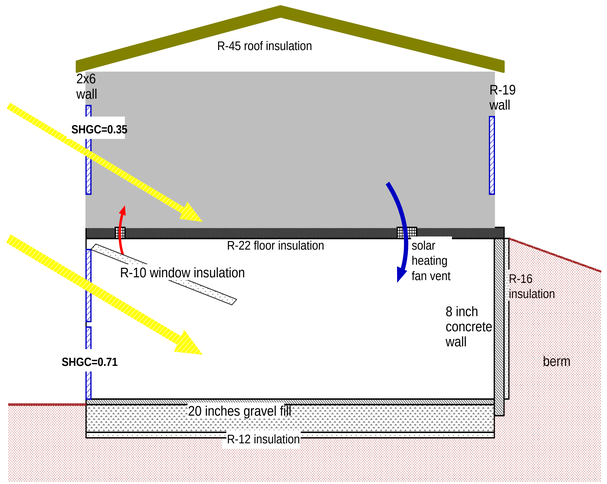
A Passive Solar Manufactured House

Susanna J. Gross[1] and K. Franklin Evans[2]
[1]CIRES, [2]ATOC , University of Colorado, Boulder, CO

Overview

- Passive solar manufactured houses are not commercially available.
- This design uses a solar basement to heat a double-wide manufactured house.
- The key insight is that the basement can get hot to store more heat, since it is not a living area. Basement window area is 22% of the house floor area.
- Basement air and house temperatures are monitored and used to control a single fan that blows air into the basement from the house, forcing warm air up.
- Backup heat is provided by an ordinary forced-air propane furnace. There is no fireplace or wood-burning stove.
- Basement windows are automatically insulated at night and during cloudy days.
- The house is off the grid; all electricity is solar generated.
- The house was built in 2004 in the cold, sunny San Luis Valley of Colorado at 8250 feet elevation, and monitored for two years.
- Temperatures in the basement and house are recorded by a computer and used to control the basement fan, backup furnace, and basement window insulation. An on-site weather station provides outdoor temperature and solar flux data.
- A control house with the same insulation but no solar basement was modeled with the Lawrence Berkeley Home Energy Saver web application. If the modeling is accurate, the house is 90-95% solar heated, saving approximately 700 gallons of propane (~$1400) per year.
- The solar basement cost roughly $30-$40K more than a stem wall foundation or regular basement it replaces.

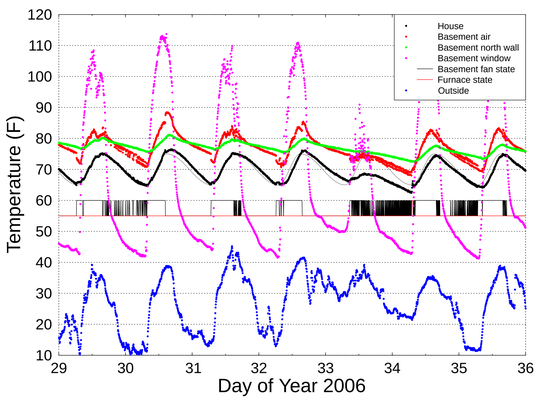
Solar Basement Design



- Sunlight enters the basement windows and is absorbed by a black painted concrete floor. Basement glazing is 12 46”x76” low-E double panes (U=0.35, SHGC=0.70) and one 8 foot patio door (328 ft^2 total).
- Solar gain augmented by reflection from white plastic tarps outside.
- The 4” concrete floor is underlain by 20” of gravel fill, and then by a 3 inch thick layer of expanded polystyrene (EPS) insulation (R=4.0/inch).
- 8 inch thick reinforced concrete walls are surrounded by 4 inch thick EPS insulation, and covered by a berm on 3 sides.
- Basement window insulation is raised and lowered using a counterweight and pulley system driven by a computer-controlled garage door opener. Polyisocyanurate insulation is used for its durability at high temperature.
- Warm basement air can rise passively through 7 vents in the insulated house floor, or it can be driven by a 24 volt, 50 W, 1200 CFM fan.
- Fresh air enters the house through a heat recovery ventilator.
- The solar basement also provides space for the battery bank and inverter for the solar electrical system, the house water system, and storage.

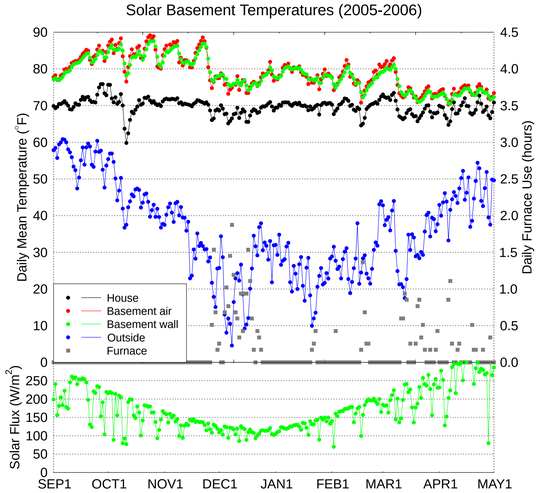
Control and Monitoring System

Example Temperatures



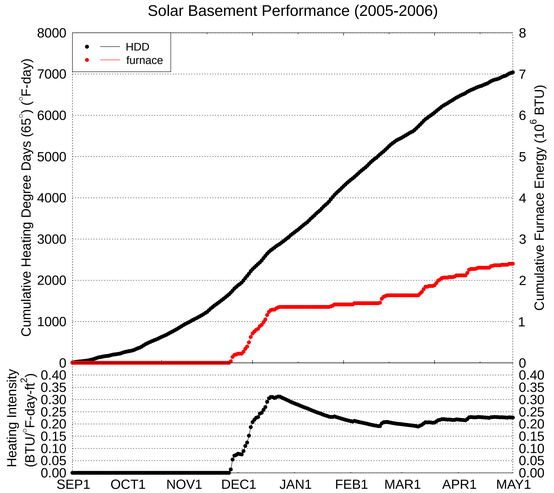
- This graph shows one week of temperatures logged by the house control program early in 2006. The black and red lines between 55 and 60 indicate the times the basement fan and the backup furnace were operating. The furnace only ran on day 34 (for 25 minutes).
- The house control program runs the basement fan when the house temperature falls below the desired temperature, and the basement is at least 5 to 8 F warmer than the house.
- The desired house temperature (gray line on graph) increases from 65F in the morning to 75F in the afternoon because it is most efficient to transfer heat to the house when the basement is warmest.
- The control program opens the basement insulation when the window temperature climbs above the basement air temperature. The insulation is closed if the window becomes colder or the sun sets.
- The temperature and weather data are automatically uploaded and plotted on web pages for remote monitoring.

Solar Basement Temperatures (2005-2006)



The graph above shows the observed daily average temperatures and solar flux for the last heating season. The gray squares (and righthand axis) show how long the backup propane furnace ran each day.

Solar Basement Performance (2005-2006)



The upper graph shows the heating degree days and backup furnace energy use during the season. The lower graph shows the heating energy intensity index, which is the furnace BTUs normalized by the heating degree days and the house floor area (1508 sq ft). For the 2005-2006 heating season, the heating intensity index was 0.23, and for the 2004-2005 season it was 0.67. The Home Energy Saver control house had 6.5 BTU/(sq ft HDD).

Issues

- Construction errors:
  1)Concrete wall EPS insulation missing below foundation level
  2)Air gap between house and basement (partially filled with expanding foam)
- Design problems:
  1)Basement air temperature has to be 10F higher than house for good heat transfer.
  2)Basement windows should be tilted for more solar gain in spring.

Future Plans

- Install a solar hot water system.
- Publish an article in Solar Today.

Electrical System

- 1440 watts of polycrystalline photovoltaic panels
- 57 kwh battery bank
- 4000 watt (continuous) inverter
- Loads include refrigerator, well pump, and UV water purifier.