The Lutz Passive House Inspired Retrofit (Urbana, OH)

Meets the Thousand Home Challenge!

Goal: 90% reduction in heating energy

Updated 03-10-2012
Ward Lutz
Urbana, Ohio
(Oct 2009-Sept 2010)

One of the 1st 3 homes in North America to officially meet the Thousand Home Challenge!

1st project in Ohio!
Case Study Outline

1) Project Overview

2) 1000 Home Challenge & Energy Use

3) Phase 1 (2009)
   - Insulating 6 sides
   - Addressing durability & IAQ
   - Lessons learned

4) Phase 2 (2010)
   - Rocket stove, PV array, ductless heat pump, diagnostic visit

5) Project Update (2011-12)
1) Project Overview
Primary Objective:
- Reduce the use of fossil fuels for heating/cooling in order to limit the adverse effect on climate change & air pollution

Secondary Objectives:
- Learn from the experience
- Inform & motivate public
Summary

- Built in 1950; purchased August 2008
- Bungalow
- Western Ohio
- 576 ft$^2$ finished floor area (24 x 24 ft)
- Frame construction, recent new roof
- Remedial opportunities: wet crawl space
- Original systems: All electric, electric forced-air furnace (in attic), central air conditioning unit, electric hot water tank
Compact! No Wasted Space Here!

24’ x 24’ Floor Plan
Project Highlights

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

R-40 added to house floor/crawl space ceiling

R-40 added to walls
Final: 200 CFM50 (2.64 ACH50)
2) 1000 Home Challenge & Energy Use
Annual Site Household Energy Use (measured pre-retrofit)

- **Heating**: 5,773 kWh
- **Hot Water**: 15.5 therms natural gas\(^1\) (465 kWh)
- **Everything Else**: 1,908 kWh
- **Total**: 8,056 kWh
- **Heating Degree Days/Yr.**: 5,400

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1. Extrapolated based on 9 months usage; tankless water heater installed November 2008 to replace electric water heater tank
Two Options to Meet the THC

THC OPTION A (75% reduction from previous use) cannot be used because the energy value of the previous year’s wood use is not verifiable. OPTION B is not relative to previous use; inputs include weather, house size, number of occupancy and type of fuel used for heating.
Meeting the Thousand Home Challenge

■ The customized threshold for this project is 3,040 kWh/yr. THC Threshold Allowance OPTION B  Electric Heat.

■ This household exceeded its threshold for the year September 2009 to September 2010!
Thousand Home Challenge
Annual Site Energy Threshold

- **Heating:** 1,230 kWh (if electric)
- **Cooling:** 189 kWh
- **Hot Water:** 606 kWh
- **Everything Else:** 1,015 kWh
- **Total:** 3,040 kWh

1. OPTION B Inputs: 1 occupant, Dayton Airport weather station, 576 ft² finished floor area, electric heat; If fossil heated, the total annual allowance would be 4,270 kWh

[www.thousamdhomechallenge.org](http://www.thousamdhomechallenge.org)
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)

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

Pre- to Post-Heating Use – 89% Reduction! (Technical & Behavioral)
Total Household
Monthly Energy Use (1st Year)
(Comparing kWh/Month)

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

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)
### The Lutz Retrofit First Year Results

#### First Year Results: kWh/Day

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

#### Comparing 2008 & 2009

*Winter interior temperature: 2008 ~ 63° F; 2009 50 – 55° F*
Electricity Used & Produced Since PV Installation

3.5 KW PV Array
1,300 kWh Surplus as of 1 Year¹

¹In this case, surplus is electricity produced – electricity used (not including gas & wood)
2011 Household Energy Production, Use, & Net

831 kWh excess over use in 2011

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Basis for Predicting Reductions

- Evaluation of previous nonheating use with a Kill A Watt™ meter & by analyzing bills
- No modeling, rather Passive House Institute concepts were applied
- Willing to continue to creatively reduce energy through lifestyle choices
3) Phase 1 (2009)

Insulating 6 sides
Addressing durability & IAQ
Lessons learned
Project Opportunities

- Not in a hurry: more time to think & to make improvements on the design
- We added more insulation than originally planned
- Better products than 30 years ago
- Good public exposure, highly visible project, on main road
- Small, simple house – lower project cost!
Wall Thickening

- Removed vinyl siding
- Pressure treated 4x6 bolted to foundation cap block
- 2x4 added to 4x6 to create 7" cavity
Eliminated back door & back stoop
Lower cost - better insulation & air tightness. Eliminates thermal bridge!
Exterior 2x4 Wall Framed

Top left - One back window eliminated (utility room)

Framing prior to new window installation
Gable End with Flashing
Wall Thickening

- High density fiberglass batt (R15 x 2) added horizontally & vertically

No Gaps! Careful installation, but diagnostic inspection should have verified air tightness of wall cavity, particularly at bottom and top of wall.
Construction Sequence

Overlapping joints in extruded polystyrene & particle board
Exterior Wall Detail

Ground moisture a potential problem – Clearance to particle board edge & 2x4 (Addressed summer 2010)
Windows & Doors

- Framing for new windows installed
- Windows (Outies) mounted on particle board
Walls – Nearly Done!

- Particle board added for racking & air tightness
- 2" (R10) extruded polystyrene (XPS) added outside
Walls – Done!
New Siding on Exterior
Isolated Crawl Space

- Temporarily removed block on non-load bearing side to provide access for 4’x8’ rigid insulation
- Insulated floor cavity with R15 (x2) fiberglass batts
- Installed 2" extruded polystyrene (R10) under floor joists; taped joints
- Installed 1.5" (R7.5) extruded polystyrene on interior of crawl space exterior walls
Crawl Space

- Installed sand to protect ground cover from sharp rocks
- Installed ground cover, sealed at walls
- Monitored temperature & RH
- Installed dehumidifier

NOTE: These steps were taken as soon as condensation was observed in the crawl space (late summer 2009)
Open Cell Foam Against Roof Sheathing

Foam applied – very hot day; Monitoring of attic temp & RH leads to concern for effectiveness re insulation & air sealing at perimeter

14” of blown-in fiberglass insulation also added on ceiling over 5.5” of existing cellulose. Air barrier intended to be at roof deck.
Installation techniques that worked!

- Building a 2x4 wall on the exterior to create a double wall
- Layered high density batt installation to reduce gaps in the new 7" cavity
- Using 2" of foam (XPS) outside of new exterior particle board sheathing

Material cost of this system was less than other superinsulation systems

Added R40 wall (new) plus 3½" of pre-existing cellulose in wall cavity = R50 wall
**Winter (Creative) Comfort**

- **Creative Comfort**
  - Psychological – the satisfaction of reducing fossil fuel consumption, of increasing awareness in my community - it is the right thing to do!
  - Physical – regard the reduced temperature not as a hardship, but rather as an adaptation, such as wearing extra cloths
  - In my view (Ward) psychological comfort trumps physical adaptation

- **Temperature Settings**
  - Pre retrofit 63° F (thermostat)
  - 2009-10 post retrofit 50-55° F (turn on electric space heater when needed)
  - 2010-11 temperature ~60 (after ductless heat pump installed)
Phase 1 - Summer Comfort

- **Reduce Solar Gains**
  - One south-facing window with solar gain coefficient of 0.25 (minimize summer heat gain)

- **Reduce Internal Gains**

- **Creative Comfort**
  - Practice nighttime flushing (opening windows at night & closing them during the day)
  - Acclimate to warmer summer temperatures

- **Mechanical Solutions (Phase 1)**
  - Ceiling fans

- **Bottom Line** (check update)
  - Reduced but did not eliminate need for AC
Hot Water

- **Delivery Efficiency**
  - Small house - minimal plumbing
  - Bathroom next to utility room

- **Creative Solutions – Water Use Reductions**
  - Quick showers
  - Low-flow shower head
  - No hot water used for clothes or dishwashing

- **Hot Water – What Worked Well**
  - Tankless gas water heater
  - No standby loss
  - High combustion efficiency
  - Direct vent - compatible with tight house
Phase 1 - Air Quality

Source Control Strategies

- Not much cooking in the house
- Ground cover installed in crawl space
- Crawl space isolated from house
- Instantaneous water heater sealed combustion
- Use dehumidifier & ERV to reduce humidity & window condensation

See Radon Update Part 5
Phase 1 - Mechanical Ventilation
RecoupAerator® Whole House Unit
(200 DX) ERV

- 70 watts six months/yr (~300 kWh)
- 70-250 CFM
- May use CO\textsuperscript{2} to monitor ventilation
- 1 kW inline electric heating element
- See update part 5

Fully ducted within conditioned space
Phase 1 - Electrical Use

ERV: 70-210 watts
Refrigerator: ~291 kWh/yr
Dehumidifier (in crawl space): .5 kWh/day
Washer: 0.14 kWh/load & 1 load/week
Lighting: All CFLs
Fans in summer
Using Kill a watt™ meter to track energy use
Optimization Strategies

- Eliminated need for conventional central heating & AC system through significantly improving the building enclosure
- Could have used instantaneous water heater for space heating to lower electric use/source energy even further
- See update part 5
Tracking Down Out of the Ordinary Products

- **ERV** (Katrin Klingenberg from Passive House Institute US helped) as well as online research

- **Windows**: went with Marsh Building Products of Dayton after comparing them (performance & cost) to a Canadian company
2009 Timeline & Major Steps

- **March**: crawl space
- **April & May**: exterior walls
- **June**: windows, attic, indoors
- **July**: installing ducting system, exterior siding
- **Sept**: crawl space modifications to address moisture (sand, moisture barrier)
- **Dec**: some interior air sealing
Plan for Rapid Feedback

MANUAL

- Remote monitoring temperature & RH in crawl space & attic
- Monitoring electric use of specific equipment
- Tracking utility consumption/daily meter reading
Phase 1 Project Budget

- $36,000 (Labor & Materials)
- Ward’s labor is not reflected in budget
Phase 1 - Cost Breakout

- **Labor** - $21,321
- **Windows** - $2,327
- **Siding & Front Door** - $2,029
- **Insulation** (attic blown-in & batt insulation) - $1,420.84
- **Spray Foam Insulation** (attic) - $1,744
- **Materials** (lumber, foam board insulation, etc.) - $6,063
- **Ultimate Air Energy Recovery Unit** - $1,745
- **Crawl space Moisture** - Moisture barrier $489, Sand $151, Dehumidifier $319
- **Total** - $37,609

576 square feet $65.29 per square foot
Previous Cost

Rinnai tankless water heating system
Installed Nov. 2008

Cost - $2,475.06
Plus $500 for gas line

ISSUE: Using this system for space heating was not considered. This could result in lower CO$_2$ emissions than electric resistance heating (source energy).
Phase 1 Projected Energy Savings

- **Estimated Target:** 80% reduction in household total electricity use
- **Pre-retrofit Electric Cost:** $843/yr
- **Natural Gas use for Water Heating:** 1-2 ccf per month (400-600 kWh/yr) (pre-post no change)

Note: 1 ccf ~ 1 therm
Conundrum: Gas Costs in Low Energy House

- Monthly service cost for natural gas is fixed, regardless of gas use
- Service charge often exceeds cost of gas used
- Annual cost of gas service $120 to $200/year
- Average cost per MMBtu much higher (~double) when service charge factored in
Lessons Learned

- More expensive windows may be less likely to experience wintertime condensation.
- Attic insulation might not be installed or functioning properly.
- Need to evaluate air barrier effectiveness; this could impact insulation performance.
- Possible issues (moisture/air sealing/varmints) bottom of new exterior wall (addressed summer 2010).
- Inline duct heater was not used; space heater was more effective.
What Would You do Differently?

- Obtain pre-retrofit data from a blower door & infrared camera test
- In-process inspections to verify air tightness & continuity of air barrier
- Not have attic foam installed on such a hot day; inspect at time of installation
- Reconsider approach to attic insulation & air sealing – possibly move air barrier to ceiling, rather than roof
- Consider using water heater for space heating, too or use electric water heating (HPWH)
- Consider ductless heat pump initially instead of inline duct heater
- Do radon test early on
What Worked Well?

- Small & simple house
- Significant reduction in heating energy use (89%)
- Moisture control strategy in the crawl space
- Project has increased public awareness in the community
External Feedback

Project Weaknesses

- Project could have benefitted from a home performance contractor, energy rater, and/or passive house consultant with experience with low energy homes.

- The feedback from blower door, IR, & pressure differential tests to assess effectiveness of thermal boundary as implemented would be very valuable. (Ward has expressed frustration in not being able to find local professionals with these skills). (addressed 12-2010)

- Lack of team’s familiarity with air sealing led to some missed opportunities that are much more difficult to address now.
Unprotected wood too close to grade & not protected from moisture/rain splash

It is not clear if air sealing between new exterior wall & foundation/house is effective

Small space under wall – Critter chase way
External Comment – re Timing

If the deep energy retrofit had been done at point of prior siding, roof, & window remodel, it would have fallen in the home’s ideal upgrade life cycle. As it was, those earlier “Improvements” were not assets. The siding & windows were removed, & the new roof was a psychological barrier to a more comprehensive “chain-saw” retrofit, totally encapsulating the roof.
External Feedback: Project Strengths

- Ward is committed to goal & results
- Small, simple house (millions like this one)
- Desire to learn from experience
- Comprehensive project scope
- Got it done – on time & on budget!
- Consistent monitoring follow-up
- Resulting energy use: Impressively low! *(reflects both lifestyle & retrofit)*
In the News!

SPRINGFIELD NEWS-SUN

Urbana man tries out ‘passive house’ ideas

So much insulation has been installed in the house that it should not need a furnace or A/C.

By Matt Sanctis, Staff Writer
7:49 PM Saturday, July 19, 2009

URBANA — Driving past a small, gray, one-story house on East Water Street, there are few signs that essentially, the home itself is an unusual experiment.

At first glance, it simply looks like a quiet, peaceful home with a gravel driveway and a large garden in the back yard. But once inside, the home’s owner, Ward Lutz, is eager to point out the little details that make his house so unusual. The walls, for example, appear thicker than most. At the end of a roughly foot-long ledge, a living room window is composed of three panes of glass, and krypton gas fills the spaces in between to provide additional insulation.

Ward, a retired researcher at the Mayo Clinic, is one of the few people in the United States who is experimenting with a “passive house,” a concept that originated in Germany in the late 1980s. Essentially, the home has been so highly insulated that it requires no air conditioning in the summer and no furnace in
4) Phase 2 (2010)

- Rocket wood stove for canning
- 2.5 kW ground-mounted PV array (+1 KW added 2011)
- Diagnostic visit with blower door & infrared (208 CFM50)
Rocket Stove for Canning

Rocket stove construction based on description in this video -
http://video.google.com/videoplay?docid=797446823830833401#

“Using twigs (47 pounds) falling from trees on property I canned 39 pints of vegetables this summer”
Photovoltaic Array
Completed Nov 2010

Array is shaded somewhat in the morning from trees not on my property.

Power generated
Nov 1, 2010 – Jan 8, 2011
340 kWh

Grid-tied ground mounted system
Photovoltaic Array

Initially 10 Kyocera 235 watt panels (KD235GX-LPB) - www.kyocerasolar.com

Enphase microinverters (M190) - one for each panel
(Enphase Energy Inc., Petaluma, CA)

• Ground Mounted System
• (POWER-FAB Albuquerque, NM)
3.5 KW PV Array

House roof too shaded; Backyard nearly a perfect spot
Diagnostic Visit – Dec 2010

Photo credits: John Morgan, Raven Rocks Press
The Results are In!

208 CFM$_{50}$ (2.6 ACH$_{50}$)
0.1 CFM$_{50}$/6-sided Surface Area

Remaining air leakage points - crawl space band joist & top plate/soffit intersection

Fiberglass insulation performance did not appear to be adversely affected by air movement within wall cavities

Photo credit: John Morgan, Raven Rocks Press
Weakest Link of Thermal Enclosure?

Due to relatively new roof, no consideration was given to removing shingles & insulating on top of roof deck. Therefore, the thermal bridge at the framing & exterior top plate was not addressed.
The small space between the exterior top plate (original wall) and the roof sheathing does not appear to be consistently air sealed & insulated.

Photo credit: John Morgan, Raven Rocks Press

Theatrical fog verified modest air leakage between the attic & outside at this point.
5) Project Update (2011-12)

- Fujitsu RLS9 ductless heat pump (heating & AC)
- Radon mitigation
- Ongoing monitoring
3.5 KW PV Array

Four more PV panels added bringing array to 3.5 kW
Mini-split Ductless Heat Pump

Indoor unit →

Outdoor unit →

ASU9RLS / AOU9RLS - Fujitsu Halcyon 9,000 BTU 26 SEER heat pump single zone ductless mini-split air conditioner
“The outdoor unit was installed in the crawl space under my house. I have a daily record of crawl space humidity & temperature for over a year to date. During that time the maximum & minimum recorded temperatures were 69 °F & 46° F, respectively.

Given that these temperatures are much different than the corresponding maximum & minimum outdoor temperatures, I reasoned that the unit would be more efficient in the crawl space versus outdoors.

This as an experiment to assess if a ductless mini-split heat pump located in my crawl space can provide the small heating & cooling needs of my house without creating temperature extremes in the crawl space.”

Installed February 2011.
Monitoring Ductless Heat Pump Experiment:
Outside Unit in Unconditioned Crawl Space 2011

Cooling: 2 kWh max/day
Ambient 90°-100° F

Vapor Pressure

Additional data posted:
Ductless Heat Pump Cooling: Temperature & RH
(23 kWh Used by DHP - 1.64 kWh/day)

- Temp. crawl space
- Temp. living space
- Temp. outside
- Relative Humidity crawl space
- Relative Humidity living space
More Data! 11/22/11 - 2/2/2012

DHP kWh Use & Temperature of Crawl Space, Living Space, Outdoors & RH of Crawl Space

Heating Energy (kWh)
Radon Test Results – Oops!

EPA recommendation: 4 pCi/L

Living Area

Crawl Space
Solution... Phew!

Radon level
Continuous monitoring
~ .5 pCi/L
WHO rec < 2.2 pCi/L

House ventilation rate
Right on
Less than 1,000 PPM CO²

¹Monitoring air in living space, not crawl space
Panasonic Whisper fan exhausting from crawl space to outside
Lowest fan setting
Drawing only 3 watts (<.1 kWh/day)

NOTE: This system does not meet US radon system compliance specifications due to the location of fan & height of vent termination.
Observations

- Small house less expensive!
- Motivated homeowner biggest driver
- Summer comfort a challenge (before DHP)
- Radon solution also addressed house ventilation - <.1 kWh/day
- Ductless heat pump experiment performance impressive to date
- Humidity monitoring essential
- Meets THC without PV
- Net energy producing with 3.5 kW PV
## Contractors

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<th>Energy Recovery Ventilator (RecoupAerator 200DX)</th>
<th>Photovoltaic Panel Array</th>
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<tr>
<td>Jason Morosko UltimateAir Inc. Athens, Ohio <a href="http://www.ultimateair.com">www.ultimateair.com</a> 800-535-3448</td>
<td>Ohio Solar Electric LLC James Groeber Springfield, Ohio <a href="mailto:jgroeber@aol.com">jgroeber@aol.com</a> 937-244-1402</td>
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Home Owner & Project Team

Project Team Members:
Ward Lutz &
Greg Ward,
Ward Construction

Ward.lutz@gmail.com
937-484-4896

Ward Lutz, Owner

Photo credit: John Morgan, Raven Rocks Press