The Brownsbergers’
Two-family Home
Belmont, MA
Jan. 2011 to Dec 2011

The 6th home in North America to officially meet the Thousand Home Challenge!
1st project in Massachusetts!
"We provided a good tool when we retrofitted their house, but they've used that tool in a masterly way to reach their goals."

Paul Eldrenkamp, contractor
(Byggmeister, Inc.)
“The successful completion of the substantial challenge presented by Thousand Homes Challenge OPTION B, illustrates the value of an dedicated team paying careful attention to design details, and a rigorous inspection and verification process.”

Mike Duclos - DEAP Energy Group
Here’s the Story...
Project Background
Major Partners

- Two Families
  - Susan & Carl Brownsberger
  - Carolyn & Will Brownsberger
- Byggmeister
- Synergy Companies Construction, LLC
- Building Science Corporation, LLC
- National Grid
- New England Breeze, LLC
- ACI/Thousand Home Challenge
Project Timeline

12/08, Downsizing DER project conceived
01/09, Both families’ homes on the market
07/09, Both homes sold; temporary housing
07/09, Commit to buy 118-120 Gilbert Rd
08/09, Select project design/build team
02/10, Begin construction
08/10, Will & Carolyn occupy upstairs
09/10, Susan & Carl occupy downstairs
Pre-move Energy Savings

25 Russell Ave, Watertown
- UFFI in walls (70s)
- New storms (70s)
- Misc. weatherproofing
- Hot water tank wrapped
- New oil burner in 2006
- CFL lighting

6 Stella Road, Belmont
- New windows in 1993
- Reinsulated attic 2004
- Misc. weatherproofing
- Whole house fan for efficient cooling
- CFL lighting
- Thermostat moved

... further improvements possible, but not financially practical.
## Pre-move Energy Measures

<table>
<thead>
<tr>
<th></th>
<th>25 Russell (2 people)</th>
<th>6 Stella (4 people)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square footage</td>
<td>3,770</td>
<td>2,456</td>
</tr>
<tr>
<td>KWh/yr. (all energy)</td>
<td>74,994</td>
<td>42,475</td>
</tr>
<tr>
<td>% of NE avg./person</td>
<td>231%</td>
<td>66%</td>
</tr>
<tr>
<td>EPA Energy Yardstick</td>
<td>1.4</td>
<td>6.3</td>
</tr>
</tbody>
</table>

See this table from the 2005 Energy Information Administration Residential Energy Consumption Survey for average per household site energy use & average household size in New England:

Convert to BTU per kWh: 3,412

Note: Same survey says average floor space per household member is just over 1,000 ft² (2,472ft²/2.34 people).

https://www.energystar.gov/index.cfm?fuseaction=HOME_ENERGY_YARDSTICK.showGetStarted
Pre-project Conditions
118-120 Gilbert Road, Belmont
Pre-project Conditions -- Poor

- Uninsulated/unfinished attic
- Uninsulated/unfinished basement
- No wall insulation
- Aging single pane windows
- Two oil burners: one new, one old “snowman”
- All appliances outdated & in poor condition
- Roof & siding in poor condition
- Interior in poor condition
The Project

For a more complete description of the technical aspects of the project:

Project Components

- Building enclosure
- HVAC
- Renewables
- Improvements/repairs
  - Finish unfinished basement & attic
  - Internal repairs & upgrades
Enclosure

Cellulose in stud/rafter bays plus exterior foam paneling (R-40 walls; R-60 roof); basement walls also insulated (foam & rock wool). New windows -- a unitary project – removed & replaced all exterior detail.
Remove old oil boilers & chimney. Install two high-efficiency sealed-combustion gas furnaces; hot air ducts; mechanical energy recovery ventilation & air conditioning through same duct systems.
Solar Hot Water & Electricity

Solar hot water with two electric backup tanks metered separately for each unit. Solar photovoltaic power linked to upstairs unit (power generation value shared with lower unit by monthly accounting).
Project Cost-Benefit Analysis
Benchmarking Summary

- HERS: From 197 to 32
- Energy Yardstick: From 0 to 9.9
- Thousand Home Challenge: Met in 2011
- Energy per person as % of NE average: Down from 123% to 15% in 2011
- Environmental cost benefit: Net beneficial
Project Benefits

- Energy/carbon savings
- Reduced exposure to energy cost volatility
- Durable exterior
- Low vulnerability to interior moisture -- warm wall cavity
- Low maintenance systems
- Interior comfort
  - Temperature stability
  - Zero drafts
  - Air quality
  - Low exterior noise
- Contributing to industry prototyping efforts
- Leading by example
Project Cost Factors

- Poor initial home condition
  - Need/opportunity for systems replacement
  - Need/opportunity for envelope replacement

- Requirement for professional equipment
  - Two-story (plus attic) home on a slope
  - Steep roof

- Tight project timeline

- Choices about insulation levels
Where Is the Insulation Sweet Spot?

Last insulation layers have lower energy-saving return, but may contribute to non-energy benefits.

Chart Source: David White, Insulation GWP Tool v1.1
Sweet Spot Depends on Unknowns

- Project specifics – cost, structure
- Gas price trends
- Real cost of carbon emissions
- General price inflation
- Interest rate assumptions
- Cost & value of comfort/durability increments

Move quickly to do basic code insulation. Model project elements individually & in alternative combinations before choosing further steps, but keep future improvement options open.
## Energy Only Benefit-Cost Analysis

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost $</th>
<th>Annual Saved $</th>
<th>Payback Years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Renewables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar DHW with Backup (exclude cost &amp; load of backup)</td>
<td>$11,000</td>
<td>$489</td>
<td>22</td>
</tr>
<tr>
<td>Solar PV</td>
<td>$37,810</td>
<td>$803</td>
<td>47</td>
</tr>
<tr>
<td><strong>Enclosure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Code insulation: Cellulose in walls/ceilings, foam in basement</td>
<td>$24,417</td>
<td>$4,628</td>
<td>5</td>
</tr>
<tr>
<td>Additional insulation: Foam walls/ceilings, rock wool basement</td>
<td>$75,392</td>
<td>$815</td>
<td>92</td>
</tr>
<tr>
<td>Windows with associated CFM reductions</td>
<td>$46,263</td>
<td>$704</td>
<td>66</td>
</tr>
<tr>
<td>Residing &amp; reroofing</td>
<td>$37,595</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total enclosure project, including resiing/reroofing</strong></td>
<td>$183,668</td>
<td>$6,148</td>
<td>30</td>
</tr>
<tr>
<td><strong>Heating Plant Change</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency upgrade at reduced load</td>
<td></td>
<td>$313</td>
<td></td>
</tr>
<tr>
<td>Fuel switch (savings on whole amount of final heating load)</td>
<td>$372</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total heating plant change (at final load)</td>
<td>$25,690</td>
<td>$685</td>
<td>38</td>
</tr>
<tr>
<td><strong>Environmental Project Total</strong></td>
<td>$258,168</td>
<td>$8,124</td>
<td>32</td>
</tr>
</tbody>
</table>

Note: High est. of collateral social benefits raises total annual benefits by $2,936. For links to full analysis, see [http://willbrownsberger.com/index.php/archives/6244](http://willbrownsberger.com/index.php/archives/6244)
With available support, all project components except windows achieve break even returns or better on a hard $ basis.

Making the Project Work
After the Project: Measure!

- Set goals: Thousand Home Challenge¹
- Measure details
  - Electricity use by circuit
  - Air quality
  - Thermostat/heating usage
    - Project approach: Being uncomfortable is cheating
    - Avoid unnecessary heating in the 24-hour cycle
  - Hot water use

¹. www.ThousandHomeChallenge.org
Meeting the Thousand Home Challenge

- This home’s customized 2011 threshold to meet or exceed was 16,680 kWh/yr. (Threshold Allowance OPTION B)

- The two households in this project officially met the THC after providing documentation that their total 2011 energy use was less than 16,680 kWh (net total site household energy)

NOTE: THC OPTION A (75% reduction from previous use) cannot be used because the pre-renovation energy use is not available.

OPTION B Assumptions: 2 households; 4,092 ft² finished floor area (FFA); 6,308 ft² surface area (5 sides); Boston Logan Airport weather station; 4.75 occupants; & 100% natural gas heating.
Pre-use & THC Threshold
Annual Energy Use (in kWh)
Actual “Stella” & “Russell” = Energy used by two households in previously occupied homes

THC OPTION B
(Gas heat)

Actual 6 Stella

Actual 25 Russell

- Heating
- Cooling
- Hot Water
- Everything Else
- Total

0 10000 20000 30000 40000 50000 60000 70000 80000

30
Deep Reductions in Heating Cost

2011 total gas use was 16% of New England average use for heating for units heating with gas.

Natural gas use in 2011 for heating for both units plus one dryer & one stove: 240 CCF ($633.63 gas utility charges, including $251.12 in daily minimum charges). New England avg. is 740 CCF per household for heating alone.
Deep Reductions in Electric Cost

2011 net usage was 34% of NE average despite using electric for water heating & central air

DHW use reduced by solar; central A/C by insulation; other by CFLs; all (net) by PV.
Project Energy Use 3,000 kWh Below THC Threshold! (2011)

THC OPTION B (Gas heat)

2011 Actual Household Energy (excluding PV)

2011 Solar PV Contribution

2011 Actual kWh (Net)

Heating
Cooling
Hot Water
All Else
2011 kWh
CO²/Person = 20.5% of MA Average

- MA DEP estimated emissions of 13.0 MMtCO² directly from residences & 22.9 from electric power in 2008, of which, according to DOE, 35.8% is for residences, for a total of 21.2 MMtCO² from residences – 3.22t /person for 6.6 million pop.

- Project CO² = 1.3 tCO² from gas (at 53kg/MMBTU) & 1.8 tCO² from electric (at .41kg/kwh) -- 0.66t/person for 4.75 occupants.
Ecobee.com recording thermostat system shows that morning get-out-the-door heat lasts all day while we are not home; allows decision to change thermostat schedule. On sunny days even afternoon heat burn not necessary.
Mechanical Ventilation
Electric/Infiltration Load

Image from emonitor.us – electric load (watts in over 24 hours) of ERV in upstairs apartment. Running at 30%, reduced from 90%, based on CO$_2$ measuring to <1,000 ppm.
Emonitor.us readout for upstairs domestic hot water heating load (kWh). November was a partial month. Reduced usage from 16 gallons per person per day to 13 from December to January (and have maintained that level). February monitoring was disrupted. March drop reflects more sunshine & less snow.
Blocking & Tackling KWhs

Where I've used electricity in the past 30 days: All Circuits.

- Dedicated Outlet: $7
- Washer/Dryer: $8
- A/C: $0
- Disposal: $0
- Bath GFCI: $0
- Smoke Detector alarm: $1
- Kitchen Counter: $1
- Kitchen and Outdoors: $1
- 3d Floor Lighting: $1
- Master Bedroom HA: $1
- 3d Floor Outlets: $1
- Blue Room Lights: $2
- Stove: $2
- LR DR Nook WB Lig: $4
Key Success Factors

- Core team committed to energy-saving green construction
  - Lots of decisions require expertise
  - New construction techniques
- Partner with 3rd parties also committed
  - Oversight
  - Peer review
  - Additional ideas
- Owner follow-through – measurement
Key Project Web Links

- [https://www.powerofaction.com/der/](https://www.powerofaction.com/der/) (National Grid, utility sponsor)