Impact Evaluation of Business Lighting Program for FY 2016-2017

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Table of Contents

Executive Summary

The City of Roseville's municipal electric utility, Roseville Electric, engaged Cadmus to conduct an evaluation, measurement, and verification (EM&V) impact study of its Business Lighting Program—Exterior Lighting. The study assessed LED outdoor lighting projects completed through the program between July 1, 2016, and June 30, 2017. In accordance with the California Energy Commission's (CEC's) EM&V guidelines[1] for publicly owned utilities' (POUs') energy efficiency programs, Cadmus' evaluation determined the annual energy efficiency savings and reduction in energy demand achieved by the program.

Through the Business Lighting Program, customers apply for a commercial exterior lighting rebate by submitting a completed lighting schedule detailing the existing and proposed fixture type, quantity, and wattage for each fixture to be replaced. Additionally, for each new fixture type, customers must submit manufacturers' specification sheets, as well as proof from the DLC website that the fixtures are included on the qualifying product list.

This report describes how Cadmus conducted the impact evaluation for this program and presents findings and recommendations.

Methodology

To create the sample design for the Business Lighting Program, Cadmus divided the projects into two strata based on reported savings. We did this to achieve at least 90% confidence and 10% precision for the evaluated overall program savings. With Roseville Electric, Cadmus set the maximum sample size at 16 to be consistent with the study scope and allocated the projects between the two strata:

- We assigned the 10 projects with the highest reported kWh energy savings to Stratum 1. The sample included a census of these projects.
- We assigned the remaining 22 projects to Stratum 2. Cadmus randomly selected six of these 22 sites to make up the remaining sample.

Our team reviewed the project documentation for the 16 sites selected for evaluation. The information was available from the program's Salesforce tracking database. Cadmus used other documentation, such as project descriptions, to corroborate the program tracking data, and to confirm the pre-installed case fixture wattages (where available). This documentation was also reviewed to determine whether any special control types were installed or used in the pre-installed case.

Next, we conducted visits to the 16 sites to:

- Verify that installed fixture models match cutsheets
- Verify fixture quantity, using project drawings (where available)

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[1] California Energy Commission. January 2011. *EM&V Guidelines POU Energy Efficiency Programs.*

- Confirm special control types (where applicable)

Based on the results of the on-site observations, as well as review of the project documentation, Cadmus modified the savings analyses to reflect the observed fixture quantities. All projects were considered retrofits (early replacement); thus, we based evaluated savings on the previously installed fixture wattages. To estimate evaluated kWh energy savings, ΔkWh, Cadmus used the following engineering algorithm:

$$\Delta kWh = (fixture\ watt_{base} \times fixture\ qty_{base} \times HOU_{base} \\ - fixture\ watt_{ee} \times fixture\ qty_{ee} \times HOU_{ee}) \div 1,000$$

Where:

fixture watt$_{base, ee}$	= Fixture wattage, previously installed (fixture watt$_{base}$) or energy-efficient (fixture watt$_{ee}$)
fixture qty$_{base, ee}$	= Fixture quantity, previously installed (fixture qty$_{base}$) or energy-efficient (fixture qty$_{ee}$)
HOU$_{base, ee}$	= Annual hours of use, for previously installed lighting (HOU$_{base}$) or for energy-efficient lighting (HOU$_{ee}$).

Based on the California Municipal Utilities Technical Reference Manual (TRM) Coincident Demand Factor (CDF) for exterior lighting, site lighting projects generally have no peak demand savings because, for the most part, exterior lighting only operates at night, whereas the Roseville Electric peak demand period is from 4pm to 7pm. However, for lights that operate 24/7, then the CDF is 1.0.

We used the following calculation is used to estimate the evaluated peak demand savings:

$$\Delta kW = (fixture\ watt_{base} \times fixture\ qty_{base} - fixture\ watt_{ee} \times fixture\ qty_{ee}) \div 1,000 \times CDF$$

Where:

fixture watt$_{base, ee}$	= Fixture wattage, previously installed (fixture watt$_{base}$) or energy-efficient (fixture watt$_{ee}$)
fixture qty$_{base, ee}$	= Fixture quantity, previously installed (fixture qty$_{base}$) or energy-efficient (fixture qty$_{ee}$)
CDF	= Coincident Demand Factor, the fraction (0.0 to 1.0) of connected lighting load operating during the utility peak period.

In addition to engineering analysis, we conducted a brief survey with program participants on satisfaction and asked questions for estimating the net-to-gross (NTG) ratio. After assigning a freerider

rate to every survey respondent based on their responses, Cadmus calculated a savings-weighted average freeridership rate for the program using the following calculation:

$$Savings\ Weighted\ Freeridership\ Rate = \frac{\sum\{[Respondent\ Freeridership\ Rate] * [Evaluated\ Measure\ Gross\ Energy\ Savings]\}}{\sum[All\ Respondents'\ Evaluated\ Measure\ Gross\ Energy\ Savings]}$$

Cadmus utilized the freeridership rate results to calculate the NTG ratio, using the following equation:

$$NTG = 1 - Savings\ Weighted\ Freeridership\ Rate$$

We did not include spillover in this estimation, so it underestimates the NTG.

Findings

Our document review and project site visits revealed gaps or inconsistencies among different forms of documentation or between documentation and what we observed on-site for many of the 16 sites evaluated including:

- Differences in fixture quantities
- Differences in fixture model numbers
- Unknown locations of installed fixtures (drawings were unclear or not provided)

Individual project gross realization rates ranged from 47% to 105%, with seven of the 16 achieving at least 100%.

Table 1 presents the gross savings at both a stratum level and a program level.

Table 1. Gross Savings Summary

Stratum	Population Size	Sample Size*	Reported Sample Savings (kWh)	Evaluated Sample Savings (kwh)	Reported Total Savings (kWh)	Evaluated Total Savings (kWh)	Realization Rate
1	10	10	1,942,404	1,834,938	1,942,404	1,834,938	94.5%
2	22	6	134,775	129,863	428,982	413,348	96.4%
Total	**32**	**16**	**2,077,179**	**1,964,801**	**2,371,386**	**2,248,285**	**94.8%**

Cadmus utilized the freeridership results to calculate an energy savings NTG ratio of 90%. Table 2 shows the savings-weighted freeridership rate and the resulting NTG ratio.

Table 2. Self-Reported Freeridership Rate and NTG Ratio

Year	Survey Respondents	Freeridership Rate (%)	NTG Ratio
FY 2017	12	10%*	90%

*Weighted by gross evaluated energy savings

Table 3 summarizes the overall program evaluation findings. The program achieved net evaluated electricity savings of 2,248,285 kWh.

Table 3. Net Savings Summary

Reported Gross Savings (kWh)	Gross Savings Realization Rate	Evaluated Gross Savings (kWh)	NTG Ratio	Evaluated Net Savings (kWh)	Evaluated Net Standard Error	Net Savings Relative Precision at 90% Confidence Interval
2,371,386	95%	2,248,285	90%	2,023,457	133,563	12%

Participants expressed high satisfaction with their overall experience with the program; 10 out of 12 respondents reported they were "very satisfied" and the other two indicated they "didn't know." In addition, participants reported high satisfaction with the exterior LED lighting they installed, with 11 of 12 respondents (92%) being "very satisfied" and one respondent "somewhat satisfied."

Recommendations

To help Roseville to ensure the accuracy of savings for the commercial exterior lighting program, Cadmus presents the following recommendations:

1. To ensure that the savings estimates are accurate, it would be useful to improve documentation of the existing case lighting. It would be useful to require photos of the lighting to be replaced (including showing bulb wattages, where possible), or any other documentation to provide sufficient evidence of the pre-retrofit lighting power.
2. Cadmus recommends using a default CDF of 0 for exterior lighting, except in those cases in which lighting is on during the peak period.
3. We recommend that the program update the invoice documentation requirements. Cadmus recommends that only the final set of invoices be accepted. If possible, it may be useful to request a proof of payment to ensure that the products listed in the invoices are those which were purchased.
4. We recommend that Roseville Electric examine what might have accounted for the high freeridership among the three customers with the smallest savings and, based on the findings, consider ways that might be used to reduce the freeridership rate for similar projects in the future.

Introduction

The City of Roseville's municipal electric utility, Roseville Electric, engaged Cadmus to conduct an evaluation, measurement, and verification (EM&V) impact study of its Business Lighting Program—Exterior Lighting. The study assessed LED outdoor lighting projects completed through the program between July 1, 2016, and June 30, 2017. In accordance with the California Energy Commission's (CEC's) EM&V guidelines[2] for publicly owned utilities' (POUs') energy efficiency programs, Cadmus' evaluation determined the annual energy efficiency savings and reduction in energy demand achieved by the program.

Through the Business Lighting Program, Roseville Electric currently offers exterior lighting rebates for the installation of LED fixtures in place of existing fixtures over 70 watts. The LED replacements are required to reduce the fixture wattage by at least 50%, and all eligible fixtures must be listed on the DesignLights Consortium (DLC) qualifying product list.

Customers apply for a commercial exterior lighting rebate by submitting a completed lighting schedule detailing the existing and proposed fixture type, quantity, and wattage for each fixture to be replaced. Additionally, for each new fixture type, customers must submit manufacturers' specification sheets, as well as proof from the DLC website that the fixtures are included on the qualifying product list. For projects with more than 30 new fixtures, the customers must also provide a site map detailing the location of each new fixture.

Once the new fixtures are installed, customers must submit an installation confirmation form, which must include any changes to the project since the first set of documentation was submitted. After Roseville Electric reviews the provided documentation, customers must then submit a payment request form, with itemized invoices listing each fixture type and quantity.

This report describes how Cadmus conducted the impact evaluation for this program and presents findings and recommendations.

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[2] California Energy Commission. January 2011. *EM&V Guidelines POU Energy Efficiency Programs.*

Methodology

To conduct this evaluation, Cadmus followed the approach shown in Table 4.

Table 4. Evaluation Activities

Evaluation Activities	Overview of Approach
Sample Design	Develop stratified sample to achieve desired confidence/precision.
Initial Documentation Review	Compile project information for site visits.
Site-Visit Verification	Verify the following parameters: fixture models and quantities.
Engineering Analysis	Assess whether project documentation is consistent with on-site observations. Adjust savings estimates where appropriate.
Customer Interviews	Interview participating customers to understand net-to-gross factors.

Sample Design

To create the sample design for the Business Lighting Program, Cadmus divided the projects into two strata based on reported savings. We did this to achieve at least 90% confidence and 10% precision for the evaluated overall program savings. With Roseville Electric, Cadmus set the maximum sample size at 16 to be consistent with the study scope and allocated the projects between the two strata:

- We assigned the 10 projects with the highest reported kWh energy savings to Stratum 1. The sample included a census of these projects.
- We assigned the remaining 22 projects to Stratum 2. Cadmus randomly selected six of these 22 sites to make up the remaining sample.

Table 5 shows the distribution of all projects across the two strata and the projects selected in the sample. Overall, and for the majority of the evaluated sites, pole-mounted fixtures were the largest source of savings. Many projects also involved the installation of wall-mounted LEDs. The table also presents sample reference numbers, project incentives, and reported savings.

Table 5. Project Stratification

	Sample Reference Number	Incentive	Reported Savings (kWh)	% of Total Reported Savings
Stratum 1 (82% savings)	1	$61,653	474,251	20.0%
	2	$37,444	288,033	12.1%
	3	$24,632	270,633	11.4%
	4	$24,240	186,464	7.9%
	5	$19,701	151,548	6.4%
	6	$18,582	142,938	6.0%
	7	$17,230	132,537	5.6%
	8	$16,062	123,558	5.2%
	9	$11,849	91,143	3.8%
	10	$10,569	81,299	3.4%

	Sample Reference Number	Incentive	Reported Savings (kWh)	% of Total Reported Savings
	11	$10,378	79,827	3.4%
	-	$7,064	54,341	2.3%
	-	$6,838	52,603	2.2%
	-	$2,955	22,730	1.0%
	-	$2,921	22,468	0.9%
	-	$2,910	22,386	0.9%
	-	$2,876	22,120	0.9%
	-	$1,467	20,951	0.9%
	-	$1,834	17,425	0.7%
	12	$2,153	16,564	0.7%
Stratum 2	13	$1,088	15,547	0.7%
(18% savings)	-	$2,014	15,490	0.7%
	-	$1,921	14,781	0.6%
	-	$1,489	11,450	0.5%
	14	$720	10,291	0.4%
	15	$1,113	8,565	0.4%
	-	$876	6,740	0.3%
	-	$433	6,191	0.3%
	16	$279	3,981	0.2%
	-	$346	2,665	0.1%
	-	$139	1,066	0.0%
	-	$104	800	0.0%
Total		**$293,880**	**2,371,386**	**100.00%**

Table 6 shows a summary of each stratum's reported savings and projected precision. Stratum 1's energy savings make up about 82% of reported savings. Cadmus sampled and evaluated all 10 of these sites, so the sampling precision for these evaluated savings will be 0%. Stratum 2's energy savings make up the remaining 18% of reported energy savings. Based on the reported savings and an error ratio of 0.5, Cadmus expected the precision of the evaluated savings to be 35% at 90% confidence for Stratum 2.[3] After combining the stratum results, we estimated overall projected precision to be 6% at 90% confidence, exceeding the requirement for 90/10 confidence/precision for the program overall.

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[3] The error ratio represents the variation we expect to see in evaluated project savings with respect to the realization rate estimate, where the realization rate is the sum of evaluated savings divided by the sum of reported savings among sampled projects within each stratum. We selected the error ratio based on observed error ratios in evaluations of similar programs.

Table 6. Stratum Statistics

Stratum	Population Size	Sample Size*	Reported Savings (kWh)	Error Ratio	Confidence	Projected Precision**
1	10	10	1,942,404	0.5	90%	0%
2	22	6	428,982	0.5	90%	35%
Total	**32**	**16**	**2,371,386**	**0.5**	**90%**	**6%**

* Maximum sample size was set at n=16 sites total.

** Projected precision of 0% in Stratum 1 reflects zero sampling uncertainty resulting from a census of these projects.

Initial Documentation Review

Cadmus reviewed the project documentation for the 16 sites selected for evaluation. The information was available from the program's Salesforce tracking database. The purpose of this review was to collect the following information on each project in preparation for the on-site data collection:

- Completed Lighting Schedule – Used to determine the fixture wattages and quantities applied in the estimate of project savings.
- Cutsheets – For installed case fixtures, used to verify on-site that the correct models were installed (based on appearance). These were also used to confirm the installed case fixture wattages.
- Drawings – Used to determine the location of the installed fixtures. Also used to confirm fixture quantities.
- Invoices – Used to substantiate fixture quantities and models.

Cadmus used other documentation, such as project descriptions, to corroborate the information above, and to confirm the pre-installed case fixture wattages (where available). This documentation was also reviewed to determine whether any special control types were installed or used in the pre-installed case.

Site Visit Verification

Activities for the 16 site visits included the following:

- Verify that installed fixture models match cutsheets
- Verify fixture quantity, using project drawings (where available)
- Confirm special control types (where applicable)

In most cases, fixture model numbers were not observable on-site, so we compared our observations of the fixtures on-site against fixture cutsheets to confirm that the fixtures listed in the documentation

were installed. This comparison was based on overall appearance, manufacturer (if observable), and engine quantity.[4]

Engineering Analysis

Based on the results of the on-site observations, as well as review of the project documentation, Cadmus modified the savings analyses to reflect the observed fixture quantities.

In cases where the fixture models did not match the exact models listed in the project documentation, Cadmus requested additional documentation. If the requested documentation was not available, Cadmus estimated the installed case fixture wattages where possible. For example, if the fixture engine quantity did not match the quantity indicated in the documentation, Cadmus estimated the fixture wattage based on the observed engine quantity using information provided in the manufacturer's specification sheets.

Additionally, Cadmus reviewed the original analysis files for errors in the analysis methodologies.

Energy Savings Engineering Calculations

All projects were considered retrofits (early replacement). Thus, we based evaluated savings on the previously installed fixture wattages. To estimate evaluated kWh energy savings, ΔkWh, Cadmus used the following engineering algorithm:

$$\Delta kWh = (fixture\ watt_{base} \times fixture\ qty_{base} \times HOU_{base} \\ - fixture\ watt_{ee} \times fixture\ qty_{ee} \times HOU_{ee}) \div 1{,}000$$

Where:

fixture watt$_{base, ee}$	= Fixture wattage, previously installed (fixture watt$_{base}$) or energy-efficient (fixture watt$_{ee}$)
fixture qty$_{base, ee}$	= Fixture quantity, previously installed (fixture qty$_{base}$) or energy-efficient (fixture qty$_{ee}$)
HOU$_{base, ee}$	= Annual hours of use, for previously installed lighting (HOU$_{base}$) or for energy-efficient lighting (HOU$_{ee}$).

In general, the estimated HOU was the same for the previously installed and energy-efficient cases, and Cadmus assumed 4,100 hours of use annually, based on the California Municipal Utilities Technical Reference Manual (TRM), for HOU$_{base}$ and HOU $_{ee}$. For parking garage lighting (without special controls), Cadmus assumed 8,760 hours of use, based on TRM guidance. Additionally, in cases where we observed lights operating during the daytime (for example, under-canopy lighting), we used 8,760 HOU in the analysis.

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[4] "Engine" refers to an individual LED installed in a fixture.

Because all program fixtures are located outside conditioned space, there are no interactive cooling or heating effects.

Demand Savings Engineering Calculations

Based on the TRM's Coincident Demand Factor (CDF) for exterior lighting, site lighting projects generally have no peak demand savings. This is because, for the most part, exterior lighting only operates at night, whereas the Roseville Electric peak demand period is from 4pm to 7pm. Therefore, the exterior lighting savings are not coincident with the Roseville Electric peak period.

However, there are some exceptions to this rule. If there are lights that operate 24/7, then the CDF is 1.0. Additionally, the TRM lists a CDF of 1.0 for parking garage lighting, which the TRM assumes operates 8,760 hours annually.

We used the following calculation is used to estimate the evaluated peak demand savings:

$$\Delta kW = (fixture\ watt_{base} \times fixture\ qty_{base} - fixture\ watt_{ee} \times fixture\ qty_{ee}) \div 1,000 \times CDF$$

Where:

fixture watt$_{base,\ ee}$	= Fixture wattage, previously installed (fixture watt$_{base}$) or energy-efficient (fixture watt$_{ee}$)
fixture qty$_{base,\ ee}$	= Fixture quantity, previously installed (fixture qty$_{base}$) or energy-efficient (fixture qty$_{ee}$)
CDF	= Coincident Demand Factor, the fraction (0.0 to 1.0) of connected lighting load operating during the utility peak period.

Satisfaction and Net-To-Gross Estimation

We conducted a brief survey with program participants that included two questions on satisfaction and a series of questions for estimating the net-to-gross (NTG) ratio (see Appendix. Participant Survey Instrument). The satisfaction questions included one regarding the respondents' overall satisfaction with the program, and the second addressed their satisfaction with lighting installed under the program.

We typically estimate NTG based on two components—freeridership and spillover—to determine the net effects of the program after we estimate the gross savings. Freeriders are customers who would have purchased a measure without the program's influence. Spillover is the amount of additional savings associated with customers investing in additional, non-incentivized energy-efficient measures or activities because of their program participation.

Cadmus used self-report surveys to assess freeridership for this program, following the CEC EM&V Guidelines for POU Energy Efficiency Programs (version January 2011). Cadmus, however, did not

include spillover research questions in the participant surveys, as Roseville Electric determined during the evaluation planning process that quantifying spillover was not a priority for this evaluation. Because this evaluation includes only freeridership, net savings are potentially underestimated.

After assigning a freerider rate to every survey respondent based on their responses, Cadmus calculated a savings-weighted average freeridership rate for the program. Each respondent's freeridership rate was weighted by the evaluated project gross energy savings for the respondent's project, using the following calculation:

$$Savings\ Weighted\ Freeridership\ Rate$$
$$= \frac{\sum\{[Respondent\ Freeridership\ Rate] * [Evaluated\ Measure\ Gross\ Energy\ Savings]\}}{\sum[All\ Respondents'\ Evaluated\ Measure\ Gross\ Energy\ Savings]}$$

Net-to-Gross Ratio

Cadmus utilized the freeridership rate results to calculate the NTG ratio, using the following equation:

$$NTG = 1 - Savings\ Weighted\ Freeridership\ Rate$$

As noted earlier, spillover was not included in this estimation of the NTG ratio. Refer to Appendix. Net-To-Gross Methodology for a detailed description of the freeridership questions, methodology, and findings.

Impact Evaluation Findings

Documentation

Cadmus' review of the project documentation and our project site visits revealed gaps or inconsistencies among different forms of documentation or between documentation and what we observed on-site for many of the 16 sites evaluated (see Appendix. Summary of Documentation Limitations). These gaps or inconsistencies included the following:

- Differences in fixture quantities
- Differences in fixture model numbers
- Unknown locations of installed fixtures (drawings were unclear or not provided)

Site Visits Completed

Cadmus visited all 16 of the sites selected for evaluation. Table 7 provides the reported savings, evaluated savings, and realization rate for each site visited and a brief description of the main differences or information gaps that affected the calculation of the evaluated energy savings.

Table 7. Overview of Evaluated Gross Savings

	Ref. No.	Reported Savings (kWh)	Evaluated Savings (kWh)	Gross Savings Realization Rate (%)	Major Differences or Gaps
Stratum 1	1	474,251	499,637	105%	Canopy lighting assumed to be on 24/7 based on observations. 4,100 hours used in reported savings analysis.
	2	288,033	252,318	88%	Significantly fewer pole fixtures observed than indicated in documentation.
	3	270,633	245,811	91%	Original analysis assumes 25% savings for parking garage motion controls. TRM recommends 15% savings for this control type.
	4	186,464	161,261	86%	Many fixtures in reported savings analysis were not observed on-site or in project documentation.
	5	151,548	151,192	100%*	Ground flood fixtures did not match models in project documentation, but were the same wattages as listed. The installed fixtures were not listed on the DLC. Based on observation, one wall fixture was not installed.
	6	142,938	142,938	100%	No differences or gaps
	7	132,537	130,811	99%	Minor error in reported savings analysis.
	8	123,558	81,418	66%	Building mounted flood fixtures were not observed. Canopy fixtures did not match

	Ref. No.	Reported Savings (kWh)	Evaluated Savings (kWh)	Gross Savings Realization Rate (%)	Major Differences or Gaps
					the models indicated in the documentation.
	9	91,143	90,138	99%	Discrepancy in pole fixture engine quantity. Fixture wattage estimated based on observed engine quantity and manufacturer's specification sheet.
	10	81,299	79,413	98%	Pole fixture quantities varied slightly from what was indicated in project documentation.
Stratum 2	11	79,827	79,827	100%	No differences or gaps
	12	16,564	16,216	98%	Pole fixture documentation indicates slightly higher wattages than observed. Observed wall fixture matches higher wattage model listed in original analysis spreadsheet.
	13	15,547	15,547	100%	Evaluated pole fixtures included decorative textured lens, so LED retrofit could not be confirmed. Assumed to be installed as documented based on invoices and observed pole fixture quantities.
	14	10,291	10,291	100%	No differences or gaps
	15	8,565	4,014	47%	Observed wall and pole fixtures did not match the models in documentation. Fewer flood fixtures observed than indicated in documentation.
	16	3,981	3,969	100%	Ramp lighting fixture wattages were slightly higher than indicated in the provided cutsheets.

*Technically, some ground flood fixtures did not meet the program specifications because they were not listed in the DLC. Cadmus discussed this with Roseville Electric and we agreed to evaluate the savings even though they were not listed. If they were not included, the realization rate for the project would be 97%.

The most common cause of differences between the reported and evaluated project savings was variations in fixture quantities. In some cases, the quantity of fixtures indicated in the project drawings did not match what was observed on-site. In other cases, the project drawings reflected the on-site observations, but these quantities did not match the reported fixture quantities. In the case of Reference Number 2, Cadmus counted significantly fewer fixtures than indicated in the documentation, and project drawings were not available.

For Reference Numbers 4, 8, and 15 (the three projects with the lowest realization rates), findings from the on-site observations varied significantly from what was indicated in the project documentation. For all of these projects, there was at least one fixture type that could not be located at all. In this case, savings for these fixture types were not included in the total evaluated project savings. Additionally, for

Reference Numbers 4 and 15, several of the observed fixtures varied significantly from what was indicated in the documentation. Because information was not available for these fixtures (including wattages and product eligibility), Cadmus could not calculate savings for these fixture types. In these cases, Cadmus took the conservative approach and did not calculate any energy savings for these fixtures.

For Reference Number 8, we found that there were several pole-mounted LED fixtures at the site than those recorded for the project. Because no savings were claimed for them, we did not evaluate these fixtures.

Demand Savings

As previously described, most exterior lighting projects do not provide peak demand savings. The table below indicates the peak demand savings realization rate for the three sites that did produce savings during the peak period.

Table 8. Peak Demand Savings

Ref. No.	Reported Peak Savings (kW)	Evaluated Peak Savings (kW)	Gross Savings Realization Rate (%)
1	115.7	7.5	6%
3	30.8	24.4	79%
9	22.2	0.1	1%

Reference Number 1 includes savings for canopy lighting observed to operate 24/7. Reference Number 9 includes one wall-mounted fixture located on a mechanical building, which is also expected to operate 24/7.

Reference Number 3 includes parking garage lighting. We excluded peak savings for the lighting on the top level, as well as the fixtures mounted to the exterior of the parking structure, because they are expected to operate only at night.

The remainder of the evaluated exterior lighting projects have an evaluated peak demand savings value of zero.

Evaluated Gross Savings

Cadmus calculated the program gross savings based on reported savings, evaluated savings, and realization rates for Strata 1 and 2. We calculated Stratum 1 evaluated savings as the sum of evaluated savings for the census of evaluated projects and Stratum 2 evaluated savings as the product of the stratum total reported savings and the realization rate (ratio of sample evaluated to sample reported).

$$Total\ Evaluated\ Savings_{Stratum\ 1} = Total\ Evaluated\ Savings_{Stratum\ 1}$$

$$Total\ Evaluated\ Savings_{Stratum\ 2} = Realization\ Rate_{Stratum\ 2} \times Total\ Reported\ Savings_{Stratum\ 2}$$

$$Realization\ Rate_{Stratum\ 2} = \frac{Sample\ Evaluated\ Savings_{Stratum\ 2}}{Sample\ Reported\ Savings_{Stratum\ 2}}$$

We calculated program total gross evaluated savings as the sum of the evaluated savings for the two strata and the program gross realization rate as the ratio of the program total gross evaluated savings to program total reported savings.

$$Program\ Total\ Gross\ Evaluated\ Savings$$
$$= Total\ Evaluated\ Savings_{Stratum\ 1} + Total\ Evaluated\ Savings_{Stratum\ 2}$$

$$Realization\ Rate_{Program} = \frac{Program\ Total\ Gross\ Evaluated\ Savings}{Program\ Total\ Reported\ Savings}$$

Table 9 presents the gross savings at both the stratum level and program level.

Table 9. Gross Savings Summary

Stratum	Population Size	Sample Size*	Reported Sample Savings (kWh)	Evaluated Sample Savings (kwh)	Reported Total Savings (kWh)	Evaluated Total Savings (kWh)	Realization Rate
1	10	10	1,942,404	1,834,938	1,942,404	1,834,938	94.5%
2	22	6	134,775	129,863	428,982	413,348	96.4%
Total	**32**	**16**	**2,077,179**	**1,964,801**	**2,371,386**	**2,248,285**	**94.8%**

We calculated relative precision of the evaluated savings for each stratum and for the program using the sampling weights and finite population correction methodology specified in the Uniform Methods Project Sampling Protocol for stratified sample ratio estimators. Table 10 presents confidence, precision, and standard errors for the savings values at a stratum and program level. Cadmus estimated the program evaluated total savings and realization rate with 1% relative precision and 90% confidence.

Table 10. Confidence and Precision

Stratum	Population Size	Sample Size*	Confidence	Total Standard Error	Precision
1	10	10	90%	0	0%
2	22	6	90%	17,315	1%
Total	**32**	**16**	**90%**	**17,315**	**1%**

Freeridership

Cadmus used the self-report survey method to determine the program's freeridership level for FY 2017. We attempted to interview all participants, and were able to complete interviews with 12 key decision makers and obtained answers to the freeridership questions relating to one of their projects out of the

overall population of program projects. Cadmus estimated an average self-reported freeridership rate of 10%, weighted by gross evaluated savings, as shown in Table 11.

Table 11. Self-Reported Freeridership Rate

Year	Survey Respondents	Freeridership Rate (%)*
FY 2017	12	10%**

*Weighted by gross evaluated energy savings

** ±10% absolute precision at 90% confidence interval

The three respondents with the largest savings were the main drivers of the freeridership estimate. These three accounted for 69% of the total analysis sample gross evaluated savings and had an average weighted freeridership rate of 11%. However, the three respondents with the smallest savings had a weighted average freeridership rate of 95%. We reviewed these three projects and did not find any common characteristics across them, other than their relatively small scope. For detailed findings refer to Table 15 in the Appendix. Net-To-Gross Methodology.

Cadmus utilized the freeridership results to calculate an energy savings NTG ratio of 90%. Table 12 shows the savings-weighted freeridership rate and the resulting NTG ratio.

Table 12. Self-Reported Freeridership Rate and NTG Ratio

Year	Survey Respondents	Freeridership Rate (%)	NTG Ratio
FY 2017	12	10%*	90%

*Weighted by gross evaluated energy savings

Because this evaluation only includes freeridership and not participant spillover, the net savings in this report are likely to be underestimated.

Evaluated Net Savings[5]

Table 13 lists the program's reported gross energy savings, gross savings realization rate, evaluated gross savings, NTG ratio, and evaluated net savings along with the relative precision of the evaluated net savings at the 90% confidence interval. The program achieved net evaluated electricity savings of 2,248,285 kWh.

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[5] References to net savings in this report refer only to the application of freeridership to gross evaluated savings and do not include a spillover component.

Table 13. Net Savings Summary

Reported Gross Savings (kWh)	Gross Savings Realization Rate	Evaluated Gross Savings (kWh)	NTG Ratio	Evaluated Net Savings (kWh)	Evaluated Net Standard Error	Net Savings Relative Precision at 90% Confidence Interval
2,371,386	95%	2,248,285	90%	2,023,457	133,563	12%

The program reported demand savings for all projects, but, as noted earlier, outdoor lighting projects typically do not provide savings during the peak demand period. The reported demand savings for the sampled projects totaled 488.6 kW. However, only three of the evaluated sites provided savings during the peak period. The total reported demand savings for these three sites was 168.7 kW, while their evaluated demand savings was 32.0 kW.

Satisfaction

Participants interviewed expressed high satisfaction with their overall experience with the program, with 10 out of 12 respondents (83%) reporting they were "very satisfied" and the other two respondents indicating they "didn't know." In addition, participants reported high satisfaction with the exterior LED lighting they installed through the program, with 11 of 12 respondents (92%) being "very satisfied" and one respondent "somewhat satisfied" with the equipment.

Conclusions and Recommendations

To help Roseville to ensure the accuracy of savings for the commercial exterior lighting program, Cadmus presents the following conclusions and recommendations:

1. In most cases, there was no, or very limited, documentation of the pre-retrofit lighting fixtures to determine the existing baseline, upon which the savings are based.
   Recommendation: To ensure that the savings estimates are accurate, it would be useful to improve documentation of the existing case lighting. It would be useful to require photos of the lighting to be replaced (including showing bulb wattages, where possible), or any other documentation to provide sufficient evidence of the pre-retrofit lighting power.
2. A Coincident Demand Factor of 1 was used to calculated reported savings. However, in most cases the exterior lighting was on only during non-peak dark hours for which the CDF would be 0.
   Recommendation: Cadmus recommends using a default CDF of 0 for exterior lighting, except in those cases in which lighting is on during the peak period.
3. For more than half of the sites, we found that the products or quantities listed in the invoices did not match data based on the on-site observations.
   Recommendation: We recommend that the program update the invoice documentation requirements. Cadmus recommends that only the final set of invoices be accepted. If possible, it may be useful to request a proof of payment to ensure that the products listed in the invoices are those which were purchased.
4. Although the overall freeridership rate was relatively low, the freeridership incidence was very high for the three smallest energy savings projects. This is counter to usual findings about freeridership.
   Recommendation: We recommend that Roseville Electric examine what might have accounted for the high freeridership among these customers and, based on the findings, consider ways that might be used to reduce the freeridership rate for similar projects in the future.

Appendix. Participant Survey Instrument

Roseville Electric Business Program
(2017) Participant Survey

Researchable Questions		
Key Research Topics	**Areas of Investigation**	**Related Questions**
Screening	Project initiation process	B1-B2
Satisfaction	Assess satisfaction with program and measures installed	C1-C3
Freeridership	Assess net savings	D1-D8

General Instructions
- Interviewer instructions are in green **[LIKE THIS]** (the style is "Survey: Interviewer Instructions").
- CATI programming instructions are in red **[LIKE THIS]** (the style is "Survey: Programming").
- Items that should not be read by the interviewer are in parentheses like this ( ).

Variables to be pulled into Survey
- **[CONTACT NAME] CONTACT NAME**
- **[COMPANY NAME] CUSTOMER NAME**
- **[SITE ADDRESS] SITE ADDRESS**
- **[PROGRAM YEAR] PROGRAM YEAR**
- **[MEASURE_1] UPDATED MEASURE NAME**

A. *Introduction*

Hello, I'm **[INSERT NAME]** calling on behalf of Roseville Electric**.** May I speak with **[INSERT CONTACT NAME]**? OR **[IF NO NAME OR NAMED RESPONDENT NO LONGER WORKS FOR COMPANY]** May I speak with the FACILITY MANAGER, ENERGY MANAGER OR SOMEONE WHO IS FAMILIAR WITH THEIR PARTICIPATION IN THE ROSEVILLE ELECTRIC COMMERCIAL LIGHTING PROGRAM INCENTIVE FOR. **[INSERT COMPANY NAME]**? **[IF THAT PERSON IS NOT AT THIS PHONE NUMBER, ASK FOR THEIR NAME AND PHONE NUMBER AND START AGAIN]**

1. **Respondent not available**: **ASK IF YOU CAN LEAVE A MESSAGE ON THEIR VM**
98. (Don't know) **[ASK TO SPEAK WITH SOMEONE WHO KNOWS AND BEGIN AGAIN]**

A1. Hello, I'm **[INSERT NAME]** calling on behalf of Roseville Electric**.** Are you the person who handles energy decisions for **[INSERT COMPANY NAME]**? **[IF THAT PERSON IS NOT AT THIS PHONE NUMBER, ASK FOR THEIR NAME AND PHONE NUMBER AND START AGAIN]**

    1.   (Yes)

    2.   (No or not a convenient time) **[ASK IF RESPONDENT WOULD LIKE TO ARRANGE A MORE CONVENIENT TIME OR IF YOU CAN LEAVE A MESSAGE FOR A MORE APPROPRIATE PERSON]**

    98.   (Don't know) **[ASK TO SPEAK WITH SOMEONE WHO KNOWS AND BEGIN AGAIN]**

    99.   (Refused) **[THANK AND TERMINATE]**

A2.   Are you the person responsible for making energy-efficiency decisions for your company at the **[SITE ADDRESS]** location?

    1.   (Yes)

    2.   (No, person is able to come to phone) **[ASK FOR PERSON WHO IS AND START AGAIN]**

    3.   (No, person is not able to come to phone) **[GET NAME AND PHONE NUMBER, SCHEDULE CALL BACK]**

    98.   (Don't know) **[ASK TO SPEAK WITH SOMEONE WHO KNOWS AND BEGIN AGAIN]**

    99.   (Refused) **[THANK AND TERMINATE]**

A3.   We are conducting an important survey today about Roseville Electric's Business Lighting program. Roseville Electric is actively seeking your opinions to help improve their business efficiency programs and to better understand how to assist customers in saving money and energy. This call may be monitored or recorded for quality assurances purposes. Anything you share with us today will be confidential and not attributed to any one individual or business.

    1.   **[IF RESPONDENT ASKS HOW LONG, SAY "APPROXIMATELY 20 MINUTES."]**

    2.   **[IF NEEDED, STATE "THIS SURVEY IS FOR RESEARCH PURPOSES ONLY AND THIS IS NOT A MARKETING CALL. THIS IS THE PRIMARY WAY FOR CUSTOMERS TO PROVIDE INPUT INTO THE INCENTIVE PROGRAMS ROSEVILLE ELECTRIC OFFERS. YOUR PERSPECTIVES HELP ROSEVILLE ELECTRIC DESIGN ENERGY-EFFICIENCY PROGRAMS TO HELP THEIR CUSTOMERS SAVE MONEY AND ENERGY."]**

B.   Screeners

B1.   Our records show that you installed energy efficient equipment including Exterior LED Lighting at **[INSERT SITE ADDRESS]** in **[INSERT PROGRAM YEAR]**? Is this correct?

    1.   (Yes)

    2.   (No, wrong year) [RECORD CORRECT YEAR IF POSSIBLE]

    3.   (No, wrong address) [RECORD CORRECT ADDRESS]

    4.   (No, wrong measure) [CORRECT BELOW]

        (MEASURE1 IS INCORRECT [Correct: _____]) [CALL THIS VARIABLE Exterior LED Lighting]

5. (No, I did not participate) [THANK AND TERMINATE]
98. (Don't know) [ask to speak with someone who would know and start again **AT A2. IF NO ONE, THEN** THANK AND TERMINATE**]**
99. (Refused) [THANK AND TERMINATE]

B2. To ensure our records are correct, can you confirm that you received an incentive for this upgrade?
1. (Yes)
2. (No) [THANK AND TERMINATE]
98. (Don't know) **[ASK TO SPEAK WITH SOMEONE WHO WOULD KNOW AND START AGAIN AT A2. IF NO ONE, THEN** THANK AND TERMINATE**]**
99. (Refused) [THANK AND TERMINATE]

C. *Satisfaction*

Thank you. I'd like to ask you about your project.

C1. Thinking about your overall experience with the Roseville Electric Business Lighting program, how would you rate your satisfaction? Would you say you are … **[READ LIST]**
1. Very satisfied
2. Somewhat satisfied
3. Not too satisfied
4. Not satisfied at all
98. (Don't know)
99. (Refused)

[IF C1=3, OR 4]

C2. Why do you say you were **[INSERT ANSWER FROM C1]** with the Roseville Electric Business Lighting program?
1. **[RECORD VERBATIM: _____]**
98. (Don't know)
99. (Refused)

C3.   How satisfied are you with the Exterior LED Lighting you installed through the Roseville Electric Business Lighting program?   Would you say…? **[READ LIST]**
1.   Very satisfied
2.   Somewhat satisfied
3.   Not too satisfied
4.   Not satisfied at all
98.   (Don't know)
99.   (Refused)

D.   Freeridership

Thank you. Next I'd like to ask you about your decision to purchase the Exterior LED Lighting.

D1.   Without the program, meaning without either the technical assistance or the financial incentive, would you have still completed the exact same Exterior LED Lighting project?
1.   (Yes)
2.   (No) [SKIP TO D3]
98.   (Don't know) [SKIP TO D3]
99.   (Refused) [SKIP TO D3]

D2.   Without the program, meaning without either the technical assistance or the financial incentive, would you have still installed the Exterior LED Lighting at the same time?
1.   (Yes) [SKIP TO D5]
2.   (No) [SKIP TO D4]
98.   (Don't know) [SKIP TO D4]
99.   (Refused) [SKIP TO D4]

D3.   Without the program, would you have installed any Exterior LED Lighting equipment?
1.   (Yes)
2.   (No) [SKIP TO D8]
98.   (Don't know) [SKIP TO D8]
99.   (Refused) [SKIP TO D8]

D4.   Without the program, in terms of timing, when would you have installed the Exterior LED Lighting?
1.   Within one year from original participation date
2.   In one to two years from original participation date
3.   More than two years from original participation date [SKIP TO D8]
98.   (Don't know)
99.   (Refused)

D5.   Relative to the energy efficiency of Exterior LED Lighting installed through the program, how would you characterize the efficiency of equipment you would have installed without the program?
1.   Just as efficient as installed with the program
2.   Lower than installed through the program, but better than standard efficiency
3.   Standard efficiency
98.   (Don't know)
99.   (Refused)

D6.   Would you have installed more, less, or the same amount of Exterior LED Lighting without the program?
1.   (More)
        D6a.   **COMPARED TO THE INSTALLED AMOUNT, HOW MUCH MORE?**
                [RECORD PERCENTAGE: _____]
2.   (Less)
        D6b.   **COMPARED TO THE INSTALLED AMOUNT, HOW MUCH LESS?**
                [RECORD PERCENTAGE: _____]
3.   (Same)
98.   (Don't know)
99.   (Refused)

D7.   Prior to hearing about the program, was the cost of Exterior LED Lighting included in your organization's most recent capital budget?
1.   (Yes)
2.   (No)
98.   (Don't know)
99.   (Refused)

D8.   In your own words, can you please describe what impact the program had on your decision to complete these energy efficiency improvements for Exterior LED Lighting?

This completes the survey. Your responses are very important to Roseville Electric. We appreciate your participation and thank you for your time. Have a good day.

Appendix. Net-To-Gross Methodology

Overview

We estimated the NTG ratio to determine the net evaluated savings from the gross evaluated savings. Two components—freeridership and spillover—constitute NTG. True freeriders are customers who would have purchased a measure without a program's influence. Spillover is the amount of additional savings obtained by customers investing in additional, non-incentivized energy-efficient measures or activities because of their program participation.

Cadmus used self-report surveys to assess freeridership for this program, following the CEC EM&V Guidelines for POU Energy Efficiency Programs. Cadmus designed the freeridership questions to elicit the impact of the program on the respondent's decision to purchase the high-efficiency equipment. Cadmus, however, did not include spillover research questions in the participant surveys as Roseville Electric determined during the evaluation planning process that quantifying spillover was not a priority for this evaluation. Because this evaluation includes only freeridership, net savings are potentially underestimated.

Direct questions such as "Would you have installed measure X without the program incentive?" tend to result in exaggerated "yes" responses. Participants often provide answers they believe surveyors seek, so a question becomes the equivalent of asking: "Would you have done the right thing on your own?" Effectively avoiding such bias involves asking a question in several different ways, then checking for consistent responses.

Basing freeridership estimates on a series of questions, rather than a single question, can help evaluators recognize and minimize response biases. Not all questions are weighted equally. For example, if the participant would have installed the measures, but fewer without the program, the participant's initial freeridership rate of 100% is reduced to 50%. But if a respondent would have installed the measure(s) to standard or baseline level of efficiency without the program, that respondent is automatically a 0% freerider. If the participant would not have installed the measure(s) within two years without the program, that participant is automatically a 0% freerider.

Other questions included in the freeridership analysis are assigned partial weights for responses that are indicative of a non-freerider. This method prevents labeling a respondent a 100% freerider based on a single answer to a single question; a customer must provide consistent responses across the relevant questions in the freeridership analysis.

The survey questions addressed five core freeridership dimensions for this program:

- Would participants have installed measures without the program?
- In the program's absence, would participants have installed the measures at a different time?
- Would participants have installed the measures at the same efficiency levels without the program incentive?

- Would participants have installed the same quantity of measures without the program?

- Was the purchase of the measures in the organization's most recent capital budget?

The survey design included several skip patterns, allowing interviewers to confirm answers previously provided by respondents by asking the same question in a different format. Specific freeridership questions used for the program are presented in the Appendix. Participant Survey Instrument.

Methodology Details

Cadmus developed a rate for all participants, using their responses to the freeridership questions, and developed a matrix for assigning a single rate to each participant, using his or her objective responses to targeted survey questions.[6] Cadmus applied the freeridership rate to question-response patterns in the matrix and calculated confidence and precision estimates for the distribution of these rates.

This matrix approach provides these key benefits:

- Derivation of a partial freeridership rate, based on the likelihood of a respondent taking similar actions in the incentive's absence

- Use of a rules-based approach for consistency among multiple respondents

- Ability to change weightings in a "what if" exercise, testing the response set's stability

Experience has shown that program participants do not fall neatly into freerider and non-freerider categories. For example, Cadmus assigned partial freeridership rates to participants who had plans to install a measure; although the program exerted some influence over their decisions, these respondents were also influenced by other market factors outside of the program. Further, Cadmus could assign partial credit to "don't know" and "refused" responses, rather than removing respondents entirely from the analysis.

Cadmus assessed freeridership at three levels:

- Each participant survey response was converted into a freeridership matrix terminology.
  - "Yes" (indicative of freeridership)
  - "No" (indicative of non-freeridership)
  - "Partial" (indicative of partial freeridership)

- Each participant's combination of responses received a freeridership rate from the matrix.

- All participants were aggregated into an average freeridership rate for the entire program by weighting individual freeridership rates by the gross evaluated program energy savings achieved by that participant's project.

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[6] As specified in Khawaja, M. S. *The National Action Plan for Energy Efficiency Handbook on DSM Evaluation.* 2007 edition, page 5-1.

Convert Responses to Matrix Terminology

Table 14 lists the freeridership questions and illustrates how initial survey responses are translated into matrix terminology: "yes," "no," or "partially" indicative of freeridership (matrix terminology is shown in parentheses in the table). All participants start out as full (100%) freeriders and through their answers to the questions prove they are not freeriders. The value in brackets (following the response option and scoring matrix translation) is the decrement that is applied to a respondent's freeridership rate for a response option.

▪ **Table 14. Raw Survey Response Translation to Freeridership Scoring Matrix Terminology**

D1. Without the program, meaning without either the technical assistance or the financial incentive, would you have still completed the exact same Exterior LED Lighting project?	D2. Without the program, meaning without either the technical assistance or the financial incentive, would you have still installed the Exterior LED Lighting at the same time?	D3. Without the program, would you have installed any Exterior LED Lighting equipment?	D4. Without the program, in terms of timing, when would you have installed the Exterior LED Lighting?	D5. Relative to the energy efficiency of Exterior LED Lighting installed through the program, how would you characterize the efficiency of equipment you would have installed without the program?	D6. Would you have installed more, less, or the same amount of Exterior LED Lighting without the program?	D7. Prior to hearing about the program, was the cost of Exterior LED Lighting included in your organization's most recent capital budget?
Yes (Yes) [-0%]	Yes (Yes) [-0%]	Yes (Yes) [-0%]	Within one year from original participation date (Yes) [-0%]	Just as efficient as installed with the program (Yes) [-0%]	More (Yes) [-0%]	Yes (Yes) [-0%]
No (No) [-0%]	No (No) [-0%]	No (No) [-100%]	In one to two years from original participation date (Partial2) [-50%]	Lower than installed through the program, but better than standard efficiency (Partial2) [-50%]	Less (No) [-50%]	No (No) [-25%]
Don't Know (Partial) [-0%]	Don't Know (Partial) [-0%]	Don't Know (Partial) [-100%]*	More than two years from original participation date (No) [-100%]	Standard efficiency (No) [-100%]	Same (No) [-0%]	Don't Know (Partial) [-0%]
			Don't Know (Partial) [-25%]	Don't Know (Partial) [-25%]	Don't Know (Partial) [-25%]	

Table 15illustrates the unique response combinations from participants answering the freeridership questions (actual responses mapped to "yes," "no," or "partial," as indicative of freeridership), the freeridership rate assigned to each combination, and the number of responses. Cadmus calculated a freeridership rate for the program based on the distribution of rates within the matrix.

Table 15. Frequency of Freeridership Scoring Combinations (n=12)

D1. Without the program, meaning without either the technical assistance or the financial incentive, would you have still completed the exact same Exterior LED Lighting project?	D2. Without the program, meaning without either the technical assistance or the financial incentive, would you have still installed the Exterior LED Lighting at the same time?	D3. Without the program, would you have installed any Exterior LED Lighting equipment?	D4. Without the program, in terms of timing, when would you have installed the Exterior LED Lighting?	D5. Relative to the energy efficiency of Exterior LED Lighting installed through the program, how would you characterize the efficiency of equipment you would have installed without the program?	D6. Would you have installed more, less, or the same amount of Exterior LED Lighting without the program?	D7. Prior to hearing about the program, was the cost of Exterior LED Lighting included in your organization's most recent capital budget?	Freerider Rate	Frequency	Evaluated Gross Savings (kWh)
Yes	Yes	x	x	Yes	Yes	Yes	100%	1	3,969
Yes	Yes	x	x	Yes	Yes	No	75%	1	4,014
Yes	Yes	x	x	Partial	Yes	No	50%	1	142,938
Partial	x	Yes	Yes	Yes	Yes	Yes	100%	1	10,291
Partial	x	Yes	Partial	Yes	Yes	No	25%	1	16,216
Partial	x	No	x	x	x	x	0%	3	476,416
No	x	Yes	No	x	x	x	0%	1	130,811
No	x	Partial*	x	x	x	x	0%*	1	15,547
No	x	No	x	x	x	x	0%	2	169,965

* Respondent answered, "Don't know" to D3 and was not asked any additional FR questions. Cadmus assigned a 0% freeridership rate based on a verbatim response of "Would not have done the project without the program."

Participant Freeridership Scoring

Following conversion of survey responses into matrix terminology, Cadmus inserted the responses into a freeridership matrix, allowing each participant's combined responses to be assigned a freeridership rate. All combinations of survey question responses were considered in creating the matrix, with each combination receiving a freeridership rate of 0% to 100%.

Cadmus' process for determining a freeridership rate is as follows:

- Customers were categorized as 0% freeriders in these instances:
  - They had no plans to install the measure in the absence of the program's incentives and would not have installed the measure within two years.
  - In the absence of program incentives, the customer would not have purchased or installed equipment to the same level of efficiency.
- Customers were categorized as 100% freeriders if they would have installed the same amount of the measure, to the same level of efficiency, and at the same time in the absence of the program.
- Customers received a partial freeridership rate (ranging from 25% to 75%) if they had plans to install the measure and their decision was influenced by the program. (This influence may have been installation timing, the number of measures installed, or the efficiency levels of measures installed.) For customers who were highly likely to install a measure and for whom the program had less influence over their decision, a higher freeridership rate was applied.

Savings-Weighted Freeridership

After assigning a freeridership rate to every survey respondent, Cadmus calculated a savings-weighted average freeridership rate for the program. The respondents' freeridership rates were individually weighted by evaluated energy savings of equipment installed, using the following calculation:

$$Savings\ Weighted\ Freeridership\ Rate \\ = \frac{\sum\{[Respondent\ Freeridership\ Rate] * [Evaluated\ Measure\ Energy\ Savings]\}}{\sum[All\ Respondents'\ Evaluated\ Measure\ Energy\ Savings]}$$

Net-to-Gross Ratio

Cadmus utilized the freeridership results to calculate the NTG ratio, using the following calculation:

$$NTG\ Ratio = 1 - Savings\ Weighted\ Freeridership\ Rate$$

As noted earlier, we did not include spillover in this estimation of the NTG ratio.

Appendix. Summary of Documentation Limitations

The table below provides a summary of the documentation provided for each of the evaluated projects.

Table 16. Adequacy of Provided Documentation

Ref. No.	Invoices	Cutsheets	Analysis	Drawings
1	Yes	Yes	Yes	Yes
2	Partial	Yes	Yes	No
3	Partial	Partial	Yes	Yes
4	Partial	Yes	Yes	Yes
5	Yes	Yes	Yes	Yes
6	Yes	Partial	Yes	Yes
7	Yes	Partial	Yes	Yes
8	Yes	Yes	Yes	Yes
9	Yes	Yes	Yes	Partial
10	Yes	Yes	Yes	Yes
11	Yes	Yes	Yes	Partial
12	Yes	Yes	Yes	No
13	Yes	Yes	Yes	Yes
14	Yes	Yes	Yes	No
15	Partial	Partial	Yes	Yes
16	Yes	Partial	Yes	Partial