Integrated DSM:

Communicating Thermostats and Energy Management for Resistance HVAC, and Inverter Driven Heat Pumps

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1 Problem Statements

1. Thermostat controls sold with DHPs, zonal heat, forced air furnaces, and hearth heaters do not reflect current state of art technology, leading to reduced energy and capacity savings
2. Existing homes that install DHPs often have secondary heating sources that are separately controlled and reduce overall energy and capacity savings.

2 Summary

Communicating Thermostats (WCT) are currently 20% of the new residential thermostat market, and expected to increase to 50% by 2020. Recent residential studies using WCTs show both electric energy and capacity savings. These savings are occurring through:

a. Improved technical control of equipment and fault detection and diagnosis (FDD),
b. Learning algorithms and use of sensor information, e.g., weather and occupancy,
c. User behavior changes,
d. First step to full Home Energy Management (HEM), lighting, water heater, etc.,
e. Automatic response to grid events or pricing (capacity).

The primary market now for WCTs are single family homes with ASHP, Central Air, and Gas FAF. However, the Pacific Northwest residential HVAC load remains over 60% in other HVAC types that could benefit from WCT integration and functionality, including Electric Resistance zonal and FAF, inverter driven Mini-split heat pumps, and sectors, e.g., Multifamily, Manufactured Homes, and Small Commercial.

2.1 Findings

2.1.1 Residential electric resistance HVAC usage continues to grow in the Pacific Northwest

<u>PNW residential electric resistance HVAC market is expected to grow 1% annually.</u> In the next 20 years the number of homes with non-heat pump electric HVAC will move from 1.9MM, consuming 1,185aMW/yr to 2.9MM, consuming 2,260aMW/yr. (Navigant, 2015) This PNW market trend is reinforced by Cadet Manufacturing who expects to sell 200,000 units/yr of electric zonal heat, or

regional estimates of manufactured homes with electric Forced Air Furnaces being sold at 2,200 to 4,000 units/yr. Strategies to reduce this energy usage include improvement in building codes, weatherization, improved windows, and use of various heat pumps to replace or supplement non heat pump HVAC. We think there are further savings in this market by integrating WCTs and energy management systems with new and retrofitted electric HVAC.

2.1.2 DHPs have penetrated 6% of electric HVAC PNW market, and getting 50% of home potential savings.

Ductless Heat Pump market penetration in PNW has been slower than expected; an Illume study recommends moving the 85% stock penetration forecasted in 2028 to 2034. (Illume, 2015) To date, the PNW has installed over 100,000 DHPs, or about 6% of the market. Most of the installations are in single family homes and represent supplemental HVAC to existing electric resistance heating, and may add cooling. Energy savings from these installations are about 24 aMW/yr. Given continued growth in inefficient electric resistance (ER) HVAC, pursuing WCTs and controls for this equipment is a good hedge against slower DHP and HP penetration.

Homes that have installed supplemental DHP are getting 50% of potential savings due to continued use of other less efficient HVAC systems, and behavior that increases energy use. (Ecotope Inc., 2014). Non-HP heat continued to provide 50% of home heating, and DHP modeling studies (SEEM) estimated a 20% increased use to provide other benefits, e.g., increased temperature setpoints in main living and secondary spaces, reduced non-electric supplemental fuel consumption, and increased occupancy during heating season.[1] Interviews of DHP users found few occupants used setback capabilities and found DHP thermostats not user friendly.

2.1.3 Web-enabled communicating thermostats have demonstrated electric energy and capacity savings through changes in user behavior, improved sensor and equipment control, and customer satisfaction.

Through an Energy Trust of Oregon (ETO) study of Nest WCT thermostat with Air Source Heat Pumps (ASHP) energy savings ranged from 5-20% of heating load (average of 786kWh/yr). (Apex Analytics, 2014) . Savings were not achieved uniformly by all participants, which ***suggests*** that savings are dependent on situation and customer behavior. Apex analyst, Noah Lieb, suggested these findings were directional, not statistically significant, based on a sample size of 161 participants. Findings included:

a. Manufactured homes had almost double the average savings.
b. Lower income homes had almost double average savings (1,654 kWh/yr)
c. Prior programmable thermostat users had higher savings than non-programmable.
d. Use of Auto away feature had higher savings than average.
e. Energy savings higher in Zone 2 than Zone 1.

[1] Ecotope estimated a 2.7F takeback in temperature increase. This analysis guessed at baseline indoor setpoint and tried to calibrate billing data with pre and post installation results using SEEM. Higher billing analysis post installation could also be attributed to more use of inefficient ER use, since the pre-installation setpoint was not measured.

f. Homes in Portland/Metro area had slightly higher savings than Southern Oregon or Willamette Valley.

This study described savings differences, but did not attempt to provide reasons for differences. The hypothesis for the study was that savings would occur because WCT feature would lock out the resistance strip heat when outside temperatures allowed for efficient heat pump operation.[2] While this may have contributed to some savings, it appears sensors and behavioral changes were also a contributor to participant energy savings.

California studies on Small Commercial use of communicating thermostats and Building Automation show energy savings over 20%, but equipment type was not homogeneous.

Studies show that use of WCT improve customer program participation and capacity savings by 67 to 200%. (Energy Insights, 2015) More utilities are considering pricing programs as the means to achieving demand response objectives. While this may fit utility and revenue models, these price only programs get less capacity savings, less reliability, and can lead to higher customer bills.

Seasonal peak capacity savings with WCT and HEM have been demonstrated for summer months in territories outside the PNW. For example, Nest's demand response program, called Rush Hour rewards, reduced Air Conditioning load by 50% for 2 hour peak periods in Texas, California, (Austin Energy, 2015) (Nest, 2013) These programs had no customer complaints with only a handful of customer questions. Nest ran a winter 2015/2016 demand response program at PGE, no results available at writing.

2.1.4 Web-enabled communicating thermostats exist for all residential HVAC, though few examples in resistance HVAC and inverter driven heat pumps

There are some vendors of WCT and HEM that work with ER HVAC (Sinope, Honeywell Redlink, Aube, Energex, Iotas, Verve) and with ductless mini-split heat-pumps (Daikin, Mitsubishi, LG), and only one aftermarket energy management vendor that will work with both (PowerWise). WCTs, sensors, and software are in early maturity stage and expanding into all HVAC segments.

Despite available WCT technology with ER HVAC, companies like Cadet, Nordyne, Evcon, etc. are not offering WCTs with their HVAC equipment. The pace of improvement and adoption is fast, yet getting these products focused on energy savings in ER HVAC and DHP will require further study and market transformation attention.

In the Pacific Northwest, there are no WCTs installed with ER zonal/FAF, or inverter driven heat pumps (unless a very early adopter customer). **This HVAC is responsible for 66% of the residential heating load in 2015 (1,185aMW)** This suggests a market transformation opportunity if WCT integration can be proven cost effective for energy and capacity.

[2] *This study has shown that the Nest thermostat, when used as an alternative approach to an outdoor thermometer controlling the lockout of resistance backup heat, can offer considerable energy savings. The Nest thermostat prevents expensive resistance heat from running, by using algorithms to optimize energy use under given weather conditions. It is this "smart algorithm" feature of the Nest that makes it so attractive for a program like this.*

77% of Americans use a smartphone, and over 50% homes have constant broadband service.

2.1.5 Use of WCTs in residential electric HVAC will provide the region with 226aMW of cost effective energy savings and over 2,000MW of seasonal capacity.

With 85% WCT penetration on ASHPs, and 700aMW use in 2034, a 12% energy savings, as demonstrated in Apex study, would save **73aMW**.

For Non-ASHP electric HVAC we conservatively estimate **a 7% energy savings from the use of WCT** . This includes dwellings with Electric HVAC, DHP, or a combination of the two. for the following reasons:

1. RTF is using **5% savings on a measure to move electric zonal heating from bi-metal to electronic thermostats**. [3] This RTF measure is simply providing improved accuracy on setpoint, or narrowing deadband, and does not necessarily include programmable features.
2. 2002 EWEB study shows average 18% savings (1,475kWh/yr) from use of programmable thermostats over bi-metal with zonal HVAC. [4] WCT will do better than this.
3. 90% of thermostats for zonal HVAC are bimetallic. (big savings opportunity)
4. Many people point to Nest savings with ASHP (12%) as coming from lockout of resistance strip heat, but that is only one element for savings. Energy savings from WCTs are found in Gas FAF and Central AC. Recent ETO Study found Nest use with **Gas FAF had 6% energy savings**.[5] This suggests savings coming from something other than strip heat control.
5. In ETO Nest ASHP study, WCT use had higher than average savings in markets, e.g,. low-income and manufactured homes. This suggests savings coming from something other than strip heat lockout. The Energy Trust of Oregon existing buildings program manager suggested this makes sense because lower income homes pay closer attention to measures that can provide $20/month of savings, and they have smart phones. These are also target markets for high percentage use of electric resistance HVAC.
6. Savings from behavioral tools, e.g., Opower are coming in around 2%. These tools provide only social information. WCTs can provide more informed feedback to help consumers save energy.
7. This does not include Cooling load savings.

With 85% WCT penetration on Non-ASHP HVAC, and 2,260aMW baseline use in 2034, a 7% energy savings (guess), The region could save **153aMW**, and over 2,000MW in Winter capacity. This is in addition to a 442aMW savings that could come from moving 85% of this market into DHP or inverter driven heat pumps. (See table 2 for breakdown)

WCT heating electric savings: ASHP 73 aMW + non-ASHP 153 aMW = 226 aMW

[3] http://rtf.nwcouncil.org/meetings/2016/04/
[4] http://rtf.nwcouncil.org/meetings/2016/04/
[5] http://assets.energytrust.org/api/assets/reports/Smart_Thermostat_Pilot_Evaluation-Final_wSR.pdf

2.2 Recommendations

To date, most studies with WCTs are with ASHP, central air conditioning, or natural gas furnaces. We recommend studies that examine WCT and HEM in all electric HVAC equipment and customer markets, including SF, MH, MF, and small commercial.

WCTs, sensors, and software are in early maturity stage and expanding into all HVAC segments. In addition to proving energy/capacity savings, they also provide occupants, HVAC contractors, and utility with important data, analytics, FDD (Fault Detection and Diagnosis). Often times WCTs come with other sensors, e.g., occupancy, outdoor temperature, and ability to receive pricing or utility information. Manufacturers of electric zonal, FAF, and inverter driven HP (DHP) don't seem to be moving quickly, or at all, to incorporate WCT into their products. The pace of WCT improvement and adoption is fast, yet getting these enhancements and a focus on energy/capacity savings in ER HVAC and DHP will require further study and market transformation attention.

2.2.1 Market Research and operational details of WCT/HEM

Work with electric HVAC systems, and DHP manufacturers and understand their views toward WCT use with their product. Understand better the product development drivers of the electric HVAC manufacturers, and their willingness to work with 3rd party thermostats.

1. Evaluate market opportunity for WCTs to focus on the Electric HVAC residential market. The RTF is suggesting electronic thermostat replacements for bimetallic for zonal heat. Most of the cost of measure is installation on line voltage. Time to look at WCT instead of electronic thermostats.
2. How is Home Management market (Nest, Alarm.com, Iris, Wink, etc.) looking at energy management? What strategies to get these home management systems to work with residential control of HVAC, lighting, other appliances.
3. Detailed research for market barriers to WCT integration with DHP and electric HVAC.
4. Look at barriers of getting WCTs with FAF, especially in Manufactured Homes.

2.2.2 Lab Studies.

Since WCT control of ER HVAC and Inverter Driven Heat Pumps is relatively new, it is worthwhile understanding some of the technical integration features that would lead to energy savings. Just as Nest focus on ASHP strip heat lock out, there may be integration benefits. For instance WCT use of occupancy or learning algorithms might identify reasons for savings.

1. Studies with zonal and FAF
2. Studies with Inverter driven heat pumps,
3. Studies with WCT controlling both ER and DHP.

Examine how WCT work versus ASHP, and explore technical, vendor, and cost issues.

2.2.3 SEEM modeling.

Much of the savings from WCT involves use of occupancy and temperature sensors, learning home user behavior and patterns, and better equipment control. SEEM modeling may be able to consider WCT savings from various baselines, and a WCT would look like other programmable thermostats. We don't think SEEM modeling can capture energy savings from use of sensors, learning algorithms, or user behavioral changes. Potential Modeling analysis:

1. Evaluate technical interactions between DHP and secondary HVAC, and evaluating various control strategies.
2. Demonstrate energy savings from better control strategies with various HVAC equipment. For instance, in DHP studies, occupants did not use programmable features. WCTs might improve this with improved user friendliness and feedback features.
3. Use SEEM to generalize savings from lab testing data and field data. This aspect was used in Ecotope's DHP evaluations which did include both lab and field study data.

SEEM modeling could assist provide energy savings estimates, and inform discussions with vendors.

2.2.4 Field Studies

We think that field studies incorporating WCTs will be the most beneficial tool at gauging specific equipment and segment energy savings, because of the use of sensor data, behavioral, and learning features cannot be uncovered in the lab, and can only be guessed in modeling.

1. **Manufactured Homes.** <u>One year study of energy and capacity savings using WCT specifically in Manufactured Home markets, for both new construction standards and retrofits.</u> Use WCT/HEM vendors that can communicate and control <u>both DHP, and FAF</u>. Though WCTs are not often sold with Electric FAF, there are WCTs that will work with FAF. In new construction, work with Christopher Dymond and the NEEM and HPMH standard effort to define study parameters and technologies. For retrofit study, work with program managers at BPA, ETO, and utilities to define technology and study specifics.

In Washington 2,500 heat pumps (both ASHP and DHP) are installed in Manufactured Homes every year. The State of Washington Energy Office is working with Labor & Industries (L&I) to commission and evaluate energy usage data on these sites. This data and market access could be used as a research project to determine savings with and without WCTs, for ASHP and DHP. This is also an opportunity to engage L&I to install WCTs when commissioning homes with heat pumps and electric resistance heat.

2. **Multifamily.** <u>One year study of energy and capacity savings using WCT/HEM specifically in Multifamily market.</u> Use WCT/HEM vendors (e.g., Iotas, Energex, Verve, other) to construct a study using 3 groups (1. control group, 2. information only, 3. Automation, sensors, and control, and 4. Information PLUS Automation/control). Study will look to measure the marginal benefit of control which will cost more to implement. EQL Energy has begun the funding process with BPA Technology Innovation, ETO, and Oregon Best. Sites have been

identified and target groups per building are 90 units. We would like to also perform studies on smaller multifamily dwellings.

EQL visited a 2015 constructed multifamily building with Cadet wall heaters and inefficient Amana PTACs. There are WCT opportunities for savings in this market with or without DHP.

3. **Single Family.** One year study of energy and capacity savings using WCT/HEM specifically in Single Family market electrically heated and cooled with something other than ASHP. Use WCT/HEM in single family homes new and retrofits that heat with ER, zonal or FAF. Integrated Inverter driven HP, including ductless, short run ducted, and central. Study of HEM/WCT with 1) DHP and 2) zonal heat. Likely vendor would be PowerWise or other vendor because WCT/HEM technology to manage DHP and Zonal Heat is only in the after market, at this time. The study would need to be a detailed dive into the communication technology and integration of more than one vendor's HVAC. This study will be dictated by available technology and cooperation of DHP vendors.

3a. WSU Energy Office submitted a funding request through BPA TI that looks at a sample of similarly situated townhomes in King County. Study includes homes with existing zonal heat, and installing units with short run ducted mini splits (DMS), and some with Ductless Mini Splits (DHP).

EQL Energy proposed adding the WCT study feature that will work will all HVAC types to examine marginal energy savings and peak capacity reductions. Controls for ER heaters in homes where they are not the primary heating source, in conjunction with a DHP installed in the main living area. WSU proposes to work with KCHA and Johnson Controls to evaluate web-controlled thermostats (WCTs) as well as potentially simpler and lower-cost non-WTC ability to curtail ER use based on outside temperature, acceptable occupant bedroom comfort swings, and/or bedroom zone occupancy. The results of that evaluation will inform what is used in the 10 case study homes.

4. **Small Commercial.** One year study of energy and capacity savings using WCT/BEM specifically in Small Commercial market that use electric resistance HVAC or residential HVAC. Markets include lodging, elder care, small office/retail with Electric HVAC. Vendors would include Iotas and Energex. Costs for these systems are overall higher than residential WCT ($750-$1,200), but savings and capabilities will also be higher. Commissioning and user training is important to achieve energy savings and improve user perceived comfort.[6]

[6] http://wcec.ucdavis.edu/wp-content/uploads/2014/10/OutcaultACEEE_Thermostats.pdf

3 Background

3.1 Market Size and Energy/Capacity Savings Potential

3.1.1 Market Size

There are about 2 Million electrically heated residential living spaces in the Pacific Northwest (single family, manufactured homes, and multifamily). These dwellings use about 1,950 aMW/yr, with 1,185 aMW coming from resistance heating (zonal, plugin, and FAF). A 2015 Navigant report estimated that use of resistance heating will continue to increase to 2,260 aMW by 2034, a 1% annual increase. Using this data to forecast increase in dwellings with electric HVAC reveals values used in our analysis and shown in **Table 1** below.

Table 1: Market for Electric HVAC (non-HP) in the Pacific Northwest

Electric HVAC (non-heatpump)		2015				2034				
	Units	SF	MH	MF	Total	SF	MH	MF	Total	Source
Electric HVAC homes	Units	728,047	483,920	750,900	1,962,867	1,092,071	725,880	1,126,351	2,944,301	(4)&(6)
zonal	Units	505,066	9,678	600,720	1,115,465	757,599	14,518	901,081	1,673,197	(4)&(6)
FAF	Units	222,981	309,709	15,018	547,708	334,472	464,563	22,527	821,561	(4)&(6)
DHP installed (based on penetration)	DHP units	97,149	3,871	22,527	123,547	928,260	616,998	957,398	2,502,656	(4)
DHP Penetration	%	13%	0.8%	3%	6%	85%	85%	85%	85%	(1)
Measured DHP Savings										
Average Annual electric space heat	kWh	8,116	8,848	3,900						(2)&(4)
Actual savings per house with DHP	kWh	1,900	2,071	844						(5)
Actual DHP savings percentage of HVAC	%	23%	23%	22%		23%	23%	22%		calc
Total Possible savings if all HP		48%	62%	45%		60%	62%	60%		(5)

(1) 2015 Illume, MPER 4 for Northwest Ductless Heat Pump Initiative (number based on 2010 RBSA Ecotope Sep 18, 2012) http://neea.org/docs/default-source/reports/ductless-heat-pump-market-continues-to-increase-dhp-mper-4.pdf?sfvrsn=12

(2) 2012 Ecotope RBSA summary http://neea.org/docs/reports/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf?sfvrsn=8

(3) 2015 ETO Nest study with ASHP (12% heating load, cooling was not part of study)
http://energytrust.org/library/reports/Nest_Pilot_Study_Evaluation_wSR.pdf

(4) 2014 NEEA RBSA for MH and MF
http://neea.org/resource-center/regional-data-resources/residential-building-stock-assessment

(5) 2014 Ecotope DHP Final Summary report impact and process evaluation, Ecotope
http://neea.org/docs/default-source/reports/e14-274-dhp-final-summary-report-(final).pdf?sfvrsn=8
48% of potential savings from DHP west, 23% savings in east, because of secondary heat source lose 30-40% of savings

(6) 2015 Navigant, Residential Inveter-Driven Heat Pump Technical and Market Assessment:
https://neea.org/docs/default-source/reports/residential-inverter-driven-heat-pump-technical-and-market-assessment.pdf?sfvrsn=4

We think there is a market transformation opportunity to accelerate the integration of WCTs for both DHP and resistance electric heat. WCTs already are 21% annual sales of thermostats and are expected to be over 50% by 2020. (Talpur, 2015) We only found one manufacturer, Daikin, selling DHP with WCTs

(Daikin resells the Ecobee). We found a few 3rd party WCT equipment providers working with resistance heat (Sinope, Honeywell/Aube, and Powerwise), and a few working with multifamily/lodging (Energex and Iotas).

Another interesting research finding was that resistance heating manufacturer Cadet has over one million units in the PNW and still sells 200,000 units/yr of resistance heaters in the Northwest, primarily wall heaters. EQL visited a 2015 constructed multifamily building with Cadet wall heaters and inefficient Amana PTACs. There are WCT opportunities for savings in this market with or without DHP.

3.1.2 Energy and Capacity Savings Summary

Based on several studies on existing DHP installations we think annual average MW savings for DHP installations to be about 24 aMW/yr. If these same installations had WCT that controlled the secondary HVAC (zonal, FAF) we estimate an improved savings would be 7 aMW. This represents 7% savings. If we look out to 2034 where residential electric HVAC is expected to increase and WCT has 85% market penetration of electric HVAC the annual savings would be **153 aMW.** See **Table 2** This savings is looking at WCT use for all ER HVAC and DHPs.

Using Ecotope's calculated energy savings and a 85% stock penetration the savings potential is 442 aMW/yr.

Table 2: Estimated Energy and Capacity Savings from WCT use with DHP and Secondary HVAC

Electric HVAC (non-heatpump)		2015				2034			
	Units	SF	MH	MF	Total	SF	MH	MF	Total
DHP Penetration	%	13%	0.8%	3%	6%	85%	85%	85%	85%
Annual Energy Usage and Savings Calculations									
Usage Electric Resistance HVAC	aMW	675	489	334	1,498	1,018	738	504	2,260
Savings Potential if DHP 100% market and 100% of HVAC	aMW	324	304	150	778	611	459	303	1,372
Actual Savings: DHP savings 23% x market penetration	aMW	21	1	2	24	203	147	93	**442**
% savings when adding ER controls or WCT		7.0%	10.0%	7.0%		7%	10%	7%	guess
Estimated savings based on guess for ER control or WCT	aMW	**6.3**	**0.4**	**0.7**	**7**	**61**	**63**	**30**	**153**
Capacity Savings if WCT on DHP and Supplemental									
Winter Capacity	kW	1.0	1.0	0.5		1.0	1.0	0.5	
Summer Capacity	kW	0.5	0.5	0.5		0.5	0.5	0.5	
Winter Capacity	MW	97	4	11	**112**	928	617	479	**2,024**
Summer Capacity	MW	49	2	11	**62**	464	308	479	**1,251**

Energy Savings Research (Ecotope 2014)

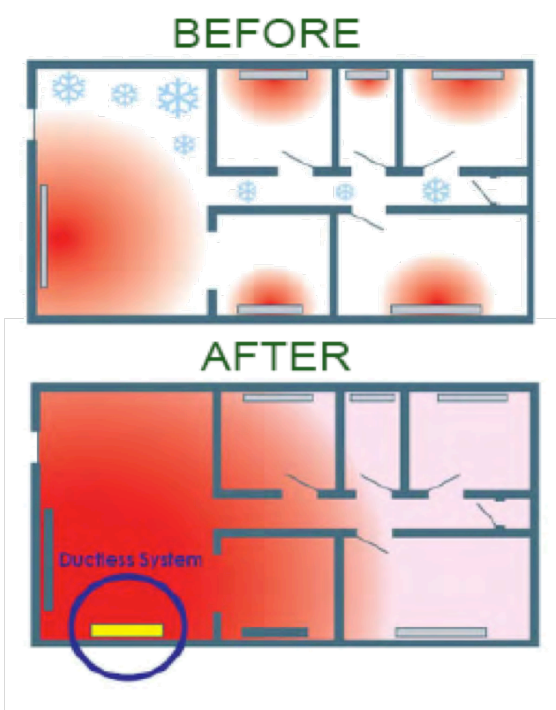
Studies on ASHP savings from use of WCTs (Nest and Honeywell) show average savings between 7 and 20%, which generally come from avoiding or reducing use of strip resistance heat present in most ASHPs. (Apex Analytics, 2014) We expect WCTs to achieve an average of 7% savings with HVAC other than ASHP and will be dependent on housing stock and customer behaviors.

Regional DHP initiative savings estimates are being informed by studies conducted by Ecotope, RTF, ETO, and BPA. The 2014 Ecotope Final Summary on DHP Impact Evaluation looked at 3,899 DHP installations which displaced electric zonal heating. Average savings in single family homes were 1,900kWh/yr from a baseline average of 8,116 or **23%.** DHP COPs in PNW average 3 with a range from 2 to 4. Savings were reduced from COP or lab results because :

1. Homes continued use of secondary heat was 30-40%. See Figure below that shows use of supplemental heat continues. Depending on how thermostats are set, the supplemental could even become the primary heat source. Having a thermostat thatcontrol both would help utilize DHP more often.

2. Savings were also reduced by 20% based on behavioral changes that increased use. Ecotope inferred this from data analysis between a metered sample and billing analysis. RTF has recognized the non-energy benefit to the DHP Measure for increased comfort ($40/yr). Ecotope found increased use with DHP for following reasons:
    a. Classic takeback customers turned up setpoint (this was demonstrated via pre and post energy use for space heating)
    b. Customers left heat on all day and night
    c. Unoccupied heating

Figure 1: DHP Supplementing Zonal Electric Heat



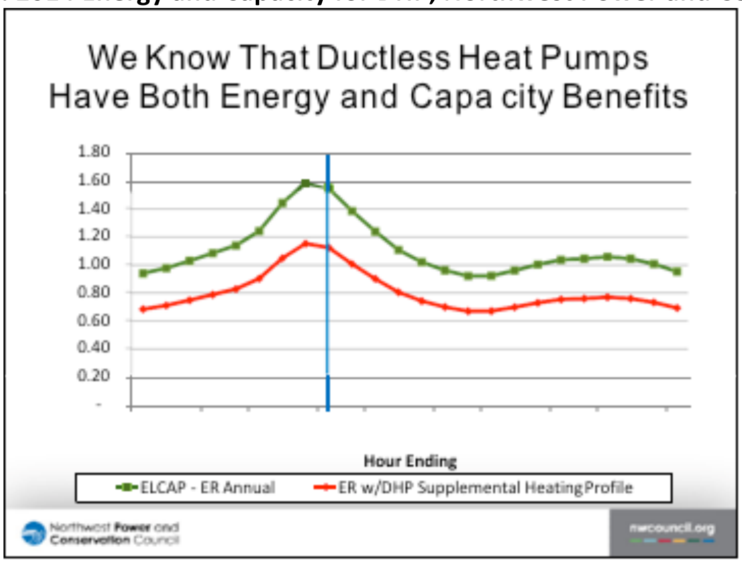
Peak Demand Savings

In order to achieve peak demand reductions in home HVAC, it is important to include WCTs and communicating controls to all heating circuits. These devices automate the process of participating in rate or load control programs and leads to higher demand savings.

LBNL 2015 report found that peak demand reductions for pricing programs using WCTs were 27% to 45%, while without WCTs (-1% to 37%). WCTs "lower the transaction costs associated with responding to prices and critical peak events by making it easier for customers to alter their electricity consumption at specified times." (LBNL, 2015) A SMUD WCT pilot evaluating energy and capacity savings in multifamily found capacity savings of 29 to 35% when tied with a peak pricing program. (ACEEE, 2014) This is compared to a 5-7% capacity savings when customers are on peak pricing program and education.

The NPCC Regional Technical Forum (RTF) has discussed the capacity and energy savings from DHP see **Figure 2** below.

Figure 2: 2014 Energy and Capacity for DHP, Northwest Power and Conservation Council



3.1.3 Savings by Equipment, Sector, and Region

Equipment

Two studies by Ecotope evaluated pilots for Single family supplementing zonal heat and Single Family and Manufactured homes supplementing electric forced-air furnaces (FAF).

Both studies showed that savings were reduced by 30-40% from the use of secondary heat sources. The study on FAF found savings of about 5,500 kilowatt hours (kWh) resulting from the use of DHPs. The driver of these savings was the occupant's FAF and DHP control strategy: occupants who made the DHP their primary heat source saved considerably more energy than those who retained the FAF as their primary heat source. The savings resulted from a combination of DHP efficiency, reduced energy waste from duct losses, and a change from heating the whole house to keeping the main part of the house comfortable with the DHP.

Inventory of heating equipment was provided in Navigant 2015 and summarized in **Table 3** below.

Table 3: Electric Heating Use by System Type and Sector (Navigant 2015)

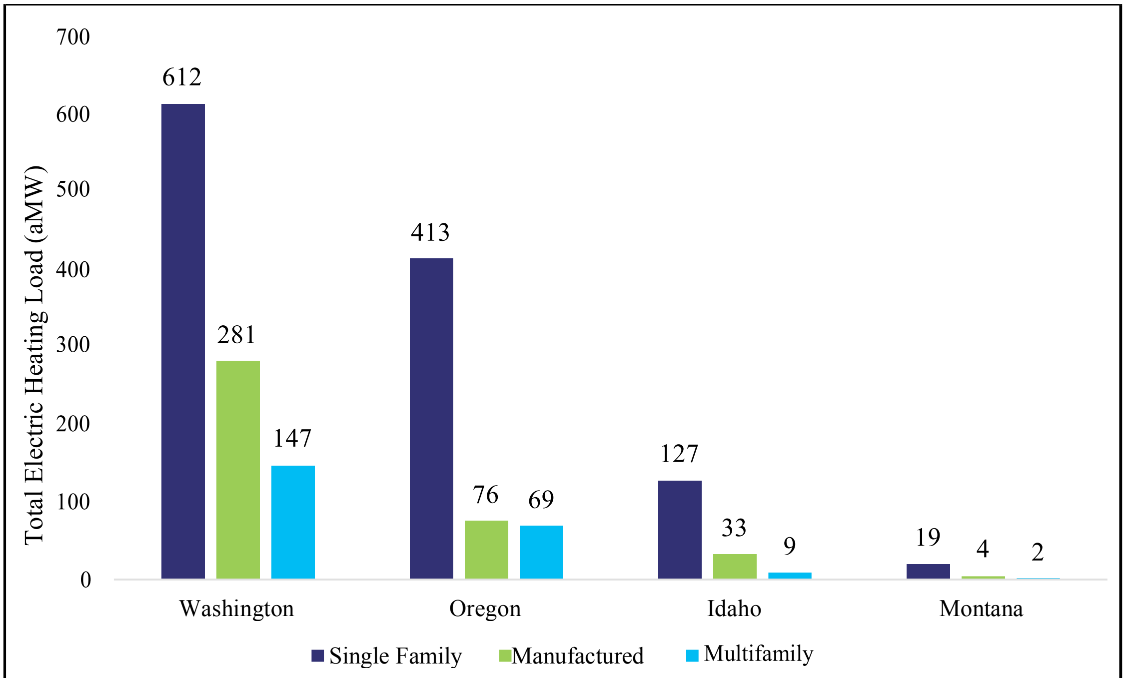
Primary Heating System Type	Total Load (aMW)	Single Family	Manufactured	Multifamily
Air Source Heat Pump	478	83%	17%	1%
Baseboard Heater	638	66%	1%	33%
Boiler	19	100%	0%	0%
Dual Fuel Heat Pump	41	100%	0%	0%
Ductless Heat Pump	55	92%	8%	0%
Forced Air Furnace	484	38%	60%	2%
Ground Source Heat Pump	25	100%	0%	0%
Packaged Terminal Air Conditioner or Heat	8	0%	0%	100%
Plug-In Heater	44	78%	22%	0%

Source: Navigant 2015 Analysis of RBSA data

Single Family

There are 728,047 single family electrically heated homes, of which 505,066 have zonal resistance heat, and 222,981 with FAF. (Illume, 2015) NEEA has an ambitious goal of 85% of these homes with DHP by 2028, which may be moved out to 2034, based on recommendations by (Illume, 2015) . Since the 2008-2009 large scale PNW DHP pilot there have been lab tests, field monitoring, billing analysis, cost analysis, impact and process evaluations (Ecotope), as well as regular market progress evaluations (Illume). This previous work has been our source to estimate market size and opportunity for better control and integration with secondary heating sources. 13% of SF new construction gets electric heating. (RLW Analytics, 2007) The goal for DHP supplemental heat is to reduce use of zonal heating as shown in

Figure 3: Electric Heating by Sector and State (Navigant 2015)



Source: Navigant Analysts

Manufactured Homes

From **Table 2** above, Manufactured homes comprise 22% of the Northwest's new construction market electric load (approx. 2,000 to 4,000 units/yr) and 14% of the existing homes in the Northwest. (Navigant Market Assessment, 2015) Almost all new manufactured homes are shipped with electric forced air furnaces, dominated by two vendors Evcon and Nordyne (Nortek). This equipment can cost $200 for a 16kW unit, plus $100 for ducting. This market would require intervention to get manufacturers to move to DHP or ASHP, or including WCTs.

February 2016 the RTF approved the UES (Unit Energy Savings) measure to use DHP in Manufactured homes. At its February 2015 meeting, the RTF agreed with the professional judgment that savings, cost, and life are not significantly different than the savings, cost, and life for the same measure in single family applications. The single family results were used directly for this measure.

Multifamily (MF) and Commercial lodging

We think in MF there are similar saving percentages in modifying customer behavior and avoiding use of secondary or primary heat sources that use electric resistance or PTAC (Packaged Terminal Air Conditioner) units. The per unit savings will be lower than single family or manufactured homes, but opportunities exist to combine savings for all units at a given location. That said, if market transformation efforts were successful in combining control of DHP and secondary heat, then MF could take advantage of improved energy savings. Ecotope 2012 found in MF installations of DHPs 824 kWh/yr savings in units from 400-1,100 sf. (Ecotope, 2012).

We also recognize that multifamily is a large opportunity to achieve energy savings through better controls of baseboard/wall heat and PTAC units, with or without DHPs. As part of this research paper, EQL Energy walked through a 500-unit Portland apartment building that was built in 2015. The HVAC included inefficiency electric resistance PTAC and wall heaters and electric water heat.

Technology to achieve energy savings in hotel and multifamily are generally based on occupancy sensors. According to testing done by BC Hydro and Pacific Gas & Electric, Energex systems reduce HVAC and lighting costs by up to 40%, as well as increase equipment life and decrease noise. See **Table 4** summarizing studies with these technologies show average annual energy savings of 900kWh/yr. EQL has worked with Energex on a project at University of British Columbia - Vancouver.

Table 4: Occupancy Sensor Energy Savings in Multifamily

Location		units	kWh savings	per unit savings
		#	kWh/yr	kWh/yr-unit
Conestoga College		275	150,000	545
Univ Towers		470	210,077	447
Weinbrenner Place		72	120,889	1,679
Creeburn Lake Lodger		600	573,271	955

http://www.nrgee.com/energex-inc-removes-wasted-energy-from-empty-rooms/

BPA looked at hotel occupancy sensor savings in 2010 and 2011 and found an average savings of 12%, from turning off lights and HVAC. (BPA, 2010) In speaking with BPA manager, Erik Boyer, BPA did not pursue a program of Occupancy Control Sensors (OCS) for hotels because the baseline study showed that hotel staff would turn off room HVAC and lights after cleaning. Mr. Boyer felt that this type of control technology may be cost effective in apartments, college residence, or multifamily. US DOE had a more comprehensive report that found increased savings, but included areas not relevant to Northwest. (US DOE, 2012)

New Construction

From a 2007 report on Single Family residential new construction, it appears that 13% of new homes have electric heat in in OR and WA. Navigant 2015, based on RBSA, estimated that electric resistance heating will continue to increase in use by 1% a year from 1,185 aMW today to 2,260 aMW by 2034.

Table 5: 2007 study on SF New Construction, heating type

State	Gas		Electricity		Pellets		Propane		n
	%	EB	%	EB	%	EB	%	EB	
ID	90%	5%	3%	3%	0.4%	0.6%	6%	4%	179
MT	100%	-	-	-	-	-	-	-	18
OR	82%	6%	17%	6%	-	-	0.5%	0.8%	178
WA	77%	5%	16%	4%	-	-	6%	3%	229
Overall	82%	3%	13%	3%	0.1%	0.1%	4%	2%	604

Washington energy code requires that heat pumps must have outdoor thermostats and lock out use of resistance heat when temperature is above 35F. This seems an opportunity to do this whenever resistance heating is being specified in any sector new construction. Selling main living area has to have DHP. So a home with 4 heating areas would have 3 resistance heat areas still using resistance heat.

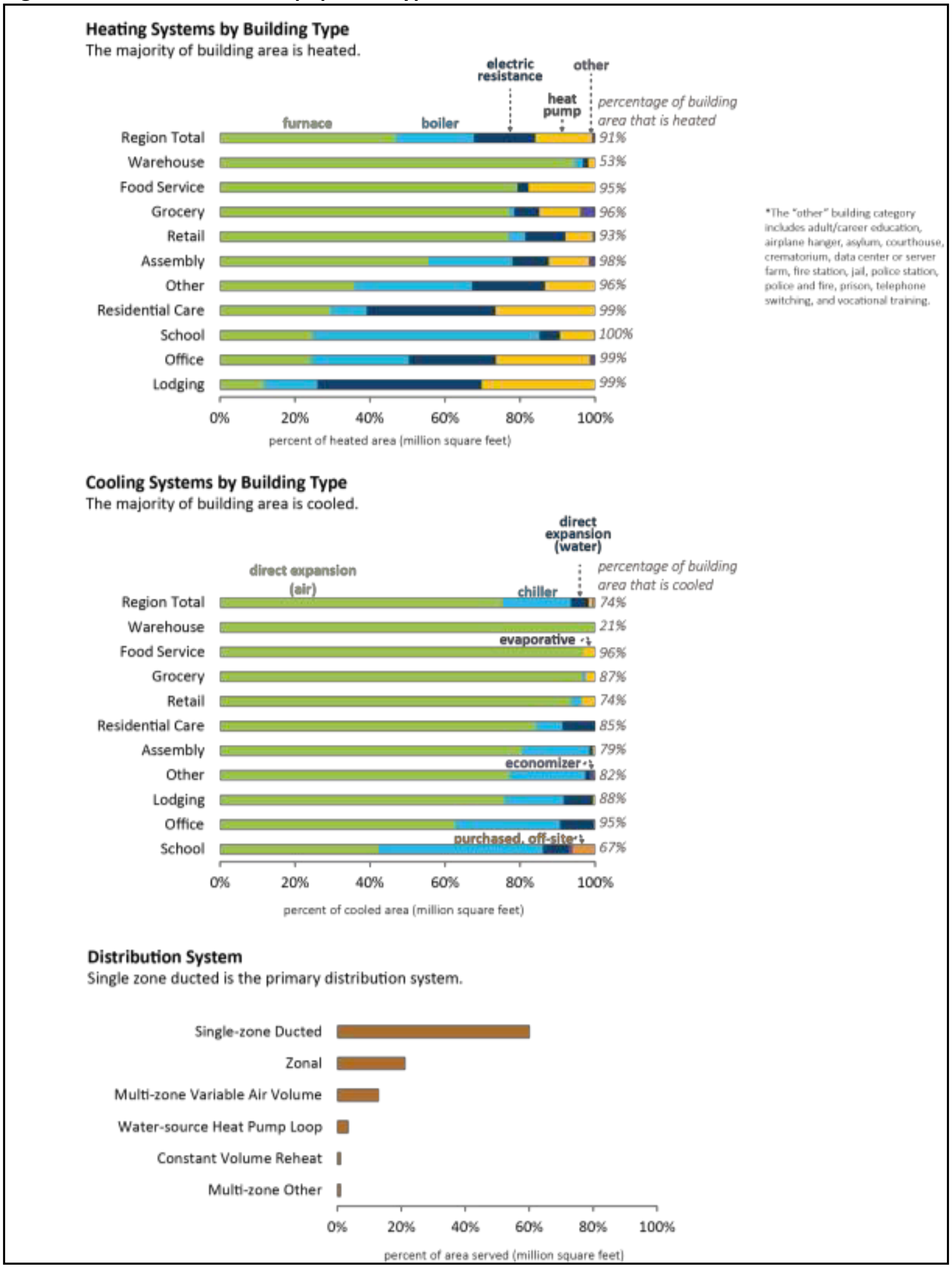
Small Commercial

We also noticed from the 2014 CBSA that there are several Commercial sectors that are appropriate for WCT and Building Energy Management similar to residential, e.g., lodging, residential care, university residences, schools, and small office/retail. See Figure below from CBSA. Larger Commercial BMS have energy/capacity savings opportunities, but the technology is very specific to sector

Retrofitting small commercial with DHPs can have tremendous energy savings. A BPA sponsored report by Ecotope found an average of 4,185 kWh/yr energy savings at six sites. This report found that more than half the sites had DHP providing more than 90% of the heat. This is in contrast to residential DHP retrofits where DHP only provided 45-80% of the space heat. (Ecotope BPA, 2012) We do think that as we learn more about savings from HEM and WCT optimization and managing compressor cycles, that there will be savings in this sector.

EQL Energy worked with Cypress Envirosystems to replace pneumatic thermostats with communicating thermostats. Our study focused on demand response and we did not measure energy savings.

Figure 4: 2014 CBSA HVAC Equipment type



3.1.4 Regional HVAC Controls and DHP Measures and Research

Thermostats Measures

ETO provides a $50 rebate for Nest thermostats with ASHP, FAF electric or gas. (ETO, 2016) This was supported by pilot studies that showed 12% electric savings, and undocumented gas savings.

PacifiCorp and PSE in Washington provides rebates to customers for installation of WCTs. (PacifiCorp, 2015) Currently the RTF's only residential thermostat and control measure is Replacement of bi-metal thermostats with electronic thermostats in new and existing single family homes. Line and low voltage thermostats are eligible. Measures specific include: Cost is $235, life of 15 yrs, new and existing construction, benefit cost ratio is positive in Heating zone 2 and 3, and neutral in Heating Zone 1. We expect the RTF to consider adding WCTs as a measure for ASHP, and would like to prepare market to use WCTs for DHP and electric resistance heating.

RTF has not added communicating thermostats to UES measures. They still have an electronic Tstat replacement for bi-metal savings/cost, and they are examining savings from residential behavior, e.g., Opower. We are surprised that WCTs have not been added to RTF measures.

Table 6: RTF Measure on Electronic Tstat replacement for bi-metal (2012)

Annual Savings Assumptions 5%

Heating Climate Zone	Pre80 Post ResWX Use (kWh)	Annual Savings (kWh)	Average Cost/Dwelling
Heating Zone 1	8,716	436	$235
Heating Zone 2	11,941	597	$235
Heating Zone 3	14,453	723	$235

Based on EWEB's Comfort STAT program. Average of 5 Thermostats per dwelling.

RTF Residential Behavior

RTF has a subcommittee on residential behavior savings and is currently (2016) exploring UES measure. (RTF, 2016) Most residential behavior discussions are around generic metering feedback, e.g., OPower. These tools show whole house savings of 1-3%. For instance, Seattle City Light and PSE studies found 1.7 to 2.0% savings – about 200kWh. This type of low value generic information is hard to capture savings and the subcommittee is debating how to proceed. With regard to HVAC, WCTs provide higher value information, sensors, and learning methods that demonstrate higher percentage savings than merely repackaged billing data.

RTF WCT Optimization Layer

RTF has a proposal (Mar. 2016) from WeatherBug to consider adding a controls optimization layer to WCTs based on weather data. Josh Rushton, RTF analyst, has reached out to industry participants, e.g., Robert Weber (BPA), Paul Sklar (ETO), Bobbette Wilhelm (Idaho Falls), and Ken Agnew (DNV-GL) to consider the proposal. In our view RTF should consider a more comprehensive look at WCTs, disaggregated in-home information and control systems for end uses, e.g, water heat, lighting, EV Charging, pool/spa pumps, etc.

We think that focusing on the optimization layer is important and that WeatherBug may be a good platform for communicating with certain WCTs. They promote open standards, which is not the case with all WCT (e.g., Nest).

ETO

Currently ETO has a DHP incentive for new construction and RTF is evaluating this measure. NEEA is the best source of data on DHP for existing homes.

Cooling

We think that using DHPs with WCTs can improve both energy and capacity savings in the summer. We did not estimate the savings value because we could not find any detailed reports that discussed energy savings from cooling. In cases where DHPs are used to displace window shakers or small air conditioners, cooling savings will happen. Yet the electric savings from cooling is still less than 10% of heating savings. Of course adding a DHP where there was no previous AC increases energy use and provides added benefits. We would argue that across the PNW, summer peaks are increasing due to more use of AC and higher CDD. Supporting technology that assists in reducing AC capacity will benefit the region.

Several studies found that DHPs either displaced less efficient cooling or were not used much in locations that did not have previous AC.

> *There is no apparent evidence, based on the current data, that the installation of DHPs has created a significant new cooling load. Sites that had a notable pre-installation cooling load evident in bills continue to have it in DHP usage, but the sites that did not have much cooling before do not seem to use their DHPs much in cooling mode.* (Ecotope, 2010)

Washington Code

Washington building codes requires residential buildings with ER HVAC to add a DHP to largest zone in dwelling. This means that there is an opportunity to improve savings by finding controls and setup procedures that could lockout ER HVAC.

With R403.1.1 there is an opportunity to increase savings by installing WCT instead of programmable tstat.

> ***R403.1.1 Programmable thermostat.*** *Where the primary heating system is a forced-air furnace, at least one thermostat per dwelling unit shall be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature set points at different times of the day.*
> *EXCEPTIONS:*
> *1. Systems controlled by an occupant sensor that is capable of shutting the system off when no occupant is sensed for a period of up to 30 minutes.*
> *2. Systems controlled solely by a manually operated timer capable of operating the system for no more than two hours.*

With R403.7.1 there is an opportunity to provide improved savings by using WCT that works with both DHP and secondary heat.

R403.7.1 Electric resistance zone heated units. *All detached one- and two-family dwellings and multiple single-family dwellings (townhouses) up to three stories in height above grade plane using electric zonal heating as the primary heat source shall install an inverter-driven ductless mini-split heat pump in the largest zone in the dwelling. Building permit drawings shall specify the heating equipment type and location of the heating system.*

With R403.1.2 there is WCT opportunity to provide improved savings while managing strip heat lock out.

R403.1.2 Heat pump supplementary heat (Mandatory). *Unitary air cooled heat pumps shall include controls that minimize supplemental heat usage during start-up, set-up, and defrost conditions. These controls shall anticipate need for heat and use compression heating as the first stage of heat. Controls shall indicate when supplemental heating is being used through visual means (e.g., LED indicators). Heat pumps equipped with supplementary heaters shall be installed with controls that prevent supplemental heater operation above 40°F. At final inspection the auxiliary heat lock out control shall be set to 35°F or less.*

3.2 Residential Electric HVAC products and controls

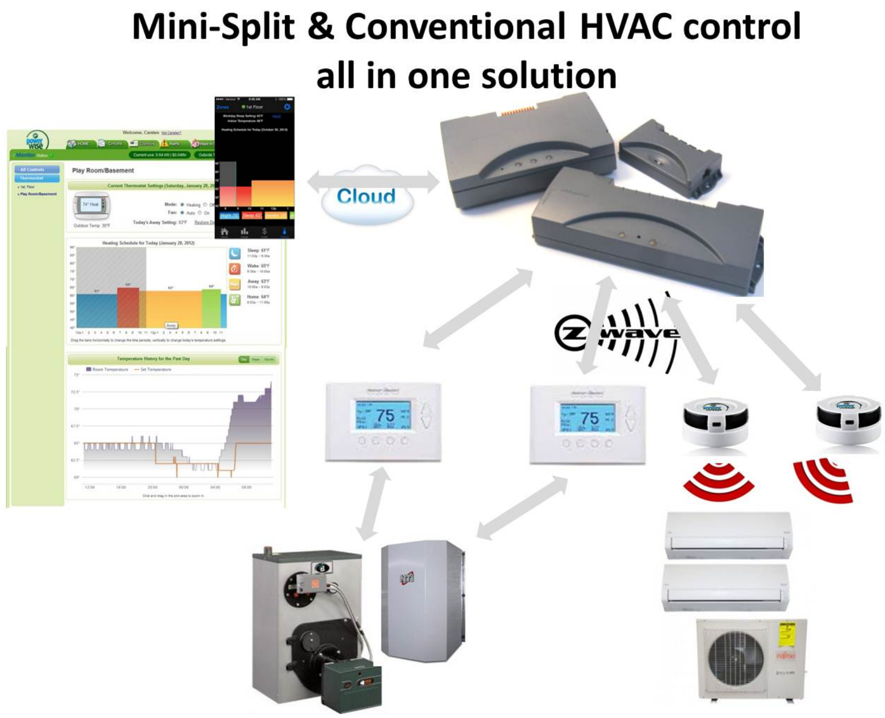
WCTs already have 21% annual sales of thermostats and are expected to be over 50% by 2020. (Talpur, 2015) However, WCTs are primarily being used with ASHP, gas furnaces, and central air conditioners.

3.2.1 Only a few DHP vendors operate with WCTs

DHP manufacturers are beginning to include WCTs into their product, Daiken, Fujitsu, Mitsubishi, Panasonic, LG, etc. They are doing this to respond to customer preferences, and energy savings has not been tested or proven.

1. Daikin resells Ecobee with some of their DHPs. They call it the Envi.
2. Powerwise has iPhone and Android apps are available for controlling the mini-split heat pumps, and remotely monitoring their energy use. It supports controls for Mitsubishi (including Mr Slim), Fujitsu, Daikin, Panasonic, LG, and Samsung mini-split heat pumps. **Figure** 5 shows a graphic of PowerWise system working with DHP and conventional HVAC.
3. Fujitsu has a Wifi enabled module and thermostat. http://www.fujitsugeneral.com/wifi.htm

Figure 5: PowerWise 2015 WCT for mini-splits and other HVAC



WCT with DHP and resistance heating is a limited group of vendors. Current use of WCT with DHP and zonal heat in the PNW is near zero. The development stage is early and is faced with market, cost, technical, and commercial barriers.

a. DHP with fully integrated WCT (method A)

Two DHP manufacturers that we are aware of (Daikin and Mitsubishi) have worked with WCT vendors (EcoBee and Honeywell) to integrate control of the DHP with the WCT. These products are available from DHP installers. It is not known if this configuration impacts energy efficiency compared with traditional DHP controls nor the extent to which further integration work between these vendors is occurring. Because only two DHP vendors have adopted this approach – each with a single WCT vendor – significant additional market development would need to occur if the DHP segment of residential HVAC market adopts it as standard practice.

b. DHP integration with WCT using dry contact terminal binary input (method B)

we are aware of two vendors, Mitsubishi and LG, that have incorporated dry contact terminals. We understand this allows them to work with most thermostats (including WCT) using 24V controls. This approach is also at an early stage in development because only two DHP vendors have adopted it. It is not known the extent to which the use of binary control logic with DHPs will degrade energy efficiency, if at all. One outcome of this study will be to assess this question. Additional learnings from this study could assist NEEA in determining where lever points may exist to engage in market intervention with DHP and WCT vendors and identifying specific aspects to consider with regard to integration method e.g., whether one should be prioritized over the other and why. We are also unsure if this method allows control of secondary HVAC.

c. WCT control of secondary electric resistance heat + DHP

Most DHP installations retain or include some electric resistance heating system in the house. Adding WCT control to this heat source will have both energy and capacity savings. Because significant savings have been shown to occur through control of resistance elements in air-source heat pumps (Energy Trust Nest Heat Pump Control Pilot Evaluation), connecting WCTs that are installed in customer homes with any resistance heat located in relevant locations is an obvious opportunity. This capability is available today only as a home energy management system or expensive retrofit of existing secondary circuits and in-line voltage controls. Significant market development is likely to be needed before this configuration is standard practice or cost effective. Part of our project proposal is to assess the feasibility as well as energy and capacity savings from incorporating zonal resistance heat control with a WCT/DHP installation.

3.2.2 There are a handful of WCTs that work with electric zonal and FAF, and three aftermarket WCTs that work with both DHP and resistance HVAC.

WCTs are not widely used for DHP or electric resistance heating. The aftermarket WCTs in this space, and often from small, sometimes startup, companies. This technology is not being deployed in the PNW.

WCTs that work with resistance heating and DHPs Include:

a. PowerWise
b. Pebble. http://www.minisplitwarehouse.com/product/mini-split-wifi-thermostat-controller-with-7-day-schedule
c. Ecobee (called Envi by Daikin). Integrated with some Daikin units. Ecobee is not involved in product development. They just sell a tstat to Daikin.

.

List of WCT companies is growing and includes: Nest, Ecobee, Emme, Venstar, Mountain Logic, Ecofactor. (WSU Energy Office, 2012) Sinope, Honeywell, Emerson, Enerjoy, Magnum Energy Solutions[7] etc.

3.2.3 Resistance Heating Manufacturers

We researched and spoke with firms in both the electric zonal and FAF market. This group does not appear to moving quickly towards WCT offerings. There are several aftermarket solutions, but the HVAC manufacturers we spoke to felt WCT price point is too high for their market.

Zonal heat includes: Cadet, QMark, Dimplex, and EnergyJoy, [8]

We spoke with Cadet who estimates they have over 1 Million units in the PNW, and sell 200,000 units per year in the PNW. This equipment is clearly relevant now and into the future. They have created more efficient wall heaters with use of fans, and do include programmable thermostats from Honeywell in the equipment they sell and support. They do not offer WCT and have no near term plans.

[7] http://www.magnumenergysolutions.com/uploads/Mx-PFC-E02036.pdf
[8] http://baseboard-heaters-review.toptenreviews.com/

Electric FAF, e.g., Johnson Controls, who markets Coleman FAF under license by York. Nordyne branded under names e.g., Frigidaire, Maytag, Broan, Intertherm, and Miller. Nordyne Inc.
8000 Phoenix Pkwy. O'Fallon, MO 63366-3827 (636) 561-7300

Getting WCTs to work with FAF equipment is much easier than zonal, or line voltage controls. This could be done in new construction or after market.

3.2.4 What benefits other than saving electricity do WCTs provide this market?

WCTs provide multiple customer benefits including:

1. Convenience of using a smart phone or other web-enabled interface to manage the thermostat.
2. Detect and inform of equipment issues or maintenance needs.
3. Learning features that focus on user comfort and energy savings.
4. Information and communication with other home devices, e.g., smoke alarms, camera monitoring, water heater, etc.
5. WCTs provide utility with data, communication and control features for demand and pricing programs. WCTs provide HVAC installers and equipment information regarding HVAC equipment performance and signal maintenance needs. (Information may lead to behavioral changes that save energy – requires more research in this market)
6. Forced air furnaces. The market will be retrofits and replacement electric heating systems.
7. Ability to receive utility communication re: pricing or grid needs. (demand response)
8. WCTs with home energy management have many other benefits, including other energy savings approaches, e.g., lighting, water heat.

HEM benefits. CleaResult has done several surveys that summarizes other benefits of Home Energy Management systems (WCT being one element). These include:

1. Automated energy savings (i.e. appliance knows to turn on when energy rates are cheapest, only applicable in areas with time-of-use (TOU) rates) - 53.2 percent
2. Enjoying a more comfortable home that "learns" heating & cooling preferences - 49.8 percent
3. Using smart phone apps to control the home while away (lights, heating/cooling, etc.) - 48.6 percent.
4. Improving the environment with decreased energy use - 48.2 percent.
5. Receiving alerts when appliances need attention (water heater, air filter, furnace, etc.) - 47.2 percent

3.2.5 What limitations does the product have that a typical customer may not expect?

These limitations were discovered in the Energy Trust of Oregon Nest study in 2015.[9]

a. Equipment incompatibility. At present, customers with DHPs, and zonal heat cannot get off the shelf functionality with WCTs.
b. Wifi and router issues. If WCT uses wifi, then their user may run into technical difficulties, e.g., passwords, incompatibility with router or other connectivity issues, can't use with hotspots,

[9] http://energytrust.org/library/reports/NestPilotStudyEvaluationwSR.pdf

Some WCTs are incompatible with Routers. Signal strength at thermostat location is too weak. (This is being addressed with proprietary communication protocols, e.g., Weave, Zigbee, Insteon, Z-wave, Emo)

c. WCT technical and wiring issues. WCTs are relatively new and will experience errors. Depending on type of HVAC, wiring may need to change.

WCT (Web-enabled communicating thermostats) capabilities current and emerging: Ecobee, Nest, Honeywell, DHP vendors, etc.

Dual Control options for other HVAC: a) zonal electric, b) Forced Air Furnace, and 3) hearth heaters: Aube relays, Energex, Nest, Powerwise, etc.

3.3 Gaps and market barriers to adoption of WCT and HEM with electric resistance HVAC and DHP

3.3.1 Gaps and market barriers to potential energy and capacity efficiency

WCTs are relatively new and the vendors of DHPs and zonal heat have just begun to address the increasing customer interest in using WCTs. We see market barriers including:

a. Cost of WCTs more expensive than traditional thermostat.
b. DHP and resistance heating found more often in lower income dwellings, who may be less willing to get a more expensive thermostat.
c. DHP and zonal heat customer segment interest in WCT may be less than other residential HVAC segments.
d. Utility pricing programs for capacity don't yet exist in the Pacific Northwest. They are coming.
e. Lack of awareness by customers of WCT benefits.
f. Electric HVAC market usually in lower income market, which means focus on lowest possible initial cost, e.g., Manufactured homes with FAF costing $250, or low cost PTACs and wall heaters in apartments, etc.
g. Landlord tenant issues.
h. Lack of standards and communication protocols in HVAC controls and WCTs.
i. Setup and installation cost and challenges.

3.3.2 Communication protocols being used and standards perspective.

Communication between DHP and thermostat is proprietary. Therefore, using a 3rd party WCT may be challenging. Some DHP vendors are integrating WCTs with DHP units, but we are unsure what energy saving value this may have.

Regarding WCTs and home monitoring each company supports their own protocol.
Nest and partners – Weave, Home Depot – Wink, Lowes – Iris, Amazon – Echo, Apple – Home kit.

3.3.3 Themes for continued research, and field studies

In PNW residential sectors (SF, MH, MF), what are the energy/capacity savings and other benefits from using: 1) WCTs with DHPs, 2) WCTs with DHP and secondary HVAC, and 3) WCTs with Electric HVAC and no DHP? See Recommendations section for specific studies.

If savings can be verified, then consider:

1. Participate or contribute to studies looking at communication and protocol standards, e.g., CEA 2045. Presently, EPRI and others are involved in CEA 2045 communication with water heaters, pool pumps, air conditioners, etc. This may not be the best standard for WCT market, but is an example of projects to promote standard energy end use equipment communication interfaces.

2. Market Transformation planning with WCTs to provide energy and capacity savings in the PNW. Once WCT savings are proven and cost effectiveness is expected to be achievable, we recommend NEEA and partners consider a market transformation study to evaluate.

3. Evaluate consumer behavior with WCT and Electric HVAC (DHP, zonal, FAF). Look at distinction between total savings observed and savings in billing analysis.

   In Ecotope's studies they found approximately 20% loss in energy savings between the net savings observed from the billing analysis and the total savings observed from the operation of the DHP. It is likely that the conditions that warrant this increase in savings also exist in the larger pilot population, and a similar adjustment could be applied. Overall, it would appear that more detailed understanding of the distinction between the total savings observed in the metering study and the savings derived from the billing analysis should be more clearly understood.

4. Evaluating building codes and market to provide lock out of secondary HVAC. Use thermostat stage controls with ER HVAC equipment.

3.4 NEEA stakeholders are interested in WCT and Building Energy Management.

In the Northwest, BPA, public power, ETO and metro utilities (multifamily) are perhaps the stakeholder that would benefit the most from further research and progress in getting WCTs to work with electric space heating. In January, Mike Lubliner spent time with Janice Peterson, from BPA's energy efficiency group, at AHRI and ASHRAE talking with vendors and considering the opportunities for communicating controls for DHP and electric resistance HVAC. IOUs and ETO have piloted projects using Nest and other WCTs. Results are showing positive signs, and

BPA Technology Innovation roadmap identifies control of secondary electric heat as in conjunction with the installation and operation of DHP mini-splits.

BPA TI Roadmap

Control of electric resistance zonal heaters in conjunction with ductless mini-split heat pumps. With the installation of ductless heat pumps (DHPs) in homes with zonal electric heat there is no control of the interaction of the two systems. Occupants do not get clear signals when the electric resistance system is operating when it is not needed (i.e. when DHP is cooling on or when DHP could handle the load if not being out powered by electric resistance).

Key research questions:

1. Are there commercial available controllers of electric resistance heaters that can communicate with other controls?
2. Are there commercial available controllers the clearly indicate when they are on and have to turn the electric resistance heat off at the controller?
3. What is the energy savings penalty when electric resistance and DHP system compete?
4. What control strategies produce the most energy saving?
5. What is technically possible?

Northeast and Canada

Outside the Northwest, there are other markets with high percentages of electric zonal and FAF HVAC equipment, such as Canada and Northeast. Some of the vendors we've discussed in this paper are located and selling into these markets. NEEA could connect with similar organizations I these markets to evaluate the technologies and manufacturers discussed in this paper, e.g., NEEP[10]. 27% of Canadian households are electrically heated and have standards and code related to Line Voltage Thermostats (LVT)[11]. Several provinces use communicating thermostats and use it for capacity focused programs.

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