A discussion on electrification

Electrification & Natural Gas Decarbonization: Opportunities & Challenges
October 22, 2019
Power & Gas Taskforce/PNUCC SPC report

• Load and carbon impacts of vehicle and space heating electrification
  - Small scale (not economy wide)
  - Current technologies

• Report provides discussion on key questions, not answers
  - Target audience: planners studying electrification

• Report and this slide deck at www.pnucc.org/system-planning/reports
Today

• EV loads
• HVAC loads
• Emissions in the Northwest
• EV emissions
• HVAC emissions
• Other Northwest studies

Your results will vary

For EV loads and especially HVAC loads, assumptions must be tailored to your area of study, future technology options, future DSM programs, and more
Electric vehicles

Load impacts

Report used historical data with 7.5% line loss added

7.5% line loss assumption from US EPA Clean Power Plan Technical Support Document, average 2012 US value. (more recent NW values are closer to 5% - 6%)
Electric vehicles in the Northwest today

Council’s 7th Plan estimates 400,000 to 1,500,000 EVs in the Northwest by end of 2030

Data from the Alliance of Automobile Manufacturers
NW defined as ID, MT, OR and WA
### Electric vehicle annual energy usage

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>kwh/mile</th>
<th>Annual MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 Chevy Bolt</td>
<td>0.28</td>
<td>2.3 to 3.6</td>
</tr>
<tr>
<td>2018 Nissan LEAF</td>
<td>0.30</td>
<td>2.4 to 3.9</td>
</tr>
<tr>
<td>2018 Tesla Model S 100D</td>
<td>0.33</td>
<td>2.7 to 4.3</td>
</tr>
<tr>
<td>2018 Tesla Model X 100D</td>
<td>0.39</td>
<td>3.2 to 5.1</td>
</tr>
</tbody>
</table>

Average Northwest home uses 10 to 12 MWh per year

Based on annual mileage (7,500 to 12,000)

Average electric usage value from US EIA (avg. res. bill), kwh/mile data from US EPA
Schedule diversity reduces EV peak impact

Max charging day in Q4 2013 of DOE EV Project

Participants had level 2 (6 kw+) chargers, schedule diversity reduces peak impact

15 minute data
Other studies have similar peak results

2018 CEC study sees peak impact of 0.76 kw / car (1.3 million EVs)

Avista seeing average EV peak demand around 0.8 kw/car
Your results will vary – EV loads

• How much driving does your average customer do?
• How many cars per home do you expect?
• Do you have a DR program and/or TOU rates for EVs?
• Can increased non-home charging lead to lower peaks?
• How will charging change with new EVs and charging technologies?
HVAC electrification

Load impacts

Modeling assumptions:

- Used the SEEM model
- 2,000 sq. ft. single family home
- Insulated about 50\textsuperscript{th} & 90\textsuperscript{th} percentile
- 68.7 / 64.7 temperature setpoints
- Focus on ducted heat pump at 3 & 4 tons
- Range of temperature profiles
- Focus on heating, not cooling
- Includes line loss (7.5%) and fan energy
Existing single family home heating fuel

2016 NEEA RBSA data

- Natural gas (less than 90% efficient)
- Natural gas (more than 90% efficient)
- Electric, heat pumps
- Electric, other
- Other fuel
## Annual energy usage for heating

2,000 sq. ft. insulated *roughly* to regional 50\(^{th}\) percentile

<table>
<thead>
<tr>
<th>Location (heat pump type)</th>
<th>Reference Home</th>
<th>Well-Insulated Home</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle (3-ton HSPF 9.0)</td>
<td>5.3 MWh</td>
<td>2.5 MWh</td>
</tr>
<tr>
<td>Spokane (4-ton HSPF 9.0)</td>
<td>10.5 MWh</td>
<td>5.4 MWh</td>
</tr>
</tbody>
</table>

Insulated *roughly* to regional 90\(^{th}\) percentile

See extra slides for info on cooling loads
Avg. temp is 20 F, falling to 15 F on peak

A HSPF 12 unit lowered peaks ~20% in these example (see extra slides).
HVAC load – climate matters (ref. home)

4-ton HSPF 9.0 heat pump in ref. home in all load profiles

Four different daily temperature profiles

Note the lower peak on the 20°F day as compared to previous slide – this is due to larger (4 ton v. 3 ton) heat pump.
HVAC load – climate matters (well insulated)

4-ton HSPF 9.0 heat pump in well insulated home in all load profiles

Four different daily temperature profiles
Your results will vary – HVAC load impact

**Net load impact equals** = (new load) – (existing load) – (new DSM)

**Higher if**
- Climate is colder
- Homes are larger
- Homes are poorly insulated
- Additional EE is difficult to acquire
- Demand response programs hard to implement and/or expensive
- Less scheduling diversity and more homes running thermostat setbacks
- Electric HVAC controls set less efficient (heat pump compressor lock out used)

**Lower if**
- Climate is warmer
- Homes are smaller
- Homes are well insulated
- Additional EE easy to acquire
- Converting older electric HVAC to heat pumps
- Combined with successful DR programs
- Higher scheduling and/or geographic diversity
- More efficient HVAC (maybe DHP?)
- Dual fuel units available
Load questions?

Up next, carbon emissions
Northwest energy sector carbon emissions (2016)

Total - 178 million tons

- Light duty vehicles
- Other transportation
- Natural gas residential
- Other residential
- Other commercial
- Other industrial
- Electric residential
- Electric commercial
- Electric industrial

Other fuels (natural gas, oil, etc.) 24.3%

Electric power gen. 26.2%

Transportation 49.5%

Data from US EPA and EIA. Transportation and other fuel residential sector break-out based on national values. Electric power breakout based on NW sales data. All tonnage values in deck are metric tons.
Carbon emissions comparison

Toyota Corolla

Usage: 12,000 miles
Efficiency: 34 MPG
Fuel CO$_2$ intensity: 17.6 lbs CO2/gallon
2.8 metric tons CO2/year

Chevy Bolt

Usage: 12,000 miles
Efficiency: 0.28 kwh/mile
Fuel CO$_2$ intensity: it depends
X metric tons CO2/year
Electric power intensity tricky to calculate

• Are you considering Western Interconnection load/emission interactions?

• Do your power system emissions change by season/day/hour?

• Are your emissions assumptions (for all fuels) changing in the future?

• Report recommends running a production cost model to determine electric power system carbon impact
Electric power carbon intensity examples

- **NWPPCC marginal rate with 50% RPS**
  - 0.21 tons CO2/MWh

- **NWPPCC marginal unit study**
  - 0.42 tons/MWh

- **CO2 free resource**
  - 0 tons/MWh

- **Modern CCCT**
  - 0.36 tons/MWh

- **Gas peaker**
  - 0.50+ tons/MWh

- **Coal power plant**
  - 1 ton/MWh
Vehicle emissions vs. power CO$_2$ intensity

Annual vehicle emissions from 12,000 miles/year

MPG and kwh/mile data from US EPA.
Heating emissions vs. power CO$_2$ Intensity

Values for the reference home in Seattle

Data from in-house modeling with SEEM. RNG not available in large quantities today.
Impact of energy efficiency on HVAC emissions

Values for the well insulated home in Seattle

95% efficient gas furnace (well insulated home)

HSPF 9.0 heat pump (well insulated home)
Other studies

Focus on E3/NW Natural & EER/PGE studies
Both studies met 2050 carbon goals both under high electrification (no gas heating) and low electrification (retention of gas heating) pathways.

Both studies maintained power system adequacy under all pathways.

Studies required near total decarbonization of the electric power system and partial decarbonization of pipeline and/or liquid fuels.

Both studies required high levels of energy efficiency.

Studies disagreed on pathway costs.
Recent NW studies, cont.

- Both studies required high levels of light duty vehicle decarbonization by 2050 to reach carbon goals.
Questions?

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Extra slides
Why the report was drafted

**Climate change**
Electrification is part of most decarbonization pathways

**System adequacy concerns**
Planners are concerned about the load impacts due to electrification

From Council presentation via David Rupp (OSU). Projected winter temperature increase under one GCM by 2040s

From Council presentation on 2024 resource adequacy. Adequacy target is a 5% LOLP
Electric vehicle charging equipment

- Level 1 charger, 1.4 kw
- Level 2 charger, 6+ kw
- DC fast charger, 50+ kw
EV correlation between kwh and max kw

Red indicates $R^2 > 0.5$
Orange $R^2$ between 0.20 and 0.5
Green $R^2 < 0.20$

Data are from 6 quarters of the EV Project, 15 minute readings, not adjusted for line loss. Location with highly impactful TOU rates excluded.
Modeled home parameters

Reference home roughly used 50th percentile values, well insulated home 90th percentile values

<table>
<thead>
<tr>
<th></th>
<th>Reference home</th>
<th>Well insulated home</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square footage</td>
<td>2002</td>
<td>2002</td>
</tr>
<tr>
<td>Attic R value</td>
<td>23</td>
<td>43</td>
</tr>
<tr>
<td><strong>Wall R value</strong></td>
<td><strong>14</strong></td>
<td><strong>21</strong></td>
</tr>
<tr>
<td>Floor R value</td>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>Foundation type</td>
<td>Crawl</td>
<td>Crawl</td>
</tr>
<tr>
<td>Window U value</td>
<td>0.35</td>
<td>0.27</td>
</tr>
<tr>
<td>Duct insulation</td>
<td>R3</td>
<td>R10</td>
</tr>
</tbody>
</table>

50th percentile is just past the middle of R11-R16 bin; 90th percentile upper end of R17-R22 bin
HVAC – scheduling diversity

Seven schedules averaged together. Setpoints at 68.7 and 64.7 F or flat at 68.7 F

Flat schedule (red) has lowest peaks

Graph uses the 3-ton HSPF 9 heat pump in the well insulated home on a day that averages 20 F
More efficient heat pump example

Avg. temp. is 20 F (15 F on peak).
3-ton HSPF 9.0 and 12.0 heat pumps (12.0 is a rating seen with ductless units today, not common with ducted units)
What about cooling?

Cooling loads/peak lower than heating in Seattle. This is due to climate and efficiency.

Aggregated peak loads in Seattle for cooling slightly above 2 kw/heat pump in the reference home, rising to 3 kw in Spokane (higher temps).

Data for a HSPF 9.0 heat pump in the 2,000 sq. ft. reference home under an average Seattle temperature profile.
Electric power intensity tricky to calculate

Are you considering Western Interconnection wide load/emission implications?

Do your emissions change by season/day/hour?

Are your emissions assumptions (for all fuels) changing in the future (i.e. cleaner power system, decarbonized pipeline, etc.)?

Report recommends running a production cost model to determine carbon impact

<table>
<thead>
<tr>
<th>Specific resource values</th>
<th>lbs./MMBtu</th>
<th>tons/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon free resource</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Efficient gas CCCT</td>
<td>233</td>
<td>0.36</td>
</tr>
<tr>
<td>Gas peaking unit</td>
<td>323+</td>
<td>0.50+</td>
</tr>
<tr>
<td>Coal power plant</td>
<td>581+</td>
<td>0.90+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System values</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Council marginal rate (2018)</td>
<td>271</td>
<td>0.42</td>
</tr>
<tr>
<td>Marginal rate with a 50% RPS (est.)</td>
<td>136</td>
<td>0.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-electric fuel values</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E10 gasoline</td>
<td>141</td>
</tr>
<tr>
<td>Natural gas</td>
<td>117</td>
</tr>
<tr>
<td>30% RNG natural gas</td>
<td>82</td>
</tr>
</tbody>
</table>
Peak comparison to E3/NWN study

From page 58:
“...the average gas home in Oregon and Washington is almost 2,000 square feet and most likely was built in the 1990s or 2000’s”

Figure to the right from page 101:
“...a peak load was estimated for each fuel-switching single-family home in the region...”

For comparison, without line loss, the reference home in the PNUCC study with a HSPF 9.0 heat pump generated an aggregate peak impact of 7.9 kw at 15 F, falling to 4.1 kw in the well insulated home (and around 10% lower if running a flat schedule only).

Unsure of the building stock mix and heat pump assumptions in this figure (the E3 study looked various home sizes, insulation levels, heat pump efficiencies, and climate zones)
Cold weather heat pump metering study. 4-ton unit, 2,010 sq ft. house, flat temperature setpoint.

During hour ending 8, when temps were around 5 F, “The heat pump... had an average demand of 6.7 kW from 7:00 a.m. to 7:30 a.m. and 4.7 kW from 7:30 a.m. to 8:00 a.m. on the day shown”

This (5.7 kw 1 hr. avg) is similar to the peak in the well-insulated home on the 10 F day (earlier slide)

https://www.nrel.gov/docs/fy13osti/56393.pdf
Energy comparison to NEEA metering study

NEEA estimate of heat pump kbtu/sq ft. is 10.55

10.55 \times 2,002 = 56,336 \text{ kbtu} = \mathbf{21.1 \text{ MMBtu}}

<table>
<thead>
<tr>
<th>Location (unit size)</th>
<th>Reference Home</th>
<th>Well-Insulated Home</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle (3-ton HP)</td>
<td>18.1 MMBtu (5.3 MWh)</td>
<td>8.5 MMBtu (2.5 MWh)</td>
</tr>
<tr>
<td>Seattle (95% gas furn.)</td>
<td>54.5 MMBtu</td>
<td>25.4 MMBtu</td>
</tr>
</tbody>
</table>

NEEA estimate of gas furnace kbtu/sq ft. is 28.14 (heat zone 1)

28.14 \times 2,002 = 56,336 \text{ kbtu} = \mathbf{56.36 \text{ MMBtu}}

Annual energy loads in reference home 18\% lower than NEEA 2011 metering study estimate for heat pumps, 3\% lower for gas homes.

Equipment used in this study is newer/more efficient than equipment metered in NEEA study, unsure about building stock differences (metering study had a low number of homes)
Average January shape close to 4 kw on peak (without losses). 9 out of 10 homes in example located in heating zone 1 (mildest).

Average Jan. shape in Taskforce study close to 3 kw on peak for the reference home in the Seattle area. NEEA units on average were less efficient.
Heat pump controls

Units ran efficient control settings (roughly PTCS controls) and used compressor in tandem with auxiliary heat at low temperatures.

Units did not miss setpoints and if running setbacks had to come up to temp within the hour.

**Loads may be higher** with less efficient controls (e.g. compressor lockout employed).

**Peak impacts may be lower** if units allowed more time to makeup setbacks (e.g. 2 hours); **energy impacts** may be lower if furnace lockout were set (example below).

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Models listed below qualify for Heat Pump Control incentives. Eligible thermostats must be able to determine the outdoor temperature and prevent secondary heat source operation at temperatures above 35 degrees Fahrenheit. If you have questions about model eligibility, please contact us at [residential@energytrust.org](mailto:residential@energytrust.org) for single family homes, and [multifamily@energytrust.org](mailto:multifamily@energytrust.org) for duplex, triplex, fourplex, townhomes or side-by-side buildings.