



DE-FC26-99GO10478 (UCF 2012-6003)

Deliverable for task 1.2 Side by Side tests of HUD code Homes , September 27, 2006

Project: Zero Energy Manufactured Home Project (ZEMH)

Builder: Kit Manufacturing, Clearwater Homes

Location: Nez Perce Reservation, Cherry Lane, Idaho

Introduction:

The Zero Energy Manufactured Home Project has demonstrated and promoted innovative energy saving technologies to the manufactured housing industry and home buying public, and evaluated those technologies' energy performance. The ZEMH project examined two 1600 ft² double section manufactured homes, built by the same manufacturer, using an identical floor plan. HVAC measurements, envelope and duct leakage tests were conducted and remote monitoring equipment installed to track the performance of each home over a three year period. Both homes were built by Kit Manufacturing in the summer of 2002 and installed by Clearwater Homes for housing staff working at the newly built Nez Perce tribal fish facility.

A comparison home was built to Energy Star Program requirements as part of the Northwest Energy Efficient Manufactured Home program. NEEM Energy Star homes are the most energy efficient HUD code homes available in the United States today.

Project coordination and technical assistance was provided by the WSU Energy Program and the Bonneville Power Administration (BPA.). The project was funded by BPA and the U.S. Department of Energy's (DOE) Building America Industrialized Housing Program (BAIHP).

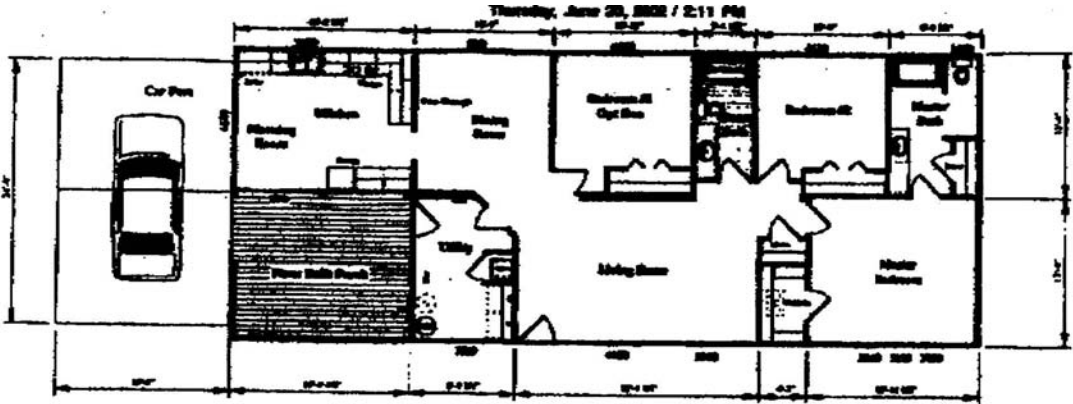
Figure 1: ZEMH at Nez Perce Tribal Fish Facility



Features and Specifications:

Building envelope	
Foundation	R21 perimeter 3” foam wall in vented crawlspace
Frame Floor	R22-33 Icynene in floor joists above R11 “belly” blanket
Walls	R21 Icynene w/2x6 16”o.c and insulated headers
Windows	U=0.33 Vinyl frame with LowE and Argon, SHGC = 0.4 Heavy drapes and duel blind window treatments
Infiltration	Air sealed with Icynene, Nomaco gaskets and Tyvek house wrap resulted in blower door test of 2.0 ACH
Mechanical systems	
Heat	HSPF 7.7 Insider Crawlspace Assisted Heat Pump
Cooling	SEER 10 Insider Crawlspace Assisted Heat Pump
DHW	.93 EF tank with 64ft2 SDHW closed loop system w/80 gal pre-heat tank and PV powered pump
Ducts	Insulated with Icynene, air sealed with mastic and performance tested at plant and at set-up
Duct Leakage	37 CFM leakage to outside at 25 PA =
Ventilation	Venmar HEPA3000 HRV with HEPA filter on 70 CFM low-speed continuous operation with high speed override
Appliances and Lighting	100% Energy Star Lighting Fixtures. Energy Star Laundry, Refrigerator and Dishwasher Energy Star Ceiling Fans

Figure 2: ZEMH floor plan

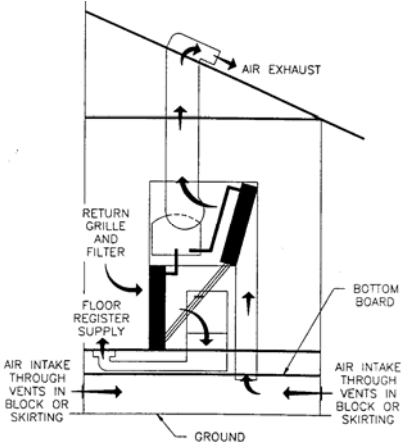


The Nez Perce Tribe / Next House Project II

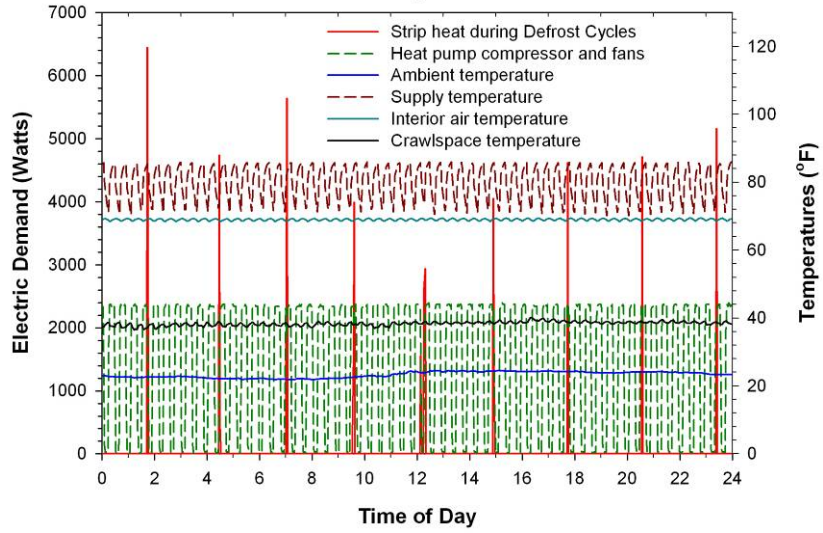
Figure 3: Icynene; Ceiling, Wall and Floor Insulation System



Figure 4: ZEMH – Insider™ Crawlspace Air-Source Heat Pump



**Defrost Energy on December 16th 2005
Experimental Zero Energy Manufactured Home
Lewiston, Idaho**



Calculated Energy Performance Using BA Benchmark Analysis

End Use	Benchmark Source Energy Use (kWh/y)	ZEMH Source Energy Use (kWh/y)
Heating	48787	17980
Cooling	3507	1327
Water Heating	17828	5530
Lighting	6475	3196
Miscellaneous	16509	15742
Ventilation	583	3322
PV	0.0	-11841
Total	93689	35256

Calculated Energy Savings Using BA Benchmark Analysis

Case	Source Energy Savings over BA Benchmark
ZEMH with no on-site energy produced	42.0%
ZEMH with solar DHW	49.7%
ZEMH with solar DHW and PV	62.4%

Measured Annual Energy Performance

Total Space Heating Energy - ZEMH 2842 kWh/year, ESTAR 5335 kWh/yr

Total Space Cooling Energy - ZEMH 1148 kWh/year, ESTAR 700 kWh/yr

Total DHW Energy - ZEMH 1547 kWh/year, ESTAR 1709 kWh/yr

Total Energy - ZEMH 11737 kWh/year, ESTAR 12164 kWh/yr

Innovations:

The Zero Energy Manufactured Home (ZEMH) was built with highly efficient and cutting edge technologies, including a photovoltaic system, sun-tempering, solar water heating, spray-in foam insulation, heat recovery ventilation, and Energy Star appliances, HVAC and lighting. An innovative Insider Heat Pump™ along with tight ductwork, well insulated and air sealed floor and insulated vented foundation wall was employed as an innovative “poor mans” crawlspace-air source heat pump. The concept of “Solar Ready” manufactured housing was also introduced and evaluated, as a potential way to reduce installation and code compliance costs.

Lessons Learned:

1. The ZEMH daily average total energy use (with PV & SDHW) was 29.4 kWh/day.
2. The PV system provides an average of 9.9 kWh/day providing roughly one third of the total ZEMH energy use.
3. The solar DHW system provides most, if not all, of the energy needed during the summer months, and roughly 56% of the overall water heating energy use. The ZEMH used 60% more hot water than the Energy Star home, at 10% less energy use.
4. Measured net energy use of the ZEMH was 12% lower than the Energy Star home, not normalized for occupant behavior.
5. The ZEMH required 44% less space heating energy than the Energy Star Home.
6. Measured envelope and duct leakage in the ZEMH was much lower than the Energy Star home (indeed, lower than any other NEEM home tested in the field).

7. The project highlights the importance of occupant behavior. The old inefficient “elk freezer located in the car port, as a second freezer, consumed a daily average of 3.2 kWh/day or roughly 1/3 of the PV energy produced.

Published Research Papers:

1. *Introducing “Solar Ready” Manufactured Housing*, Lubliner, Hadley, Gordon, Nelson – American Solar Energy Society Annual Conference, Portland, OR, 2003
2. *Manufactured Home Performance Case Study: A Preliminary Comparison of Zero Energy and Energy Star* – Lubliner, Hadley, Gordon – ASHRAE Building Thermal Envelope Conference, Clearwater Beach FL, 2004
3. *Heat and Non-Heat Recovery Ventilation Performance in Energy-Efficient HUD-code Manufactured Housing* – Lubliner, Gordon, Hadley, Parker – Air Infiltration and Ventilation Center 26th Annual Conference, Brussels, 2005
4. *HVAC Improvements in Manufactured Housing - Crawlspace-Assisted Heat Pump* – Lubliner, Hadley, Parker – ASHRAE Annual Meeting HVAC Improvements in Manufactured Housing - Symposium Long Beach, CA, 2007
5. *Manufactured Home Performance Final Report: A Comparison of Zero Energy and Energy Star* – Lubliner, Hadley, Gordon – ASHRAE Annual Meeting HVAC Improvements in Manufactured Housing - Symposium Long Beach, CA, 2007

Project Web link:

<http://www.infomonitors.com/zmh/>

<http://www.bpa.gov/energy/n/tech/zemh/>

Figure 5– ZEMH Building America Tour at Spokane Fair - BAIHP researcher Michael Lubliner (left) with Congressman George Nethercutt



Other Comments:

The ZEMH project successfully met the overall project goal - to demonstrate and promote innovative energy saving technologies to the manufactured housing industry and home buying public and documenting energy performance research in numerous publications and presentations.

ZEMH project has successfully demonstrated and promoted the concept and implementation of cutting-edge efficiency measures and methods in HUD-code housing. Lessons learned in the project to future regional and national HUD-code housing programs.