

UES Portfolio Evaluation:  
Findings from the CY2017  
Evaluation Activities



# Contributors

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# Executive Summary

This report presents the findings from the impact evaluation of a set of Bonneville Power Administration's (BPA) energy efficiency measures that contributed to the FY2016 Unit Energy Savings (UES) portfolio. These measures include residential heat pump water heaters (HPWH), ductless heat pumps (DHP), advanced power strips (APSS), showerheads, agricultural transformer de-energization, and the Green Motors Rewind Initiative (GMRI). This report also includes the findings from a review of the deemed savings estimates included in the State Grant Low-Income Weatherization program and an assessment of the methodology used by the Retail Sales Allocation Tool.

Additionally, this report also includes an investigation of leveraging existing program oversight for Residential HVAC Performance Tested Comfort Systems (PTCS) measures which include Air Source Heat Pumps (ASHP), Commissioning Controls and Sizing (CCS), Duct Sealing – Prescriptive and PTCS (Performance Tested Comfort System), Ground Source Heat Pumps (GSHP) and Variable Speed Heat Pumps (VSHP).

## Background

BPA, with its public power utility partners, acquires savings from a portfolio of energy efficiency programs and measures. The majority of BPA's total reported savings comes from UES measures,<sup>1</sup> which utilize a constant deemed savings value for each measure application. By evaluating the residential HVAC UES and other UES measure groups chosen for CY2017, BPA will achieve roughly 85 percent coverage of the entire UES portfolio across the past 4 years of evaluation activities.

## Objectives

The objectives for this study include:

- Evaluate the energy savings achieved for consistency with the savings claimed.
- Assess the cost-effectiveness of the evaluated savings using ProCost<sup>2</sup> and the updated 7th Plan inputs.
- Provide feedback to improve program operation and measures.
  - Where appropriate, assess savings to inform RTF or BPA Qualified estimates.
  - Develop recommendations on data collection, oversight and program procedures, including but not limited to documentation and data

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<sup>1</sup> In FY2016, 87% of the total savings in the BPA tracking database (Interim Solution 2.0 or IS2.0) were from UES measures.

<sup>2</sup> ProCost is a model developed by the Northwest Power and Conservation Council and is used by the RTF to estimate the cost effectiveness of efficiency measures.

handling, to improve reliability and reduce cost for future evaluation years.

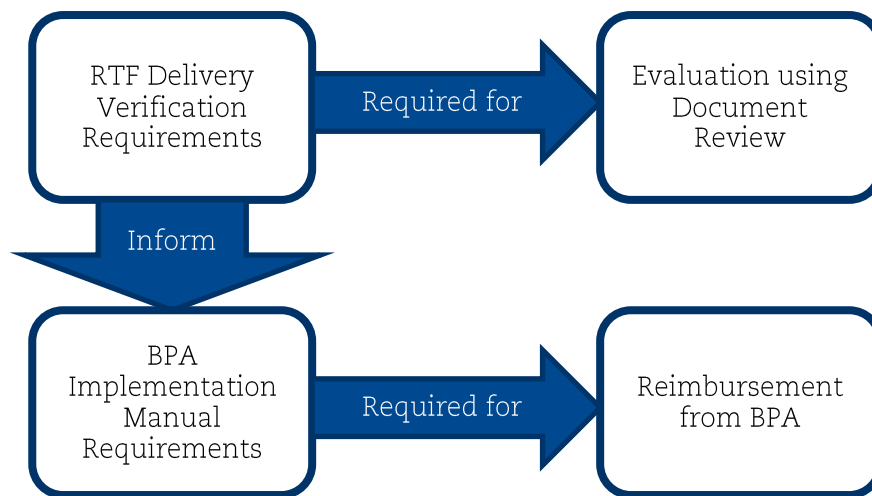
- Explore whether existing program oversight (QA) can function as impact evaluation of residential PTCS HVAC UES measures via document review.

## Methodology

The evaluation team conducted a delivery verification analysis using document review for the measure groups included in this evaluation. Per RTF Guidelines, document review can function as impact evaluation for Proven measures if delivery verification requirements are satisfied.<sup>3</sup> Conducting document reviews of un-Proven measure groups provides BPA with insight and may ultimately flag areas of additional research.

Delivery verification requirements are defined by the RTF and include a pre-defined set of key measure specifications. These requirements also typically inform the data that BPA requires from utilities for reimbursement according to the Implementation Manual. Figure ES-1 shows the relationship between the RTF and BPA with respect to measure documentation.

**Figure ES-1: Relationship between RTF and BPA Documentation Requirements**



The requirements in the Implementation Manual can be designed to align with the RTF delivery verification requirements so that utilities can use the same project documentation for reimbursement and evaluation purposes. For this impact evaluation, the evaluation team collected invoices and other project documentation from utilities and BPA to verify delivery of the sampled projects. Table ES-1 summarizes the data collected for each measure group.

<sup>3</sup> Regional Technical Forum, *Roadmap for the Assessment of Energy Efficiency Measures*, June 2014. <https://nwcouncil.box.com/s/qdr0wvbvo4wrk8g9j5nmiklasmpqv41>

**Table ES-1: Summary of Data Collected for Each Measure Group**

Evaluation Measure Group	Data Source	Type of Data
HVAC Ductless Heat Pumps – Zonal	Utilities	Installation form and invoice
Heat Pump Water Heater	Utilities	Installation form and invoice
Showerheads	Utilities	Invoice and (for by-request and direct install) measure distribution log
Power Strips	Utilities	Invoice and (for by-request and direct install) measure distribution log
Ag Transformer De-energization	BPA	Savings calculation file
BPA Green Motors	BPA	Invoice

Source: Navigant analysis

Once the evaluation team collected and analyzed the data, they assigned savings in the following manner:

- **Verified savings.** No discrepancies between the project documentation and the reported savings; the team assigned the full reported savings to the project.
- **Revised savings.** Project documentation included all data but indicated a different unit energy savings (UES) than reported. The team revised the UES value and recalculated savings for that project.
- **No savings.** Data required by the RTF was missing in the project documentation; team assigned zero savings.<sup>4</sup>

As part of the impact evaluation activities, the team conducted a review of the deemed savings estimates included in the State Grant Low-Income Weatherization program. The evaluation team analyzed the methodology and findings from relevant low-income weatherization evaluations, as well as the methodology and findings from the on-going billing analysis of residential weatherization measures, to provide BPA with insight into the reasonableness of the current assumptions. The evaluation team also reviewed documentation for the Retail Sales Allocation Tool.

#### Residential HVAC PTCS Measures Investigation:

The evaluation team investigated whether existing program oversight of Residential HVAC PTCS measures could be leveraged to conduct an impact evaluation. The PTCS program receives Quality Assurance (QA) visits and the findings are collected through

<sup>4</sup> Evaluated savings are presented in this report and included as the numerator in all realization rates calculated and shown herein. As of the time of this writing, these evaluated savings were not used to replace or update the savings reported in IS2.0 or the BPA BOOM report.



QA forms. This was the first time that existing oversight was used to investigate feasibility of impact evaluation using the data collected in the QA forms.

The evaluation team conducted a document review for the measure groups included in the Residential HVAC PTCS investigation similar to the above measure groups. For this document review, the evaluation team worked with BPA’s PTCS team which provides oversight for the Residential HVAC UES measures included in this investigation. Both the teams collaborated to align the PTCS data collection with the required data for document review according to the RTF DV requirements.

The evaluation team collected PTCS Quality Assurance (QA) inspection forms, other relevant documents (i.e., installation forms if applicable) and databases from the PTCS team to verify delivery of the sampled projects. Table ES-2 summarizes the data collected for each measure group.

**Table ES-2: Summary of Data Collected for Each Measure Group**

Measure Group	Data Source	Type of Data
Duct Sealing Prescriptive	PTCS Team	QA Inspection Forms and PTCS Installation Forms (if available)
Duct Sealing PTCS		
Commissioning Controls Sizing		
Heat Pumps - All Other		

Source: Navigant analysis

## Results

Overall, the impact evaluation verified the savings reported for the six FY2016 UES measure groups. The high realization rates shown in Table ES-3 reflect that the data included in project documentation align very closely with the measure data reported to BPA.

**Table ES-3: Realization Rate by FY2016 UES Measure Group**

Measure	Reported Savings (aMW)	Evaluated Savings (aMW)	Population-Level Realization Rate
Ductless Heat Pumps – Zonal	1.01	0.95	94%
Advanced Power Strips	0.71	0.71	100%
Showerheads	0.94	0.94	100%
Heat Pump Water Heaters	0.11	0.12	109%
Transformer De-energization	0.20	0.20	100%
Green motors	0.06	0.06	100%

Source: Navigant analysis

Table ES-4 shows cost-effectiveness results by measure and delivery mechanism.

**Table ES-4: Cost-Effectiveness Results for FY2016 UES Measure Groups**

Measure Group	Delivery Mechanism	Present Value of Benefits	Present Value of Costs	Total Resource Benefit/Cost Ratio
Ductless Heat Pumps – Zonal	-	\$939,161	\$487,616	1.93
Advanced Power Strips	By-Request	\$8,412,458	\$4,863,688	1.73
	Direct Install	\$234,834	\$98,683	2.38
	Retail	Not Sampled		
	<b>Measure Total</b>	<b>\$8,647,293</b>	<b>\$4,962,371</b>	<b>1.74</b>
Showerheads	By-Request	\$6,171,671	\$474,484	13.01
	Direct Install	\$195,286	\$13,522	14.44
	Retail	\$291,694	\$29,467	9.90
	<b>Measure Total</b>	<b>\$6,658,650</b>	<b>\$517,474</b>	<b>12.87</b>
Heat Pump Water Heaters	-	\$103,669	\$108,756	0.95
Transformer De-energization	-	\$1,566,547	\$801,772	1.95
Green Motors	-	\$234,930	\$41,498	5.66

Source: Navigant analysis

### Res HVAC PTCS Investigation

Overall, the investigation process for the residential HVAC PTCS measures verified the savings reported using the data collected during the program oversight. However, this was the first time that this approach was utilized and the team believes that more research and investigation is needed before this approach can be used to conduct an impact evaluation of these measures.

The interim draft results for this approach are provided in the table below. The team found that the overall draft realization rate for the Res HVAC UES measures is on the lower side since some logistical issues still need to be worked out for this approach. These results will not be used to update savings estimates for program planning purposes.

**Table ES-5: Summary of Draft Results for Res HVAC PTCS Measures<sup>5</sup>**

Measure Groups	Reported Savings (aMW)*	Reviewed Savings (aMW)	Population-Level Realization Rate
Duct Sealing Prescriptive	0.25	0.20	78%
Duct Sealing PTCS	0.07	0.04	57%
Commissioning Controls Sizing	0.02	0.01	42%
Heat Pumps - All Other	0.98	0.36	37%
<b>Overall</b>	<b>1.32</b>	<b>0.62</b>	<b>46%</b>

Source: Navigant analysis

\* Include only the savings from Main Population. Refer to section 2.5.2.1 for more details.

## Conclusions and Recommendations

### UES Impact Evaluation Conclusions and Recommendations:

**Overall, project documentation supports savings claimed.** Nearly all reported savings across the sampled measure groups were accounted for in project documentation, as indicated by the high overall realization rate.

**Misalignment of Implementation Manual documentation requirements and RTF delivery verification requirements may present risk to utilities.** Delivery verification requirements, as used for evaluation, are defined by the RTF. The documentation required by Bonneville for reimbursement is based on the Implementation Manual (IM) which usually, though not always, aligns with the RTF requirements. In cases where there is misalignment, utilities may be at risk of not receiving credit in the evaluation despite having all the documentation required per the IM. For example, one utility’s DHP Zonal installation forms did not directly indicate that the measure was installed in a “main living area” – a parameter required by the RTF in their measure specification.<sup>6</sup> In this instance, the evaluation team judged that other information on the form was sufficient to show that the systems met the requirement.

### Recommendation:

The evaluation team recommends that the requirements in the IM be closely aligned with the RTF requirements. Alternatively, the evaluation team also recommends the BPA team (including, as necessary, the PTCS team) reach out to RTF if they feel that some of the current DV requirements do not align with their understanding of the measures so that the current DV requirements can be studied further and revised if necessary.

**Some DHP zonal installation forms had missing/ineligible information.** Incomplete or ineligible information on installation forms were the primary reason DHP Zonal

<sup>5</sup> The final sample contained 10 projects which were reported in FY2017. The evaluation team used applicable deemed measure list (UES Deemed Measure List Version 5.1) to evaluate these 10 projects.

<sup>6</sup> RTF Measure Specification for Ductless Heat Pumps Replacing Zonal Heat.  
<https://rtf.nwcouncil.org/measure/ductless-heat-pumps-zonal-heat-sf>

projects received a realization rates less than 1.0. In these instances, the implemented measure received a realization rate of 0.0, as it did not comply with RTF delivery verification requirements as reported.

**There was a slight discrepancy in reported versus verified quantity of advanced power strips (APSs).** Project documentation for sampled APS projects revealed that some utilities reported quantities different than those identified in the project documentation. However, these discrepancies were too small to have a noticeable impact on the realization rate for this measure.

**There was a slight discrepancy in reported versus verified data for heat pump water heaters (HPWHs).** Some utilities reported quantities, reference number tiers, and installation locations for sampled HPWHs that were different than those identified in project documentation. These discrepancies account for the majority of the difference in reported versus evaluated energy savings. The evaluation team found that some utilities were conservatively reporting efficiency tiers of HPWHs. When the correct, higher tier was applied, this led to higher evaluated savings than reported; i.e., realization rates greater than 1.

**Claimed savings estimates used in the Low-Income Weatherization State Grant program are higher than comparable estimates in other studies.** Navigant found that BPA's current deemed savings estimates for low-income weatherization measures in single-family and manufactured homes are high compared to other studies that include similar weatherization measures. This is more pronounced for single-family homes than manufactured homes.

#### [Recommendation:](#)

To reduce uncertainty in these estimates, Navigant suggests updating the per-unit savings value using a more robust estimation method such as a billing analysis. In the meantime, we recommend that BPA consider reducing their single-family savings value by approximately 50% and their manufactured home savings value by approximately 25%.

**The Retail Sales Allocation Tool (RSAT) methodology is reasonable.** The evaluation team finds the RSAT allocation methodology robust and recommends on a few areas of future research, including exploring the potential for double-counting and the impact of the allocations methods used by regional utilities.

#### [Residential HVAC PTCS Investigation Conclusions and Recommendations:](#)

**Overall, PTCS QA inspections are a good resource to leverage for a future residential HVAC impact evaluation.** The data collected through existing PTCS QA inspections and oversight has a significant overlap with the evaluation data needs, which means there is the potential to save significant time and resources while reducing the burden on customer utilities. The evaluation team worked with the PTCS team to revise the Inspection forms to include most if not all data needs for evaluation and then leveraged the existing QA inspection and data collection effort for this investigation. In

the future, BPA may be able to perform a Residential HVAC evaluation in-house using the mechanisms established in this CY2017 evaluation.

This work was originally intended to function as a full-scale impact evaluation for PTCS measures, but during the process, there were important questions and findings which required the evaluation team to stop collecting data and reconsider the purpose of the project. Ultimately, in collaboration with BPA, the evaluation team decided to treat the project as an investigation that could support a potential future impact evaluation. Some of those findings and questions are provided below:

**There is a disconnect between QA Inspection grades and delivery verification requirements.** PTCS QA inspections do not completely align with the DV requirements set forth by the RTF. During the preliminary phase of this investigation, the evaluation team, with the help of the PTCS team, revised the original version of the PTCS QA inspection forms so that all the DV requirement needs are included in the current QA inspection forms. However, the grading criteria and weightages do not align between QA inspection and DV requirements. As defined by the RTF, a project must meet all DV requirements to receive full savings under an impact evaluation, but the PTCS QA inspection does not have this requirement. Certain specifications, such as equipment efficiency rating, must pass for the project to pass the QA inspection, as shown in the example below. This data point is also one of the DV requirements. However, certain other DV requirements (e.g. compressor lockout) can fail in the QA inspection, but the project can still pass the inspection overall. In this case, if this were an impact evaluation, the evaluation team would be required to assign zero savings to the project because not all DV requirements were met.

**Figure 1: Heat Pumps QA form – Must pass data point**

The graded items below will be weighted upon entry into the registry to calculate an overall grade.			
**Overall fail: These noted 'F' grades will result in an overall inspection fail regardless of other results.			
<b>Low Heat Pump Equipment Data</b>		<input type="checkbox"/> All Equipment Data matches technician's form. If not, record below.	
Inspection Type: <input type="checkbox"/> PTCS Heat Pump with HSPF		<input type="checkbox"/> Controls, Commissioning & Sizing (CC&S)	
Outdoor and Indoor Unit Make		AHRI number	HSPF
Outdoor Unit Model #		Indoor Unit Model #	
<b>Meets HSPF or CC&amp;S Grade</b> <small>(Check one)</small>	<input type="checkbox"/> <b>A (Above Spec)</b> 9.0 or higher (Fed standard for CC&S) and matches what tech reported	<input type="checkbox"/> <b>B (Meets Spec)</b> 9.0 or higher (Fed standard for CC&S)	<input type="checkbox"/> <b>**F (Fails)</b> Below 9.0 or Federal Standard
Notes			
For Air-Source Heat Pump Conversion in Manufactured Homes: Has the house previously had its ducts sealed through a utility offered duct sealing program? <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't Know			

Source: PTCS QA Inspection form for ASHP, VSHP and CCS

**Recommendation:**

The evaluation team recommends that for QA inspection data to function as delivery verification for the purposes of impact evaluation, the QA inspection forms must

require that the project pass all DV requirements in order to pass the QA inspection. Alternatively, the evaluation team also recommends the BPA team reach out to RTF if they feel that some of the current RTF DV requirements do not align with their understanding of the measures so that the current DV requirements can be studied further and revised if necessary.

**Project Remediation by PTCS contractors.** If a project fails in the QA inspection, the PTCS team provides feedback to the installation contractor and the contractor visits the site to remediate the issues which resulted in a project failure. There is uncertainty as to whether the savings for a remediated project are reported to IS2.0 before or after remediation. During this investigation, the team did not consider remediation of the projects in the document review.

#### Recommendation:

The team recommends more research to determine how and when the project is reported in IS2.0. The team suggests using the values from remediation for the evaluation only if the remediation happens before the project is reported to IS2.0.

**Document review sample fulfillment was not achieved.** Based on the analysis of historic PTCS QA visits and reported IS2.0 data, the team believed that the document review sample drawn by the team can be fulfilled within 4-6 months of PTCS QA visits. However, the seasonality and geographical constraints limited the ability of PTCS QA visits to meet the required sample.

**Ground source heat pump QA inspections used versions of the QA/QC inspection forms that did not contain the DV requirements.** This resulted in two key data needs for DV requirements not being collected during the inspection for all 8 GSHP projects in the sample. Due to the unavailability of data, the evaluation team assigned 0 savings for these GSHP projects, which is one of the key drivers for a lower realization rate.

#### Recommendation:

The team recommends the BPA and PTCS teams to use the revised QA/QC forms moving forward and/or collect the installation documents for GSHP projects which will help filling this data gap.

**The evaluation team believes that the approach adopted for Residential HVAC measures—i.e., document review leveraging the existing oversight—can work with other measure groups.** The team believes that with a typical program oversight (PTCS or COTR) review or inspection, there is a significant overlap between what BPA's oversight team would be doing and what an evaluation team would do. The team understands that not all oversight activities will include onsite visits which are unique to PTCS QA oversight. However, even with typical oversight activities (for example: document reviews or phone interviews of sampled participants), there is a good opportunity to leverage the data being collected. Leveraging an existing oversight process will reduce the burden on the customers and at the same time will help in running an evaluation in a cost-effective manner. Thus, the team recommends using

similar approach to the different measure groups which receive oversight from BPA, if feasible.

**Recommendation:**

For this suggested approach to work efficiently, the team recommends BPA align the oversight data collection with the RTF delivery requirements before undertaking the evaluation.

# 1. Introduction

This report presents the findings from the impact evaluation of a set of Bonneville Power Administration's (BPA) energy efficiency measures that contributed to the FY2016 Unit Energy Savings (UES) portfolio. These measures include residential heat pump water heaters (HPWH), ductless heat pumps (DHP), advanced power strips, and showerheads, agricultural transformer de-energization and the Green Motors Rewind Initiative (GMRI). This report also includes the findings from a review of the deemed savings estimates included in the State Grant Low-Income Weatherization program and an assessment of the methodology used by the Retail Sales Allocation Tool.

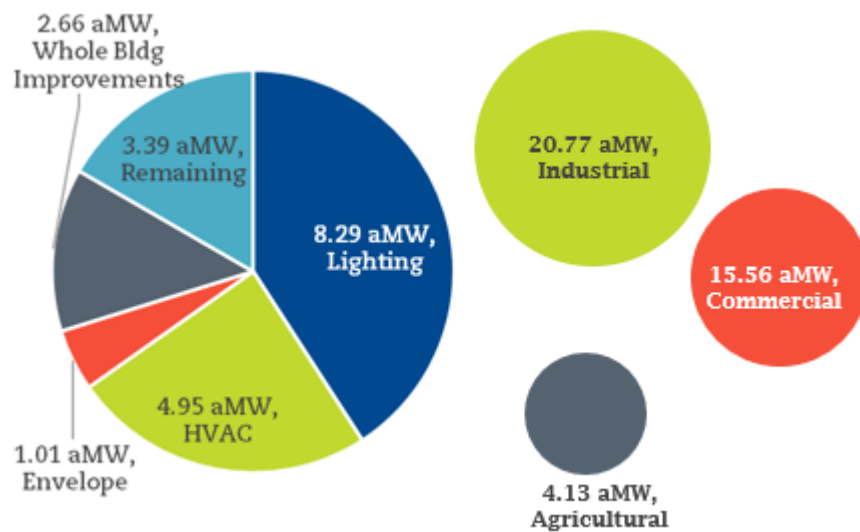
Additionally, this report also includes an investigation of Residential HVAC measures which include Air Source Heat Pumps (ASHP), Commissioning Controls and Sizing (CCS), Duct Sealing – Prescriptive and PTCS (Performance Tested Comfort System), Ground Source Heat Pumps (GSHP) and Variable Speed Heat Pumps (VSHP).

## 1.1. UES Portfolio Summary

BPA, with its public power utility partners, acquires savings from a portfolio of energy efficiency programs and measures. The majority of BPA's total reported savings comes from UES measures,<sup>7</sup> which utilize a constant deemed savings value for each measure application.

UES measures fall into several categories of residential, commercial, and industrial equipment. Figure 2 shows the fiscal year (FY) 2016 UES savings by key end-use.

**Figure 2: FY2016 UES Portfolio Summary by End Use and Sector\***



<sup>7</sup> In FY2016, 87% of the total savings in the BPA tracking database (Interim Solution 2.0 or IS2.0) were from UES measures.

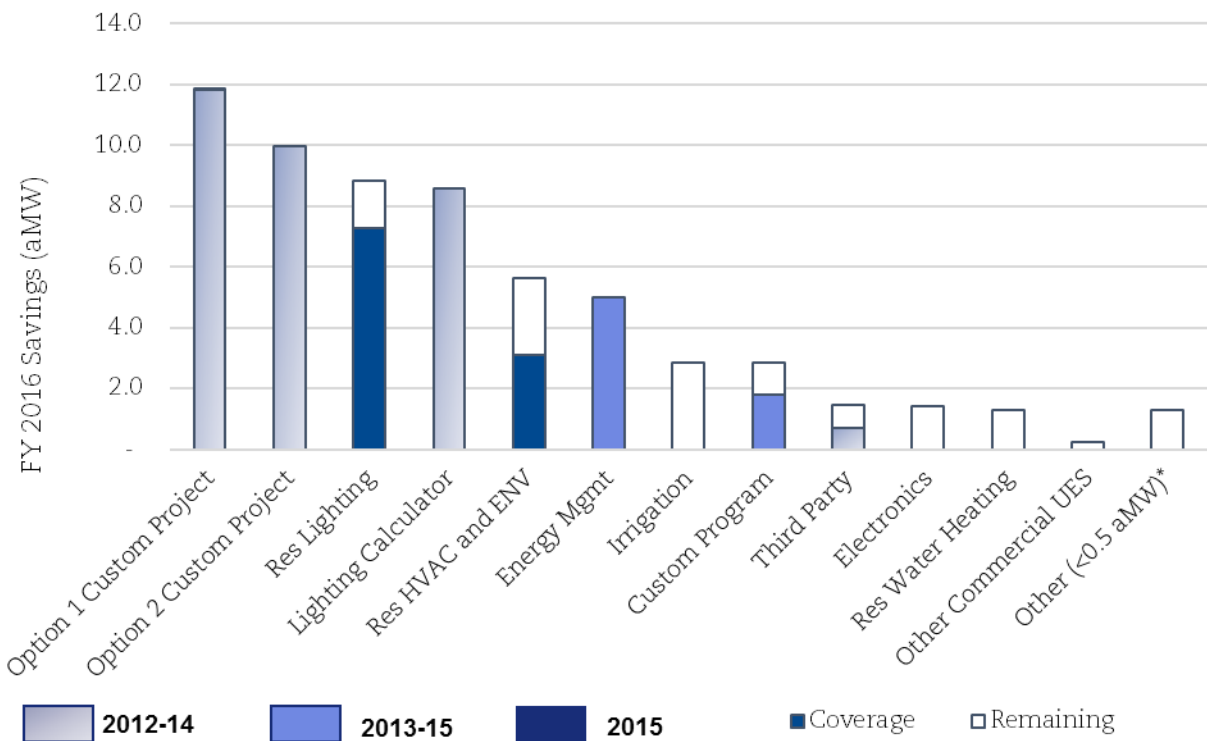


\* Savings from Energy Smart Grocers deemed measures are not included in this summary.  
 Source: Navigant analysis summarized from BPA's IS2.0 data extract, accessed 12/10/2017

## 1.2. CY2017 UES Impact Evaluation

To select the next set of measure groups to evaluate, the team first considered the existing evaluation coverage of the UES portfolio, as summarized in Figure 3.<sup>8</sup> The shading in this figure reflects whether an evaluation has been conducted and how recently. The darkest shading indicates the measure groups that have received the most recent (or even on-going) evaluations. White indicates measure groups that had not yet been evaluated through FY2015.

**Figure 3: Between 2012-2016, BPA has conducted impact evaluation on ~76% of its UES Portfolio**



\*Includes all measures that contribute <0.5 aMW each of FY-2015 savings  
 Source: Summarized evaluation coverage between FY2012-2016, shown using FY2016 IS2.0 savings data (aMW)

BPA identified many measure groups across the Residential, Agricultural and Industrial sectors to be evaluated during CY2017. Evaluating these measure groups will allow BPA to achieve roughly 85 percent coverage of the entire UES portfolio. These measure groups, organized by sector and size of savings, are listed in Table 1.

<sup>8</sup>This summary includes all evaluations that occurred between FY2012 and the present.

**Table 1: Evaluation Measure Groups Included in CY2017 Activities**

Sector	Evaluation Measure Group	RTF Measure Status*	Savings (aMW)**
Residential	Phase II CY2016 Residential HVAC and Envelope Billing Analysis	Mixed	5.72†
	HVAC Ductless Heat Pumps - Zonal	Proven	2.34
	Power Strips	Planning	1.54
	Water Heating - Showerheads	Proven	0.99
	Water Heating – Heat Pump Water Heater	Provisional	0.26
	State Grants - Low Income Weatherization <sup>9</sup>	Mixed	0.16
	Retail Sales Allocation Tool (RSAT)	N/A	N/A
Agricultural & Industrial	De-energization	Small Saver	0.20
	BPA Green Motors <sup>10</sup>	Small Saver	0.11

\* The RTF allows DV to be used as impact evaluation for Proven measures only. BPA and stakeholders felt that conducting document reviews of non-proven measure groups provides BPA with insight and may ultimately flag areas of additional research.

\*\* Summarized from FY2016 data included in an extract from IS2.0 dated 12/10/2017.

†FY2015 savings.

In addition to evaluating these measure groups, BPA together with stakeholders identified the following two research needs:

- **Retail Sales Allocation Tool (RSAT) review.** Confirm the current allocation methodology is still accurate and representative, and review allocation methods used by non-participating utilities.
- **Low-Income Weatherization State Grant claimed savings review.** Conduct a literature review of relevant low-income weatherization studies to provide BPA with insight into the veracity of current savings estimates for single and manufactured homes.

### 1.3. Residential HVAC PTCS Investigation

In this study, BPA also investigated whether certain residential HVAC measures could be evaluated using a similar method as used for the measure groups listed above. For the investigation, BPA identified six measure groups to be reviewed during CY2016-17. These measure groups, organized by the size of savings, are listed in Table 2.

<sup>9</sup> These savings are for FY2015 sourced from BOOM report for October 2016. These savings will be revised once the FY2016 savings are available.

<sup>10</sup> These savings are for FY2015 sourced from BOOM report for October 2016. These savings will be revised once the FY2016 savings are available.

**Table 2: Measure Groups included in Residential HVAC PTCS Investigation**

Sector & End Use	Measure Group	RTF Measure Status*	Savings (aMW)*
<b>Residential HVAC</b>	Air-Source Heat Pumps w/o Duct Sealing	Planning	0.93
	Prescriptive Duct Sealing	Planning	0.31
	Variable Speed Heat Pumps w/o Duct Sealing	Planning	0.19
	Ground-Source Heat Pumps w/o Duct Sealing	Proven	0.12
	PTCS Duct Sealing	Planning	0.08
	Commissioning Controls & Sizing	Planning	0.03

\*The RTF allows DV to be used as impact evaluation for Proven measures only. BPA and stakeholders felt that conducting document reviews of non-proven measure groups provides BPA with insight and may ultimately flag areas of additional research.

Source: Summarized from FY2016 data included in an extract from IS2.0 dated 12/10/2017

## 1.4. Study Objectives

The objectives for this study include:

- Evaluate the energy savings achieved for consistency with the savings claimed.
- Assess the cost-effectiveness of the evaluated savings using ProCost<sup>11</sup> and the updated 7th Plan inputs.
- Provide feedback to improve program operation and measures.
  - Where appropriate, assess savings to inform RTF or BPA Qualified estimates.
  - Develop recommendations on data collection, oversight and program procedures, including but not limited to documentation and data handling, to improve reliability and reduce cost for future evaluation years.
- Explore the use of existing program oversight for residential PTCS HVAC UES measures for the impact evaluation.

<sup>11</sup> ProCost is a model developed by the Northwest Power and Conservation Council and is used by the RTF to estimate the cost effectiveness of efficiency measures.

## 2. Methodology

This section describes the approach used to evaluate the impact of the selected UES measures. This methodology builds on the guidelines set forth in the Quality System Strategy & Implementation (QSSI) document, RTF Guidelines and the BPA Implementation Manual (IM).

### 2.1. Delivery Verification via Document Review

The evaluation team decided to conduct a document review for the measure groups included in this evaluation. This was the best approach for balancing contribution to savings, uncertainty, program needs and evaluation resources. Delivery verification requirements are defined by the RTF and include a pre-defined set of key measure specifications.<sup>12</sup> Per RTF Guidelines, document review can function as impact evaluation for Proven measures if delivery verification requirements are satisfied.<sup>13</sup> While not all sampled measure groups were Proven in FY2016, BPA and stakeholders felt that conducting document reviews of these measure groups provides BPA with insight and may ultimately flag areas of additional research.

For determining the per-unit energy savings to be assigned to each sampled project, the evaluation team referred to BPA's UES Measure List, which contains the deemed per-unit savings and specifications for all UES measures.<sup>14</sup> This list is updated regularly to reflect the region and BPA's most current savings estimates and assumptions. For the purposes of this evaluation, we verified savings using the UES measure list that was in place at the time of project delivery because this aligns to the savings that was reported in BPA's system.<sup>15</sup>

Each specific measure in the UES measure list is identified with a unique reference number (RefNo), and each line item in IS2.0 lists the RefNo associated with that project. In that way, the evaluation team was able to use the RefNo of the IS2.0 line item to assign a UES value to each sampled measure.

The evaluation team reviewed the required project documentation, defined delivery verification requirements and detailed UES specifications to assign one of the following three types of savings for each sampled project in the evaluation:

1. **Verified Savings.** If the evaluation team did not identify any discrepancies between the provided project documentation and the claimed utility savings, the team attributed full credit to each sampled project.

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<sup>12</sup>The detailed delivery requirements for each measure group are provided in the appendices.

<sup>13</sup>Regional Technical Forum, Roadmap for the Assessment of Energy Efficiency Measures, June 2014. <https://nwcouncil.box.com/s/qdr0wvbo4wrk8g9j5nmiklasmpqv41>

<sup>14</sup> BPA updates the UES measure list regularly. It is downloadable from the Interim Solutions 2.0 Files website. <https://www.bpa.gov/EE/Policy/Solutions/Pages/default.aspx>

<sup>15</sup> UES Measure List Version 4.1 was used for FY2016 UES measures. For FY2017 UES measures, the team used UES Measure List Version 5.1.

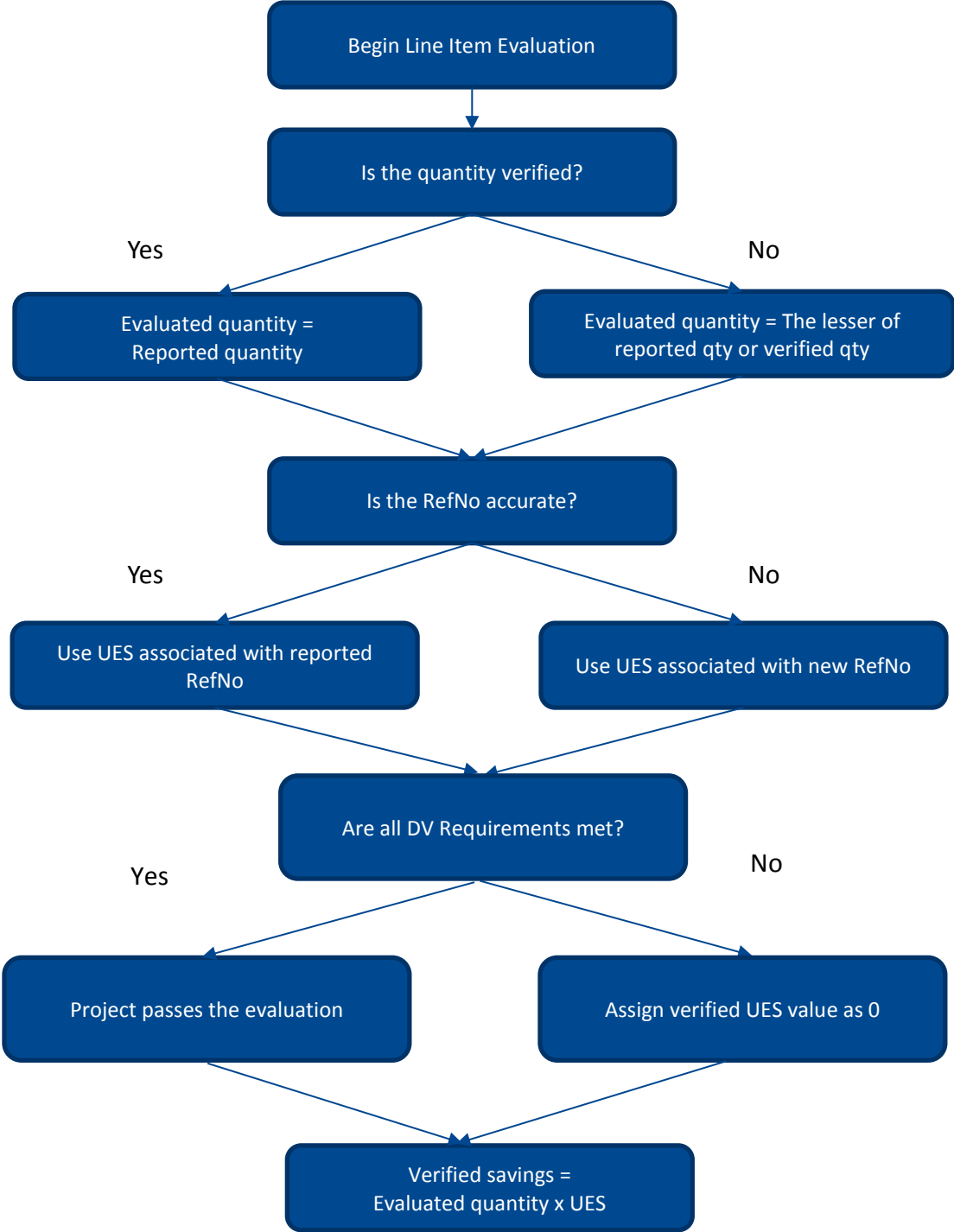
2. **Revised Savings.** If the evaluation team identified that the appropriate data were collected, but included minor discrepancies (e.g., different efficiency tier for Heat Pump Water Heaters) indicating that the utility had assigned the incorrect RefNo to the project, the team assigned evaluated savings using the appropriate UES value for each sampled project.<sup>16</sup>
3. **No Savings.** If the evaluation team identified that any project documentation was missing (e.g. the installation form), or, if the provided documentation indicated that one or more DV requirements are not satisfied, the team attributed zero credit to that project in the evaluation.

Figure 4 depicts this process visually.

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<sup>16</sup> Evaluated savings are presented in this report and included as the numerator in all realization rates calculated and shown herein. These evaluated savings were not used to replace or update the savings reported in IS2.0 or the BPA BOOM report.

Figure 4: Process for Verifying Savings Using Document Review-Based Delivery Verification



Source: Navigant

After awarding verified savings using the method described above, the evaluation team calculated the realization rate, defined as the evaluated savings divided by the reported savings. The team calculated a realization rate for each line item, each utility and the sample. Finally, the team calculated a realization rate for the overall population, extrapolated from the sample.<sup>17</sup>

## 2.2. UES Measures Impact Evaluation Approach

This section outlines the approach to sample design and data collection for the six measures covered in the impact evaluation: residential heat pump water heaters (HPWH), ductless heat pumps (DHP), advanced power strips (APSs), showerheads, agricultural transformer de-energization, and the Green Motors Rewind Initiative (GMRI).

### 2.2.1. Sample Design

BPA's QSSI policies have established a target for impact evaluation, striving for measure group-level evaluations to attain relative error of 10% at the 90% confidence level, with a minimum acceptable level of 80/20. The evaluation team sampling strategy targeted a 90/10 confidence and precision around this year's largest measure group, residential zonal DHP, and at least<sup>18</sup> 80/20 for the remaining smaller measure groups, attempting to reduce the number of utilities included in the evaluation, to minimize the burden on utilities and evaluation cost.

For residential zonal DHP<sup>19</sup> and residential HPWH, the evaluation team used a two-stage cluster sampling design, first sampling utilities, then sampling projects within each utility's participant population. The first stage sample of utilities was stratified by size, according to a common set of criteria:

- Large contributors, making up greater than 6% of a measure group, were all sampled (i.e., certainty sample).
- Small contributors, making up 0.25 or 0.5<sup>20</sup> to 6% of a measure group, were sampled randomly to meet confidence and precision objectives.
- Tiny contributors, including the smallest contributors with savings that sum to 5% of the savings or less, were excluded from the sample.

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<sup>17</sup> For Res HVAC UES Measures, the team calculated a realization rate for each project, each measure group and the whole sample. Finally, the team calculated a realization rate for the overall population for FY2016 reported data, extrapolated from the sample.

<sup>18</sup> Based on interest expressed in conversations with the BPA residential program team in December 2016, the evaluation team used 90/20 to determine the target sample size for the residential heat pump water heater measure group.

<sup>19</sup> Where possible, the evaluation team worked directly with the third party implementer to get project files.

<sup>20</sup> The evaluation team adjusted the threshold to 0.25 or 0.5%, on a case-by-case basis, in order to maintain 50-55% of total measure group level savings in the Small contributors.

Two additional steps were taken at the first-stage sample, to ensure representativeness and minimize burden.

1. To the extent possible, any utility drawn as a small contributor in FY2016 that received FY2015 evaluation was dropped and replaced.<sup>21</sup>
2. After the sample was drawn, representativeness quotas were checked to ensure that the random sample of utilities faithfully represented the overall FY2016 population.

After the utility sample was stratified and drawn, project-level samples were randomly drawn. The second stage of cluster sampling was performed differently for the large contributor stratum versus the small contributors, to optimize the sample efficiency.<sup>22</sup> For the large contributors, a stratified random sample of projects were pulled across all of the large contributors combined. For the small contributors, a random sample of project files weighted by the saving's contribution or a census of billing data was requested per utility. The project-level samples were stratified as necessary to effectively capture efficiency and representativeness of the population.

For the Green Motors, residential power strips, and residential showerheads measure groups, the evaluation team used stratified random sampling. In addition to having smaller populations, the savings varied significantly from one project to another within these measure groups due to the following reasons:

1. For Green Motors, savings vary according to the size of the motor.
2. For residential power strips and showerheads, many projects (a project is an individual row in the IS2.0 database) represent large batch orders which have significantly higher savings than the remaining projects which have single or <10 power strips batched together.

The evaluation team segmented the existing populations of projects within each of these three measure groups into three strata. These were large, medium, and small, each composing approximately one-third of the total energy savings of each measure group. The evaluation team randomly selected projects proportionately within each stratum.

Finally, for the de-energization measure group, the team evaluated a census of FY2016 projects. Table 3 summarizes the target sample design for the CY2017 evaluation activities by measure group.

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<sup>21</sup> FY2015 evaluation was conducted for Residential HVAC, Envelope and Lighting domains. The evaluation team tried to reduce utility burden where possible, and we do not currently believe this represented a bias to the sample.

<sup>22</sup> In general, a two-stage random sample design trades a reduction in the number of clusters drawn (in this case, utilities) for an increase in the number of individual projects drawn, unless the variability in the means of the clusters is higher than the variability in the means of the projects within a cluster. For the 2017 UES evaluation measure groups, the differences amongst the clusters (utilities) were not very large, compared to the differences between projects. In order to gain an efficiency from clustering, the realization rates of projects for a given utility would need to be consistently high or consistently low compared to another utility.



**Table 3. Sample Design for the CY2017 Impact Evaluation Activities**

Measure Group	Sampling Technique	Strata	Assumed CV	Number of Utilities	Target Number of Projects
Res - HVAC DHP Zonal (document review only)	Two Stage Cluster Sampling	Large Contributors	0.3	5	48
		Small Contributors	0.3	5	50
		<b>Subtotal</b>		<b>10</b>	<b>98</b>
Res - Power Strips	Stratified Random Sampling	<b>Subtotal</b>	0.3	<b>5</b>	<b>5*</b>
Res - Showerheads	Stratified Random Sampling	<b>Subtotal</b>	0.3	<b>9</b>	<b>9</b>
Res - Heat Pump Water Heater	Two Stage Cluster Sampling	Large Contributors	0.3	5	9
		Small Contributors	0.3	3	22
		<b>Subtotal</b>		<b>8</b>	<b>31</b>
Agricultural – De-energization	N/A	N/A	N/A	<b>3</b>	<b>3 (census)</b>
Agricultural - BPA Green Motors	Stratified Random Sampling	<b>Subtotal</b>	0.3	<b>N/A</b>	<b>9</b>

\*This measure group has comparatively smaller sample size because there is one line-item in the population representing ~9000 units and >40% of total savings for this measure group.

Source: Navigant analysis of complete FY2016 IS2.0 data, pulled on 03/07/2017

### 2.2.2. Life-cycle Cost-Effectiveness

For each sampled measure, the team used the RTF model ProCost<sup>23</sup> to estimate the lifetime sum of costs and benefits. This model implements the Total Resource Cost (TRC) methodology.

For each unique measure, our team selected a matching RTF measure from the corresponding measure workbook. Each of these measures inputs were reformatted from their existing formats to match the format of the *Seventh Power Plan*<sup>24</sup> workbooks. Our team then ran ProCost to determine the costs and benefits for each measure. The cost effectiveness for a given measure was then weighted by the claimed and evaluated measure quantities (Equation 1, Equation 2).

$$(1) \quad \text{Total Measure PVcost} = \text{Unit PVcost} * \text{Claimed Measures}$$

<sup>23</sup> ProCost is a model developed by the Northwest Power and Conservation Council and is used by the RTF to estimate the cost-effectiveness of efficiency measures.

<sup>24</sup> Seventh Power Plan (2016). <https://www.nwcouncil.org/energy/powerplan/7/plan/>

$$(2) \quad \textit{Total Measure PVbenefit} = \textit{Unit PVBenefit} * \textit{Verified Measures}$$

We calculated the cost effectiveness for a single measure or domain of measures using the following equation (Equation 3).

$$(3) \quad \textit{Benefit Cost Ratio} = \frac{\sum \textit{Total Measure PVbenefit}}{\sum \textit{Total Measure PVCost}}$$

To calculate the Total Resource Cost test (benefit divided by costs) for each domain and for the portfolio, the team used the sample case weights to calculate an appropriately weighted sum of costs and benefits. The team also calculated the Total Resource Cost test for each sampled measure excluding any non-electric benefits.

Agricultural De-Energization does not have an RTF measure workbook or defined load shape. Since the mix of end uses for these transformers was unknown, the team felt it was prudent to assume the TRC is the same as that for the least favorable relevant load shape in the Seventh Power Plan, i.e. irrigation measures.<sup>25</sup>

## 2.3. Literature Review of Low-Income Weatherization Studies

BPA supports utility low income weatherization programs by providing funding for home weatherization through state grants. BPA currently estimates savings per home weatherized through the program as 3,228 kWh per year for single-family homes and 2,000 kWh per year for manufactured homes.

The evaluation team analyzed the methodology and findings from relevant low-income weatherization evaluations, as well as the methodology and findings from the on-going billing analysis of residential weatherization measures, to provide BPA with insight into the reasonableness of the current assumptions. The complete list of sources and findings from this review, including a table of results and commentary on their applicability to the BPA region were presented to BPA in a memo, which is included in Appendix H.

## 2.4. Retail Sales Allocation Tool Review

In November 2011, BPA contracted with Portland Energy Conservation Inc. (PECI)—now called CLEAResult—to build the Retail Sales Allocation Tool (RSAT). The goal of the project was to provide public and investor-owned utilities in BPA’s region with a dynamic tool that provides percentage allocation, by utility service territory, of sales of energy efficient retail products from a variety of retail outlets.

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<sup>25</sup> In the Seventh Power Plan under default parameters, the least favorable load shape is used for irrigation measures.

Based on the Simple Steps process evaluation<sup>26</sup> and recently completed residential lighting impact evaluation<sup>27</sup>, BPA identified the following research opportunities regarding the RSAT:

- Confirm the current allocation methodology is still accurate and representative
- Review allocation methods used by non-participating utilities

The evaluation team reviewed all available documentation and provided BPA a memo summarizing our findings. This memo is provided in Appendix I.

## 2.5. Residential HVAC PTCS Measures Investigation Approach

At the outset of this study, BPA intended to investigate whether an impact evaluation could be conducted for certain residential HVAC PTCS measures. The evaluation team applied many of the same approaches to delivery verification via document review as in the previous section. The approaches, including sample design and data collection, are described below.

### 2.5.1. Background - PTCS Oversight and Quality Assurance (QA) Inspections

BPA categorizes all the measure groups selected in this Res HVAC investigation (except Prescriptive Duct Sealing measures) as Performance Tested Comfort System (PTCS) measures. These measures involve performance testing before and after installation and can only be installed by a PTCS certified technician. As a part of the oversight on these installed PTCS measures, BPA already has a dedicated PTCS team which samples random projects every month and performs Quality Assurance (QA) inspections on these sampled projects. More information on this oversight and QA inspection approach and data collection is provided in Appendix J.

There is a significant overlap between data being collected as a part of the PTCS installation<sup>28</sup> and the oversight process and data needs for an evaluation. Thus, to increase the efficiency, the evaluation team investigated an approach to leverage the ongoing PTCS oversight process to evaluate the selected measure groups. The evaluation team worked directly with the PTCS team to obtain the required data.

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<sup>26</sup> Navigant, Simple Steps Smart Savings Process Evaluation, September 2016, [https://www.bpa.gov/EE/Utility/research-archive/Documents/Evaluation/160808\\_Final\\_Simple\\_Steps\\_Report.pdf](https://www.bpa.gov/EE/Utility/research-archive/Documents/Evaluation/160808_Final_Simple_Steps_Report.pdf)

<sup>27</sup> Navigant, Impact Evaluation of FY2015 UES Residential Lighting Projects, February 2017 [https://www.bpa.gov/EE/Utility/research-archive/Documents/Evaluation/170215\\_BPA\\_Evaluation\\_UES\\_Res\\_Lighting\\_Report.pdf](https://www.bpa.gov/EE/Utility/research-archive/Documents/Evaluation/170215_BPA_Evaluation_UES_Res_Lighting_Report.pdf)

<sup>28</sup> PTCS Installation forms are filled out and submitted at the time of the measure implementation as a part of the BPA Implementation Manual document requirements for these measures. During QA inspections as a part of PTCS Oversight, QA inspectors fill out QA/QC forms for the selected project.

## 2.5.2. Sample Design

Based on a review of fiscal year (FY) 2016 IS2.0 data and expected variation, the evaluation team estimated the number of projects required to represent each measure group with an overall confidence and precision target of 90/10.

The evaluation team also looked at 20 prescriptive duct sealing projects to understand the feasibility of this approach to evaluate such projects in the future.<sup>29</sup>

Table 4 outlines this sample design.

**Table 4. Investigation Sample Design**

Measure Group	Population* (FY2016 IS2.0)	Assumed Coefficient of Variation	Target Sample
Performance Duct Sealing	292	0.5	60
Prescriptive Duct Sealing	1451	NA	~20**
Heat Pumps (incl. ASHP, VSHP, and GSHP)	1641	0.5	70
Commissioning Controls & Sizing (CCS)	129	0.3	25

\*Unique Measure IDs

\*\*Not a statistically significant sample. Rather a small number of projects were reviewed to determine feasibility to conduct delivery verification via document review in future years.

Source: Navigant analysis

Based on the evaluation team's review of the overlap that exists between QA inspections and projects reported into IS2.0 in previous fiscal years<sup>30</sup>, the evaluation team estimated that the number and distribution of QA inspections planned for calendar year 2017 by the PTCS QA team were sufficient to satisfy the investigation sample design.

Table 5 shows the investigation sample quotas per region based on FY2016 IS2.0 data.

<sup>29</sup> The savings achieved by prescriptive duct sealing projects are currently being analyzed via the on-going billing analysis of residential HVAC and envelope measures. Details on that evaluation can be found in the evaluation plan located online at [https://www.bpa.gov/EE/Utility/research-archive/Documents/Evaluation/BPA\\_UES\\_Evaluation\\_Plan\\_FINAL\\_04012016\\_V3.pdf](https://www.bpa.gov/EE/Utility/research-archive/Documents/Evaluation/BPA_UES_Evaluation_Plan_FINAL_04012016_V3.pdf)

<sup>30</sup> The evaluation team reviewed the QA/QC visits data and IS2.0 data for FY2014 and 2015. The analysis revealed that there are at least 50% of the sites receiving PTCS QA/QC visits are reported in the IS2.0 database.

**Table 5. Investigation Sample Design – Regional Quotas**

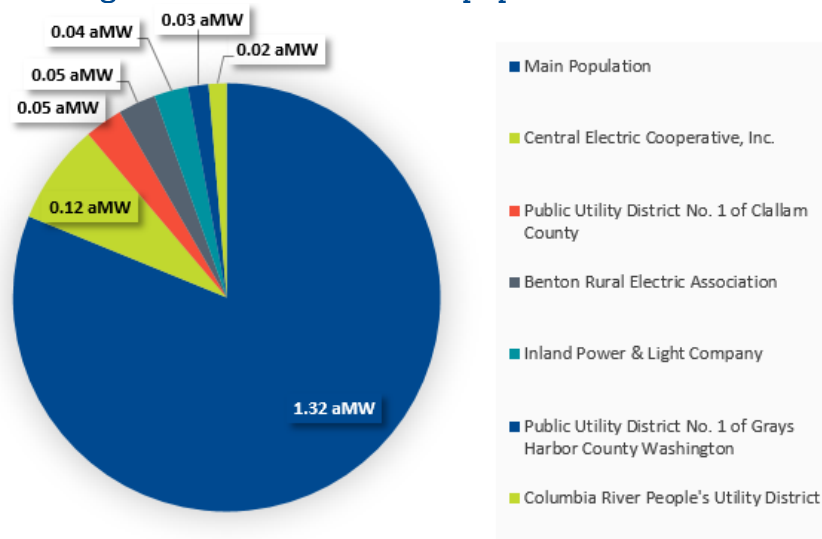
Region	Sample Size Quota by Region				
	CCS	Heat Pumps - All Other	Performance Duct Sealing	Prescriptive Duct Sealing	Total
Bend	0	3	4	0	7
Central WA Route 2016	1	16	11	0	28
Eugene/Springfield	1	5	16	1	23
I-84	1	9	15	1	26
ID	4	3	0	0	7
MT	0	16	1	0	17
Oregon Coast	0	1	1	2	4
Oregon Coast – almost	0	1	2	0	3
Portland Metro	21	18	11	4	54
Puget Sound	0	2	4	12	18
S. OR	0	1	1	0	2
<b>Grand Total</b>	<b>28</b>	<b>75</b>	<b>66</b>	<b>20</b>	<b>189</b>

Source: Navigant’s sample calculations

**2.5.2.1. Utilities Excluded from the 2016 Investigation**

There are six utilities in the BPA portfolio which conduct their own QA inspections. The evaluation team designated these six utilities as a sub-population. After discussions with the BPA PTCS team, the evaluation team decided to exclude this sub-population from the investigation. Figure 5 shows that these six utilities from the sub-population contribute to about 25% of the residential performance HVAC measure savings for FY2016.

**Figure 5: Savings from Main versus Subpopulation – FY2016 IS2.0 Data**



Source: Summarized from FY2016 data included in an extract from IS2.0 dated 12/10/2017

### 2.5.3. Approach

The team adopted the unique approach of leveraging program oversight for document review of the PTCS measures, which was done for the first time.

As summarized in Table 6, the evaluation team used delivery verification to estimate the impacts of select residential performance HVAC measures. Not all measures included in these measure groups were Proven, and therefore, they could not be evaluated using delivery verification alone. However, the existing measures that were in the Planning category were there due to a lack of baseline research for commissioning, controls and sizing, which BPA was undertaking separately. To minimize burden on customer utilities and leverage research being conducted, the evaluation team used delivery verification to preliminarily investigate the savings from these measure groups.

**Table 6. Residential HVAC Measures CY2017 Investigation Approach Summary**

Fiscal Year	Measure Group	Measure Status <sup>31</sup>	Proposed Approach	Data Sources
2016/17	Performance Duct Sealing	Planning	Delivery verification	<ul style="list-style-type: none"> <li>▪ IS2.0</li> <li>▪ PTCS Site Registry</li> <li>▪ Installation Forms</li> <li>▪ Inspection Forms</li> </ul>
2016/17	Heat Pumps	Mixed <sup>32*</sup>		
2016/17	Commissioning, Controls & Sizing	Planning		

Source: Navigant review

\* Ground Source Heat Pump measures have RTF Measure Status as “Proven”.

This approach attempted to verify measure delivery via verification of a pre-defined set of key measure parameters which are provided by RTF. The evaluation team determined that the data collected across the most current versions of the PTCS installation and inspection forms (discussed in Appendix J) were sufficient to satisfy the delivery verification requirements for the selected measures.

Table 7 provides an example of the delivery verification requirements and existing data sources for ground source heat pump projects.

**Table 7. Using Existing Data for DV - Ground-Source Heat Pumps<sup>33</sup>**

DV Component	Specification	DV Requirement Checklist	Data Source
	Measure Type	Check measure type (including upgrade	QA/QC Form <sup>34</sup>

<sup>31</sup> Measure Status - In the RTF Guidelines, a measure’s category defines the savings estimation that should be used to evaluate savings. The RTF approves three measure categories within the UES portfolio; Proven, Provisional and Other.

<sup>32</sup> This measure group has a mix of Proven and Planning Measure Statuses.

<sup>33</sup> The Delivery Verification requirement for this measure can be found at RTF website using following link: <https://nwcouncil.box.com/s/xpuvq0kgwnego43l256ky7iyu6sy60m9>. In general, DV requirement for the selected measures included in this evaluation can be found in the measure workbooks available on RTF website: <https://rtf.nwcouncil.org/measures>.

DV Component	Specification	DV Requirement Checklist	Data Source
Measure Identifiers		vs conversion, with desuperheater or without, with CAC or without CAC)	
	Climate Zone	Check climate zone (Heating zone 2 or 3, any cooling zone)	Can be derived from QA/QC Form
	House Size	Check house size (<4000 sq.ft. or ≥ 4000 sq.ft.)	QA/QC Form
	House Vintage	Check house vintage (new construction or retrofit)	PTCS Installation Form
Savings Baseline	Pre-Conditions	Check previous heating system was either ASHP or electric FAF	QA/QC Form
		If applicable, check existing water heater was an electric tank without desuperheat	QA/QC Form
Implementation and Product Standards	Installation Specification	Check if GSHP is installed	QA/QC Form
		If applicable, check that electric water heater with desuperheat pre-heating is installed	QA/QC Form

Source: RTF, Navigant analysis

#### 2.5.4. Data Collection

The evaluation team determined that no additional data was required for this investigation beyond that already collected by the PTCS team as a part of installation and oversight process. The evaluation team collaborated with PTCS program team to update the PTCS QA forms before the recent rounds of PTCS QA inspections which started in January 2017.

As outlined in Appendix K, the evaluation team worked directly with the PTCS team to receive regular data exports from the Site Registry, as well as electronic copies of completed installation and inspection forms for the sampled sites.

The evaluation team created a comprehensive workbook housing all relevant data required and collected for each sampled project.

## 3. Results

This section provides the detailed results of the impact evaluation of the sampled measure groups, and includes results from the research activities into the savings claimed by the Low-Income Weatherization State Grant program and the RSAT

<sup>34</sup> QA/QC Inspection forms revised on January 16, 2017. Per discussion with the third party contractor, this version of the QA inspection forms would be in use beginning February 2017.

methodology. Finally, the evaluation team presents the results of the initial investigation into residential HVAC PTCS measures.

### 3.1. UES Measures Impact Evaluation Results

#### 3.1.1. Ductless Heat Pumps - Zonal

The evaluation team calculated an overall realization rate of 0.95 for residential DHPs in zonal electric heat applications.

**Table 8: Summary of Results for the DHP (Zonal) Measure Group**

Measure	Reported Savings (aMW)	Evaluated Savings (aMW)	Population-Level Realization Rate
Ductless Heat Pump – Zonal	2.09	1.99 <sup>a</sup>	0.95 <sup>a</sup>

a. One utility's install form did not directly indicate if the unit was installed in a main living area, a precondition of the DHP Zonal Program as per the RTF delivery verification requirements. The documentation indicates that the install location was indoors, which is assumed to constitute a main living space for the purposes of this report. The values presented in this table for evaluated savings and population-level realization rate are based on this assumption.

Source: Navigant analysis

The installations verified for one of the utility territories were found to be incomplete in some regards. Consistently, the installation forms installed from that utility's territory did not directly indicate that the measure was installed in a "main living area" as defined by the RTF delivery verification requirements. In the installation form, there is an area that references that installation is required in a main living area (Figure 6) adjacent to check boxes for Rebate, Loan, and/or Grant, but for some of the forms, none of the boxes was checked, although the form was being used to receive a rebate for the ductless heat pump. It is not clear if the form, as designed and filled out, is sufficient to determine that the system is eligible under the RTF requirements.

**Figure 6: Example Ductless Heat Pump Installation Form (Partial)**

Product	Requirements (see KnowYourPower.com/forms)	Rebate	Loan	Grant	Contractor Information
Duct sealing	Duct system must meet minimum leakage requirements. A certified Performance Tested Comfort Systems (PTCS) technician must test and seal ductwork to program standards.	<input checked="" type="checkbox"/>	n/a	n/a	Company name Phone
Central heat pump system	New system must be primary heating system. A certified PTCS technician must test and certify the new system. For the highest incentive amount, equipment must be minimum 9.0 HSPF and 14 SEER. Ducts must be sealed to program standards.	<input type="checkbox"/>	n/a	n/a	Company name Phone
Ductless heat pump	Home must be at least one year old, occupied year round, insulated to minimum program standards, and have zonal heating such as baseboard wall heater. System must be installed in the main living area by a manufacturer-certified and trained technician listed at nwductless.com. "Basic install" cost cannot exceed \$3,500 before sales tax. HOME MUST BE OWNER-OCCUPIED FOR GRANT. <b>NOT ELIGIBLE: Manufactured homes; homes with central forced air, oil or gas heating systems.</b>	<input type="checkbox"/>	or <input type="checkbox"/>	or <input type="checkbox"/>	Company name Phone

Source: Utility Installation Form



The documentation provided by the utility did, however, indicate that the ductless heat pumps were installed at an indoor location. For the purposes of this report, Navigant assumed that this evidence, coupled with the stated requirement on the form that the system must be installed in the main living area to receive a rebate, was sufficient to show that the system met this requirement. It is recommended that Bonneville move towards alignment with the RTF requirements for future installations, whether by updating the form or by requesting that the RTF change their requirements.

Excluding ambiguity in the installation forms, the primary reasons realization rates were less than 1.0 overall were incomplete installation forms or ineligible installation locations. A project received zero savings if not all RTF delivery verification requirements were met.

Table 9 provides a detailed breakdown of the evaluated savings, segmented by sample strata.

**Table 9: Detailed Savings Breakdown for the DHP-Zonal Measure Group**

Domain	Realization Rate	Relative Precision	Reported Savings (aMW)	Evaluation Savings	
				aMW	% of Portfolio
DHP	0.93	4.4%	0.93	0.87	44%
Zonal	0.97	1.9%	1.09	1.05	53%
		Not Sampled <sup>a</sup>	0.07	0.07	3%
<b>Overall</b>	<b>0.95</b>	<b>2.7%</b>	<b>2.09</b>	<b>1.99</b>	<b>100%</b>

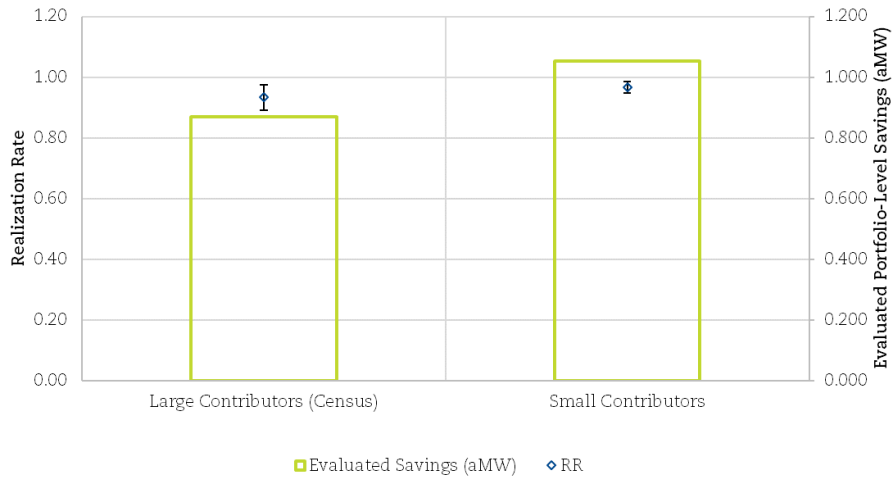
a. Sample strata that were deemed small enough to be excluded from sample set were assigned the overall realization rate and a relative precision of 50% in order to calculate evaluated savings.

Source: Navigant analysis

#### 3.1.1.1. Key Drivers

As shown in Figure 7, the evaluated savings by strata were 0.87 and 1.05 average megawatts for large contributors and small contributors, respectively. The lower evaluated savings were primarily provided by large contributors.

**Figure 7: Evaluated Savings and Realization Rate by Sample Strata for DHP Zonal UES Measure**



Source: Navigant analysis

### 3.1.1.2. Cost-Effectiveness

Using ProCost and the adjusted savings values, where necessary, the evaluation team calculated updated cost-effectiveness based upon a Total Resource Cost (TRC) ratio defined as the ratio of benefits to costs. A TRC ratio greater than one indicates that the measure is cost-effective as the benefits outweigh the costs of implementation. Table 10 presents the benefits, costs, and TRC ratio for the Ductless Heat Pumps (Zonal) measure group.

**Table 10: Cost-Effectiveness of the Ductless Heat Pumps (Zonal) Measure Group**

Measure Group	Delivery Mechanism	Present Value of Benefits	Present Value of Costs	Total Resource Benefit/Cost Ratio
Ductless Heat Pumps (Zonal)	-	\$939,161	\$487,616	1.93

Source: Navigant ProCost Analysis

### 3.1.2. Advanced Power Strips

The evaluation team calculated an overall realization rate of 1.0 for the advanced power strips measure. This overall realization rate is based upon the sampled savings using project documentation provided by the third-party implementer data for the advanced power strips measure.

During verification, evaluators found the delivery mechanism reported by one of the utilities to be difficult to verify. For all advanced power strips measures sampled, the utility reported a 'By-Request' delivery mechanism. Upon review during the evaluation process, all advanced power strips measures sampled were found to have documentation confirming delivery of the measure, but the documentation was ambiguous as to whether the measures were delivered using the 'By-Request' or the 'Direct Install' delivery mechanism. Albeit the ambiguity in delivery mechanism, the

defined energy saving *did not* change as per the Unit Energy Savings (UES) Measures List between direct install or by-request delivery mechanism. Therefore, Navigant deemed the savings valid (and assumed that the evaluated delivery mechanism was also ‘By-Request’), with the recommendation that the utility review reporting procedures for measure delivery mechanism.

**Table 11: Summary of Results for Residential Advanced Power Strips**

Savings Channel	Reported Savings (aMW)	Evaluated Savings (aMW)	Population-Level Realization Rate
By-Request	0.81	0.81	1.00
Direct Install	0.20	0.20	1.00
<b>Overall</b>	<b>1.04</b>	<b>1.04</b>	<b>1.00</b>

Source: Navigant analysis

Table 12 provides a detailed breakdown of the evaluated savings, segmented by sample strata.

**Table 12: Detailed Savings Breakdown for Residential Advanced Power Strips**

Domain		Realization Rate	Relative Precision	Reported Savings (aMW)	Evaluation Savings		RR of Meas. Group	Relative Precision of Meas. Group
Delivery Mechanism	Size Strata				aMW	% of Portfolio		
By-Request	Large	1.000	N/A <sup>a</sup>	0.34	0.34	32%	1.000	0.67% <sup>c</sup>
	Med	0.960	N/A <sup>a</sup>	0.33	0.33	31%		
	Small	1.000	N/A <sup>b</sup>	0.13	0.13	13%		
	Tiny	Not Sampled <sup>d</sup>		0.01	0.01	1%		
Direct Install	Small	0.998	0.48%	0.18	0.18	17%	0.998	5.57%
	Tiny	Not Sampled <sup>d</sup>		0.01	0.01	1%		
	Med	Not Sampled <sup>d</sup>		0.03	0.03	3%		
Retail	Small	Not Sampled <sup>d</sup>		0.01	0.01	1%		
	Tiny	Not Sampled <sup>d</sup>		0.002	0.002	0.2%		
<b>Overall</b>				<b>1.04</b>	<b>1.04</b>	<b>100%</b>	<b>1.000</b>	<b>1.60%</b>

b. All of the projects in these strata were sampled; therefore, a relative precision could not be calculated.

c. Too few projects in these strata were sampled for a relative precision to be calculated.

d. A relative precision of zero indicates either census-level results or approaching census-level results.

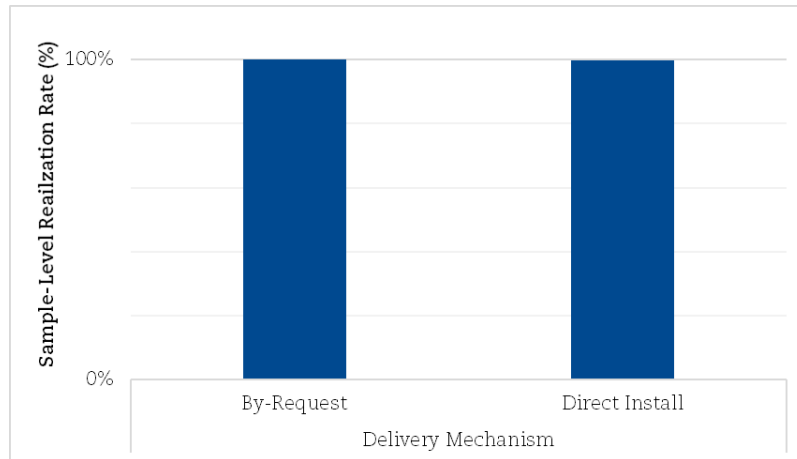
e. Sample strata that were deemed small enough to be excluded from sample set were assigned the overall realization rate and a relative precision of 50% in order to calculate evaluated savings.

Source: Navigant

### 3.1.2.1. Key Drivers

As seen in Figure 8, the realization rates for the advanced power strips measure were 100.0% and 99.8% for By-Request and Direct Install, respectively.

**Figure 8: Advanced Power Strip Realization Rate by Delivery Mechanism**

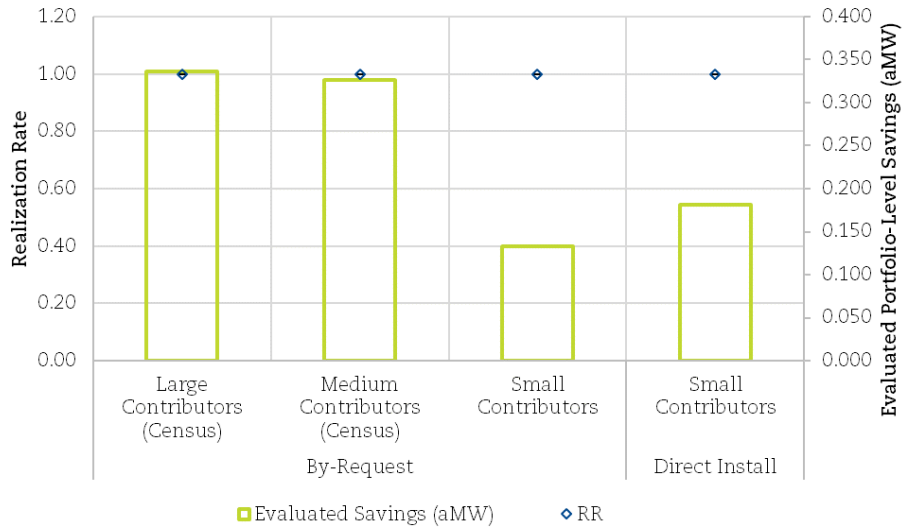


Source: Navigant analysis

The realization rate for the direct install of advanced power strips was less than 100% primarily due to discrepancies in the reported and verified quantity of installed power strips.

Figure 9 provides the evaluated savings (aMW) and realization rate at the more granular level. The savings verified for the By-Request delivery type were primarily provided by one large contributor in a single utility's territory. The savings attributed to the Direct Install delivery mechanism are relatively evenly distributed with the majority coming from medium sized contributions.

**Figure 9: Evaluated Savings and Realization Rate by Sample Strata for Residential Advanced Power Strips**



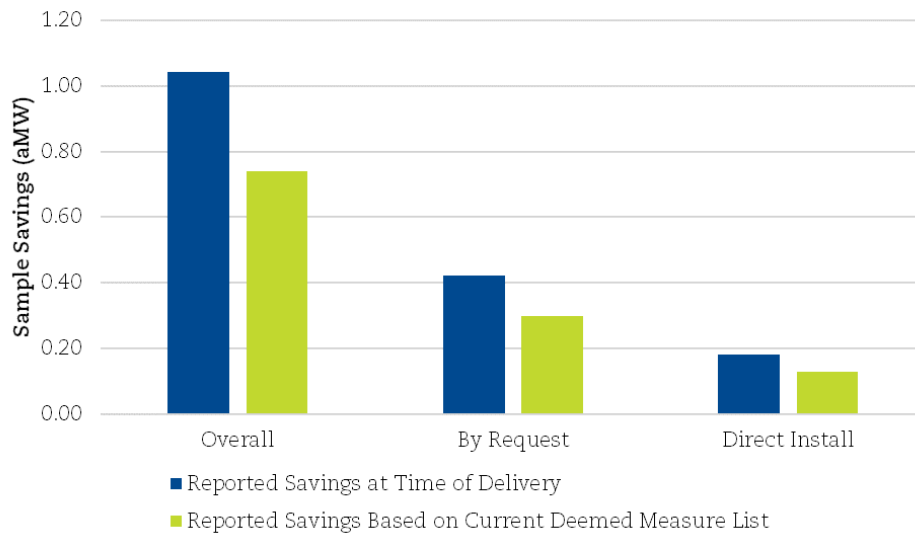
Source: Navigant analysis

### 3.1.2.2. Measure Changes

As described above, the deemed savings BPA assigns to its UES measures change over time and are stored in the UES Measure List BPA maintains. In FY2016, advanced power strips UES measures referenced version 4.1 of the UES Measure List.

To understand the impact of changes made to the deemed savings values for the sampled advanced power strips measures, the evaluation team recalculated reported savings using the most current UES Measure List, version 6.0. Figure 10 shows the impact of the variations in UES savings for advanced power strips measures. Deemed savings decreased proportionally across each delivery mechanism.

**Figure 10: Effect of Deemed Measure List Changes for Residential Advanced Power Strips**



Source: Navigant analysis

### 3.1.2.3. Cost-Effectiveness

Using ProCost and the adjusted savings values, where necessary, the evaluation team calculated updated cost-effectiveness based upon a Total Resource Cost (TRC) ratio defined as the ratio of benefits to costs. A TRC ratio greater than one indicates that the measure is cost-effective as the benefits outweigh the costs of implementation. Table 13 presents the benefits, costs, and TRC ratio for the Advanced Power Strips measure group.

**Table 13: Cost-Effectiveness of Residential Advanced Power Strips**

Measure Group	Delivery Mechanism	Present Value of Benefits	Present Value of Costs	Total Resource Benefit/Cost Ratio
Advanced Power Strips	By-Request	\$8,412,458	\$4,863,688	1.73
	Direct Install	\$234,834	\$98,683	2.38
	Retail	Not Sampled		
	Measure Total	\$8,647,293	\$4,962,371	1.74

Source: Navigant ProCost Analysis

### 3.1.3. Showerheads

As shown in Table 14, the evaluation team calculated an overall realization rate of 1.0 for the showerheads UES measure. This overall realization rate is based upon the sampled savings using project documentation provided by the third-party implementer data for the showerheads measure.

**Table 14: Summary of Results for Residential Showerheads**

Savings Channel	Reported Savings (aMW)	Evaluated Savings (aMW)	Population-Level Realization Rate
By-Request	0.66	0.66	0.998*
Direct Install	0.07	0.07	1.00
Retail	0.21	0.21	1.00
<b>Overall</b>	<b>0.94</b>	<b>0.94</b>	<b>1.00</b>

\*Navigant provides an extra significant figure in this estimate to show the very slight difference from 1.0.  
Source: Navigant analysis

Table 15 provides a detailed breakdown of the evaluated savings, segmented by sample strata.

**Table 15: Detailed Savings Breakdown of Residential Showerheads**

Domain	Realization Rate	Relative Precision	Reported Savings (aMW)	Evaluation Savings	RR of Meas. Group	Rel. Prec. of Meas. Group	
Delivery Mechanism	Size Strata			aMW	% of Portfolio		
By-Request	Certainty	1.00	N/A <sup>a</sup>	0.20	0.20	22%	0.997
	Large	1.00	N/A <sup>b</sup>	0.22	0.22	23%	
	Med	0.99	0.59%	0.15	0.15	16%	
	Small	Not Sampled <sup>d</sup>		0.08	0.08	9%	
	Tiny	Not Sampled <sup>d</sup>		0.01	0.01	1%	
Direct Install	Med	1.00	N/A <sup>b</sup>	0.02	0.02	2%	0.996
	Small	0.99	1.38%	0.04	0.04	4%	
	Tiny	Not Sampled <sup>d</sup>		0.005	0.005	1%	
Retail	Large	1.00	N/A <sup>b</sup>	0.03	0.03	3%	0.9992
	Med	Not Sampled <sup>d</sup>		0.07	0.07	7%	
	Small	1.00	N/A <sup>b</sup>	0.10	0.10	10%	
	Tiny	Not Sampled <sup>d</sup>		0.01	0.01	2%	
<b>Overall</b>			<b>0.94</b>	<b>0.93</b>	<b>100%</b>	<b>0.936</b>	<b>5.71%</b>

a. All of the projects in these strata were sampled; therefore, a relative precision could not be calculated.

b. Too few projects in these strata were sampled for a relative precision to be calculated.

c. A relative precision of zero indicates either census-level results or approaching census-level results.

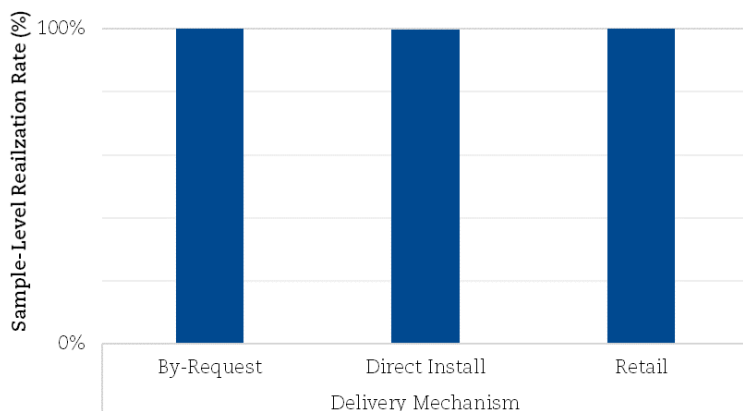
d. Sample strata that were deemed small enough to be excluded from sample set were assigned the overall realization rate and a relative precision of 50% in order to calculate evaluated savings.

Source: Navigant

### 3.1.3.1. Key Drivers

As seen in Figure 11, the realization rates for the showerheads measure were 100%, 100% and 99.8% for Retail, By-Request and Direct Install, respectively. The realization rate for the direct install of showerheads was less than 100% primarily due to discrepancies in the reported and verified quantity of installed showerheads.

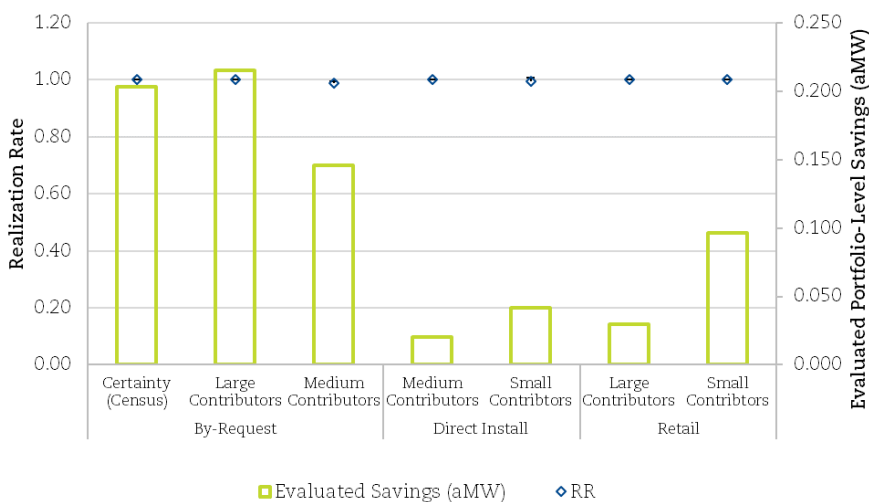
**Figure 11: Showerheads Realization Rate by Delivery Mechanism**



Source: Navigant analysis

Figure 10 provides the realization rate at the more granular level. The total evaluated savings by delivery mechanism were 0.21, 0.66 and 0.07 average megawatts for Retail, By-Request and Direct Install, respectively. The majority of savings is derived from the by-request delivery type.

**Figure 12: Evaluated Savings and Realization Rate by Sample Strata for Residential Showerheads**



Source: Navigant analysis

### 3.1.3.2. Measure Changes

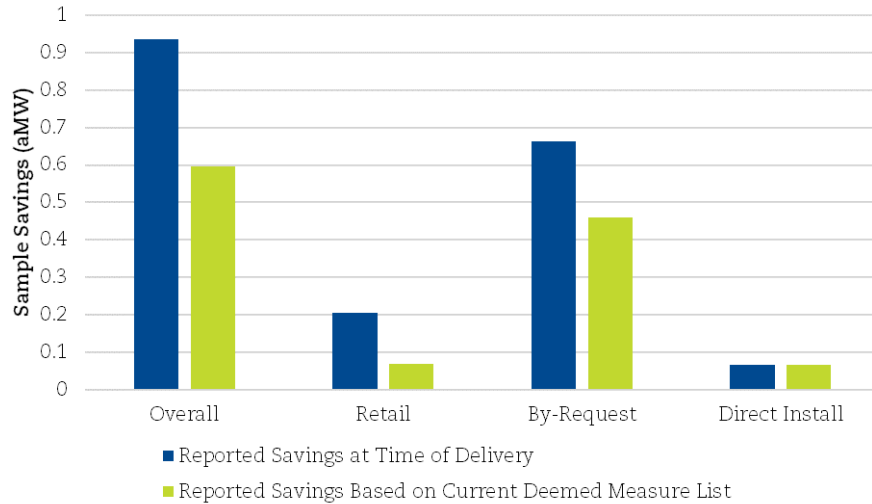
As described above, the deemed savings BPA assigns to its UES measures change over time and are stored in the UES Measure List BPA maintains. In FY2016, showerheads UES measures referenced version 4.1 of the UES Measure List.

In order to understand the impact of changes made to the deemed savings values for the sampled showerheads measures, the evaluation team recalculated evaluated savings using the most current UES Measure List, version 6.0. Figure 13 shows the



impact of the variations in UES savings for showerheads measures. Deemed savings decreased for retail and by-request measures, but remained consistent for directly installed measures.

**Figure 13: Effect of Deemed Measure List Changes for Residential Showerheads**



Source: Navigant analysis

### 3.1.3.3. Cost-Effectiveness

Using ProCost and the adjusted savings values, where necessary, the evaluation team calculated updated cost-effectiveness based upon a Total Resource Cost (TRC) ratio defined as the ratio of benefits to costs. A TRC ratio greater than one indicates that the measure is cost-effective as the benefits outweigh the costs of implementation. Table 16 presents the benefits, costs, and TRC ratio for residential showerheads.

**Table 16: Cost-Effectiveness of Residential Showerheads**

Measure Group	Delivery Mechanism	Present Value of Benefits	Present Value of Costs	Total Resource Benefit/Cost Ratio
Showerheads	By-Request	\$6,171,671	\$474,484	13.01
	Direct Install	\$195,286	\$13,522	14.44
	Retail	\$291,694	\$29,467	9.90
	Measure Total	\$6,658,650	\$517,474	12.87

Source: Navigant ProCost Analysis

### 3.1.4. Heat Pump Water Heaters

As shown in Table 17, the evaluation team calculated an overall realization rate of 1.11 for residential HPWHs. The primary reason that the realization rate was not equal to one were discrepancies in the reported versus verified install location and efficiency tier. The evaluation team found that some utilities were conservatively reporting

efficiency tiers of HPWHs. When the correct, higher tier was applied, this led to higher evaluated savings than reported; i.e., realization rates greater than 1.

**Table 17: Summary of Results for Residential Heat Pump Water Heaters**

Measure	Reported Savings (aMW)	Evaluated Savings (aMW)	Population-Level Realization Rate
Heat Pump Water Heater	0.23	0.25	1.11

Source: Navigant analysis

Table 18 provides a detailed breakdown of the evaluated savings, segmented by sample strata.

**Table 18: Detailed Savings Breakdown for Residential Heat Pump Water Heaters**

Domain		Realization Rate	Relative Precision	Reported Savings (aMW)	Evaluation Savings	RR of Meas. Group	Relative Precision of Meas. Group
Delivery Mechanism	Size Strata				aMW	% of Portfolio	
	Large	1.09	7.6%	0.09	0.10	40%	
By-Request	Small	1.11	15.3%	0.13	0.14	55%	1.11
	Tiny	Not Sampled <sup>a</sup>		0.01	0.01	4%	
<b>Overall</b>				<b>0.23</b>	<b>0.25</b>	<b>100%</b>	<b>1.11</b>
							<b>7.0%</b>

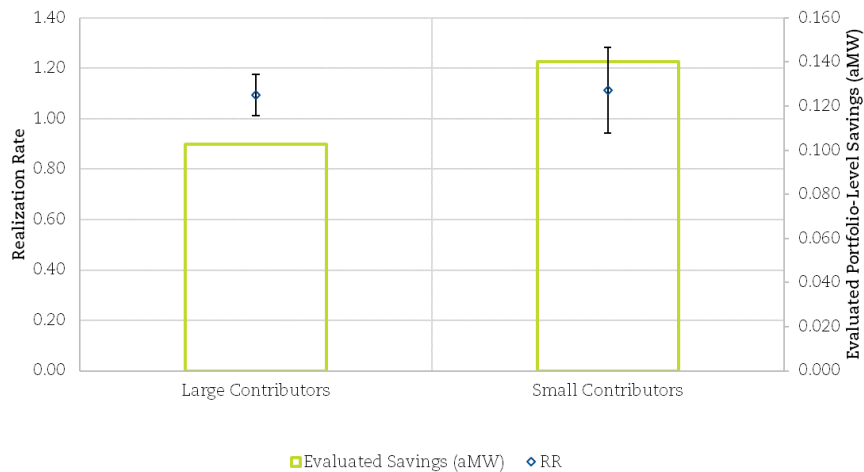
a. Sample strata that were deemed small enough to be excluded from sample set were assigned the overall realization rate and a relative precision of 50% in order to calculate evaluated savings.

Source: Navigant analysis

#### 3.1.4.1. Key Drivers

Figure 14 provides the evaluated savings (aMW) and realization rate at the more granular sample strata level. The total evaluated savings by strata were 0.10 and 0.14 average megawatts for large contributors and small contributors, respectively. The savings verified were primarily provided by large contributors.

**Figure 14: Evaluated Savings and Realization Rate by Sample Strata for Residential Heat Pump Water Heaters**



Source: Navigant analysis

### 3.1.4.2. Cost-Effectiveness

Using ProCost and the adjusted savings values, where necessary, the evaluation team calculated updated cost-effectiveness based upon a Total Resource Cost (TRC) ratio defined as the ratio of benefits to costs. A TRC ratio greater than one indicates that the measure is cost-effective as the benefits outweigh the costs of implementation. Table 19 presents the benefits, costs, and TRC ratio for the HPWH measure group.

**Table 19: Cost-Effectiveness of Residential Heat Pump Water Heaters**

Measure Group	Delivery Mechanism	Present Value of Benefits	Present Value of Costs	Total Resource Benefit/Cost Ratio
Heat Pump Water Heater	-	\$103,669	\$108,756	0.95

Source: Navigant ProCost Analysis

### 3.1.5. Agriculture De-Energization

The evaluation team calculated an overall realization rate of 1.0 for this measure. Verification was conducted through a rigorous analysis of the calculations conducted to report savings associated with this measure. The calculations and methodologies were assessed against the RTF guidance provided within the Transformer De-Energizing Standard Protocol. Our team found all calculations to be aligned with those provided by the reference material.

**Table 20: Summary of Results for Agricultural Transformer De-Energization**

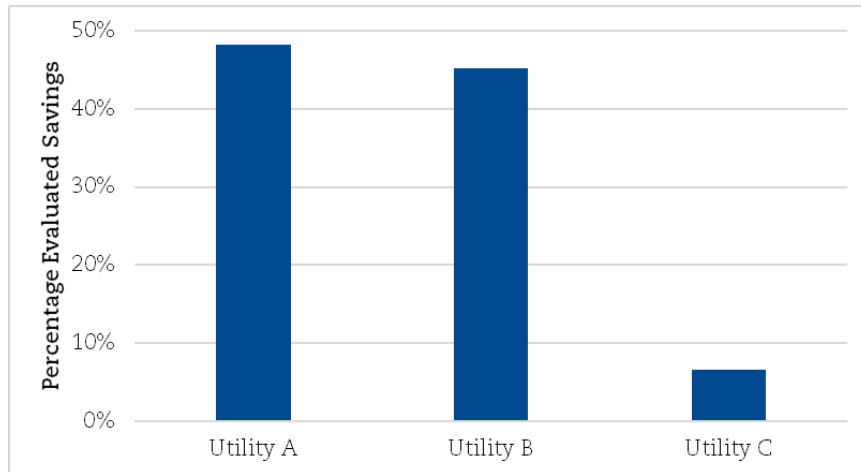
Measure	Reported Savings (aMW)	Evaluated Savings (aMW)	Population-Level Realization Rate
Transformer De-energization	0.20	0.20	1.00

Source: Navigant analysis

### 3.1.5.1. Key Drivers

For the de-energization measure group, the team evaluated a census of FY2016 projects. Three utilities submitted projects within the evaluation period, and the evaluation team reviewed the calculations for each of them. Two of the three utilities accounted for over 90% of the savings.

**Figure 15: De-energization Evaluated Savings Proportion by Utility**



Source: Navigant analysis

### 3.1.5.1. Cost-Effectiveness

Using ProCost and the adjusted savings values, where necessary, the evaluation team calculated updated cost-effectiveness based upon a Total Resource Cost (TRC) ratio defined as the ratio of benefits to costs. A TRC ratio greater than one indicates that the measure is cost-effective as the benefits outweigh the costs of implementation. Table 21 presents the benefits, costs, and TRC ratio for the De-Energization measure group.

**Table 21: Cost-Effectiveness of Agricultural Transformer De-Energization**

Measure Group	Delivery Mechanism	Present Value of Benefits	Present Value of Costs	Total Resource Benefit/Cost Ratio
De-energization	-	\$1,566,547	\$801,772	1.95

Source: Navigant ProCost Analysis

### 3.1.6. Green Motors

The evaluation team calculated an overall realization rate of 1.0 for this measure.

**Table 22: Summary of Results for the Green Motor Rewind Initiative**

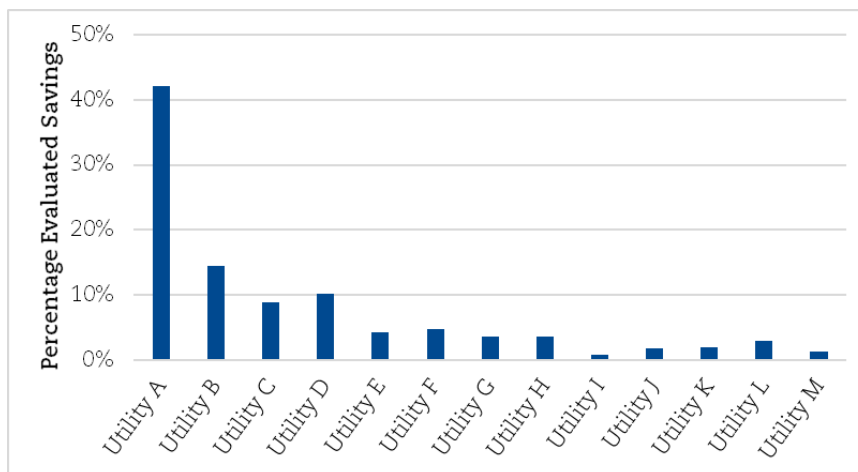
Measure	Reported Savings (aMW)	Evaluated Savings (aMW)	Population-Level Realization Rate
Green motors	0.06	0.06	1.00

Source: Navigant analysis

### 3.1.6.1. Key Drivers

Of the 13 utilities sampled in the green motor rewind measure group, two of them accounted for most of the sample-level savings, as seen in Figure 16.

**Figure 16: Green Motor Sampled Savings Proportion by Utility**



Source: Navigant analysis

### 3.1.6.1. Cost-Effectiveness

Using ProCost and the adjusted savings values, where necessary, the evaluation team calculated updated cost-effectiveness based upon a Total Resource Cost (TRC) ratio defined as the ratio of benefits to costs. A TRC ratio greater than one indicates that the measure is cost-effective as the benefits outweigh the costs of implementation. Table 23 presents the benefits, costs, and TRC ratio for the Green Motors measure group.

**Table 23: Cost-Effectiveness of the Green Motor Rewind Initiative**

Measure Group	Delivery Mechanism	Present Value of Benefits	Present Value of Costs	Total Resource Benefit/Cost Ratio
BPA Green Motors	-	\$234,930	\$41,498	5.66

Source: Navigant ProCost Analysis

## 3.2. Low-Income Weatherization State Grants

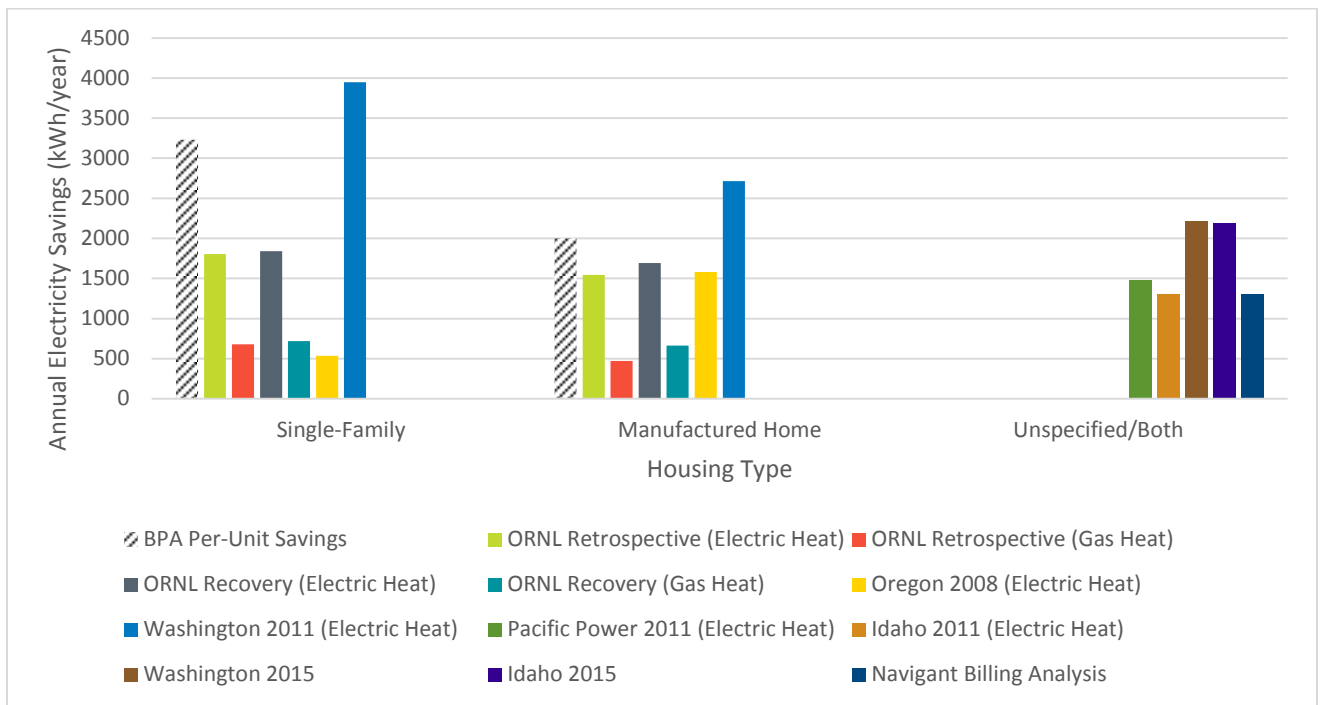
Navigant found that BPA’s current deemed savings estimates for low-income weatherization measures in single-family and manufactured homes are high compared to other studies that include similar weatherization measures. This is more pronounced for single-family homes than manufactured homes. Specifically, BPA’s current per-unit savings estimate is approximately 2 times higher than the average estimate for single-family homes and approximately 40% higher than the average estimate for multi-family homes derived from the studies summarized in the memo included in Appendix H.

Figure 17 compares the electricity savings on a per-home basis derived from the various studies summarized above. Most programs found fewer savings than the

current per-unit savings assumed by BPA. The differences in values are due, in part, to the different approaches used to derive savings estimates. Savings also varied based on the type of home, and the measures analyzed.

In general, homes with electric heating obtained higher savings than homes with gas heat, as would be expected. (Washington 2015 and Idaho 2015 studies did not specify the type of heating.) The Washington 2011 study appeared to have a relatively high savings result, for reasons that could not be determined.

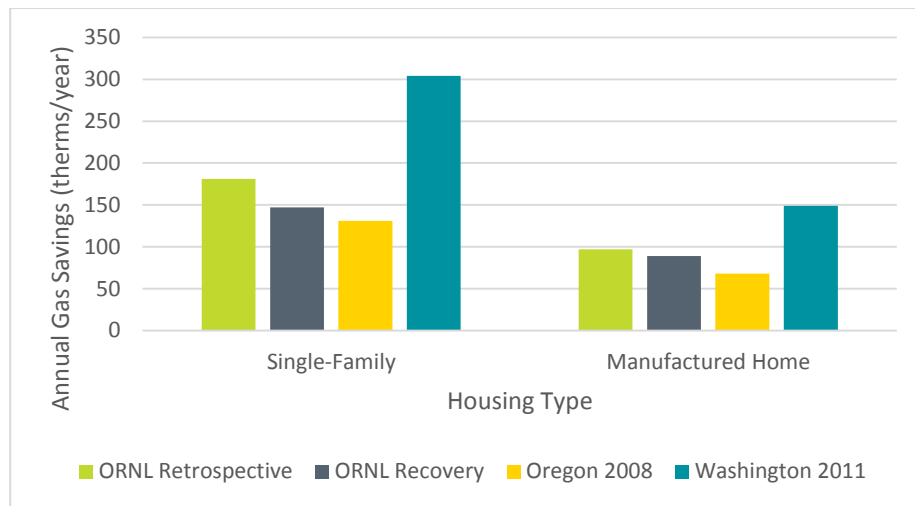
**Figure 17: Comparison of Electricity Savings Values from Low-Income Weatherization Programs**



Source: Navigant analysis of various cited sources

Figure 18 compares the gas savings obtained for those studies, where it was measured. Although BPA does not have a deemed value for gas savings for low-income weatherization, this figure shows a range of typical savings.

**Figure 18. Comparison of Gas Savings Values from Low-Income Weatherization Programs**



Source: Navigant analysis of various cited sources

### 3.3. RSAT Methodology

Overall, the evaluation team finds the RSAT allocation methodology robust. The following sub-sections provide additional detail and some potential considerations for future research.

**Robustness.** Short of directly tracking purchaser zip codes, the current methodology appears to use the best available data. An alternative approach tracking zip codes would improve certainty, but would require requesting additional data from participating retailers and customers and may not substantially change allocations.

**Green Aware Customer Segments.** Increasing the weight of the Green Aware customer segment makes intuitive sense, but it is not clear whether there are any data to support the weighting factor of 2. A few potential research questions here include:

- Has CLEAResult (formerly PECCI, the company that originally built the RSAT) or BPA researched this factor?
  - Is double weight too high?
- If this group correlates strongly with certain Mosaic groups, does this extra weighting double-count effects of those groups' population spread?

**Annual Update.** It is unclear, from the material available, what is included in the annual update. The evaluation team would recommend that the update should include, at least, refreshing stores and customer distribution/segmentation data.

### 3.4. Residential HVAC Measures

This section provides the detailed interim draft results of the investigation of the Residential HVAC PTCS measure groups.

Overall, the investigation process verified the savings reported using the data collected during the program oversight. However, this was the first time that this approach was utilized and the team believes that more research and investigation is needed before rolling this approach out as a full-scale impact evaluation.

The interim draft results for this approach are provided in the table below. The team found the overall draft realization rate for the Residential HVAC measures to be low. It should be noted that these results will not be used for any program planning purposes.

As shown in Table 24, the evaluation team calculated an overall draft realization rate of 46% for the Residential HVAC measures. This overall draft realization rate is based upon the sampled savings using project and QA/QC documentation provided by the PTCS team for the Residential HVAC measures.

**Table 24: Summary of Results for Residential HVAC Measures<sup>35</sup>**

Measure Groups	Reported Savings (aMW)*	Investigated Savings (aMW)	Population-Level Realization Rate
Duct Sealing Prescriptive	0.25	0.20	78%
Duct Sealing PTCS	0.07	0.04	57%
Commissioning Controls & Sizing	0.02	0.01	42%
Heat Pumps (incl. ASHP, VSHP, and GSHP)	0.98	0.36	37%
<b>Overall</b>	<b>1.32</b>	<b>0.62</b>	<b>46%</b>

Source: Navigant analysis

\* Includes only the savings from Main Population. Refer to section 2.5.2.1 for more details.

The evaluation team included the projects which received QA/QC visits in the January 2017 to November 2017 timeframe. With these data, 69% of the total investigation sample was satisfied. Future investigation may include additional data collection. Table 25 shows the required sample size and achieved sample size for this investigation.

<sup>35</sup> The final sample contained 10 projects which were reported in FY2017. The evaluation team used the applicable deemed measure list (UES Deemed Measure List Version 5.1) to investigate these 10 projects.



**Table 25: Required and Achieved Sample sizes**

Measure Groups	Required Sample Size	Achieved Sample Size	Remaining Sample Size
Duct Sealing Prescriptive	20	20	0
Duct Sealing PTCS	66	34	32
Commissioning Controls & Sizing	28	15	13
Heat Pumps	75	69	6
<b>Overall</b>	<b>189</b>	<b>138</b>	<b>51</b>

Source: Navigant analysis

Key drivers of low realization rates included the following:

**Projects not meeting RTF delivery verification**

As described in section 2.1, the evaluation team assigned 0 savings to any project for which one or more RTF DV requirements were not satisfied. The tables below show the number of projects that did not meet RTF delivery requirements. (Not all the DV requirements were necessary in order to pass the QA inspection; these are indicated in the second column of each table.) There were a few RTF DV requirements which failed more frequently than others for the measure groups under consideration; these are marked with red text in the tables below.

**Table 26: Duct Sealing – Number of Projects Failing RTF DV Requirements**

RTF Delivery Verification Requirements	Must Pass to Pass QA Inspection?	# of Projects Not Meeting All RTF DV Requirements			
		Prescriptive	PTCS	Duct Sealing - ALL	% of Total
Check that 30% of ducts are located in unconditioned space OR that there were supply leaks to unconditioned space within 15 feet of the air handler	Yes	3	1	4	7%
Check the house has not previously had its ducts sealed through a utility duct sealing program.	No	0	2	2	4%
Check that accessible non-flex duct joints and connections located in unconditioned space are sealed with UL-181 listed mastic	No	3	10	13	24%
Check that accessible flexible duct connections located in unconditioned space have interior and exterior liners secured and are air-sealed and tightened appropriately.	No	4	8	12	22%
<b>Total Projects Received</b>		<b>20</b>	<b>34</b>	<b>54</b>	

Source: Navigant analysis.

**Table 27: ASHP, VSHP & CCS – Number of Projects Failing RTF DV Requirements**

RTF Delivery Verification Requirements	Must Pass to Pass QA Inspection?	# of Projects Not Meeting All RTF DV Requirements				
		ASHP	VSHP	CCS	Total*	% of Total
HSPF Rating meets 9.0 or higher	Yes	1	0	NA	1	1%
Balance Temperature: Check heat pump balance point is at 30 F or lower	Yes	3	1	0	4	5%
Auxiliary heat is controlled to Single stage OR Multi stage w/out air temperature sensor control (lockout grade)	Yes	5	1	3	9	12%
Thermostat has manual changeover feature or heating/cooling lockout (if applicable)	No	4	3	4	11	14%
Compressor does not cutout at temps above 5F	No	5	2	3	10	13%
Airflow across indoor coil is either: specified in manufacturers literature OR >325CFM/ton	No	7	3	2	12	16%
External static pressure does not exceed 0.8 in of water (200 PA)	No	3	1	1	5	7%
<b>Total Projects Received</b>		<b>50</b>	<b>11</b>	<b>15</b>	<b>76</b>	

Source: Navigant analysis.

\* Excludes GSHP projects.

### Ground Source Heat Pumps

None of the 8 GSHP projects met the two DV requirements. The PTCS QA inspectors who visited<sup>36</sup> these projects did not use the updated GSHP QA inspection (updated on 16<sup>th</sup> Jan 2017) form which had these two DV requirements added as a required data point. The evaluation team also tried to obtain the installation documents for this projects with the help of the PTCS team but was not able to obtain it. Thus, the evaluation team assigned 0 savings to all 8 GSHP projects.

<sup>36</sup> These QA visits occurred in May 2017.

**Table 28: GSHP – Number of Projects Failing RTF DV Requirements**

RTF Delivery Verification Requirements	Must Pass to Pass QA Inspection?	# of Projects Not Meeting RTF DV Requirements	% of Total
Airflow across indoor coil is either: specified in manufacturers literature OR >325CFM/ton	No	1	13%
External static pressure does not exceed 0.8in of water (200 PA)	No	4	50%
Was previous heating system ASHP or electric FAF?*	No	8	100%
Is existing water heater electric tank without desuperheater?	No	8	100%
<b>Total Projects Received</b>		<b>8</b>	

Source: Navigant analysis.

\*The PTCS team noted that this data point is available in the PTCS Site Registry. However, the old forms used in the QA inspections for these projects did not collect this data.

## 4. Conclusions and Recommendations

The evaluation team presents the following conclusions and recommendations from the project:

### 4.1. UES Impact Evaluation Conclusions and Recommendations

**Overall, project documentation supports savings claimed.** Nearly all reported savings across the sampled measure groups were accounted for in project documentation, as indicated by the high overall realization rate.

**Misalignment of Implementation Manual documentation requirements and RTF delivery verification requirements may present risk to utilities.** Delivery verification requirements, as used for evaluation, are defined by the RTF. The documentation required by Bonneville for reimbursement is based on the Implementation Manual (IM) which usually, though not always, aligns with the RTF requirements. In cases where there is misalignment, utilities may be at risk of not receiving credit in the evaluation despite having all the documentation required per the IM. For example, one utility’s DHP Zonal installation forms did not directly indicate that the measure was installed in a “main living area” – a parameter required by the RTF in their measure specification.<sup>37</sup> In this instance, the evaluation team judged that other information on the form was sufficient to show that the systems met the requirement.

<sup>37</sup> RTF Measure Specification for Ductless Heat Pumps Replacing Zonal Heat. <https://rtf.nwcouncil.org/measure/ductless-heat-pumps-zonal-heat-sf>

## Recommendation:

The evaluation team recommends that the requirements in the IM be closely aligned with the RTF requirements. Alternatively, the evaluation team also recommends the BPA team (including, as necessary, the PTCS team) reach out to RTF if they feel that some of the current DV requirements do not align with their understanding of the measures so that the current DV requirements can be studied further and revised if necessary.

### 4.1.1. Ductless Heat Pumps - Zonal

**Some DHP zonal installation forms had missing/ineligible information.** Incomplete or ineligible information on installation forms were the primary reason DHP Zonal projects received a realization rates less than 1.0. In these instances, the implemented measure received a realization rate of 0.0, as it did not comply with RTF delivery verification requirements as reported.

### 4.1.2. Advanced Power Strips

**There was a slight discrepancy in reported versus verified quantity of advanced power strips.** Project documentation for sampled APS projects revealed that some utilities reported quantities different than those identified in the project documentation. However, these discrepancies were too small to have a noticeable impact on the realization rate for this measure.

### 4.1.3. Heat Pump Water Heaters

**There was a slight discrepancy in reported versus verified data for heat pump water heaters.** Some utilities reported quantities, reference number tiers, and installation locations for sampled HPWHs that were different than those identified in project documentation. These discrepancies account for the majority of the difference in reported versus evaluated energy savings. The evaluation team found that some utilities were conservatively reporting efficiency tiers of HPWHs. When the correct, higher tier was applied, this led to higher evaluated savings than reported; i.e., realization rates greater than 1.

## 4.2. Low-Income Weatherization Conclusions and Recommendations

**Claimed savings estimates used in the Low-Income Weatherization State Grant program are higher than comparable estimates in other studies.** Navigant found that BPA's current deemed savings estimates for low-income weatherization measures in single-family and manufactured homes are high compared to other studies that include similar weatherization measures. This is more pronounced for single-family homes than manufactured homes.

### Recommendation:

To reduce uncertainty in these estimates, Navigant suggests updating the per-unit savings value using a more robust estimation method such as a billing analysis. In the meantime, we recommend that BPA consider reducing their single-family savings value by approximately 50% and their manufactured home savings value by approximately 25%.

## 4.3. RSAT Methodology Conclusions and Recommendations

**RSAT methodology is reasonable.** The evaluation team finds the RSAT allocation methodology robust and recommends a few areas of future research, including exploring the potential for double-counting and the impact of the allocations methods used by regional utilities.

## 4.4. Residential HVAC PTCS Measures Investigation Conclusions and Recommendations

**Overall, PTCS QA inspections are a good resource to leverage for a future residential HVAC impact evaluation.** The data collected through existing PTCS QA inspections and oversight has a significant overlap with the evaluation data needs, which means there is the potential to save significant time and resources while reducing the burden on customer utilities. The evaluation team worked with the PTCS team to revise the Inspection forms to include most if not all data needs for evaluation and then leveraged the existing QA inspection and data collection effort for this investigation. In the future, BPA may be able to perform a Residential HVAC evaluation in-house using the mechanisms established in this CY2017 evaluation.

This work was originally intended to function as a full-scale impact evaluation for PTCS measures, but during the process, there were important questions and findings which required the evaluation team to stop collecting data and reconsider the purpose of the project. Ultimately, in collaboration with BPA, the evaluation team decided to treat the project as an investigation that could support a potential future impact evaluation. Some of those findings and questions are provided below:

**There is a disconnect between QA Inspection grades and delivery verification requirements.** PTCS QA inspections do not completely align with the DV requirements set forth by the RTF. During the preliminary phase of this investigation, the evaluation team, with the help of the PTCS team, revised the original version of the PTCS QA inspection forms so that all the DV requirement needs are included in the current QA inspection forms. However, the grading criteria and weightages do not align between QA inspection and DV requirements. As defined by the RTF, a project must meet all DV requirements to receive full savings under an impact evaluation, but the PTCS QA inspection does not have this requirement. Certain specifications, such as equipment efficiency rating, must pass for the project to pass the QA inspection, as shown in the

example below. This data point is also one of the DV requirements. However, certain other DV requirements (e.g. compressor lockout) can fail in the QA inspection but the project can still pass the inspection overall. In this case, if this were an impact evaluation, the evaluation team would be required to assign zero savings to the project because not all DV requirements were met.

**Figure 19: Heat Pumps QA form – Must pass data point**

The graded items below will be weighted upon entry into the registry to calculate an overall grade.  
**\*\*Overall fail:** These noted 'F' grades will result in an overall inspection fail regardless of other results.

**View Heat Pump Equipment Data**  All Equipment Data matches technician's form. If not, record below.

Inspection Type: <input type="checkbox"/> PTCS Heat Pump with HSPF <input type="checkbox"/> Controls, Commissioning & Sizing (CC&S)		AHRI number	HSPF
Outdoor and Indoor Unit Make			
Outdoor Unit Model #	Indoor Unit Model #		
Meets HSPF or CC&S Grade <u>    </u> (Check one)	<input type="checkbox"/> <b>A (Above Spec) 9.0</b> or higher (Fed standard for CC&S) and matches what tech reported	<input type="checkbox"/> <b>B (Meets Spec) 9.0</b> or higher (Fed standard for CC&S)	<input type="checkbox"/> <b>**F (Fails)</b> Below 9.0 or Federal Standard
Notes			
For Air-Source Heat Pump Conversion in Manufactured Homes: Has the house previously had its ducts sealed through a utility offered duct sealing program? <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't Know			

Source: PTCS QA Inspection form for ASHP, VSHP and CCS

**Recommendation:**

The evaluation team recommends that for QA inspection data to function as delivery verification for purposes of impact evaluation, the QA inspection forms must require that the project pass all of the RTF DV requirements to pass the QA inspection. Alternatively, the evaluation team also recommends the BPA team reach out to RTF if they feel that some of the current RTF DV requirements do not align with their understanding of the measures so that the current DV requirements can be studied further and revised if necessary.

**Project Remediation by PTCS contractors.** If a project fails in the QA inspection, the PTCS team provides feedback to the installation contractor and the contractor visits the site to fix the issues which resulted in a project failure. There is uncertainty as to whether the savings for a remediated project are reported to IS2.0 before or after remediation. During this investigation, the team did not consider remediation of the projects in the document review. The team believes that more research and investigation is needed on this issue before adopting this approach as a full-scale evaluation.

**Recommendation:**

The team recommends more research to determine how and when the project is reported in IS2.0. The team suggests using the values from remediation for the evaluation only if the remediation happens before the project is reported to IS2.0.

**Document review sample fulfillment was not achieved.** Based on the analysis of historic PTCS QA visits and reported IS2.0 data, the team believed that the document review sample drawn by the team can be fulfilled within 4-6 months of PTCS QA visits. However, the seasonality and geographical constraints limited the ability of PTCS QA visits to meet the required sample.

**Ground source heat pump QA inspections used versions of the QA/QC inspection forms that did not contain the DV requirements.** This resulted in two key data needs for DV requirements not being collected during the inspection for all 8 GSHP projects in the sample. Due to the unavailability of data, the evaluation team assigned 0 savings for these GSHP projects, which is one of the key drivers for a lower realization rate.

#### Recommendation:

The team recommends the BPA and PTCS teams to use the revised QA/QC forms moving forward and/or collect the installation documents for GSHP projects which will help filling this data gap.

**The evaluation team believes that the approach adopted for Residential HVAC measures—i.e., document review leveraging the existing oversight—can work with other measure groups.** The team believes that with a typical program oversight (PTCS or COTR) review or inspection, there is a significant overlap between what BPA's oversight team would be doing and what an evaluation team would do. The team understands that not all oversight activities will include onsite visits which are unique to PTCS QA oversight. However, even with typical oversight activities (for example: document reviews or phone interviews of sampled participants), there is a good opportunity to leverage the data being collected. Leveraging an existing oversight process will reduce the burden on the customers and at the same time will help in running an evaluation in a cost-effective manner. Thus, the team recommends using similar approach to the different measure groups which receive oversight from BPA, if feasible.

#### Recommendation:

For this suggested approach to work efficiently, the team recommends BPA align the oversight data collection with the RTF delivery requirements before undertaking the evaluation.

## Appendix A. Glossary

### *Coefficient of Variation (CV)*

A normalized measure of dispersion of a probability distribution and defined as the ratio of the standard deviation,  $\sigma$ , to the mean,  $\mu$ :

$$c_v = \frac{\sigma}{\mu}$$

*Delivery Verification* - RTF Guidelines stipulate that Impact Evaluation may be accomplished using delivery verification to estimate savings for Proven UES (Unit Energy Savings) measures, i.e., savings equal the verified delivery quantity multiplied by the proven UES savings value. Delivery verification may also be useful in measure development and providing feedback to programs.

*Evaluation Measure Group* - In order to design an efficient evaluation, the evaluation team defined subsets within sectors as a group of measures that have similar end-uses, measure statuses and/or that use similar program delivery method.

### *Impact Evaluation*

Impact evaluation is used to estimate savings from energy efficiency measures. According to the RTF Guidelines, “program impact evaluations estimate savings from a period of program operation. Program impact evaluations involve the analysis of a reliable sample of program participants (and possibly non-participants) to determine the savings.” The RTF Guidelines generally refer to evaluation of a portfolio or program, but are flexible in how evaluators define “program.”

*Measure Status* - In the RTF Guidelines, a measure’s category defines the savings estimation that should be used to evaluate savings. The RTF approves four measure categories within the UES portfolio; Proven, Small Saver, Provisional and Other.

### *Realization Rate*

The term is used in several contexts in the development of reported program savings. The primary applications include the ratio of project tracking system savings data (e.g., initial estimates of project savings) to savings that (1) are adjusted for data errors and (2) incorporate evaluated or verified results of the tracked savings. In the Updated Guidelines, the realization rate does not include program attribution.

### *Relative Precision*

Measures the expected error bound of an estimate on a normalized basis. It must be expressed for a specified confidence level. The relative precision ( $rp$ ) of an estimate at 90% confidence is:

$$rp = 1.645 \frac{cv}{\sqrt{n}} \sqrt{1 - \frac{n}{N}}$$



where  $n$  is the sample size,  $N$  is the population size, and the coefficient of variance is  $cv = \text{standard deviation} / \text{estimate mean value}$ . The square root expression at the end of the equation is the finite population correction factor, which becomes inconsequential and unnecessary for large populations.

#### *RTF Proven*

These are measures for which the RTF has determined that savings estimation methods are proven and reliable.

#### *Savings Realization Rate (RR)*

The ratio of the field of evaluation energy savings to the program's claimed savings. The RR represents the percentage of program-estimated savings that the impact evaluation team estimates as being achieved based on the results of the evaluation M&V analysis.

#### *Savings Validation*

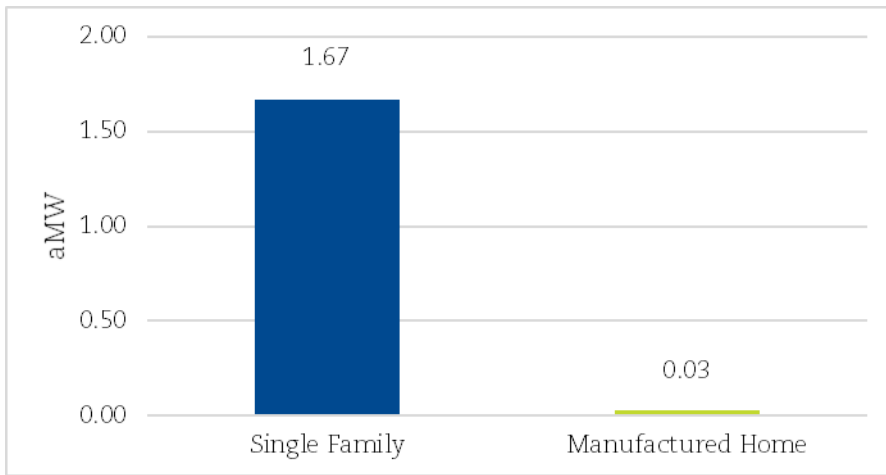
Savings validation uses impact evaluation to provide a comparison of savings for a measure or group of measures to the deemed UES values. For the purposes of this document, existing measure savings validation is considered a measure development activity, in that it informs savings estimates associated with a measure. If the savings validation shows a significant deviation from the deemed savings estimates, additional measure development may be needed.

# Appendix B. Residential HVAC DHP - Zonal

## Savings

Figure B1 shows the breakdown of energy savings for the residential HVAC ductless heat pump (DHP) zonal evaluation measure group by house type.

**Figure B1: Residential HVAC DHP – Zonal: Breakdown by House Type (FY2016)**



Source: Summarized from 10/31/2016 IS2.0 data pull for FY2016 data.

Table B1 shows the breakdown of energy savings by measure status.

**Table B1: Residential HVAC DHP – Zonal: Breakdown by House Type (FY2016)**

Measure Status <sup>38</sup>	Savings (aMW)	Fraction of Measure Group
RTF Proven	1.67	98%
BPA Qualified <sup>39</sup>	0.03	2%

\*The RTF allows DV to be used as impact evaluation for Proven measures only. BPA and stakeholders felt that conducting document reviews of non-proven measure groups provides BPA with insight and may ultimately flag areas of additional research.

Source: Summarized from 10/31/2016 IS2.0 data pull for FY2016 data.

<sup>38</sup> Measure Status from UES Deemed List Version 4.1

<sup>39</sup> Residential HVAC DHP Zonal measures for Manufactured Homes are categorized as “BPA Qualified” in the UES Deemed Measure List version 4.1.

## Sample Size

Table B2. 2016 Sample Size for Residential HVAC DHP - Zonal

Measure Group	Strata	Assumed CV	Number of Utilities	Target Number of Projects	Actual Number of Projects*
Res HVAC DHP - Zonal	Large Contributors	0.3	5	48	60
	Small Contributors	0.3	5	50	58
	<b>Subtotal</b>		<b>10</b>	<b>98</b>	<b>118</b>

\*Includes backups

Source: Navigant Analysis

## RTF Delivery Verification Requirements

Table B3: Ductless Heat Pump replacing Zonal Electric Heat DV Requirement

DV Component	Specification	DV Requirement Checklist	Available in Utility Customer Files?
Measure Identifiers	Heating Zone	Check for heating zone	Can be derived
	Cooling Zone	Check cooling zone	Can be derived
Savings Baseline	Pre-Conditions	Check pre-conditions were electric resistance zonal system	Yes, checked in installation form
	Pre-Conditions	Check that house does not have a heat pump, ductless heat pump, or a whole house forced air heating system	Yes, checked in installation form
Implementation and Product Standards	HSPF Rating	Check inverter drive DHP with nominal 0.75 tons or more and HSPF rating of 9.0 or higher is installed	Size can be derived. HSPF rating collected in installation form.
	Installation Location	Check DHP is installed in main living area	Sometimes included in installation form

Source: RTF

## Documentation Requirements

The following table provides the detailed documentation requirements for the evaluated measure groups included in impact evaluation of FY2016 projects.

**Table B4: Ductless Heat Pump replacing Zonal Electric Heat Documentation Requirements**

Measure	Documentation Requirements
Ductless Heat Pump – Zonal	<ul style="list-style-type: none"> <li>• End-user identifying information including unique site ID and address</li> <li>• Equipment/contractor invoice showing (a) measure requirements have been met (e.g., manufacturer, model number, type, size and quantity of equipment or product installed/used), (b) the order/purchase date and (c) cost</li> <li>• Ductless Heat Pump Installation Form (or other form(s) that contain the same information) (available in the Document Library)</li> </ul>

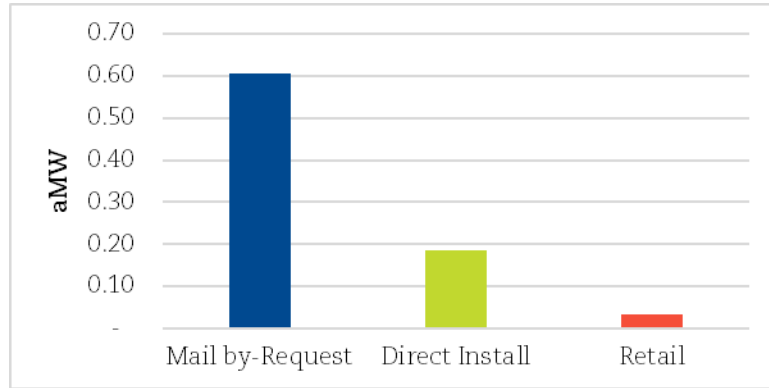
Source: BPA Implementation Manual, Oct 2015-16

# Appendix C. Advanced Power Strips

## Savings

Figure C1 shows the breakdown of energy savings for the residential power strips evaluation measure group by delivery mechanism.

**Figure C1: Residential Power Strips: Breakdown by Delivery Mechanism (FY2016)**



Source: Summarized from 10/31/2016 IS2.0 data pull for FY2016 data.

Table C1 shows the breakdown of energy savings by measure status.

**Table C1: Residential Power Strips: Breakdown by Measure Status (FY2016)**

Measure Status <sup>40</sup>	Savings (aMW)	Fraction of Measure Group
Planning <sup>41</sup>	0.82	100%

\*The RTF allows DV to be used as impact evaluation for Proven measures only. BPA and stakeholders felt that conducting document reviews of non-proven measure groups provides BPA with insight and may ultimately flag areas of additional research.

Source: Summarized from 10/31/2016 IS2.0 data pull for FY2016 data.

<sup>40</sup> Measure Status from UES Deemed List Version 4.1

<sup>41</sup> Measure status for the Residential Power Strips is changed to “Provisional” on the RTF website as of May 15, 2016

## Sample Size

Table C2. 2016 Sample Size for the Residential Power Strips

Measure Group	Strata	Assumed CV	Target Number of Projects	Actual Number of Projects*
Power Strips	Large	0.3	1	1
	Medium	0.3	2	4
	Small	0.3	2	3
	<b>Subtotal</b>		<b>5</b>	<b>8</b>

Source: Navigant Analysis

\*Includes backup sites. This measure group has comparatively smaller sample size because there is one line-item in the population representing ~9000 units and >40% of total savings for this measure group.

## RTF Delivery Verification Requirements

Table C3: Residential Power Strips DV Requirement

DV Component	Specification	DV Requirement Checklist	Available in Utility Customer Files?
Measure Identifiers	None	IR-sensing ("Tier II") installed in home entertainment setting.	Yes
Savings Baseline	Pre-Conditions	N/A	
Implementation and Product Standards	IR-sensing APS, home-entertainment: APS shuts off power to controlled devices (including television) when no IR signal is detected for a set period of time regardless of the level of power draw (typically considered a "Tier II" technology). APS must control television.	- APS unit must control television.  - Verification should take place approximately 6 to 9 months after the customer receives the APS.	Yes.*

\* The DV requirements can be satisfied from the customer survey that is required from the by-retail and DI customers within 30 days of receiving the power strip. In order to satisfy the 'after 6-9 months' requirement, the evaluation team will have to call the sampled sites in order to collect the data.

Source: RTF

## Documentation Requirements

The following table provides the detailed documentation requirements for the evaluated measure groups included in impact evaluation of FY2016 projects.

**Table C4: Residential Power Strips Documentation Requirements**

Measure	Documentation Requirements
Advanced Power Strips	<ul style="list-style-type: none"><li>• Equipment/contractor invoice showing (a) measure requirements have been met (e.g., manufacturer, model number, type, size and quantity of equipment or product installed/used), (b) the order/purchase date and (c) cost</li><li>• See the Measure Distribution Processes section in the Multi-Sector chapter for additional requirements.</li><li>• Completed end-user surveys received for APS delivered via By Request or Direct Install. This survey is available in the Document Library and is also available as an APS End User Survey Monkey tool.</li></ul>

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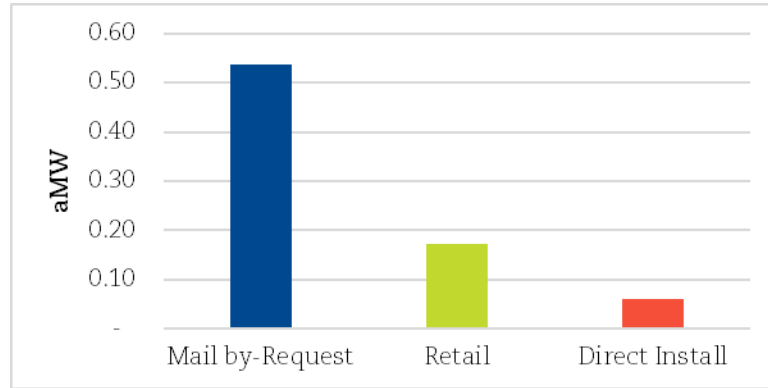
Source: BPA Implementation Manual, Oct 2015-16

# Appendix D. Showerheads

## Savings

Figure D1 shows the breakdown of energy savings for the residential showerheads evaluation measure group by delivery mechanism.

**Figure D1: Residential Showerheads: Breakdown by Delivery mechanism (FY2016)**



Source: Summarized from 10/31/2016 IS2.0 data pull for FY2016 data.

Table D1 shows the breakdown of energy savings by measure status.

**Table D1: Residential Showerheads: Breakdown by Measure Status (FY2016)**

Measure Status <sup>42</sup>	Savings (aMW)	Fraction of Measure Group
Proven <sup>43</sup>	0.77	100%

\* The RTF allows DV to be used as impact evaluation for Proven measures. As such, this research constitutes impact evaluation for this measure.

Source: Summarized from 10/31/2016 IS2.0 data pull for FY2016 data.

<sup>42</sup> Measure Status from UES Deemed List Version 4.1

<sup>43</sup> Measure status for the Residential Showerheads is changed to “Planning” on the RTF website as of Aug 16, 2016



## Sample Size

Table D2. 2016 Sample Size for the Residential Showerheads

Measure Group	Strata	Assumed CV	Target Number of Projects	Actual Number of Projects*
Res Power Strips	Certainty	0.3	2	2
	Large	0.3	1	4
	Medium	0.3	2	5
	Small	0.3	2	4
	<b>Subtotal</b>		<b>9</b>	<b>15</b>

Source: Navigant Analysis

\*Includes backup sites

## RTF Delivery Verification Requirements

Table D3: Residential Showerheads DV Requirement

DV Component	Specification	DV Requirement Checklist	Available in Utility Customer Files?
Measure Identifiers	Delivery: {Retail, Mail-by-Request, Direct Install}	Check Delivery Mechanism	Yes
	Water Heating System Type: {Electric, Gas, Any}	Check the water heating system type	Yes*
	Rated Flow Rate: {2.0 gpm, 1.75 gpm, 1.5 gpm}	Check the flow rate	Can be derived.
Savings Baseline	Retail (Current Practice)	N/A	
	Mail-by-Request, Direct Install (Pre-Conditions)	N/A	
Implementation and Product Standards	N/A	N/A	

\* For by-request and DI measures only.

Source: RTF

## Documentation Requirements

The following table provides the detailed documentation requirements for the evaluated measure groups included in impact evaluation of FY2016 projects.

**Table D4: Residential Showerheads Documentation Requirements**

Measure	Documentation Requirements
Showerheads	<ul style="list-style-type: none"><li>• Equipment/contractor invoice showing (a) measure requirements have been met (e.g., manufacturer, model number, type, size and quantity of equipment or product installed/used), (b) the order/purchase date and (c) cost</li><li>• Fuel source documentation (By Request or Direct Install showerheads)</li><li>• See the Measure Distribution Processes section in the Multi-Sector chapter for additional requirements.</li></ul>

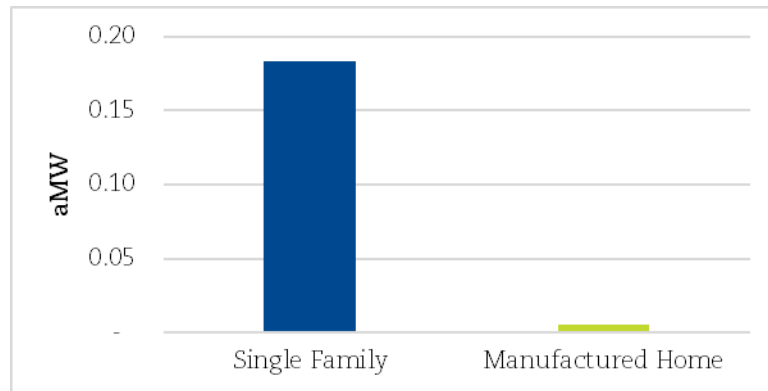
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Source: BPA Implementation Manual, Oct 2015-16

# Appendix E. Heat Pump Water Heaters Savings

Figure E1 shows the breakdown of energy savings for the residential heat pump water heater (HPWH) evaluation measure group by house type.

**Figure E1: Residential HPWH: Breakdown by House Type (FY2016)**



Source: Summarized from 10/31/2016 IS2.0 data pull for FY2016 data.

Table E1 shows the breakdown of energy savings by measure status.

**Table E1: Residential HPWH: Breakdown by Measure Status (FY2016)**

Measure Status <sup>44</sup>	Savings (aMW)	Fraction of Measure Group
Provisional <sup>45</sup>	0.19	100%

\* The RTF allows DV to be used as impact evaluation for Proven measures only. BPA and stakeholders felt that conducting document reviews of non-proven measure groups provides BPA with insight and may ultimately flag areas of additional research.

Source: Summarized from 10/31/2016 IS2.0 data pull for FY2016 data.

<sup>44</sup> Measure Status from UES Deemed List Version 4.1

<sup>45</sup> Measure status for the Residential HPWH is changed to “Planning” on the RTF website as of Nov 9, 2016

## Sample Size

Table E2. Sample Size for Residential HPWH

Measure Group	Strata	Assumed CV	Number of Utilities	Target Number of Projects	Actual Number of Projects*
Residential – HPWH	Large Contributors	0.3	5	9	14
	Small Contributors	0.3	3	22	29
	<b>Subtotal</b>		<b>8</b>	<b>31</b>	<b>43</b>

\*Includes backups

Source: Navigant Analysis

# RTF Delivery Verification Requirements

Table E3: Residential HPWH DV Requirement

DV Component	Specification	DV Requirement Checklist	Available in Utility Customer Files?
Measure Identifiers	Efficiency Tier	Check Efficiency Tier	Can be derived
	Install Location	Check whether unit is installed in an unconditioned garage/basement or a conditioned interior space.	Yes
	HVAC Type	If unit is installed in conditioned interior space, check whether heating system is a gas furnace, resistance type (electric furnace or electric zonal) or a heat pump.	Yes
	Exhaust ducting	Check whether exhaust air is ducted to the outside.	Yes
	Heating Climate Zone	Check the heating zone.	Can be derived
Savings Baseline	Current Practice	N/A	
Implementation and Product Standards	NEEA Northern Climate Heat Pump Water Heater Specification	<p>- Check that unit is listed on the Northern Climate Specification QPL for the claimed efficiency tier or the unit meets all efficiency requirements of the Northern Climate specification for the claimed tier.</p> <p>- If tier qualification is dependent on operation mode, check that operation mode is set to the one required by the claimed tier.*</p>	Yes

\* The PTCS Installation Form does not cover this conditional requirement. The evaluation team will contact the sampled sites if any such heat pump is selected in the evaluation sample.

Source: RTF

## Documentation Requirements

The following table provides the detailed documentation requirements for the evaluated measure groups included in impact evaluation of FY2016 projects.

**Table E4: Heat Pump Water Heater Documentation Requirements**

Measure	Documentation Requirements
Heat Pump Water Heaters	<ul style="list-style-type: none"><li>• End-user identifying information including unique site ID and address</li><li>• Invoice showing installed cost and new equipment order/purchase date.</li><li>• Completed Project Information Form for Heat Pump Water Heaters (located in the IM Document Library) showing that the measure requirements have been met. A utility may create and submit their own form if it collects the same information as the Project Information Form and has been BPA-approved.</li></ul>

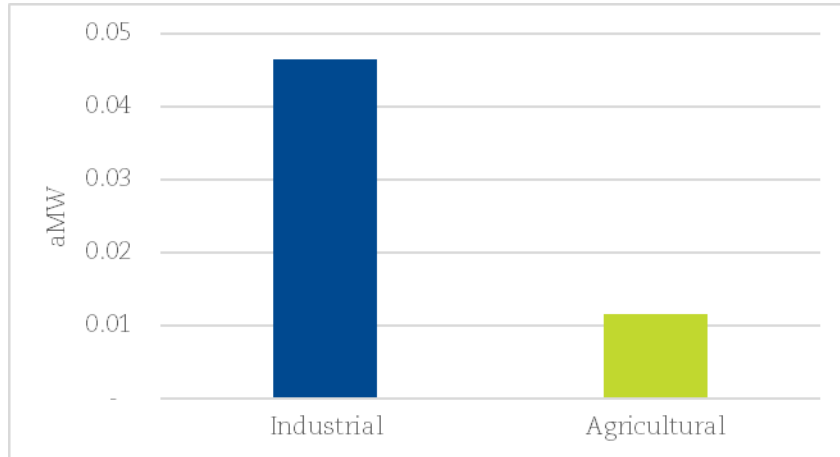
Source: BPA Implementation Manual, Oct 2015-16

# Appendix F. Green Motors

## Savings<sup>46</sup>

Figure F1 shows the breakdown of energy savings for the BPA Green Motors program by sector.

**Figure F1. BPA Green Motors: Breakdown by Sector (FY2016)**



Source: Summarized from EEDB for FY2016, provided by BPA on 12/30/2016

Table F1 shows the breakdown of energy savings by measure status.

**Table F1: BPA Green Motors: Breakdown by Measure Status (FY2016)**

Measure Status <sup>47</sup>	Savings (aMW)	Fraction of Measure Group
Small Saver*	0.06	100%

\* The RTF allows DV to be used as impact evaluation for Proven measures only. BPA and stakeholders felt that conducting document reviews of non-proven measure groups provides BPA with insight and may ultimately flag areas of additional research.

Source: Summarized from EEDB for FY2016, provided by BPA on 12/30/2016

<sup>46</sup> Savings for BPA Green Motors evaluation measure group are summarized from Energy Efficiency Data Base (EEDB) for FY2016 provided by BPA on December 30, 2016.

<sup>47</sup> Measure Status from the [RTF website](#). The UES Deemed Measure List Version 4.1 has “Proven” as a measure status for these measures.

## Sample Size

Table F2: 2016 Sample Size for BPA Green Motors

Measure Group		Assumed CV	Target Number of Projects	Actual Number of Projects*
BPA Green Motors	<b>Subtotal</b>	<b>0.3</b>	<b>9</b>	<b>13</b>

\*Includes backups

Source: Navigant Analysis

## RTF Delivery Verification Requirements

Table F3: BPA Green Motors Delivery Verification Requirements

DV Component	Specification	DV Requirement Checklist	Available in Third Party Database?
Measure Identifiers	Measure Type	Check measure type and match with specification	Yes
	Horsepower (HP) Rating	Check motor HP rating	Yes
Savings Baseline	Pre-Conditions	N/A	
Implementation and Product Standards - Continued	Motors are rewound by Green Motors Practices Group (GMPG) program participants to the GMPG specifications. Measures are identified by motor horsepower ratings that range from 15 to 5,000.	- Check motors rewound by Green Motors Practices Group (GMPG) certified shop	Yes*

\* No utility customer files are required for this measure group. BPA provided invoices for this measure that indicated whether the work was performed by a GMPG Certified Shop.

Source: RTF

## Documentation Requirements

Table F4: BPA Green Motors Documentation Requirements

Measure	Documentation Requirements
BPA Green Motors	<ul style="list-style-type: none"> <li>• Third-party provided monthly reports</li> <li>• Third-party provided annual reports</li> </ul>



# Appendix G. Agricultural De-Energization

## Savings

Table G1 shows the breakdown of energy savings for the agricultural de-energization evaluation measure group by measure status.

**Table G1: Agricultural De-energization: Breakdown by Measure Status (FY2016)**

Measure Status <sup>48</sup>	Savings (aMW)	Fraction of Measure Group
Small Saver*	0.20	100%

\* The RTF allows DV to be used as impact evaluation for Proven measures only. BPA and stakeholders felt that conducting document reviews of non-proven measure groups provides BPA with insight and may ultimately flag areas of additional research.

Source: Summarized from 10/31/2016 IS2.0 data pull for FY2016 data.

## Sample Size

**Table G2: 2016 Sample Size for Agricultural De-energization**

Measure Group	Strata	Assumed CV	Number of Utilities	Number of Projects Sampled*
Agricultural De-energization	N/A	N/A	3	3

\* Agricultural – De-energization measure group has only three projects in the FY2016 IS2.0 data. The evaluation team reviewed all three projects for the 2017 evaluation.

Source: Navigant Analysis

## RTF Delivery Verification Requirements

There is currently no RTF measure workbook or RTF defined delivery verification requirements for the de-energization measure. BPA’s IM describes “Transformer De-energization Worksheet” as a documentation requirement. The evaluation team reviewed these worksheets for the sampled three projects for the evaluation.

<sup>48</sup> Measure Status from the [RTF website](#). The UES Deemed Measure List Version 4.1 does not have any measure status assigned to the Agricultural De-energization measure.

# Documentation Requirements

Table G3: Agricultural De-energization Documentation Requirements

Measure	Documentation Requirements
De-energization	<ul style="list-style-type: none"><li>• Complete the Transformer De-energization Worksheet (available in the Document Library)</li></ul>

## Appendix H. Low-Income Weatherization Memo



BPA\_TO47\_LIWx  
memo\_FINAL\_2017L

## Appendix I. RSAT Memo



BPA\_TO47\_RSAT  
memo\_20171204\_FIT

# Appendix J. PTCS Installation, Data Collection and QA Process

BPA's PTCS team uses data collection forms and an online storage tool to collect and track PTCS duct sealing, air source and ground source heat pump, and prescriptive duct sealing project data.

## Forms

The PTCS team uses various data collection forms across the installation and quality assurance/quality control (QA/QC) processes. These include:

- Installation forms. These are used for to collect data during measure installation. When necessary, these forms include supplementary forms, such as the Balance Point Worksheet/Sizing Calculator.
- QA Inspection forms. These are used to collect data during the QA inspections.

The evaluation team reviewed and iterated on both sets of these forms with the PTCS QA/QC team. The data collection approach for this evaluation is based on the most current version<sup>49</sup> of both sets of forms, which are included at the end of this chapter.

## Site Registry

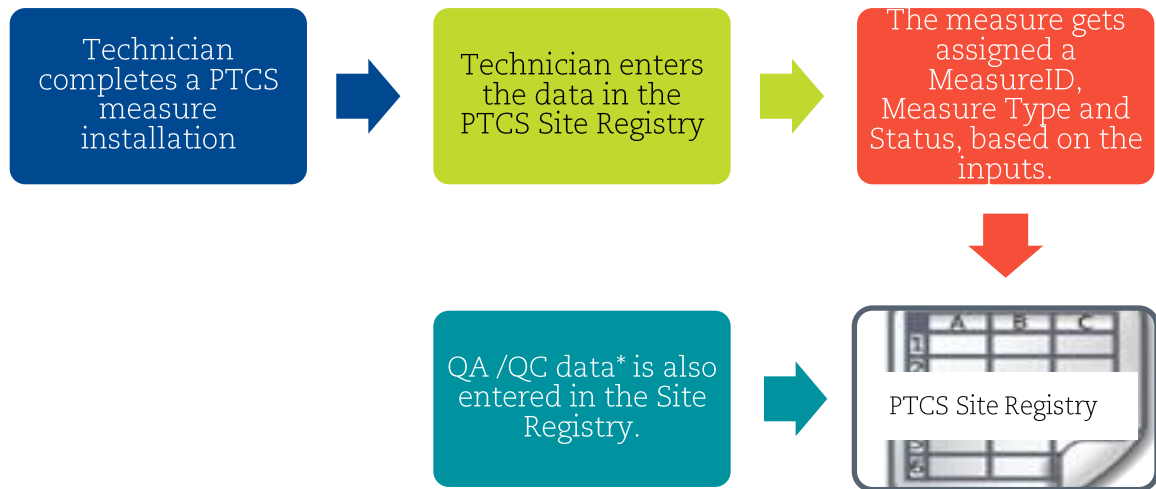
Select installation and field inspection data is captured in the PTCS Online Site Registry<sup>50</sup>. Figure shows the PTCS data collection process and connection to the Site Registry.

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<sup>49</sup> QA/QC Inspection forms revised on January 16, 2017. Per discussion with the third-party contractor, this version of the QA inspection forms would be in use beginning February 2017.

<sup>50</sup><https://ptcs.bpa.gov/>

Figure J1: PTCS Data Collection Process



\*Up to 10% of projects receive a QA inspection.  
Source: Navigant, based on discussion with the BPA PTCS team

## QA Field Inspection Sample Design

The PTCS team uses a sample designed to ensure sufficient coverage and representation of installed projects, contractors and regions<sup>51</sup>. This plan is summarized below:<sup>52</sup>

1. A summary of activity in a territory that has occurred since the previous QA inspections is created and reviewed for high-volume contractors, unusual activity and other outliers.
2. The PTCS team draws an appropriate number of jobs for:
  - a. Technicians with a high failure rate or on probation.
  - b. High-volume contractors
  - c. GSHP jobs, if any
3. A sample consisting of approximately 40% of duct sealing jobs and 60% of ASHP jobs is randomly pulled.

**Note:** This may vary widely depending on what types of jobs are present in an individual utility territory. Some utilities have mostly heat pump jobs and some have mostly duct sealing jobs. The PTCS team strives to be representative at the individual utility level.

<sup>51</sup>The PTCS team uses the Site Registry as the database from which the sample is pulled.

<sup>52</sup>This summary is based on the evaluation team's review of 'PTCS Sample Strategy 10-24-16' document and subsequent discussions with the third-party contractor.

4. The sample is inspected for its representativeness across a wide range of technicians.
  - a. Excessive jobs of individual technicians are randomly deselected.
  - b. If the sample is not wide enough, random technicians from the unselected pool are added.

This full sample is trimmed down to 150-250% of the total jobs by removing random instances of multiple jobs performed by individual technicians to preserve the needed breadth of sample. If the sample is overly broad, random instances of jobs of non-oversampled technicians are removed.

Table J1 shows planned PTCS QA inspections by region for the CY 2017.

**Table J1: Planned QA inspections for CY2017**

Region	Planned QA Visits
Bend	21
Central WA Route 2016	77
Eugene/Springfield	83
I-84	40
ID	19
MT	26
Oregon Coast	20
Oregon Coast - almost	10
Portland Metro	132
Puget Sound	232
S. Oregon	5
<b>Grand Total</b>	<b>664</b>

Source: CLEAResult

## PTCS Installation Forms

The most recent PTCS Installation Forms are available on the BPA website. They can be accessed using the following link: <https://www.bpa.gov/ee/policy/imanual/pages/im-document-library.aspx>.

## PTCS QA Inspection Forms

The data collection approach described for this evaluation is based on the set of QA Inspection forms dated January 16<sup>th</sup>, 2017 and embedded below.

### PTCS Air Source Heat Pump QA/QC Form



PTCS Air Source Heat  
Pump QA Form\_2016\_

### PTCS Ground Source Heat Pump QA/QC Form



PTCS Ground Source  
QA Form\_W-A\_2016\_F

### PTCS-Prescriptive Duct Sealing QA/QC Form



PTCS\_Prescriptive  
Duct Sealing QA Form

# Appendix K. Approach to Leverage PTCS Processes for Evaluation

## Process

The process flow for leveraging PTCS QA inspection data collection is outlined below:

### 1. Refresh reported measure population

By the 10<sup>th</sup> of each month the evaluation team provided the QA team and contractor:

- a. The current set of reported performance HVAC projects for all utilities with projects installed within the 12-months immediately preceding the upcoming calendar month.
  - i. The evaluation team filtered projects using the 'CompletionDate' data field within the IS2.0 database.
  - ii. This list was limited to reported projects by only including Measure IDs that appear in both the Site Registry and the IS2.0 data system.
- b. All customer personal identifying information was removed from the data, and only the set of Measure IDs were delivered to the QA contractor via email.

### 2. List of completed QA inspections

Near the 20<sup>th</sup> of each month, the PTCS QA/QC team provided:

- a. A list of Measure IDs for which QA inspections were completed.
- b. An updated extract of the QA portion of the Site Registry, previously referred to as the 'QA Data Export' spreadsheet. This is the excel/.csv export of all of the QA inspection data (no date restrictions or filters).
- c. An updated PTCS Site Registry<sup>53</sup>: this is the excel/.csv export of all the installation data with no date restrictions or filters and which includes both rejected and record only measures.
- d. Electronic copies of the complete set of projects included in the evaluation sample which received QA inspections during the last month.

The evaluation team provided access to a secure file transfer process for the project files.

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<sup>53</sup> The evaluation team's understanding is that an updated extract of PTCS Site Registry is pulled every week by BPA's internal PTCS team.



### 3. Progress Updates

Near the 25<sup>th</sup> of each month, the evaluation team provided:

- a. A status update summarizing progress towards achieving the target sample design. This included a summary table showing target and completed sample sizes by region and quota.

The evaluation team provided these updates via email.

## Achieving the PTCS QA/QC Target Sample

The PTCS QA/QC team did not constrain their sample design to the population of projects reported to BPA, unlike the evaluation team. As such, they followed the process below to ensure they could achieve their target sample.

1. The PTCS team used the reported project population to develop the PTCS QA/QC plan sample every month according to the sampling procedure described in the Appendix J.
2. The PTCS team pulled additional projects from the PTCS Site Registry, if required to make sure that the sample was representative of the overall PTCS Site Registry population.
3. Upon achieving the evaluation team's target sample design, the PTCS team would have been able to decide to pull the remainder of the PTCS QA/QC visit sample from the Site Registry.

## Escalation Protocol

Striving to provide timely and actionable evaluation results, the team used the monthly progress updates to track progress toward completing the target evaluation sample design. In case the progress appeared to begin to differ significantly from the timeline proposed, the evaluation team alerted the BPA evaluation lead immediately via email.

## Data Transfer Protocols

The evaluation team understood the following data sources might contained sensitive customer Personal Identifying Information (PII).

- IS2.0 data
- Installation and Inspection forms

To receive this data securely, Navigant requested data using a secure file transfer process (FTP).

Wherever possible, the evaluation team created and shared data exports and summaries that contained only Measure IDs to remove PII data. The evaluation team transmitted this data electronically via email.

# Appendix L. RTF Delivery Verification Requirement for Res HVAC UES Measure Groups

The following tables provide the detailed delivery verification requirements for the residential HVAC measure groups included in the CY2016 evaluation.

**Table L1: Duct Sealing – Performance and Prescriptive**

DV Component	Specification	DV Requirement Checklist
Measure Identifiers	Heating Zone	Check for heating zone
	Heating System Type	Check heating system type
Savings Baseline	Pre-Conditions	Check that 30% of ducts are located in unconditioned space OR - that there were supply leaks to unconditioned space within 15 feet of the air handler
	Pre-Conditions	Check the house has not previously had its ducts sealed through a utility duct sealing program.
Implementation and Product Standards	Installation Specification	Check that accessible non-flex duct joints and connections located in unconditioned space are sealed with UL-181 listed mastic
	Installation Specification	Check that accessible flexible duct connections located in unconditioned space have interior and exterior liners secured and are air-sealed and tightened appropriately.

Source: RTF

**Table L2: Air-Source Heat Pumps**

DV Component	Specification	DV Requirement Checklist
Measure Identifiers	Heating Zone	Check Heating zone
Implementation and Product Standards	HSPF Rating	Check system meets 9.0 HSPF or greater

Source: RTF

DV requirements for Air-Source Heat Pumps w/o Duct Sealing TAP are the combination of DV requirement for the following two TAPs:

1. Air-Source Heat Pumps w/o Duct Sealing, and;
2. Commissioning, Controls and Sizing.

**Table L3: Ground-Source Heat Pumps**

DV Component	Specification	DV Requirement Checklist
Measure Identifiers	Measure Type	Check measure type (including upgrade vs conversion, with desuperheater or without, with CAC or without CAC)
	Climate Zone	Check climate zone (Heating zone 2 or 3, any cooling zone)
	House Size	Check house size (<4000 sq.ft or ≥ 4000 sq.ft.)
Savings Baseline	House Vintage	Check house vintage (new construction or retrofit)
	Pre-Conditions	Check previous heating system was either ASHP or electric FAF If applicable, check existing water heater was an electric tank without desuperheat
Implementation and Product Standards	Installation Specification	Check if GSHP is installed If applicable, check that electric water heater with desuperheat pre-heating is installed

Source: RTF

DV requirements for Ground-Source Heat Pumps w/o Duct Sealing TAP are the combination of DV requirement for the following two TAPs:

1. Ground-Source Heat Pumps w/o Duct Sealing, and;
2. Commissioning, Controls and Sizing.

**Table L4: Commissioning, Controls and Sizing**

DV Component	Specification	DV Requirement Checklist	
Measure Identifiers	Heating Zone	Check Heating zone	
	Product Specification	Check heat pump is new and rated by AHRI	
	Balance Temperature	Auxiliary Heat	Check heat pump balance point is at 30°F or lower
			Check auxiliary heat is controlled to one of the following: <ul style="list-style-type: none"> <li>- Single stage OR multi stage without air temperature sensor control: auxiliary heat is controlled so that it does not engage when the outdoor temperature is above 35°F, except when supplemental heating is required during a defrost cycle or when emergency heating is required during a refrigeration cycle failure.</li> <li>- Multi stage with air temperature sensor control: auxiliary heat is controlled so that it does not engage when the supply air temperature is above 85°F.</li> </ul>
Implementation and Product Standards	Thermostat Controls	Check thermostat has manual changeover feature or heating/cooling lockout (if applicable)	
	Temperature change across indoor coil	Check temperature change across indoor coil is at or above temperature in Table below:	
	Compressor cutout	Check that compressor is not cutout at temperatures above 5°F (if applicable)	
	Airflow across indoor coil	Check airflow across indoor coil is either: <ul style="list-style-type: none"> <li>- As specified in manufacturer’s literature.</li> <li>- ≥ 325 CFM per ton of nominal heating capacity</li> </ul>	
Implementation and Product Standards (Continued)	External static pressure	Check that external static pressure does not exceed 0.8 in of water (200 Pa)	

Source: RTF

**Table L5: Temperature Change Across Indoor Coil Table**

Outdoor Temperature (°F)	Minimum Temperature Split (°F)			
	CFM per Ton			
	300	350	400	450
5	13	11	10	9
10	15	13	11	10
15	17	15	13	11
20	19	17	15	13
25	20	18	16	14
30	21	19	17	15
35	23	21	18	16
40	25	23	20	18
45	28	25	22	20
50	31	27	24	22
55	34	29	26	23
60	36	31	28	25
65	38	33	29	26

Source: RTF - Air Source Heat Pump Commissioning, Controls, and Sizing Specification” Adopted: May 12, 2015; Revised July 21

**Table L6: Variable Speed Heat Pumps**

DV Component	Specification	DV Requirement Checklist
Measure Identifiers	Heating Zone	Check for heating zone
	Cooling Zone	Check cooling zone
Implementation and Product Standards	Installation Specification	Check system is variable speed with inverter driven compressor
	HSPF Rating	Check system meets 9.0 HSPF or greater

Source: RTF

DV requirements for Variable Speed Heat Pumps w/o Duct Sealing TAP are the combination of DV requirement for the following two TAPs:

1. Variable Speed Heat Pumps w/o Duct Sealing, and;
2. Commissioning, Controls and Sizing.

## Appendix M. Current Weightage of RRF Delivery Verification Requirements in the PTCS QA forms

The following section describes current weightage of the delivery requirements in the PTCS QA forms by measure group. The team assigned the following categories to the DV requirements based on their importance in the current QA forms.

**Must Pass:** These are the delivery requirement data points which must pass for the overall project to pass in the QA inspection. On the QA inspection forms, these data points are typically marked with \*\*.

**Can Fail:** These are the delivery requirements in the current QA forms which can fail (get a F grade) but still the project can pass overall.

**No grade assigned:** These are the data points which are available on the QA forms but there is no grade assigned to them. In short, these data points do not make a difference on the passing/failing of the projects.

**Table M1: Duct Sealing – Weightage in QA forms**

DV Component	Specification	DV Requirement Checklist	Must Pass	Can Fail	No Grade Assigned
Measure Identifiers	Heating Zone	Check for heating zone	Can be derived		
	Heating System Type	Check heating system type			√
Savings Baseline	Pre-Conditions	Check that 30% of ducts are located in unconditioned space OR	Install Forms		
		- that there were supply leaks to unconditioned space within 15 feet of the air handler	Install Forms		
	Pre-Conditions	Check the house has not previously had its ducts sealed through a utility duct sealing program.			√
Implementation and Product Standards	Installation Specification	Check that accessible non-flex duct joints and connections located in unconditioned space are sealed with UL-181 listed mastic		√	
	Installation Specification	Check that accessible flexible duct connections located in unconditioned space have interior and exterior liners secured and are air-sealed and tightened appropriately.		√	

Source: RTF and Navigant analysis

**Table M2: Air-Source Heat Pumps – Weightage in QA forms**

DV Component	Specification	DV Requirement Checklist	Must Pass	Can Fail	No Grade Assigned
Measure Identifiers	Heating Zone	Check Heating zone	Can be derived		
Implementation and Product Standards	HSPF Rating	Check system meets 9.0 HSPF or greater	√		

Source: RTF and Navigant analysis

**Table M3: Ground-Source Heat Pumps – Weightage in QA forms**

DV Component	Specification	DV Requirement Checklist	Must Pass	Can Fail	No Grade Assigned
Measure Identifiers	Measure Type	Check measure type (including upgrade vs conversion, with desuperheater or without, with CAC or without CAC)			√
	Climate Zone	Check climate zone (Heating zone 2 or 3, any cooling zone)	Can be derived		
	House Size	Check house size (<4000 sq.ft or ≥ 4000 sq.ft.)	Can be derived		
	House Vintage	Check house vintage (new construction or retrofit)	Install forms		
Savings Baseline	Pre-Conditions	Check previous heating system was either ASHP or electric FAF			√
		If applicable, check existing water heater was an electric tank without desuperheat			√
Implementation and Product Standards	Installation Specification	Check if GSHP is installed			√
		If applicable, check that electric water heater with desuperheat pre-heating is installed			√

Source: RTF and Navigant analysis



**Table M4: Commissioning, Controls and Sizing – Weightage in QA forms**

DV Component	Specification	DV Requirement Checklist	Must Pass	Can Fail	No Grade Assigned
Measure Identifiers	Heating Zone	Check Heating zone	Can be derived		
Implementation and Product Standards	Product Specification	Check heat pump is new and rated by AHRI	Can be derived		
	Balance Temperature	Check heat pump balance point is at 30°F or lower	√		
	Auxiliary Heat	Check auxiliary heat is controlled to one of the following: - Single stage OR multi stage without air temperature sensor control: auxiliary heat is controlled so that it does not engage when the outdoor temperature is above 35°F, except when supplemental heating is required during a defrost cycle or when emergency heating is required during a refrigeration cycle failure. - Multi stage with air temperature sensor control: auxiliary heat is controlled so that it does not engage when the supply air temperature is above 85°F. <sup>54</sup>	√		
	Thermostat Controls	Check thermostat has manual changeover feature or heating/cooling lockout (if applicable)			√
	Temperature change across indoor coil	Check temperature change across indoor coil is at or above temperature in Table		√	

<sup>54</sup> Based on PTCS team’s experience, there is a rare chance of the multi stage ASHP occurring so the team decided not to add this data point to the QA forms. If a project with multi stage does come through, it will get 0 realization rate.

DV Component	Specification	DV Requirement Checklist	Must Pass	Can Fail	No Grade Assigned
		below:			
	Compressor cutout	Check that compressor is not cutout at temperatures above 5°F (if applicable)		√	
Implementation and Product Standards (Continued)	Airflow across indoor coil	Check airflow across indoor coil is either: - As specified in manufacturer's literature. - ≥ 325 CFM per ton of nominal heating capacity		√	
	External static pressure	Check that external static pressure does not exceed 0.8 in of water (200 Pa)		√	

Source: RTF and Navigant analysis

**Table M5: Variable Speed Heat Pumps – Weightage in QA forms**

DV Component	Specification	DV Requirement Checklist	Must Pass	Can Fail	No Grade Assigned
Measure Identifiers	Heating Zone	Check for heating zone	Can be derived		
	Cooling Zone	Check cooling zone	Can be derived		
Implementation and Product Standards	Installation Specification	Check system is variable speed with inverter driven compressor	Can be derived		
	HSPF Rating	Check system meets 9.0 HSPF or greater	√		

Source: RTF and Navigant analysis