50 Pilot Deep Energy Retrofits

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Deep Energy Retrofit Project
Goal and Scope

- What is a deep energy retrofit?
  - Energy savings of >30% on a whole-house basis

- Why deep energy retrofits?
  - Currently few and expensive. Trying to prove technical feasibility by leveraging homes that are planning major renovations.

- What are we hoping to learn?
  - Actual vs. modeled savings
  - Bill analysis and post retrofit tests and surveys to understand why savings are different from expectations (Behavior?)
  - Health, safety, comfort and durability impacts
  - Cost effectiveness

- Outcomes
  - Barriers and lessons learned
  - Climate specific case studies
  - Guidelines for remodelers and trades
Deep Retrofit Case Study #1
Habitat for Humanity, South Sarasota, FL

Pre-Retrofit
- 1978-1,814 SF
- R-19 vented attic
- Uninsulated CBS walls
- ACH50=31!
- Pre-retrofit HERS=189
- Thousands of such homes in Florida
  - Field technical assistance by Calcs-Plus
  - Metering by FSEC (12 channel EMonitor + interior HOBOs)
Deep Retrofit Case Study #1
Habitat for Humanity, Sarasota, FL

Post Retrofit
- White roof
- R-21 unvented attic
- R-7.5 wall insulation
- SEER 16.25 HSPF9 (2 ton)
- Heat pump water heater
- Run time vent with electric damper
- U-.33, SHGC-.22 impact resistant windows
- 100% CFL lighting
- Final HERS= 57, >60% projected savings
Deep Retrofit Case Study #2
Build San Antonio Green

► Pre-Retrofit

- 1949 vintage -3BR, 1BA, 942 SF
- 3 window a/c (1 heat pump)
- No ceiling insulation, R-4 wall
- Gas water heater inside cond. space
- Pre- retrofit HERS=161
- 1 of 4 such retrofits by BSAG in San Antonio in 2011, 3 metered

- Field technical assistance by Calcs-Plus
- Metering by FSEC (TED 4 channel system + interior HOBOs)
Deep Retrofit Case Study #2
Build San Antonio Green

Post Retrofit
- Gut rehab, floor area 1,047 SF
- 80% AFUE, SEER 14 A/C (attic)
- 0.62 EF gas water htr in exterior closet
- Central duct system Qn=.043
- R-30 ceiling under radiant barrier roof
- R-13 walls
- Filtered outside air via run time vent system (38 cfm)
- Return registers over bedroom doors
Deep Retrofit Case Study #2
Build San Antonio Green – Energy Modeling

<table>
<thead>
<tr>
<th></th>
<th>Actual Use Pre Retrofit</th>
<th>Initial Model Pre Retrofit</th>
<th>Calibrated Pre Retrofit</th>
<th>Projected Post Retrofit</th>
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</thead>
<tbody>
<tr>
<td>Electric, kWh</td>
<td>11,459</td>
<td>13,878</td>
<td>11,232</td>
<td>5,442</td>
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<tr>
<td>Gas, therms</td>
<td>611</td>
<td>224</td>
<td>611</td>
<td>403</td>
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<tr>
<td>Source Mbtu</td>
<td>198</td>
<td>184</td>
<td>196</td>
<td>107</td>
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</table>

Low predicted gas use led to discovery of oven being used as heating source.

<table>
<thead>
<tr>
<th>Post Retrofit HERS</th>
<th>93</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated $ Savings</td>
<td>&gt;30%</td>
</tr>
<tr>
<td>Estimated Source Energy Savings</td>
<td>&gt;45%</td>
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</table>
Deep Retrofit Case Study #2
Pre Retrofit Energy Modeling

Electricity Consumption (Model v. Actual)

NG Consumption (Model v. Actual)
Deep Retrofit Case Study #3
100-year-old home in Dayton, WA

1. Recruitment
2. Pre-retrofit home energy assessment
3. Model and report generation
4. Implement retrofit measures
5. Post-retrofit home energy assessment
6. Ongoing metering
Deep Energy Retrofit Project
Recruitment

http://deepenergyretrofits.pnnl.gov

Looking for Participants

Are you interested in saving money on your utility bills? Do you wish your home used less energy and was more comfortable? If you are considering major renovations to your house this spring, such as reroofing, residing, repainting the interior, or replacing your heating/cooling system, windows, or plumbing system, you may be especially interested in this website.

The Pacific Northwest National Laboratory (PNNL) research team and associated subcontractors are looking for homeowners to participate in a research project funded by the U.S. Department of Energy, to save 30% or more on their annual utility costs through home energy retrofits. The PNNL team can help make energy retrofitting affordable, now and in the long run by identifying incentives available through local utilities and other local, state, federal sources, and providing a free home energy assessment and free technical assistance. In addition, your house will be part of a PNNL research study that can help inform the nation about best practices for residential retrofits.

PNNL is looking for homes that meet the following criteria:

- Home was built prior to 2005. The home must be at least 5 yrs old.
- The homeowners do not allow smoking inside the home. (Smoking is allowed if limited to porches, patios, or other outdoor areas of the home.)
- The homeowners do not have business (other than small home office) or other unusual energy-intensive equipment in the home.
- The homeowners primarily use a central heating and cooling system. Wood stoves, fireplaces, whole house fans or other unusual systems cannot be primary heating or cooling system.
- The home is occupied year round by the owner.
- The homeowners do not open windows often when the HVAC system is on.

If your home meets the preceding criteria and you are interested in saving money on your utility bills and improving the indoor air quality and comfort in your home, please download and complete the informational questionnaire. Contact the PNNL research team at deepenergyretrofits@pnnl.gov to submit your questionnaire, express your interest or to request more information.
Deep Energy Retrofit Project
Home Energy Assessment

► Building and Appliance Characteristics
  ■ 100-yr-old boiler (est. 58% AFUE)
  ■ Knob & tube wiring
  ■ No insulation in cantilevered floor
  ■ Falling down insulation and no blocking in sloped ceilings (R-15 on flat)
  ■ No insulation in basement
  ■ Leaky casement windows

► Building Leakage

<table>
<thead>
<tr>
<th>Conditioned Floor Area</th>
<th>2,638 ft²</th>
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<tbody>
<tr>
<td>Conditioned Volume</td>
<td>21,104 ft³</td>
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<tr>
<td>Airflow in cubic feet per minute at -50 Pascals</td>
<td>3,676 cfm50</td>
</tr>
<tr>
<td>Air Changes per Hour at -50 Pascals</td>
<td>7.19 ACH50</td>
</tr>
<tr>
<td>Effective Leakage Area</td>
<td>201.8 in.²</td>
</tr>
<tr>
<td>Relative airflow at -50 Pascals</td>
<td>1.39 cfm50/ft²</td>
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</table>
Deep Energy Retrofit Project
Home Energy Assessment

- Combustion Testing
  - 2 ppm CO and -2 Pa in CAZ @ worst case

- IAQ Testing
  - TVOCs, CO, PM2.5/10, Temp, and RH using EVM 7 Monitor
  - NOx, SOx, and Formaldehyde using Dreger sample tubes
  - Potential moisture problems assessed visually and with tape sampler for mold and allergens
  - Radon using RadStar radon monitor
Deep Energy Retrofit Project
Modeling the Home

Use EnergyGaugeUSA

1. Create existing house model calibrated to utility bills
2. Model individual retrofit measures to determine savings and cost effectiveness

Existing Energy Consumption Breakdown

- Heating, 80.4%
- Lighting, 6.4%
- Refrigerator, 1.8%
- Range, 1.0%
- Misc., 2.3%
- Dishwasher, 0.4%
- Dryer, 1.5%
- Hot Water, 4.5%
- Heating Fan/Pump, 1.7%
Deep Energy Retrofit Project Calibration Process

- Model output compared to utility bills
- To make electricity match
  - Decreased lighting load based on recorded number of lights
  - Decreased misc. load based on observed misc. appliances
  - Recorded appliance specific loads based on name plate data
  - No AC in this house
Deep Energy Retrofit Project Calibration Process

► To make diesel match
  ■ Only related to heat load
  ■ Compared totals since diesel bills were sporadic
    ● Amortized utility bills over the relevant months to compare monthly
  ■ Adjusted efficiency of furnace
    ● Only adjustable input since we know building leakage and thermostat set points

<table>
<thead>
<tr>
<th>Diesel Billing</th>
<th>end date</th>
<th># of Days:</th>
<th>Diesel Delivered: (gallons)</th>
<th>Diesel Avg Monthly Use: (gallons)</th>
<th>Diesel Model</th>
<th>Diesel Avg Monthly Use: therms</th>
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<tbody>
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<td>start date</td>
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<tr>
<td>1/3/2011</td>
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<td>16</td>
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<td>5/18/2011</td>
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<td>5/4/2010</td>
<td>-</td>
<td>161</td>
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<td>10</td>
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<td>200</td>
<td>116</td>
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![Diesel Consumption (Model v. Actual) chart]

![Table of Diesel Consumption (Model v. Actual) data]
Deep Energy Retrofit Project
Recommended Retrofits

Summary of Recommended Retrofit Measures

<table>
<thead>
<tr>
<th>Retrofit Measure</th>
<th>Total Utility Bills</th>
<th>Estimated Savings</th>
<th>Estimated Energy Cost Savings</th>
<th>Estimated Capital Cost</th>
<th>Simple PBP*</th>
<th>Estimated Diesel Savings (gallons)</th>
<th>Estimated Electricity Savings (kWh)</th>
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<tbody>
<tr>
<td>Existing Home</td>
<td>$3,536</td>
<td>$60</td>
<td>1%</td>
<td>$1,161</td>
<td>17</td>
<td>35</td>
<td>6</td>
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<tr>
<td>Air sealing and knee wall insulation</td>
<td>3,496</td>
<td>40</td>
<td>1%</td>
<td>1,161</td>
<td>17</td>
<td>35</td>
<td>6</td>
</tr>
<tr>
<td>Air seal and insulate basement</td>
<td>$3,152</td>
<td>384</td>
<td>11%</td>
<td>$5,107</td>
<td>12</td>
<td>342</td>
<td>116</td>
</tr>
<tr>
<td>Insulate walls and cantilever</td>
<td>3,466</td>
<td>70</td>
<td>2%</td>
<td>924</td>
<td>8</td>
<td>64</td>
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<tr>
<td>Ductless mini split</td>
<td>$1,143</td>
<td>2393</td>
<td>68%</td>
<td>$9,300</td>
<td>4</td>
<td>2712</td>
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<tr>
<td>TOTAL SAVINGS</td>
<td>970</td>
<td>2566</td>
<td>73%</td>
<td>16,492</td>
<td>6</td>
<td>2712</td>
<td>-6130</td>
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*PBP = payback period. PBP includes potential incentives and rebates

Notes: 1) The total energy savings is not simply the sum of savings from each measure because of interactive effects between measures. 2) Electric use increases due to switch from gas furnace to heat pump.

Estimated savings of 75%!!
Payback of 6 years
Deep Energy Retrofit Project
Post-Retrofit Home Energy Assessment

► Post retrofit home energy assessment
  ■ Same as pre-retrofit assessment
  ■ To document whole-house energy savings and improvements in health, safety and comfort of the home due to implemented retrofit measures

► Ongoing metering
  ■ To collect more detailed, long-term energy consumption data on a whole-house and sub-metered level