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Heat Pump Water Heater ACE Model Review

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RE: Heat Pump Water Heater ACE Model Review

Ecotope has been contracted by the Northwest Energy Efficiency Alliance (NEEA) to review the current Heat Pump Water Heater (HPWH) Alliance Cost Effectiveness (ACE) Model. Specific review questions were:

Task 1: In reference to the recent 2019-2020 Washington Residential New Construction Code Study[1] (NCCS) of the 2015 Washington state energy code residential provisions (WSEC-R), NEEA has updated assumptions regarding HPWH installations in new construction and requests review of the updated methodology[2].

Additional topics:

- Is it fair/reasonable to use the recent study of WSEC-R 2015 code compliance as representative for HPWH adoption in Washington state new construction?
- Should NEEA consider using this information to update Oregon new construction estimates at some level?
- Are there additional considerations when applying this new survey data to Washington code homes?
- In regards to WSEC-R 2018, are there any code developments that should be considered to refine future forecasting?
- The current methodology does not account for new construction homes in Idaho and Montana – should market penetration rates for those geographies be addressed at some point?

Task 2: Review of product incremental cost assumptions used in cost effectiveness calculations. Specifically:

- Is referencing the baseline-adjusted RTF measure values appropriate for NEEA's market transformation assumptions?

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[1] Flynn, P. and E. Caudill. 2020. 2019-2020 Washington Residential New Construction Code Study. Prepared for Northwest Energy Efficiency Alliance. Report #E20-405. https://neea.org/resources/2019-2020-washington-residential-new-construction-code-study

[2] HPWH ACE Model Review 2021 workbook. Provided to Ecotope 11 January 2021.

- Is the weighting method to get to a regional average value reasonable?
- Is it appropriate to use the same method for discounting energy savings and costs for new construction installs?
- Regarding costs, is it reasonable to assume that all tiers have very similar costs and to use the same costs for small and large tanks since the savings values are also the same?
- How should NEEA be thinking about long-term incremental costs after a federal standard is in place? Relatedly: Is there an improved way to estimate this long-term cost?
- Is it reasonable that there would be no incremental labor cost in a post-federal-standard world?

Task 3: Does NEEA's forecast of Tier 4 weights appear reasonable when considering adoption rates of new tiers in prior years? Are there other considerations NEEA should be accounting for with these estimates?

This memorandum is organized according to each of the above topics. Heat pump water heater efficiency tiers are defined in NEEA's Advanced Water Heating Specification[3].

Task 1: Update of Washington new construction assumptions based on Washington Code Compliance Study

WSEC-R is largely modeled after the International Energy Conservation Code (IECC), with the most notable difference being that it utilizes an "option table" (Table R406.2, referred to as the Energy Credit Table). In each code cycle, options in the table are adjusted to improve energy performance design over the previous code. This approach also allows builders flexibility to meet the WSEC-R energy credit requirements. One of the goals of the recent New Construction Code Study (NCCS) was to quantify the pathways chosen to fulfill those requirements. To provide insights into the combination of options used in the construction of new homes under the WSEC 2015 provisions, the study team performed document reviews for 342 homes permitted through 13 jurisdictions[4]. Sampling design aimed to capture information from different sized jurisdictions from across the state.

The study found over 30 combinations of options used by builders to meet code, but the vast majority (92%) of homes were built using six combinations from the energy options table, all of which selected one of two options for energy efficient water heating equipment (option 5b or 5c). Specific to HPWHs meeting NEEA's Northern Climate Specifications for Tier 1 equipment – option 5c requires a HPWH with a minimum energy factor (EF) of 2.0. Given the prevalence of water heating efficiency options in compliance pathways, the NCCS reported additional insights into water heating systems collected during the field survey portion of the study. Those

[3] https://neea.org/img/documents/Advanced-Water-Heating-Specification.pdf

[4] Original sampling methodology targeted 20 jurisdictions, but 13 were in the final sample. The final sample distribution impacts intra-group summaries but does not impact overall weighted summaries.

summaries show 93% of Washington new construction homes with electric water heat installed a HPWH as part of their code compliance.

NEEA's HPWH ACE model calculates projected savings over a 20-year measure life, and attributes savings for existing and new construction markets into the future. Information in the NCCS is particularly useful for understanding the fraction of newly constructed homes that select the efficient water heating option and specifically the fraction of homes that install a heat pump water heater. This study provides an improved estimate for forecasting the percent of Washington code homes with HPWHs. Additionally, the new NCCS was designed to provide a representative sample for the state, and the model review team supports the use of the study findings as a state-wide metric for ACE Model calculations.

The model review team also reviewed the NCCS for other HPWH insights into the new construction market. Three topics are of relevance to HPWH ACE Model projections[5]:

1) Thirty-seven percent (37%) of sampled new construction homes had electric water heating. This measure of water heater fuel selection is a combination of homes with electric space heat and electric water heat, and homes with gas space heat and electric water heat.
2) When comparing space heating fuel fractions to water heating fuel fractions, there is a greater fraction of homes using electric water heat (37%) than electric space heating (20%). Put another way, some proportion of homes that use fossil fuels for space heat, use electricity for water heating.
3) The NCCS found that 95% of installed HPWHs (through option 5c) had efficiency ratings higher than 2.0 EF (as required by Table R406.2 option 5c).

The fraction of new homes with electric water heat in Washington agrees well with the electric water heating share estimated from 2016 Northwest Energy Star program data (36.3%) previously used in the HPWH ACE Model and appears to be a good estimate for the Washington new construction market. Similar code compliance studies in other states in the region may provide state-specific estimates for this value. This topic is discussed further in the following 'New construction in other Northwest states' section of this memo.

Historically, a home's space heating fuel has been assumed to coincide with the fuel used for water heat. NCCS findings suggest that there is some fuel mixing in new construction and a small preference for electric water heat - approximately 17% of homes with fossil fuel space heat, use electric water heat. The newly adopted WSEC-R 2018[6] has several new options for efficient water heating equipment and increased credits for HPWH equipment in higher

[5] Although some of these are from unweighted additional data summaries, they are comprised from substantial sample sizes (>100 homes) and represent the current best estimates for Washington new construction.

[6] Effective 2/1/2021

efficiency tiers (> Tier 1), as well as increased energy efficiency credit requirements. With 0.5 to 1.5 more credits being available for HPWH equipment (over the credit available for an efficient fossil fuel water heating equipment), heat pump water heaters will be an attractive pathway to code compliance regardless of space heating fuel. The model review team believes the fraction of homes with fossil fuel space heat and electric water heat is likely to increase as WSEC-R 2018 is implemented. Future new construction research should continue to provide insights on this topic similar to the NCCS.

The last point summarized from the NCCS suggests that equipment with efficiency above the energy credit requirements (EF 2.0) is being installed in new construction. The prevalence of equipment above the Tier 1 requirements is most likely due to the availability of the more efficient products during (and leading up to) the 2019/2020 study period of the NCCS. More information on equipment market saturation is contained in the Task 3 section of this memo.

New construction in other Northwest states

The NEEA analysis team also requested feedback on possible updates to the new construction market for other states included in the HPWH ACE Model (i.e., Idaho, Montana, Oregon). Oregon's Residential Specialty Code (ORSC) has an 'Additional Measures' table (Table N1101.1(2)) in addition to the prescriptive code requirements. Unlike the WSEC-R 2015 approach, which required a total number of energy credits be implemented based on the size of the house, the Oregon 2017 table has a suite of six 'Envelope Enhancement Measures' and four 'Conservation Measures'. Each new construction project must select one measure from each of the two measure categories. A high efficiency water heater upgrade, which requires a fuel UEF of 0.85 or a HPWH Tier 1 is 'Conservation Measure' "D", with the other three[7] focusing on HVAC upgrades.

Similar to the NEEA NCCS, a parallel study examining ORSC 2017 code compliance was recently completed[8]. The ORSC compliance study sought to understand the common pathways used to fulfill Table N1101.1(2) requirements. However, credible compliance information was difficult to obtain during field visits and selected measure combination details were only collected for 21% of sampled homes. A more robust sample[9] of installed water heating equipment was collected from field-observations, which showed that HPWHs were installed in

[7] The other ORSC Conservation Measures are: "A" – a high efficiency HVAC system, "B" – ducting for HVAC systems within conditioned space, and "C" – ductless heat pump with an HSPF 10.0.

[8] Pacific Northwest National Laboratory. 2020. Oregon Residential Energy Code Field Study. Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830. https://www.energycodes.gov/sites/default/files/documents/Oregon_Residential_Field_Study.pdf

[9] Although these summaries are not defined as statistically representative, these samples are comprised of over 100 homes (and represent the best available information on ORSC 2017 new construction).

47% of Oregon code homes with electric water heat[10]. Also, of note, is that Oregon showed a slightly lower fraction of homes that use electric water heat (30%) compared to Washington. Similar to Washington, there is some fuel mixing in new construction - gas heated homes were 81%, whereas gas water heating was a lower proportion (70%), indicating a fuel preference for electric water heating (11%, which is lower than the rate recorded in the Washington study). Pending NEEA's review of the Oregon study, this information could be used to parse out state-specific electric water heating, HPWH installation, and fuel selection fractions (rather than using one value for the region's new construction market).

The lower HPWH installation rate in Oregon compared to Washington can be at least partially attributed to the affordability of the mechanical HVAC conservation measure upgrades (options A and C), meaning space heating system upgrades were a commonly selected option over options B and D. Currently, ORSC 2021 is in its final draft form and the anticipated effective date is April 2021. In this most recent code cycle, Table N1101.1(2) requirements have changed – envelope and duct sealing measures have been moved from the 'Envelope Enhancement Measures' into the prescriptive code, and two new envelope/mechanical measures have been added to the table. Now instead of one measure from the two sub-tables, only a single measure from eight options is required[11]. This may reduce the installation of HPWHs as a compliance pathway for the 2021 code cycle. At this time, ORSC provisions do not have the same drivers for water heating energy efficiency improvements as the WSEC-R does. However, Oregon Executive Order (EO) 17-20, Section 4C requires newly constructed residential buildings to achieve equivalent performance levels with the 2017 U.S. Department of Energy (DOE) Zero Energy Ready (DOEZER) specification by 2023. DOEZER Home National Program Requirements (Rev. 07)[12] do require HPWHs for electric homes, so increased HPWH installations in Oregon new construction may coincide with the next ORSC cycle.

Unlike Washington and Oregon, Idaho and Montana do not have code compliance options in their residential provisions that encourage mechanical system efficiencies above the minimum

[10] The ACE Model review team also noted that 29% of the sampled Oregon homes participated in an above-code program. The model review team recommends that NEEA review the included above-code programs to ensure the Oregon Residential Energy Code Field Study can provide suitable information for HPWH ACE Model analysis.

[11] Odom, H., Frankel, M., and P. Kintner. 2021. Oregon Residential Specialty Code: 2005 Baseline and Code Roadmap to Achieve the 2030 Goal. Prepared for Northwest Energy Efficiency Alliance. Report #21-010. https://neea.org/resources/oregon-residential-specialty-code-2005-baseline-and-code-roadmap-to-achieve-the-2030-goal

[12] https://www.energy.gov/sites/prod/files/2019/04/f62/DOE%20ZERH%20Specs%20Rev07.pdf

federal standards. In both states, recent studies[13,14] describe maximum water heating system efficiencies of EF 0.92 suggesting that no HPWH were observed in new construction. Recent HPWH Market Progress Evaluation Reports[15,16] also describe low market penetration in those states. Until code changes are implemented, the new construction fraction with HPWHs is likely to remain low in these states. However, as HPWH prices decrease this may lead to increased market penetration in Idaho and Montana new construction. NEEA should continue to monitor the new home markets in these states.

Task 2: Review of product incremental cost assumptions used in cost effectiveness calculations.

NEEA's HPWH ACE Model aims to estimate the cost effectiveness of specific HPWH market sectors from a market transformation perspective. To do so, NEEA uses the baseline-adjusted Regional Technical Forum (RTF) measure values[17], to effectively remove the market baseline and focus the analysis on HPWHs added through NEEA's market transformation efforts. HPWH incremental costs are also sourced largely from RTF sources. However, NEEA's analysis differs from the RTF lens, as NEEA is assessing cost effectiveness over a 20-year market transformation period, rather than the thirteen-year measure-life of the heat pump water heater. The longer analytical timeframe means that NEEA wants to account for the HPWH equipment being replaced within the analysis period and to allow for the replacement cost to decline over time as market drivers eventually reduce the incremental cost. This task centered on review of NEEA's current cost estimation methods assumption and a cost decrementing estimate to account for a reduced capital cost when HPWHs are replaced within NEEA's analysis timeframe.

NEEA's saving estimation uses a weighting method to calculate a regional average savings and costs value. Assumptions for climate zone, installation location, and heating system (from RBSA

[13] Pacific Northwest National Laboratory. 2019. Idaho Residential Energy Code Field Study. Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830. https://neea.org/resources/oregon-residential-specialty-code-2005-baseline-and-code-roadmap-to-achieve-the-2030-goal

[14] Pacific Northwest National Laboratory. 2019. Montana Residential Energy Code Field Study. Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830. https://www.energycodes.gov/sites/default/files/documents/Montana_Field_Study_State_Report_Final.pdf

[15] Cadeo Group. 2018. Northwest Heat Pump Water Heater Initiative Market Progress Evaluation Report #4. Prepared for Northwest Energy Efficiency Alliance. Report # E18-375. https://neea.org/resources/northwest-heat-pump-water-heater-initiative-market-progress-evaluation-report-4

[16] NMR Group. 2019. Northwest Heat Pump Water Heater Initiative Market Progress Evaluation Report #5. Prepared for Northwest Energy Efficiency Alliance. Report # E19-394. https://neea.org/resources/northwest-heat-pump-water-heater-initiative-market-progress-evaluation-report-5

[17] Residential Heat Pump Water Heaters v4.2. Regional Technical Forum UES Measure Workbook.

II) survey data are used to weight the baseline-adjusted 'Any Size' savings and costs values from RTF sources.[17] These values are then used in cost-effectiveness estimations. NEEA's current estimation methods are sound given the analytical aims. The RTF recently approved updated costs and savings estimates for existing home measures (approved 20 January 2021), which show a small cost increase to HPWH installations and represent current best cost estimates[18]. The model review team suggests NEEA consider updating the HPWH ACE Model existing homes costs and savings values with current RTF information. Findings from recent RTF work continue to support similar costs across HPWH efficiency tiers (as assumed in the HPWH ACE Model).

For the new construction market, NEEA tracks water heating savings in both the HPWH ACE Model and the New Homes ACE Model. To avoid double-counting savings across programs, NEEA applies a savings derate within the HPWH ACE Model to account for savings attributed to above-code homes (through the New Homes ACE Model). To make the cost-benefit assumptions uniform, NEEA applies a similar deduction to new construction costs. Through this estimation process, costs for HPWH replacement in existing homes is uniform across tank sizes (based on the 'Any Size' RTF measure and the regional weighting) and higher than the costs for installation in new homes (which differ by tank size). Because the RTF 'Any Size' measure savings and costs estimates have implicit assumptions about tank size fractions (90% 0-55gallon tanks[17]), ACE Model tank size fractions should not vary greatly from these estimates. Currently, NEEA estimates the proportion of large and small tanks in new construction based on RBSA 2012 data[2] which are within a few percent of the RTF values for tank size fractions and appears to be in-line with the 'Any Size' measure identifiers. Upcoming RTF meetings will be reviewing baseline and efficient case values, and subsequent changes to the 'Any Size' RTF measure assumptions should be reviewed for potential ACE Model implications.

Longer-term NEEA is looking to estimate decreasing capital costs as the HPWH market matures. Because NEEA's analysis timeframe encompasses the expected HPWH equipment life-time, they also want to capture the replacement of HPWHs with new HPWHs at the end of measure-life (13 years). Additionally, changes to federal efficiency standards could shift the electric baseline to HPWH equipment, and NEEA's model needs to forecast past that potential. NEEA staff solicited input on a proposed cost-decrementing method and assumptions about future incremental costs given the likelihood of a new federal standard in the coming years.

The model review team asserts that both scenarios – an improved federal standard requiring minimum HPWH efficiencies, as well as future replacement of a 'retired' HPWH with a new HPWH – have the same new baseline, that of a HPWH. In both cases, the incremental equipment cost to the new HPWH baseline would be zero. Similarly, although installation time (and therefore labor costs) are greater for HPWH when compared to an electric resistance baseline, the labor incremental costs become zero when the baseline is a HPWH. The model review team assessed the adjusted capital cost methodology proposed by NEEA, and believes it is a sound approach to allow reduced capital costs over the program life but suggests that the future

[18] Residential Heat Pump Water Heaters v5.0. Regional Technical Forum UES Measure Workbook.

incremental cost could be zero once the federal minimum standard aligns with minimum HPWH efficiencies.

Prior to the next cycle of updated federal efficiency requirements, another consideration in incremental costs that will likely have an impact more near-term is state-level requirements for electric storage water heaters. In Washington state, RCW 19.260.080, requires electric storage water heaters (manufactured as of January 1, 2021) to include a modular demand response communication port (CTA-2045 or equivalent). Similar equipment standards are drafted for Oregon rulemaking to take effect in 2022. And Oregon House Bill 2062, which addresses energy efficiency standards for certain appliances including the requirement of a modular demand response communications port for electric storage water heaters, is currently in house committee[19]. This port is effectively a communications protocol and related controls strategy that is intended to allow utilities to interact with electric storage water heaters to implement load shifting. This requirement impacts both electric resistance and HPWHs; however, integrating this new requirement may impact electric resistance equipment costs more. The rationale is that HPWHs already have digital electronics on board which are basically micro-computers. Adding a CTA-2045 port requires updates, but is a simpler adjustment based on how HPWHs are already manufactured. Electric resistance water heaters, by comparison, currently use simple relays and temperature sensors. The new legislation will require more sophisticated electronics be added – which will be a bigger lift for traditional electric resistance water heater manufacturing. Although the potential cost-increase for electric resistance equipment is not yet known (as the requirement became effective only recently in Washington), it is likely to be relatively low, around $10-50 increase to the baseline cost.

Task 3: Review of forecasting logic for Tier 4 HPWHs.

Each year NEEA receives market information from distributor and retail sources, as well as manufacturers. Manufacturer insights include product development timelines that could be useful for estimating the future market share of increasingly efficient HPWHs. Historical market share by Tier is shown in Figure 1. This figure shows the market shift from a Tier 1- to a Tier 3-dominated market and demonstrates that almost 100% of the HPWHs sold in 2019 were Tier 3 HPWHs. Preliminary 2020 market numbers show Tier 4 products entering the market.

[19] https://olis.oregonlegislature.gov/liz/2021R1/Measures/Overview/HB2062

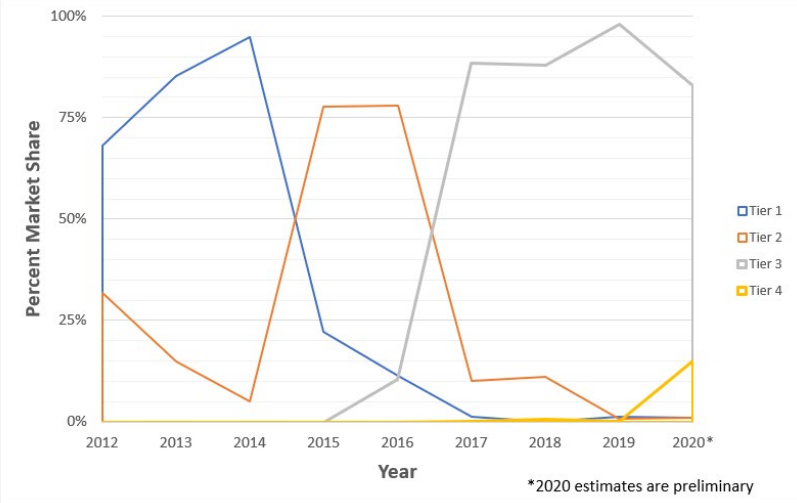

Figure 1. Percent market share of HPWHs by Year and Efficiency Tier[20]

In forecasting to future years, NEEA is looking to estimate the transition to Tier 4 equipment over the next four to five years. At the time of writing of this memo, NEEA has preliminary estimates that show increased prevalence of Tier 4 HPWH sales in 2020. Additionally, NEEA assumes that most HPWH manufacturers will have 100% of their new units qualifying as Tier 4 by the end of 2022.

NEEA's analyst staff proposed a market forecast method that weights the Tier 3 and Tier 4 market fractions by the assumptions made for individual manufacturer's Tier 4 market share, and the overall market share of a given manufacturer. The approach leads NEEA to estimate that Tier 4 qualified units would account for 88% of the overall market by 2022. This approach also assumes that Tier 1 and Tier 2 equipment will not be readily available moving forward. This is supported by NEEA's market analysis which shows that Tier 1 and Tier 2 products are no longer being produced and reported small numbers of these units are likely from stock carryover.

The model review team supports the market shift to higher efficiency equipment in the coming years; however, the challenge is to make the best forecast given an as-yet unknown future. Using insights from manufacturer development timelines may be optimistic. Other considerations may be the continued production of Tier 3 equipment. For example, Rheem recently launched Tier 4 products[21], but will likely continue to manufacture Tier 3 products. The availability of Tier 3 units into 2022 (and beyond), as well as demand by builders for economical equipment to fulfill additional energy efficiency requirements, at least within the Washington energy code (WSEC-R

[20] Percent market share estimates provided by NEEA in the HPWH ACE Model Review 2021 workbook. Provided to Ecotope 11 January 2021.

[21] Advanced Water Heater Specification Qualified Products List for Heat Pump Water Heaters. Updated 18 January 2021. https://neea.org/resources/hpwh-qualified-products-list

2018), may prolong the transition to a majority Tier 4 market. Regionally, state codes may include additional energy efficiency requirements that more strongly encourage even more efficient HPWHs. However, the next code development cycle is still several years away (in Oregon and Washington). For these reasons, the market research team suggests a more tempered market transition, which has more overlap in the availability of Tier 3 and Tier 4 equipment over the coming years.

Although the exact shape of the future transition is unknown, incremental increases of 10-15% per year would keep both products co-mingled in the market over the five-year forecast window, which is a likely scenario. Table 1 shows NEEA's original proposed future Tier 4 market share transition, while Table 2 shows one possible modified approach to modeling a more prolonged transition period. Each row in the Tier 4 market share estimate is multiplied by the individual manufacturer's total market share (not shown) to represent the overall market, which is plotted in Figure 2. Table 1 and Table 2 correspond to the top and bottom panels of Figure 2, respectively with the bottom panel representing a more moderate transition between Tier 3 and Tier 4 market shares.

Table 1. Tier 4 Share – NEEA Estimates by Manufacturer and Year – original estimates

Manufacturer	2021	2022	2023	2024	2025
A	50%	100%	100%	100%	100%
B	0%	0%	75%	100%	100%
C	25%	100%	100%	100%	100%

Table 2. Tier 4 Share – NEEA Estimates by Manufacturer and Year – modified estimates

Manufacturer	2021	2022	2023	2024	2025
A	25%	40%	55%	70%	90%
B	0%	0%	25%	50%	75%
C	25%	40%	55%	70%	90%

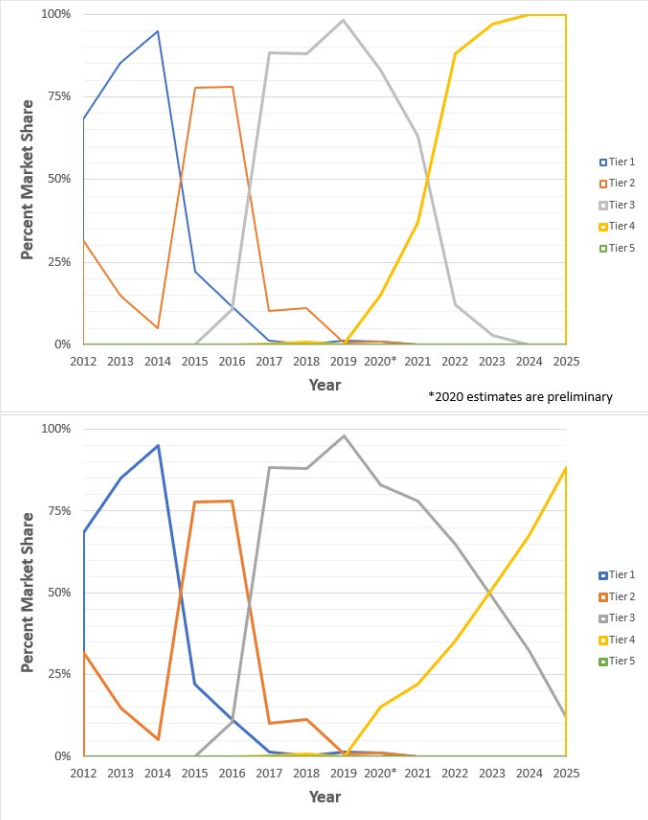

Figure 2. Forecast scenarios with accelerated (top panel) and moderate (bottom panel) Tier 4 market penetration

Conclusion

The ACE model review team focused on three main research topics as requested by NEEA's HPWH ACE Model analysts.

1) In regards to the update of Washington new construction assumptions based on the recent Washington Code Compliance Study, the review team supports the use of the new study for updated estimates for Washington's new homes market. Looking forward in Washington state, the implementation of WSEC-R 2018 is anticipated to increase the installation of heat pump water heaters in electric- and gas-heated homes as HPWHs will be attractive options to meet new energy efficiency credit requirements. Due to differing code requirements by state, the Washington Code Compliance Study information is only suitable for Washington state estimates. Similar studies have been performed in Oregon, Idaho, and Montana, and those resources may be useful for describing state-specific electric water heating and HPWH installation fractions. The Oregon code compliance study supports different fractions for Oregon (compared to Washington) with regards to the proportion of electric water heat, the installation of HPWHs, and mixed fuels (for space and water heat) in new construction. It is anticipated that the Idaho and Montana new construction markets will lag until codes change or greater overall market penetration takes place in those states. At this time, these new construction studies provide the best available information for state-specific new construction in the region, and the model review team supports their use for ACE Model assumptions. Future code compliance studies will be useful to understand the role of HPWHs in meeting energy efficiency requirements by state as state energy codes evolve in future code cycles.
2) The model review team assessed NEEA's use of baseline-adjusted RTF measure values, weighting methodology to arrive at a regional average value, and costs/savings assumptions and supports the current analytical approach. The model review team's further examination of NEEA's incremental cost assumptions used in cost effectiveness calculations, found the approach to be sound and changing capital costs with lower replacement costs in-line with NEEA's market transformation focus. The prorated capital cost approach has merit and can be used to reflect the longer analysis window of NEEA's market transformation program. Specific to the case of an improved federal minimum standard, or a HPWH replacing a HPWH (when the unit is no longer serviceable), the review team suggests that there would effectively be no incremental costs (in parts or labor) once HPWHs become the baseline case. However, before the next cycle for the review of federal efficiency standards, an additional consideration in baseline cost assumptions are new state-specific requirements for a CTA-2045 port in electric water heaters. The costs increase is anticipated to be low, but to impact the baseline electric resistance technology disproportionately.
3) Because NEEA's analysis window requires forecasting into the future, NEEA requested review of a proposed forecasting model to describe the future market share of Tier 4 products. The review team supports the manufacturer-weighted approach to estimating market share by Tier but suggests a more moderate transition period, and longer overlap with both Tier 3 and Tier 4 market availability.