Gloucester, MA
Deep Energy Renovation

Thousand Home Challenge
CASE STUDY
August 2013

John Livermore, Livermore Energy Associates
08-09-13
Answer the Questions…

Why we did it?
What we did?
What we learned?
John Livermore…
“The motivation for taking action to reduce our family’s carbon footprint was the understanding that carbon emissions need to be reduced by about 90% by 2030 in order to stabilize the earth’s climate (at 350 ppm), and the realization that I needed to take personal responsibility for reducing our emissions. Also, I’d been in the energy efficiency business for over 20 years & I felt it was time to put my money where my mouth was (to walk the talk), taking everything I’d learned about building science & had dreamed about doing over the years, & applying it toward retrofitting my own house.”
John continued…

“The purpose of performing the energy retrofit & renewable energy installations on the Livermore residence was primarily to demonstrate what can be done to reduce the carbon footprint of a suburban homeowner on a budget of approximately $50,000. The overall goal is to reduce our home’s carbon footprint by 90%, & in doing so to help others by changing the current paradigm of what is possible.”
The retrofit strategy has struck a balance between three objectives:

1. Make it **affordable**
2. Make it **feasible** (use off-the-shelf technologies)
3. Make it **replicable**

The sweet spot in the middle, where the three circles overlap, is where we primarily focused our strategy.
Project Cost Breakout (approximate)

Lumber & materials: $9,000
Closed-cell foam insulation: $7,000
Thermotech windows/doors: $19,000
Solar hot water system: $11,500
Solar PV system: $9,000
Bill’s labor: $4,000
Total: $59,500

Note: Costs do not include John’s time, but do factor in all rebates & tax credits.
Project Team

Marc Rosenbaum, P.E.
Project Engineer

John Livermore
Project Designer & Owner

Caleb Ewing
Lead Carpenter

Bill Hallaren
Project Assistant
Other Team Members

John’s daughters, Alix & Samantha

John’s 93-year-old father

Jasmine, “the supervisor”
Starting Point: Typical 1973 Garrison Ranch

- **Finished floor area:** 2,480 ft²
- **Walls:** R-13 FG batt
- **Attic:** R-19 FG batt
- **Windows:** DH single-pane w/storms
- **Basement:** Uninsulated
- **Air sealing?**: ...Ha ha ha...None! (3,000 cfm50)
- **Lighting:** All incandescent
- **Appliances:** Vintage
Interim Projects (2001-2007)

- Replaced oil furnace w/87 AFUE gas boiler w/indirect-fired DHW tank
- R-76 attic insulation w/air sealing & radiant barrier
- Started insulating basement slab & foundation walls
- R-5 foam on north wall
Project Target Specs

- **Walls:** R-43 (5” closed-cell foam added)
- **Attic:** R-76 w/radiant barrier
- **Windows:** Triple-pane, low-E, argon (R-5)
- **Bsmt:** Slab (R-7.5), Walls (R-22)
- **Air Sealing:** Reduce to 300 cfm50
- **Lighting:** All LED/SSL & CFL
- **Appliances:** All ENERGY STAR®
- **Renewables:** 4.3 kW solar electric system & 3-panel solar hot water system
Goal: Dramatic Performance Improvement
Meeting the Thousand Home Challenge

• This home’s customized threshold to meet or exceed is 11,247 kWh/Yr (Threshold Allowance OPTION B)
• This household will officially meet the THC when the application is completed, & documentation of 1 year of household consumption verifies that energy use is less than 11,247 kWh (net total site household energy)
• *This household has exceeded its THC threshold and achieved zero net energy use in 2010!*

NOTE: 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.
Thousand Home Challenge Threshold compared with Usage/Production (kWh/yr by use)

Approximate Pre-Consumption: Averaged over several previous years

THC Option A (75% reduction)

THC Option B

09-10 Actual / Predicted (excluding PV)

09-10 Actual / Predicted (Net; including PV credit)

Legend:
- Heat
- Cooling
- Water Htg
- Everything Else
- Net

1 Approximate Pre-Consumption: Averaged over several previous years
Thousand Home Challenge
Threshold Compared with our Usage/Production

THC Option A (75% Reduction): 6,730 kWh/Yr (Equiv.)
THC Option B¹: 11,247 kWh/Yr (Equiv.)

Actual/Projected Usage 2009-10: 5663 kWh/Yr (Equiv.)

<table>
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<tr>
<th>Select Energy Source</th>
<th>Enter annual use</th>
<th>MMBtu</th>
<th>kWh</th>
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</thead>
<tbody>
<tr>
<td>Nat Gas - therms</td>
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<td>3.0</td>
<td>879</td>
</tr>
<tr>
<td>Electricity - kWh</td>
<td>-1986.0</td>
<td>-6.8</td>
<td>-1,986</td>
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<td>Wood pellets - lbs.</td>
<td>2817.0</td>
<td>23.1</td>
<td>6,770</td>
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<tr>
<td>Other</td>
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<td>0.0</td>
<td>0</td>
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<tr>
<td><strong>TOTALS</strong></td>
<td><strong>19.3</strong></td>
<td><strong>5,663</strong></td>
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</table>

1. **Option B Assumptions:** 6,594 DD, 3 occupants, wood/fossil heat, 2480 Ft² FFA

• For more information on the Threshold Allowance:  [www.ThousandHomeChallenge.org](http://www.ThousandHomeChallenge.org)
Pre\(^1\) (red) & Predicted\(^2\) (blue)
Peak Heating Loads (Btu/Hr)

1 Existing in 2008, before basement partially insulated
2 Predicted Final Condition, with DER, SDHW, & PV
Design Heat Loss (Btu/Hr)

Predicted Final Condition, w DER, SDHW, & PV

Bar chart showing the heat loss for various elements of a building:
- Above Grade North Wall
- Above Grade Base Wall (unfinished)
- Below Grade Base Wall (heated)
- Slab on grade (heated)
- Fireplace Wall
- Frame Walls
- Floor over Outdoors
- Windows
- Sloped Ceiling
- Flat Ceiling
- Opaque Door
- Glass Door
- Infiltration
## Pre-condition vs. Predicted Final

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<th>Pre (08)</th>
<th>Predicted</th>
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<tr>
<td>Design Heat Loss (Btu/hr)</td>
<td>39,352</td>
<td>15,712</td>
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<tr>
<td>Design Heat Loss (kW)</td>
<td>11.5</td>
<td>4.6</td>
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<tr>
<td>Design Heat Loss/Ft(^2) (Btu/hr/Ft(^2))</td>
<td>16.1</td>
<td>6.2</td>
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<tr>
<td>Heating MMBtu/Yr</td>
<td>63.7</td>
<td>21.4</td>
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<td>DHW MMBtu/Yr</td>
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<td>Electric Use (kWh/Yr)</td>
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<td>kWh/Meter(^2)</td>
<td>129</td>
<td>33</td>
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Construction details designed & drawn by Marc Rosenbaum, P.E.
Overhang

Existing
Cellulose

3" Polyiso foam

3-1
Line

Terminate per 14

2x3 PT w/ 1/2" Polyiso between

3" Polyiso foam
Meditating on Marc’s Sketches
Getting the Building Permit

• The code officials began as skeptics (“You want to do WHAT to the house?!”) but we were able to turn them into supporters.

Excerpt from my journal entry, July 24, 2008:
“This is your house, right?” Bill asked. I knew he didn’t want me experimenting on someone else’s home. “I like the approach,” Bill said, with a skeptical thought bubble almost visible over his head saying, “But I want you to show/convince me that it’s going to work.” By the end of our chat, we all shook hands & Bill wished me luck & asked me to keep him posted on how the project is going.
Creating the Spirit of Experimentation

Poster created by John’s daughter, Samantha
Extending the Utilities

Gas Meter & Spigots

Boiler Intake & Exhaust
Gable Roof Extensions

August 2008
Re-roofing

Prep for the PV system
Slider to Clerestory

Reduced area of glass & maximized opportunity for insulation
Wall Truss System
(aka ‘Larsen Trusses’)

Rip a 2x4 down the middle & nail together with plywood gussets the thickness of the desired wall cavity
Trusses & More Trusses

Installed directly over existing siding to minimize construction waste
Testing the strength of the wall trusses
Window Frame Extensions

Trimmed 2x6s with 9” TimberLok™ screws
Window Frame Extension on Foundation Wall
The Neighbors

John…

“One of the most satisfying experiences during the construction was the evolving reactions of my neighbors. I had prepped them prior to construction about what was going to happen so it wouldn’t be a surprise to them. At one point, I think they pretty much thought I had fallen out of a tree & hit my head way too hard. As the truss walls began to take shape, however, & the first phase of spray foam was installed, several of them came over and, almost to a word, said, ‘Wow, NOW I get it. This is great! I might consider this for my own house.’ They needed to see it to understand it.”
Closed-Cell Foam

R-6 per Inch
Prepping for Foam
Spraying Foam
Scraping Foam
Windows
Thermotech™, triple-pane, Low-E, argon-filled, foam-filled fiberglass frame, R-5
Sequencing of Job: Trusses/Window frames/Windows/Head flashing/More trusses
Aluminum mesh strips nailed to bottom plate, bent into a U-shape to hold Cobra™ vent material. Surface of foam acts as the wall drainage plane, & sill flashing directs any moisture out through the ½” mesh area.
Primed Outer Truss Face
‘The Yellow Cake’
It’s December…
Cold hands, dull saw blade, tired bodies
Siding Last (rear) Wall

December 2008
June 2009

A big hunk of masonry & a piece of paper
Insulating the Chimney
Roxul™ mineral wool (2 2/8”, R-10)
Reflections on the Chimney

“We should have torn it down!”

Marc Rosenbaum
Basement Floor Insulation system

Install 2’x3’ grid

Cut & fit 1½” EPS foam board

Install ¾” T&G plywood

2 coats of DryLok™ paint
Foundation Wall Insulation System
Interior Wall Insulation System (North wall - Basement)
Interior Wall Insulation System (North wall - Bedroom)
Lighting

All LEDs & CFLs
Appliances

Gave away dryer

Other appliances are ENERGY STAR®-rated
Ventilation

17-watt Panasonic™ fan (50 cfm) on ventilation schedule controlled by digital timer
Solar Hot Water System

3-panel Schuco™ system with 110 gallon stainless steel storage tank
### Solar Hot Water Production-Usage
#### Jan 2009 - Nov 2009

<table>
<thead>
<tr>
<th>Solar DHW HP cumul. (hrs)</th>
<th>Solar pump usage (kWh)</th>
<th>Solar DHW cumul. (kWh)</th>
<th>Solar DHW Cumul. (kWh)</th>
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<td>9</td>
<td>270</td>
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<tr>
<td>245</td>
<td>17</td>
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<td>89</td>
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- 110 gallon solar tank heats up to 145° F
- Estimated annual gas usage: 30 therms (previous baseline about 180 therms)
- Offset approximately 150 therms of gas annually
- 4 therms of gas usage over 7-month period (Apr-Oct)

HP is hours the 70 watt pump operated

Solar DHW Cumul (KWH) is electricity offset assuming DHW is electric resistance (it is not)
Hot Water Usage

- Bricor™ 1.125 gpm showerhead
- Could take a 2-hour shower on 1 full tank of solar hot water
Solar PV System

4.3 kW system
(14) 310-watt Schott™ panels

Inverter
Electricity Production-Usage  
Oct 2008 - Sept 2009

<table>
<thead>
<tr>
<th>PV Prod. (kWh)</th>
<th>PV Cumul. (kWh)</th>
<th>Exterior Meter Reading (kWh)</th>
<th>Electric Calculat. Usage (kWh)</th>
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<tr>
<td>342</td>
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<td>559</td>
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<td>494</td>
<td>4889</td>
<td>-1986</td>
<td>220</td>
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- Ann. Prod: 4,889 kWh
- Ann. Use: 2,903 kWh  
  (previous baseline: 6,000 kWh)
- Produced 146% of electricity needs!
- As of Aug 2013, have $1,000 credit on electric bill !!!
Scan Woodstove w/Biobrick

Sole heat source for house
Carbon Reductions: Closing in on Net Zero Energy

<table>
<thead>
<tr>
<th></th>
<th>Usage</th>
<th>Carbon</th>
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<tr>
<td><strong>Baseline</strong></td>
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<tr>
<td>Electricity</td>
<td>6,000 kWh</td>
<td>4.1 tons</td>
</tr>
<tr>
<td>Hot Water</td>
<td>180 therms</td>
<td>1.1 tons</td>
</tr>
<tr>
<td>Heating</td>
<td>700 therms</td>
<td>4.1 tons</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>9.2 tons</td>
</tr>
</tbody>
</table>

| **Retrofit** |        |        |
| Electricity  | -1,986 kWh | -1.3 tons |
| Hot Water   | 30 therms | 0.2 tons |
| Heating     | 231 therms | 1.4 tons |
| **Total**   |        | 0.2 tons |

Note: Gas used as heating fuel for before and after comparison.
A Boatload of Other Benefits

- Higher comfort at lower air temps (heating season)
- Easy to maintain good RH
- Significantly fewer colds & viruses than previous winters
- Quiet interior
- More durable home: No ice dams & less maintenance (with new building exterior)
- Wide window sills
- Keeps money in the local economy (green jobs)
- Reduces U.S. dependence on foreign energy supplies, strengthening national energy security
- Provides buffer against energy price increases
Lessons Learned

- Start earlier than August
- It takes longer than you think
- Planning, planning, planning
- Understand what you’re doing deeply before you start
  - Break down into individual tasks for planning & ordering materials
- Educate both code officials & neighbors
- Larsen trusses hard to make level over lap siding, & hard to find studs
  - 3½” deck screws worked well for attaching trusses
- 9” Timberlok™ screws worked well for attaching window frames, which were built as a unit & attached as such
- Next time, steel L brackets instead of trusses (save time)
For More Information

www.onthepathtosustainability.com
This is what a suburban renewable power plant looks like

Thank You!

jglivermore@yahoo.com