Northwest **Power** and **Conservation** Council

March 4, 2014

MEMORANDUM

TO: **Power Committee**

FROM: **Tom Eckman**

SUBJECT: **Estimated Capacity Impacts of Regional Energy Efficiency Savings**

At the January Council meeting, staff presented the results of its annual survey of regional utility conservation achievements in 2012 and projected savings for 2013 – 2015. Cumulative savings during the first three years of implementation of the Sixth Northwest Power Plan totaled nearly 780 average megawatts.

The amount of *annual* energy savings (in average megawatts) from energy efficiency is the sum of *hourly* reductions in electricity consumption (in megawatts) across all 8,760 hours in a year. Since not all electricity consuming devices operate every hour of the year (e.g., lights) or are equally sensitive to outside temperatures (e.g., space heating vs. televisions), savings from energy efficiency measures do not occur uniformly across all hours of the year. Therefore, in order to determine the impact that improvements in energy efficiency have on the hourly demand for power, information on their end use load profiles is needed.

The Council's annual survey of regional conservation achievements requests only sector level (e.g., residential, commercial) savings and expenditure data from utilities, NEEA and the Energy Trust of Oregon. While this level of detail is adequate to judge annual energy (MWa) savings, it is not sufficiently granular to determine the hourly load (MW) impacts of efficiency measures. In order to assess these impacts, detailed information on the specific end uses impacted by programs is needed. In preparation for the development of the Seventh Plan, Bonneville contracted with The Cadmus Group to collect program and measure level savings for 2010 through 2013. The availability of

this granular data on regional efficiency achievements provides the first opportunity to directly estimate the hourly load impacts of conservation resources.

At the request of Council staff, Bonneville staff agreed to task its consultant to develop an estimate of regional hourly load impacts from the 2010 through 2012 conservation programs. Cadmus staff, with assistance from the Council staff began by attempting to assign an hourly end use load "profile" to each of the reported conservation measures. In some cases data limitations did not permit the assignment of savings to specific load shapes. For example, significant portions of the industrial sector savings are developed via custom projects. Since such projects often involve multiple measures effecting differing end uses (e.g. motors, lighting) assignment to such savings to a single end use is inaccurate. However, since only "project level" savings were reported, such savings could only be assigned to that industry's overall load shape or the number of daily shifts the plant operates. Nevertheless, even with these limitations the resulting estimate of regional capacity impacts using this granular data is judged to be more accurate than using more generalized assumptions for the savings such as shaping the savings equally across all hours or shaped equivalent to the regional system load.

The process of assigning load profiles reinforced the limitations of the region's (and nation's) end use load data. While the savings from some conservation measures (e.g., more efficient water heaters, lighting and refrigerators) could be assigned using available load profile data, no such load profile data existed for other measures (e.g. efficient televisions). Moreover, since the available end used load profile data is based on research conducted a quarter-century ago, even for those measures for which end use load profiles existed, there was significant concern about its current applicability. To test whether these concerns were justified Council staff compared the existing hourly load profiles with more recent load research data collected by NEEA.

The NEEA research, while more recent, only covers the residential sector and is not based on as large a sample nor as long a monitoring period as the much older load research. Therefore, staff limited its comparisons to four end uses, residential water heating, refrigerators, lighting and electric space heating where sample sizes were considered large enough to be statistically meaningful. This comparison revealed that while some load shapes (e.g., residential refrigerators) have not changed significantly over the past twenty-five years, others (e.g., residential water heating and lighting) have.

At the Power Committee meeting staff will present the results of the analysis of the impact of the 2010-2012 energy savings on regional peak loads as well as its review of how the use of more recent load research data might alter the results. The major conclusions from this analysis are as follows:

- Estimates of regional capacity impacts of energy savings are limited by the vintage and scope of the available load research data

- Comparison of four existing residential load shapes with the results of more recent load research revealed that two of the three load shapes (water heating and lighting) have changed significantly and a third (ductless heat pumps) was not available
- Regional energy savings from 2010 through 2012 were just under 780 MWa. These annual savings are estimated to have reduced the winter peak hour loads by 950 MW using the existing end use load profiles.

- Just over one-fifth (170 MWa) of the 780 MWa cumulative annual savings from 2010 through 2012 were produced by efficiency improvements in residential water heating and lighting. Savings from these two end uses alone are estimated to reduce winter peak hour loads by 185 MW using existing load profile data. However, use of more recent load profile data for these end uses is estimated to reduce peak winter hour loads to 305 MW, increasing the total winter peak hour impact from 950 MW to 1070 MW.

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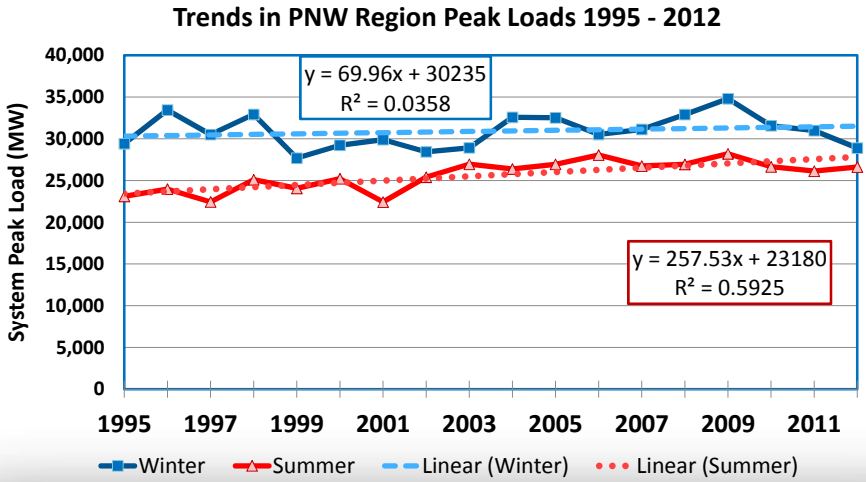
Capacity Impacts of Energy Efficiency

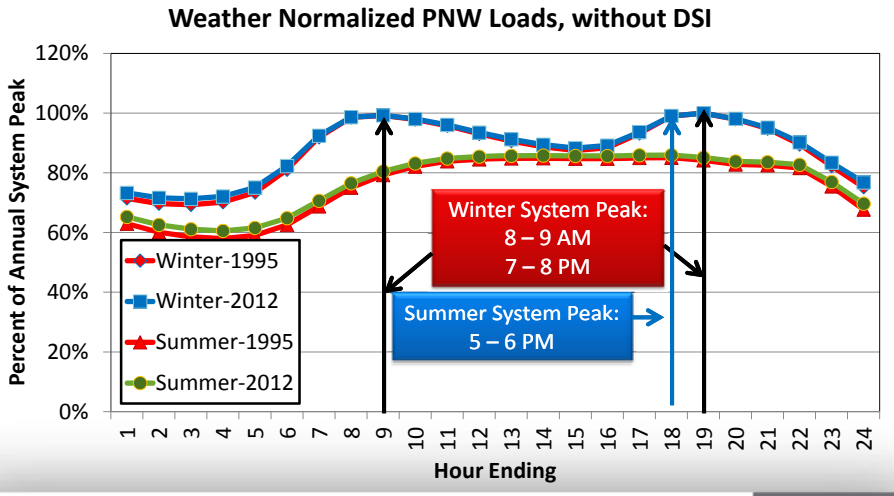
What We Know
and
What We Don't Know

March 11, 2014

We Know That Winter Peaks Aren't Growing, While Summer Peaks Probably Are



We Know The PNW System's Daily Load Profile Has Not Changed Significantly Since 1995



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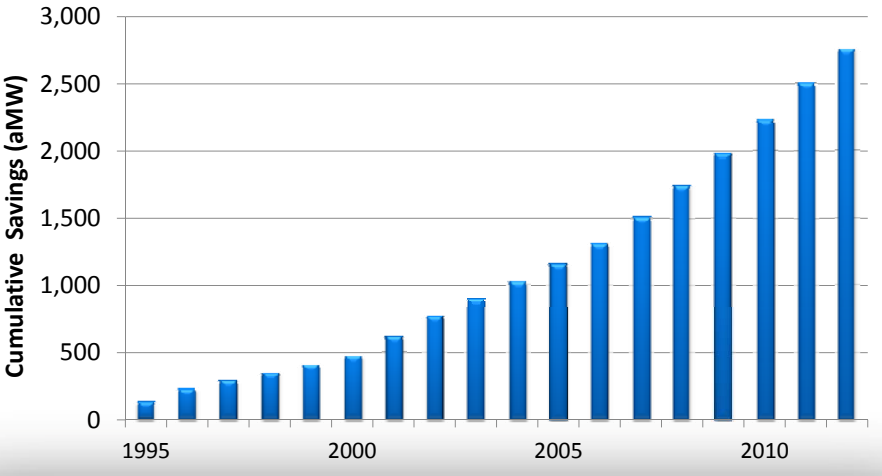
We Know That Since 1995 PNW Utilities Have Acquired Over 2,700 Average Megawatts of Conservation Savings



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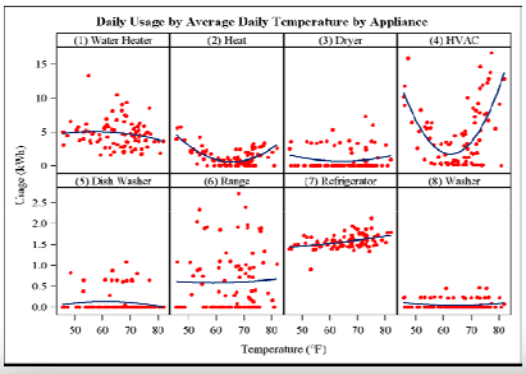
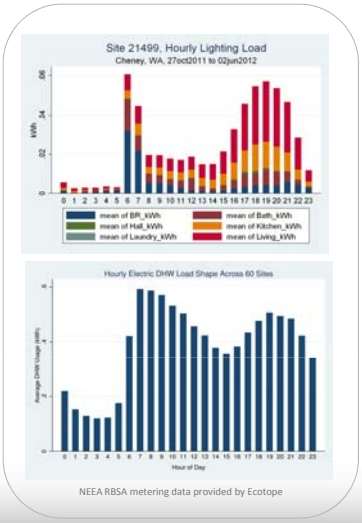
We Don't Know What Impact (If Any) Did These Energy Savings Have On the Region's Need for Capacity Resources

However:

- We Do Know That Improvements in Energy Efficiency also change hourly demands
  - Savings shape matches end use load profile:
    - If a device uses 20% less total energy over the course of the year, it uses 20% less each hour of the year (e.g., installation of lower wattage lighting)
  - Savings shape is the difference between the *pre-case* end-use profile and the *post-case* end-use load profile
    - If a device uses 20% less total energy over the course of the year, but the reduction in uses in not proportional across all hours (e.g., occupancy sensors for lighting turn lights off during business hours)
- We Do Know That End Use and Energy Efficiency Savings Load Profiles Are Needed to Assess Capacity Impacts

What Is End-Use Data?





NEEA RBSA metering data provided by Ecotope

We Know The Current State of End Use Load Research

- *The Good News* - Bonneville conducted a comprehensive End Use Load Research (EULR) project, the End-Use Load and Consumer Assessment Program (ELCAP)*
- *The Bad News* – This year marks the 25th anniversary of when the last ELCAP data was collected
  - There have been no comparable studies in the US or Canada since then
  - There are none planned

*The ELCAP was later designated as the Regional End-Use Metering Project (REMP)

We Know What Was Collected in ELCAP

- ELCAP began in 1983 and ended in 1991
- ELCAP's Goal – Collect a comprehensive set of customer characteristics and hourly end-use electricity consumption and weather data from residential and commercial sector consumers
- ELCAP's Product - Created hourly (8760) load profiles at the individual end use and building level along with associated customer characteristics and weather data

We Know The Concerns Raised About ELCAP and Existing EULR Data Sources*

- **They're Old**
  - The last ELCAP data was collected in 1989
- **They Don't Reflect Current Building and Equipment Stock**
  - Appliance characteristics and usage have changed (e.g., increased efficiency standards);
  - There are new emerging/growing technologies (e.g., computers, plasma TVs, Electric Vehicles, variable speed drives, demand controlled loads, LED's, etc.);
  - New appliances, lighting and equipment are "electronic" and may have differ Power Factors than existing "resistance" based appliance, lighting and equipment
- **They Don't Provide Energy Savings Load Shapes**
  - Energy Efficiency measure savings, especially controls, do not have the same shapes as their end-use load shapes (e.g., occupancy sensors are designed to turn off lights during the day when no one is present)

*Results of a RTF Regional and National Review of the Business Case for End Use Load Research

We Don't Know If These Concerns Warranted

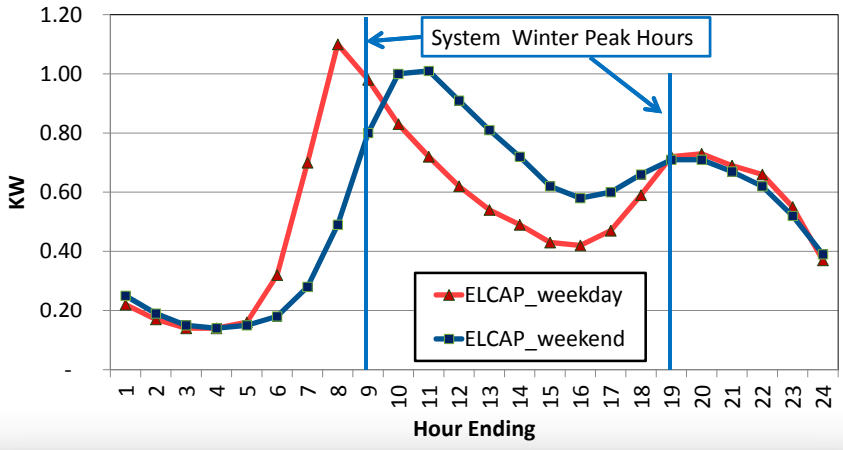
To Test This Premise Staff Compared ELCAP Data To More Recent, But Less Comprehensive Studies

- The Northwest Energy Efficiency Alliance (NEEA) Research
  - Residential Building Stock Assessment "Test Bed"
    - EULR study of approximately 100 single family homes
    - Preliminary (1st year) results are now available
  - Ductless Heat Pump Pilot Program
    - Detailed 5 minute interval data on approximately 100 ductless heat pumps
  - Heat Pump Water Heater Pilot Program
    - Detailed 5 minute interval data on approximately 50 heat pump water heaters
- While not as comprehensive as ELCAP these studies do provide some insights into what's changed and what hasn't, but only in the residential sector

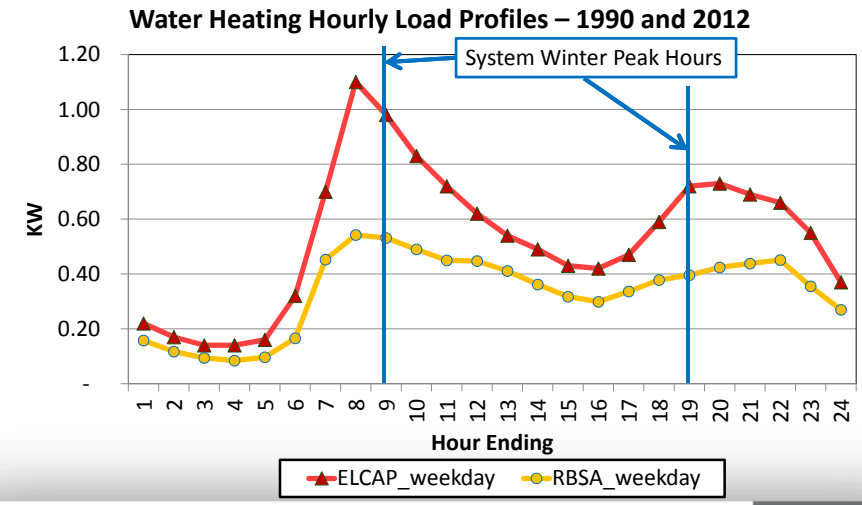
Five Tests of the ELCAP Data

- Electric water heating
  - What impact did improvements in efficiency since 1990 that reduced annual energy consumption from 4,700 kWh/yr to 3,000 kWh/yr have on winter peak demands?
- Residential Refrigerators
  - What impact did improvements in efficiency since 1990 that reduced annual energy consumption from 1,500 kWh/yr to less than 500 kWh/yr have on winter peak demands?
- Residential space heating
  - What impact will supplementing existing zonal electric heating systems (e.g. baseboard, radiant ceiling, wall heaters) with Ductless Heat Pumps have on winter and summer peak demands?
- Residential lighting
  - What impact will federal efficiency standards that are changing the mix of lighting technologies from primarily (90%) incandescent lamps to over primarily (60% - 80%) fluorescent (CFLs) /solid state (LED) lamps have on winter peak demands and power factor?
- Total System Impacts
  - Is ELCAP data "good enough"? (i.e., Is there a significant difference between using ELCAP load profiles and more recent data to estimate the impact of energy efficiency measures on system peaks?)

ELCAP Residential Water Heating Load Shape



We Know That Residential Water Heating Load Profiles Have Changed



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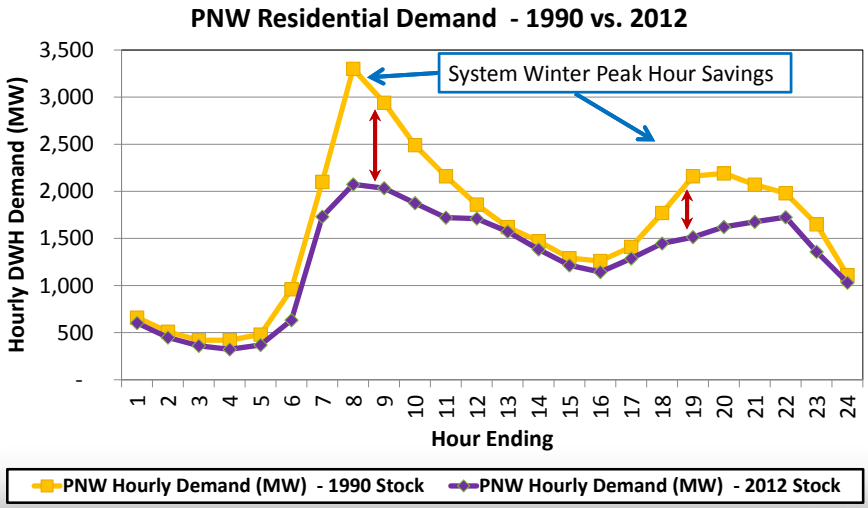
We Know That PNW Residential Water Heating Hourly Demand Has Decreased



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We Know That Capacity Savings From Residential Water Heating Efficiency Improvements Between 1990 and Today Were *Three Times* Their Annual Energy Savings

	1990	2012
Annual Use (kWh)	4,700	3,000
Savings/Unit (kWh)		1,700
Water heater stock ≤55g	2,701,000	3,489,700
Water heater stock >55g	300,100	337,800
Water heater stock - Total	3,001,200	3,827,500
Annual Load (aMW)	1,610	1,310
PNW 2012 Savings (aMW)		300
Coincident Peak Load (MW)	2,940	2,035
Coincident Peak Savings (MW)		905

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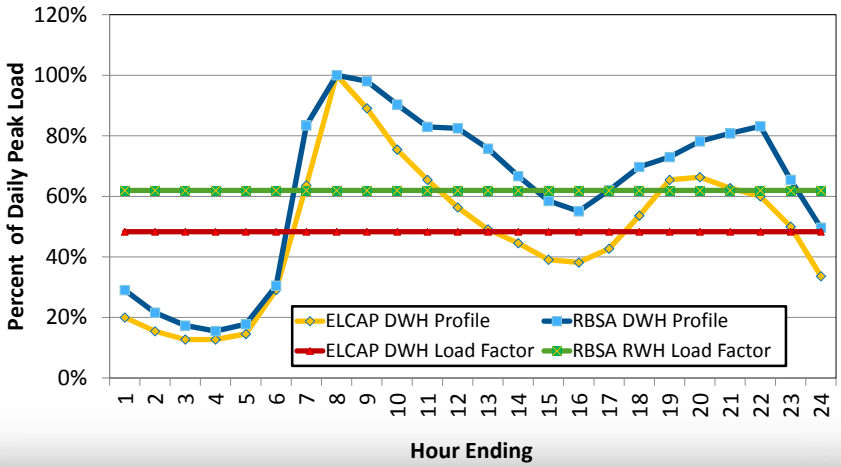
We Know That Current Water Heating Load Factors Now Higher



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We Now Know That Using Old (ELCAP) Load Profiles *Understate* the Capacity Impact of Changes in Water Heater Efficiency

	1990	2012 – ELCAP Load Shape	2012 – RBSA Load Shape
Annual Use (kWh)	4,700	3,000	3,000
Savings/Unit (kWh)		1,700	1,700
Water heater stock ≤55g	2,701,000	3,489,700	3,489,700
Water heater stock >55g	300,100	337,800	337,800
Water heater stock - Total	3,001,200	3,827,500	3,827,500
Annual Load (aMW)	1,610	1,311	1,311
PNW 2012 Savings (aMW)		300	300
Coincident Peak Load (MW)	2,940	2,370	2,035
Coincident Peak Savings (MW)		570	905

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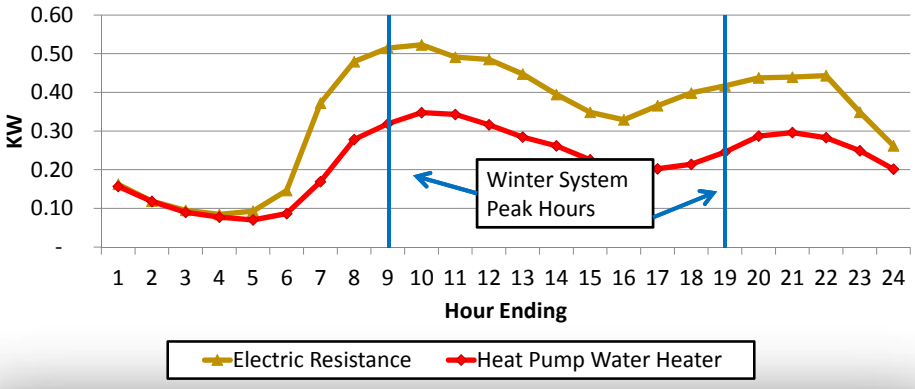
We Know That Federal Standards Will Decrease Water Heating Energy Use Further Altering This End Use's Load Shape

Electric Resistance vs. Heat Pump Water Heater Hourly Load Profiles



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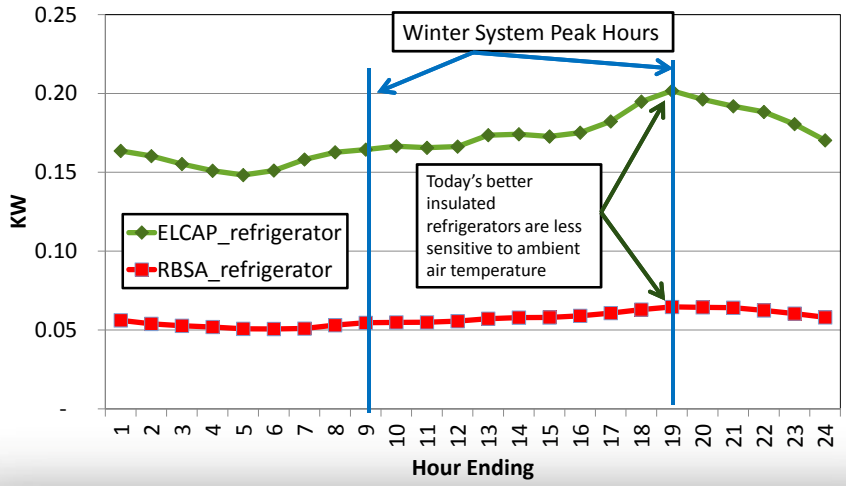
Capacity Impact of Changes in Water Heater Efficiency Due to New Federal Standards

	2012 ER	2012 HPWH
Annual Use (kWh)	3,000	2,000
Savings/Unit (kWh)		1,000
Water heater stock >55g	337,815	337,815
Annual Load (aMW)	115	75
PNW 2012 Savings (aMW)		40
Coincident Peak Load (MW)	175	110
Coincident Peak Savings (MW)		65

We Know That Without More Recent End Use Load Research We Would Not Be Able to Estimate the Capacity Impacts of Heat Pump Water Heaters.

We Know That Compared to the Stock in 1990 the Current Stock of Refrigerators Uses *One-Third* the Energy and Requires *One-Half* the Capacity



We Know That Since Refrigerator Load Profiles Have Not Changed Significantly ELCAP Data Is Still A Reasonable Representation of Capacity Impacts

	1990	2012 – ELCAP Load Shape	2012 – RBSA Load Shape
Annual Use (kWh)	1,500	500	500
Savings/Unit (kWh)		1,000	1,000
Water heater stock - Total	4,635,880	7,148,900	7,148,900
Annual Load (aMW)	795	410	410
PNW 2012 Savings (aMW)		385	385
Coincident Peak Load (MW)	760	390	390
Coincident Peak Savings (MW)		370	370

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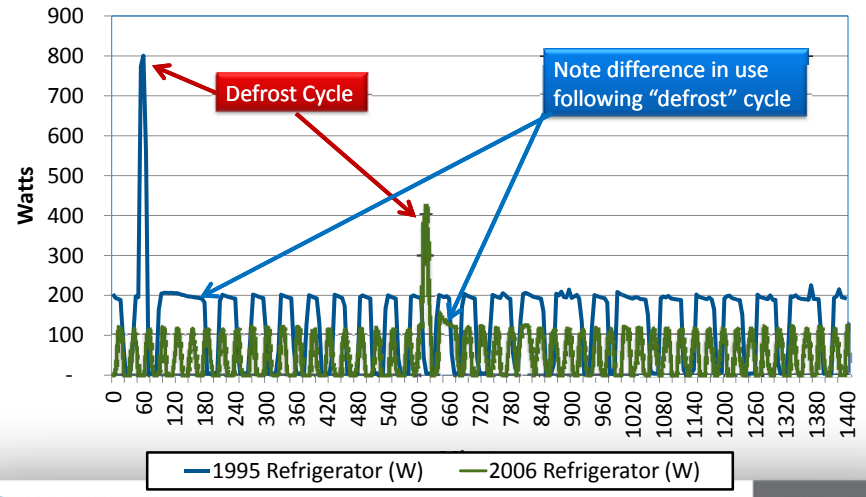
On the Other Hand, There Are Subtle "Within Hour" Differences That Might Matter for Demand Response



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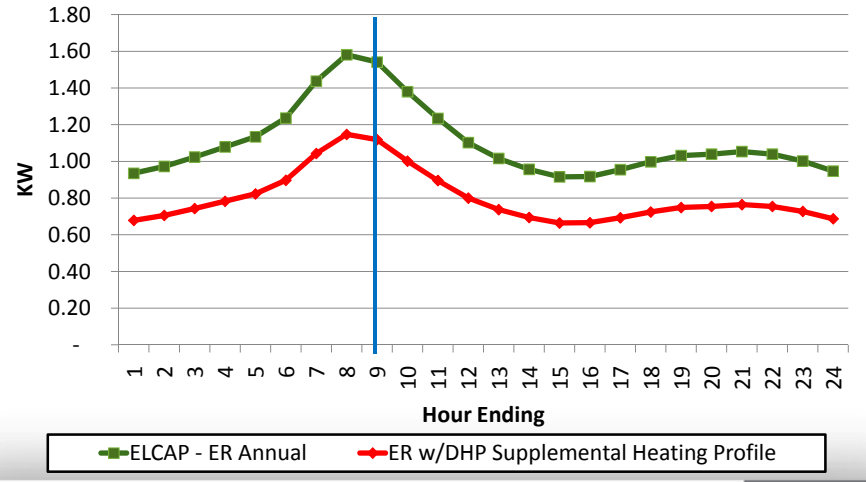
We Know That Ductless Heat Pumps Have Both Energy and Capacity Benefits



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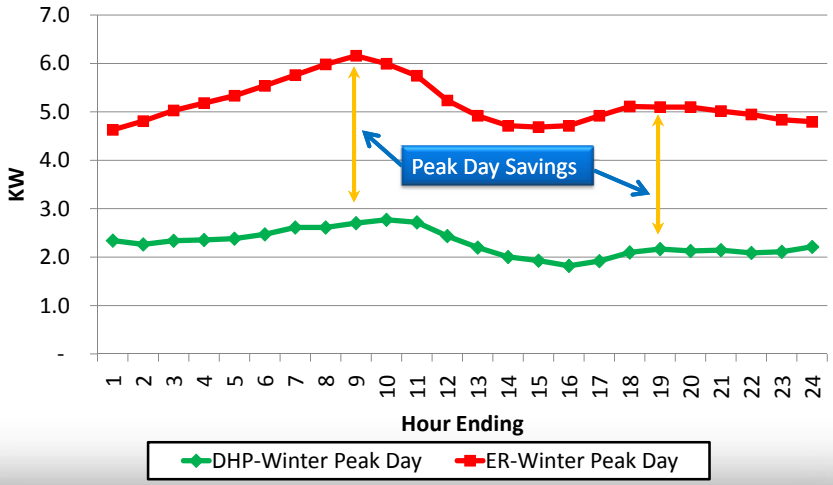
We Know That Ductless Heat Pumps Capacity Benefits ***Even*** On Extreme Winter Peak Days



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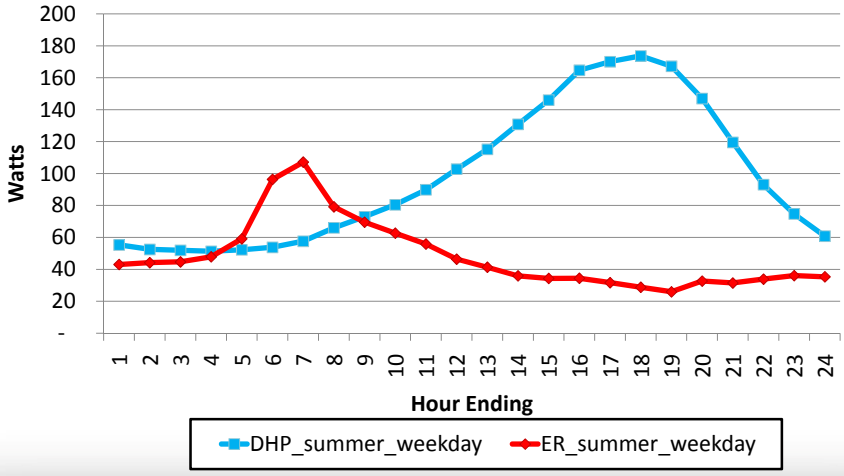
We Know That Ductless Heat Pump Provide Air Conditioning – So Summer Peak Loads Will Increase



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Potential System Impacts from Ductless Heat Pumps

	Electric Zonal Heat	Electric Zonal w/DHP Supplement	Electric Zonal Extreme Peak	Electric Zonal w/DHP Supplement
Annual Use (kWh)	9,680	6,360	6.2 (KW)	2.7 (KW)
Savings/Unit (kWh)		3,320		3.46 (KW)
Existing Baseboard Heated Stock	542,600	542,600	542,600	542,600
Annual Load (aMW)	600	395	N/A	N/A
Potential Savings (aMW)		205		N/A
Winter Coincident Peak Load (MW)	1,725	485	3,345	1,465
Winter Coincident Peak Savings (MW)		1,245		1,880
Summer Coincident Peak Load (MW)	45	115		
Summer Coincident Peak Savings (MW)		(70)		

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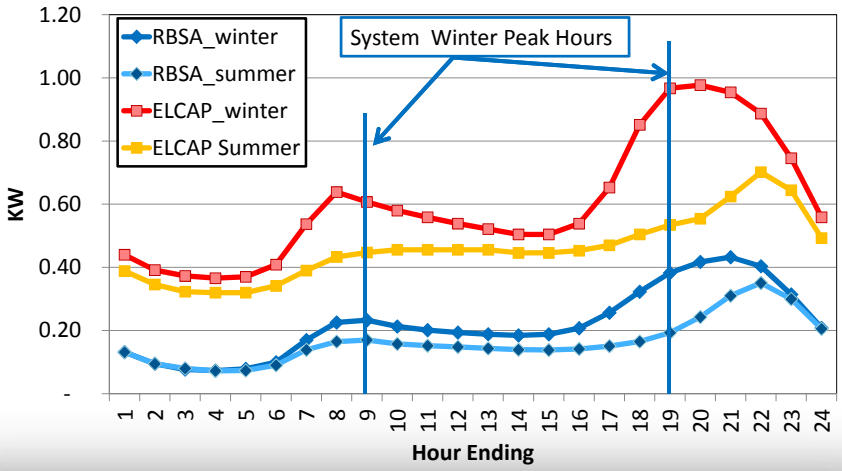
Lighting Energy Use

Scenario	LPD (W/ft^2)	Annual Energy (kWh/yr)
ELCAP	3.54	4500
Current Survey (RBSA)	1.40	1845
Full EISA Compliance w/ EISA targets	1.18	1555
Full EISA Compliance w/ CFLs	0.85	1120

- Four scenarios
  - 1990 – Lighting load as measured in ELCAP
  - 2012 – Lighting load as measured in RBSA
  - Full EISA compliance with EISA targets assume all currently non-complying, non-exempt lamps are replaced with their minimum compliance equivalents
  - Full EISA compliance with CFLs assumes all non-complying, non-example lamps replaced with CFL equivalents
- Annual energy use is for 2,006ft^2 house with 1.8 hours per day of on-time (Source: RBSA sample house size and lighting on-time metering)

Residential Lighting Load Profiles

Lighting Is Now Contributing Significantly Less to Both Morning and Evening Peaks



Historical and Forecast System Impacts from Residential Lighting Efficiency Improvements

	Lighting Loads (ELCAP) - 1990 Stock & Efficiency	Lighting Loads (ELCAP load shape, 2012 stock & efficiency)	RBSA Lighting Load Shape - 2012 Stock & Efficiency	Post-EISA 2020 Lighting Standards Loads (2012 Stock)
Annual Use (kWh)	4,500	1,770	1,770	1,080
Savings/Unit (kWh)		2,730	2,730	690
Single Family Residential Stock	4,021,700	5,798,220	5,798,220	5,798,220
Total Annual Lighting Loads (aMW)	2,065	1,170	1,170	715
PNW 2012 Savings (aMW)		895	895	455
Coincident Peak Load (MW) - Morning	2,080	1,180	1,230	750
Coincident Peak Load (MW) - Evening	2,885	1,640	1,850	1,135
Coincident Peak Load Savings (MW) - Morning		900	850	480
Coincident Peak Load Savings (MW) - Evening		1,245	1,030	725

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What's All This Mean

- The region's development of energy efficiency resources also has capacity impacts
- Our knowledge of the relationship between energy and capacity savings is largely based on data collected 25 years ago
- Let's see just how much difference using updated data for just two end uses makes

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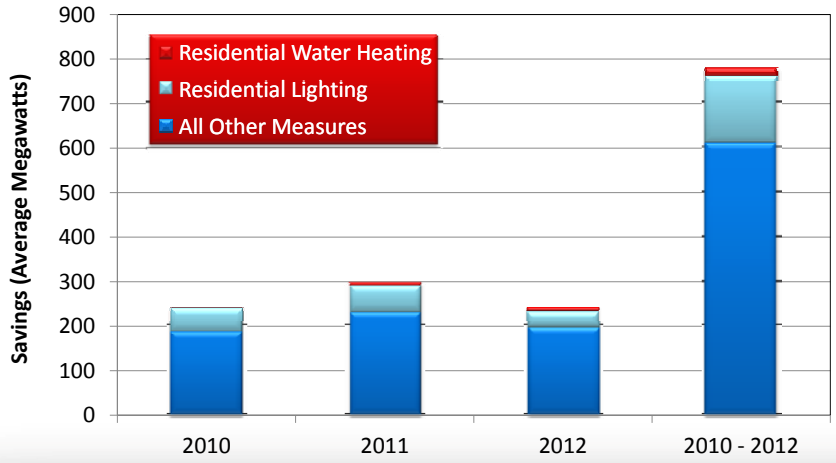
2010 -2012 Utility Efficiency Program Savings



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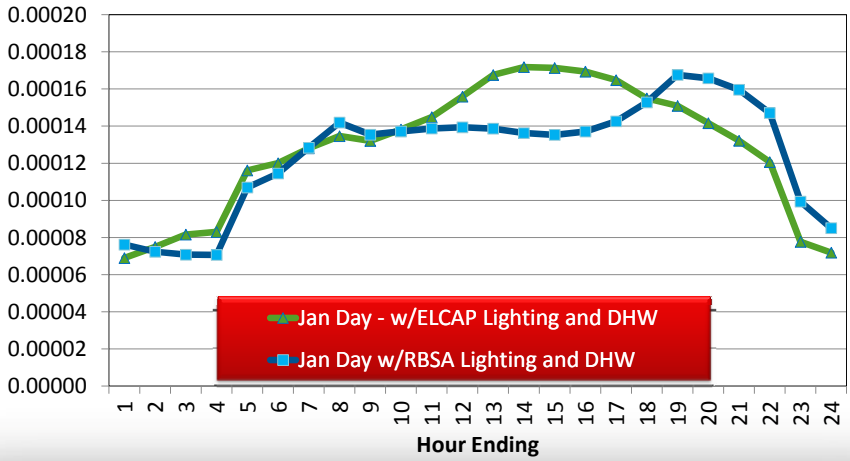
January Day Hourly Savings Change with Updated Data



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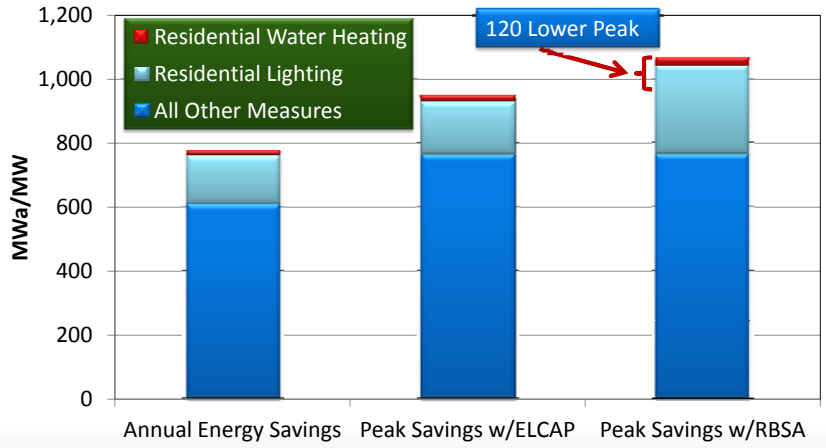
Updating Load Profile Data Annual Energy and Winter Capacity Savings from 2010-2012 Utility Efficiency Programs



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