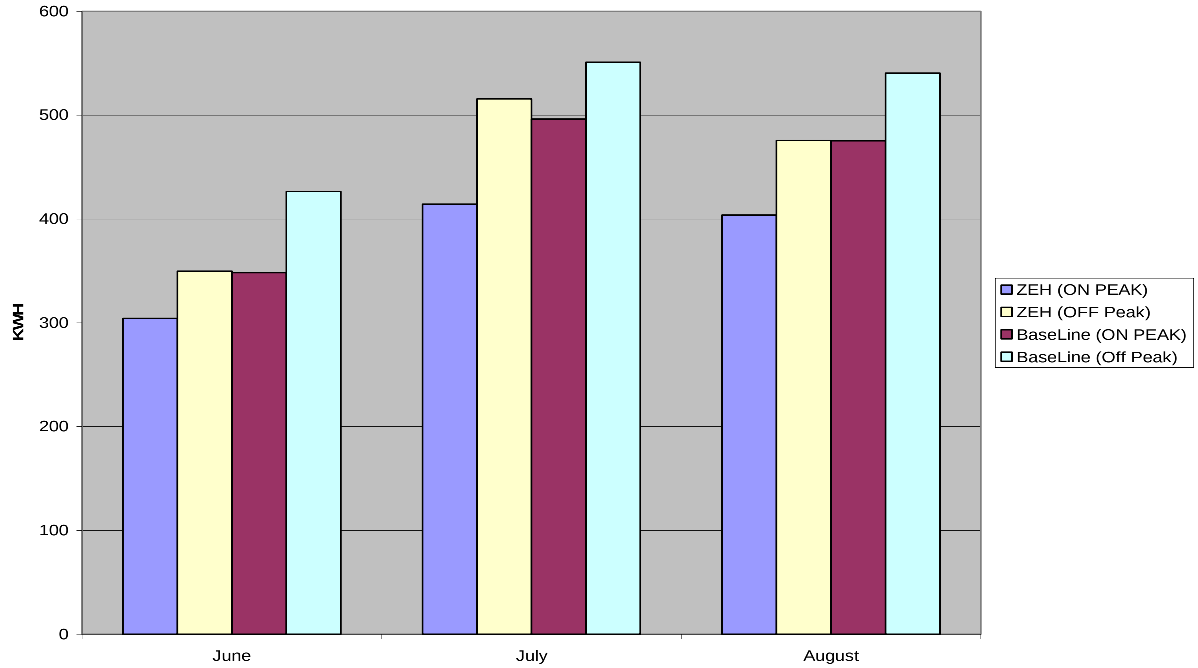


Figure C-1 Peak Vs Non Peak kWh Used

As Figure C-1 shows the Zero Energy Home does a good job of shifting the load percentage wise to off peak hours especially in the months of July and August. However in June the Baseline home does as a percentage use less Peak KWH than the zero energy home. As a total the Zero Energy Home does use about 14.5% less energy for cooling during the summer months than the Baseline home does. To see how this energy use costs in actual dollars both the Normal Residential Rate and the Time of Use Rate were applied. These results are shown in Figure C-2.

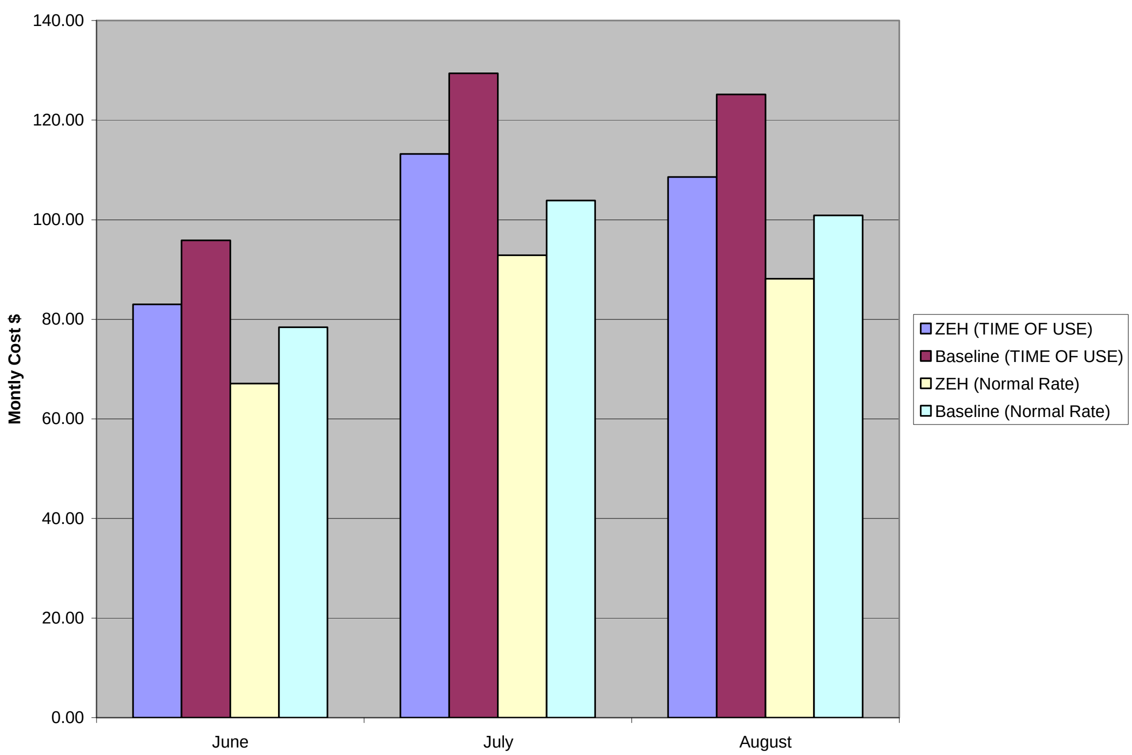


Figure C-2 Energy Rate Comparison

As the results show using the time of use rate structure actually results in higher monthly costs than using the Normal Residential Rate for both homes. Although the ZEH does a better job of offsetting the peak charges it is not enough to overcome the costs of using the Time of use structure. This could be expected as the Time of Use structure was devised for those who completely shut down or lower the use of there cooling system and overall electrical usage. This simulation was done by having the cooling system in operation at all times maintaining an indoor temperature of 75 F. Since the these rate structures are in effect for the entire year, with the time of use having a lower rate for the winter time, it is important to look at the energy costs for the entire year. Figure C-3 shows the total kWh used for cooling for both homes over an entire year.

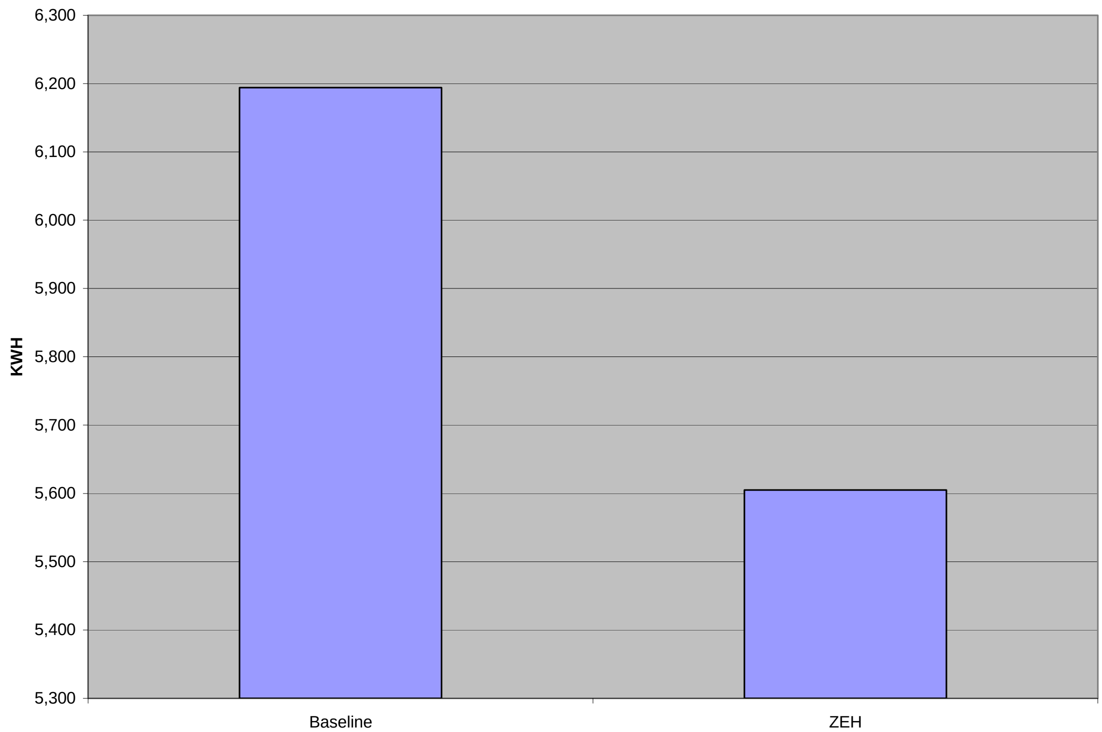


Figure C-3 Yearly Cooling Energy Use

As shown in figure C-3 if both the ZEH and the Baseline were outfitted with the same cooling system there would be a 10% reduction in the energy used because of the walls alone. Now applying the two rate structures for the entire year the total cost of cooling can be calculated and is shown in Table C-3

Table C-3 Yearly Cooling Energy Cost

	Normal Single Family Rate	Time Of Use Rate
ZEH	$530.00	$531.00
BaseLine	$585.00	$593.00

Table C-3 shows that using the Time of Use Rate does cost more for both homes yearly than the normal single family residential Rate. However for the Zero energy home the cost is only 1 dollar more per year. This means that if the zero energy home were put on a cooling schedule, for example shutting down or lowering the cooling system from around 1 to 4 pm during the summer there would be a greater savings than if the same schedule were applied to the baseline home. In fact taking out the extra $1.30 more per month for the Time of Use Rate that Nevada Power charges as a flat fee the Time of use rate would actually end up being less for the entire year, even with the Air conditioning system running at all hours.