A Net Zero Retrofit: Just an Exception, or Implications for the Rest of Us?

Data, Not Dogma
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Retired researcher from Mayo Clinic

Manually collected 25,000 data points on this house since 2009

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Photo credit: John Morgan, Raven Rocks Press
The Lutz Passive House Inspired Retrofit (Urbana, OH)

2010: One of first 3 homes to meet 1,000 Home Challenge (without PV)

2011: Achieved net zero energy site energy (3.5 KW PV)

Goal: 90% reduction in heating energy

Updated 07-12-2012
Issues to Explore

• Lessons learned on path to NZE
  – Initial results from deep retrofit
  – Outside DHP unit in isolated crawlspace
  – Radon control
  – HPWH

• Implications for other housing stock

• Behavior & EE (one of a kind “eccentric” or role model for transformation)
Project Summary

PHASE 1: Summer 2008
Passive House-Inspired Retrofit

PHASE 2: 2010
Add DHP, PV, & Rocket Stove

PHASE 3: 2011-12
Add more PV, Address Radon; Add HPWH

Monitor & Track Performance Throughout
Project Retrofit Highlights

Insulate all six sides of a small home to achieve higher performance than most believe is possible

- Isolated crawl space; R-40 added to house floor/crawl space ceiling; PEX pre-existing
- Open cell foam against roof deck;
- Fiberglass added to existing cellulose on flat

R-40 added to walls
Final: 200 CFM50 (2.64 ACH50)
Comparing Pre- and Post-use (kWh/Yr) with Average & THC Threshold

Home Energy Yardstick (Average)

Pre-retrofit Use (kWh)

THC Opt B Threshold (kWh)

THC Opt A Threshold (kWh)

Post Use (kWh)

89% Reduction Heating Energy

Pre Period: 9/15/08-9/14/09
Post Period: 9/15/09-9/14/10

2008 winter interior temperature ~ 63°F
2009 winter interior temperature ~ 50°–55°F (by choice)
Total Household
Monthly Energy Use (1st Year)
(Comparing kWh/Month)

Pre Period: 9/15/08-9/14/09
Electric furnace; ducts in attic
Post Period: 9/15/09-9/14/10
Electric space heater, when needed

NOTE:
Pre- to Post-Heating Use
89% Reduction
(Technical & Behavioral)

2008 winter interior temperature ~ 63°F
2009 winter interior temperature ~ 50°–55°F (by choice)
Monitoring Ductless Heat Pump Experiment:
Outside Unit in Unconditioned Crawl Space

2011 Cooling: 2 kWh max/day
Ambient 90-100 °F; T-stat 78

NOTE: This installation voids the warranty of the unit

Additional data posted:
3.5 KW PV Array

House roof too shaded; Backyard nearly perfect spot

• Kyocera 235 watt panels
• Enphase microinverters (M190) - one for each panel
Radon!

Pre-test 143 Pc/l crawl – 43 Pc/l living space (fall 2011)
Panasonic Whisper fan exhausting from crawl space to outside

✓ Lowest fan setting
✓ Only drawing 3 watts (<.1 kWh/day)

Continuously monitor house radon (.5 - 2 Pc/l)

NOTE: This system does not meet US radon system compliance due to the location of fan or height of the exhaust termination
Exhaust Ventilation From the Crawl

- Still uses ERV ~ 1 hr/day (morning)
- CO$_2$ level climbs slowly over 24 hours
- Applications & implications other crawl space homes (integration of ventilation & source control)?
kWh/Day by Month Over Time

- Retrofit Completed
- Rocket Stove Added
- 9K Fujitsu DHP Installed
- GeoSpring HPWH Installed
- Radon - Panasonic Exhaust Installed In Crawl Space
- 2.35 KW PV Installed
- .94 KW PV
- .235 KW PV

- Oct
- Nov
- Dec
- Jan
- Feb
- Mar
- Apr
- May
- June
- July
- Aug
- Sept
- Oct
- Nov
- Dec
- 2008
- 2009
- 2010
- 2011
- 2012

Net
2011 Monthly Data
(total household energy in kWh – site energy)

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<td>Production</td>
<td>134</td>
<td>170</td>
<td>303</td>
<td>277</td>
<td>324</td>
<td>345</td>
<td>395</td>
<td>411</td>
<td>245</td>
<td>281</td>
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<td>211</td>
<td>120</td>
<td>116</td>
<td>150</td>
<td>31</td>
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2011 Energy Use/Production Vs. THC Threshold (in kWh\(^1\))

THC OPTION B (Electric Heat)

2011 Use By Energy Source

2011 Production (-)

2011 Net Use (-)

841 kWh Surplus!

Probably NZE even with conventional temperature set-point
**Energy Use Index (EUI)**

<table>
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<th>Year</th>
<th>kBtu/Yr/Ft²</th>
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<tr>
<td>2008-09</td>
<td>41.7</td>
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<tr>
<td>THC OPTION B</td>
<td>16</td>
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<td>2009-10</td>
<td>11.3</td>
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<td>2010-11 (Gross Use)</td>
<td>12.8</td>
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<tr>
<td>2010-11 (Produced)</td>
<td>-16.6</td>
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<tr>
<td>2010-11 (Net)</td>
<td>-3.8</td>
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~5500 DD, 650 square feet
Ductless Heat Pump use from 11/22 to 2/22 = 348 kWh (~12 therms)
DHP kWh per Month

2011-12 Heating Use: 435 kWh

- Nov-11: 30 kWh
- Dec-11: 110 kWh
- Jan-12: 130 kWh
- Feb-12: 120 kWh
- Mar-12: 35 kWh
- Apr-12: 20 kWh
What If???

Thermostat setting was 70, not 60?
House was not as well insulated?
House was 1,200 or 2,400 ft\(^2\), not 650 ft\(^2\)

• Would crawl space temperature drop too much?
• Would crawl space surfaces meet dew point more of the year?
• Would warmer house air leaking into crawl space help compensate for increased DHP run time?
• Would benefits (kW & kWh) diminish or increase?
(23 kWh Used by DHP - 1.64 kWh/day)

- Outside °F
- Living Space °F
- Crawl Space °F
- RH Living
- RH Crawl

Temp. °F  % RH

Temp. crawl space
Temp. living space
Temp. outside
Relative Humidity crawl space
Relative Humidity living space

Date:
2012 Cooling Data
78°F & 74°F Thermostat Settings

Temperature (°F) vs. Kilowatt-Hours (kWh) for different settings:
- T-Crawl
- T-Living
- T-Out

Graph shows fluctuations in temperature and kWh usage from June 20 to July 10.
What About Spring?  
When Crawl Space Surface Temperature Drops Below the Dew Point?

• Warm up the space?  
• Reduce outside air flow?  
• Reduce the RH?  
• Make crawl space water resistant/drainable?
Is this Relevant to the Pacific NW?

Coastal weather
  Milder winters
  Minimal cooling load
Ventilation/radon integration
Rethink buffered spaces?
How important are peak kW vs kWh reductions?
Bill Rose: “What you see is that vapor pressure tracks temperature. High temperature, high vapor pressure, for both living & crawl. This is typical of highly buffered spaces with low ventilation. High temperature drives moisture out of the exposed wood—low temperature drives humidity into the wood. In normal leaky construction, the vapor pressure tends to equalize in all spaces—equalizing with the outdoors”

Based on Summer 2011 data from July 20 to August 2

Thanks to Bill Rose for analyzing the data.
Go Gas-less?

Water heating gas use – 16 therms/year!
Admirable!

QUESTION:

HOW CAN YOU COST-JUSTIFY A HPWH??

($999 plus installation)
GeoSpring
Heat Pump Water Heater

34 Day Performance

- 16.5 kWh total
- .48 kWh/day
- ~7 gpd avg. hot water use

NOTE: Wintertime energy use will be higher

1 May - July 2012
Comfort is in the Eye of the Beholder

• Climate change & resource depletion are serious & immediate threats

• We need to adapt & demonstrate alternatives

• Physical acclimation to achieve comfort is not the challenge, the significant barrier is psychological

• Winter: 2008-09: Low 60’s

• Winter: 2009 - March 2010: Low 50’s

• Winter: March 2010 - 2012: (DHP) Low 60’s
Implications for Other Projects

- Small simpler house = lower job cost
- Solo occupancy = better control of T-stat!
- Go deeper w/integration of efficiency, behavioral choices, & renewables
- Value of ongoing monitoring
- Value of ongoing investment
- Synergies may offer value (buffer zone, radon control)
- Better results with highly motivated occupant!
- Value of tapping committed homeowners/early adopters
Lessons Learned

• House thermal performance not quite up to expectations (attic insulation? air sealing?)
• Summer comfort significant challenge (before DHP)
• Radon solution also helped with house ventilation - <.1 kWh/day!
• Ductless heat pump experiment works under current load conditions
• HPWH exceeding expectations to date
• Net energy producing with 3.5 kW PV
**Feedback Welcome**

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- Deep Energy Reduction Case Studies  
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