Ductless Heat Pumps “mini-splits” in PNW Cold and Marine Climates

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BA-PIRC

Building America
Partnership for Improved Residential Construction

WASHINGTON STATE UNIVERSITY
EXTENSION ENERGY PROGRAM

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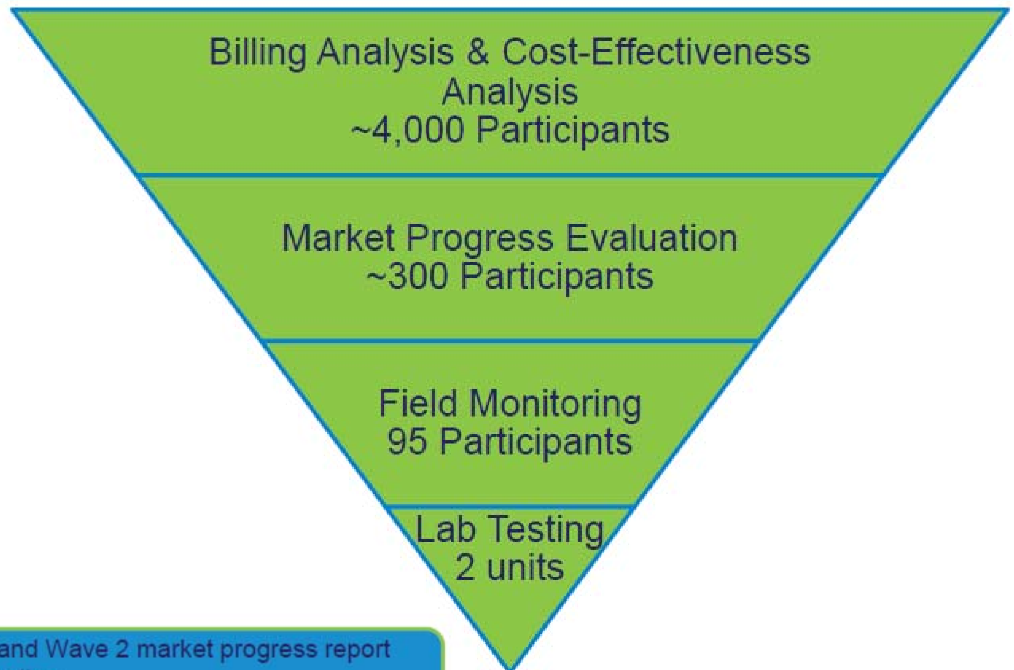
Overview of Presentation

- NEEA/BPA funded research – Hales/Ecotope
  - Utility Billing Analysis
  - Field Monitoring
  - HVAC Lab Testing
- WSU case study of deep energy retrofit w/DHP - Howard
- BA/WSU case study of DHP in HUD-code retrofit - Lubliner
- Discussion of Gaps/Barriers –Lubliner

NEEA Supported DHP Research

DHP Impact & Process Evaluation Overview



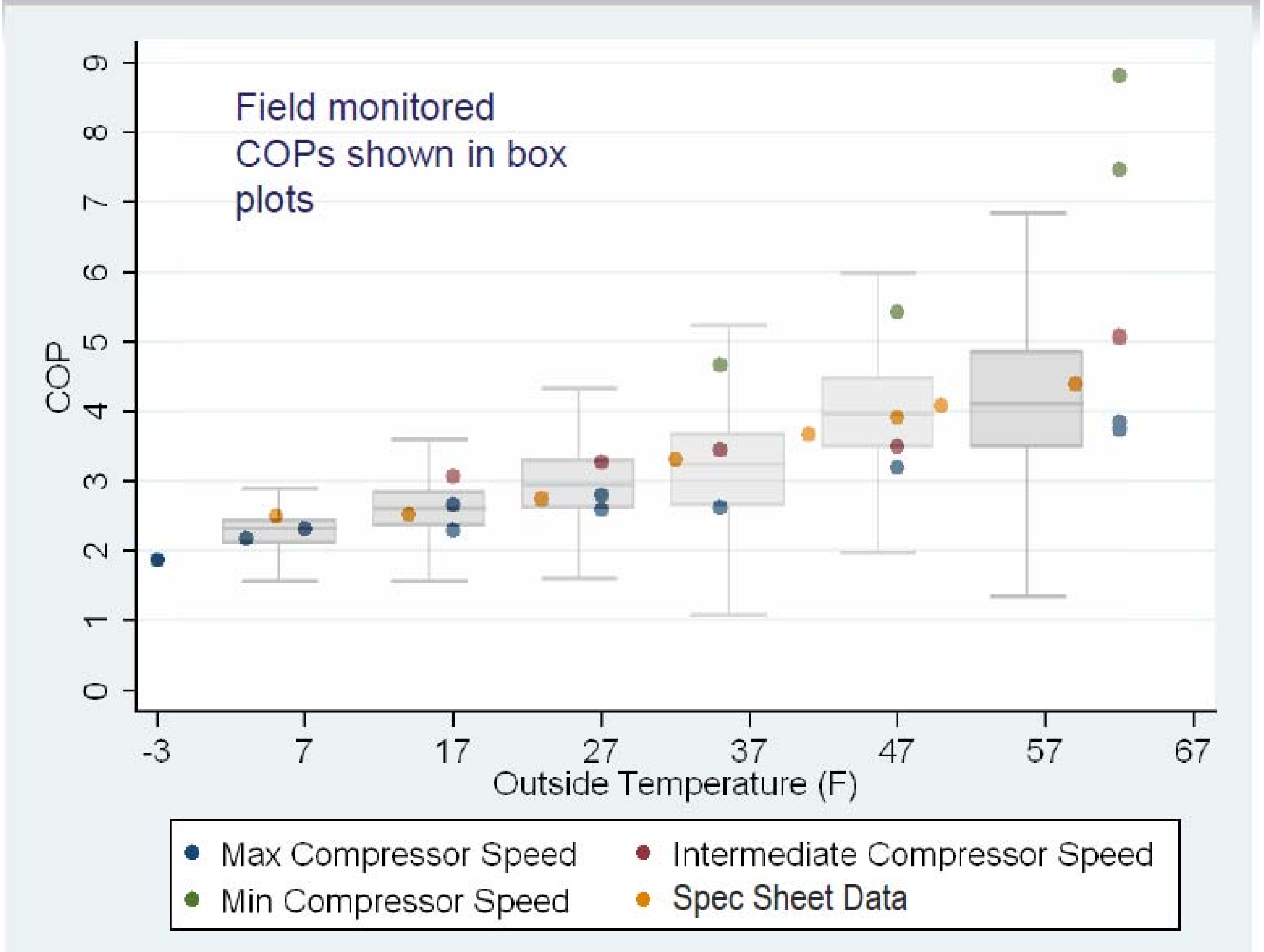
2011
- Q1 = lab analysis report and Wave 2 market progress report
- Q2 = decommission field sites
- Q4 = field monitoring analysis report

2012
- Q1 = billing analysis report
- Q2 = cost-effectiveness analysis
- Q3 = final summary report

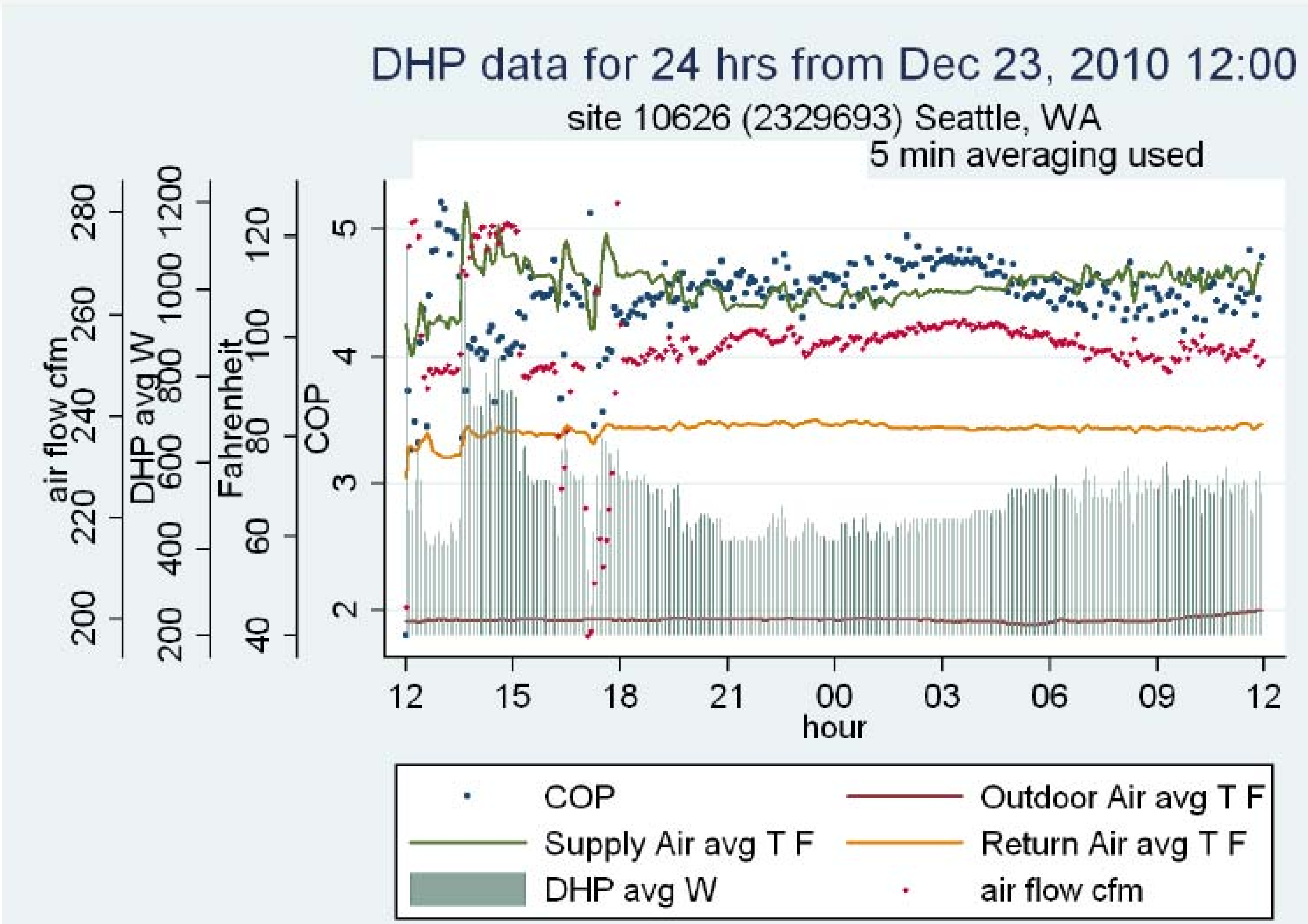
neea

NEEA Supported DHP Research

Unit A COP Lab & Field Data Comparison



Unit B Sample Field Data, 40F Outside

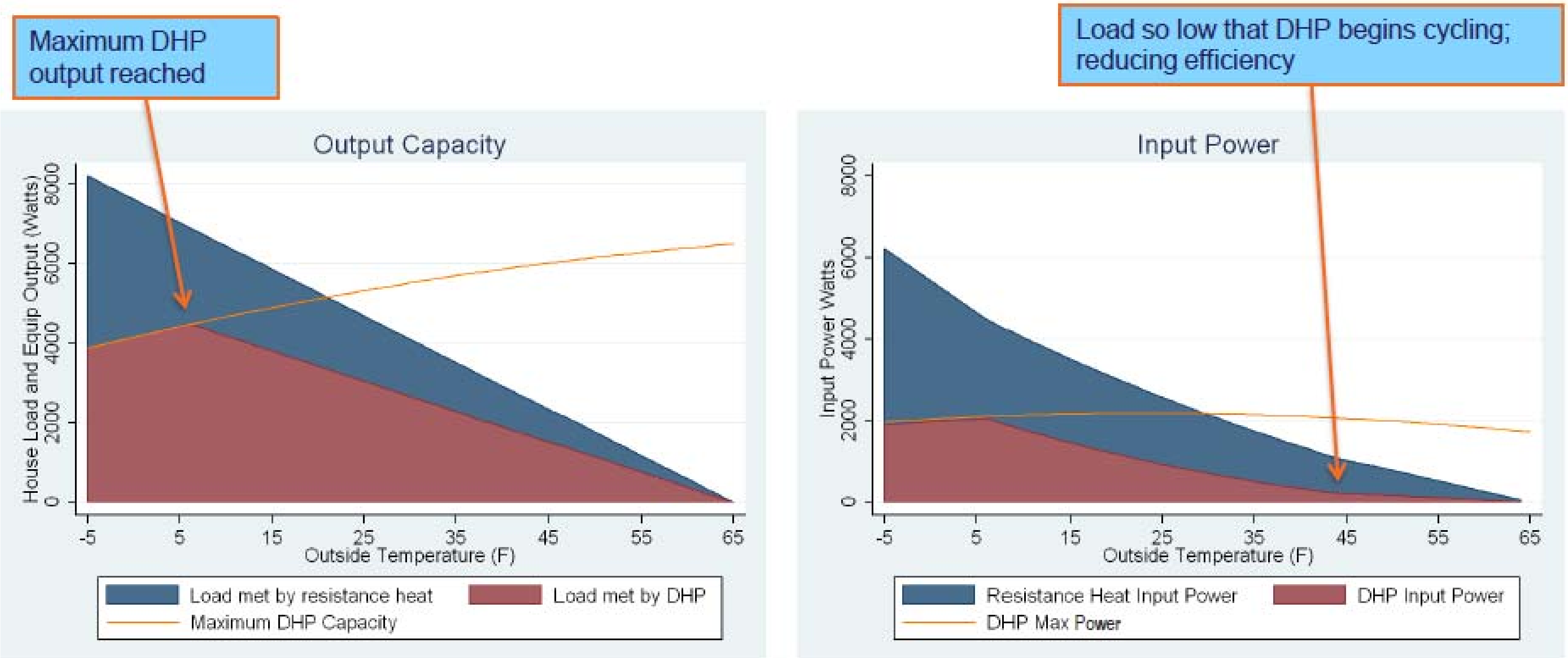


Heating Performance Model

Example:

- House UA=400Btu/hrF. 65F balance point.
- DHP assumed to heat 65% of house. Remaining 35% heated with resistance baseboards.
- Using “Unit A” DHP. Defrost not yet in model

- DHP capacity increases to match load until maximum output reached (near 5°F).
- Simultaneously, DHP input power is also increasing (not linearly – this follows the empirical performance curve) until maximum is reached.
- After maximum DHP output is reached, the house is heated with as much resistance heat (>35%) as needed in the colder temperature bins



Cooling

- Similar to heating, both models show high performance levels
  - SEER= 16 to 17
  - Rated points somewhat higher SEER=23 to 25
- Very good cooling performance for real conditions

Summary of Conclusions

- The lab data demonstrates the high performance of both models.
  - Both equipment models have the potential to deliver generous energy savings.
  - House will depend on a number of factors including the installation occupant behavior
- Lab and field COP measurements show good agreement.
  - Field data compares well to the lab measurements.
  - The field metering of COP shows which equipment operating modes are most common and therefore the most important parameters to measure in the lab.
- Both equipment models perform well at low outdoor temperatures.
  - Installers and home-owners should be made aware of equipment performance at low temperatures
- The current HSPF and SEER ratings are not well suited to DHPs.
  - The testing standard do not always produce ratings that characterize the range of performance
  - More data is needed to assess both the relative performance between models
  - An updated testing procedure should include changes to the testing conditions, compressor speeds in particular

Resource Links

- NEEA reports:

  http://neea.org/research/reports/E11-225-DHP-Lab-Testing.pdf

  http://neea.org/research/reportdetail.aspx?ID=1554

- Northwest Ductless Heat Pump Project:

  http://goingductless.com/

- Lab testing results:

  http://www.nrel.gov/docs/fy11osti/52175.pdf

WSU Case Study
DHP in "deep energy retrofit" - Pre

	HDD	Natural Gas MMBtu's	Electric MMBtu's	Natural Gas $	Electric $	Total $
Pre Retrofit 2008	**5686**	**105.2**	**10.6**	**$1,248**	**$345**	**$1,593**

- 1288sf 3 bed, 2 bath
- 21 ACH_{50}
- Ceiling - ~R-25 Attic, Shed Roof not Insulated
- Walls - R-10
- Floors – Not Insulated (Vented Crawl)
- Windows – Single Pane Wood
- UA – 766 Btu/hr/degF
- 68% AFUE NG Fireplace (1st Floor)
- 50 Gal. NG DHW - .55 EF
- 75% High Efficacy Lighting

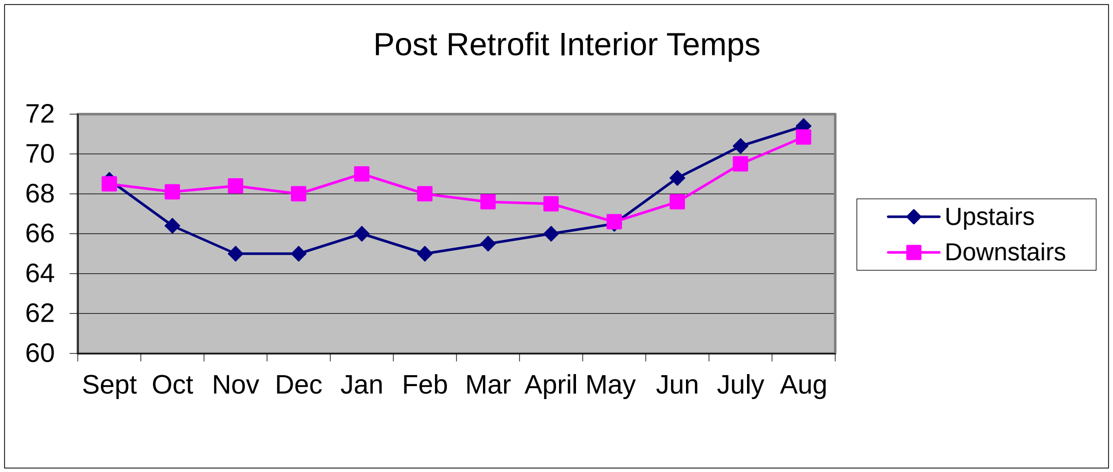
WSU Case Study
DHP in "deep energy retrofit" - Post

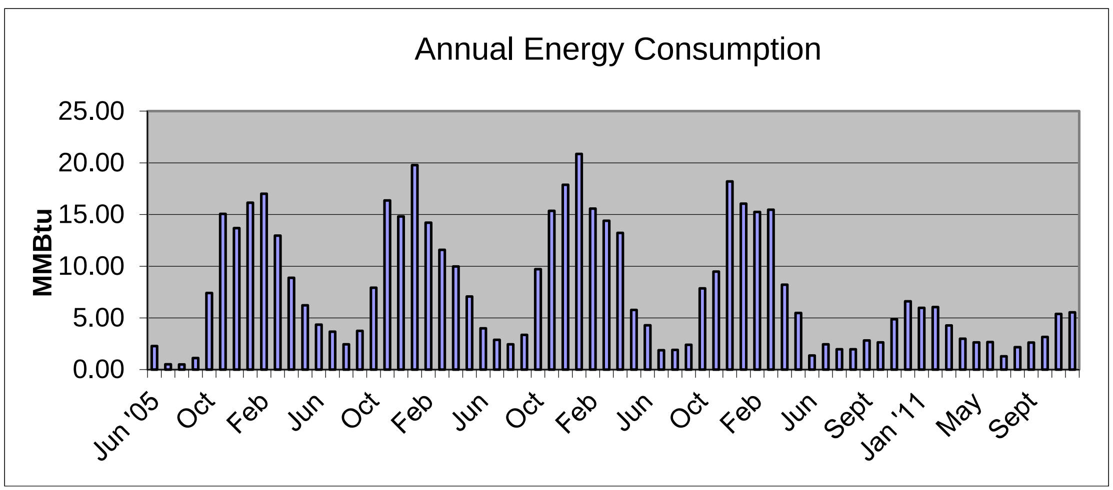
Home is now on the Historic Registry

	HDD	Natural Gas MMBtu's	Electric MMBtu's	Natural Gas $	Electric $	Total $
Post Retrofit 2011	**5911**	**26.2**	**18.5**	**$400**	**$538**	**$938**

- 1640sf 3 bed, 2 bath (added 352sf)
- 5.0 ACH_{50}
- Ceiling;
  - Existing R-49 Attic
  - Added R-38 Scissor
- Walls;
  - Existing R-13+R-2.5
  - Added R-21 ADV+ R-5
- Floors - R-30 Vented Crawl
- Windows ~U-0.47 (Reproductions)
- UA – 284 Btu's/hr/degF
- 1 Ton DHP (1^{st} Floor)
- DHW Tankless NG - .82 EF
- Ventilation - 30 CFM, 24/7
- 75% High Efficacy Lighting

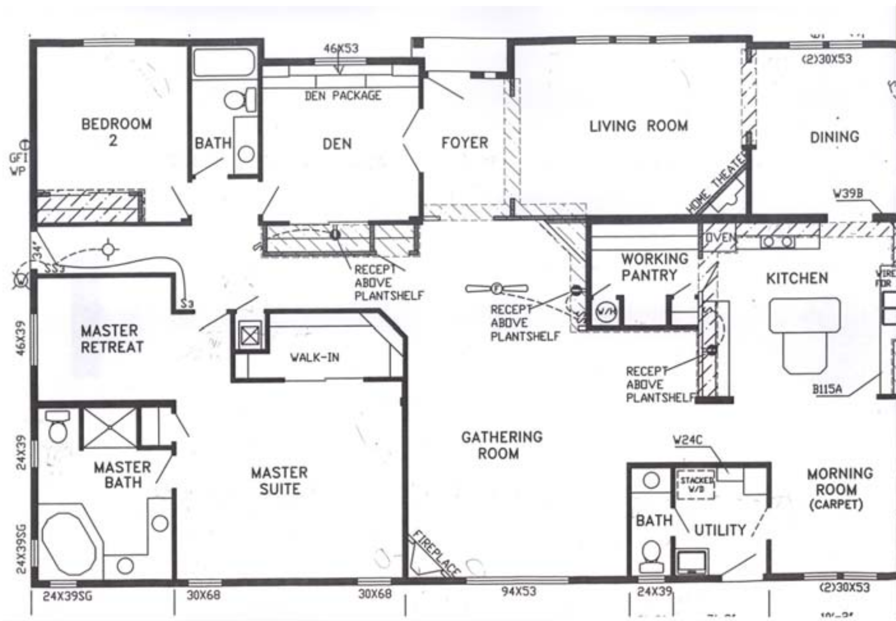
WSU Case Study
DHP in "deep energy retrofit" - Performance





- ~60% reduction in annual energy use
- ~75% reduction of air leakage
- ~82 therms of backup heat provided by existing fireplace
- No sizeable reduction in DHW fuel consumption
- Upstairs bedrooms 3 degrees cooler than downstairs.
    - Master BR min = 60.1, Living RM = 66.0 at 18 Deg. F Ambient
- Heating season increase in RH from 35% - 45%
- DHP still supplying heat at 10 Deg. F.

Ductless Heat Pump (DHP) Retrofit in HUD-code Manufactured Housing



Built in 1998, 2400 ft2 “triple” Most EE mfg home when built; R21 walls, R49 roof, R33 floor, glass U0.31, 2.5ACH50pa, 100cfm@25pa, Insider™ HP w/electric strip heat for “Flip-flop” tests help evaluate the research questions:

- What is energy performance of a ductless heat pump (DHP) benchmarked against a ducted electric furnace (EF)?

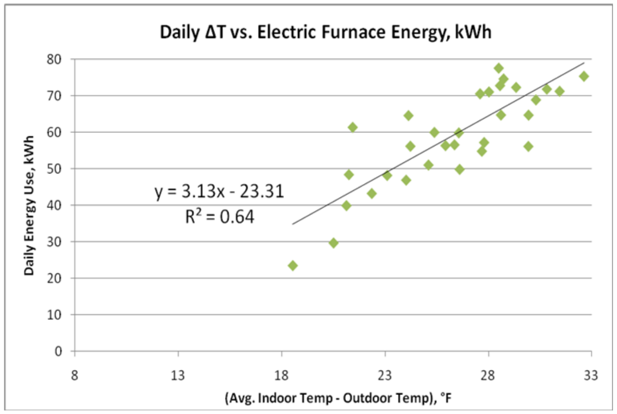
- How well do the DHP or EF maintain acceptable indoor temperature for thermal comfort?

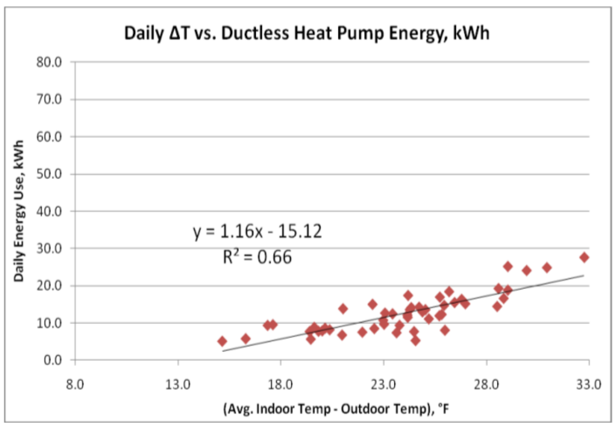
Slide 14

ML2 need to mark on drwaing where DHP is located
MIKLUB, 2/3/2012

Ductless Heat Pump (DHP) Retrofit in HUD-code Manufactured Housing

Flip Flop Tests:





Results:

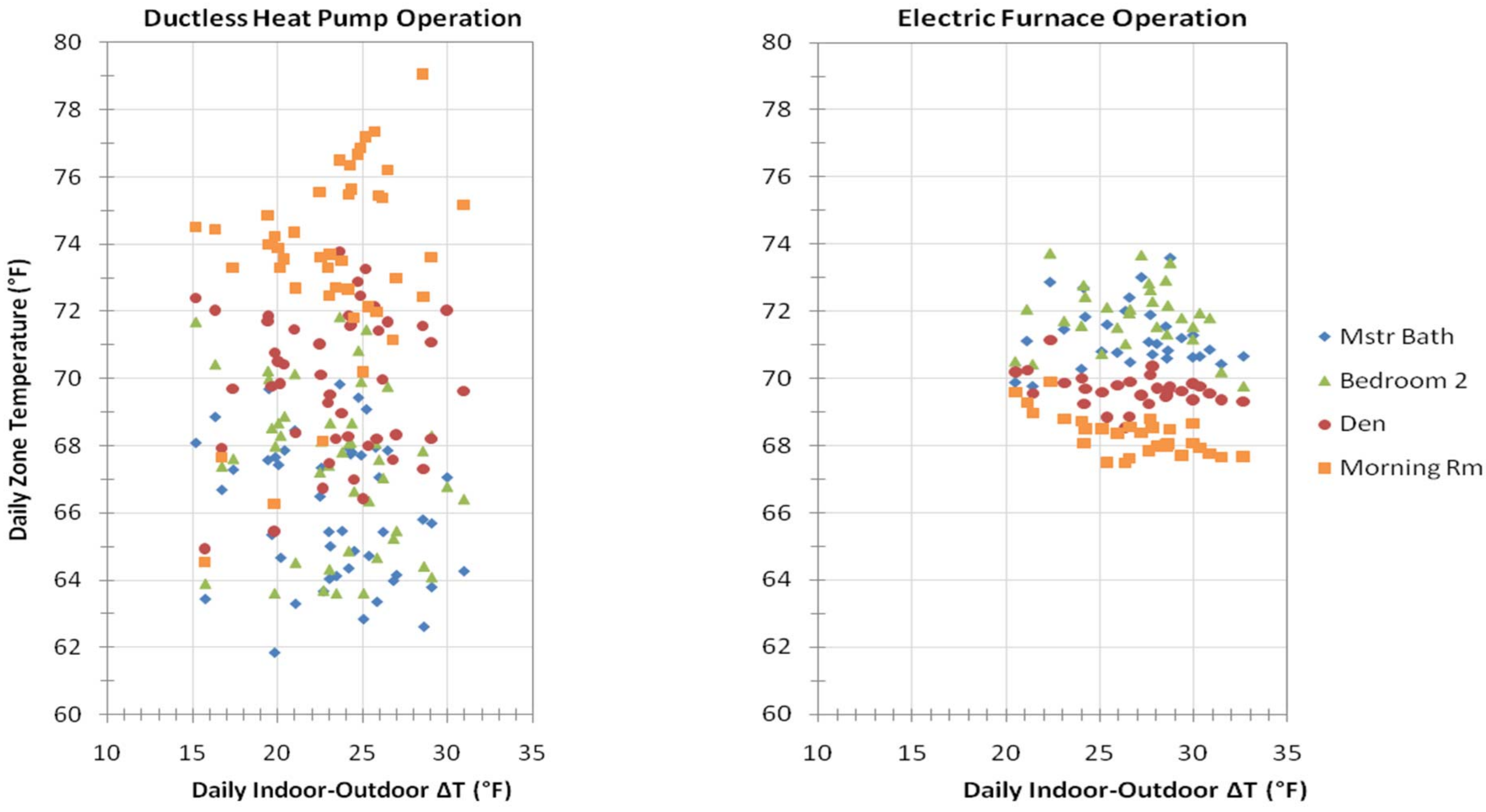
Dividing the slope of the ER furnace fit by the DHP fit will give an estimate for the DHP's COP of 2.7.

Given the directly measured and manufacturer reported COP, this number is slightly lower than may be expected, and can be explained by higher return air temperatures and higher demand on the unit than specified by the manufacturer.

Nevertheless, the calculated COP of 2.7 for the ductless heat pump represents substantial savings.

Ductless Heat Pump (DHP) Retrofit in HUD-code Manufactured Housing

Zonal Temperature Distribution:



Ductless Heat Pump (DHP) Retrofit in HUD-code Manufactured Housing

Ongoing field research is proposed to investigate:

1. How much of the electric furnace can be displaced with DHP and/or central heat pump?
2. How well do the DHP or EF maintain acceptable indoor temperature for thermal comfort?
3. What are the pros and cons of various approaches to DHP air distribution mixing that improve thermal comfort and reduce back-up electric resistance heat?
   - Fan recycler w/EE ducts (tight/inside)
   - Thru interior wall supply fan
   - Stage DHP with central system w/o zoned stats?
   - Make the envelope tighter, home smaller to improve temperatures
   - Add more indoor units

Residential Gaps/Barriers:

- Impact of reduced resistance space heating using DHP's:
  - New and/or existing with DHP's to offset some or all of space load
  - Single, multi family and HUD-code mfg homes opportunities
  - Performance in cold and marine homes
- Over 14,000 DHP installed/retrofitted in PNW in the past few years, identifying and now supporting an emerging business model for residential HVAC industry and other stakeholders.
  - HSPF10-12, SEER 20-25 ductless heat pumps (DHP) or "Mini-splits".
  - Inverter driven variable refrigerant systems;
  - Typical; Fujitsu, Daiken, Mitsubishi, LG typical

What have we achieved so far?

- BA-PIRC and utility, builder, HVAC stakeholders research of; equipment costs, thermal performance & customer satisfaction:
  - Lab testing of DHP (2 units in heating/cooling from -5 deg F etc..)
  - Utility pre-post retrofit billing analysis on over 3900 SF homes
  - Detailed monitoring of in-situ performance in 95 homes
- Single Home preliminary case studies
  - WSU Energy House “flip/flop tests” (HUD-code home)
  - Howard Deep Energy Retrofit (Victorian home)
  - Cohen high performance home (new site built SF)

Risks

Utility Cost Effectiveness & Market Acceptance:

- resistance heat "offset" and impact of occupant behavior/controls
- single vs. multiple head DHP first cost vs. annual energy savings
- zonal temperature distribution (floor plan, door closures)
- Impact of AC availability (customer like, but added cooling to utility)
- Need HVAC /Builder/Consumer training & education for success

The net market benefits

- High performance home option (just say no to central ducts)
- Low cost retrofit in site built homes w/baseboard heat
- Lower cost than typical ducted systems in new and retrofit
- Higher efficiency in broader temperatures (high and low)
- Now accepted by HVAC contractors and customers in PNW
- Ideal for PNW utility program rebates

14,532 INSTALLATIONS AND COUNTING!
SINCE OCT. 2008

What is left to achieve?

- Highest priority issues:
  - Continue field /billing/occupant research on BA communities and case studies (PIRC)
  - Technical support to HVAC and Utility stakeholder (PIRC/ASHRAE/ACEEE/ACI)
  - Offset central ducted electric furnace in new and retrofit mfg homes (PIRC/HUD/WX)

  - Sizing of single vs. multi head DHP for design & annual performance (BA/NIST/ACCA)
  - Comfort and cost effectiveness ;single head vs. multi-head systems (BA/NIST/Ecotope)
  - DHP Multi-zone model to offset resistance heat (Ecotope/NREL/BA)
  - Support lab testing on new equipment (Ecotope/NREL/NEEA/AHRAE)

- Possible risks going forward include:
  - long term performance and impact of M&O issues?
  - Electric vs. Gas Utilities fuel switching (source vs. site conflict of utility vs. customer)
  - Limited BA $ to implement (best to partner with others to leverage $$)

BA opportunities w/DHP

- Single Home preliminary case studies
- JBLM Military family NW Energy Star housing at Town Center
- Affordable Energy Star housing at HFH at High Point
- Affordable LEED Platinum/Energy Star at Salishan phase 7
- DHP Retrofits at Salishan phase 1-6

- Manufactured Housing DHP retrofits programs and case studies
- Manufactured Housing DHP new construction programs – HUD code?

- Support ASHRAE TC6.3/9.5, ACCA Manual S, ACI; program, std. & research