BONNEVILLE POWER ADMINISTRATION

2022 Nonresidential Lighting Portfolio Impact Evaluation Report

1 EXECUTIVE SUMMARY 2
1.1 Methodology 2
1.2 Summary of Findings and Recommendations 2
2 INTRODUCTION 4
2.1 Key Terms 4
2.2 Background 4
2.3 Evaluation Objectives 5
3 METHODOLOGY 5
3.1 Sample Design 5
3.2 Data Collection 6
3.3 Measure Savings Analysis 6
3.4 Study and Domain Analysis 6
4 FINDINGS 7
4.1 Overall portfolio Results 7
First-Year Savings 7
4.2 Site-Level Results 9
4.3 Key Drivers of Savings Differences 10
4.4 Lifetime Savings 12
4.5 Cost-Effectiveness 13
5 KEY FINDINGS AND RECOMMENDATIONS 14
APPENDICES 16
APPENDIX A: DEFINITION OF KEY TERMS 16
APPENDIX B: SITE-SPECIFIC SAVING ESTIMATION 21
APPENDIX C: DETAILED METHODOLOGY 22
Sample Design 22
Data Collection 23
Measure Savings Analysis 25
Study and SubDomain Analysis 26

1 EXECUTIVE SUMMARY

This document presents the results of Bonneville Power Administration's (BPA) nonresidential lighting portfolio impact evaluation. This report addresses the third of four total studies of a rolling evaluation plan that will address the entire custom measure and commercial, industrial and agricultural (nonresidential) lighting portfolios for both Option 1 and Option 2 utilities.[1,2] Option 1 utilities are required to use BPA's custom lighting calculator, while Option 2 utilities may use their own lighting calculators. The primary objectives of this evaluation were to:

- **Estimate first-year kWh savings and cost-effectiveness** for the nonresidential lighting portfolio to understand the savings performance.
- **Develop recommendations** as appropriate for program documentation and savings calculators that may be contributing to lower reliability of savings.

1.1 METHODOLOGY

This evaluation represents the population of nonresidential lighting measures with completion dates between Oct. 1, 2021, and Sept. 30, 2022. The sample design targeted a 90/10 confidence level and precision and was developed based on a combination of project files for Option 1 sites and BPA tracking data for Option 2 sites.

The sampling was conducted with a conventional optimum allocation stratified design based on utility type and reported kWh savings for each project across 38 sample sites.[3]

The data collection approach utilized a combination of sources, including file review, site visits and time of use metering. Lighting measure analysis was conducted using a multistep process starting with a review of the lighting calculator savings, collecting supplemental data where needed, running the lighting model, and estimating savings.

Once data collection and analysis were completed for the sample, project-level results were compiled to estimate the electric savings and cost-effectiveness for the lighting program portfolio using a ratio analysis.

1.2 SUMMARY OF FINDINGS AND RECOMMENDATIONS

The overall results for BPA's nonresidential lighting portfolio showed that evaluated savings delivered slightly less than reported savings, for an overall realization rate (the ratio of evaluation savings to reported savings) of 98 percent, as shown in Table 1. The overall

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[1] Utilities are categorized as Option 1 or 2 for measurement and verification (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.

[2] The 2020-2021 Evaluation Plan separated this nonresidential lighting study into two domains, one for Option 1 utilities and the other for Option 2 utilities. After completing the Custom Industrial evaluation for Option 1 utilities (the first study domain) and planning it for Option 2 utilities (Domain 2), the evaluation team and BPA decided to collapse the nonresidential lighting study domains into a single domain to increase efficiency for BPA program and evaluation teams.

[3] There was one project per unique site, so the sample may also be expressed as projects.

realization rate of 98 percent is close to the previous evaluation of this program portfolio,[4] which had a realization rate of 100 percent. The overall sampling precision totaled 4 percent for a 90 percent two-tailed confidence interval, which was better than the target design of 10 percent (at 90%).[5]

Table 1: Evaluated first-year savings utility type

Utility Type	Realization Rate	Sampling Relative Precision (90% two-tailed)	Reported Savings (kWh)	Evaluation Savings	
				kWh	Percent of Portfolio
Option 1	94%	6%	6,291,672	5,933,233	36%
Option 2	101%	3%	10,238,119	10,345,846	64%
Total	**98%**	**4%**	**16,529,792**	**16,279,079**	**100%**

The program's estimates of savings are well aligned with the evaluation results for both Option 1 and Option 2 utilities, which had remarkably similar results. While there were some deviations in program savings compared to evaluation results, those cases were few and mostly associated with smaller projects. The evaluation identified the main reasons for deviations between evaluation and program savings. The first issue concerns a busbar factor that is applied to site level savings. The evaluation noted an inconsistency between the busbar factor that Option 2 utilities use in their reporting compared to what is used by Option 1 utilities. The second issue relates to differences in lighting used for growing plants and lighting used to increase visibility and brightness for human occupants. The evaluation includes recommendations to address these issues to improve the accuracy of nonresidential lighting program savings reporting (see Section 5 for more detail):

- BPA makes policy and procedural changes regarding how T&D loss factors are applied to ensure consistent and fair reporting of savings across Option 1 and 2 utilities.
- BPA consider reclassifying lighting used for industrial and agricultural processes to the category of "process lighting" (i.e., light that is used for something other than enhancing human vision) so its use cases are treated appropriately when reporting savings. These additional types of lights should include custom lamp efficiency and HVAC factors.

The evaluation also identified two additional issues that were relatively less impactful on the accuracy of program savings reporting. These issues are that gas heating penalties are not being reported to end use customers, and the BPA lighting calculator does not include specific values for all wattage categories. These issues are raised for BPA's consideration, along with recommendations on how they could be addressed at BPA's discretion (see Section 5).

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[4] See results for the nonresidential lighting domain from the prior evaluation completed in 2015: SBW Consulting, Inc. 2015. *Impact Evaluation of the FY2012-2013 Site-Specific Savings Portfolio*. https://www.bpa.gov/-/media/Aep/energy-efficiency/evaluation-projects-studies/impact-evaluation-site-specific-portfolio-final-report.pdf.

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

2 INTRODUCTION

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

- Unit Energy Savings (UES) measures utilize a constant savings value for each measure application.
- Custom measures require calculation of savings for each project.
- Calculator measures have standardized savings estimation algorithms and project-specific parameter values (typically lighting).

The subject of this report is an impact evaluation of BPA's commercial, industrial and agricultural lighting portfolio.

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

Consistent with the Regional Technical Forum (RTF) guidelines, BPA aims to achieve 90 percent coverage of the energy efficiency portfolio through impact evaluation in a four-year period.[6] When selecting which programs to evaluate each year, BPA balances the objectives of portfolio coverage, strategic research needs, timely feedback, annual budgets, and the cost and effort required.

BPA conducted impact evaluation planning in 2019-2020 to determine what evaluation activities had occurred previously and what evaluation needed to occur in the next four years to satisfy BPA's policy of evaluating measure savings equivalent to 90 percent of the energy efficiency portfolio every four years. The outcome of this effort was the 2020-2021 evaluation plan,[7] which categorized the portfolio into unique domains, which are components of BPA's program portfolio that are grouped by similar delivery approaches for the purposes of evaluation (including by utility type, measure type and sector).[8] Aligned with the priorities identified in the 2020-2021 evaluation plan, BPA has completed an evaluation of its custom industrial portfolio for both Option 1 and Option 2 utilities, and this report documents the results of the evaluation of its nonresidential lighting portfolio (for both Option 1 and 2 utilities).

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[6] 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).
[7] Evergreen Economics. 2020. *Bonneville Power Administration 2020-2021 Evaluation Plan*. https://www.bpa.gov/-/media/Aep/energy-efficiency/evaluation-projects-studies/bpa-2020-21-impact-evaluation-plan.pdf.
[8] In 2022, BPA revisited its evaluation strategy and 2020-2021 evaluation plan, and refined the rolling evaluation approach that was recommended in the prior evaluation plan. BPA condensed and streamlined the domains into four major measure categories, with an updated plan to begin one study per year on a rolling basis across the four-year period. (See: https://www.bpa.gov/-/media/Aep/energy-efficiency/evaluation-projects-studies/2023-2024-bpa-ee-evaluation-strategy-presentation.pdf.)

2.3 EVALUATION OBJECTIVES

The evaluation objectives for this study were to:

1. **Estimate first-year kWh savings and cost-effectiveness** for the nonresidential lighting portfolio to understand the savings performance.
2. **Develop recommendations** as appropriate for program documentation and savings calculators that may be contributing to lower reliability of savings.

3 METHODOLOGY

This section summarizes the methods used by the Evergreen Economics evaluation team (the evaluation team), which includes SBW Consulting and Apex Analytics, to conduct this evaluation. The section is organized by the following topics: Sample Design, Data Collection, Measure Savings Analysis, and Study and Domain Analysis. Appendix C provides additional detail on the study methods.

3.1 SAMPLE DESIGN

Table 2 shows the number of nonresidential lighting projects and associated savings completed during the study period, by utility type and size strata. It also includes the study sample allocation of 38 projects from 38 sites (with 67 unique measures), which includes 2 certainty projects and a stratified random sample of 36 additional measures.

Table 2: Nonresidential lighting sample design

Utility Type	Strata*	Reported Savings (kWh)		Number of Reported Projects	Sample Size (Projects)
		Average	Total		
Option 1	0	3,391	610,346	180	0
	1	22,317	11,136,371	499	4
	2	106,155	11,146,229	105	4
	3	315,969	11,058,927	35	5
	4	628,682	11,316,272	18	5
	Subtotal	**54,084**	**45,268,145**	**837**	**18**
Option 2	0	3,773	113,180	30	0
	1	26,142	5,908,192	226	4
	2	112,962	5,874,016	52	4
	3	252,919	5,817,138	23	5
	4	625,285	6,252,851	10	5
	Certainty	2,006,849	4,013,697	2	2
	Subtotal	**81,572**	**27,979,074**	**343**	**20**
Total		**62,074**	**73,247,219**	**1,180**	**38**

*Stratum 0 denotes the excluded projects (based on small savings). The *certainty* projects represent a significant portion of total reported energy savings within a given program or portfolio and are considered as necessary for the evaluation and therefore are not subject to random selection.

3.2 DATA COLLECTION

The evaluation team's general approach to evaluation data collection was to fully leverage the data collected by BPA, project engineers, and utility program staff throughout the process of developing each project and to collect additional data from end users to achieve reliable estimates of savings for the sampled projects. The evaluation team 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 MEASURE SAVINGS ANALYSIS

The evaluation team estimated savings for sampled lighting projects and measures using the following steps (each of which is described in more detail in Appendix C):

1. Review existing BPA lighting calculator.
2. Standardize lighting models.
3. Assess determinant reliability.
4. Collect supplemental data.
5. Run evaluation model and estimate evaluated savings.

The evaluation approach for dividing the savings reported at a site into individual projects was insufficiently accurate, so the unit of sample analysis was changed to the whole site. All projects at the sampled site were evaluated and then rolled up to a total savings amount for each site.

3.4 STUDY AND DOMAIN ANALYSIS

Once data collection and analysis were completed for the sample, the evaluation team compiled a workbook containing all individual site-level 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 nonresidential lighting portfolio and by this study's domain category (which is utility type) using a ratio analysis. The details of this approach are presented in Appendix C.

4 FINDINGS

This section presents impact evaluation results for BPA's nonresidential lighting portfolio.

The section is organized as follows:

- Overall results for BPA's nonresidential lighting portfolio.
- Project measure level results.
- Key drivers of savings.
- Lifetime savings.
- Cost-effectiveness.

Appendix B provides site-specific savings estimation details.

4.1 OVERALL PORTFOLIO RESULTS

This subsection provides the overall results for this impact evaluation of commercial, industrial and agriculture lighting projects installed by subdomain (Option 1 and Option 2 utility customers) with completed reporting between Oct. 1, 2021, and Sept. 30, 2022.

The overall results showed evaluated savings estimates for Option 1 and Option 2 sites as 94 percent and 101 percent, respectively, of the savings that BPA reported. Across all the sites, evaluated savings estimates were 98 percent of the savings that BPA reported, proving the overall reported savings are highly accurate. Evaluators observed that utilities generally followed BPA Implementation Manual and M&V protocols correctly and that the difference in realization rates did not result from deviations in procedure.

FIRST-YEAR SAVINGS

As shown in Figure 1, evaluated savings were slightly lower than reported savings for Option 1 sites while they were slightly higher than reported for Option 2 sites. When averaged across the entire sample, the higher-than-expected savings from the Option 2 sites, combined with the lower-than-expected savings for Option 1, resulted in slightly lower than expected savings within the total sample, as shown in Table 3.

Note that there is a difference in how Option 1 and Option 2 utilities calculate savings for nonresidential lighting projects. Option 1 utilities rely on BPA's lighting calculator, while Option 2 utilities may use their own.

Figure 1: Reported first-year savings by utility type compared to evaluated savings by utility type

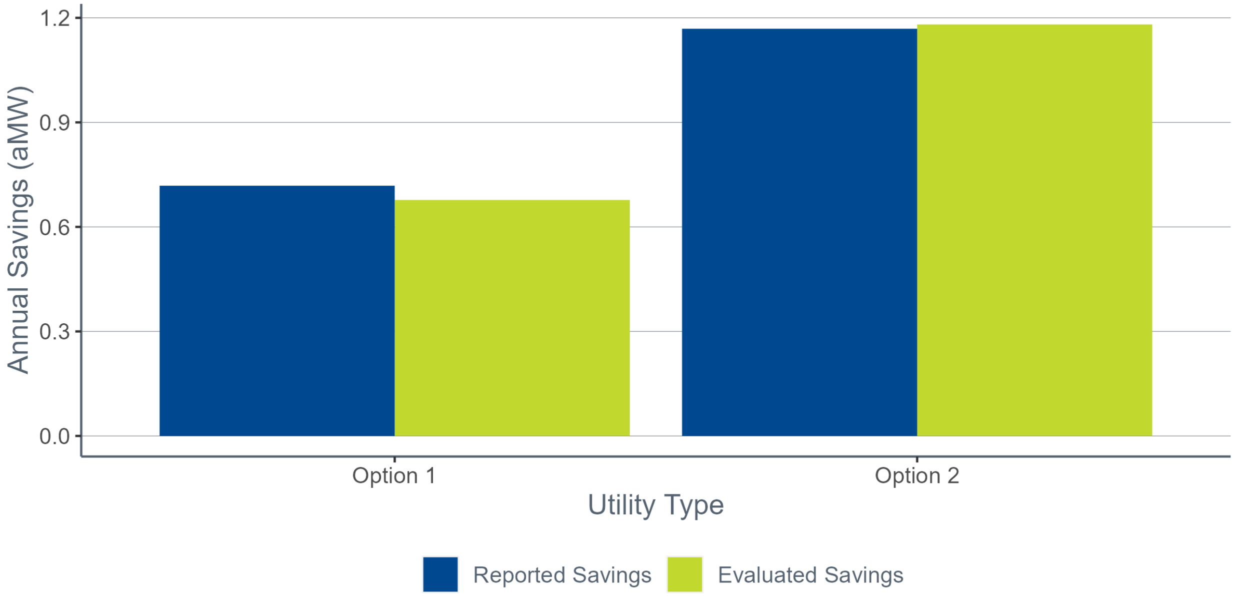


Table 3: Evaluated first-year savings by utility type

Utility Type	Realization Rate	Sampling Relative Precision (90% two-tailed)	Reported Savings (kWh)	Evaluation Savings	
				kWh	Percent of Portfolio
Option 1	94%	6%	6,291,672	5,933,233	36%
Option 2	101%	3%	10,238,119	10,345,846	64%
Total	**98%**	**4%**	**16,529,792**	**16,279,079**	**100%**

The realization rate estimated by the 2015 evaluation of the lighting portfolio was 100 percent.[9] Note that the evaluation methodology and program cycle differed between the 2015 evaluation and the current evaluation.

The actual sampling relative precision totaled 4 percent for a 90 percent two-tailed confidence interval. This precision is slightly better than predicted during the sample design development (10 percent precision). The sample design was based on an expectation of slightly higher variability than observed in the last evaluation of BPA's nonresidential lighting portfolio, but the actual variability was substantially lower.

[9] See results for the Option 2 Non-Lighting Industrial domain from the prior evaluation completed in 2015. SBW Consulting, Inc. 2015. *Impact Evaluation of the FY2012-13 Site-Specific Savings Portfolio*. https://www.bpa.gov/-/media/Aep/energy-efficiency/evaluation-projects-studies/impact-evaluation-site-specific-portfolio-final-report.pdf.

4.2 SITE-LEVEL RESULTS

Site-level results based on the evaluation sample of 38 sites were highly variable, with realization rates ranging from 0.4 to 1.4, as shown in Figure 2, with each site in the sample represented by a single point. Sites are arranged along the x-axis by utility type, with blue representing Option 1 sites and orange representing Option 2 sites. The size of each point corresponds to its evaluated savings value (aMW). Option 1 realization rates showed a negatively skewed distribution, with few sites demonstrating realization rates below 1.0, bringing the average realization rate of this group down to 94 percent. While Option 2 realization rates showed more variability than Option 1, their approximate distribution was evenly distributed around 1.0, resulting in an average realization rate of 101 percent.

Figure 2: Site-level realization rates

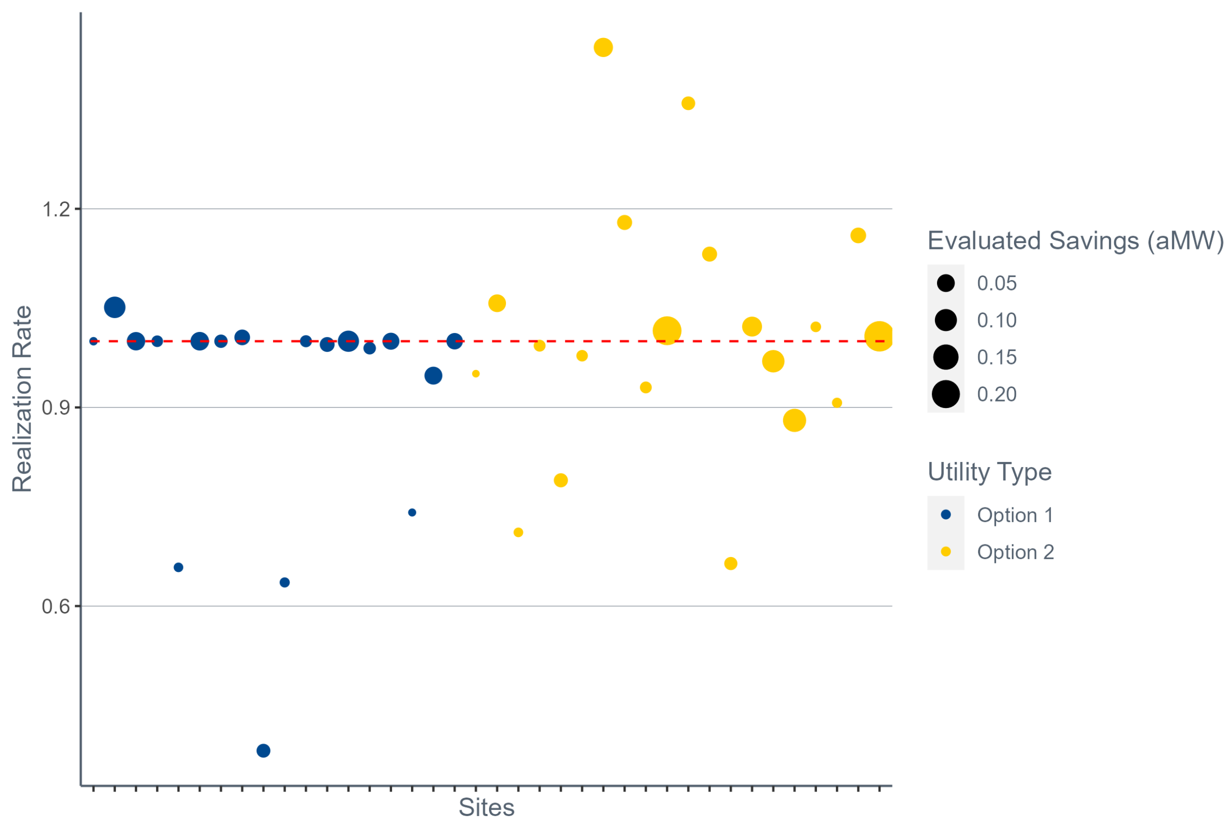
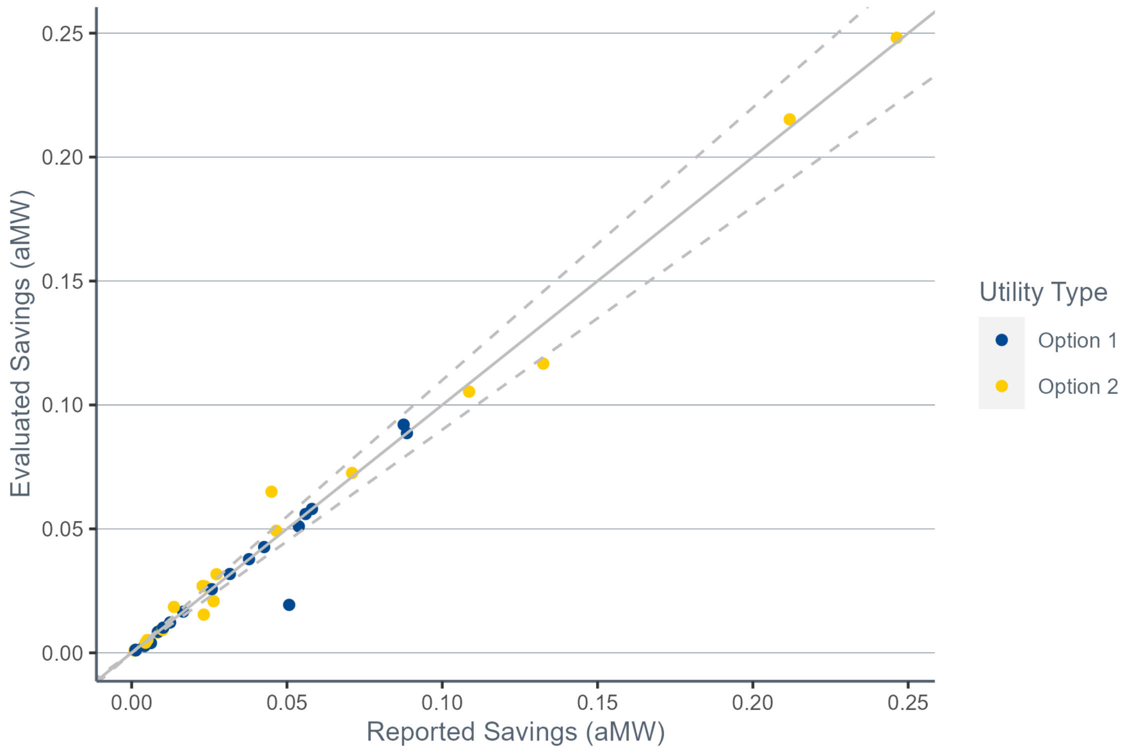


Figure 3 shows evaluated savings results by site for the evaluation sample, expressed in average megawatts (aMW). Points lying above the gray diagonal line represent sites with evaluated savings higher than reported savings, while those lying below the gray diagonal line represent sites with evaluated savings lower than reported savings. The dashed lines indicate +/- 10 percent of reported savings. Most projects have evaluated savings within 10 percent of reported savings.

Figure 3: Evaluated savings versus reported savings by site

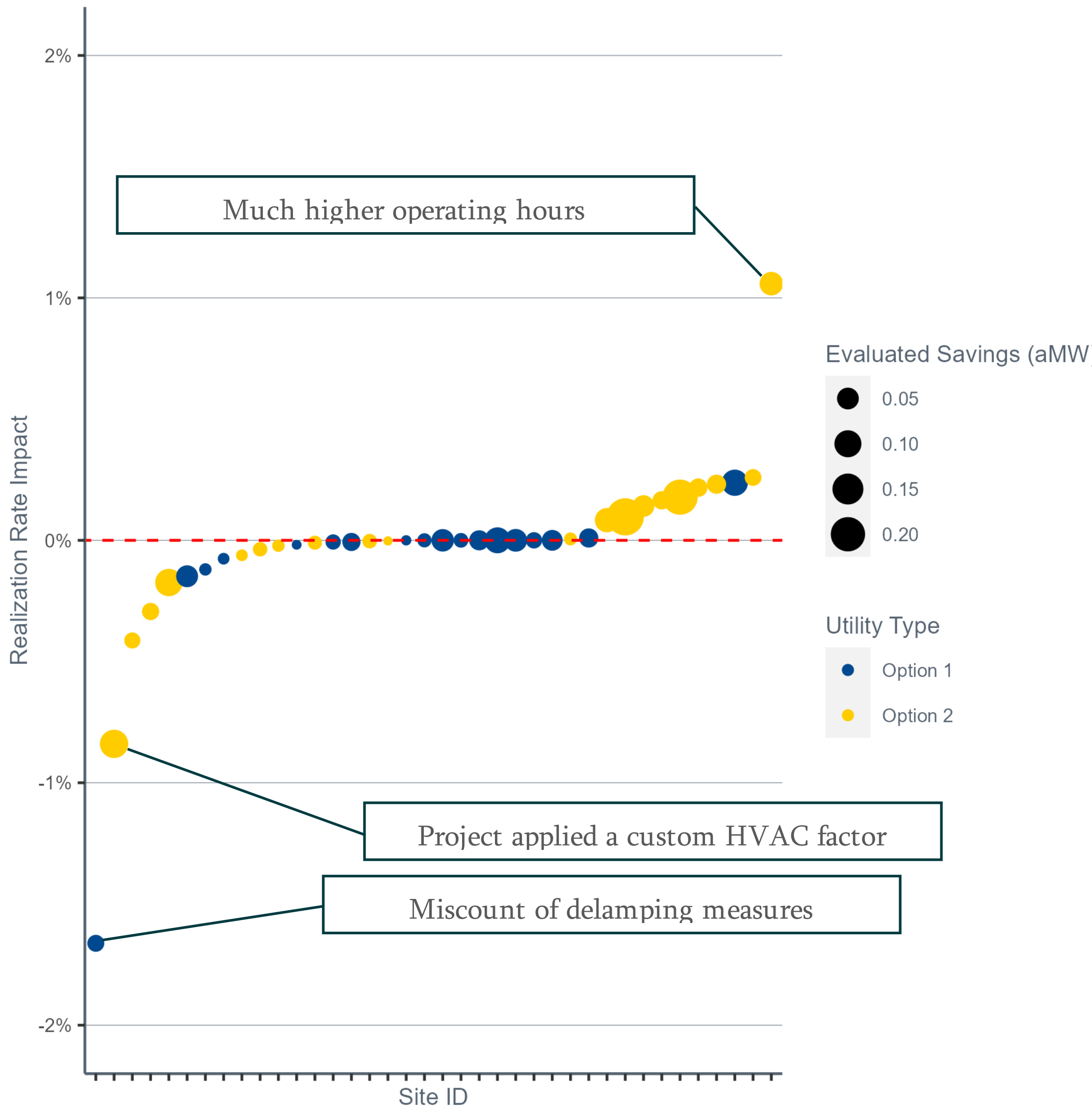


4.3 KEY DRIVERS OF SAVINGS DIFFERENCES

Figure 4 shows the impact of each reviewed project measure in the evaluation sample on the overall study realization rate. Project measures below the red dashed line are driving the realization rate below 1.0, while project measures above the line are driving the 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 did not influence the total.

While most projects had realization rates near 1.0, there were a few notable exceptions, with two relatively large sites with negative realization rates lowering the overall realization rate to below 1.0. The callout boxes within the figure summarize the reasons for some of the most influential projects on the deviation in the realization rate from 1.0, which are discussed in more detail after the figure.

Figure 4: Deviations in realization rates



The most influential project measures **negatively** impacting the overall realization rate had the following issues:

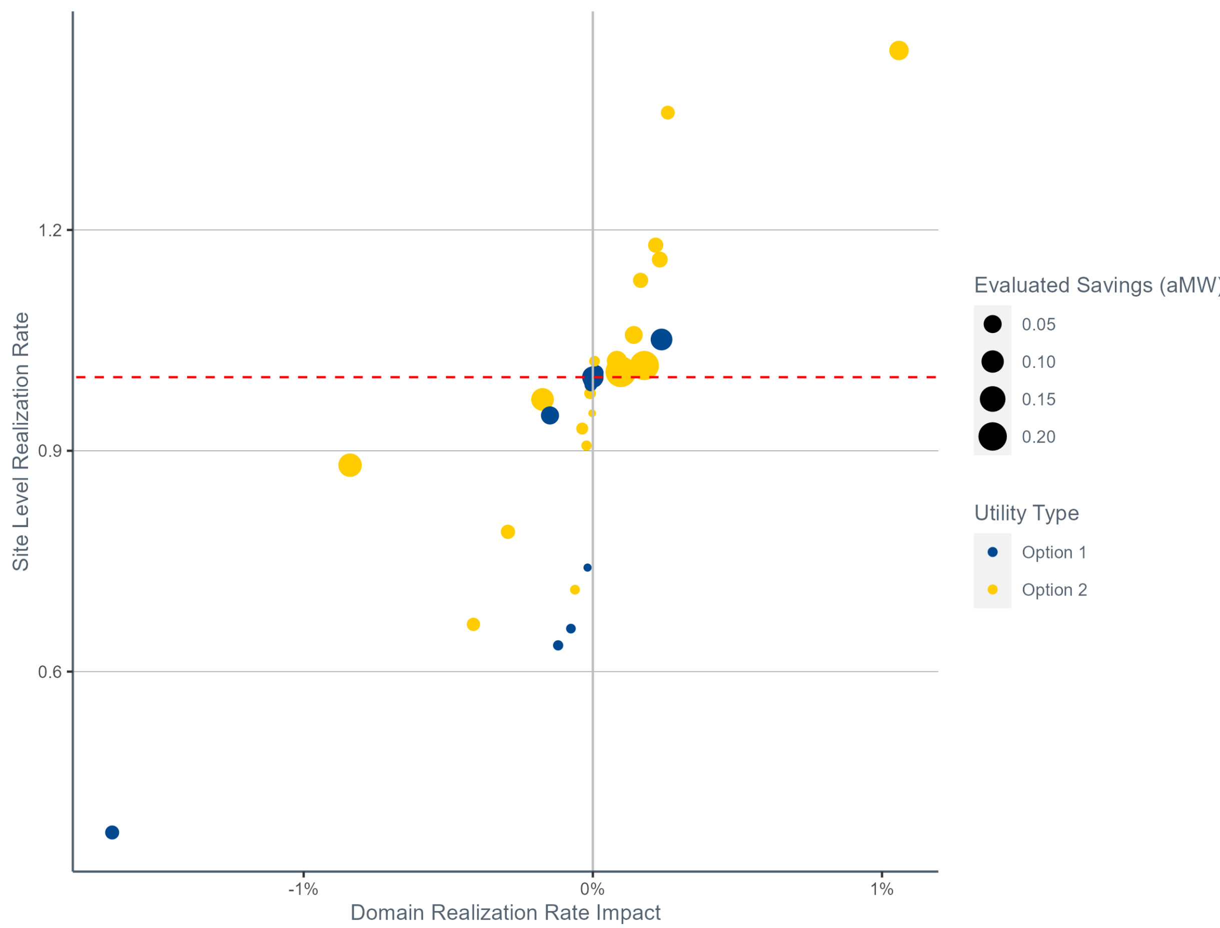
1. **Miscount of delamping measures.** A project included both delamping and lamp replacement in a warehouse, and the reported values of each were incorrect compared to evaluator observation on-site. A total of 286 fixtures were initially reported as delamps and 213 fixtures as lamp replacements. Evaluators found that 79 fixtures were delamped, and 208 fixtures had lamps replaced (287 total fixtures).
2. **Project applied a custom HVAC factor.** An indoor agriculture lighting project had exceptionally high interaction with cooling and dehumidification loads. The utility-estimated interaction factor was ~47 percent. The standard BPA lighting calculator allows an interaction factor of up to 30 percent. There is not a standard RTF protocol or estimate for this factor, but evaluators estimated that a custom factor between 20 and 40 percent would be reasonable depending on the type of facility.

The most influential project measure **positively** impacting the realization rate had the following issue:

1. **Much higher operating hours than originally estimated.** One sampled project originally estimated 2,250 hours of use on average, while the evaluation found through metering and occupant interviews that typical use since the project installation was approximately 3,230 hours. Offices and hallways were the spaces with higher use.

The site impact map in Figure 5 shows the relationship between realization rate, size of site, and resulting overall impact on the realization rate based on the evaluation sample results. The site impact map combines all 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 site level realization rate. Sites in the lower left quadrant are driving the realization rate below 1.0, while sites in the upper right quadrant are driving the realization rate above 1.0. Larger dots represent sites with larger measures, which generally increases their impact on overall realized energy savings.

Figure 5: Site impact map



4.4 LIFETIME SAVINGS

Table 4 shows the estimated evaluated lifetime savings for the sampled sites. The evaluated lifetime savings estimates are slightly lower than the reported lifetime savings. No adjustments to lifetime were made because the evaluation team's review found that measure lifetimes for evaluated measures were the same as stated for all projects. The resulting lifetime savings realization rate of 98 percent is the same as the first-year savings realization rate (98%).

Table 4: Lifetime savings

Utility Type	Evaluated Lifetime Savings (kWh)	Reported Lifetime Savings (kWh)	Lifetime Savings Realization Rate
Option 1	70,953,299	75,166,422	94%
Option 2	111,088,336	109,972,636	101%
Total	**182,041,635**	**185,139,058**	**98%**

4.5 COST-EFFECTIVENESS

The nonresidential lighting portfolio is strongly cost-effective overall, based on the evaluation results, producing $1.99 in benefits for every $1 spent, as shown in Table 5. The program does not track gas heating penalties for Option 2 utility lighting projects. As a result, there are no complete total resource cost test benefits and costs to compare to, and only evaluated benefits and costs are presented.

Table 5: Benefit-cost results

Utility Type	Evaluated		
	Benefits ($)	Costs ($)	Benefit-Cost Ratio
Option 1	$5,016,046	$2,497,050	2.01
Option 2	$9,485,207	$4,807,347	1.97
Total	**$14,501,252**	**$7,304,397**	**1.99**

5 KEY FINDINGS AND RECOMMENDATIONS

In general, BPA's nonresidential lighting portfolio's estimates of savings are well aligned with the evaluation results, with an overall realization rate of 98 percent for the portfolio. While there were deviations in program savings compared to evaluation results, those cases were few and mostly associated with smaller projects.

The evaluation team developed key findings and recommendations based on the results of this evaluation, summarized below.

Key Finding: Option 2 utilities systematically report savings 1.5 percent higher than Option 1 utilities because of using a higher busbar factor. The Implementation Manual allows the Option 2 utilities to claim savings with a busbar factor of 1.0905 while Option 1 utilities use BPA's recommended busbar factor of 1.0746. which matches the Regional Technical Forum recommended value. Further, Option 2 utilities have no option to use a different factor as they must use the same busbar factor for all their reported custom projects. Even though the Option 2 utilities' use of a higher busbar factor is allowed by BPA policy as outlined in its Implementation Manual, there is no engineering reason to support the use of two different factors.

The evaluation team recommends that BPA make one of the following policy and procedural changes (i.e., both to the Implementation Manual and to how savings are entered into the BPA program reporting database) to ensure consistent and fair reporting across Option 1 and 2 utilities:

1. If BPA prefers the use of a static busbar factor in its reporting system, apply a consistent factor for Option 1 and Option 2 utilities (which would be similar to how BPA's Custom program handles this issue).
2. If the intent is to reflect actual transmission and distribution (T&D) losses for each particular project, then utilities should calculate busbar factors (e.g., either by project or overall, for their service territory or other subcategory) and apply it to projects on a customized basis.
3. A third option is to report site savings excluding busbar factors and treat busbar savings as a separate block calculation for each utility.

Key Finding: Indoor agriculture lighting does not fit with typical lighting use cases and requires different treatment than other lighting measures. Indoor agriculture lighting has a use case closer to industrial production than lighting for human eyesight, including using different baselines. This issue is relevant for other kinds of "process lighting" (i.e., light that is used for something other than enhancing human vision) that use lamps/fixtures that can be replaced with more efficient lamps/fixtures (e.g., heat lamps, tanning lamps, ultraviolet [UV] disinfection). These use cases also have different load shapes, hours of use, and interaction factors than other lighting measures. Standard practice for these types of measures also cannot apply lighting code requirements. For example, indoor agriculture lighting typically measures efficiency in micromole per joule (μmol/j).[10] The industry standard for most other

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[10] The industry standard for measuring grow light efficiency is micromole per joule. For every joule of electrical energy (joule = watt * second), a certain number of photon micromoles are produced.

lighting applications is measured in lumens of visible brightness per watt of electricity consumed (lm/W).

The evaluation team recommends BPA consider reclassifying process lighting using either of these two options:

1. Have special consideration for unique lamp types and baselines in calculator tools.
2. Treat the measures as custom projects.

There were two additional findings that were relatively less impactful, which are described below. The evaluation team developed considerations for BPA for addressing these issues, however, given the relatively minor impacts of the potential fixes, BPA would need to consider the appropriate resources and timing for addressing the issues.

Additional Finding: Gas heating penalties are not reported in Option 2 project documentation, and both Option 1 and Option 2 utilities are not publishing gas heating penalties in end use customer project proposals. As a result, end use customers may not be receiving information about potential negative gas savings associated with their projects.

BPA tracks this information in its calculator (for Option 1 utilities) as part of cost-effectiveness testing—but it is not published for the end use customer.[11]

The evaluation team offers a recommendation for consideration that BPA and utilities publish their estimated gas penalties and cost impacts up front along with the estimated electric savings in the project proposal to better inform the end user.

Additional Finding: The BPA lighting calculator introduces uncertainty in wattage calculations for some lighting types. Approximately 15 percent of the sampled projects had rounding errors when dropdown menu options for fixture wattage did not list the value needed for specified fixtures. In these cases, the wattage was rounded up or down to the nearest value available. The rounding error introduced was not calculated in all instances, but for projects where it was calculated, the error was between 1 percent and 8 percent of total project savings.

The evaluation team also offers a recommendation for consideration that BPA update its lighting calculator to offer more flexibility in wattage reporting. This may be a nontrivial update to the calculator, but it could be considered by BPA at a future point in time when the calculator is updated.

[11] The total evaluated gas penalties were $42,024, which is 0.61 percent of the total evaluated incremental project costs. Option 1 projects accounted for $21,140, and Option 2 gas penalties totaled $20,884. The total evaluated gas penalties in projects with gas heating were 2.66 percent of the incremental cost of the project. Gas penalties were found to be 2.25 percent of Option 1 and 3.28 percent of Option 2 project costs, respectively.

APPENDICES

APPENDIX A: DEFINITION OF KEY TERMS

This report relies on the following definitions of key terms.

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 BPA Custom Lighting Calculator). Option 2 utilities report high-level project information through a custom project completion report into the BPA system periodically (Option 2 Custom Project Calculator).

Domain

Domains are components of the portfolio that are designated for the purposes of evaluation planning and sample design for an individual evaluation. They are defined by Option (utilities are Option 1 or 2 for measurement and verification [M&V] purposes), Measure Type (e.g., Lighting, Non-Lighting), and Sector (Industrial and Commercial or the combination of commercial and agricultural for Option 1 utilities). Within a given domain, there may be subdomains (such as for this evaluation of the lighting portfolio, the subdomain is utility type).

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. For custom lighting projects, Option 1 utilities must estimate lighting project savings with BPA's Custom Lighting Calculator.

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. Option 2 utilities may use their own savings estimation methods, although they do have the option to use BPA's Custom Lighting Calculator.

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 contains 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 several possible lighting TAP descriptions to each physical measure or change implemented as part of a project.

Project Engineers

Project engineers and program staff 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 / Lighting Calculator

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 BPA Custom Lighting calculator is the tool of choice for Option 1 lighting projects; Option 2 utilities use similar calculators.

Reported Savings

Reported savings are the savings estimated by the project engineers and entered into 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 report completion 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 (see the term busbar savings defined later in this section), equal to 1.09056 times site savings for Option 2 utilities and 1.07465 for Option 1 utilities.

Evaluation Savings

Evaluation savings are the savings estimated by the evaluation team. These savings are based on the evaluation model and rely on the 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 the measure’s 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.

Existing Condition Baseline

For retrofit measures, the baseline would include the efficiency of existing equipment with remaining useful life.

Current Practice Baseline

BPA and the Regional Technical Forum have different definitions of current practice baseline for custom measures, based on BPA's M&V selection guide[12] and RTF guidelines,[13] 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 the evaluation found more savings than were reported.

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.

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[12] Bonneville Power Administration (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)

[13] 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

Reasons for Difference

The reasons for difference are what was changed that caused a modification to one or more key determinants and ultimately savings. Impacts were ranked as causing a primary or secondary change in savings to give a sense of their scale. The evaluation team 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 contradictory 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 are 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.

Busbar Factor

Busbar Factor is a term used to characterize transmission and distribution energy loss between a source of generation and the point of consumption. Busbar factors are applied to savings calculations to represent additional savings due to electricity not needing to be transmitted.

Process Lighting

Process lighting refers to any specialty bulb/lamp generated light that is used for something other than enhancing human vision. Possible uses could include but are not limited to heating (infrared), sterilization (ultraviolet), and grow lamps (mixed wavelengths).

APPENDIX B: SITE-SPECIFIC SAVING ESTIMATION

This appendix provides the site level results for the sample.

Detail ID	Stratum	Site Realization Rate	Site Impact on Overall Realization Rate
100_195	Option 2 Small	0.95	0.00%
105_115	Option 2 Very Large	1.06	0.14%
110_295	Option 2 Small	0.71	-0.06%
115_205	Option 1 Small	1.00	0.00%
120_285	Option 2 Medium	0.99	0.00%
125_310	Option 1 Very Large	1.05	0.24%
135_230	Option 2 Large	0.79	-0.29%
140_275	Option 1 Very Large	1.00	0.00%
150_140	Option 2 Medium	0.98	-0.01%
155_100	Option 1 Medium	1.00	0.00%
160_120	Option 1 Small	0.66	-0.08%
165_305	Option 2 Very Large	1.44	1.06%
170_235	Option 1 Very Large	1.00	0.00%
175_165	Option 2 Large	1.18	0.22%
180_225	Option 2 Medium	0.93	-0.04%
185_290	Option 1 Medium	1.00	0.00%
190_300	Option 1 Large	1.01	0.01%
195_280	Option 2 Certainty	1.02	0.18%
210_145	Option 1 Large	0.38	-1.66%
215_170	Option 1 Small	0.64	-0.12%
230_240	Option 2 Medium	1.36	0.26%
235_175	Option 2 Large	1.13	0.17%
240_320	Option 1 Medium	1.00	0.00%
245_245	Option 2 Large	0.66	-0.41%
250_125	Option 2 Very Large	1.02	0.08%
255_150	Option 1 Large	1.00	-0.01%
260_155	Option 2 Very Large	0.97	-0.17%
265_250	Option 2 Very Large	0.88	-0.84%

Detail ID	Stratum	Site Realization Rate	Site Impact on Overall Realization Rate
275_105	Option 2 Small	1.02	0.01%
280_260	Option 2 Small	0.91	-0.02%
285_315	Option 1 Very Large	1.00	0.00%
295_185	Option 2 Large	1.16	0.23%
300_180	Option 2 Certainty	1.01	0.10%
305_210	Option 1 Medium	0.99	-0.01%
310_325	Option 1 Large	1.00	0.00%
315_160	Option 1 Small	0.74	-0.02%
320_200	Option 1 Very Large	0.95	-0.15%
325_135	Option 1 Large	1.00	0.00%

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 evaluation sampling strategy targeted a 90/10 confidence level and precision for the custom and nonresidential lighting evaluation.

The nonresidential lighting evaluation focused on projects with claimed savings that were completed between Oct. 1, 2021, and Sept. 30, 2022. For Option 1 sites, the evaluation team extracted the contents of the lighting calculators for all projects in the sample frame, including identifiers for the site, project and all installed measures. For Option 2 sites, the sample is based on IS2.0 data, pulled in mid-January 2023. The sampling unit of this study is a project, defined as all Technology/Activity/Practice [TAP] measures at a distinct site (as defined by utility-assigned site ID and facility address) that were completed and invoiced at the same time.[14]

The sampling was conducted with a conventional optimum allocation stratified design based on utility type and reported kWh savings for the project.[15] Excluded strata (i.e., stratum 0) contain small projects; this is the group of measures that collectively account for less than 1 percent of the savings within each utility type. Projects that represent a significant portion

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[14] For uniformity of the evaluation approach, evaluation and project resource management, and cost control, sampling is based on project.
[15] It would be feasible to meet the relative precision target with a smaller sample if the sample were stratified by project size alone (i.e., not also by utility type). The benefit of utility type stratification is that a wider range of projects and utilities were included in the evaluation, which provided a better representation of the domain.

(more than 1,500,000 kWh) of total reported energy savings were assigned to a priority "certainty" stratum. These projects were considered necessary for the evaluation; thus, they are not subject to random selection. Moderately sized projects were then allocated to a probabilistic strata. Between the probabilistic strata and the certainty strata, the study sample included a mix of project sizes.

The sample contains all projects from 38 unique sites with 95 unique TAPs (i.e., distinct measures within sites), including 47 TAPs in Option 1 and 48 TAPs in Option 2. The selected projects include one new construction project and five projects with lighting controls.

The sample size of 38 sites (with 2 certainty sites) yielded a relative precision of +/- 4 percent at a 90 percent confidence level for the evaluation over the 12-month period (compared to our expectation of +/- 6 percent at 90 percent). At the utility-type level, the samples for Option 1 and Option 2 utilities should yield at least a relative precision of +/- 6 percent and 8 percent, respectively, at a 90 percent confidence level. The sample ultimately achieved a relative precision of +/- 6 percent and 3 percent for Option 1 and Option 2 utilities (at 90%), respectively.

DATA COLLECTION

The evaluation team developed procedures for data collection, adapting the procedures that were used for the evaluation of BPA's 2019-2021 custom industrial portfolio.

The evaluation team closely coordinated with BPA to notify utilities that had projects selected for the study sample and provided them with the necessary information consistent with the communication protocols developed for this study (see Appendix D). The team developed materials for and hosted a utility webinar to introduce utilities to the study, notify them of upcoming data collection activities (including end-user contact protocols), and clarify roles and expectations.

The study included collecting data from 38 sites. The evaluation team tracked and recorded dispositions for completed sites in an Excel-based project tracker. The tracker was updated and shared with BPA on a weekly basis and recorded the status of each site and relevant information about the site (e.g., utility, assigned engineer, number of contacts made, level of complexity). The tracker supported follow-up required by BPA to ensure response by end users.

The evaluation team's approach to data collection was to fully leverage the data collected by BPA and the utility program staff throughout the process of developing each project and to only collect additional data from end users if needed to achieve reliable estimates of savings for the sampled measures. The evaluation team collected the necessary data using the following approach:

- **File review.** The file review involved extracting all project information relevant to savings estimation. This included:
  - Measure descriptions that detail lighting systems, affected systems and determinants of savings.
  - Baseline and efficient condition inputs to the lighting calculator, 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 to verify incremental measure costs.
    - Data and documentation relating to space use types and HVAC systems.
    - Data used to determine nonelectric energy impacts.
- **Telephone/email discussion with program staff.** The utility program staff were another possible source of data. As needed, the evaluation team contacted them by telephone or email to obtain information needed for the evaluation that was not found in the project files. These discussions also informed practical strategies for minimally intrusive data collection from end users, and to clarify history and circumstances at the site.
- **Telephone/email discussion with end users.** In some cases, it was necessary to obtain information from the end user via telephone or email contacts. Discussions were held with operations staff and/or vendors to gather data baseline and post-installation conditions of affected buildings, systems and equipment. When necessary, these communications were used to plan site visits or remote data collection.
- **Site visits.** Based on the file review and discussions with program staff, in some cases the evaluation team determined that more information would be needed from inspection of affected systems and equipment, in person interviews with operation staff, review of electrical plans, inspection of control settings, review of manufacturers' specifications, and one-time measurements. For projects where site visits were not possible, the evaluation team developed a more robust data collection survey that was administered via telephone and email with the appropriate end user and vendor staff. This included greater reliance on file review findings, customer staff providing as-built plans and specifications, control system trend data and screen prints, or taking photos or videos and sending them to the evaluation team.
- **Affected system trend metering.** For lighting projects, if there were insufficient trend data to verify operating hours, the evaluation team collected additional metering data. In most cases, these data were derived from the time of use light loggers and on-premise electric metering. Interval premise data was collected from existing on-site instrumentation or from instruments installed by evaluators and on-site operations staff. Where on-site visits were not possible, the evaluation team 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.
- **Cost-effectiveness parameters.** To estimate measure cost-effectiveness, the evaluation team collected data for measure life, incremental costs, nonelectric energy use and nonenergy benefits, relying on data found in file reviews; this data was updated only if there was compelling evidence to the contrary found during evaluation. The evaluation team 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 were developed using BPA-provided or default RTF values.

MEASURE SAVINGS ANALYSIS

The evaluation team estimated savings for the sample of lighting measures as described below.

- **Review existing BPA lighting calculator**: The team based the evaluation model on the most recent version of the BPA lighting calculator. We started by reviewing BPA's lighting calculator to confirm that the model conforms to BPA's M&V protocol and assess savings calculations to determine reliability of savings estimates. The team also compared BPA's existing lighting calculator with the RTF lighting protocol to determine whether baseline and efficient conditions were treated in a similar fashion for various types of fixtures, lamps, and controls and to report on important differences. As necessary, the evaluation team developed an updated evaluation version of the lighting calculator for sampled sites to accurately represent the conditions observed during evaluation data collection.
- **Standardize lighting models**: While most Option 1 utilities use a version of BPA's lighting calculator, some Option 2 utilities may use their own lighting calculators. Where these calculators differ, the team made modifications to the inputs to align them with the updated evaluation version of BPA's most recent standard lighting calculator. This updated calculator was the standardized site evaluation model for the lighting impact evaluation.
- **Assess determinant reliability and collect supplemental data**: Next, installed lighting power, baseline lighting power, hours of use, and HVAC interaction factors were examined. The evaluation team then identified the corresponding values used in the evaluation model, assessed the data and/or documentation underlying those values, and determined whether those values were reliable. For unreliable critical determinants, the evaluation team assessed what level of data collection involving the end user would be necessary to obtain reliability for that determinant (telephone/email interview, site visit or metering) and gathered supplemental data as needed to support sufficiently reliable savings estimates.
- **Run the model and estimate evaluated savings**: After reliable determinant values were confirmed or obtained through data collection, the evaluation model was applied for each site and generated estimated site-level energy savings.
- **Treatment of interactive measures**: Savings achieved by one measure can affect the savings of another measure—for example, a lighting upgrade that coincides with an HVAC upgrade that affects the same spaces within a building. If the two improvements were completed at different times, this should not be an issue for this evaluation. However, an issue may arise if one or more projects were completed at the same time. Using information collected from the reporting system, project engineers and end users, the evaluation team determined whether this occurred for any of the measures in the sample. If it did, the team obtained documentation for all the interactive measures at the end user site to determine how the M&V models accounted for the interactions. The evaluation team also identified the measure order that was assumed in estimating each measure's savings and used the same measure order to account for measure interaction in estimating the evaluation savings.
- **Time-based value of savings and cost-effectiveness**: Load shapes were assigned to individual measures using ProCost by BPA TAP reporting code. Cost-effectiveness and peak savings were calculated based on the generic calculator. The default approach

was to use the ProCost model associated with the Seventh Council Power Plan that was in effect during the program period being studied.

STUDY AND SUBDOMAIN ANALYSIS

During the site-level analysis phase, the evaluation team discovered that the approach to splitting savings tracked at the site into measure level savings was not precise. As a result, the team made the decision to switch from using "measure" as the fundamental unit of analysis to using "site" as the fundamental unit of analysis. All measures at a site were analyzed, regardless of whether they were in the sample, so that results from all projects within a site could be added up and compared to the reported savings at the site level. Once analysis was completed for each site in the sample, the team compiled site-level results to estimate the electric savings and cost-effectiveness for the portfolio using a ratio analysis. The team estimated first-year savings for Option 1 and Option 2 subdomains, using the evaluation model results for the sample, weighted by stratum contribution to savings. Cost-effectiveness was analyzed using BPA's lighting calculator and with ProCost analysis with inputs from the Seventh Council Power Plan matching the sampled sites.

Before portfolio analysis, the evaluation team developed an analysis template workbook for BPA review. This workbook served as a template for conducting the subdomain and portfolio-level rollup calculations. The subdomain-level rollup analysis took the evaluation results for the sample of sites, extrapolated them to the stratum and subdomain levels, and ultimately calculated stratum and subdomain-level results.

The evaluation team also identified the most important drivers for sites that show deviations from a realization rate of 1.0. The team developed graphical results showing the realization rate and impact of each site on results and showed the drivers graphically in the final report.