New Construction Hybrid-Ductless Heat Pump Study
(Resistance is Futile)

Emerging Technologies Showcase
Bruce Carter – Tacoma Power
March 11, 2015

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New Construction Hybrid-Ductless Heat Pump Study (Resistance is Futile)

Bruce Carter
Tacoma Power
Conservation Supervisor
What is a Ductless Heat Pump (DHP)?

1. Fan coil (indoor)
2. Compressor (outdoor)
3. Remote
Unlike central heat pumps, DHPs have outstanding cold weather performance, requiring no supplemental heat.

They also maintain COPs above 2 even at extreme cold temperatures.
A DHP fan coil located in the main living area in combination with electric resistance zone heaters located in the perimeter rooms.

The DHP carries the bulk of the homes heating/cooling load while the zone heaters provide supplemental heat.
How DHP Hybrid Displacement Works

• Ideal alternative to electric resistance zonal heated homes

• Reduces heating bills by displacing the large share of zonal electric heat

• DHP installed in the main living area
No Deemed Savings for DHP in New Homes

- RTF new construction DHP deemed savings workbook deactivated
- No BPA deemed savings for stand alone DHP installs in new construction
- Tacoma Pierce Co. Habitat for Humanity presented an opportunity to get some real world savings #'s
New Construction Hybrid DHP/ER Study

- **February 2011** – Habitat for Humanity seeks help for new housing project from Tacoma Power using DHPs
- **Fall 2012** - Tacoma Power recruits BPA, SnoPUD, Cowlitz PUD for new construction hybrid DHP study
- **Spring 2012** – Habitat breaks ground
- **Spring 2013** – Habitat starts construction, first five homes take shape
- **Late fall 2013** – All co-funder agreements in place. Monitoring begins on first homes, weather station erected onsite
- **2014/15** – Construction continues, additional 7 homes completed and added to study. Monitoring continues on all homes. One year data collected on first 7 homes
- **2015/17** – Neighborhood built out (30 homes). Monitoring continues
Project Site
HFH Sustainable Community

- Community of single-family, zonal electric heated dwelling community
- 30 planned, 12 built to date
- 5 distinct designs (950 to 2,200 ft²)
- Homes comply with NWESH v2
  - 5% more efficient than 2012 code.
- No chimneys for wood stoves/natural gas
Homes at the Woods
New Habitat Homes

Specifications

• Continuous R-15 under slab insulation
• R-21 + R5 exterior walls
• R-49 ceiling
• U-.28 windows
• Energy Star certified lighting
• Continuous heat recovery ventilation
• Hybrid ductless heat pump / electric resistance heating
Energy Efficiency
Emerging Technologies
**Homeowner Orientation**

### Operating and maintaining your heating system

- Clean ductless heat pump filters every three months

### Let the DHP “heat” the house

- **DHP thermostat**
  - Set the ductless heat pump thermostat to maintain a comfortable temperature in the main living area
- **Bedroom thermostats**
  - Set the bedroom thermostat to 62°F or where you are comfortable
  - Remember, the DHP should help heat the bedrooms as well

### Maintaining your heat recovery ventilator

- Remove and wash HRV filters monthly

### Heating systems switch weekly

**WEEK 1**
- **DUCTLESS HP**
- Baseboard off

**WEEK 2**
- **ZONE HEAT**
- All baseboards on

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**E3T Energy Efficiency Emerging Technologies**
Key research questions

What are the performance characteristics of a hybrid DHP-electric resistance (ER) heating system to an all-ER heating system in new construction single family homes in a marine climate in the Pacific Northwest?

1. What are the average annual electricity savings of the hybrid DHP system over an all electric resistance system?

2. What are the total and incremental installed costs of this system?

3. What are the average expected life-cycle impacts of such a system?

4. What are the occupant perceptions of a hybrid system? Does a hybrid system produce the same comfort levels as an all electric resistance system?
Study Design of Energy Use

• Compare electrical use of hybrid DHP/ER heat VS all –ER heat in new construction

• Common area contains both DHP and ER heat switched between the two weekly
  • Switching schedule staggered between homes

• Each home to act as its own control over a range of temperatures

• Temperature and relative humidity captured

• Homeowners given choice at end of study which heating system they would like to keep
Technical Implementation

- Total Electric Service
- Common Area
- All Other Zone Heat
- Data Captured
- Site Weather Data
- Domestic Hot Water
- DHP Vapor Line Temp
- Common area - Bedroom Temp/RH
Project Equipment - Installed

- U30-Data logger with cellular communications allows us to monitor data hourly and instant error notification
- Relay
- Time Clock
- Watt Nodes used to convert energy consumption pulse data from the current transducers
- Pulse Input Adapter tracks pulses
- Current Transducers (CT’s) connected to electrical circuits to measure current.
Web Based Hourly Monitoring

[Graph showing energy usage over a month with labels for electric resistance and DHP.]
Observations

Energy Use in all-ER Heating Mode

Observed from case study

Daily kWh/ft²

Daily Average Temperature

- All-ER
- Poly. (All-ER)

R² = 0.7166
Observations

Energy Use in Hybrid DHP-ER Heating Mode
Observed from case study

Daily KWh/ft² vs. Daily Average Temperature

- Hybrid DHP-ER
- Poly. (Hybrid DHP-ER)

R² = 0.7161
Savings Analysis (Heating)

Comparison of All-ER vs Hybrid DHP-ER
Observed from case study

Daily kWh/ft² vs Daily Average Temperature
- Poly. (All-ER)
- Poly. (Hybrid DHP-ER)
Adjusted savings accordingly to account for DHP cooling

No information for cooling in ER mode:
- Common areas placed in DHP mode Jul 11-Sep 19, 2014
- Don’t know what equipment would have been bought in absence of DHP

Apply daily average observed in data (0.00067 kWh/ft²) to Jul & Aug in our “normal” year for DHP energy estimate
- Assume no cooling in all-ER system

Assumed conservative estimate of DHP savings because:
- Study year was warmer than normal
- No accounting for alternate cooling equipment in ER mode
## Hybrid DHP System Savings Estimates

<table>
<thead>
<tr>
<th>Energy Used (kWh/ft²)</th>
<th>Hybrid DHP-ER</th>
<th>All-ER</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Season</td>
<td>2.47</td>
<td>4.71</td>
<td>2.24</td>
</tr>
<tr>
<td>Cooling Season (Jul &amp; Aug)</td>
<td>0.04</td>
<td>-</td>
<td>-0.04</td>
</tr>
<tr>
<td>Total</td>
<td>2.52</td>
<td>4.71</td>
<td>2.19</td>
</tr>
</tbody>
</table>

47% savings over all-ER system
## Costs

### Common Living Area Incremental First Costs

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Electric Resistance Home</th>
<th>Hybrid Home</th>
<th>Net Incremental Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>$31</td>
<td>$23</td>
<td>-$8</td>
</tr>
<tr>
<td>Heating Systems</td>
<td>$152</td>
<td>$1702</td>
<td>$1550</td>
</tr>
<tr>
<td>Wiring Labor</td>
<td>$85</td>
<td>$63</td>
<td>-$22</td>
</tr>
<tr>
<td>Adders</td>
<td>$54</td>
<td>$358</td>
<td>$304</td>
</tr>
<tr>
<td>Total</td>
<td>$321</td>
<td>$2146</td>
<td>$1825</td>
</tr>
</tbody>
</table>
## Economic Data & Assumptions

<table>
<thead>
<tr>
<th>Item</th>
<th>All-ER</th>
<th>Hybrid DHP-ER</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating System Cost</td>
<td>$321</td>
<td>$2,146</td>
<td>$1,825</td>
</tr>
<tr>
<td>Replacement Cycle</td>
<td>30 Years</td>
<td>18 Years</td>
<td></td>
</tr>
<tr>
<td>Maintenance Allowance</td>
<td>$0</td>
<td>$11/Year</td>
<td>$11/Year</td>
</tr>
<tr>
<td>Annual kWh Use</td>
<td>6,027</td>
<td>3,221</td>
<td>2,806</td>
</tr>
<tr>
<td>Annual Utility Bill</td>
<td>$524</td>
<td>$280</td>
<td>$244</td>
</tr>
</tbody>
</table>
Life Cycle Impacts

Economic analysis run using Washington State Office of Financial Management (OFM) economic analysis tool

- Hybrid DHP-ER heating systems life-cycle present value benefit = $5,154
- Down payment increase (@ 20% of principle amount) = $365
- Home owner recovers principle increase in 2.5 years
- Sensitivity analysis determined positive present value even if incremental cost more than double
Occupant Perceptions

Homeowner survey in progress (11/12 interviewed so far)

On performance: “How did [system] perform in heating your common living area to a comfortable temperature?”

- 6 homeowners gave the DHP a higher rating than electric resistance
- 4 homeowners rated them the same
- Only 1 homeowner rated the electric resistance higher

When asked “Which system they would choose at end of study?”:

- 10/11 have already decided to keep DHP
- 1 preferred DHP but wants to see energy savings first

Many reasons why DHP is preferred

- Heating performance, cooling function, furniture placement & curtain use, fire hazard & child safety concerns with baseboards
Thank You
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