Manufactured Homes
New Efficiency for the Lowest Cost Housing Option

BPA E3T Emerging Technologies Showcase
September 10, 2015

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Manufactured Homes
New Efficiency for the Lowest Cost Housing Option

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Sr. Building Science Specialist, WSU Energy Program

Emerging Technology Showcase
September 10, 2015
Utility Funded Non-Profit
- $169 M for 2015-2019
- Bonneville Power Administration, on behalf of more than 140 utilities
- Energy Trust of Oregon
- Seven public and five investor-owned utilities
- 80+ staff
- Advisory committees, regional workgroups
Outline

Background
HUD Code
BPA Demo Projects
Next Steps

One of the eight High Performance Manufactured Home Demonstration Homes shortly after set up
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEEM</td>
<td>Northwest Energy Efficient Manufactured Home</td>
</tr>
<tr>
<td>HPMH</td>
<td>High Performance Manufactured Home</td>
</tr>
<tr>
<td>MAP</td>
<td>Manufactured Home Acquisition Program</td>
</tr>
<tr>
<td>HUD</td>
<td>Housing and Urban Development Department</td>
</tr>
<tr>
<td>IECC</td>
<td>International Energy Conservation Code</td>
</tr>
<tr>
<td>RTF</td>
<td>Regional Technical Forum (Part of NW Power and Conservation Council)</td>
</tr>
<tr>
<td>LCC</td>
<td>Life Cycle Cost</td>
</tr>
<tr>
<td>NEW</td>
<td>Northwest Energy Works</td>
</tr>
<tr>
<td>MHI</td>
<td>Manufactured Home Institute</td>
</tr>
<tr>
<td>NEG REG</td>
<td>Negotiated Regulation</td>
</tr>
</tbody>
</table>
Manufactured Homes

- High Quality
- Low Cost
- Rural Availability
- Efficient
Cost of Home, Including Energy and Financing

Specs at Different Mortgage Rates

Lowest cost of Housing is High Performance Manufactured Home
History of EE Manufactured Homes

- Research Phase, utilities began industry engagement

- 50,000 homes built under MAP
- Utility support led to HUD standard change in 1994

NEEM Housing Program 1996 to present
- Industry funded
- Utility incentives promote program uptake
- Homes branded Super Good Cents and Natural Choice (gas heated), later transitioned to Energy Star and Eco-rated
Characterization

- 3,000 sold per year
- 9 Northwest Factories
- ~50 Retailers
- Sales trending upward

Current Situation

- Future HUD code will be in effect in 2-4 years (*best estimate*)
- Factories operating at 30-40% of capacity
- Appraisers don’t recognize incremental value
- The industries traditional market is not willing to pay more
E3T
Energy
Efficiency
Emerging Technologies

Kit Homebuilders
- Fleetwood of ID
- Golden West
- Marlette
- Skyline
- Palm Harbor
- Golden West

Champion

Fleetwood

Northwest Factories
HUD Code vs. Site Built Code

IECC Zone 5 - Marine

Heat Loss Rate

0%
50%
100%
150%
200%
250%
300%
350%

1976 HUD
1994 HUD
IECC 2009
IECC 2012

IECC Zone 6

Current NEEM Spec

* Bonneville Power Administration Analysis
Housing and Urban Development Department (HUD)

- Federal Manufactured Housing Construction Safety Standards (MHCSS aka the “HUD Code”) – Established in 1976
- Preempts state building energy codes
- Last updated in 1994

US Congress

- Energy Independence and Security Act of 2007 required DOE to establish standards for energy
- Deadline for completion = December 2011  
  Overdue
DOE ASRAC in Fall 2014

- Negotiated Rule Making (aka “NEG REG”)
- 20 Stakeholders
- Life Cycle Cost (LCC) method
- Developed Consensus Term Sheet

LCC methodology
Rough Equivalence to IECC

- Walls = R19
- Roof = R38
- Floor = R30
- Windows = 0.32 U-Value
- Electric Resistance FAF allowed
- Air Tightness = 5.0 ACH50

Slightly higher efficiency requirements for multi-section
NEEM Program
(Northwest Energy Efficient Manufactured Housing)

Industry voluntary efficiency program
3rd Party admin by Northwest Energy Works

Branding
- Super Good Cents
- Natural Choice
- Energy Star
- Eco-rated

Provides value to manufacturers, retailers, and consumers
Beyond just the specs

- Reduced voids
- Setup at the site
- Homeowner issue resolution
- Industry uniformity
- Spill-over to non-NEEM
8 homes built to a very high efficiency spec
  – BPA paid for capital costs
  – NEEA paying for the data acquisition and analysis
  – 4 built in 2013, 4 built by early 2015

Project Goal
  – Have each manufacturer build one
  – Determine manufacturing costs, challenges
  – Monitor savings to calibrate models
## Demonstration Homes

<table>
<thead>
<tr>
<th>Home</th>
<th>Manufacturer</th>
<th>Location</th>
<th>Floor Area</th>
<th>UA (incl. 0.28 ACHn)</th>
<th>ACH50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fleetwood Homes of Oregon</td>
<td>Toledo, WA</td>
<td>1,279</td>
<td>187</td>
<td>3.02</td>
</tr>
<tr>
<td>2</td>
<td>CMH - Golden West Homes</td>
<td>Pullman, WA</td>
<td>1,296</td>
<td>193</td>
<td>3.57</td>
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<tr>
<td>3</td>
<td>Skyline</td>
<td>Otis, OR</td>
<td>1,404</td>
<td>207</td>
<td>2.86</td>
</tr>
<tr>
<td>4</td>
<td>Palm Harbor Homes</td>
<td>Bothell, WA</td>
<td>1,137</td>
<td>169</td>
<td>2.75</td>
</tr>
<tr>
<td>5</td>
<td>Fleetwood Homes of Oregon</td>
<td>Chehalis, WA</td>
<td>1,492</td>
<td>223</td>
<td>2.40</td>
</tr>
<tr>
<td>6</td>
<td>Palm Harbor Homes</td>
<td>Sixes, OR</td>
<td>587</td>
<td>112</td>
<td>1.17</td>
</tr>
<tr>
<td>7</td>
<td>Marlette Homes</td>
<td>Siletz, OR</td>
<td>2,100</td>
<td>286</td>
<td>not yet tested</td>
</tr>
<tr>
<td>8</td>
<td>Kit Homebuilders West</td>
<td>Boring, OR</td>
<td>1,138</td>
<td>187</td>
<td>3.99</td>
</tr>
</tbody>
</table>
Demonstration Homes

Bothell
Chehalis
Toledo
Otis
Siletz
Sixes
Pullman
Demonstration Homes
## Manufactured Homes Specifications

<table>
<thead>
<tr>
<th>Component</th>
<th>Units</th>
<th>Proposed New HUD</th>
<th>NEEM</th>
<th>HPMH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Envelope</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceiling</td>
<td>R-Value</td>
<td>R38</td>
<td>R40</td>
<td>R49</td>
</tr>
<tr>
<td>Wall</td>
<td>R-Value</td>
<td>R21</td>
<td>R21</td>
<td>R21 + R5 Foam Sheathing</td>
</tr>
<tr>
<td>Window U-Value</td>
<td>U-Value</td>
<td>0.32</td>
<td>0.34</td>
<td>0.22</td>
</tr>
<tr>
<td>Glazing %</td>
<td>% of CFA</td>
<td>Part of Uo calc</td>
<td>12% ave</td>
<td>12% ave</td>
</tr>
<tr>
<td>Door</td>
<td>U-Value</td>
<td>0.4</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Floor</td>
<td>R-Value</td>
<td>R30</td>
<td>R33</td>
<td>R38</td>
</tr>
<tr>
<td>Infiltration</td>
<td>ACH 50</td>
<td>5.0 (sort of)</td>
<td>3.9 ave</td>
<td>3.0</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Exhaust Fan</td>
<td>Market Base</td>
<td>ENERGYSTAR®</td>
<td>ENERGYSTAR®</td>
</tr>
<tr>
<td>Uo</td>
<td>Btu/hr-ft²-°F</td>
<td>0.059</td>
<td>0.054</td>
<td>0.040</td>
</tr>
</tbody>
</table>

### Notes
- **HUD**
- **NEEM**
- **HPMH**
## Manufactured Homes Specifications

<table>
<thead>
<tr>
<th>Component</th>
<th>Units</th>
<th>Baseline &quot;HUD+&quot;</th>
<th>NEEM</th>
<th>HPMH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HVAC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating System</td>
<td></td>
<td>Electric FAF</td>
<td>Electric FAF</td>
<td>DHP HSPF 10 &amp; Wall Heaters</td>
</tr>
<tr>
<td>Cooling System</td>
<td></td>
<td>none</td>
<td>none</td>
<td>DHP SEER 20</td>
</tr>
<tr>
<td>Supply Duct Leakage</td>
<td>% system flow</td>
<td>12.5%</td>
<td>5%</td>
<td>No Ducts</td>
</tr>
<tr>
<td>Return Duct Leakage</td>
<td>% system flow</td>
<td>None - Interior</td>
<td>None - Interior</td>
<td>No Ducts</td>
</tr>
<tr>
<td><strong>DHW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Heater</td>
<td>EF</td>
<td>0.9 EF</td>
<td>0.93 EF</td>
<td>HPWH</td>
</tr>
<tr>
<td>Shower Head</td>
<td>gpm</td>
<td>2.5</td>
<td>2.5</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting Power Density</td>
<td>W/ft²</td>
<td>1.4</td>
<td>1.4</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Appliances</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dishwasher</td>
<td></td>
<td>Market Base</td>
<td>Market Base</td>
<td>ENERGYSTAR®</td>
</tr>
<tr>
<td>Refrigerator</td>
<td></td>
<td>Market Base</td>
<td>Market Base</td>
<td>ENERGYSTAR®</td>
</tr>
</tbody>
</table>
Envelope Measures
Mechanicals, Appliances, Lighting
Energy Efficiency Merging Technologies
Energy Efficiency
Emerging Technologies
1. U-0.22 Windows are a 5x cost increase over U-0.30
2. Ductless HP installation in the factory is not a good fit for all floor plans
3. HP Water Heaters can be ducted to draw air from crawlspace
4. Foam sheathing creates some production challenges
# Demo Home Annual Energy Consumption

<table>
<thead>
<tr>
<th>Home</th>
<th>Location</th>
<th>Floor Area</th>
<th>UA¹</th>
<th>Total kWh²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Toledo, WA</td>
<td>1,279</td>
<td>187</td>
<td>9,542</td>
</tr>
<tr>
<td>2</td>
<td>Pullman, WA</td>
<td>1,296</td>
<td>193</td>
<td>17,254³</td>
</tr>
<tr>
<td>3</td>
<td>Otis, OR</td>
<td>1,404</td>
<td>207</td>
<td>6,896</td>
</tr>
<tr>
<td>4</td>
<td>Bothell, WA</td>
<td>1,137</td>
<td>169</td>
<td>~ 6,800</td>
</tr>
<tr>
<td>5</td>
<td>Chehalis, WA</td>
<td>1,492</td>
<td>223</td>
<td>~ 9,200</td>
</tr>
<tr>
<td>6</td>
<td>Sixes, OR</td>
<td>587</td>
<td>112</td>
<td>~ 8,100</td>
</tr>
<tr>
<td>7</td>
<td>Siletz, OR</td>
<td>2,100</td>
<td>286</td>
<td>TBD</td>
</tr>
<tr>
<td>8</td>
<td>Boring, OR</td>
<td>1,138</td>
<td>187</td>
<td>TBD</td>
</tr>
</tbody>
</table>

1. Includes assumption of 0.28 ACHn
2. Estimated based on current use projections
3. Not being used as a home – 24/7 housing for emergency services staff
Example Energy Breakdown

HPMH #3 (Otis, OR) Monthly Usage Breakout
Mar 20, 2015 to Apr 19, 2015

Monthly Total: $63
Heating Load

HPMH #1 Heating Use by Outdoor Temperature (kWh)

Master Bed ER: 2.4 kWh
Bathroom ER: 26 kWh
DHP: 1,240 kWh
Room Temperatures with a Single DHP Providing over 95 Percent of the Heating During Typical Western Washington or Oregon Winter Weather
Crawlspace Buffering for the HPWH

HPMH Site 1 Crawl Space to Outside Temperature Difference

Outdoor Temperature (F)

Temperature Difference (F)

Impact tips at 59 degrees (F)

HPWH Active

HPWH Inactive
1. Annual Energy Use appear on target
   6,500-8,500 kWh (roughly 8000 kWh savings)
2. DHPs Carry ~99% of space condition load
3. Comfort remains good with central DHP
   Effects of door closure still warrant study
4. HPWH works well in a manufactured home
   Drawing from Crawlspace provides good tempering benefit
   (confirms PNNL lab home findings)
   Noise not a problem
Annual Energy Comparison

Annual energy bill

Energy Use (kWh/yr)

Portland
Boise
Missoula

Baseline
NEEM
HPMH
Baseline
NEEM
HPMH
Baseline
NEEM
HPMH

HVAC
DHW
Lights
Plug Loads
The Next Step = NEEM 2.0 Spec

<table>
<thead>
<tr>
<th>Performance Tier</th>
<th>kWh/yr</th>
<th>Savings/unit</th>
<th>Incremental Cost Est.</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUD</td>
<td>15,900</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>HUD+</td>
<td>15,500</td>
<td>-</td>
<td>$</td>
</tr>
<tr>
<td>NEEM 1.1</td>
<td>12,900</td>
<td>2,600</td>
<td>$ 2,500</td>
</tr>
<tr>
<td>NEEM 2.0</td>
<td>10,300</td>
<td>5,200</td>
<td>$ 7,000</td>
</tr>
<tr>
<td>HPMH</td>
<td>7,500</td>
<td>8,000</td>
<td>$ 20,000</td>
</tr>
</tbody>
</table>
NEEM 2.0 Upgrade

**GOAL:** Upgrade and establish NEEM 2.0 spec before future HUD Code is implemented

**VISION**
1. The Federal “HUD code” is equal to site built homes.
2. **50% of homes are built to NEEM 2.0 specification.**
3. A vibrant market exists for early retirement of pre-1984 mobile homes. (pending additional market research and clear strategy)

**SAVINGS Technical Potential:**
- HUD code 18 aMW underway
- NEEM upgrade 18 aMW
- Early Retirement 48 aMW in scanning
- 84 aMW
Market Transformation Opportunity

<table>
<thead>
<tr>
<th>Tier</th>
<th>Now</th>
<th>During</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best</td>
<td></td>
<td>NEEM 2.0</td>
<td>HPMH</td>
</tr>
<tr>
<td>Good</td>
<td>NEEM 1.1</td>
<td>NEEM 1.1</td>
<td>NEEM 2.0</td>
</tr>
<tr>
<td>Minimum</td>
<td>HUD+</td>
<td>HUD+</td>
<td>NEEM 1.1</td>
</tr>
</tbody>
</table>

NEEM 1.1 is roughly equal to the future HUD Code.

### Performance

<table>
<thead>
<tr>
<th>Tier</th>
<th>kWh/yr</th>
<th>Savings/unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUD</td>
<td>15,900</td>
<td>n/a</td>
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<tr>
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<tr>
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<td>10,300</td>
<td>5,200</td>
</tr>
<tr>
<td>HPMH</td>
<td>7,500</td>
<td>8,000</td>
</tr>
</tbody>
</table>

Assumes the future HUD code is roughly equivalent to the current NEEM 1.1 spec.

Use based on 85% of RTF workbook values (2012 values), aMW based on 80,000 units sold over 20 years.
Possible Program Timeline

Possible Program Timeline

Date When New HUD Code Takes effect is unknown

Note - This does not include all program development activities, stakeholder engagement, database upgrade, field validation of specification, etc.
Questions?
Questions?

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Upcoming Showcase Webinars

September 24 – Mogul Base LED Lamps for Retrofits
October 22 – Easily Commissioned Lighting Controls

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Conduit: www.ConduitNW.org

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