BONNEVILLE POWER ADMINISTRATION

2020-2021
Custom Industrial Impact Evaluation for Option 1 Utilities
Final Report

Bonneville Power Administration

2020-2021 Custom Industrial Impact Evaluation for Option 1 Utilities – Final Report

Submitted by Evergreen Economics

In partnership with SBW Consulting and Apex Analytics, LLC

July 1, 2022

1 EXECUTIVE SUMMARY

This document presents the results of an impact evaluation of the Bonneville Power Administration's custom portfolio for industrial customers of Option 1 utilities. This report addresses Domain 1 of a rolling plan with additional domains that will address the entire custom measure and commercial, industrial and agriculture (C/I/Ag) lighting portfolios (which include all nonresidential lighting and custom measures).

The evaluation objectives were to:

1. **Estimate first-year kWh savings** including savings based on as-operated conditions (actual post-installation conditions that include any changes due to the COVID-19 pandemic) and evaluated (as-expected) conditions (had COVID-19 not occurred) for the custom industrial portfolio for Option 1 utilities, and for separate portions of the portfolio as needed to understand the savings performance of important program delivery channels.
2. **Develop recommendations on measurement and verification (M&V) procedures**, including when savings can be reliably estimated, for custom measures, using the BPA *Measurement and Verification Protocol Selection Guide and Example M&V Plan* and applying the protocol called *Engineering Calculations with Verification* (ECwV).

1.1 METHODOLOGY

This evaluation represents the population of measures with completed reporting between September 2019 and August 2020. The sample design targeted a 90/10 confidence level and precision and was developed based on BPA tracking data.

The sampling was conducted with a conventional optimum allocation stratified design based on end use category and reported kWh savings for each measure. The sample size was 40 measures.

The data collection approach included a combination of sources such as file review, site visits and trend metering. Custom measure analysis was conducted using a multistep process starting with review of the M&V model, collecting supplemental data where needed, running the evaluation model, and estimating savings. The evaluated savings were calculated with any changes to site operations resulting from COVID-19 removed. Additional sets of "as observed" savings and ECwV-estimated savings were calculated for comparison.

Once data collection and analysis were completed for the sample, site-level results were compiled to estimate the electric savings and cost-effectiveness for the domain and individual end uses within the domain using a ratio analysis.

1.2 SUMMARY OF FINDINGS AND RECOMMENDATIONS

The overall results for this domain showed evaluated savings coming in below reported savings, for an overall realization rate (ratio of evaluation savings to reported savings) of 85 percent, as shown in Table 1. This is lower than the previous evaluation of this domain,[1] which had a realization rate of 102 percent. As shown in the table, the lower realization rates were estimated for HVAC,

[1] See results for the Option 1 Non-Lighting Industrial domain: https://www.bpa.gov/energy-and-services/efficiency/evaluation – from there click "Impact Evaluation" under "Presentations and Reports," then find "Industrial" and choose "Impact Evaluation Site-Specific Portfolio Highlights, Presentation, Final Report & BPA Response Memo (04/2017)".

motors/drives, and refrigeration projects. Process loads and compressed air evaluation results were very close to reported savings. These results are shown for the entire domain, where sample-level results have been applied to the population of projects. The overall sampling precision was 7 percent for a 90 percent two-tailed distribution, which was slightly better than the target design of 10 percent.[2]

Table 1: Evaluated first-year savings by end use

End Use	*Realization Rate*	*Sampling Relative Precision (90% two-tailed)*	*Reported Savings (kWh)*	*Evaluation Savings*	
				kWh	*Percent of Domain*
Compressed Air	100%	10%	3,843,633	3,859,169	12%
HVAC	54%	73%	1,778,498	969,013	3%
Motors/Drives	81%	11%	12,792,799	10,406,622	31%
Process Loads	108%	2%	8,072,600	8,735,732	26%
Refrigeration	74%	21%	12,456,922	9,259,773	28%
Total	**85%**	**7%**	**38,944,452**	**33,230,310**	**100%**

Evaluators observed that BPA *Implementation Manual* and measurement and verification protocols were generally followed correctly and that the difference in realization rates did not result from deviations in procedure. The main reasons for realization rates lower than 100 percent include the following:

- A documentation error in the largest sampled project measure;
- Program baseline assumptions inconsistent with Regional Technical Forum (RTF) guidelines (for evaporative cooling use in potato sheds); and
- Differences in observed operating conditions.

For some projects, the evaluators observed issues with the model used to estimate savings missing key elements that would improve the accuracy of savings estimates. This would not notably impact the overall realization rates for the sampled population but would improve the reliability of individual models.

The evaluation also included an assessment of the BPA *Engineering Calculations with Verification* (ECwV) protocol. The evaluators found that small and medium-sized projects showed little bias in

[2] The realized sample precision was better than the original estimate because there was less variation between evaluated and reported savings than expected.

evaluated results using the protocol, and the results using the protocol were similar to evaluated results overall.

The evaluation team developed recommendations resulting from the key findings of this study:

- **Recommendation 1:** BPA should consider applying its ECwV measurement and verification protocol to a wider size range of projects.
- **Recommendation 2:** BPA should revisit quality control procedures to reduce the potential for major reporting errors.
- **Recommendation 3:** BPA should consider updating its policy for determining baseline to adhere to RTF guidelines.
- **Recommendation 4:** Project engineers should make an explicit statement of the current practice assumed for all lost opportunity projects for which a code baseline is not specified. Baselines not specified by code are where the BPA M&V selection guide differs from the RTF. This process should reference the appropriate *Regional Technical Forum Guidelines for the Assessment of Energy Efficiency Measures*[3] and should be included in planning and completion reports. This step will ensure that project reviewers continuously consider what is current practice and empower them to recommend changes when they find inconsistencies.
- **Recommendation 5:** Project engineers should specify models that are well-suited to calculating part load savings for the project where applicable to ensure that the best possible model was chosen according to best practices and BPA protocols.

[3] Regional Technical Forum. 2020. https://nwcouncil.app.box.com/v/2020RTFGuidelines

2 INTRODUCTION

The Bonneville Power Administration (BPA), along with its public power utility partners, acquires savings from a portfolio of energy efficiency programs and measures. Currently, the portfolio includes the following measures and savings estimation techniques:

- Unit Energy Savings (UES) measures utilizing a constant savings value for each measure application;
- Custom measures, requiring calculation of savings for each project; and
- Calculator measures with a standardized savings estimation algorithm and project-specific parameter values (typically lighting).

The subject of this report is an impact evaluation of BPA's custom portfolio for industrial customers of Option 1 utilities.[4]

2.1 KEY TERMS

See Appendix A for definitions of key terms such as reported savings, measure and realization rate, which are used throughout this report.

2.2 BACKGROUND

Over time, BPA and the Regional Technical Forum (RTF) have developed a series of policies and procedures to provide guidance on how BPA should estimate savings from the projects that comprise its energy efficiency portfolio.

The RTF provides guidance on delivery verification for UES and Standard Protocols and specifies that 90 percent of the portfolio of savings should be evaluated every four years, with additional guidelines by measure type.[5] Consistent with this, BPA has established policies for impact evaluation[6] that state that within a four-year cycle, impact evaluations should sample from at least 90 percent of savings within the BPA portfolio. Additionally, for custom projects, the policies state that BPA should sample from 99 percent of the portfolio over four years and include sampled projects within a domain that sum up to at least 20 percent of the custom savings.

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[4] Utilities are categorized as Option 1 or 2 for M&V purposes. For Option 1 utilities, BPA is often involved throughout the project lifecycle by providing technical support for project development, implementation, approval, and M&V. Option 2 utilities provide their own technical support including M&V and custom project quality control, e.g., project proposal and completion report review.

[5] Regional Technical Forum. 2020. *Regional Technical Forum Operative Guidelines for the Assessment of Energy Efficiency Measures*: https://nwcouncil.app.box.com/v/2020RTFGuidelines (see Section 5.2.1).

[6] BPA has developed policies for Standards; Planning; Oversight; Impact and Process Evaluation; and Savings for Custom Projects, Calculators, and UES measures.

In addition, BPA has developed an implementation manual[7] that specifies reporting requirements for energy efficiency programs, and measurement and verification (M&V) protocols[8] specifically for custom measures.

The Evergreen Economics team (which includes SBW Consulting and Apex Analytics) conducted a detailed assessment of BPA's portfolio in late 2019 to understand evaluation coverage, priorities and opportunities. Using the results of the data assessment and guided by the BPA evaluation documents listed above, the Evergreen team identified that the highest priority was to conduct evaluation on custom and commercial, industrial and agriculture (C/I/Ag) lighting projects. These projects, which require M&V or calculators for savings estimation, represent approximately 65 percent of the portfolio and were most recently evaluated for Fiscal Year (FY) 2012-2013 savings.

The team developed a rolling plan with several domains to evaluate the entire custom measure and C/I/Ag lighting portfolio (which includes all nonresidential lighting and custom[9] measures).[10,11] The evaluation was designed to be an ongoing process, establishing a model for consistently timed evaluation in future years and providing feedback to BPA on the quality of data collection and use of M&V protocols.

2.3 EVALUATION OBJECTIVES

This document presents the first set of results from this plan, an impact evaluation of BPA's custom portfolio for industrial customers of Option 1 utilities, conducted by the Evergreen team. The evaluation objectives for this first domain were to:

1. **Estimate first-year kilowatt-hour (kWh) savings** including savings based on as-operated conditions (actual post-installation conditions that include any changes due to the COVID-19 pandemic) and evaluated (as-expected) conditions (had COVID-19 not occurred) for the custom industrial portfolio for Option 1 utilities, and for separate portions of the portfolio as needed to understand the savings performance of important program delivery channels.
2. **Develop recommendations on M&V procedures**, including when savings can be reliably estimated, for custom measures, using the BPA *Measurement and Verification Protocol Selection Guide* and applying the protocol called *Engineering Calculations with Verification* (ECwV).

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[7] Bonneville Power Administration. 2019. *2020-2021 Implementation Manual*. https://www.bpa.gov/-/media/Aep/energy-efficiency/measurement-verification/12-bpa-ci-sem-mv-ref-guide-v10.pdf

[8] Protocols include the M&V Protocol Selection Guide; reference guides for sampling, regression, and glossary; and protocols on metering, indexing, engineering calculations with verification, energy modeling, and existing building commissioning. To support M&V of strategic energy management projects, M&V protocols also include the *Monitoring, Tracking and Reporting (MT&R) Reference Guide*. The protocols are currently on their ninth revision and will soon be referred to as the *Commercial & Industrial SEM M&V Reference Guide*, found at https://www.bpa.gov/energy-and-services/efficiency/implementation-manual

[9] For Option 2 utilities, both lighting and custom projects are reported to BPA through the custom project pathway. For this evaluation, Option 2 custom projects are technically those projects with non-lighting end uses.

[10] The comprehensive Fiscal Year (FY) 2020-2021 evaluation approach is described in the evaluation plan the team developed in January 2020: https://www.bpa.gov/-/media/Aep/energy-efficiency/evaluation-projects-studies/BPA-2020-21-impact-evaluation-plan.pdf

[11] The FY2020-21 plan also included strategic energy management (SEM) evaluation and assessment of BPA Qualified Commercial HVAC measure savings.

3 METHODOLOGY

This section summarizes the methods used to conduct this evaluation, and is organized as follows: Sample Design, Data Collection, Custom Measure Analysis, and Study and Domain Analysis. Appendix C provides additional detail on the study methods.

3.1 SAMPLE DESIGN

Table 2 on the next page shows the number of measures and savings associated with Option 1 utilities' custom industrial measures completed during the study period by end use and strata, and the study sample allocation of 40 measures (at 39 sites), which includes six certainty sampled measures and a stratified random sample of 34 additional measures. As part of the review of tracking data associated with producing the sample, the team noted that there was a potential duplicate project. The team brought this to the attention of BPA staff, who subsequently removed the duplicate project from program records.[12]

[12] In future evaluations, evaluators should also do a systematic review of tracking data to flag any duplicate projects for removal.

Table 2: Option 1 custom industrial sample design

End Use	Strata*	Reported Savings (kWh)		Number of Measures	Sample Size
		Average	Total	Count	Count
Compressed Air	Very Small	34,785	69,569	2	0
	Small	145,034	725,170	5	4
	Medium	371,347	1,856,734	5	3
	Certainty	1,192,160	1,192,160	1	1
HVAC	Very Small	61,045	61,045	1	0
	Small	250,264	750,793	3	2
	Certainty	966,660	966,660	1	1
Motors/Drives	Very Small	45,857	320,998	7	0
	Small	140,978	704,891	5	4
	Medium	502,849	6,537,037	12	7
	Certainty	5,229,873	5,229,873	1	1
Process Loads	Very Small	14,327	28,653	2	0
	Small	273,246	1,366,228	5	3
	Certainty	3,338,859	6,677,718	2	2
Refrigeration	Very Small	42,000	209,999	5	0
	Small	169,752	679,007	4	3
	Medium	537,259	8,058,880	15	8
	Certainty	3,509,036	3,509,036	1	1
	Total	**510,898**	**38,944,452**	**77**	**40**

* Stratum *"very small"* denotes the excluded measures (based on very small savings). The *certainty* measures represent a substantial portion of total reported energy savings within the end use and are considered to be necessary for the evaluation, and therefore are not subject to random selection. HVAC and process loads have a single probabilistic stratum due to the small number of measures below the size threshold of 200,000 kWh.

3.2 DATA COLLECTION

Our general approach to evaluation data collection was to fully leverage the data collected by the BPA Energy Smart Industrial (ESI) team and utility staff throughout the process of developing each project and to only collect additional data if needed to achieve reliable estimates of savings for the sampled measures. We collected the necessary data using a combination of the following approaches (each of which is described in more detail in Appendix C):

- File review
- Telephone/email discussion with project engineers
- Telephone/email discussion with end users
- Site visits
- Affected system trend metering

- Supplemental weather data gathering
- Cost effectiveness parameter data collection

3.3 CUSTOM MEASURE ANALYSIS

We estimated savings for sampled custom measures using the following steps (each of which is described in more detail in Appendix C):

1. Select reliable evaluation model
2. Assess determinant reliability
3. Collect supplemental data
4. Run evaluation model
5. Estimate savings using engineering calculations with verification (ECwV)

3.4 STUDY AND DOMAIN ANALYSIS

Once data collection and analysis were completed for the sample, we compiled a workbook containing all of the individual site level quantitative outputs and qualitative findings about key drivers for deviations between evaluated savings and original savings estimates. The site-level results were used to estimate the electric savings and cost-effectiveness for the domain and individual end uses within the domain using a ratio analysis. For custom measures with ECwV protocol savings estimates, we also determined when the ECwV protocol provides a reliable estimate of savings. The details of this approach are presented in Appendix C.

4 FINDINGS

This section presents impact evaluation results for BPA's custom portfolio for industrial customers of Option 1 utilities. These findings address Domain 1 of a rolling evaluation plan for Fiscal Year (FY) 2020-2021 with additional domains that will address the entire custom measure and C/I/Ag lighting portfolios (which include all nonresidential lighting and custom measures).

The section is organized as follows:

- Overall results for this first FY2020-2021 impact evaluation domain (Custom Industrial for Option 1 utility customers)
- Project measure level results
- Key drivers of savings
- Lifetime savings
- COVID-19 pandemic savings estimation
- ECwV savings adjustments
- Cost-effectiveness

Appendix B provide site-specific savings estimation details.

4.1 OVERALL DOMAIN 1 RESULTS

This subsection provides the overall results for this impact evaluation of custom measures installed by Option 1 utility industrial customers with completed reporting between September 2019 and August 2020.

The evaluators calculated "evaluated savings" using adjustments to remove any changes to facility operation due to COVID-19. Evaluated savings estimates are intended to represent what would have happened had COVID-19 not occurred. "As-observed" savings were calculated separately, with those results presented for comparison in a separate section.

The overall results showed evaluated savings estimates for Option 1 custom industrial measures as 85 percent of the savings that BPA reported. Evaluators observed that BPA *Implementation Manual* and M&V protocols were generally followed correctly and that the difference in realization rates did not result from deviations in procedure.

FIRST-YEAR SAVINGS

Evaluated savings were lower than reported savings for all end uses except process loads and compressed air, which were close to the same as reported savings. The most impactful issues were observed in refrigeration and motors and drives, as shown in Figure 1 and Table 3 (both of which report on the evaluation results for the entire domain).

Figure 1: Evaluated first-year savings by end use compared to reported savings by end use

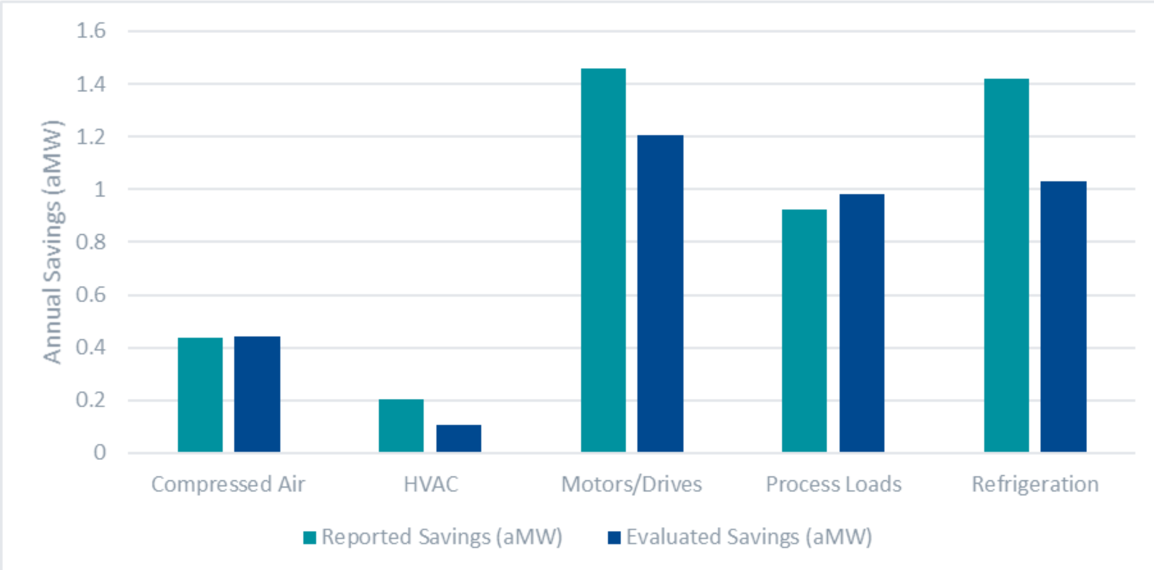


Table 3: Evaluated first-year savings by end use

End Use	*Realization Rate*	*Sampling Relative Precision (90% two-tailed)*	*Reported Savings (kWh)*	*Evaluation Savings*	
				kWh	*Percent of Domain*
Compressed Air	100%	11%	3,843,633	3,859,169	12%
HVAC	54%	68%	1,778,498	969,013	3%
Motors/Drives	81%	11%	12,792,799	10,406,622	31%
Process Loads	108%	2%	8,072,600	8,735,732	26%
Refrigeration	74%	20%	12,456,922	9,259,773	28%
Total	**85%**	**7%**	**38,944,452**	**33,230,310**	**100%**

The realization rate estimated by the prior evaluation of this domain[13] was 102 percent. Note that the evaluation methodology and program cycle differed over the two evaluation periods.

The actual sampling relative precision came in at 7 percent for a 90 percent two-tailed confidence interval. This precision is slightly better than predicted during the sample design phase (10 percent precision), due to lower variability than expected in evaluated savings relative to reported savings.

[13] See results for the Option 1 Non-Lighting Industrial domain: https://www.bpa.gov/energy-and-services/efficiency/evaluation – from there click "Impact Evaluation" under "Presentations and Reports," then find "Industrial" and choose "Impact Evaluation Site-Specific Portfolio Highlights, Presentation, Final Report & BPA Response Memo (04/2017)".

The sample design was based on an expectation of slightly higher variability than observed in the last evaluation of this domain, but the actual variability came in substantially lower.

4.2 MEASURE LEVEL RESULTS

Results at the project measure level based on the evaluation sample of 40 projects were highly variable, with realization rates ranging from 0 to 2.2, as shown in Figure 2, with each project measure in the sample represented by a single point. The points are grouped by end use (color) and size stratum (shape). For HVAC, motors/drives, and refrigeration measures, there were more low realization rate project measures than high realization rate project measures, leading to low overall realization rates at the end use level. For compressed air and process loads, the largest project measures each had realization rates near 1.0, which mitigated mixed results on the smaller project measures. Refrigeration and motors/drives projects had high amounts of variability in realization rates, with more projects coming in below 1.0 than above, driving down the overall realization rate for the end use.

Figure 2: Project measure-level realization rates

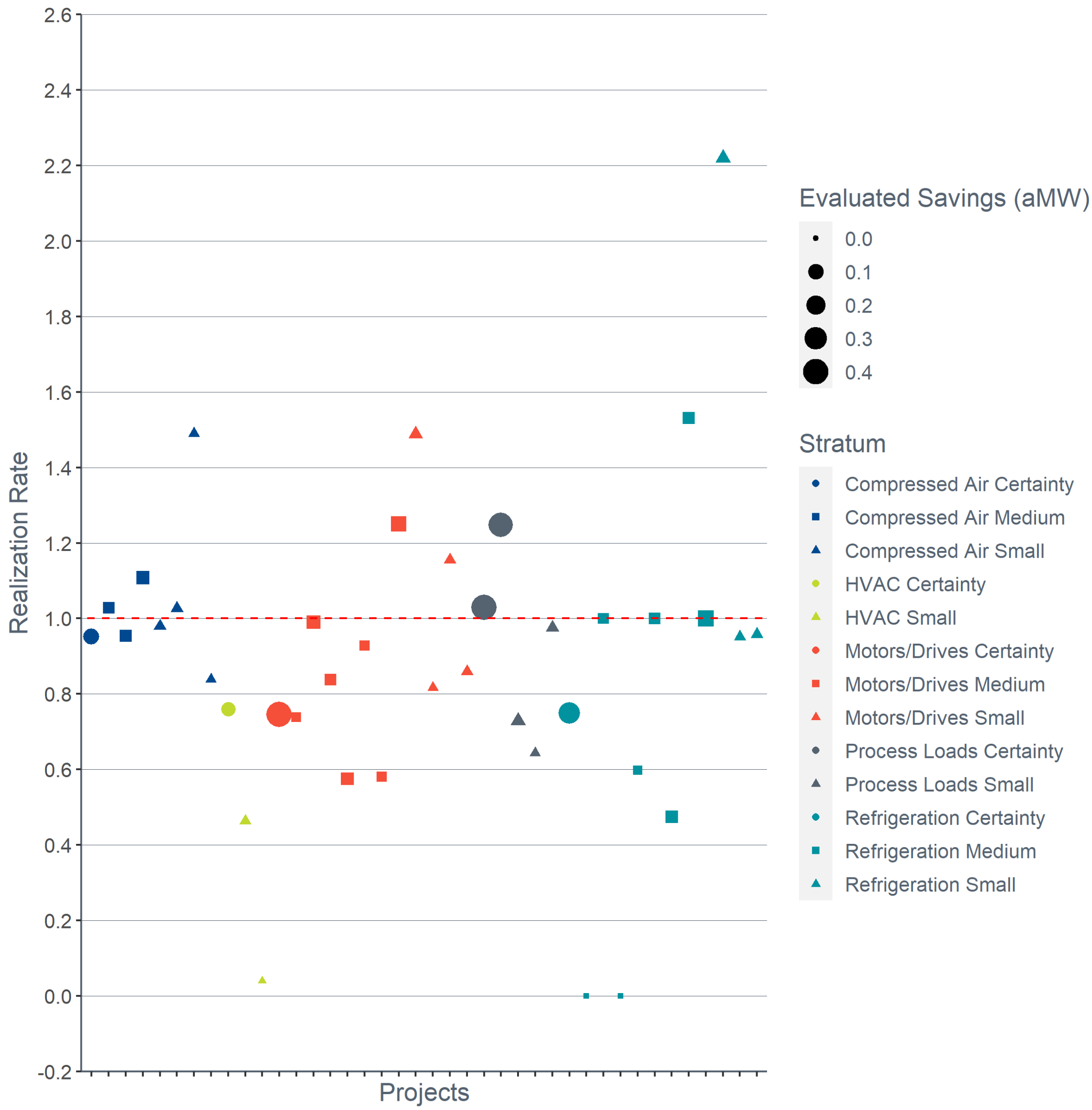
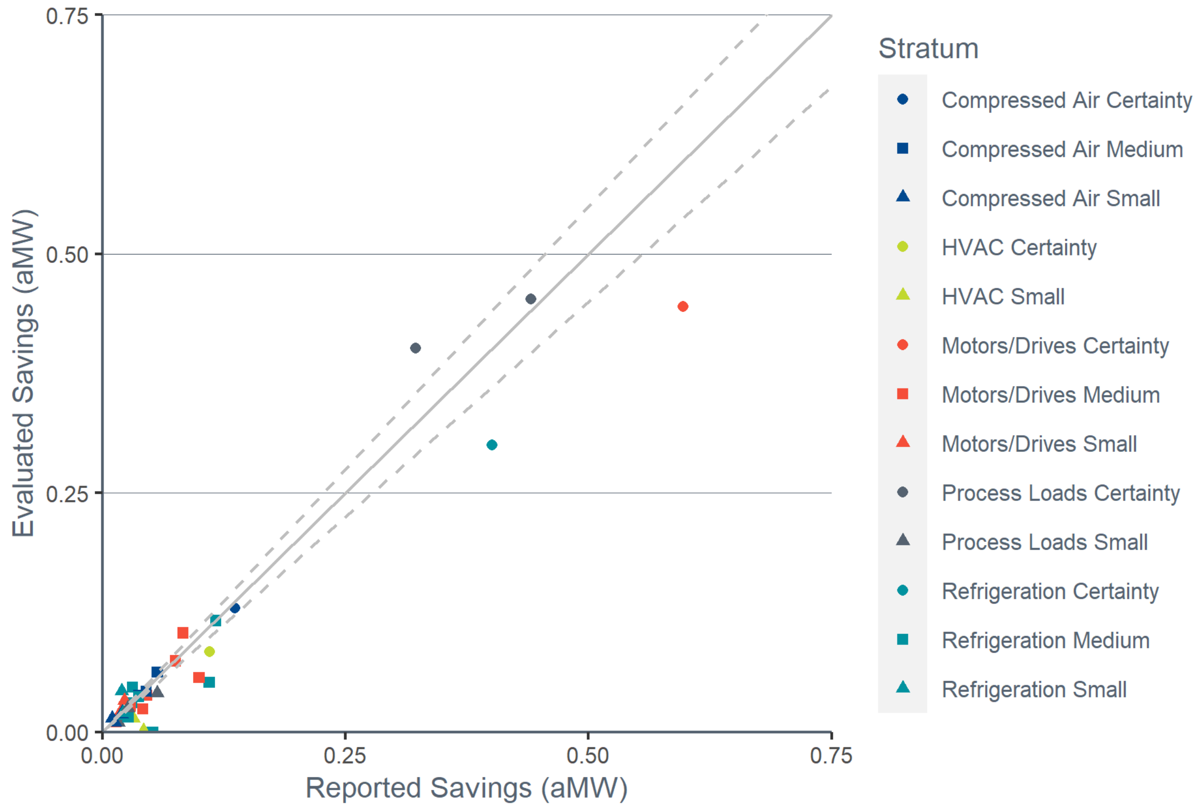


Figure 3 below shows evaluated savings results by project measure for the evaluation sample, expressed in average megawatts (aMW). Points lying above the gray diagonal line had evaluated savings higher than reported savings, while those lying below the gray diagonal line had evaluated savings lower than reported savings. The dashed lines indicate +/- 10 percent of reported savings.

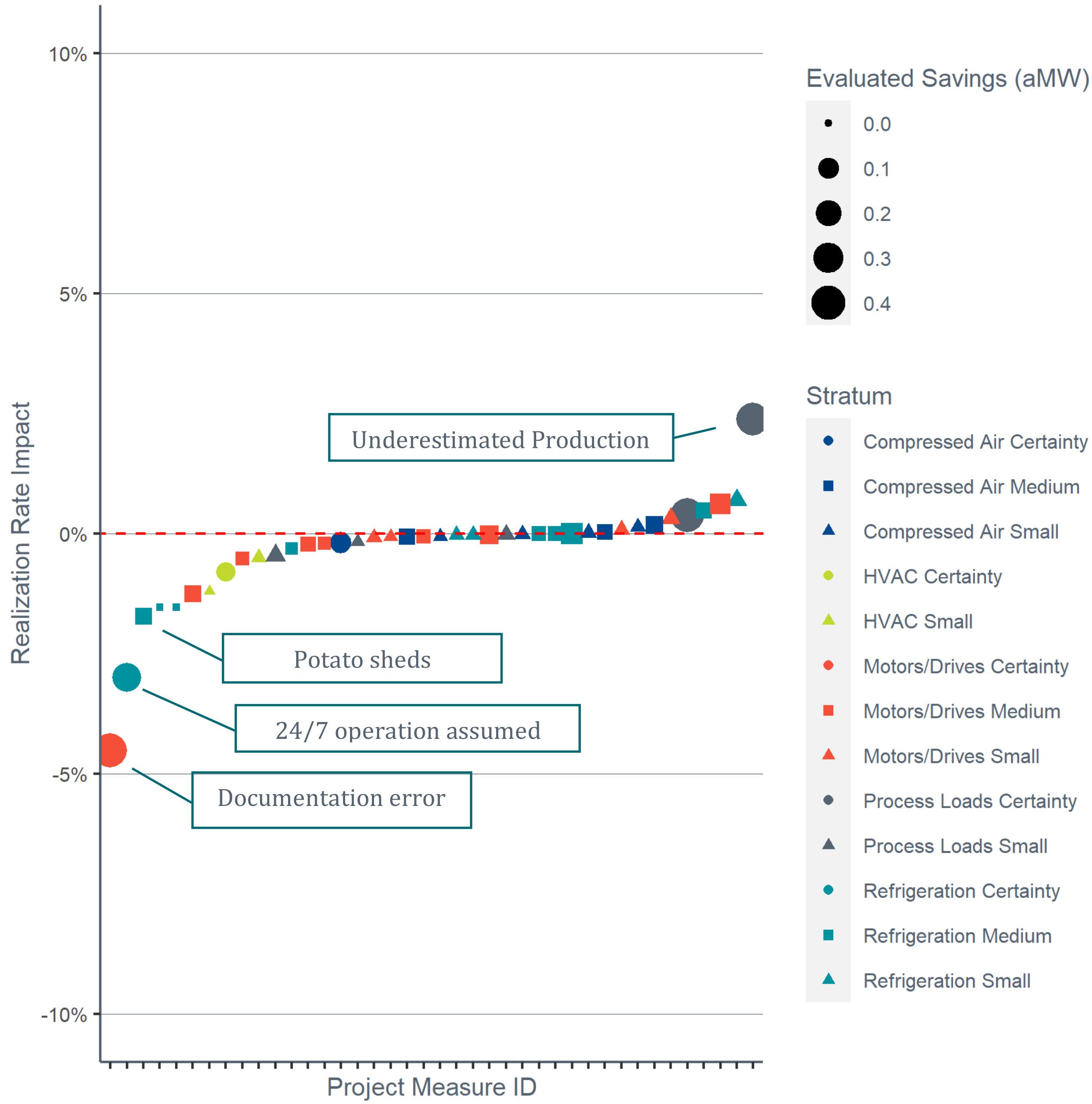
Figure 3: Evaluated savings vs reported savings by project measure



4.3 KEY DRIVERS OF SAVINGS DIFFERENCES

Figure 4 below shows the impact of each reviewed project measure in the evaluation sample on the overall domain realization rate. Project measures in the lower left are driving the domain realization rate below 1.0, while project measures in the upper right are driving the domain realization rate above 1.0. Most projects had little or no influence on the overall realization rate either because their realization rates were near 1.0 or their small size made them noninfluential on the total. However, a handful of projects were highly impactful, including projects with potato shed baseline issues, incorrect operating hours assumptions, and a documentation error, as labeled on the figure.

Figure 4: Domain-level realization rate impact



The most influential project measures negatively impacting the domain-level realization rate had the following issues:

1. **Documentation error.** The largest project in the sample, a motors/drives project, had a documentation error where the number reported as savings was actually the post-installation consumption.
2. **Baseline issues with potato sheds.** Multiple refrigeration projects at potato sheds included savings from evaporative cooling. The evaluation found that evaporative cooling is actually the current practice in potato sheds, eliminating savings from evaporative cooling

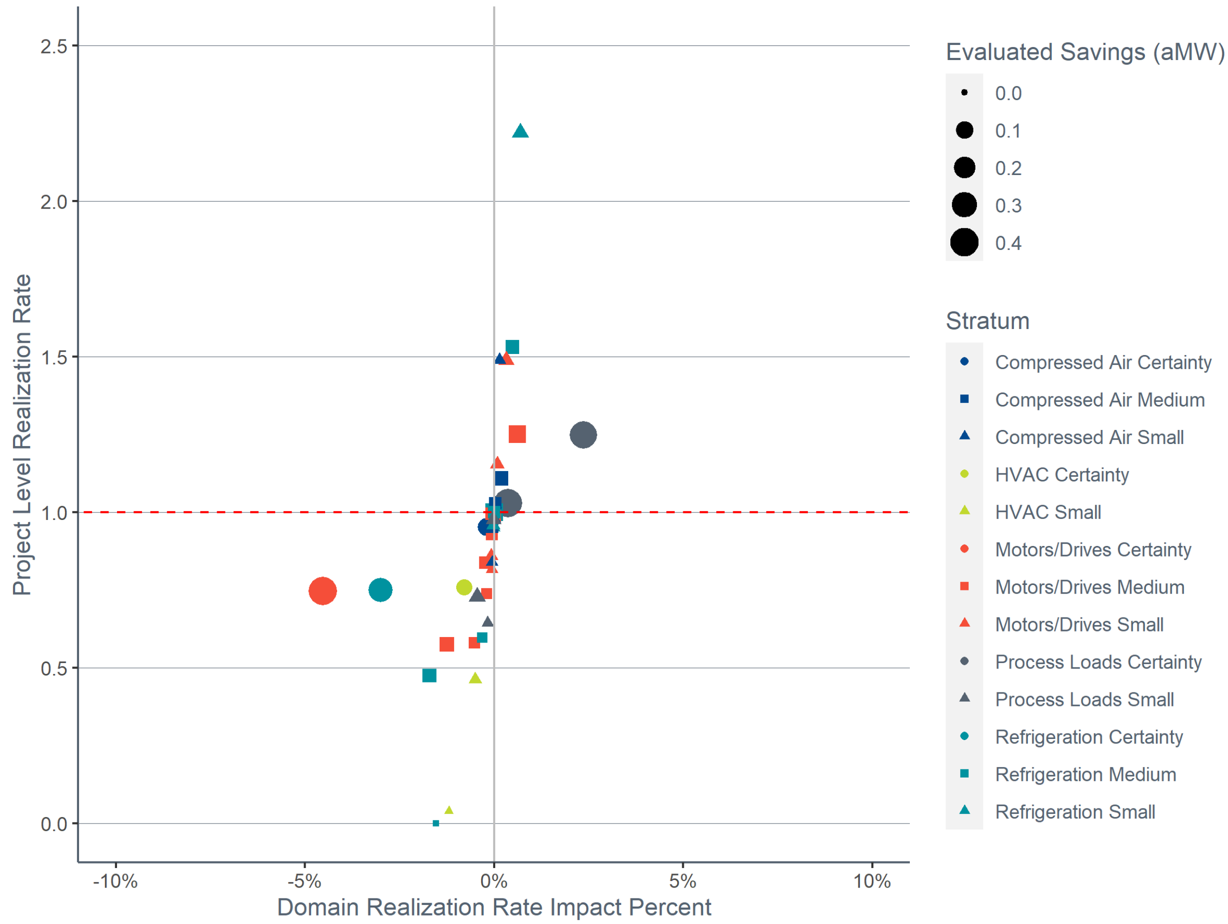
in these projects. The evaluators observed that BPA's program guidelines for determining baseline (i.e., code) for evaporative cooling use in potato sheds are inconsistent with RTF guidelines (i.e., current practice). The program team noted that broad market adoption of evaporative cooling for potato sheds has occurred in part due to program efforts supporting this energy saving technology.

3. **Differences in observed operating conditions**. Some projects had different observed conditions for the first year of operation than what was documented in the original M&V period.
   a. One very large refrigeration project overestimated the evaporator fan duty during implementation.
   b. One large process project used an M&V production value that was substantially lower than was found on-site during the first year.
   c. Two different projects included variable speed drives (VSDs) that ultimately saved minimal energy, because they rarely, if ever, ran at part load.

One project measure had a significant impact to increase the overall realization rate. This measure used a production load which was underestimated for the first year of operation. The team found that the production had Increased which led to adjusting the baseline condition and increasing the first year of energy savings.

The project measure impact map in Figure 5 shows the relationship between realization rate, size of project, and resulting overall impact on the domain realization rate based on the evaluation sample results. The project impact map combines all of the information presented in the previous series of exhibits. The x-axis shows the impact on the overall realization rate, while the y-axis shows the project measure realization rate. Project measures in the lower left are driving the domain realization rate below 1.0, while project measures in the upper right are driving the domain realization rate above 1.0. Larger dots represent larger project measures, which generally increase the total impact on realized energy savings.

Figure 5: Project measure impact map



4.4 LIFETIME SAVINGS

The estimated evaluated lifetime savings for the sampled sites are shown in Table 4 below. As shown, the realized lifetime savings estimates are lower than the reported lifetime savings. Some minor adjustments to lifetime savings were made by changing the TAPs[14] and their corresponding lifetimes for evaluated measures including changing:

- HVAC Control Improvements (variable frequency drive [VFD]) (5-year lifetime) to Motors/Drives Installation on Fan System (10 years);
- HVAC Control Improvements (VFD) (5-year lifetime) to Motors/Drives Control Improvements (VFD) (10 years); and
- Interactive Refrigeration System Improvements (10-year lifetime) to Packaged Refrigeration System Improvements (15 years).

[14] TAP stands for Technology/Activity/Practice. The BPA reporting system uses a standardized taxonomy (TAP) for classifying measures. For most projects, BPA or utility staff assigns one of 86 TAP descriptions to each physical measure or change implemented as part of a project.

However, the net impact of lifetime adjustments was very small compared to the adjustments in first-year savings. The resulting lifetime savings realization rate of 84 percent is slightly lower than the first-year savings realization rate (85 percent).

Table 4: Lifetime savings

End Use	*Evaluated Lifetime Savings (kWh)*	*Reported Lifetime Savings (kWh)*	*Lifetime Savings Realization Rate*
Compressed Air	38,184,923	37,740,642	101%
HVAC	9,004,314	13,420,568	67%
Motors/Drives	95,341,053	115,661,948	82%
Process Loads	85,520,205	80,439,466	106%
Refrigeration	79,248,786	117,934,822	67%
Total	**307,299,281**	**365,197,445**	**84%**

4.5 COVID PANDEMIC SAVINGS ADJUSTMENTS – RESULTS AS OBSERVED

The evaluators calculated "evaluated savings" inclusive of adjustments to facility operation for COVID-19. Evaluated savings estimates are intended to represent what would have happened had COVID-19 not occurred. Those results were reported in Sections 4.1 through 4.4.

Evaluators also calculated savings as observed, without adjustment for COVID-19 impacts. These as-observed results are shown in Figure 6 below, which are very similar to the evaluated savings results with COVID adjustments included. Overall, the as-observed savings are slightly lower than the evaluated savings.

Figure 6: First-year savings as observed by end use compared to reported savings by end use

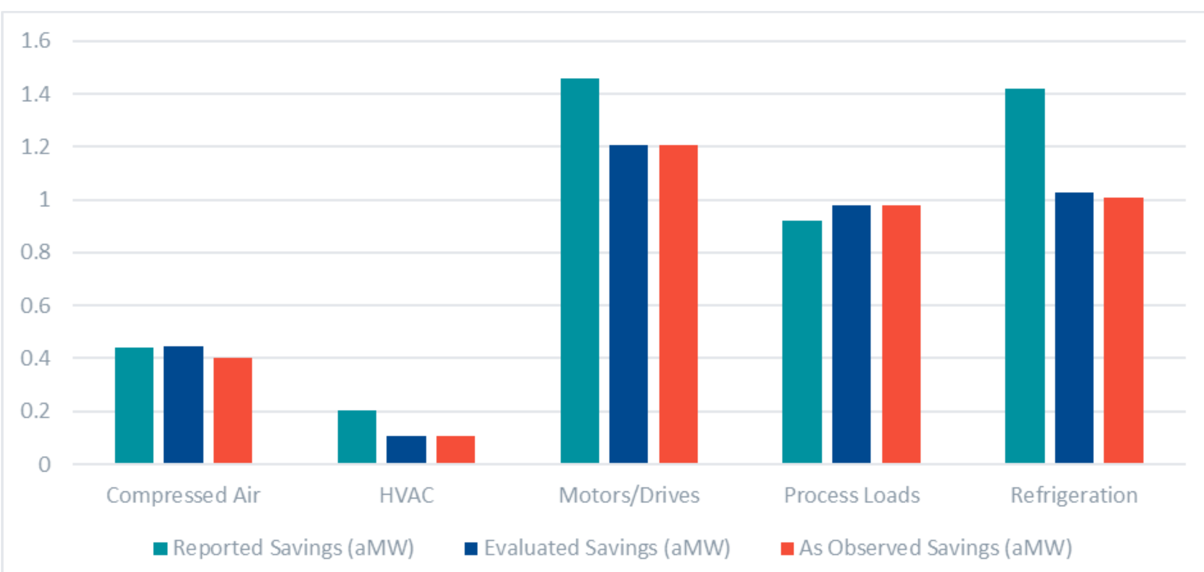
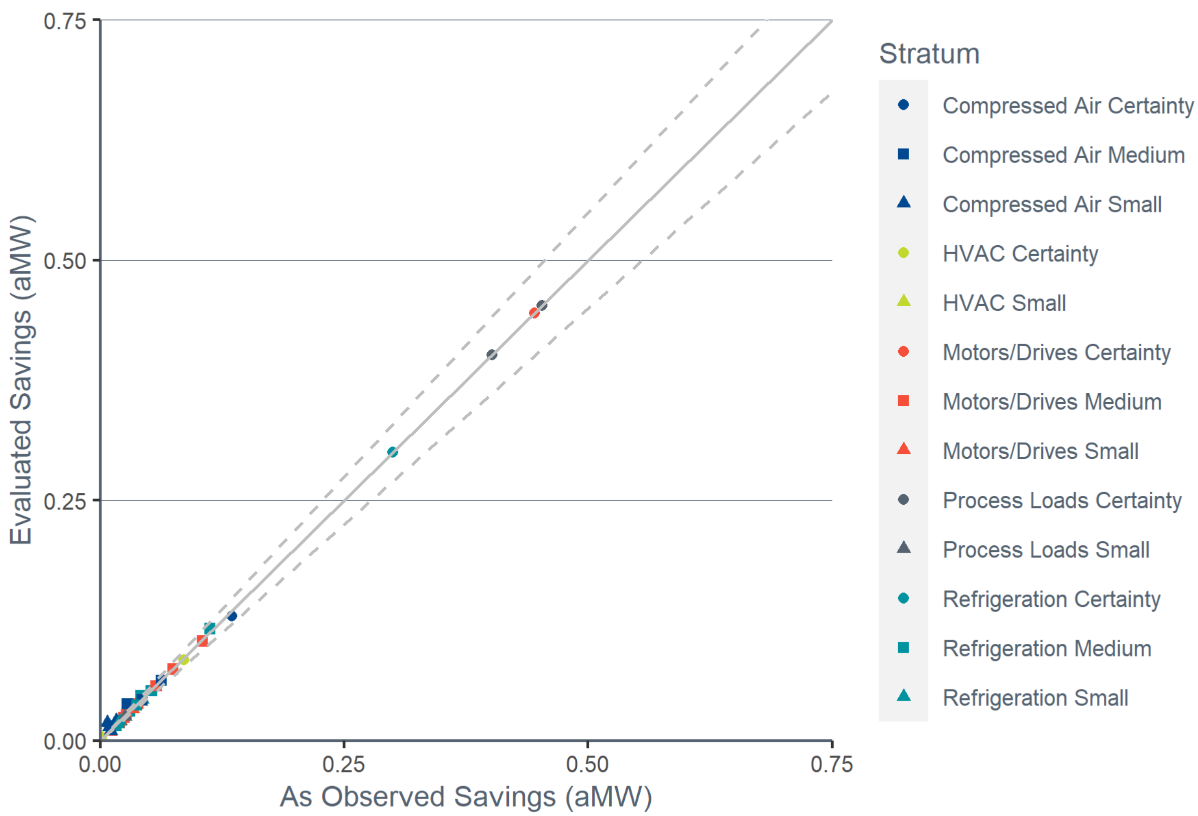


Figure 7 below compares the individual project measure results with and without COVID-19 results included. Points lying above the gray diagonal line had evaluated savings higher than as-observed savings, while those lying below the gray diagonal line had evaluated savings lower than as-observed savings. The two dashed gray lines mark +/- 10 percent of as-observed savings. Only smaller projects with little influence on results showed substantial differences. These differences were due to COVID-induced changes in business operations during the measured post-installation period. Some examples of the differences in as-observed and evaluated savings include the following:

- An evaluation regression model included a six-month period of a pandemic-driven reduction in production.
- One facility saw a 15 percent increase in production due to the pandemic.
- Some facilities reduced operating hours 50 percent to 75 percent due to COVID-driven staffing challenges and lower product demand.
- One plant had a two-week pandemic-related production shutdown.
- One facility had a three-month shutdown with an in-facility infection, followed by a three-month shutdown, nearly total product loss and retooling, and a slow ramp-up to full production.

Figure 7: Project measure comparison between evaluated results and observed results (with and without COVID-19)



4.6 ECWV SAVINGS ESTIMATION EFFICACY

The evaluation looked at two issues with *Engineering Calculations with Verification* (ECwV) savings estimation methods:

1. Can ECwV provide an unbiased estimate of energy savings?
2. Did the BPA implementation of ECwV provide an unbiased estimate of energy savings?

For the first question, the evaluation team estimated savings using an ECwV methodology and a regular high rigor evaluation method for all projects in the sample. The results show that ECwV approaches as applied by the evaluation team provided unbiased results for smaller projects while underestimating savings for larger projects, as shown in the stratum level results in Figure 8 below.

Figure 8: As-observed savings versus evaluated ECwV savings

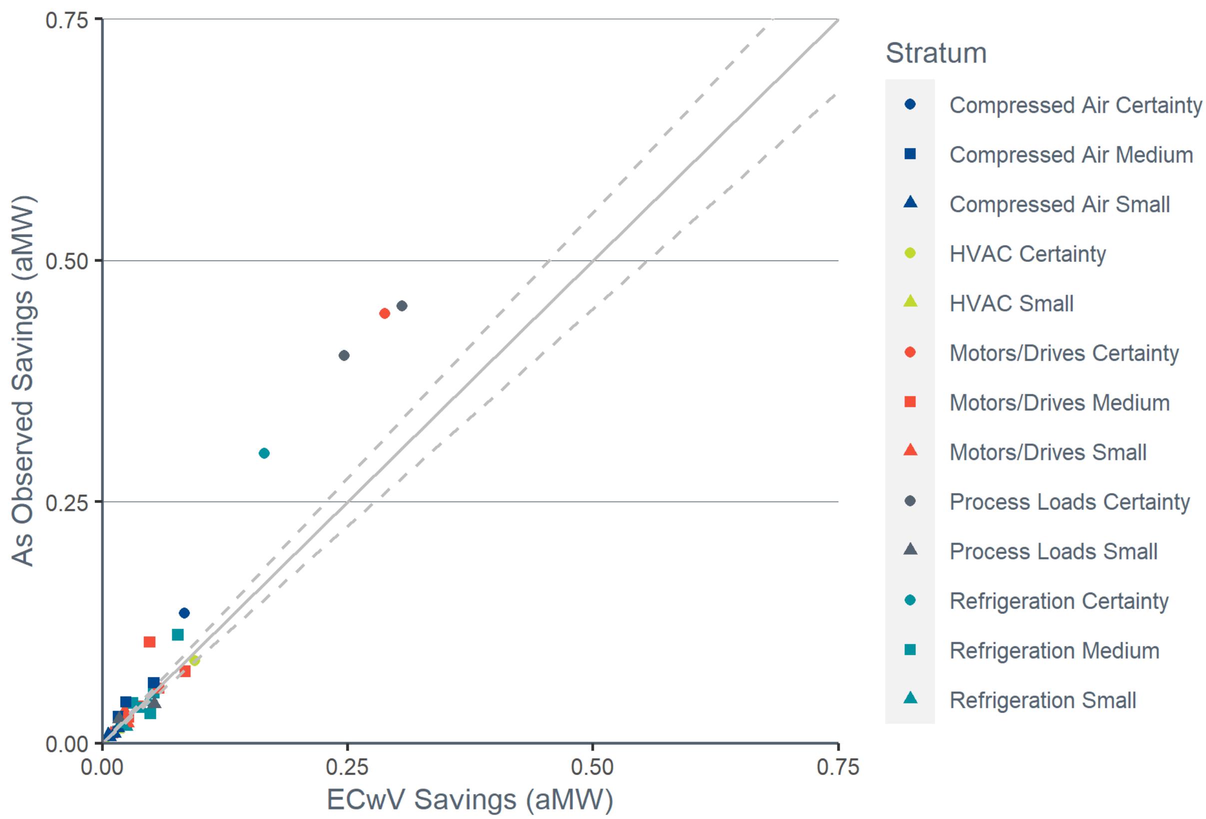


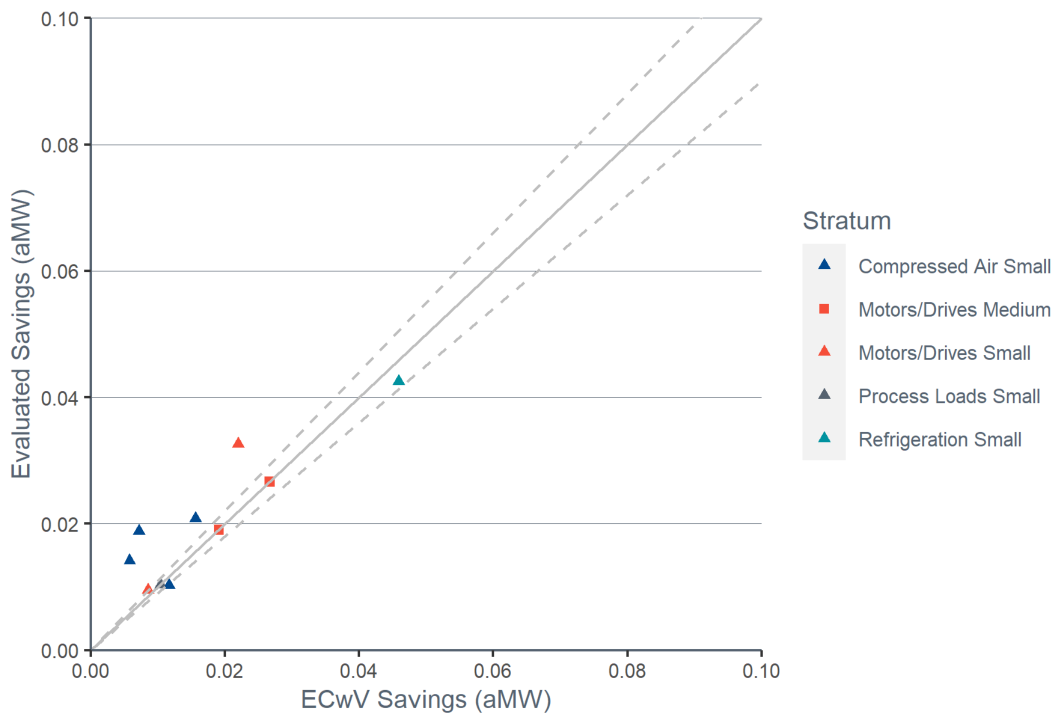
Table 5 below compares evaluated ECwV savings to as-observed savings at the stratum level. The total savings of all projects in each stratum are shown in the table; average savings per project are lower. If the ratio of the two is near 100 percent (the value in the last column of the table), it means that ECwV provided an unbiased estimate of the true savings. The small strata all have ratios near 100 percent, while the medium and large strata are more variable, with many ratios below 100 percent. This means that ECwV was relatively accurate for small projects but substantially underestimated savings for many large projects.

Table 5: Evaluated ECwV and as-observed savings by end use and size

End Use	*Size Range*	*Evaluated ECwV Stratum Savings*	*As Observed Stratum Savings*	*Ratio*
Compressed Air	Small (<200,000 reported kWh / project)	474,940	491,891	97%
Compressed Air	Medium	1,235,902	1,782,202	69%
Compressed Air	Large	727,380	1,181,497	62%
HVAC	Small	165,775	165,775	100%
HVAC	Large	821,931	747,474	110%
Motors/Drives	Small (<200,000 reported kWh / project)	744,309	789,460	94%
Motors/Drives	Medium	4,864,448	5,639,493	86%
Motors/Drives	Large	2,522,162	3,899,184	65%
Process Loads	Small	1,105,957	1,065,781	104%
Process Loads	Large	4,829,097	7,486,239	65%
Refrigeration	Small (<200,000 reported kWh / project)	1,050,992	932,958	113%
Refrigeration	Medium	3,511,660	5,130,240	68%
Refrigeration	Large	1,443,150	2,626,875	55%
Total		**23,497,702**	**31,393,071**	**74%**

Regarding BPA's current implementation of ECwV, most ECwV projects had similar evaluated savings compared to BPA's reported savings, with a few projects underestimating reported savings. Figure 9 shows each project that had reported savings based on ECwV, with the evaluated savings on the y-axis and the reported ECwV savings on the x-axis. Projects lying close to the line of y=x had little difference between evaluated and reported savings. The projects above the upper grey line underestimated savings by more than 25 percent, while the projects below the lower grey line overestimated savings by more than 25 percent. There were four ECwV projects with major underestimates and none with a substantial overestimate of savings.

Figure 9: Evaluated savings vs reported savings for ECwV projects



4.7 COST-EFFECTIVENESS

The domain is strongly cost-effective overall, based on the evaluation results, producing $2.46 in benefits for every dollar spent. The evaluated benefit-cost ratio (2.46) came in slightly lower than BPA's reported benefit-cost ratio (3.09). All end uses except HVAC have both reported and evaluated benefits greater than costs, as shown in Table 6. The HVAC results are driven by one project with relatively low cost-effectiveness, both in the reported values and in the evaluated results. This project does pass BPA's 0.5 cost-effectiveness threshold.

Table 6: Benefit-cost results

End Use	***Reported***			***Evaluated***		
	Benefits ($)	*Costs ($)*	*Benefit-Cost Ratio*	*Benefits ($)*	*Costs($)*	*Benefit-Cost Ratio*
Compressed Air	2,395,302	440,061	5.44	2,269,935	431,854	5.26
HVAC	1,004,022	1,247,473	0.80	674,201	1,247,473	0.54
Motors/Drives	8,016,037	1,246,693	6.43	6,164,111	1,297,645	4.75
Process Loads	5,799,409	2,140,677	2.71	6,275,808	2,140,677	2.93
Refrigeration	7,849,257	3,026,212	2.59	4,244,703	2,862,015	1.46
Total	**25,064,027**	**8,101,117**	**3.09**	**19,628,758**	**7,979,665**	**2.46**

5 KEY FINDINGS AND RECOMMENDATIONS

The evaluation team developed recommendations and considerations resulting from the key findings of this evaluation.

Key Finding: Evaluators observed that BPA *Implementation Manual* and M&V protocols were generally followed correctly. The difference in evaluated versus reported savings did not result from deviations in prescribed procedure.

Key Finding: Small and medium-sized projects showed little bias in evaluated results using the BPA *Engineering Calculations with Verification* (ECwV) protocol or high-rigor M&V methods. While there was variability from site to site and the ECwV results are less precise, they were similar to evaluated results overall.

> **Recommendation 1: Consider applying ECwV to a wider size range of projects.** While the evaluation sample size is not large enough to provide a suggested size level, there is some evidence that the savings threshold for ECwV could be increased. However, at least anecdotally, projects with more interactive effects between different pieces of equipment tend to have lower accuracy ECwV results, so it makes sense to add a brief assessment of the level of risk in savings estimation error due to the simpler protocol with fewer verification requirements. More ECwV projects may reduce overall engineering and administrative load for energy efficiency programs and liberate resources for more energy efficiency projects.

Key Finding: Evaluators identified a documentation error in the largest project. The largest project implemented during the evaluated period had a documentation error, where the project savings reported were equal to the post-installation consumption rather than the savings. While the evaluators only observed documentation errors in this one project, indicating that this is not a widespread problem, the fact remains that this error did get through on the largest project. This was a certainty site, so the error was not extrapolated to the overall realization rates. Based on where the error was found, evaluators determined that it was probably a one-time issue and not widespread.

> **Recommendation 2: Revisit quality control procedures.** BPA should revisit all quality control procedures leading from the initial savings claim for a project through to final reporting, to see where they can be improved to catch this type of error (and others) in the future. Independently-executable and reviewable model files should be submitted to BPA by project engineers to enable easier in-depth review of project claimed savings. This should apply to all projects, and not just to projects with large savings.

Key Finding: The evaluators observed issues with changes in current operating conditions for multiple sampled project measures. This included changes in production rates and equipment operating profiles.

Key Finding: The evaluators observed multiple potato shed project baseline issues, with claimed savings associated with evaporative cooling. Evaluator research concluded that this is equivalent to current practice and does not provide savings over a current practice baseline.

For custom measures, both BPA and RTF guidelines agree that new construction projects should apply a current practice baseline. BPA's M&V selection guide indicates when applying current practice baseline, practitioners should look to state or local energy codes as the basis for determination of the current practice. RTF guidelines also refer to local energy codes unless there are none available. When there are no applicable codes, the RTF specifies an additional step to assess what constitutes current practice.

In this evaluation, evaluators observed this inconsistency between BPA and RTF guidelines for evaporative cooling use in potato sheds. BPA's guidelines indicate that evaporative cooling is technically compliant as a new construction energy efficiency measure since it is not prescribed by energy codes for potato storage sheds. Evaluators agreed that there is no applicable energy code. Following RTF guidelines, evaluator research concluded (via literature review and end user and vendor interviews) that evaporative cooling in potato sheds is equivalent to current practice. Although a complete and comprehensive standard practice study was not practical and was out of scope for this evaluation, evaluators determined via literature review that evaporative cooling is longstanding practice with best practice documentation going back more than 30 years. Additionally, vendors and end users interviewed during the evaluation all considered evaporative cooling the default choice for new potato sheds.

Recommendation 3: BPA should consider updating its policy for determining baseline to adhere to RTF guidelines. Additionally, the evaluators recommend that BPA assume that evaporative cooling in potato sheds is current practice or identify a similar measure that represents current practice. RTF guidelines do allow for a melded baseline.

Recommendation 4: Project engineers should make an explicit statement of the current practice assumed for all lost opportunity projects. This process should reference *Regional Technical Forum Guidelines for the Assessment of Energy Efficiency Measures*[15] Section 4.3.3 and should be included in planning and completion reports. This step will ensure that project reviewers continuously consider what is current practice and empower them to recommend changes when they find inconsistencies.

BPA could also consider working collaboratively with evaluators and others in the region to establish improved current practice baseline protocols for custom industrial projects. This new industrial current practice baseline working group could develop new protocols that may be used by implementers, utilities and evaluators in the region. When a question arises as to the current practice baseline for a project type that is not covered by existing guidance, the current practice baseline working group could make itself available to provide guidance and add that guidance to the working documentation. This group may also help adapt programs to changes in national efficiency guidelines such as the work done by the Northwest Energy Efficiency Alliance (NEEA) in coordination with the U.S. Department of Energy to develop the Extended Motor Products (XMP) program.[16]

Key Finding: Nonrepresentative model specifications are sometimes used by project engineers leading to less accurate savings estimates. For some projects, the evaluators observed issues with the model used to estimate savings missing key elements that would improve the accuracy of savings estimates. This would not notably impact the overall realization rates for the sampled population but would improve the reliability of individual models. Examples included:

- Compressed air models that did not accurately capture part load performance of equipment.
- A refrigeration model that did not use an accurate part load performance polynomial.
- Compressed air models that did not represent a range of performance when conditions varied.
- A refrigeration model that did not calculate condenser savings at part loads.

[15] Regional Technical Forum. 2020. https://nwcouncil.app.box.com/v/2020RTFGuidelines
[16] Northwest Energy Efficiency Alliance. "Priming the Pump for Energy Efficiency." https://neea.org/news/priming-the-pump-for-energy-efficiency

Recommendation 5: Specify models that are well-suited to calculating savings for the project. Engineers specifying a model should make a brief qualitative list of the key features and inputs that are expected to impact savings and then ensure that the model specified accurately addresses each of those features. This step should ensure that project engineers and reviewers consider likely scenarios that may cause a major difference in observed savings for the proposed model. This step would highlight areas of concern before or after the final project M&V and allow the project reviewers to verify that the best possible model was chosen according to best practices and appropriate BPA protocols while still accounting for part load operation and actual equipment performance where possible. This may require choosing different methods prescribed by BPA protocols or modifying existing methods. For example, if a compressed air system operates at low and part loads and follows an ECwV M&V protocol, then the model should allow for part load efficiencies to be specified. A modified version of the Northwest Regional Compressed Air Savings Estimator (NWRCAT) or AIRMaster+[17] would be acceptable.

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[17] U.S. Department of Energy. 2014. "AIRMaster+." https://www.energy.gov/eere/amo/articles/airmaster

APPENDICES

APPENDIX A: DEFINITION OF KEY TERMS

We rely on the following definitions of key terms throughout this report.

Reporting System

BPA uses its reporting system to track projects completed by public power utilities under various programs and initiatives. For Option 1 utilities, BPA has detailed custom project proposals and completion reports in its system (Option 1 Custom Project Calculator). Option 2 utilities report high-level project information into the BPA system periodically (Option 2 Custom Project Calculator).

Domain

Domains are components of the portfolio. They are defined by Option (utilities are Option 1 or 2 for measurement and verification [M&V] purposes), Measure Type (e.g., Lighting, Nonlighting), and Sector (Industrial and Commercial or the combination of commercial and agricultural for Option 1 utilities).

Option 1

For Option 1 utilities, BPA manages the bundle of energy savings from custom projects. This requires that BPA manage the portfolio risk for both project performance and cost-effectiveness. Often, BPA is involved throughout the project lifecycle by providing technical support, M&V implementation, approval of projects and oversight/evaluation.

Option 2

For Option 2 utilities, the customers manage the bundle of savings from their custom projects. This entails the customers managing the risk of project performance and cost-effectiveness by conducting all aspects of M&V and custom project quality control (e.g., project proposal and project completion documentation review) internally.

Project

A project is a phase of work at an end user location that improves energy efficiency. An end user is the customer of a BPA utility. The project tracking data record a date when the project is complete. The data also contain information such as the name of the end user, the location where the work was carried out, and other data critical to this evaluation. End users may authorize the completion of many phases of work, each of which is tracked as a separate project in the BPA reporting system.

Measure

A measure is a distinct Technology/Activity/Practice (TAP) within a project. The BPA reporting system uses a standardized taxonomy (Technology/Activity/Practice) for classifying measures. For most projects, BPA or utility staff assign one of 86 TAP descriptions to each physical measure or change implemented as part of a project.

Project Engineers

Project engineers assist in the identification, development, savings estimation, cost-effectiveness analysis, M&V, and quality control review of projects. Project engineers may be BPA staff, utility staff, or staff of BPA or utility project implementation contractors. For the purposes of this evaluation, project engineers are not staff or contractors employed by the end users, even though the end user workforce may have played an important role in the development of a project.

M&V Model

This M&V model (an algorithm or calculation procedure) is the model used by project engineers to estimate savings for the measures that comprise a project. The NWRCAT compressed air calculator is an example of such a model. Models for other measures might be building simulation models such as eQUEST, custom-engineered or standardized spreadsheet calculators, and custom regression models (such as those developed using Energy Performance and Carbon Emissions Assessment and Monitoring [ECAM]).

Reported Savings

Reported savings are the savings estimated by the project engineers and entered in the BPA reporting system. These savings are based on the M&V model. Please note that the BPA system uses the term “estimated savings” for the savings estimated at the proposal stage and “actual savings” for the savings at the completion report stage. The BPA *Implementation Manual* does not require all projects to submit a formal proposal. Reported savings are based on the “actual savings” field in the reporting system. “Actual savings” is busbar savings, equal to 1.09056 times site savings.

Evaluation Model

This is the model selected by our evaluation team to re-estimate savings for sampled measures. The same types of models as listed above for the M&V models were also options under consideration. Please note that although the evaluation model may differ from the M&V model, this does not necessarily mean that the M&V model was inappropriate for the project. Therefore, there may be cases where a more reliable model is used in evaluation of a sampled measure, even though that model would not be cost-effective for M&V on all measures.

Evaluation Savings (and Evaluated versus As-Observed COVID-19-Specific Terminology)

Evaluation savings are the savings estimated by the evaluation team. These savings are based on the evaluation model and rely on best practical data collection and savings estimation practices, as laid out in the RTF guidelines and informed by evaluator experience. The evaluation estimated the savings achieved during the first year of measure operation. If any of the evaluation data collection occurs more than one year after the measure was complete, it may indicate failures in the measure performance that are relevant to measure lifetime and not to the first-year savings. Evaluation savings estimates reflect the conditions of the measure during the first year of operation.

For this evaluation where the project measure operations under evaluation occurred during the COVID-19 pandemic, the evaluators estimated two separate sets of results:

1. Evaluated savings: the definition provided above for evaluated savings, with any changes to site operations resulting from COVID-19 reported by the site respondents removed. Site-specific findings may also be referred to as as-expected savings.

2. As-observed savings: the traditional definition of evaluated savings based on actual observations, with no adjustments for COVID-19. Site-specific findings may also be referred to as as-operated, or as-found, savings.

Current Practice Baseline

BPA and the Regional Technical Forum (RTF) have different definitions of current practice baseline for custom measures, based on BPA's M&V selection guide[18] and RTF guidelines,[19] respectively.

BPA: "*When the practitioner uses a current practice baseline, the efficiency level of the baseline equipment must be consistent with any state or local mandates for new equipment, which may vary from city to city and state to state.*"

RTF: "*The practitioner needs to identify what would normally be done, based on prior experience with similar projects. The practitioner should start by using applicable codes and standards, or one of the following if they constitute a more energy efficient baseline for the measure and the information is practical to obtain and applicable to the delivered measure's location OR there is no applicable code or standard for the measure implemented.*

- *Recent similar purchases by the end user*
- *Documented end user plans or specifications*
- *End user or vendor developed alternative designs, considered as part of the measure selection process*
- *End user description of what was done in similar circumstances elsewhere in the facility or in another facility they operate*
- *Equipment vendor's description of what they would normally do for this end user*"

Realization Rate

Realization rate is the ratio of evaluation savings to reported savings. Realization rates greater than 1.0 mean that we found more savings than were reported.

[18] BPA. 2018. *Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan*. Page 7. https://www.bpa.gov/-/media/Aep/energy-efficiency/measurement-verification/1-bpa-mv-selection-guide.pdf (file will download automatically when clicking)
[19] Regional Technical Forum. 2020. *Guidelines for the Assessment of Energy Efficiency Measures*, Section 4.3.3, page 20. https://nwcouncil.app.box.com/v/2020RTFGuidelines

Key Determinants

Key determinants influence the savings from a measure. The evaluation considered the following key determinants:

- **Connected load.** Baseline or efficient-case rated kW demand and/or the quantity of the equipment.
- **Efficiency profile.** Part-load impacts on demand profile, including variable frequency drives (VFDs) and HVAC interaction factors.
- **Hours of operation.** Baseline or efficient-case schedule of operation for a measure.
- **Load profile.** Facility occupancy rates and changes not captured by other categories of key determinants.
- **Production.** Number of production units per unit of time.
- **Weather.** Weather-based data used for weather-sensitive measures, such as dry and wet-bulb temperatures, or heating and cooling degree-days.

Reasons for Difference

The reasons for difference are what we changed that caused a modification to one or more key determinants and ultimately savings. We ranked the impacts as primary or secondary increase/decrease to give a sense of their scale. We assigned all reasons to one of the following categories:

- **Documentation error.** These include errors in calculations or values entered into models.
- **Other.** Commonly, a change in inputs due to a contradicting finding in the first year. This would indicate that the value for the key determinant in the project documentation was correct, but the value entered in the savings calculation did not match what was in the documentation. It could also indicate that the key determinant in the project documentation did not match what was found during the site visit or in trend data.

Measure Baseline

Measure savings must be determined against clearly defined baseline conditions. The RTF guidelines define two possible baseline conditions that were used in this evaluation:

- **Current practice.** A current practice baseline is used if the measure affects systems, equipment, or practices that are at the end of their useful life. The baseline is defined by the recent typical choices of the end user in purchasing new equipment and services. Current practice baseline is also used for new construction projects where there is no pre-existing systems, equipment or practices.
- **Pre-conditions.** A pre-conditions baseline is used when the measure-affected equipment or practice still has remaining useful life. The baseline is defined by the existing condition at the end user site just prior to the delivery of the measure.

ProCost Model

ProCost is a spreadsheet tool, developed by the Northwest Power and Conservation Council that computes regional measure lifecycle cost-effectiveness. ProCost uses regional economic and power system assumptions that are updated with each Council Power Plan.

Measure Lifetime

Measure lifetime, according to the RTF guideline for lifetime savings, is defined as the median number of years during which at least half the deliveries of a measure are in place and operable, i.e., producing savings. For example, consider the installation of 100 VFDs on pumps. If the VFDs were regularly inspected for many years, it would be possible to determine when each one became inoperable (failed mechanically or electrically or was removed from service). The lifetime for the measure would be the median number of years to measure failure, i.e., no longer producing savings. An estimate of measure lifetime is a required input to ProCost.

Incremental Costs and Benefits

When a measure is delivered, costs are incurred and benefits realized—e.g., the value of electricity savings and other nonelectric benefits such as changes in operations and maintenance expenses. Only incremental costs and benefits are used in estimating life cycle costs and benefits.

A measure's incremental costs and benefits are those incurred in the efficient case delivery, beyond what is required to establish and maintain the baseline condition. For a precondition baseline, the baseline does not involve any change and thus baseline costs and benefits are zero. In this case, incremental costs and benefits are equal to the efficient case costs and benefits. For measures with a current practice baseline, the baseline condition does require a change and therefore has costs and benefits. In this case, the incremental costs are the difference between the efficient case and the baseline case delivery.

NEBs (Nonelectric Benefits)

Nonelectric benefits are defined as any benefit, positive or negative, that is not captured by the value of the electric savings or the measure incremental cost. NEBs include changes caused by the measure in the costs of operation and maintenance or other utilities such as gas, water or wastewater. Further explanation of these benefits can be found in the RTF guidelines (see the guideline for the estimation of incremental measure costs and benefits).

Total Resource Cost (TRC) Test

The TRC is one type of cost-effectiveness testing that includes all incremental cost and lifetime benefits of a measure, regardless of who pays for or receives them. BPA uses the definition of the TRC test consistent with the Northwest Power and Conservation Council.

APPENDIX B: SITE-SPECIFIC SAVING ESTIMATION

This appendix provides the measure level results for the sample. In the table, stratum "1" refers to small sites; "2" to medium and "99" to certainty sites.

Detail ID	*Stratum*	*Site Realization Rate*	*Site Impact on Domain Realization Rate*
2801	Compressed Air 1	98%	-0.01%
3601	Compressed Air 1	103%	0.02%
3701	Compressed Air 1	149%	0.14%
4201	Compressed Air 1	84%	-0.06%
3101	Compressed Air 2	103%	0.03%
4701	Compressed Air 2	95%	-0.06%
5201	Compressed Air 2	111%	0.18%
1001	Compressed Air 99	95%	-0.20%
2002	HVAC 1	46%	-0.50%
2202	HVAC 1	4%	-1.20%
5401	HVAC 99	76%	-0.79%
902	Motors/Drives 1	86%	-0.08%
1701	Motors/Drives 1	149%	0.32%
2101	Motors/Drives 1	82%	-0.06%
2601	Motors/Drives 1	116%	0.08%
202	Motors/Drives 2	84%	-0.22%
503	Motors/Drives 2	58%	-0.52%
1501	Motors/Drives 2	74%	-0.20%
1902	Motors/Drives 2	99%	-0.02%
4301	Motors/Drives 2	58%	-1.25%
4601	Motors/Drives 2	93%	-0.06%
5301	Motors/Drives 2	125%	0.62%
1901	Motors/Drives 99	75%	-4.52%
401	Process Loads 1	64%	-0.17%
3001	Process Loads 1	73%	-0.45%
5501	Process Loads 1	98%	-0.02%
301	Process Loads 99	103%	0.37%

Detail ID	*Stratum*	*Site Realization Rate*	*Site Impact on Domain Realization Rate*
5601	Process Loads 99	125%	2.38%
1401	Refrigeration 1	222%	0.70%
2401	Refrigeration 1	95%	-0.03%
5001	Refrigeration 1	96%	-0.03%
101	Refrigeration 2	0%	-1.53%
601	Refrigeration 2	47%	-1.72%
701	Refrigeration 2	153%	0.49%
803	Refrigeration 2	100%	0.00%
1101	Refrigeration 2	100%	0.00%
2201	Refrigeration 2	0%	-1.54%
2302	Refrigeration 2	60%	-0.31%
5101	Refrigeration 2	100%	0.00%
1205	Refrigeration 99	75%	-3.00%

APPENDIX C: DETAILED METHODOLOGY

This appendix provides more detail on the study methods (sample design, data collection and analysis).

SAMPLE DESIGN

BPA's evaluation policies have established a target for impact evaluation, striving for evaluations that attain a relative error of 10 percent at the 90 percent confidence level, with a minimum acceptable level of 80/20. The study's sampling strategy targeted a 90/10 confidence level and precision for Domain 1.[20] The sampling unit of this study is a measure, defined as a unique Technology/Activity/Practice (TAP) for a single project at a distinct site (as defined by utility-assigned site ID and facility address).[21]

This evaluation represents the population of measures with completed reporting (Contracting Officer's Technical Representative [COTR] approval date) between September 2019 and August 2020,[22] excluding eight projects that started prior to 2017, as these would have been less representative of the past 12 months.[23] The sample design was developed based on BPA tracking (or IS2.0) data pulled on September 11, 2020.

The sampling was conducted with a conventional optimum allocation stratified design based on end use category and reported kWh savings for the measure.[24] We defined an excluded stratum (i.e., stratum 0) that contains very small measures; this is the group of measures that collectively account for less than 2 percent of the domain savings. Measures that represent a significant portion (more than 25 percent) of total reported energy savings for an end use were assigned to a priority "certainty" stratum. We considered these measures necessary for the evaluation; thus, they were not subject to random selection. The remaining measures were then allocated to two strata, defined by a lower bound of 200,000 kWh savings, separating small and large measures to ensure that our sample represented a mix of projects. We used a simple random selection up to the optimal sampling fraction in these strata, allocating one additional sample point to each of the small measure strata (i.e., strata 1 for compressed aid, motors/drives, and refrigeration) to increase the likelihood that our sample contained sufficient projects for the ECwV analysis.

DATA COLLECTION

Our general approach to evaluation data collection was to fully leverage the data collected by the BPA Energy Smart Industrial (ESI) team and utility staff throughout the process of developing each

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[20] Actual precision on evaluated savings was 90/7.

[21] For uniformity of evaluation approach, evaluation and project resource management, and cost control, sampling is based on measure.

[22] Sample was selected based on when invoicing process is complete. Therefore, completion dates for projects will naturally include FY2020 and FY2019 and may include FY2018 due to natural delays from project completion to utility invoicing to BPA. The team excluded any project with completion dates more than two years prior to research start.

[23] The invoices for these measures were submitted between September 10, 2019 and August 28, 2020. Their completion reports were approved between August 28, 2019 and August 27, 2020.

[24] In BPA taxonomy, TAPs roll up into end-use groups. Therefore, where feasible, the evaluation attempted to roll up results into end uses for additional insight to BPA. There was insufficient sample to achieve 90/10 for each end use. However, the results by end use allowed us to investigate whether savings uncertainty is related to measure type versus project size.

project and to only collect additional data as needed to achieve reliable estimates of savings for the sampled measures. We collected the necessary data as follows:

- **File review.** The file review involved extracting all project information relevant to savings estimation. This included:
    - Measure descriptions that detailed how the measure saves energy, affected systems and determinants of savings.
    - Baseline and efficient condition inputs to the M&V savings estimation tool, trend data, cutsheets and other design documents.
    - Reported savings values to compare against tracking data.
    - The final M&V savings estimation tool, and any other critical final documents used to document reported savings.
    - Invoices, receipts, and other data used to verify incremental measure costs.
    - Data and documentation relating to nonenergy benefits such as water use, wastewater, and operations and maintenance labor and materials.
    - Data used to determine nonelectric energy impacts.
    - Data to inform estimates of measure life.
- **Telephone/email discussion with project engineers.** The project engineers (BPA, utility or ESI) were another source of data. As needed, we contacted them by telephone or email to obtain information needed for the evaluation that was not found in the project files. These discussions informed practical strategies for minimally intrusive data collection from end users, and to clarify history and circumstances at the site. We discussed how operations may have changed because of the ongoing COVID-19 pandemic and if they were expected to impact savings calculations.
- **Telephone/email discussion with end users.** In most cases, it was necessary to obtain information from the end user via telephone or email. Discussions included operations staff and vendors to gather data baseline and post-installation conditions of affected buildings, systems and equipment. We also discussed how operations may have changed as a result of the ongoing COVID-19 pandemic. When necessary, these communications were used to plan site visits or remote data collection.
- **Site visits.** Based on the file review and discussions with internal engineers, we sometimes determined that more information was needed from inspection of affected systems and equipment, in-person interviews with operation staff, review of electrical and mechanical plans, inspection of control settings, review of manufacturers' specifications, and one-time measurements. For projects where site visits were challenging, we developed a more robust data collection survey that we administered via telephone and email with the appropriate end user and vendor staff. This included a greater reliance on file review findings, customer staff providing as-built plans and specifications, control system trend data and screen prints, and taking photos or videos and sending them to the evaluation team.
- **Affected system trend metering.** For custom projects, if there were insufficient trend data of critical systems to verify savings, additional metering data were collected. In most cases, this came from on-premises electric metering and other interval data correlated to savings such as air temperature or production levels. Interval premise data were collected from existing on-site instrumentation or from instruments installed by evaluators and on-site operations staff. Where on-site visits were not possible, we implemented a metering plan

with the assistance of on-site staff. These plans leveraged existing metering and on-site staff with the skills necessary to install preconfigured data logging equipment.

- **Weather.** If weather data from the file review were not adequate, actual and/or typical meteorological year (TMY) weather data were acquired for the most appropriate National Oceanic and Atmospheric Administration (NOAA) weather station.
- **Cost effectiveness parameters.** To estimate measure cost effectiveness, we collected data for measure life, incremental costs, nonelectric energy use and nonenergy benefits. We relied on data found in file reviews; these only changed if there was compelling evidence found during evaluation. We did not reach out to end users solely about cost effectiveness parameters. Other cost effectiveness parameters including discount rates, administrative costs, and avoided energy costs used BPA-provided or default RTF values as necessary.

CUSTOM MEASURE ANALYSIS

We estimated savings for sampled custom measures as described below.

SELECT RELIABLE EVALUATION MODEL

Our starting point in estimating savings was a review of the M&V model. The first step was to determine whether the M&V model conformed to the BPA M&V protocols and RTF guidelines. It is important to note that determining compliance with a BPA M&V protocol was just the first step in reviewing an M&V model. The BPA M&V protocols and RTF guidelines provide guidance on general approach and specific examples, but they do not provide detailed specifications for every type of efficiency improvement and affected system or equipment. Once M&V protocol compliance and best practices were determined, we then examined the savings calculations in more detail to determine whether they provided the best practical estimate of savings.

We conducted the model review during the file review. During this review, we determined, relying on professional engineering judgment, whether the model, if provided with reliable input data for the savings determinants, would provide sufficiently reliable estimates of savings. An unreliable model would have a high likelihood of greater than 20 percent difference in the overall savings because of misspecification. For example, if a small variable frequency drive (VFD) measure in an industrial plant relied on whole-facility billing analysis to estimate the savings, we might have considered that application inappropriate because of its high unreliability. As part of the evaluation, we specified an evaluation model—such as post-metering for several weeks applied to manufacturers' pump curves—that was more likely to provide reliable savings. The outcome of each model review was a decision on whether to use the M&V model or replace it with another model when we estimated savings for the evaluation. This decision affected what was done in subsequent steps described below.

Other areas germane to the model review included whether or not the M&V model addressed significant measure interactions, and whether or not it adequately established the proper baseline (current practice or precondition as defined in the RTF Guidelines[25] and the BPA M&V protocols). We considered interactions significant if it was likely that the interactive effect exceeds 10 percent of the measure savings.

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[25] Regional Technical Forum. 2018. *Regional Technical Forum Operative Guidelines for the Assessment of Energy Efficiency Measures*. https://nwcouncil.app.box.com/v/2018RTFOperativeGuidelines

If the M&V model was determined to be reliable, then we adopted it as the evaluation model, and improved its input data if necessary. If the M&V model was found to be unreliable, and thus not suitable to serve as the evaluation model, then we either enhanced or replaced it. Enhancement meant adding or replacing certain features, such as measure interactions, while replacement entailed a wholesale change in approach, such as using the Excel-based Energy Charting and Metrics (ECAM) tool instead of a bin model.

The approach above assumed that adequate measure information was available, and that in particular, data and analysis files were transparent and accessible. For example, if an M&V model was only available as a PDF file, then it would have been generally impossible for the evaluation team to assess the underlying algorithms and formulas for appropriateness and accuracy. While this did not occur, it would have become necessary to get further supporting details from knowledgeable staff, reconstruct the original model, or build an alternative one. Consequently, missing or inaccessible M&V models and supporting data could have led to substantial costs, not only for the evaluation team to develop models from scratch and reproduce data where feasible, but also in terms of additional data collection burdens on customers. We did encounter instances where the M&V model was not functional as supplied to account for changes in savings due to evaluation findings. To resolve those cases, we worked closely with BPA, ESI, and utilities to obtain the necessary information and to create an environment where the models could be executed.

ASSESS DETERMINANT RELIABILITY

Once the evaluation model—either the M&V model or a more reliable replacement—had been selected, we then considered each of the model inputs and determined what level of data collection was needed to support a sufficiently reliable savings estimate, as well as data collection needed for as-expected operating conditions. In general terms, as laid out in the RTF guidelines, key determinants of savings include, but are not limited to:

1. Hours of operation
2. Equipment efficiency at full- and part-load operation
3. Control sequence and settings
4. Outside air temperature or other weather parameters
5. Production rate and schedule
6. Building occupancy
7. Time of day

During the file review, we developed a list of critical determinants for that particular project, where critical is defined as having a significant (possibly 10 percent or more) impact on the calculated savings. We then found the corresponding values used in the evaluation model, assessed the data and/or documentation underlying those values, and determined whether we considered those values reliable. This involved some engineering judgment. To the extent that sampled measures involved similar systems, equipment and modeling techniques, we ensured that consistent judgments were applied.

For instance, we may have determined that hours of operation was a critical determinant for a fan control measure at an industrial facility with a weekly schedule. If the evaluation model incorporated pre- and-post metering for two weeks on a random selection of affected fans, then we may have concluded that the determinant value was reliable. However, if the metering only spanned two hours, we may have concluded it was unreliable, and therefore, additional on-site metering was necessary to develop a reliable determinant value. For each measure, we documented our rationale for establishing whether determinants were reliable or not, and how the reliability was to be improved if necessary. We compared across sampled measures to ensure consistency, as well as to identify overarching trends and issues.

We also verified determinant reliability in cases where energy efficiency performance was impacted by the COVID-19 pandemic. In the described case of a fan control measure, the facility may have added a shift due to increased production for pandemic-related essentials. We assessed determinant reliability for both the actual and as-expected scenarios.

For unreliable critical determinants, we assessed what level of data collection involving the end user was necessary to obtain reliability for that determinant. In order of cost and complexity, these levels were (1) telephone/email interview, (2) site visit, and (3) metering. The highest level across all unreliable critical determinants would then determine the level of data collection for the measure.

COLLECT SUPPLEMENTAL DATA

Based on the previous step, we determined the data collection approach for each sampled measure that established how data for each critical determinant were to be obtained. After our initial review, we prepared questions, data, and model requests for key personnel. This approach was incremental and iterative depending on availability of information and new findings, beginning with internal engineering personnel and included utility staff, vendors and customers. The iterative approach adhered to the contact protocols outlined in Appendix D: Utility & Customer Contact Protocols. Our general intent was to use the least costly and intrusive approach to obtain sufficiently reliable values—starting with telephone interviews, proceeding to a site visit if necessary, and then performing metering in the most critical instances. If data could not be produced, the best available information was used.

Certain measures required extended metering. Hypothetical examples included (a) a fruit processing facility with seasonal production schedules, or (b) a complex HVAC controls project that required separate summer and winter datasets to assess cooling and heating performance, respectively. Such instances were rare and were kept to a minimum because of the inconvenience to the end user, as well as the cost to the evaluation.

The data collection approach varied based on the types of data to be collected prior to and during the site visit. For example, a site visit may have involved interviews to find out about production seasons, coupled with collection of nameplate data and short-term metering. We structured our approach to collect data efficiently, with minimal impact on the end user. The approach also included unit sampling in situations where the measure consisted of many pieces of equipment.

RUN EVALUATION MODEL

If the M&V model was deemed appropriate to serve as the evaluation model, and the critical determinant values were deemed reliable, then this step was essentially a quality control check. If the file review uncovered any clerical or procedural errors that led to a mistaken savings value being reported, then those errors were corrected, and the proper values recorded for this evaluation. If a functioning savings model was not made available to the evaluation team, the team worked with vendors and program staff to make a model executable. If a more reliable model was needed, the evaluation team created one. All evaluation models were provided to the BPA evaluation team for review. Evaluated savings consisted of running the new or existing evaluation model with as-found reliable determinant values and as-found baseline operation conditions obtained through evaluation data collection.

To account for changes in savings resulting from the global COVID-19 pandemic, savings were calculated based on as-operated conditions described above, and as-expected conditions had COVID-19 not occurred. The intent was to also estimate what savings would have been in a nonpandemic year. In cases where savings were unchanged, the savings for both scenarios were identical. We searched for self-reporting of COVID-19 impacts during file review, and inquired further if necessary, during the phone/email interview steps. We investigated operational impacts such as temporary or permanent facility closure, changes in operating schedule, added or removed work shifts, increased outdoor air in HVAC schedules, and any other major operations change where a savings impact greater than 5 percent was expected. For example, a hypothetical plastics production facility with new injection molding machines produced 10,000 parts per day of PPE equipment. The savings was a function of the number of parts made and reduced energy consumption per part. The evaluated efficient case and baseline used 10,000 parts per day for the model. Before the pandemic, this facility planned to make 5,000 parts per day. We applied the same savings model with a baseline and efficient cases producing 5,000 parts per day as the expected savings model.

ESTIMATE SAVINGS USING ENGINEERING CALCULATIONS WITH VERIFICATION (ECWV)

We also used an ECwV protocol to estimate savings for each sampled measure. Our lead engineer for the site created a version of the site data that contained only the data needed for ECwV. In general, this eliminated long term post install trend data obtained from sub-metering and any conclusions reached by the analysis of such data. It was also occasionally necessary to substitute a different savings estimation model. Our team used the ECwV model to estimate savings and compare that to the best practical evaluation model results as well as the BPA ECwV estimate, where available. We determined the relative reliability of the two estimates. To account for changes in savings resulting from the global COVID-19 pandemic, ECwV savings were calculated as first year actual.

TREATMENT OF INTERACTIVE MEASURES

Savings achieved by one measure did affect the savings of another measure in the same project—for example, an HVAC upgrade and envelope improvements that affected the same spaces within a building. The change in envelope would have reduced heating and cooling losses. How much was saved by the HVAC upgrade could be substantially lower without the envelope change. Thus, the order in which savings were estimated could have made a difference for two measures (i.e., unique Technology/Activity/Practices at a single site). If the two improvements occurred as part of separate projects that were completed at different times, this was not an issue for this evaluation. Whichever measure we sampled, we accounted for the baseline conditions of the affected systems and equipment. If the HVAC measure was sampled for evaluation and the envelope improvements happened before the HVAC measure, our evaluation model would have captured the envelope characteristic as part of the baseline conditions.

TIME-BASED VALUE OF SAVINGS AND COST EFFECTIVENESS

There were a number of strategies for characterizing the time-based value of savings for the sample of measures. For this evaluation, we assigned load shapes to individual measures, as the current custom project calculator uses load shapes by sector. Using ProCost, we assigned each measure to one of the RTF savings shapes. We then calculated cost effectiveness and peak savings based on the generic calculator and project-specific ProCost analyses and reported on any differences.

STUDY AND DOMAIN ANALYSIS

Once data collection and analysis were completed for the sample, we compiled a workbook containing all of the individual site level quantitative outputs and qualitative findings about key drivers for deviations between evaluated savings and original savings estimates.[26] These site-level results were then used to estimate the electric savings and cost-effectiveness for the domain and individual end uses within the domain using a ratio analysis. The current sample was stratified and designed to provide results for each of these end uses individually:[27]

- Compressed Air
- HVAC
- Motors/Drives
- Process Load
- Refrigeration

For custom measures with ECwV protocol savings estimates, we also determined when the ECwV protocol provided a reliable estimate of savings.

FIRST-YEAR KWH SAVINGS

We estimated first-year savings for the domain and each end use based on the evaluation model results for the sample. Stratum-level realization rates were extrapolated to estimate savings for the remaining population within each stratum. Evaluated and estimated savings for the individual strata were then summed to estimate the overall domain results, enabling us to calculate an overall domain-level realization rate. Results were calculated and presented both with and without corrections for COVID-19-induced changes to operating behaviors.

RELIABLE SAVINGS FROM ECWV

As described above, we prepared two estimates of savings for each custom measure in the sample. We then compared the two savings estimates and examined the assumptions within the ECwV model and its inputs to assess the relative reliability of the ECwV estimate to answer these questions:

1. **Can the ECwV method be implemented to deliver both unbiased[28] and precise[29] estimates of savings?** In the domain analysis, we compared ECwV-evaluated results against as-observed evaluated results to determine whether there were systematic differences between evaluated results and ECwV results and enumerated the most influential drivers of those differences observed in the individual site results.
2. **Are there issues with how BPA applied ECwV protocols?** For projects that received a BPA-implemented ECwV estimate, we compared both ECwV evaluated results and non-ECwV evaluated results. This included applying the Protocol Selection Flowchart found on page 9 of the BPA *M&V Protocols Selection Guide*[30] and noting whether or not ECwV was

[26] This workbook will be available for BPA review as a non-public data appendix accompanying the report.
[27] In BPA taxonomy, TAPs roll up into end-use groups. Therefore, where feasible, the evaluation attempted to roll up results into end uses for additional insight to BPA.
[28] Confirm total evaluated savings across sample for ECwV protocol are the same as for regular evaluation.
[29] Confirm individual measure-level ECwV and regular evaluation estimates correlate well.
[30] BPA. 2018. *Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan*. https://www.bpa.gov/-/media/Aep/energy-efficiency/measurement-verification/1-bpa-mv-selection-guide.pdf (file will download automatically when clicking)

applied according to the guide. Depending on the exact number of projects that we get with BPA ECwV estimates and the size of the difference between BPA-implemented ECwV and evaluation-implemented ECwV, we may or may not have observed statistically significant differences for the domain as a whole. In any case, we enumerated the most influential drivers of the differences observed in the individual site results to identify opportunities for improvement.

DOMAIN TIME-BASED VALUE OF SAVINGS AND COST-EFFECTIVENESS

In addition to first-year savings, the team extrapolated individual project impacts and cost-effectiveness results to the relevant stratum, end use, and total domain using the same ratio analysis framework. Because BPA provided all values necessary to calculate reported lifetime savings and reported cost-effectiveness, each of these values was used directly in the ratio estimation.

APPENDIX D: UTILITY & CUSTOMER CONTACT PROTOCOLS

This appendix describes the protocols the evaluation team used to contact utilities and end use customers while conducting the impact evaluation.

CONTACT PROTOCOLS

The evaluation team followed general end user and utility contact protocols for this evaluation related to contact with end users and utility representatives, including the following communication principles:

- Utilities are notified of their projects included in the evaluation before the start of evaluation activities and provided with clear information on samples, timelines and requirements. Utilities may reach out at this time to their customers to notify them of potential future contact by the evaluation team.
- BPA provides opportunities for utilities to understand the details of the evaluation plan and data request.
- BPA gives utilities a reasonable timeline to collect project and billing data, and uses escalation protocols if deadlines are missed, which include the BPA Contracting Officer's Technical Representative (COTR) and Account Executive (AE).
- Evaluation team provides at least one week of notice to utilities before any end user contact, including phone surveys and site visits.

UTILITY NOTIFICATION AND WEBINAR

Once the evaluation plan and sample were reviewed by the BPA evaluation team and the BPA Energy Smart Industrial (ESI) team, the BPA evaluation Energy Efficiency Representative (EER) notified utilities via email that at least one project in their territory had been selected in the evaluation sample (either the primary or secondary sample). This initial email requested the primary utility contact for the evaluation and also included an invite to a webinar that included utility-specific information associated with the evaluation plan.

The evaluation team also provided detailed information to each utility about their sampled sites through a secured file transfer protocol (FTP); details were provided on custom project ID, utility-assigned ID, project name, facility name, address, completion date, sampled measure (TAP), invoice number, and whether the site was in the primary or secondary sample.

PROJECT DOCUMENTATION OR BILLING DATA REQUESTS

BPA (and its contractors such as ESI) provided the evaluation contractor all relevant project information it had, including custom project completion files and COTR oversight documents.

The utility (or BPA, if requested by the utility) uploaded required files to a secure website. The evaluation team worked with utilities individually to support its data request as much as feasible, including extended delivery dates as needed.

To provide timely and actionable evaluation results, the team created an escalation protocol that was initiated when data collection efforts became delayed and posed an impact to the schedule. The protocol follows:

1. As noted above, initial data request emails were to be sent by the evaluation team to utility contacts with a copy to the evaluation EER and evaluation lead.

2. If a utility requested more time, within the agreed-upon time limit, the utility EER and utility COTR were notified by the evaluation lead.
3. If a utility missed the deadline, then the evaluation EER, utility EER, COTR, and AE were notified of the missed deadline. The utility EER and the utility AE then discussed an approach to the data collection, including potential escalation to utility management.

CONTACT OF INTERNAL PROJECT ENGINEERS

Following file review, the evaluation team contacted the internal (i.e., BPA/ESI/utility) project engineers to learn more about the project, on an ad hoc basis by the evaluation team. The discussion with the internal project engineer included:

- Answering questions regarding the project or files.
- Obtaining information needed for the evaluation that was not found in the project files.
- If end user contact was required, discussion was to inform the evaluation team on the history of the project and circumstances at the site and to identify the least intrusive approach for obtaining data needed by the evaluation.

PHONE SURVEYS, EMAILS, AND/OR SITE VISITS OF END USERS

Where the team utilized phone surveys, emails or site visits, the evaluation team lead engineer notified the utilities at least one week before any end user contact and provided them with a general description of information to be collected from the site. The phone survey and/or email collected relevant information and determined the necessity of site visits. The feasibility of on-site visits was at the discretion of the customer and the evaluation team. The evaluation team worked with BPA to develop materials to support any advance contact they wanted to make with end users, including email and phone call scripts. The evaluation team lead also provided a set of potential frequently asked questions to minimize any potential concerns by the end users.

Evaluation engineers followed reasonable safety and privacy requirements set by end users. This included safety training, personal protective equipment and health screenings. The site visit did not proceed until all reasonable end-user requirements for an on-site visit were met.

APPENDIX E: POTATO SHED HUMIDIFICATION AND COOLING STANDARD PRACTICES

The measure savings evaluation approach is outlined in Section 3 and Appendix C of this report. Part of evaluating custom measure savings requires examining the baseline assumptions. This approach is applied to all measures without exception. We considered both the BPA protocol selection guide and the RTF guidelines for establishing measure baselines. For custom measures, both BPA and RTF guidelines agree that new construction projects apply a current practice baseline.[31,32] Current practice is described in the BPA M&V selection guide: *"When the practitioner uses a current practice baseline, the efficiency level of the baseline equipment must be consistent with any state or local mandates for new equipment, which may vary from city to city and state to state."* [33]

The RTF measure assessment guideline recommends the following to define current practice for custom measures: "*The practitioner needs to identify what would normally be done, based on prior experience with similar projects. The practitioner should start by using applicable codes and standards, or one of the following if they constitute a more energy efficient baseline for the measure and the information is practical to obtain and applicable to the delivered measure's location OR there is no applicable code or standard for the measure implemented.*

- *Recent similar purchases by the end user*
- *Documented end user plans or specifications*
- *End user or vendor developed alternative designs, considered as part of the measure selection process*
- *End user description of what was done in similar circumstances elsewhere in the facility or in another facility they operate*
- *Equipment vendor's description of what they would normally do for this end user"*[34]

BPA's guideline indicates that evaporative cooling is technically compliant as a new construction energy efficiency measure since it is not prescribed by energy codes for potato storage sheds. The RTF guideline requires an additional step beyond searching for an applicable energy code to set the baseline to identify current practice.

When we found multiple potato shed projects in the sample, the engineering leads performed brief literature reviews to verify typical requirements for agricultural root vegetable storage. The reviews found that evaporative cooling is a longstanding practice with best practice documentation going back more than 30 years. We followed up with end users and other stakeholder experts to corroborate the established nature of these energy savings measures. With these findings in mind, we compared our observations to published guidance on choosing baselines. Evaluators conducted a limited literature search and interviewed readily available industry experts. Evaluators noted key

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[31] Regional Technical Forum Guidelines. 2020. *Regional Technical Forum Guidelines for the Assessment of Energy Efficiency Measures*, Section 3.1.6, page 12. https://nwcouncil.app.box.com/v/2020RTFGuidelines
[32] BPA. 2018. *Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan*, page 6. https://www.bpa.gov/-/media/Aep/energy-efficiency/measurement-verification/1-bpa-mv-selection-guide.pdf (file will download automatically when clicking)
[33] ibid, page 7.
[34] Regional Technical Forum Guidelines. 2020. *Regional Technical Forum Guidelines for the Assessment of Energy Efficiency Measures*, Section 4.3.3, page 20. https://nwcouncil.app.box.com/v/2020RTFGuidelines

literature documents and tabulated summaries of their interviews. A complete and comprehensive standard practice study was not practical and was out of scope for this evaluation.

A literature search revealed that best practice refrigerated storage requirements for different fresh vegetables vary widely:[35]

- Onions stored at 32°F at 65-70 percent relative humidity
- Carrots stored at 32°F at 98-100 percent relative humidity
- Potatoes (early crop) stored at 40°F at 90-95 percent relative humidity

Evaporative cooling systems equipment recommendations and requirements for fresh potato storage in arid and humid climates are well understood and prescribed in standard refrigeration literature.[36] Regional research institutions also indicate that evaporative cooling is a preferred common practice due to its relatively low cost and abundant advantages in serving key humidification needs for potato crops. Washington State University's cooperative extension noted that

> *"Cooling potatoes in storage is most commonly done with cool night air and, in many cases, some evaporative cooling. Refrigerated air is used occasionally and, of course, cools very well but is more expensive."*[37]

Humidity is a critical aspect for potato quality and to reduce shrinkage. As stated by experts at the University of Idaho,[38]

> *"The impact of maintaining the proper RH cannot be overstated…Recently constructed storages often include a humidification system consisting of both a cell and supplemental spinners to achieve the maximum plenum RH."*

Evaporative cooling as common and standard practice for potato storage was further confirmed in interviews with facility staff. After completing our initial round of data collection and collecting operating data, we followed up to ask about their experience with humidicells. The end user we interviewed on June 30, 2021, had four sampled sites in our study and indicated that the main purpose of the evaporative cooler is to maintain relative humidity. He noted that:

> *"The evaporative cooler pump is controlled to maintain RH."*

A different end user reinterviewed on August 12, 2021 indicated that the main purpose of the evaporative cooler was to maintain relative humidity:

> *"We would do this for any potato shed because they NEED the humidity. Onions don't do well with that much humidity so we don't use them in the onion storage."*

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[35] American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). *2014 ASHRAE Handbook – Refrigeration*, section 37.12.
[36] ASHRAE. *2015 HVAC Handbook – Applications*.
[37] Washington State University Cooperative Extension. 1993. *Potato Storage and Ventilation*. Page 12. https://rex.libraries.wsu.edu/esploro/outputs/report/Potato-storage-and-ventilation/99900502737401842?institution=01ALLIANCE_WSU#file-0
[38] Oberg et al. 2016. *Relative Humidity: A Key to Successful Potato Storage*. Page 3. University of Idaho.

We interviewed three additional market actors in addition to impact evaluation end users. Their observations and comments are summarized in Table 7.

Table 7: Potato storage market actor interview excerpts from Domain 1 custom industrial impact evaluation

Type of Market Actor	*Region*	*Interview Date*	*Summary of Interview*
Vendor/Builder	Nationwide (PNW Branch)	9/16/21	The interviewee is an installer, not a designer. He said that he does see facilities that do not have refrigeration if they are only storing during the winter months and cannot afford the refrigeration system. When asked specifically about humidicells, he said he sees them in pretty much all facilities regardless of whether they have a refrigeration system or not. When asked how long it has been that way, he said a lot longer than he has been installing systems.
Vendor/Builder	Nationwide (PNW Branch)	7/22/21	The interviewee designs vegetable storage systems all over the country. He indicated that occasionally they will do a design in a location where it does not make sense to include a humidicell because of the climate, but they are always included in the areas that grow potatoes.
Agricultural economist	PNW	7/24/2021	Interviewee pointed out that full refrigeration systems are common everywhere (especially in more humid places like Texas) because they help meet market conditions year-round. She also added that humidicells are common (like VFDs) but it is important to see that they are not a "competing technology" in that they cannot practically replace refrigeration in an industrial process. ‘If you are reconsidering humidicells, should probably also reconsider incentivizing VFDs.’ (Evaluator note: Potato shed VFDs are only considered a retrofit measure by RTF.)

The conclusion by evaluators from interviews was that evaporative cooling is ubiquitous and necessary for potato storage, particularly for new construction, and has been for many years. These current market conditions may have occurred as a result of energy efficiency programs advocating for evaporative cooling measures. According to RTF guidelines, this indicates that the practice should be considered a baseline technology for any refrigerated vegetable storage that requires high humidity. The group of interviewed market actors was small, and RTF guidelines do allow for a melded baseline.[39] Evaluators recommend a standard practice study to identify the proportion of the population to which evaporative cooling may be applicable in new construction projects.

[39] Regional Technical Forum. 2020. *Regional Technical Forum Guidelines for the Assessment of Energy Efficiency Measures, Section 4.3.3, page 20.* https://nwcouncil.app.box.com/v/2020RTFGuidelines