A Passive Solar Manufactured House

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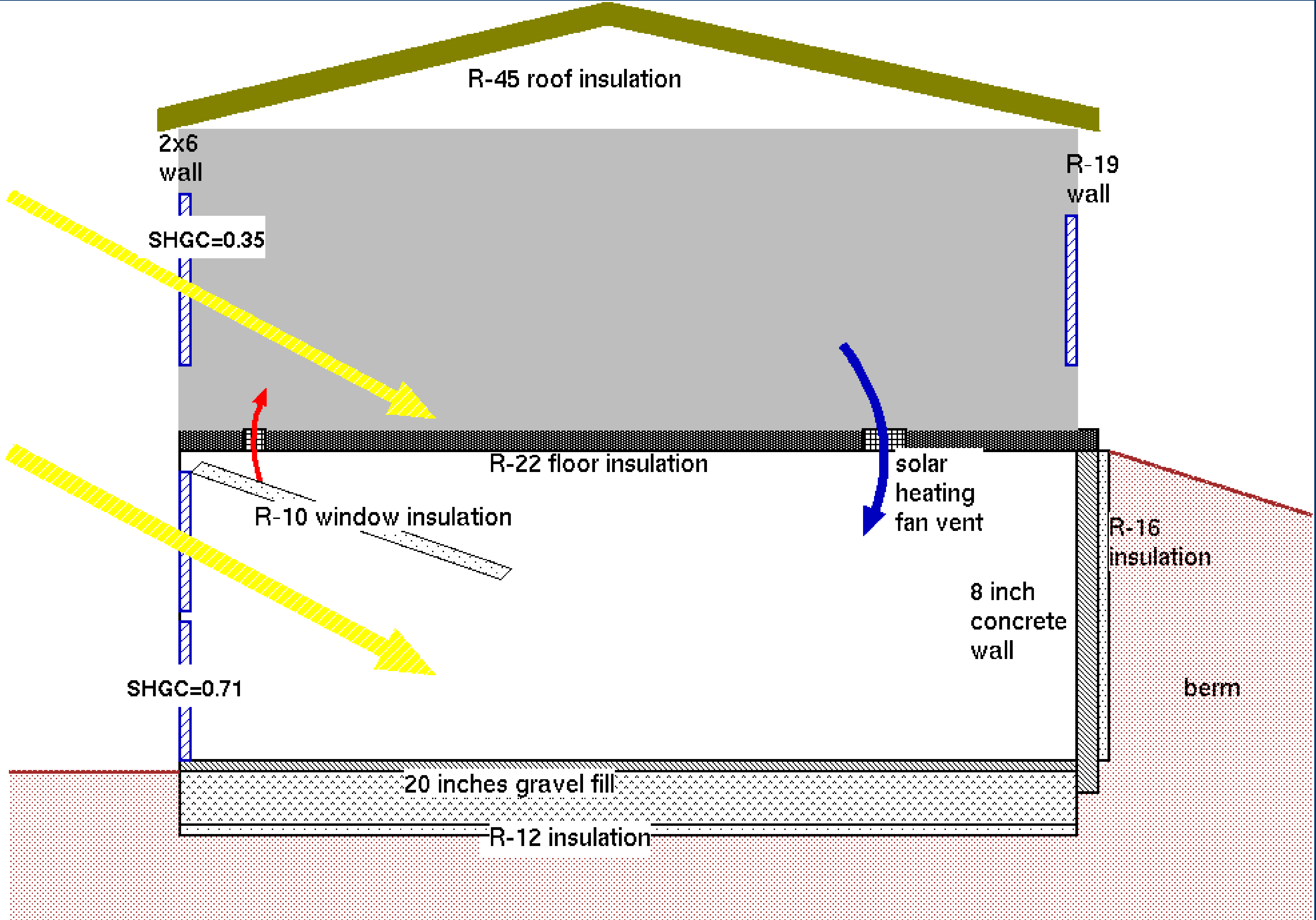
Design Goals

- Efficiency: >90% solar heating
- Low cost
- Conventional interior with windows for views
- Simplicity - easy to build
- Autonomy - runs itself
- Robust - tolerant of errors
- Not a Status Symbol!

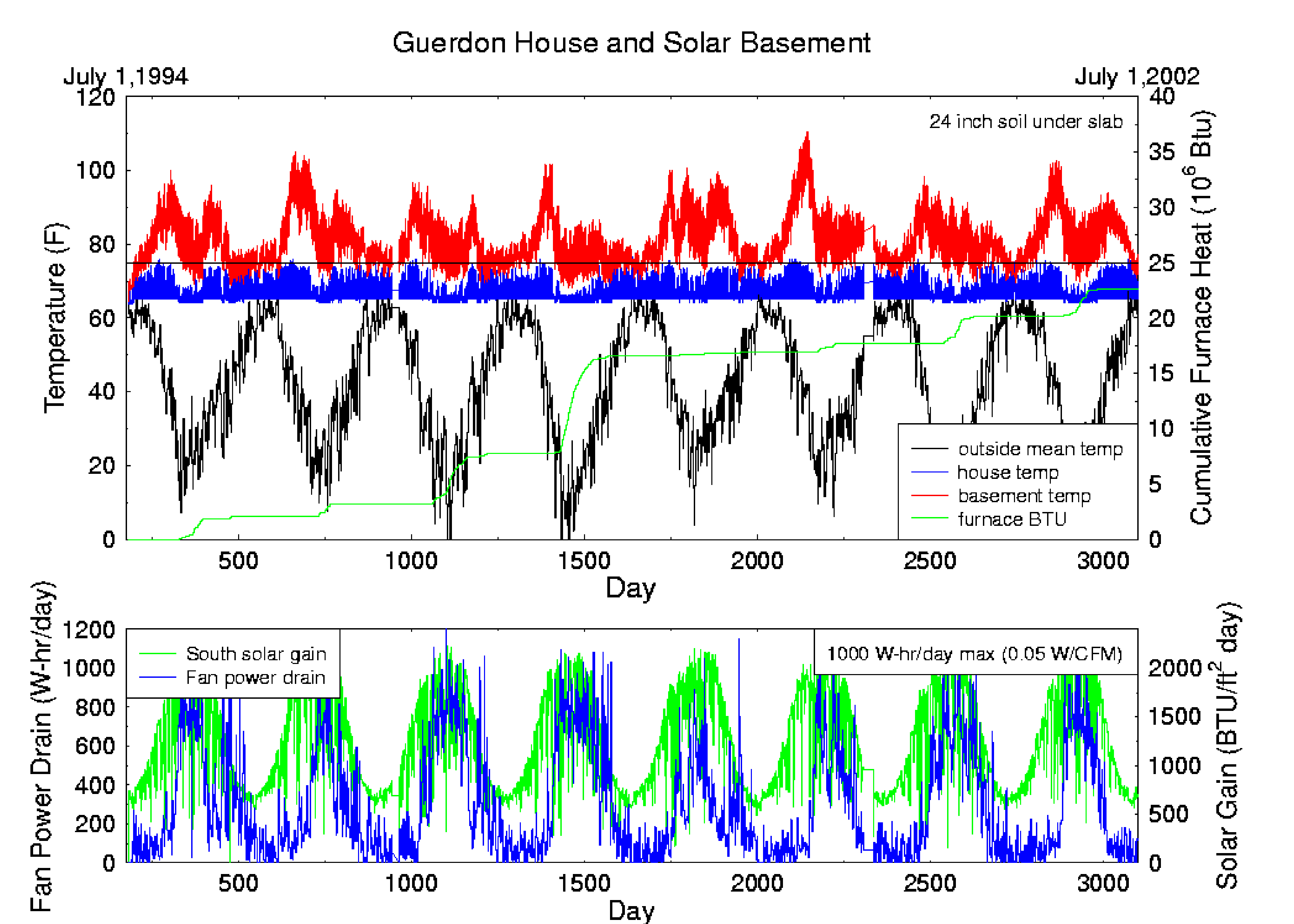
Solar Basement Design

- Basement provides solar collection and thermal mass .
- Basement is allowed to get hot, so glazing fraction can be high (22% of the floor area).
- Air circulates passively and actively.
- Basement window insulation is controlled.
- Heating system uses little electricity and provides storage space.


R-45 roof insulation
2x6 wall
R-19 wall
SHGC=0.35
R-22 floor insulation
solar heating fan vent
R-10 window insulation
R-16 insulation
8 inch concrete wall
SHGC=0.71
berm
20 inches gravel fill
R-12 insulation

Numerical Model for Design

- Fortran 90 program written to model thermal performance of solar design.
- Model driven with 8 years of hourly weather data gathered by the CoAgMet station in Center, CO.
- Model includes solar gain through windows, 1D heat transfer in concrete, 2D transfer in berm and soil, conduction through house walls, air infiltration, heat transfer with basement fan, and backup furnace use.
- Predicted propane use 7 gal/yr for solar design and ~360 gal/yr for the control.


Guerdon House and Solar Basement
July 1,1994
July 1,2002
24 inch soil under slab
Temperature (F)
Cumulative Furnace Heat (10^6 Btu)
outside mean temp
house temp
basement temp
furnace BTU
Day
Fan Power Drain (W-hr/day)
Solar Gain (BTU/ft^2 day)
South solar gain
Fan power drain
1000 W-hr/day max (0.05 W/CFM)
Day

Model Benefits and Drawbacks

- Modeling aided our decision making:
  - window placement
  - thermal mass
  - amount of insulation
- Modeling provided estimates of control case without basement.
- Modeling wasn't as accurate as expected.
- Modeling lacked turbulent and radiative heat transfer.

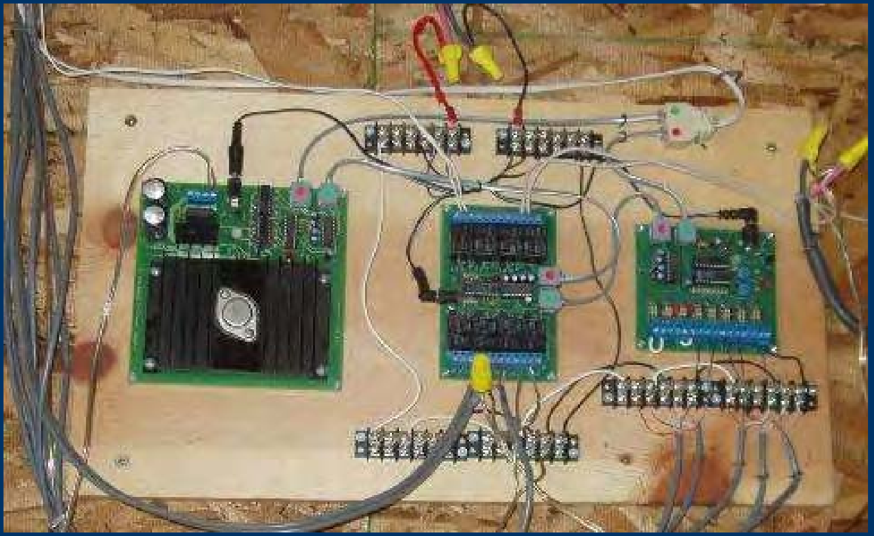

LOAD

Construction Errors

- Missing insulation around footers
- Extra infiltration due to gap between house and foundation

Control System - picnet

- Program house_control.c uses picnet to control house.
- serial bus with 3 boards
  - A/D with temperature sensors
  - Relay board
  - Variable speed motor controller (unused)



House sensors and controls

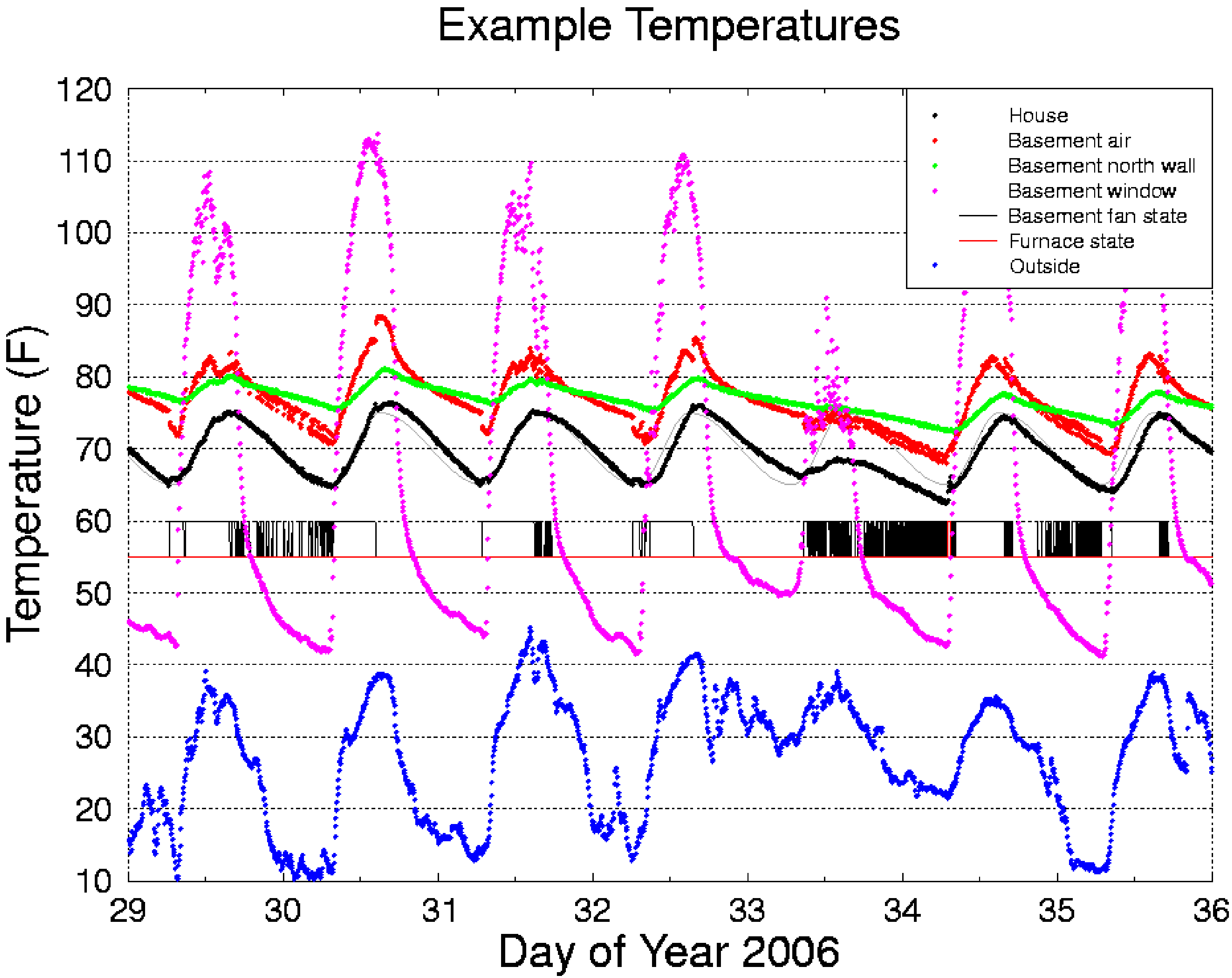
- Temperature Sensors
  - basement window
  - basement air
  - basement north wall
  - house air
  - battery box
- Control relays
  - basement fan
  - basement insulation (garage door opener)
  - furnace
  - battery cooling pump and fan
  - heat recovery ventilator
  - power to internet hardware

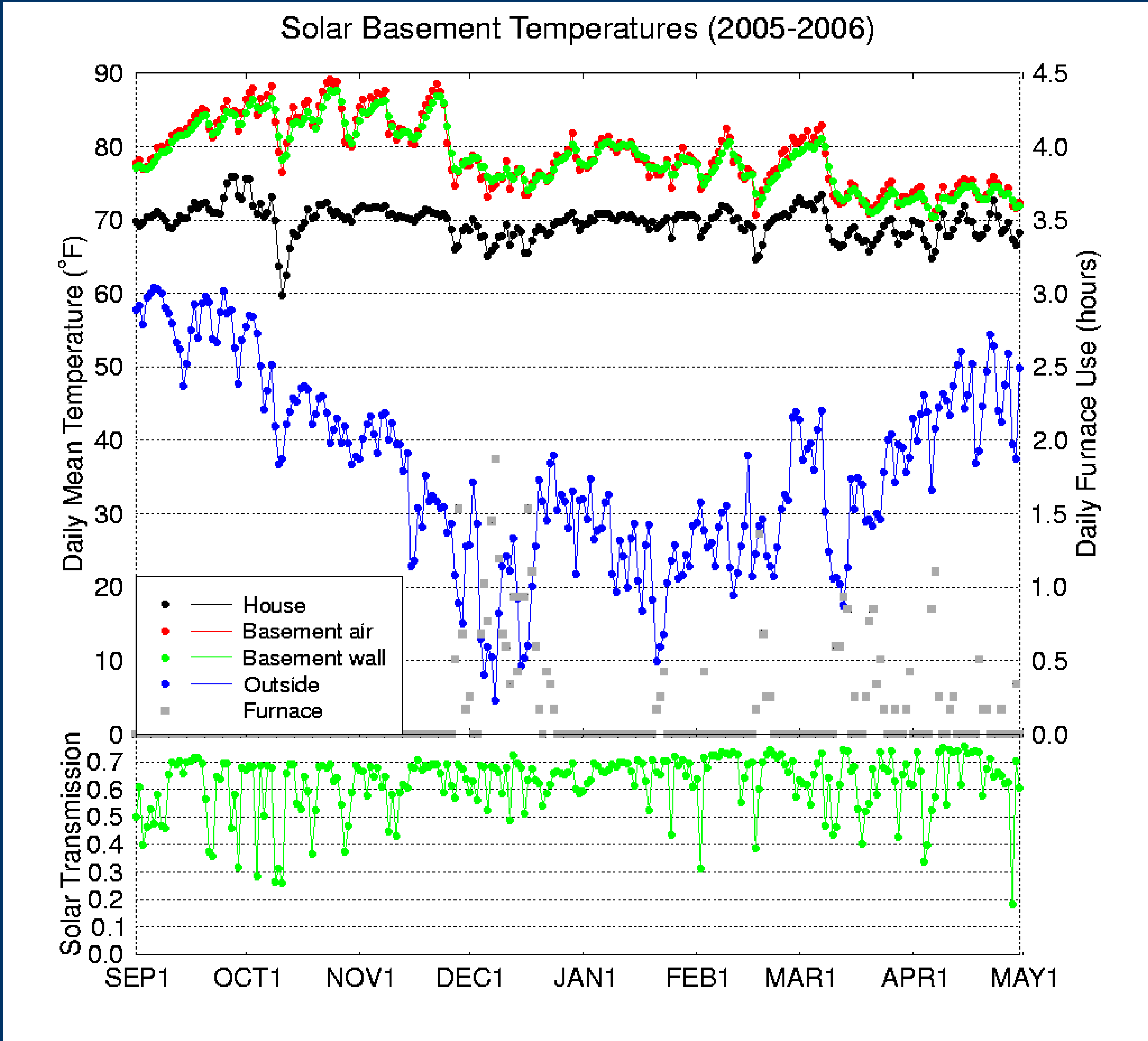
Weather Station

- Davis Vantage Pro
- data radioed to a data logger
- download via serial port on house control computer
- data uploaded to web and used to evaluate heating degree days

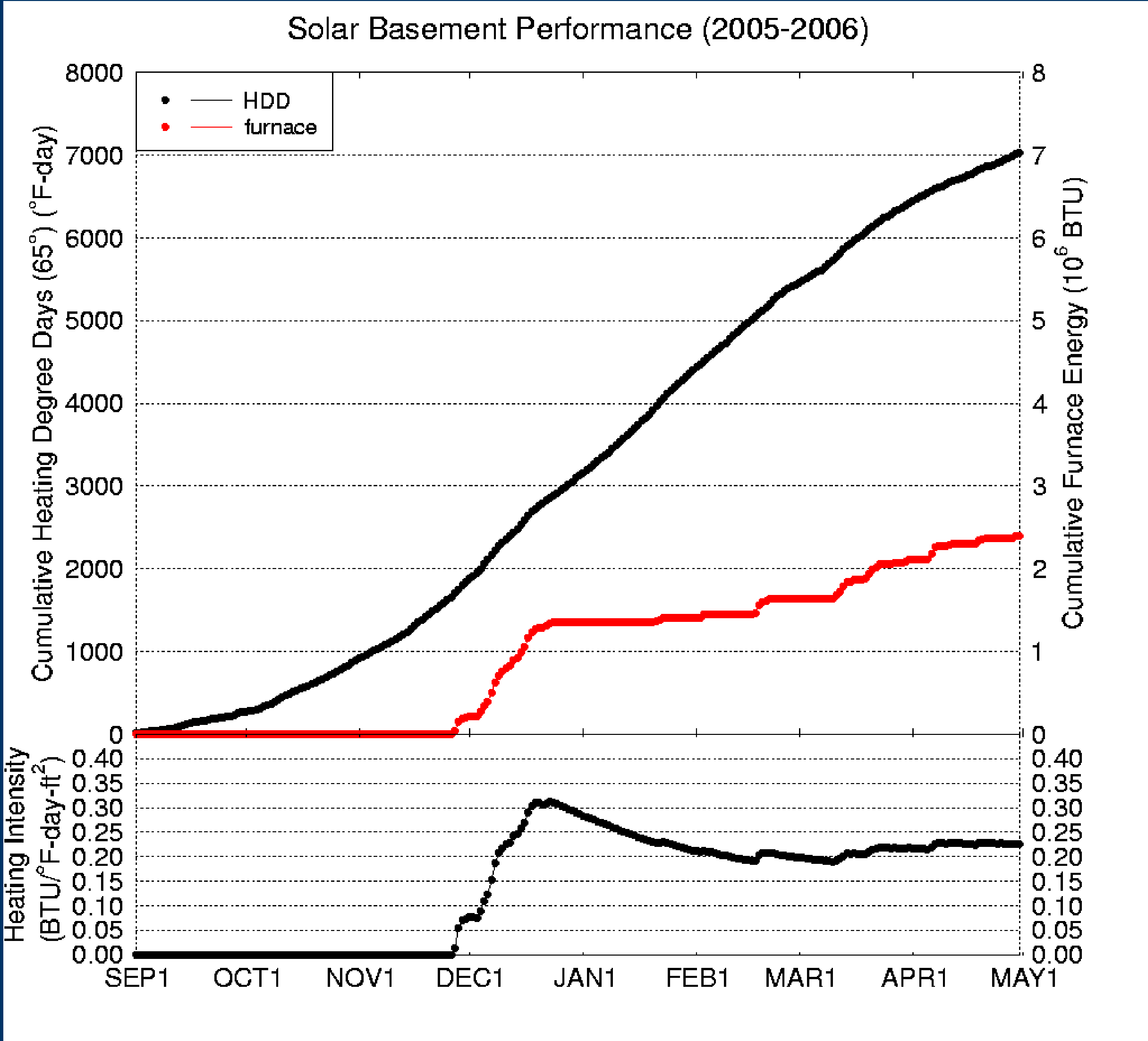
Efficiency Improvements

- House Window Insulation
  - Insulate windows at night in winter
  - 2 inch thick Styrofoam – R10
- Sine wave thermostat
  - Heat is transferred most efficiently when the basement is warmest
  - Solar system brings house to 75F at 4PM, lets it fall to 65F at 8AM
- White tarps in front of basement


Example Temperatures
Temperature (F)
120
110
100
90
80
70
60
50
40
30
20
10
29
30
31
32
33
34
35
36
Day of Year 2006
House
Basement air
Basement north wall
Basement window
Basement fan state
Furnace state
Outside

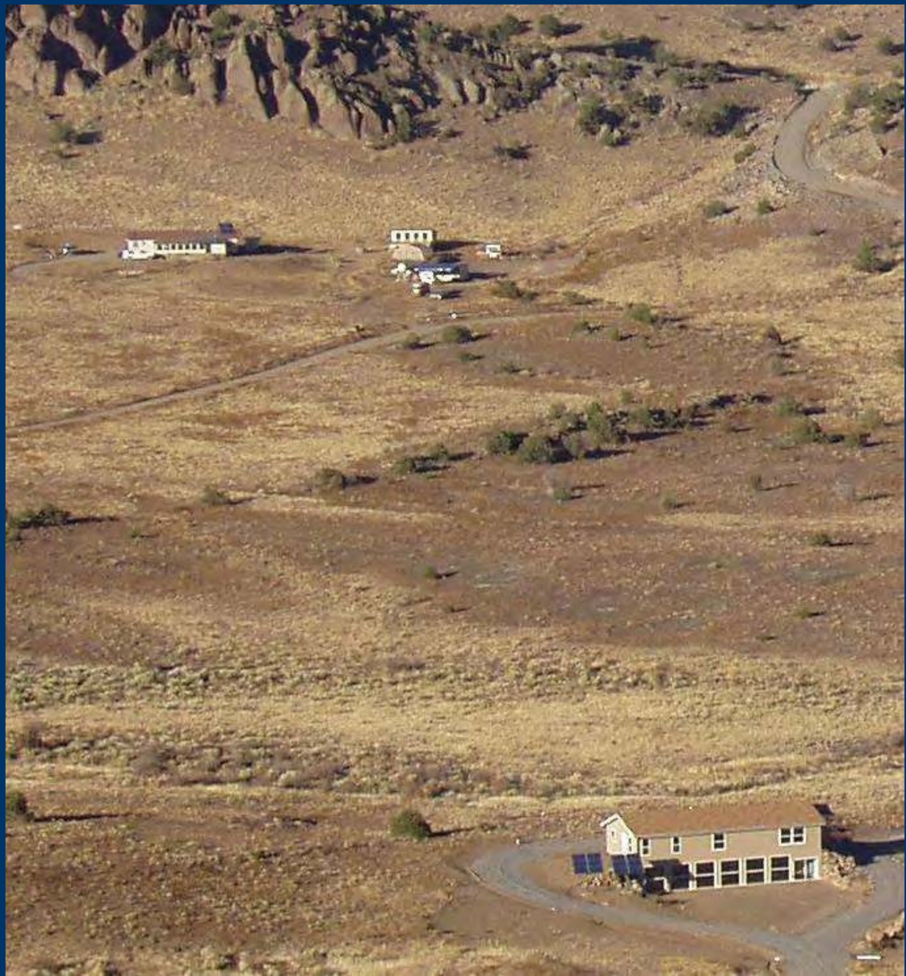


Solar Basement Temperatures (2005-2006)
Daily Mean Temperature (°F)
Daily Furnace Use (hours)
Solar Transmission
House
Basement air
Basement wall
Outside
Furnace
SEP1
OCT1
NOV1
DEC1
JAN1
FEB1
MAR1
APR1
MAY1



Solar Basement Performance (2005-2006)
HDD
furnace
Cumulative Heating Degree Days (65°) (°F-day)
Cumulative Furnace Energy (10^6 BTU)
8000
7000
6000
5000
4000
3000
2000
1000
0
8
7
6
5
4
3
2
1
0
Heating Intensity (BTU/°F-day-ft^2)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SEP1
OCT1
NOV1
DEC1
JAN1
FEB1
MAR1
APR1
MAY1

Toepfer house comparison



- Our neighbor
- Same climate, size orientation + shape
- Heated with 6 cords wood per year
- 10 BTU/(sq ft HDD)
  - our house uses 0.2-0.7 BTU/(sq ft HDD)

Home Energy Saver Control

- On the web http://homeenergysaver.lbl.gov
- Estimates energy use from
  - construction, orientation and geometry
  - SHGC of windows, R-value of insulation
  - climate from weather station in Alamosa
- Correcting for actual HDD gives 930 gallons propane per year, compared to actual furnace use of 82 gallons in 2004-5 and 26 gallons in 2005-6.
- Our house is more than 90% solar heated.

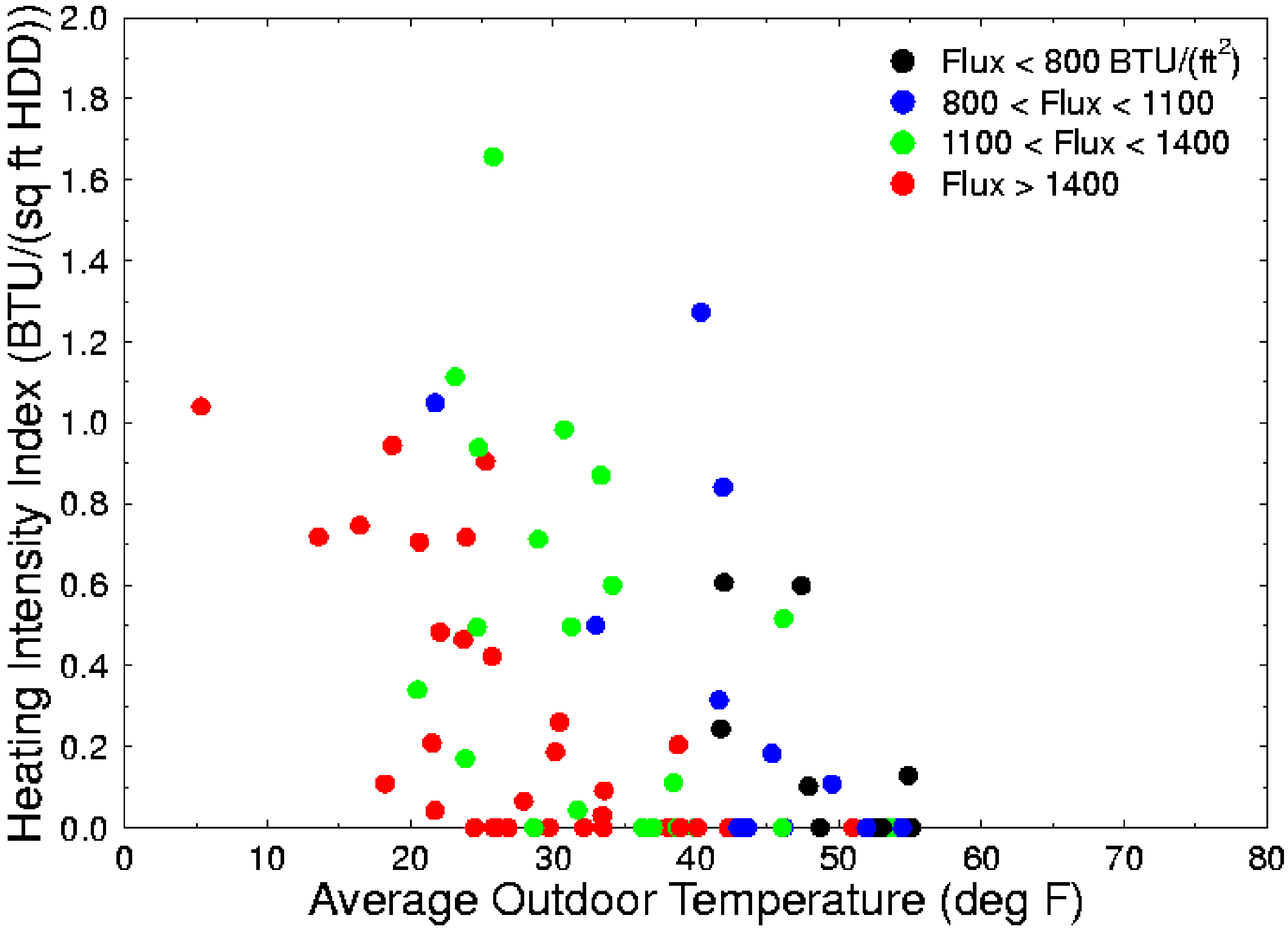
Other Utilities

- water
  - ½ horsepower pump, UV water purifier
- sewer
  - engineered septic system, too little soil
- electricity
  - 100% solar powered, 1440W PV panels
- propane – 500 gallon buried tank
- internet
  - 5.8 GHz wireless, 13 miles from AP
- telephone – 3 Watt cell phone

Conclusions

- Basement cost ~ $30-40K more than a stem wall foundation.
- Basement saves roughly 850 gallons propane, currently $1700 per year.
  - Current yield ~5% but will increase with fuel prices
- Unique design may not have broad appeal.

Weekly Solar Flux on South Windows



Embodied Energy

- Our house consumed energy in its building, especially the concrete:
  - 2MJ/kg ~ 1500 gallons propane
  - concrete energy offset in 1-2 years
- Solar panels offset their energy of manufacture in < 4 years.
  - result from Holland, much less sunny place.
- Location of the house costs ~370 gal gasoline/year, temporarily. For best efficiency, we should all live in cities.

Cost Summary

• Land (35 acres) -	$36K
• Well and pump -	8K
• Foundation -	86K
– about 70% basement	
• Solar electricity -	21K
• Septic system -	20K
• House -	80K
• Automation -	5K
Total:	$256K