CADMUS

2018-2019 New Buildings Program Impact Evaluation

October 2021

Prepared for:

Energy Trust of Oregon

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List of Acronyms

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
Btu	British thermal unit
CEE	Consortium for Energy Efficiency
CFL	Compact fluorescent lamp
CV	Coefficient of variation
EEM	Energy efficiency measure
EERE	Energy efficiency and renewable energy
EMS	Emergency management system
EUI	Energy use intensity
HOU	Hours of use
HVAC	Heating, ventilation, and air conditioning
IPMVP	International Performance Measurement and Verification Protocol
kBtu	1,000 British thermal units
kWh	Kilowatt-hour
LED	Light-emitting diode
LEED	Leadership in Energy and Environmental Design
M&V	Measurement and verification
MAD	Measure approval document
MBH	Thousand British thermal units per hour
MMBtu	One million British thermal units
PGE	Portland General Electric
PMC	Program Management Contractor
PTHP	Packaged terminal heat pump
RTF	Regional Technical Forum
RTU	Roof-top unit
UPS	Uninterruptible power supply

Energy Trust of Oregon

MEMO

Date: October 12, 2021
To: Board of Directors
From: Dan Rubado, Sr. Project Manager, Planning and Evaluation
Oliver Kesting, Sector Lead, Commercial
Fred Gordon, Director, Planning and Evaluation
Subject: Staff Response to 2018-2019 New Buildings Impact Evaluation

This impact evaluation of Energy Trust's 2018-2019 New Buildings program, conducted by Cadmus, shows the program is generally achieving the level of energy savings that it claims. The evaluation shows high electricity savings realization rates in both 2018 and 2019 (98% and 97%, respectively), and a high gas realization rate in 2019 (102%). The somewhat lower gas realization rate seen in 2018 (81%) resulted from a single large project weighing down the overall program realization rate. This project represented nearly one-quarter of the *ex-ante* gas savings for the program in 2018 and had a very low realization rate due to its complex systems not operating as expected and using a large amount of gas. If this project were removed from the results, the gas realization rate for 2018 would be in the high 90s. Overall, the evaluation demonstrates the program continues to accurately quantify and claim savings for most projects and conducts a reasonable level of engineering review and quality control.

Cadmus recommended a number of potential improvements for the program, many of which were focused on improving project documentation to simplify the evaluation process. The other recommendations focused on improving savings estimates in specific circumstances and developing more robust methods for quantifying electricity peak demand savings. Some of these recommendations have already been incorporated into the program. Other recommendations are no longer relevant – for instance, adjusting the assumed hours of use for exterior lighting measures – since these measures have been discontinued. New Buildings program staff will make the following additional process improvements to incorporate the evaluation recommendations:

- Improve documentation for whole building energy simulation projects, making them more consistent and ensuring the final modeling files are included in the completed project files provided to Energy Trust. Program staff will describe the basis for the final savings claim and include properly labeled supporting documentation, including any post-processing calculations performed on the model outputs. In addition, the program will ensure all available as-built construction documents are in the completed project files, including mechanical drawings and equipment schedules.
- Record all utility meter serial numbers during project verification site visits. Program staff will include this information in the completed project files to aid in obtaining utility billing data for the correct meters at a later date.
- When reasonable, apply the same savings analysis methodology to estimate savings for similar measures across projects, particularly condensing boiler and water heating measures. However, different types of projects or different scenarios may warrant different savings analysis methods, especially with condensing boilers.

- Work with Energy Trust Planning and Evaluation staff to determine how to encourage and incentivize program participants with EMS or BAS systems to enable data trending for key parameters. These are primarily large projects in the whole building track where trend data are needed to accurately conduct model calibration in future evaluations. Energy Trust also has a separate evaluation process for the largest projects that addresses the data trending issue (for some projects) by engaging with customers early to ensure all the required data are available.
- Work with Energy Trust Planning and Evaluation staff to determine if negative therm and kWh interactions should be reported by the program, and if so, develop guidance to consistently quantify and report them.

In addition, Energy Trust Planning and Evaluation staff will review Cadmus' recommendations for developing more robust peak demand savings estimates and applying load profiles that are more consistent with the measure and building type combinations they are applied to. These recommendations apply to more than the New Buildings program and would need to be implemented across the organization and across programs. To better quantify peak demand savings, Energy Trust would likely need to develop deemed peak summer and winter kW estimates for all prescriptive measures as part of its measure development process. For custom and whole building projects, Energy Trust would need to develop guidelines for programs on how to select load profiles and consistently compute kW demand savings. These kW values would then need to be claimed in Energy Trust's system of record, along with kWh savings, for all recognized measures. These changes would require a number of process and system updates, as well as detailed guidelines, and would need to be applied across several different programs. Energy Trust will weigh the need for more accurate peak demand savings estimates with the relative complexity of implementing these changes.

Executive Summary

Energy Trust of Oregon (Energy Trust) retained Cadmus to complete an impact evaluation of the 2018 and 2019 New Buildings program, a comprehensive effort to help owners of newly constructed or substantially renovated commercial and industrial buildings achieve energy savings through these different tracks:

- **Data Center:** Improves data center design, construction, and operation.
- **Market Solutions:** Offers packages of measures specific to different building types.
- **System-Based:** Offers a combination of prescriptive and custom-calculated measures for individual systems within a building.
- **Whole-Building:** Offers custom building simulation models developed by approved program allies to quantify whole-building and measure-level energy savings (includes Path to Net Zero).

A third-party program management contractor (PMC), CLEAResult, implemented the 2018-2019 New Buildings program. Cadmus evaluated the program savings impacts through site visits (in-person and virtual) and reviews of engineering calculations and building simulation models. During site visits, we validated the proper installation and functioning of equipment and recorded operational characteristics data to support our engineering analysis. Cadmus evaluated the prescriptive measures with deemed savings using Energy Trust's Measure Approval Documents (MADs) and the custom measures through detailed calculation spreadsheet workbooks, simulation modeling, energy management system (EMS) trend data and collected metered data. Cadmus engineers analyzed the differences between baseline and as-built simulation models for Leadership in Energy and Environmental Design (LEED) and whole-building projects that applied that methodology to estimate savings.

In addition, Cadmus and another contractor separately evaluated a set of 10 Whole-Building and System-Based projects. These evaluations typically involved a mix of on-site data logging, extensive trend data review, or simulation model calibration. Cadmus integrated the evaluation results for seven of the projects into this evaluation report.

The COVID-19 pandemic impacted the evaluation in many ways, most starkly in our ability to perform physical on-site verification. Cadmus worked with customers to determine the safest way to perform visits, or to opt for virtual visits when possible. Desk reviews were performed when project specifications allowed for straight forward calculation, and/or when customers were wholly unavailable.

Through this impact evaluation, we identified various factors that adjusted the overall program realization rate (the ratio of evaluated to reported savings). Savings listed in the impact evaluation are gross values. Calculation of a net-to-gross ratio fell outside the scope of this evaluation.

Findings

Over the 2018-2019 program years, the New Buildings program achieved over 83 million kWh and 1.4 million therms in savings. Electric savings were evaluated to have 98% realization rate at 2% precision at 90% confidence, and natural gas savings achieved 90% realization rate at 4% precision at 90% confidence. Table 1 shows the electric and gas realization rate and precision by year.

Table 1. Annual Evaluated Savings and Realization Rates

Year	Count of Sites Population	Electricity Savings				Natural Gas Savings			
		Reported (kWh)	Evaluated (kWh)	Realization Rate	Precision[b]	Reported (therms)	Evaluated (therms)	Realization Rate	Precision[b]
2018	468	45,203,931	44,436,195	98%	3%	912,897	741,858	81%	7%
2019	456	39,978,577	38,709,457	97%	2%	687,354	698,190	102%	4%
Total[a]	924	**85,182,508**	**83,145,652**	**98%**	**2%**	**1,600,251**	**1,440,048**	**90%**	**4%**

[a] Totals may not sum due to rounding.
[b] Precision estimates calculated at 90% confidence.

Cadmus' key objective for the 2018-2019 New Buildings program evaluation was to estimate program total gross electricity and natural gas savings, each with better than ±10% precision at 90% confidence, as well as to estimate total gross savings directly attributable to each building type with ±20% precision at 90% confidence. For the primary evaluation, Cadmus achieved this by evaluating 122 projects at distinct sites selected from the 2018-2019 program population, where projects were sampled using a stratified sample design with building type strata.[1] We also added the results of seven large and complex projects that Energy Trust sampled with certainty.

Overall, the 2018-2019 program implementer performed a reasonable level of review and quality control to achieve high average project savings and realization rates. The measure types with lower evaluated savings represented large, complex measures with final operating patterns that can be difficult to predict, particularly in a new construction application. The implementer's efforts to streamline and improve the program's delivery mechanisms appear to have been effective.

Realization rates were high for most measure types and tracks. The HVAC category under the Market Solution track had reduced savings due to the packaged terminal heat pump (PTHP) measure for multifamily buildings. In the separate evaluation for large and complex projects, another evaluation contractor found significantly lower natural gas savings than reported on Custom HVAC projects for two large and complex hospital projects in 2018.

[1] Although the target sample size was initially n=128, the statistically derived sample was 122. By the end of the evaluation, four sampled participants were unreachable, one refused to participate, and one did not allow people on site, resulting in a final evaluated sample of 122 projects.

The other key adjustments to analyses that resulted in deviations between claimed and evaluated savings included the following:

- Observed equipment quantities differed from reported quantities.
- Some equipment that received program incentives did not meet program requirements.
- Evaluated equipment operation that differed from the patterns expected. Cadmus used the actual operating parameters to update deemed savings estimates.
- Building simulation model calibration determined that as-built conditions and operating parameters varied from as-designed expectations.
- Multifamily PTHP evaluated savings were based on the multifamily building square footage instead of the quantity of units installed.
- Modifications to use the version of the MAD that corresponds to the incentive letter date.
- Hours of use (HOU) to reflect on-site operation.
- Modifying building areas to remove parking garage square footage for market solutions-based measure savings.
- Modifying the heating fuel type for a multifamily building.

Using evaluated project data, we estimated the population total savings and realization rates shown in Table 2 for each fuel type and years combined for building type. Throughout the remainder of this report, we present evaluation findings by fuel type as well as building type, project track, and measure category.

Table 2. 2018-2019 Evaluated Savings by Building Type

Building Type	Project Count	Electricity Savings			Gas Savings			Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Precision	Reported (therms)	Evaluated (therms)	Precision	Electricity Savings	Gas Savings
Assisted Living	21	2,896,135	2,814,902	3%	115,652	119,237	6%	97%	103%
Data Center	4	4,131,649	4,164,465	0%	0	0	0%	101%	N/A
Lodging/Hotel /Motel	27	2,277,687	2,557,449	12%	156,655	152,274	5%	112%	97%
Multifamily	182	22,386,301	20,928,305	4%	499,862	510,419	3%	93%	102%
Office	124	7,872,767	7,261,176	10%	40,400	35,192	15%	92%	87%
Warehousing and Storage	73	16,510,216	16,234,812	6%	7,886	7,021	0%	98%	89%
Grocery/ Retail	60	4,602,722	4,628,356	3%	49,228	49,069	4%	101%	100%
K-12 School	99	5,876,161	5,409,954	10%	198,817	205,651	8%	92%	103%
Food Service	93	639,316	509,713	22%	94,145	96,555	3%	80%	103%
Other	241	17,989,553	18,636,520	5%	437,607	264,628	20%	104%	60%
Total[a]	**924**	**85,182,508**	**83,145,652**	**2%**	**1,600,251**	**1,440,048**	**4%**	**98%**	**90%**

[a] Totals may not match due to rounding.

Table 3 provides the evaluated savings by project track. This table describes the magnitude of adjustments Cadmus made to reported savings for each project or measure category that contributed to the electric and natural gas savings realization rate for the program.

Table 3. 2018-2019 Evaluated Savings by Project Track

Track	Project Count	Electricity Savings		Gas Savings		Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electricity Savings	Gas Savings
Data Center	4	4,131,649	4,164,465	0	0	101%	N/A
Market Solutions	150	21,882,050	20,623,643	476,372	486,852	94%	102%
System Based	719	42,730,833	42,019,554	772,895	725,722	98%	94%
Whole Building	51	16,437,975	16,337,990	350,984	227,473	99%	65%
Total[a]	**924**	**85,182,508**	**83,145,652**	**1,600,251**	**1,440,048**	**98%**	**90%**

Peak Demand Savings

The PMC does not calculate demand savings for the program. Cadmus calculated summer and winter peak demand savings through electric load profiles and peak demand factors provided by Energy Trust. We reviewed the reported load profiles for each measure and revised them where necessary to better align with the measure's operation. We then multiplied the evaluated savings for each measure by the applicable peak demand factor. We combined the evaluated demand savings for the sample and remaining program population projects to determine total peak demand reduction for each building type, shown in Table 4 by year.

Table 4. 2018 and 2019 Evaluated Coincident Peak Demand Savings by Building Type

Building Type	2018		2019	
	Winter Demand Savings (kW)	Summer Demand Savings (kW)	Winter Demand Savings (kW)	Summer Demand Savings (kW)
Assisted Living	78	61	476	363
Data Center	27	27	581	550
Lodging/Hotel/Motel	127	114	321	280
Multifamily	2,092	1,161	2,608	1,776
Office	304	280	795	761
Warehousing and Storage	2,390	2,135	410	370
Grocery/Retail	567	572	93	83
K-12 School	296	279	501	486
Food Service	54	49	33	29
Other	1,883	1,656	1,318	848
Total	**7,817**	**6,334**	**7,136**	**5,546**

Recommendations

Cadmus offers the following recommendations for Energy Trust to consider for the New Buildings program in future implementation years.

Maintain Consistent Documentation on Simulation Model Files

Cadmus found the project documentation for simulation projects was inconsistent from one project to the next, especially those projects modeled in IESVE software. The implementer should consistently categorize and clearly label the basis of the final incentive, supporting documentation (including any post-processing calculations performed on the raw model output), final incentive amount, and simulation models across all projects.

Ensure Simulation Models Match Approved Savings

Multiple project files included simulation models that did not match the final approved building performance energy savings calculations. The implementer should clearly label the models with the information they provide or version they represent. We also recommend the implementer verify that the final models match the reported energy consumption output.

Encourage Participants to Enable Energy Management System Trends

In general, new construction facilities have EMS and are capable of enabling trending on major equipment and controls systems. These data are critical to the evaluation effort and can also provide important information to the participant about how the facility is operating. However, we were not able to obtain trend data for any of the projects that used simulation modeling to calculate energy savings. We recommend that Energy Trust and the implementer consider methods to encourage participants to enable EMS trending.

Obtain Mechanical As-Built or Construction Documents

All projects using energy simulation modeling are evaluated using model calibration. As such, the implementer should provide basic design documentation so any third party can quickly develop a clear understanding of the building. This includes a full set of mechanical and HVAC drawings and equipment schedules.

Update Exterior Lighting Calculations

We recommend that the Energy Trust use the Northwest Power Council's HOU estimates for photocell lighting for the exterior lights that are connected to the same photocells' controls. The PMC used different HOU for exterior lights, based on where these lights are installed on site.

Use Consistent Methodology to Estimate Same Measures Savings

We suggest the implementer follow the same methodology to estimate the savings of the same measure implemented across multiple projects. For example, Cadmus found a variety of methodologies used to estimate condensing boiler and tankless water heater savings. Also, Energy Trust should determine if it wants negative therm penalties calculated for interactive effects and be consistent about either reporting them or not.

Update Market Solutions Multifamily MAD

We recommend that Energy Trust update the MAD used for Market Solutions Multifamily savings. The PMC used MAD 163.1 to estimate the savings for the base and elective multifamily measures. The MAD mentions that these savings were obtained using a multifamily model that was 12-story, 198-unit building with a floor area of 220,050 sq ft. The PMC correctly used the project's floor area and per-square-foot values to calculate savings for the base and some elective measures. However, the calculations take an unusual turn for other elective measures. For other measures like the high-performance bathroom fans and PTHPs, the PMC used the original modeled savings to create a per-unit energy savings rather than applying the per-square-foot values in the MAD. We adjusted the PTHP savings to kWh per-square-foot, as specified in the MAD, but kept the kWh per-unit savings for the bathroom fans.

Document the Utility Meter Serial Numbers

We recommend the implementer document the meter numbers during their site visits. For projects that require energy modeling calibration, the evaluator would run the simulations ahead of the site visit to determine the inputs that need to be verified thoroughly.

Develop Demand Methodology to Report Savings

Cadmus recommends that Energy Trust develop methods to report peak demand savings for each project in future program years. Utilities throughout the country have already performed extensive work to characterize peak demand savings estimates, which can inform this effort. Reliable estimates of peak demand savings achieved through Energy Trust's programs will be critical to future integrated resource planning efforts.

Apply Consistent Load Profiles Specific to Measure Types

We recommend that Energy Trust apply consistent load profiles for measure and building type combinations. Energy Trust should also consider the broader range of Regional Technical Forum load profiles rather than relying on a limited set of them.

Methodology

Cadmus evaluated the 2018-2019 New Buildings program through in-person site visits, virtual site visits, phone interviews, and reviews of program assumptions, project documentation, engineering calculations, and building simulation models. We performed in-person verification site visits for 60 projects, virtual site visits for 43 projects, and desk reviews for 19 projects in the sample.[2] We used these data to evaluate energy savings based on verified equipment counts, operating parameters, and assumptions derived from engineering experience and secondary sources. For each measure, these data informed prescriptive savings calculations, calculation spreadsheets, and building simulation models.

During site visits conducted between January and August 2021, we validated the proper installation and functioning of rebated equipment and recorded operational characteristics data to support our engineering analysis. Cadmus evaluated the prescriptive measures primarily using Measure Approval Documents (MADs) and lighting calculation workbooks. We evaluated measures installed in the custom track through detailed calculation spreadsheet reviews, simulation modeling, and energy management system (EMS) trend data (when available). We analyzed the differences between baseline and as-built simulation models for whole-building custom measures and Leadership in Energy and Environmental Design (LEED) projects. Through this impact evaluation, we identified a variety of factors that adjusted the overall program realization rate (the ratio of evaluated to reported savings). Savings listed in the impact evaluation are gross values, as calculation of a net-to-gross ratio fell outside the scope of this evaluation.

We used the following steps to evaluate gross energy savings attributable to the program:

1. Sample development
2. Documentation review
3. Data collection
4. Impact analysis

Cadmus calculated savings based on changes between baseline and installed efficiency measures, using program tracking data and assessing the assumptions and accuracy in the calculations.

In addition, Cadmus and another contractor separately evaluated a set of 10 Whole-Building and System-Based projects. Energy Trust of Oregon worked with the Program Management Contractor (PMC) to identify relatively large or complex projects during the 2018 and 2019 program years that would benefit from additional coordination with participant site contacts and potentially longer evaluation timelines.

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2 The COVID-19 pandemic impacted the evaluation in many ways, most starkly in our ability to perform physical on-site verification. Cadmus worked with customers to determine the safest way to perform visits, or to opt for virtual visits when possible. Desk reviews were performed when project specifications allowed for straight forward calculation, and/or when customers were wholly unavailable.

Energy Trust contracted individually with Cadmus and the other evaluation contractor to review these projects during the program year, conduct post-installation site visits, and coordinate evaluation methods with the participant. The evaluations typically involved a mix of on-site data logging, extensive trend data review, or simulation model calibration.

Cadmus integrated the evaluation results for seven of the projects into this evaluation report. We were unable to characterize the post-occupancy performance for three other projects due to impacts of the COVID-19 pandemic. Cadmus will analyze those projects and report the results separately to Energy Trust in 2022. Therefore, we excluded those three projects from the sample and population data for this impact evaluation report.

Sample Development

Cadmus employed probability proportional to size sampling to select sites for the main 2018-2019 evaluation. Energy Trust selected the sample of 10 large and complex sites for the certainty stratum during the course of the 2018-2019 program years. Cadmus added the reported and evaluated energy savings for these projects to results for the remaining population of 2018-2019 projects. Cadmus and another contractor evaluated seven of these projects in time to include the results in this evaluation report.

Table 5 provides an overview of the building type strata, population of sites, and sample sizes. We selected the 10 building types that each account for 5% or more of the program total electric and gas savings.[3] These building types represented 82% of total electric savings and 87% of total gas savings. We pooled the remaining building types into the "other" category. In each stratum, we calculated the sample size to meet 90% confidence and ±20% precision targets within each building type and better than 90% confidence and ±10% precision for the program overall. We used a coefficient of variation (CV) specific to each building type, based on the measures and previous evaluations. For building types expected to have a broader mix of measures and heterogeneous evaluated savings, we assumed higher CV values.

Cadmus selected projects using probability proportional to size sampling in each stratum, where size refers to the reported savings estimate of each project. This approach resulted in selecting and evaluating projects that contributed more savings with higher probability and provided a highly accurate and precise estimate of the stratum-total and program-total evaluated savings. We verified that gas-only, electric-only, and dual-fuel projects were represented in the evaluation through additional stratification of projects. Within each building-type stratum, we substratified projects into gas-only, electric-only, and dual-fuel saving projects. Within each of these substrata, we allocated the building-type sample size proportional to the percentage of reported savings (Btu) each fuel substratum contributed to the total savings within the building type.

[3] Electric and gas savings in the grocery segment were less than the 5% savings threshold, but we included grocery as a building-type stratum to ensure representation of the distinct characteristics and measures implemented in the sector (primarily refrigeration).

Table 5 also provides an overview of the primary evaluation population and the sample design, with the expected precision at 90% confidence. As shown in the table, some fuel-type substrata had sample sizes of zero. It is important to note that the original scope of work proposed 122 total sites, but our sampling plan included six extra sites to account for expected attrition. That attrition was indeed realized, and the final number of sites evaluated was 122.[4]

[4] Four sampled participants were unreachable, one participant refused to participate, and another participant did not allow our analyst on-site to perform sub-metering which was required to accurately evaluate the project savings.

Table 5. Original Primary Evaluation Sampling Plan

Building Type	Population Size (Projects)				Population Energy Savings		Energy Savings Percentage		Sample Size				Expected Precision at 90% Confidence
	Total	Dual Fuel	Electric Only	Gas Only	Electricity (kWh)	Gas (therms)	Electricity	Gas	Total	Dual Fuel	Electric Only	Gas Only	
Assisted Living	21	21	N/A	N/A	2,896,135	115,652	4.2%	8.6%	8	8	0	0	±20%
Data Center	4	N/A	4	N/A	4,131,649	N/A	6.0%	0.0%	4	0	4	0	±20%
Lodging/Hotel/Motel	27	25	1	1	2,277,687	156,655	3.3%	11.7%	7	7	0	0	±20%
Multifamily	182	109	67	6	22,386,301	499,862	32.7%	37.4%	20	18	2	0	±20%
Office	124	40	82	2	7,872,768	40,400	11.5%	3.0%	13	6	7	0	±20%
Warehousing and Storage	69	7	62	N/A	4,343,962	7,886	6.3%	0.6%	8	2	6	0	±20%
Grocery/Retail	60	10	47	3	4,602,722	49,228	6.7%	3.7%	10	7	1	2	±20%
K-12 School	99	61	33	5	5,876,161	198,817	8.6%	14.9%	12	8	3	1	±20%
Food Service	93	49	18	26	639,316	94,145	0.9%	7.0%	15	12	1	2	±20%
Other	238	85	145	8	13,442,408	175,850	19.6%	13.1%	31	18	13	0	±20%
Total[a]	**917**	**407**	**459**	**51**	**68,469,109**	**1,338,494**	**100%**	**100%**	**128**	**86**	**37**	**5**	**<±10%**

[a] Stratum values may not sum to totals due to rounding.

Table 6 provides information on the seven large and complex projects evaluated for the 2018-2019 program year. Cadmus selected these projects with certainty and added the reported and evaluated savings to the total results for the primary evaluation project population.

Table 6. 2018-2019 Evaluated Large and Complex Projects

Building Type	Population Size (Projects)			Population Energy Savings	
	Total	Dual Fuel	Electric Only	Electricity (kWh)	Gas (therms)
Other	3	3	0	4,547,145	261,757
Warehousing and Storage	4	0	4	12,166,254	-
Total	**7**	**3**	**4**	**16,713,399**	**261,757**

Documentation Review

After identifying the full impact evaluation sample (n=128), we requested the 2018-2019 program activity data for each sampled project. We examined pertinent documentation for energy efficiency measure (EEM) data, scope of data, analysis methods, and building construction and operation details. These data helped our team determine the appropriate measurement and verification (M&V) methods for each site prior to developing the site-specific evaluation plan.

We reviewed information for all sampled sites, including program forms, the tracking database extract, audit reports, and savings calculation work papers for each rebated measure (if applicable). Our review examined each project file for the following information:

- Documentation on equipment installed, including the following:
  - Descriptions
  - Schematics
  - Performance data
  - Other supporting information
- Information about savings calculation methodologies, including the following:
  - The methodologies used
  - Assumption specifications and the sources for these specifications
  - Accuracy of calculations

Analysis Approach

We selected one of the following analysis methods for each site based on the project track and project complexity, typically applying the method that most closely aligned with the PMC's analysis approach:

- **Simple validation** for prescriptive measures and market solutions packages.
- **Engineering calculation models** for custom projects with spreadsheet calculated savings estimates.
- **Analysis of measurement and EMS data** (where available), in conjunction with engineering modeling or simulation modeling, to improve accuracy of results in custom project analyses.
- **Simulation model analysis** for sites with whole-building models, including Path to Net Zero.

Data Collection

Site-Specific Evaluation Plans and Data Collection Tools

Cadmus developed a site-specific evaluation plan for each building in the sample. To develop these plans, we reviewed the project files and determined the most appropriate analysis and data collection methods. We provided more detailed plans for sites with nonprescriptive measures because they are inherently more complex. We submitted site-specific evaluation plans for the five largest projects in the sample and a representative sample of 10 smaller projects to Energy Trust and the PMC for review and approval. We incorporated Energy Trust and PMC review feedback into the plans as necessary.

For projects where all measures have a corresponding MAD, we reviewed the calculations and assumptions provided against the MAD. Using the MAD, we determined the data points to be verified, either through interviews or site visits. For projects that use custom calculations, we reviewed the calculations and assumptions to determine whether additional data, such as HVAC trend data, were required for proper assessment of savings. These projects were most likely verified via a physical or virtual site visit for proper verification. Whole-building and Path to Net Zero projects required a review of energy simulation models and calibration to actual consumption.[5]

Once we identified the data points for M&V, we created a data collection evaluation plan for each sampled project. For the 2017 New Buildings impact evaluation, Cadmus developed Python code that automatically prepopulated evaluation plans using site-specific data from Energy Trust project files. We modified this code for the 2018-2019 Existing Buildings evaluation to streamline plan development and devote more budget to data collection and analysis tasks. A typical M&V plan followed a three-part format:

- **Project Summary** provides an overview of the facility and efficiency measures implemented.
- **Reported Savings Methodology** outlines the methods and assumptions employed by the PMC to estimate energy savings.
- **M&V Methodology** describes the type of M&V methodology Cadmus proposes, including International Performance Measurement and Verification Protocol (IPMVP) options or other M&V guidelines, a complete list of parameters to be collected or monitored on the site, the duration and frequency of monitoring, and the data logging equipment (quantities and type) to be used during the monitoring phases, if applicable. Whenever possible, we captured EMS trend data. For larger and more complex projects, we deployed our own metering equipment to accurately acquire the information needed to evaluate energy savings for the installed conditions as established by the M&V plan.

Data Collection Methods

Cadmus' data collection methods included virtual and on-site verification, facility staff interviews (by phone or in-person), emails to the participant, EMS trend data acquisition, or any combination of these approaches. We determined the appropriate M&V methods for each measure by reviewing the project files, measure mix, building type, building size, the project track for the measure, and the scale of reported savings.

As shown in Table 7, the evaluation approach categorized data collection activities into five different tiers, in order of complexity. We developed these tiers in conjunction with Energy Trust for the 2018-2019 Production Efficiency impact evaluation. We assigned as many hospitals and assisted living

[5] Because of the lockdowns due to the COVID-19 pandemic, many buildings were closed or unoccupied and did not reflect normal operation, thus Cadmus was not able to perform submetering, as is customary.

facilities projects as feasible into Tiers 1 through 3 due to COVID-19 precautions. We also delayed site visits for projects in those building types that require on-site verification until the point at which Cadmus and Energy Trust jointly agreed that the risk was sufficiently low as to reduce the potential for harm to customers, occupants, and field staff.

Table 7. Data Collection Tiers

Impact Evaluation Method	Data Collection Activities
Desk Review (Tier 1)	• Review incentive documentation (savings calculation methodology, PMC-collected documentation, invoices) • Calculate savings based on MADs, calculation workbooks, and project files • Email participants to confirm assumptions (e.g., hot water heater fuel type) and future normal operations • This option is most appropriate for sites that are closed or cannot be reached, and for those with sufficient documentation
Desk Review+ (Tier 2)	• All desk review actions plus the following: ▪ Request photos of equipment ▪ Request trend data from EMS ▪ Request photos of control displays (variable frequency drives, chillers, water heaters, refrigeration controls, etc.) ▪ Request controls sequence programming ▪ Conduct phone interview with contact
Virtual Audit (Tier 3)	• Everything in the desk review+, except the customer will use a video app to walk through the installed equipment and nameplate data
On-Site Verification (Tier 4)	• Everything in the desk review+ • Cadmus collects all data during a site visit with little to no assistance from customer
On-Site Metering (Tier 5)	• Paired with energy simulation modeling to determine data collection needs for model validation • Install light loggers or power metering equipment on major end uses

For large projects with many measures of the same type, we sampled within the site for data collection activities. We randomly selected floors or rooms for verification and extrapolated findings to the rest of the site. We also listed any COVID-19 considerations for each site, such as whether we proposed a virtual site visit or desk review+ with trend data.

International Performance Measurement and Verification Protocol (IPMVP)

Cadmus primarily used M&V methods established by the IPMVP.[6] This protocol was first published in 1996 to develop a consensus approach to measuring and verifying efficiency investments to overcome existing barriers to efficiency. The goal is to increase investment in energy efficiency and renewable

6 Cadmus excluded Option C, Whole Facility pre/post usage data analysis because this program applies to new buildings.

energy (EERE) by increasing energy savings, reducing the cost of financing projects, and encouraging better project engineering. The protocol also helps to demonstrate and capture the value of reduced emissions from EERE investments and increase public understanding of energy management as a public policy tool. Finally, the IPMVP also helps national and industry organizations promote and achieve resource efficiency and environmental objectives. We used the following IPMVP methods to evaluate measure performance:

- **Operational Verification**. Cadmus verified some prescriptive measures (particularly those with relatively small reported savings) on site or by phone to confirm that measures were installed in the reported quantity and operating in a manner consistent with deemed-savings assumptions.
- **IPMVP Option A: Key Parameter Measurement.** Under this method, Cadmus used engineering calculations and partial site measurements to verify savings from specific measures. We estimated parameters not measured.
- **IPMVP Option B: All Parameter Measurement.** Under this method, we used engineering calculations and ongoing site measurements to verify the savings resulting from the change in energy use.
- **IPMVP Option D: Calibrated Simulation.** Under this method, we employed computer energy simulation models to calculate savings as a function of key independent variables. The models included verified inputs that accurately characterized the system and were calibrated to monthly post-occupancy utility billing data.

Site Visits and Facility Operator Interviews

Cadmus conducted data collection activities for three primary reasons: (1) to perform rigorous investigation during our site visits, (2) to fully explain discrepancies between expected and evaluated impacts, and (3) to provide insights to Energy Trust to improve reported savings. We deployed a range of data collection methods to achieve Energy Trust's impact evaluation objectives through a systemic and transparent approach.

For all sites included in the study, we talked to the staff involved with the project and familiar with facility operation. For projects not warranting an in-person visit, we conducted interviews via phone.

The purpose of the interviews was to confirm installation and functionality of all equipment, current occupancy or facility use, adjustments in control schemes, and other items significantly impacting energy consumption. This allowed our team to further verify the accuracy of assumptions that relate to energy-savings calculations and recalculate savings, as needed.

On-Site M&V

Cadmus conducted 60 in-person site visits and 43 interview and virtual site visits. We anticipated most prescriptive and small custom measures would only require site or phone verification because of the relatively small energy savings and the deemed measure approaches. For example, for projects involving lighting, we obtained the most accurate available estimate of operating hours based on posted hours or lighting control system parameters. Although we asked facility personnel about operating hours, we typically relied on posted hours or control system data because, in our experience, self-reported operating hours are often less consistent and reliable.

Most custom measures required detailed information for analysis based on the appropriate IPMVP option. Data centers, with their exceptionally large per-project savings and limited occupancy, were good candidates for low-risk, in-person verification. For these sites, we obtained IT equipment loads from the participants prior to evaluating the savings.

Cadmus developed a comprehensive data collection form for whole-building simulation model projects. Field staff used streamlined versions of the form for all evaluated projects, focusing on specific end uses when verifying individual measures at a site. During the site visits, our field engineers focused on these three primary tasks:

- **Verifying installation of all measures for which participants received incentives.** To the extent possible, field engineers verified that EEMs were correctly installed, remained in place, and functioned properly. They conducted spot measurements, collected EMS trend data, or made visual inspections, as appropriate. Field engineers also verified operating parameters for installed equipment.
- **Collecting the physical data required to analyze energy savings realized from installed measures.** Field engineers conducted in-depth reviews of project files to determine the pertinent data regarding counts and specification of the rebated equipment, site-specific conditions and operating hours, for collection from each site.
- **Conducting interviews with the facility operations staff** to confirm project documentation accuracy and to obtain additional data on operating characteristics for installed systems.

During several site visits, Cadmus field engineers noted equipment counts that differed from those for which incentives were provided. When we found fewer measures in place, we reduced the realization rates accordingly, and vice versa. We noted that the as-built equipment quantities may vary from design counts because of changes in building structures or space usage.

Impact Analysis

The impact analysis included multiple components:

- Building-level savings, including electric savings, electricity demand savings, gas savings, realization rates, and descriptions of any adjusted parameters with rationale
- Rolled up program-level electric and gas savings and realization rates, including savings aggregated by year, fuel type, measure category, program track, and building type
- Discussion of COVID-19-related changes to operations
- Observations and recommendations for program improvements

We shared with Energy Trust and the PMC the site-level savings of the sites with realization rates larger than 110% and lower 90% for review and approval before initiating program-level analysis. We incorporated staff feedback into these results. Once Energy Trust and the PMC reviewed and approved the savings, we estimated total program-level savings using a savings-weighted extrapolation process. Energy Trust has provided the peak-period definition to estimate electricity demand savings based on the total electric savings, as well as load coincidence factors (at the measure end-use level), which we used to calculate demand savings.

COVID-19 Considerations

The pandemic affected facility use in 2020 and 2021, which impacted observations made during the evaluation for 2018 and 2019 New Buildings projects. Cadmus handled each facility individually but generally handled changes in occupancy, measure removal, and facility closures as described below:

- **Occupancy or Usage Changes.** Cadmus inquired if occupancy of facilities or use of equipment has changed compared to the expected levels of the projects completed in 2018 or 2019. If equipment use or occupancy levels changed less than ±10%, and were expected to stay constant going forward, then the assumptions used in the *ex ante* calculations were retained. If the use or occupancy levels changed more than ±10%, Cadmus asked about the facility's expectations after pandemic conditions ease into the future, and what aspects may continue to operate differently (for example, increased ventilation may persist). Specifically, Cadmus calibrated four energy models that had utility data available before the pandemic, but did not adjust for future occupancy changes.
- **Measure Removal in Operational Facilities.** If a measure was removed, Cadmus determined when the measure was removed, and prorated the savings relative to the measure lifetime.
- **Facility Closures.** In accordance with the 2011 study[7] showing nearly all capital measures remain in place after installation, Energy Trust believes that facility closures are accounted for in the measure lifetime for capital measures. Therefore, Energy Trust prefers to calculate *ex post* savings for capital measures installed in closed facilities similarly to how it would normally.

Site-Level Analysis

Cadmus completed site-level analyses as outlined in the approved site-specific evaluation plans by means of simple validation, engineering calculation models, metering analysis, or calibrated simulation modeling. Where appropriate, we used utility billing data to inform and calibrate our engineering approaches. Our analysis methods are described here:

- **Simple Validation.** Cadmus verified some prescriptive measures (particularly with relatively small reported savings) on site or by phone, confirming that they were installed in the reported quantity, using the appropriate fuel type, and operating in a manner consistent with MADs and Market Solutions workbooks. We also verified recorded nameplate efficiency data against manufacturer's specifications. If we confirmed these details, we accepted the reported savings without further investigation. If we identified inconsistencies, we adjusted savings based on the equipment and operating parameters found on site or based on the phone interview.

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7 MetaResources Group. 2011. *Industrial Plant Closure Study for Energy Trust of Oregon*.

- **Engineering Calculation Models.** In many cases, the PMC or the installation contractor developed calculation spreadsheets to analyze energy savings for a variety of measures. Calculation spreadsheets require relevant parameter inputs such as quantity, fixture wattage, square footage, and efficiency value. The project files typically have engineering algorithms to estimate energy savings using these data. We reviewed input requirements, algorithms, and output estimates to determine if the approach was reasonable. Where applicable, we created or updated calculations using on-site verification data.
- **Metering Analysis (IPMVP Options A and B).** Cadmus estimated relevant operational parameters to inform engineering calculation models using EMS trend data, spot measurements, or several weeks of data logging. During the site visits, we confirmed key factors such as setpoints, sequence of operations, and operating schedules. We estimated baseline energy performance based on program documentation, site conditions, facility interviews, and relevant energy code requirements.

  After downloading the meter data, we cleaned them to account for any outliers. Next, we analyzed key variables, such as HOU, in the metering data using spreadsheet tools or Python code. We used the resulting information to calculate savings (as input variables in an engineering model).
- **Simulation Model Analysis (IPMVP Option D).** Cadmus' whole-building simulation approach entailed the use of industry-standard software such as eQuest and IESVE. We followed methods recommended in the U.S. Department of Energy's M&V Guideline and ASHRAE Guideline 14.[8,9] We calibrated the whole-building energy model using a full year of billing data, end-use monitored data, and other information collected on site.

After obtaining existing simulation models and documentation, we compared the code baseline and as-built models. For eQuest and IESVE simulation models, we reviewed model inputs, outputs, and project documentation. We also tracked any errors or concerns, assumptions, or inputs verified on site and differences between the reported and evaluated model outputs. If we identified discrepancies, we updated the model as needed and began the calibration process. For some sites, we requested additional utility data from Energy Trust as the original dataset provided either had missing data points or data for different project sites.

Following the site visit, we input verified values into the model, plus actual weather data for the appropriate location and time period, and tested statistical calibration with the monthly utility data. We targeted a monthly model prediction accuracy with a mean bias error of ±5% and a coefficient of variation root mean square error of ±15%, per ASHRAE Guideline 14. If the analysis did not meet this target, we further reviewed graphical analysis results and made improvements based on engineering

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8 U.S. Department of Energy. 2015. *M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0*. https://www.energy.gov/sites/prod/files/2016

9 ASHRAE. 2014. *Guideline 14-2014 -- Measurement of Energy, Demand, and Water Savings.*

judgment where we identified anomalies. We also accounted for fluctuations such as those from building commissioning or first-year occupancy changes in our analysis.

We developed the baseline model, ensuring that only appropriate changes existed compared to the as-built model and that the model met any measure stipulations, such as code requirements. Finally, we determined savings by comparing results from the calibrated as-built and baseline models using typical meteorological year data. We input the results of the baseline and proposed models, as well as the results from any EEM-specific models or parametric runs, into the Savings Summary workbook to calculate the adjusted measure-level savings for each EEM.

Building-Type and Program-Level Savings

Cadmus calculated building-type and program-level realization rates and savings by year and fuel type based on the evaluated savings and reported savings observed for all evaluated projects in the sample. We developed and applied stratified sampling weights based on the probability of selecting each sampled project within building type strata and fuel-type substrata. The sampling weights were applied to evaluated projects to estimate population-level metrics. Cadmus estimated evaluated savings and realization rates for the program population and different subpopulations using the following steps:

- **Step 1.** Within each building-type stratum, each project was identified with a probability of selection to account for the probability proportional to size sampling approach.
- **Step 2.** We estimated realization rates within each building-type stratum by applying project-level sampling weights to evaluated and reported savings.
- **Step 3.** We applied the savings weighted realization rates to the project population in each stratum to estimate evaluated savings for all projects. We applied the same realization rate to all measures within projects in each stratum.
- **Step 4.** Finally, we aggregated evaluated project savings within program track and measure categories to estimate the total evaluated savings and realization rates in those subpopulations. Those realization rates were extrapolated to the rest of the population within that specific subpopulation.
- **Step 5.** Cadmus estimated the precision for each year and fuel at 90% confidence.

Demand Savings Analysis

Energy Trust does not currently report demand savings for individual measures, projects, or programs. For the impact evaluation, Cadmus calculated summer and winter peak demand savings using prescriptive peak multiplier factors provided by Energy Trust. These factors were based on regional load profiles for sectors, building types, and end uses, adjusted for the expectation of peak demand. Energy Trust calculated the summer and winter peak factors for each load profile as shown in the calculation below.

$$PeakMultiplier = \frac{Coincidence\ Factor}{8{,}760\ hours\ x\ Load\ Factor}$$

Energy Trust calculated the summer and winter coincidence factors as the weighted average load during the respective peak periods as defined by Portland General Electric (PGE) and PacifiCorp with 60% and 40% weights, respectively:

- PGE Summer: August, 12:00–22:00
- PGE Winter: December and January, 06:00–12:00 and 16:00–22:00
- PacifiCorp Summer: August, 14:00– 21:00
- PacifiCorp Winter: December and January, 07:00 – 09:00 and 18:00 – 20:00

Cadmus reviewed the electric load profile assigned to each measure to ensure it appropriately reflected the expected operation for the measure and was consistent with similar measures. We updated the profiles where necessary. We then multiplied each measure's evaluated energy savings by the peak multiplier (based on their assigned load profile) to calculate summer and winter peak demand savings for each measure. After calculating the demand savings for each measure, we combined the measure-specific peak demand savings in various combinations to determine the total peak demand savings by building type, track, and measure for each program year.

Impact Evaluation Findings

This section presents the results of the impact evaluation. This includes the results of engineering analyses, as applied to the sample; historical savings and realization rates, adjustments to reported savings; calculation of realization rates; and estimation for the 2018-2019 program population. It also includes general observations regarding discrepancies between expected and evaluated savings that influenced realization rates.

Table 8 through Table 11 on the following pages provide the evaluated savings by building-type stratum for electric and gas measures included in the sample. Although precision targets at the year and fuel levels greatly exceeded ±10% precision at 90% confidence targets, there was variation between building types.

Overall, the 2019 sample had generally less variation in realization rates, and those building types that had precision over ±20% contributed lower overall savings. The 2018 sample had more variability on the electric side with wider swings in realization rates. The 2018 sample also experienced higher levels of attrition, likely due to the COVID-19 pandemic, which decreased our sample sizes. The lower sample size resulted in less favorable precision results for several building types. The 2018 natural gas precision met targets for all building types but the “other” category. That category included two large/complex certainty strata projects with low realization rates and several randomly-selected projects with significant variance from reported savings which may have contributed to missing the precision target

Table 8. 2018-2019 Sample Evaluated Savings and Realization Rates by Building Type

Building Type	Count of Sites Evaluated	Electricity Savings		Gas Savings		Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electricity Savings	Gas Savings
Assisted Living	7	1,423,775	1,381,620	42,040	43,402	97%	103%
Data Center	4	4,131,649	4,164,465	0	0	101%	N/A
Lodging/Hotel/Motel	7	1,183,554	1,346,279	47,571	46,133	114%	97%
Multifamily	18	4,587,883	4,309,913	103,285	106,238	94%	103%
Office	12	3,319,726	3,157,038	20,380	18,040	95%	89%
Warehousing and Storage	11	13,081,033	13,332,316	4,542	4,214	102%	93%
Grocery/Retail	10	3,303,740	3,314,050	48,330	48,174	100%	100%
K-12 School	12	784,224	704,335	40,897	41,874	90%	102%
Food Service	15	187,693	143,289	34,277	35,169	76%	103%
Other	33	9,716,000	10,151,664	350,076	201,937	104%	58%
Total[a]	**129**	**41,719,277**	**42,004,970**	**691,398**	**545,181**	**101%**	**79%**

Building Type Findings

The following tables show combined and individual years of reported and evaluated savings by building type and for the program overall. These results have been extrapolated to the program population. The large electric realization rate for the Lodging/Hotel/Motel is due to verifying higher lighting savings for two out of seven sampled projects and higher HVAC savings for another sampled project. The lower electric realization for the Food Service category is due to one restaurant project that reported electric savings for a gas broiler and a mistake in entering the controlled wattage in the lighting calculator of another project. The lower therms realization rate for the Other category is mainly due to lower evaluated therm savings obtained after the calibration of two hospital projects.

Table 9. 2018-2019 Evaluated Savings by Building Type

Building Type	Project Count	Electricity Savings			Gas Savings			Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Precision	Reported (therms)	Evaluated (therms)	Precision	Electricity Savings	Gas Savings
Assisted Living	21	2,896,135	2,814,902	3%	115,652	119,237	6%	97%	103%
Data Center	4	4,131,649	4,164,465	0%	0	0	0%	101%	N/A
Lodging/Hotel/ Motel	27	2,277,687	2,557,449	12%	156,655	152,274	5%	112%	97%
Multifamily	182	22,386,301	20,928,305	4%	499,862	510,419	3%	93%	102%
Office	124	7,872,767	7,261,176	10%	40,400	35,192	15%	92%	87%
Warehousing and Storage	73	16,510,216	16,234,812	6%	7,886	7,021	0%	98%	89%
Grocery/Retail	60	4,602,722	4,628,356	3%	49,228	49,069	4%	101%	100%
K-12 School	99	5,876,161	5,409,954	10%	198,817	205,651	8%	92%	103%
Food Service	93	639,316	509,713	22%	94,145	96,555	3%	80%	103%
Other	241	17,989,553	18,636,520	5%	437,607	264,628	20%	104%	60%
Total[a]	**924**	**85,182,508**	**83,145,652**	**2%**	**1,600,251**	**1,440,048**	**4%**	**98%**	**90%**

[a] Totals may not match due to rounding.

Table 10. 2018 Evaluated Savings by Building Type

Building Type	Project Count	Electricity Savings			Gas Savings			Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Precision	Reported (therms)	Evaluated (therms)	Precision	Electricity Savings	Gas Savings
Assisted Living	8	458,081	404,692	25%	49,969	50,981	4%	88%	102%
Data Center	1	214,300	214,300	0%	0	0	0%	100%	N/A
Lodging/Hotel/ Motel	10	865,058	766,561	32%	79,493	75,644	14%	89%	95%
Multifamily	87	9,316,858	8,498,686	6%	218,003	217,956	0%	91%	100%
Office	56	2,511,929	1,885,162	41%	23,000	20,514	9%	75%	89%
Warehousing and Storage	36	13,351,728	13,802,528	6%	6,116	6,116	0%	103%	100%
Grocery/Retail	39	4,082,081	4,090,491	3%	47,464	47,305	4%	100%	100%
K-12 School	41	2,378,324	1,983,387	30%	61,405	61,774	1%	83%	101%
Food Service	56	380,888	320,366	35%	62,328	64,063	5%	84%	103%
Other	134	11,644,683	12,470,022	7%	365,120	197,505	27%	107%	54%
Total[a]	**468**	**45,203,931**	**44,436,195**	**3%**	**912,897**	**741,858**	**7%**	**98%**	**81%**

[a] Totals may not sum due to rounding.

Table 11. 2019 Evaluated Savings by Building Type

Building Type	Project Count	Electricity Savings			Gas Savings			Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Precision	Reported (therms)	Evaluated (therms)	Precision	Electricity Savings	Gas Savings
Assisted Living	13	2,438,054	2,410,210	3%	65,683	68,257	11%	99%	104%
Data Center	3	3,917,349	3,950,165	0%	0	0	0%	101%	N/A
Lodging/Hotel/ Motel	17	1,412,629	1,790,888	17%	77,162	76,630	1%	127%	99%
Multifamily	95	13,069,443	12,429,619	6%	281,859	292,464	5%	95%	104%
Office	68	5,360,838	5,376,014	2%	17,400	14,678	40%	100%	84%
Warehousing and Storage	37	3,158,488	2,432,284	26%	1,770	905	0%	77%	51%
Grocery/Retail	21	520,641	537,865	13%	1,764	1,764	0%	103%	100%
K-12 School	58	3,497,837	3,426,567	5%	137,412	143,877	14%	98%	105%
Food Service	37	258,428	189,347	25%	31,817	32,492	4%	73%	102%
Other	107	6,344,870	6,166,498	3%	72,487	67,123	13%	97%	93%
Total [a]	**456**	**39,978,577**	**38,709,457**	**2%**	**687,354**	**698,190**	**4%**	**97%**	**102%**

[a] Totals may not sum due to rounding.

Historical Results

Figure 1 and Figure 2 provide a historical context on energy savings and evaluation realization rates for the New Buildings program from 2008 to 2019. Note that Energy Trust did not conduct an evaluation for the 2013 program year.

On the electricity side, the trend has been toward higher electricity savings and relatively high realization rates between 2012 and 2018. The electric savings decreased slightly in 2019. For natural gas, energy savings had increased for three years, along with steadily increasing realization rates, but dipped in 2018 due to the impact of two very large hospital custom HVAC projects with low realization rates. The gas realization rate subsequently reached its highest historical value in 2019.

Figure 1. Historical Reported and Evaluated Electricity Savings with Realization Rates

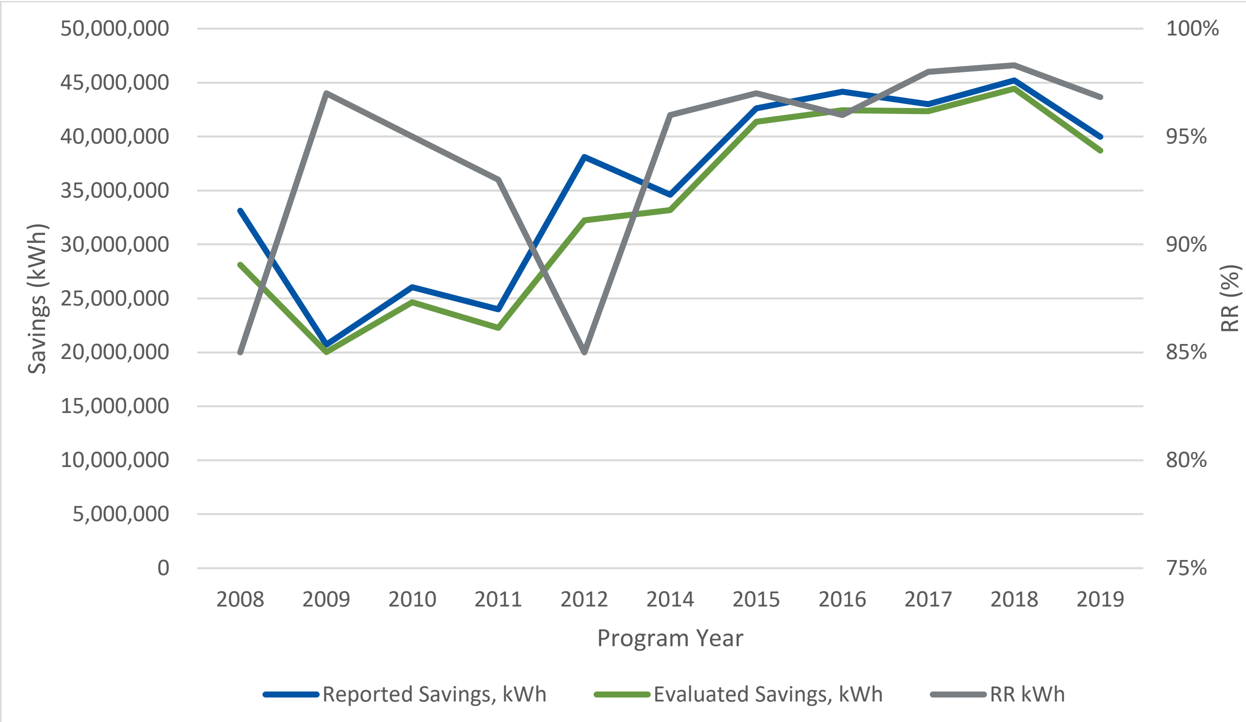
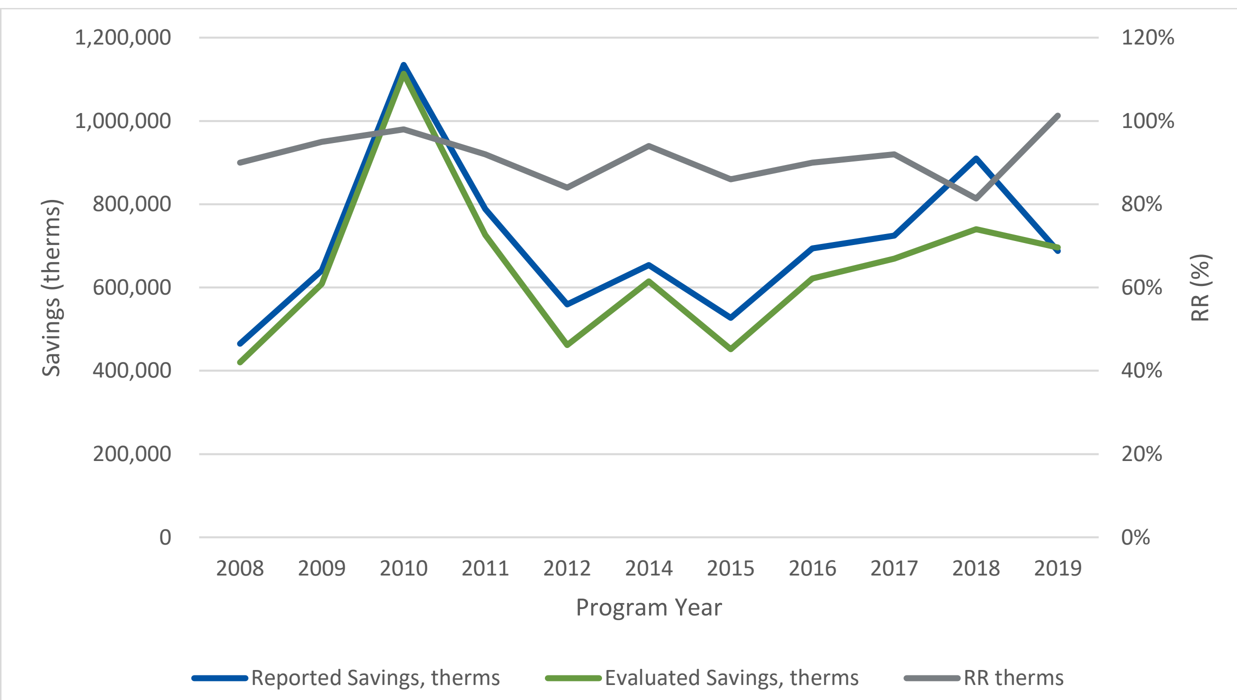


Figure 2. Historical Reported and Evaluated Gas Savings with Realization Rates



Measure Category Findings

Cadmus adjusted electricity and gas savings resulting from the measure-specific reasons described in the sections below. We allocated sites to each analysis methodology category (custom, simulation modeling, and prescriptive) based on the specific requirements for selected projects. Table 12 through Table 14 provide realization rates by measure category for the evaluated sample. These results have not been expanded to the program population because the sampling stratification was performed by building type and therefore does not align to extrapolate to measure category.

Table 12. 2018-2019 Sample Evaluated Savings and Realization Rates by Measure Category

Measure Category	Count Measures Evaluated	Electricity Savings		Gas Savings		Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electricity Savings	Gas Savings
Food Service and Appliance	94	257,240	250,473	49,594	50,959	97%	103%
HVAC	75	2,918,090	2,626,914	14,750	15,027	90%	102%
HVAC - Custom	45	8,561,424	8,672,985	369,463	219,443	101%	59%
Lighting	199	21,396,611	21,489,280	0	0	100%	N/A
Lighting - Custom	15	1,080,925	1,065,787	0	0	99%	N/A
Market Solutions	49	409,728	378,055	2,372	2,805	92%	118%
New Construction	13	1,099,721	1,271,055	401	390	116%	97%
Other - Custom	90	4,789,819	5,074,605	25,988	26,872	106%	103%
Refrigeration	43	997,443	965,841	25,297	24,572	97%	97%
Water Heating	207	208,275	209,974	203,533	205,112	101%	101%

Table 13. 2018 Sample Evaluated Savings and Realization Rates by Measure Category

Measure Category	Count Measures Evaluated	Electricity Savings		Gas Savings		Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electricity Savings	Gas Savings
Food Service and Appliance	49	132,142	129,457	32,086	32,603	98%	102%
HVAC	29	762,789	645,394	5,086	5,168	85%	102%
HVAC - Custom	26	4,697,272	5,075,131	344,621	197,697	108%	57%
Lighting	98	16,878,661	17,173,555	0	0	102%	N/A
Lighting - Custom	7	413,109	395,245	0	0	96%	N/A
Market Solutions	24	104,248	93,441	2,372	1,935	90%	82%
New Construction	6	742,102	742,102	0	0	100%	N/A
Other - Custom	48	1,326,411	1,318,778	19,614	20,041	99%	102%
Refrigeration	32	982,198	951,217	25,297	24,572	97%	97%
Water Heating	93	83,130	82,340	70,681	69,802	99%	99%

Table 14. 2019 Sample Evaluated Savings and Realization Rates by Measure Category

Measure Category	Count Measures Evaluated	Electricity Savings		Gas Savings		Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electricity Savings	Gas Savings
Food Service and Appliance	45	125,098	121,016	17,508	18,356	97%	105%
HVAC	46	2,155,302	1,981,520	9,664	9,859	92%	102%
HVAC - Custom	19	3,864,152	3,597,854	24,842	21,746	93%	88%
Lighting	101	4,517,951	4,315,725	0	0	96%	N/A
Lighting - Custom	8	667,816	670,542	0	0	100%	N/A
Market Solutions	25	305,480	284,614	0	871	93%	N/A
New Construction	7	357,619	528,953	401	390	148%	97%
Other - Custom	42	3,463,408	3,755,828	6,374	6,831	108%	107%
Refrigeration	11	15,245	14,624	0	0	96%	N/A
Water Heating	114	125,145	127,634	132,852	135,309	102%	102%

At an aggregate level, some measures performed above expectations and others below. Measure categories that performed as expected included lighting, LEED new construction, and water heating. Some of the most notable findings at the measure level include these:

- The PMC considered negative gas interactions for three market solution projects out of the entire population. Cadmus sampled one of those three projects. To be consistent across the population, Cadmus removed the negative savings on all three projects.
- Under the HVAC category, Cadmus reduced the packaged terminal heat pump (PTHP) savings under the Market Solution track for multifamily buildings by applying the savings formula from the MAD rather than the implementer's methodology.
- The lower food service equipment savings are due to two projects. For one project, Cadmus verified that the original electric convection oven failed and was not replaced with an ENERGY STAR® unit. For the second project, Cadmus found that the convection oven installed was natural gas instead of electric.
- The 2018 custom HVAC evaluated gas savings were significantly lower than reported due to issues identified by another evaluator on two large and complex hospital projects that were evaluated separately and represented the majority of the reported gas savings.

Track-Level Findings

The New Buildings program has four different tracks that dictate the measure type and savings methodologies. Table 15 through Table 17 show the electricity and gas savings for each program year by track. These results have been expanded to the program population. Each track is discussed in detail below.

Table 15. 2018-2019 Evaluated Savings by Project Track

Track	Project Count	Electricity Savings		Gas Savings		Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electricity Savings	Gas Savings
Data Center	4	4,131,649	4,164,465	0	0	101%	N/A
Market Solutions	150	21,882,050	20,623,643	476,372	486,852	94%	102%
System Based	719	42,730,833	42,019,554	772,895	725,722	98%	94%
Whole Building	51	16,437,975	16,337,990	350,984	227,473	99%	65%
Total[a]	**924**	**85,182,508**	**83,145,652**	**1,600,251**	**1,440,048**	**98%**	**90%**

[a] Totals may not sum due to rounding.

Table 16. 2018 Evaluated Savings by Project Track

Track	Project Count	Electricity Savings		Gas Savings		Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electricity Savings	Gas Savings
Data Center	1	214,300	214,300	0	0	100%	N/A
Market Solutions	74	9,936,218	9,254,993	208,619	209,030	93%	100%
System-Based	365	24,816,375	24,827,463	390,284	342,568	100%	88%
Whole-Building	28	10,237,038	10,139,439	313,995	190,261	99%	61%
Total[a]	**468**	**45,203,931**	**44,436,195**	**912,897**	**741,858**	**98%**	**81%**

[a] Totals may not sum due to rounding.

Table 17. 2019 Evaluated Savings by Project Track

Track	Project Count	Electricity Savings		Gas Savings		Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electricity Savings	Gas Savings
Data Center	3	3,917,349	3,950,165	0	0	101%	N/A
Market Solutions	76	11,945,832	11,368,650	267,753	277,823	95%	104%
System-Based	354	17,914,458	17,192,092	382,611	383,154	96%	100%
Whole-Building	23	6,200,937	6,198,550	36,989	37,213	100%	101%
Total[a]	**456**	**39,978,577**	**38,709,457**	**687,354**	**698,190**	**97%**	**102%**

[a] Totals may not match due to rounding.

Data Center Track

For the Data Center track, Cadmus evaluated a total of four projects that resulted in electric realization rates of 100% and 101% for 2018 and 2019, respectively. Cadmus found that one of the sites had ramped up more slowly than expected, and only reached half of the expected server load in February 2021. Cadmus evaluated savings based on the site operating at the half load, which decreased the energy savings of the optimized chilled water plant measure. As for the uninterruptible power supply (UPS) measure, Cadmus updated the installed UPS efficiency based on the manufacturer’s specifications, which resulted in a much higher value than reported even though the site was operating at lower load.

Another project estimated savings based on operation at partial load, although Cadmus verified the site operated at full load. We evaluated savings of three measures based on the site operating at the full load, which increased the energy savings for the installed HVAC system. For the UPS measure, we updated the installed UPS efficiency based on the manufacturer's specifications, which resulted in a lower value than reported. Cadmus adjusted the analysis of the data fan hall, aligning the system to operate at the full annual load.

Market Solutions Track

For the Market Solutions Track, Cadmus evaluated 23 projects that involved packaged Market Solutions offerings for multifamily buildings, assisted living, food service, and grocery/retail. We verified measures using the appropriate MADs for projects in this track.

All but two multifamily projects from the sample fell under this track. The electric realization rate of this track is lower primarily because Cadmus adjusted the savings of the package terminal heat pump measures for these multifamily projects.

MS Elective, Packaged Terminal Heat Pump

During the verification process of Market Solutions multifamily projects, Cadmus discussed the evaluation of this measure with both Energy Trust and the PMC. We agreed to base the savings of this measure on the square footage of the buildings, as specified in the MAD, rather than the per-unit savings the PMC estimated in its calculation workbook. The reported savings for a code compliant PTHP are 1,126.9 kWh per unit, while MAD 163.1 suggests 1.014 kWh per square foot. Cadmus used the MAD kWh per sq ft instead of the reported kWh per unit to determine the savings of this measure, which resulted in lower realization rates for eight projects. This electric measure specific realization rate ranged from 64% to 78% for seven projects and 99% for one project.

Assisted Living

Cadmus evaluated two assisted living projects that fell under the Market Solutions track. Both projects installed high-performance fixtures in units and reduced the lighting power density in common areas. The calculations for both measures required the total conditioned floor area affected, which should have included the top three floors of each building. For both projects, the implementer used four floors, including the parking garage floor, to determine the savings of the base measures. This reduced energy savings for those lighting measures. For one of these projects, the implementer also used the wrong category for the heating source. The building is heated using gas, but the implementer used the MAD savings that correspond to electric heating category. Project realization rates were 75% and 86% for electric, and 114% and 111% for natural gas.

Gas Conveyor Broiler

Cadmus evaluated three 2018 projects and one 2019 project that installed the same make and model for gas conveyor broilers at different locations. While only two of these four projects fell under the Market Solutions track, we will discuss the evaluation details for all of the similar measures in this section. The implementer used the California Gas Conveyor Energy Savings Calculator to estimate the natural gas savings of the conveyor broilers for two of the 2018 projects but used another publication to determine the savings at the third location. The implementer calculated electric savings for the same conveyor broiler.

To be consistent with remaining projects, Cadmus adjusted the savings of the third project to match those of the other two 2018 projects and did not consider any electric savings for the gas conveyor broiler (0% electric and 152% gas realization rates). For the 2019 project, the implementer used MAD 233.3 to determine the savings. Cadmus agreed with this approach and gave 100% realized savings. Note that this MAD was not approved until 2019 and was not available for the 2018 projects.

There are other measures that were included in the Market Solutions projects but are more appropriately evaluated in conjunction with those in categories for the System-Based track such as water heating and custom measures. We included all appropriate findings on the projects' measures in the following sections for those tracks.

System-Based Track

Lighting

Lighting measures included interior and exterior lighting power reductions below code allowances, LED case lighting, and controls such as occupancy sensors and daylight dimming. Lighting measures had an electric realization rate of around 96%.

There were two primary factors influencing the realization rate:

- Alterations in fixture quantities and wattages
- Different operating hours in the sample than those used to develop deemed savings estimates

Fixture Count Adjustments

Cadmus field engineers noted discrepancies between reported and observed fixture counts. During the construction phase, participants may re-evaluate their lighting needs and sometimes adjust fixture counts accordingly. For savings evaluation purposes, we adjusted baseline and as-built fixture counts to match observed quantities. In very few instances, Cadmus adjusted lighting power density calculations to account for lower space area and discrepancies in installed fixtures. This resulted in electric savings realization rates ranging from 87% to 104%, with an average of 95%.

Sample Lighting Fixture Average Operating Hours

Cadmus updated operating hours based on lighting schedules observed during the site visits in the calculation of savings. Evaluated sample project lighting fixture measures sometimes operated for different periods than values used in deemed energy savings estimates. This is expected, since the deemed savings estimates rely on assumptions of operating hours across a range of building and usage types. Cadmus evaluated lower average operating hours than reported. This, in conjunction with fixture count adjustments, resulted in reduced energy savings. This type of adjustment, in particular, resulted in the most significant reduction in electricity savings for lighting projects, with realization rates ranging from 47% to 93%, for an average of 75%.

Other Lighting Adjustment Examples

In one project, the PMC did not derate the savings of unqualified CFL fixtures. Cadmus derated the savings for that project using the same methodology the PMC used for other projects. In another project, we estimated a lower eligible floor area based on the as-built architectural drawings. Realization rates for these projects ranged from 58% to 104%, with an average of 91%.

Exterior Lighting

For multiple projects, Cadmus verified that the exterior lighting fixtures were controlled by photocells, independent from their location on site. The PMC used different HOU for exterior lights, based on where these lights are installed on site. Cadmus adjusted the HOU for these lights to be 4,383 hours, based on the Northwest Power Council's HOU estimates for photocell lighting since the control scheme of these exterior lights is similar to how a photocell would operate. The realization rates for 14 projects averaged to 138%.

Lighting Controls

Cadmus did not find a notable problem with the savings of these measures except for one instance where the implementer entered the total controlled wattage in the lighting calculator instead of the wattage controlled by each occupancy sensor. This resulted in overestimated electricity savings. We corrected the error during the evaluation, which resulted in a low realization rate of 15% for this project.

Omnidirectional LED

In one instance, Cadmus could not verify savings for the 750 to 1,049 Lumen Omnidirectional LED measure for a project. These apparently were intended to be standalone lamps not subject to the code requirements for hard-wired lighting. We were not able to locate the omnidirectional LED lamps during our virtual site visit. The PMC’s measure verification form indicated the omnidirectional LED lamps may be corridor sconces, which are hard-wired and already included in the interior lighting calculator. Thus, the 750 to 1,049 lumen LED measure was redundant and the evaluated savings for the measure was zero (realization rate of 0%).

Large and Complex Lighting

Cadmus evaluated interior lighting and controls measures at three large and complex warehouse sites through a separate evaluation process. We encountered several challenges in evaluating these projects. Site security restrictions and tenant privacy concerns prevented us from conducting a typical lighting metering study, where we deploy light loggers or power meters over a period of typical operation. Cadmus successfully conducted live power spot measurements at all three facilities before the tenant at each facility began full operations.

Despite exhaustive attempts to coordinate with all possible parties, we could not evaluate controls-related savings or HOU because neither the developer nor tenant could provide us with the necessary data and they did not permit us to leave any metering equipment in place at the facilities.

To calculate the verified lighting power density and savings, we adjusted the total expected power by the average percentage difference. We also estimated the possible savings from occupancy sensors and daylight harvesting controls installed at all three sites. We attempted to gather specific information about the configuration of the lighting controls at each site and to export data from each EMS. This effort was unsuccessful, so the estimates for the controls savings are based on the Regional Technical Forum’s (RFT’s) lighting controls savings percentage estimates.

As a result, Cadmus' evaluated savings for two projects were very close to the reported savings. For the third project, our evaluated savings and the annual consumption were much higher than reported. The implementer calculated a weighted average HOU for the facility of 4,624 hours per year, then used this value for both the baseline and installed annual energy consumption calculations. Cadmus estimated the baseline hours of use for each space type from the expected shift schedule, assuming no controls would have been installed in the baseline because they are not required in warehouse buildings by Oregon energy code.

We applied 24/7 hours of operation to all fixtures on emergency circuits regardless of where they were installed, all walkways around processing areas, all high bay lighting, and all miscellaneous spaces. We also assumed 24/7 lighting for the processing mezzanine, because without occupancy sensors it is typical for facility operators to leave lights on over processing equipment which operates 24/7 during some part of the year. We assumed lights in the office, administrative, and employee break room areas would only operate 18 hours per day during the eight months that the facility runs with two shifts and would operate 24 hours per day during the remaining four months. We assumed that without occupancy sensors, lighting in the robotic processing areas would only be turned on 10% of the time year-round, when humans enter the processing area to perform maintenance.

Our weighted average baseline hours of use for the facility are 4,966, which is 7% higher than the implementer's weighted average hours of use of 4,624. Measure realization rates ranged from 56% to 110%, with an average of 96%.

HVAC

Prescriptive HVAC projects covered a range of electric and gas space conditioning measures, including economizers, mini-split air conditioners, boilers, furnaces, ventilation, and direct-fired radiant heating. Overall, HVAC realization rates averaged 92% for electricity and 102% for natural gas. The primary findings influencing the savings are for the measures listed below.

Server Room Mini-Split AC Systems

For one project, Cadmus found that several server room mini-split AC systems did not qualify because of their lower SEER rating (0% realization rate). For the same project, we also found that the AC capacity of the qualified systems was lower than the reported value, which led to lower realization rate. For two other projects, we verified higher capacity mini-split units led to increased energy savings (113% and 132% realization rates).

Roof-Top Unit Discrepancies

For one project, Cadmus verified through nameplates and model numbers found on-site that two of the reported roof-top units (RTU) did not qualify for this measure. One RTU's rated capacity was higher than reported, disqualifying it from this measure. The second RTU did not have an economizer. This resulted in reduced energy savings for this measure (70% realization rate).

Refrigeration

Refrigeration measures included equipment such as ice machines and refrigerators, as well as energy efficiency upgrades to equipment, including cooler doors, anti-sweat heater controls, and LED case lighting. For one project, Cadmus disqualified a cooler door measure because the cooler doors were not installed on existing cases as specified in the appropriate MAD. The refrigeration measures in the sample achieved savings that resulted in an electric realization rate of 97% and gas realization rate of 97%.

Food Service and Appliance

The prescriptive food service and appliance category represented equipment used in cooking, dishwashing, and clothes washing. Cadmus verified equipment counts and ENERGY STAR eligibility for these measures. Energy savings adjustments resulted from revised calculations, based on verified equipment quantities. Overall, the realization rates averaged to 97% for electricity, and 105% for natural gas.

The primary findings influencing the savings are for the measures listed below.

Dishwasher

For one site, Cadmus learned during the site visit that the original tenant in the restaurant moved out within one year and took the dishwasher with them (zero savings). For four projects, Cadmus verified larger energy savings due to a discrepancy in selecting the right category of the dishwasher. For one of these four projects, the implementer used ENERGY STAR low temperature multi-tank conveyor savings, but the installed dishwasher is a high temperature multi-tank conveyor, which led to higher energy savings (138% realization rate).

Electric Steam Cooker

For one project, Cadmus estimated smaller electricity savings for the electric steam cooker due to the use of a different MAD version (20% realization rate). The incentive letter for this project was issued in 2018. Cadmus used MAD 101.1 to evaluate the savings, while the implementer used MAD 101.3 (valid starting January 2019) to determine the savings.

Ice Machine

Cadmus identified two instances in which the ice machine savings were incorrectly attributed. Both ENERGY STAR and Consortium for Energy Efficiency (CEE) Tier II machines have the ENERGY STAR label but there is no other label to indicate if these machines are CEE Tier II certified. Cadmus used the CEE's ice machine qualifying product list to verify the savings of the ice machines. For one project, we found that the installed ice machine had a lower harvest rate, which resulted in lower electricity savings (67% realization rate), and for another that was CEE Tier II, the realization rate was 144%.

Low-Flow Fixtures

Cadmus found several discrepancies in the count and rating of the showerheads, shower wands and faucets/aerators. We adjusted the savings of these measure to match the site visits findings. In a few instances, Cadmus disqualified the showerheads savings because of high gallon per minute ratings, which exceeded the program threshold. This reduced energy savings to 86% electric realized savings and 91% natural gas realized savings for 16 measures.

HVAC – Custom

Custom HVAC measures represented a range of projects that either did not fit the specifications needed for deemed measure savings (i.e., boilers with efficiency ratings outside the range used for deemed savings) or complex measures involving interactive effects with other systems. The calculation methodologies primarily involved Excel workbooks and prototypical model assumptions. Cadmus evaluated each measure based on the methodology employed to estimate savings and adjusted savings as necessary. The overall HVAC custom realization rates averaged to 93% for electricity and 88% for natural gas.

Condensing Boilers and Tankless Water Heaters

Cadmus accepted the savings for these measures but noted that the implementer was not consistent in determining the savings. Table 18 shows additional detail about the various methodologies the implementer used to determine the natural gas savings for some of these measures.

Table 18. Condensing Boilers and Tankless Water Heaters Projects

Project	Track	Methodology
P1	System Based	The savings of the 1,000 MBH condensing boiler were based on MAD 88.1. The PMC used the office savings of 2.86 therms per MBH installed.
P2	System Based	The savings of the 1,999 MBH condensing boiler were based on MAD 88.1. The PMC used the weighted average savings of 2.85 therms per MBH installed.
P3	System Based	The customer installed two 2,000 MBH condensing boilers. The therms savings were based on the total heating coil capacity of the various AHUs: 3,000 MBH. The PMC used the total heating coil capacity and MAD 88.1 to determine the savings. for a school the MAD lists 2.84 therms per MBH installed.
P4	System Based	The customer installed a 399 MBH condensing boiler with 92.7% efficiency. The implementer used Energy Trust school prototype energy model to conduct parametric runs to estimate the savings. The baseline model had an 80% thermal efficiency while the proposed model had a 92.7% efficiency. The PMC estimated the savings at 2.3 therms per MBH installed.
P5	System Based	The savings of the four installed tankless water heaters (199MBH each: two with 93% efficiency and two with 94% efficiency) for this gym project were based on average water consumption per square foot, using the following two sources: • Parker, D.S., P.H. Fairey, Florida Solar Energy Center, and J.D. Lutz. June 30, 2015. "Estimating Daily Domestic Hot-Water Use in North American Homes." Presented at 2015 ASHRAE Conference. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf • North Carolina Administrative Code. Eff. September 1, 2006; Readopted Eff. September 1, 2018. "15A NCAC 02T .0114 Wastewater Design Flow Rates." http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20t/15a%20ncac%2002t%20.0114.pdf Savings were estimated at 1.124 therms per kBtu/h installed. MAD 212.2 estimated the savings of a tankless water heater with 199kBtu/h capacity serving a gym/fitness center at 100 therms per water heater (0.5 therms per MBH installed).
15A	System Based	The customer installed a 2,600 MBH condensing boiler with 90% efficiency. The implementer used Energy Trust school prototype energy model to conduct parametric runs to estimate the savings. The baseline model had an 80% thermal efficiency while the proposed model had a 90% efficiency. The PMC estimated the savings at 1.976 therms per MBH installed.

Heat Recovery Ventilator Measures

Cadmus also evaluated several projects that installed heat recovery ventilation systems. We found that the assumptions used to estimate gas savings for each project were generally reasonable and most achieved 100% realization rates for gas. For one measure, we verified a higher cubic feet per minute airflow rate for the heat recovery ventilators on site, which increased the savings (132% realization rate).

These measures also involved an electricity consumption penalty due to the increased fan power needed to overcome the additional static pressure resulting from the heat exchange system. The implementer did not account for the increased electricity usage on a measure or project level. Cadmus did not account for the electric penalties.

Other – Custom

Custom "other" measures primarily include offerings through the Data Center, Market Solutions, and System-Based tracks. We evaluated 99 measures in this category, of which 22 measures involved whole-building projects. The problems encountered with those measures are discussed in the *Whole-Building Track* section below. We did not encounter any major issues with the remaining 77 measures. The higher electric realization rate in 2019 is mainly due to the Data Center measure fitting under this category. Cadmus evaluated savings of one data center based on the site operating at the full load, which increased the energy savings for the installed HVAC system.

Whole-Building Track

Cadmus evaluated 15 projects that fell under Whole-Building track, and eight of them performed to 100% of the expected savings. We did not conduct an energy modeling calibration for most of the Whole Building projects due to missing occupancy data, mainly due to COVID.

Of four projects that received Path to Net Zero (PTNZ) technical assistance, only one project achieved Net Zero. We reviewed the energy usage and production for this project and accepted the reported savings. The remaining three PTNZ projects were not occupied. Cadmus verified that they met the net zero target by reviewing the energy modeling inputs and simulation results.

For four projects, we intended to perform energy model calibration according to IPMVP Option D, but we were only able to conduct a review of the energy models due to the reasons listed below. This track overall performed with realization rates of 99% for electricity and 65% natural gas.

Model Inputs and Outputs Review

There were two core and shell projects where the implementer estimated the savings by assuming what would be the operation of the tenant fit-out area. For both projects, Cadmus toured the core areas and was able to verify the HVAC equipment. However, due to COVID-19, we did not have access to the tenant areas of one building, while around 90% of the tenant areas of the other building had not yet been constructed. Instead of performing a full calibration, we reviewed the energy model inputs and outputs and confirmed that they were reasonable and correct.

For one project, as of the time of the site visit, only a small number of staff occupied the building (approximately 25 people) and only on some floors. For another project, utility billing data that represents 12 months of typical building operation had not yet been recorded. The building was occupied in August 2019, and in March 2020, all students were sent home due to the COVID-19 pandemic. Therefore, utility billing data that represented typical building operation were not yet available. There was no basis for model calibration available for both projects. Instead of performing a full calibration, we reviewed the energy models inputs and outputs and confirmed that they were reasonable and correct.

Model Calibration

Cadmus and another evaluation contractor conducted model calibrations. Table 19 shows details of these six modeling calibration projects in addition to a seventh whole building project that did not have an energy model, but had variance from reported savings. For four calibration projects (39, 50, 79 and 124), we were not able to obtain trend data from the customers. Project 79 deleted the data following a reset to their Building Automation System. Project 124 was a police training facility that did not want provide trend data to our analyst. Projects 39 and 50 did not have trends. Our analyst was only able to see the room setpoints in the BAS. Details on each project follows the table.

Table 19. Whole Building Projects with Variance from Reported Savings

Project	Building Type	Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electric RR[a]	Gas RR
39	K-12 School	150,624	78,113	6,195	6,353	52%	103%
50	Lodging/Hotel/Motel	411,108	582,442	401	390	142%	97%
79	Office	316,998	146,247	13,157	11,170	46%	85%
97	University (Other)	187,742	171,393	2,664	2,664	91%	100%
124	Warehousing and Storage	167,488	174,252	672	344	104%	51%
130	Hospital (Other)	2,766,072	3,261,052	49,006	18,675	118%	38%
131	Hospital (Other)	1,631,435	1,712,914	212,749	93,251	105%	44%

[a] RR = realization rate

Project 39

The original energy model for this school project had an occupied schedule during the summer months and its annual electricity consumption profile predicted peak use during the months of June, July, and August. However, the school's posted academic calendar showed that the school was not in session during the summer months. The utility data support this by showing lower consumption during the summer months than during the regular school year. To bring the modeled electricity consumption into alignment with the utility billing data, the calibrated energy model used a holiday schedule for the summer months, which represented reduced occupancy compared to the rest of the regular school year. The holiday schedule still assumed some special-event use during the summer. The electricity consumption did not drop to zero during these months, but these months still represented the lowest part of the annual electricity use profile, rather than the peak. Reducing to a lower occupancy schedule during the summer months eliminated much of the opportunity to realize space cooling and fan energy savings that were originally anticipated.

Project 50

The original model for this lodging project significantly underestimated electricity use by more than 40%. The original energy model assumed heating and cooling space temperature setbacks would be in place for the guestrooms. However, during the site visit Cadmus found that the room temperature setpoints are set by the guests. Therefore, it is likely that the guests are not manually setting back temperatures overnight as originally assumed, leading to larger heating and cooling loads than originally planned. The original energy model's lighting schedule assumed very low use during the daytime hours, ranging from about 15% to 30%. However, the Cadmus site visit confirmed that the corridor lights operate at 100% during the day, and the other common area lights operate at 90% during the day, which resulted in much longer hours of use for the lighting than originally planned. Cadmus increased the heating, cooling, and lighting loads to calibrate the model, which allowed the efficient proposed systems to realize higher electricity savings.

Project 79

Cadmus calibrated the energy model for this office project using the 2019 electric and gas bills. Cadmus learned from the site contact that their building needs to be recommissioned because it is not operating as expected and it is consuming around 40% more electricity than expected. The site could not provide any 2019 trend data because it had to reset its control system and lost all pre-pandemic data. Cadmus calibrated the energy model based on its discussion with the site contact. Unfortunately, the HVAC system operation is resulting in a large electric penalty that would wipe all the electric savings of the remaining measures.

Following discussion with Energy Trust and the PMC, Cadmus agreed to calibrate the proposed model based on the inefficient operation of the system. However, we adjusted the dedicated outdoor air system to operate as expected. Then, we applied the PMC's methodology of adjusting the measure-level modeled savings to account for the lower interactive savings of the calibrated model. We proportionally split the interactive model savings of among the respective measures. Overall, we calculated an electric realization rate of 46% and a gas realization rate of 85%.

For this project, Cadmus used the metered data to estimate the regenerative elevators savings. Analysis of the metering data showed that for every 100 kWh of gross energy consumed in the elevator motors, approximately 24 kWh of electrical energy was recovered and fed back into the building circuit for use in other building systems. Thus, we found that these elevators are saving around 24% of the baseline energy instead of the 39% the PMC used in their model. Note that the metering data were not used to inform the elevator scheduling assumptions, as the building was minimally occupied due to COVID-19 measures; thus, the metered utilization of the elevators is not representative of normal conditions. Cadmus adjusted the energy model using the 24% savings factor for this measure and estimated the total savings with an electric realization rate of 77%.

Project 97

Although this university project was categorized as a Whole-Building project, it did not have an energy model. Most of the electric savings (89%) were the result of installing efficient LED lighting fixtures. We re-created the savings calculation using the provided project documents, fixture cutsheets, and site visit data collection notes. The implementer did not account for two fixture types which appear on the as-built drawings that the site contact shared with our analyst. Including these two fixture types increased the overall installed wattage, which reduced the energy savings relative to the code baseline.

Project 124

Cadmus calibrated the energy models for this warehousing and storage project, which resulted in slightly higher electricity savings and much lower natural gas savings. We could not collect any trend data for this project, but we were able to verify all the installed equipment during our site visit and the facility was not affected by COVID-19.

Cadmus used the ASHRAE 90.1-2016 method to determine the infiltration of the building and adjusted the miscellaneous plug loads for a couple spaces. Our model calibration showed some gas savings resulting from the installation of an efficient domestic hot water system measure and zero gas savings from the remaining implemented HVAC measures. The reported gas savings for the remaining implemented HVAC measures was relatively small (188 therms) and were reduced due to infiltration adjustments. Overall, we calculated an electric realization rate of 104% and a gas realization rate of 51%.

Project 130

Energy Trust contracted with another firm to evaluate the savings on this large and complex hospital project. The evaluator found that the eQuest model was largely consistent with actual building operation. The evaluator made minor adjustments to reflect parameters verified on site for equipment and control settings. The evaluator then calibrated the energy models and found that the actual natural gas heating loads were significantly higher than expected.

The evaluator found larger electricity savings, primarily due to high cooling loads in the summer as a result of the changes made to the temperature schedules. The gas savings decreased largely due to higher heating loads during the winter that resulted from increases made to the ventilation rates in some areas of the facility in the post-case model. The decrease in gas savings represented a major impact to the overall 2018 program savings due the relatively large amount of reported savings.

Project 131

Energy Trust contracted with another firm to evaluate the savings on this large and complex hospital project. The evaluator found that the OpenStudio model was largely consistent with actual building operation. The evaluator made minor adjustments to reflect parameters verified on site for equipment and control settings. As with Project 130, the evaluator then calibrated the energy models and found that the actual natural gas heating loads were significantly higher than expected.

The evaluator identified multiple sources of error upon review of the OpenStudio model of the building and, as well as the EnergyPlus model used to simulate the central plant. It appears the most significant source of error was that OpenStudio does not have built-in tools for modeling systems with chilled beams. The *ex ante* proposed model was configured with variable air volume systems with terminal reheats, which operate very differently than the installed chilled beam systems. There were several key differences between the modeled HVAC system and the installed chilled beam system, as well as between the modeled central plant operation and how the plant actually operated. After exhaustive testing of different HVAC system configurations in the OpenStudio models, the evaluator could not develop a logical workaround to adequately model the operation of the facility's HVAC system. As an alternative to calibrating the proposed model to the actual gas use of the facility, the evaluator compared the actual gas use of the facility to the baseline model to determine the gas savings for this project. This resulted in a considerable decrease in gas savings. The decrease in gas savings represented a major impact to the overall 2018 program savings due the relatively large amount of reported savings.

Demand Analysis Findings

Cadmus calculated summer and winter peak demand savings through electric load profiles and peak demand factors provided by Energy Trust. We first reviewed the reported load profiles for each measure. For some measures, we found that the assigned load profiles varied with no consistency. For example, we examined five restaurant projects with Dishwasher–Single Tank Door/Upright–Low Temp–Gas WH measures installed, but two of the five projects were assigned "Res Water Heat" load profiles while the remainder were assigned "Flat – ele" load profiles. However, Cadmus noted that none of the assigned load profiles matched ones that were likely more consistent with measure operation and demand savings, such as the RTF's restaurant hot water profile. We revised the load profiles where necessary to better align with the measure's operation

We then multiplied the evaluated savings for each measure by the applicable demand factor. We combined the evaluated peak demand savings for the sample projects to determine total peak demand reduction for each building type and track, as shown in Table 20 through
Table 23. The key equations for this analysis are as follows:

$$Measure\ Peak\ Demand\ Savings\ (kW) = Measure\ Electricity\ Savings\ (kWh)\ x\ Peak\ Multplier$$

$$Total\ Peak\ Demand\ Savings\ (kW) = \sum Measure\ Peak\ Demand\ Savings\ (kW)$$

Table 20. 2018 Evaluated Demand Savings by Building Type

Building Type	Evaluated Winter Peak Demand Savings(kW)	Evaluated Summer Peak Demand Savings(kW)
Assisted Living	78	61
Data Center	27	27
Lodging/Hotel/Motel	127	114
Multifamily	2,092	1,161
Office	304	280
Warehousing and Storage	2,390	2,135
Grocery/Retail	567	572
K-12 School	296	279
Food Service	54	49
Other	1,883	1,656
Total	**7,817**	**6,334**

Table 21. 2019 Evaluated Demand Savings by Building Type

Building Type	Evaluated Winter Peak Demand Savings(kW)	Evaluated Summer Peak Demand Savings(kW)
Assisted Living	476	363
Data Center	581	550
Lodging/Hotel/Motel	321	280
Multifamily	2,608	1,776
Office	795	761
Warehousing and Storage	410	370
Grocery/Retail	93	83
K-12 School	501	486
Food Service	33	29
Other	1,318	848
Total	**7,136**	**5,546**

Table 22. 2018 Evaluated Demand Savings by Track

Building Type	Evaluated Winter Peak Demand Savings(kW)	Evaluated Summer Peak Demand Savings(kW)
Data Center	27	27
Market Solutions	1,878	1,323
System-Based	4,148	3,763
Whole-Building	1,765	1,221
Total	**7,817**	**6,334**

Table 23. 2019 Evaluated Demand Savings by Track

Building Type	Evaluated Winter Peak Demand Savings(kW)	Evaluated Summer Peak Demand Savings(kW)
Data Center	581	550
Market Solutions	2,440	1,633
System-Based	2,934	2,591
Whole-Building	1,181	773
Total	**7,136**	**5,546**

Conclusions and Recommendations

Cadmus conducted an impact evaluation of the 2018-2019 Energy Trust New Buildings program by analyzing energy savings for a sample of 830 measures implemented across 129 projects. The measures belonged to four different project tracks (Data Center, Market Solutions, System-Based, and Whole-Building) and represented a variety of subcategories. The overall 2018 program electricity and gas realization rates were 98% and 81%, respectively. The overall 2019 program electricity and gas realization rates were 97% and 101%, respectively.

Energy Trust and the PMC applied the appropriate methodologies and assumptions for many measures; however, Cadmus' evaluated savings differed from reported energy savings for 74 of 129 projects in the sample. For many measures, the data we used to evaluate energy savings differed from those used to estimate reported savings based on site verification and phone interview findings, including equipment counts, heating and cooling loads, and controls settings based on participant feedback.

Overall, the 2018-2019 program implementer performed a reasonable level of review and quality control to achieve high average project savings and realization rates. The measure types with the lowest evaluated savings were in the HVAC (both custom and prescriptive) and food service and appliance measure categories, as well as in the food service, K-12 School, warehousing and storage, "other," and office building types.

Recommendations

Cadmus identified several areas for program improvements. The most significant involve changes in tracking energy use for simulation modeling and methods for reporting to improve future evaluation efforts. There are also steps the implementer can take to ensure appropriate measure installations and encourage participants to collect data useful for ongoing commissioning and evaluation efforts.

Cadmus recommends the following actions to improve ongoing evaluation efforts and the program overall.

Maintain Consistent Documentation on Simulation Model Files

Cadmus found the project documentation for simulation projects was inconsistent from one project to the next, especially those projects modeled in IESVE software. This made it difficult to determine the appropriate savings and relevant material to support energy savings. The implementer should consistently categorize and clearly label the basis of the final incentive, supporting documentation (including any post-processing calculations performed on the raw model output), final incentive amount, and simulation models across all projects. There should be no need to provide superseded versions of any documents as this is likely to confuse outside reviewers, including the evaluators.

Ensure Simulation Models Match Approved Savings

Multiple project files included simulation models that did not match the final approved building performance energy savings calculations. The implementer should clearly label the models with the information they provide or version they represent. We also recommend the implementer verify that the final models match the reported energy consumption output. In addition, we recommend the implementer indicate which version of the modeling software it used and the Typical Meteorological Year weather file.

Encourage Participants to Enable Energy Management System Trends

In general, new construction facilities have EMS and are capable of enabling trending on major equipment and controls systems. These data are critical to the evaluation effort and can also provide important information to the participant about how the facility is operating. However, we were not able to obtain trend data for any of the projects that used simulation modeling to calculate energy savings. For any projects that will be evaluated using simulation model calibration according to IPMVP Option D, trend data are beneficial to inform adjustments during the calibration process. Otherwise, we must rely on equipment metering or educated assumptions regarding the specifics of the building systems operations and modeled energy end-use breakdowns.

We recommend that Energy Trust and the implementer consider methods to encourage participants to enable EMS trending. Options could include a bonus incentive or requiring trending as a condition for an incentive on any project with savings estimated based on a whole building simulation model.

Obtain Mechanical As-Built or Construction Documents

All projects using energy simulation modeling are evaluated using model calibration. As such, the implementer should provide basic design documentation so any third party can quickly develop a clear understanding of the building. This includes a full set of mechanical/HVAC drawings and equipment schedules. Additionally, the implementer should provide HVAC system controls documentation, including sequences of operation for all major system types to inform the model adjustments necessary for calibration.

Update Exterior Lighting Calculations

We recommend that the PMC use the Northwest Power Council's HOU estimates for photocell lighting for the exterior lights that are connected to the same photocells' controls. The PMC used different HOU for exterior lights, based on where these lights are installed on site.

Use Consistent Methodology to Estimate Same Measures Savings

We suggest the implementer follow the same methodology to estimate the savings of the same measure implemented across multiple projects. For example, Cadmus found a variety of methodologies used to estimate condensing boiler and tankless water heater savings. Also, Energy Trust should determine if it wants negative kWh and therm penalties to be calculated for interactive effects and be consistent about either reporting them or not.

Update Market Solutions Multifamily MAD

We recommend that Energy Trust update the MAD used for Market Solutions Multifamily savings. The PMC used MAD 163.1 to estimate the savings for the base and elective multifamily measures. The MAD mentions that these savings were obtained using a multifamily model that was 12-story, 198-unit building with a floor area of 220,050 sq ft. The PMC correctly used the project's floor area and per-square-foot values to calculate savings for the base and some elective measures.

However, the calculations take an unusual turn for other elective measures. For other measures like the high-performance bathroom fans and PTHPs, the PMC used the original modeled savings to create a per-unit energy savings rather than applying the per-square-foot values in the MAD. We adjusted the PTHP savings to kWh per-square-foot, as specified in the MAD, but kept the kWh per-unit savings for the bathroom fans.

Document the Utility Meter Serial Numbers

We recommend the implementer document the meter numbers during their site visits. For projects that require energy modeling calibration, the evaluator would run the simulations ahead of the site visit to determine the inputs that need to be verified thoroughly. Having the utility meter serial numbers ready allows the evaluator to start the evaluation process before the site visit. Also, large sites have multiple utility accounts associated with them. Having the utility meter serial numbers would facilitate pulling the utility data specific the project or building under verification.

Develop Demand Methodology to Report Savings

The peak multiplier method currently employed by Energy Trust to estimate demand savings is not sufficiently rigorous to accurately account for demand impacts. Cadmus recommends that Energy Trust develop methods to report peak demand savings for each project in future program years. Utilities throughout the country have already performed extensive work to characterize peak demand savings estimates. We recommend that Energy Trust examine demand savings methods employed in Technical Reference Manuals for comparable states and utilities. That information can be used as the basis by which Energy Trust can begin developing a database of peak coincidence factors for prescriptive measures, as well as identifying more rigorous methods to calculate demand impacts from custom measures.

The effort to characterize peak demand savings is made even more urgent by recent events—a record-breaking heat wave in June 2021 that resulted in heavy air conditioning loads on the electric grid as well as Oregon House Bill 2021 to decarbonize the electric grid by 2040. At the same time, there are local and national efforts to decarbonize transportation and space and water heating that will result in continued increases in electric demand. Reliable estimates of peak demand savings achieved through Energy Trust's programs will be critical to future integrated resource planning efforts.

Apply Consistent Load Profiles Specific to Measure Types

We recommend that Energy Trust apply consistent load profiles in estimating demand savings for measure and building type combinations. Energy Trust should also consider the broader range of RTF load profiles rather than relying on a limited set of them. For example, Energy Trust could have assigned more granular load profiles to dishwasher measures on a consistent basis, such as restaurant hot water rather than residential hot water.