2011 New Buildings Program Impact Evaluation

October 29, 2013

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Executive Summary

Energy Trust of Oregon retained Cadmus to complete an impact evaluation of the 2011 New Buildings Program, a comprehensive effort to assist owners of newly constructed or substantially renovated commercial and industrial buildings to achieve energy savings through three different tracks: Standard, Custom, and LEED. These tracks are described as follows:

- The Standard Track supports prescriptive equipment measures, such as lighting, motors, HVAC, and others, through deemed savings.
- The Custom Track provides incentives to reduce a building's energy use below a minimally code-compliant value. Measures usually involve more complex energy savings analysis than do prescriptive measures.
- LEED Track projects receive incentives for achieving energy savings as part of certification by the U.S. Green Building Council.

A third-party program management contractor, Portland Energy Conservation, Inc. (PECI), implemented the 2011 New Buildings Program.

The 2011 study, conducted by Cadmus, evaluated projects permitted under both the 2007 Oregon Structural Specialty Code and the recently-adopted 2010 Oregon Energy Efficiency Specialty Code (OEESC). The 2010 code exceeded energy savings requirements for the 2007 code and required PECI to develop new calculation methods for deemed savings measures (such as economizers).

For the 2011 evaluation, Cadmus sampled 40 projects, matching the evaluation quantity requested by Energy Trust. The sample included 16 of the largest savings projects (all with reported savings greater than 2,000 MMBtu[1]) and a random sample of 24 smaller projects. As shown in Table 1, the final sample represented 71% of the program's total reported, combined savings.

Table 1. 2011 Program and Sample Total Quantities and Reported Savings

	Total Projects	Total Measures	Reported Savings		
			Electricity (kWh)	Gas (therms)	Combined Energy (MMBtu)
Program Total	291	1,235	39,980,570	788,302	215,244
Sample Total	40	228	30,167,347	506,823	153,613

Cadmus evaluated the program through site visits and reviews of engineering calculations and building simulation models. During site visits, we validated the proper installation and functioning of equipment

[1] Btu stands for British thermal units. MMBtu is used throughout this report to represent million Btu.

for which incentives were provided and recorded operational characteristics data to support our engineering analysis. We evaluated the Standard Track measures primarily using industry-standard algorithms. We analyzed measures installed in the Custom Track through algorithms, detailed calculation spreadsheet reviews, simulation modeling, and/or energy management system (EMS) trend data. Cadmus engineers analyzed the differences between baseline and as-built simulation models for LEED projects. Through this impact evaluation, we identified a variety of factors that reduced the overall program realization rate (the ratio of evaluated to reported savings), as shown in Table 2. Savings values listed in the impact evaluation are gross values. Calculation of a net-to-gross ratio fell outside the scope of this evaluation.

Table 2. Overall 2011 Program Realization Rates and Energy Savings

Measure Category	Total Measures*	Reported Savings*		Evaluated Savings*		Realization Rate	
		Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
Standard Food Service	174	2,002,170	39,461	1,997,594	40,580	100%	103%
Standard HVAC	186	512,989	97,883	509,288	102,628	99%	105%
Standard Lighting	469	3,717,814	0	3,524,029	0	95%	N/A
Standard Motors	79	497,527	0	333,077	0	67%	N/A
Standard Water Heating	143	365,385	42,257	425,977	42,135	117%	100%
Custom	100	9,657,102	218,370	8,468,144	182,800	88%	84%
Custom Food Service	42	1,739,329	71,626	1,732,462	70,395	100%	98%
LEED	33	5,409,556	308,900	5,104,045	277,759	94%	90%
Retired Measures	6	103,649	9,805	103,649	9,805	100%	100%
Total 2011 Population	**1,232**	**24,005,521**	**788,302**	**22,284,382**	**726,100**	**93%**	**92%**

* The total number of measures and electricity savings excludes three Custom measures from a large facility which has yet to be evaluated. Cadmus will finalize the report after evaluating that project.

Total combined reported energy savings (electricity and gas) represented 215,244 MMBtu. One facility with three Custom projects comprised a large portion of overall program savings, but Cadmus will not evaluate its savings until a third-party firm completes a post-occupancy evaluation. The remaining combined reported energy savings represented 160,737 MMBtu. Cadmus calculated the total combined evaluated energy savings, without the three unevaluated Custom projects, as 148,644 MMBtu, for a 92% overall realization rate for 2011 measures evaluated to date.

When combining all measure categories, the Standard Track population achieved an overall realization rate of 99.6%. The Custom Track population achieved an overall realization rate of 89%.

Most measure types achieved high realization rates. The overall program energy savings were primarily reduced by adjustments to Custom and LEED project energy savings. The 2011 program savings realization rate of 92% is slightly less than the 97% in 2010 and the 96% in 2009. The primary factors that lowered the overall realization rate were:

- Our verification process showed that some incented equipment only met baseline code efficiency and not the program requirements.
- Evaluated equipment operation differed from the expected patterns used to develop deemed savings estimates. This was usually either due to differences in as-built energy consumption or different applications than predicted for deemed savings.
- The verified cooling loads for one large project and heating loads for two large projects were much lower than reported in the incentive calculations.
- Observed equipment quantities differed from reported quantities.
- Building simulation models did not accurately reflect as-built conditions or operating parameters.
- A participant did not implement one incented measure.

Other findings that Cadmus identified included:

- A contractor submitted a custom residential HVAC project that was approved for the New Buildings program based on inaccurate information about the building's use. This project did not receive an inspection by the program management contractor because it was relatively small and did not get included in the 10% random sample of completed projects.
- Cadmus sometimes had difficulty obtaining the correct modeling files and calculations on whole building simulation projects for the Custom and LEED tracks. In several cases we had difficulty following the documentation between similar projects or determining whether the models matched those used to determine reported energy savings.
- We found limitations on data that would have been helpful to determine equipment operating patterns or calculate energy consumption for various end uses. In some cases, the participant had installed an energy management system but not enabled trending capabilities. In two cases, the building represented a portion of a larger campus served by a central steam plant or campus-wide gas service. The buildings did not have submeters to record energy consumption for their portion of the overall system. The lack of consumption data on these two projects limited our ability to calibrate their whole building simulation models. In addition, the project with a central steam plant did not account for the steam plant's conversion efficiency.

As a result of our evaluation, Cadmus recommends the following opportunities for Energy Trust to consider program improvements.

- Develop “sanity checks” to approve projects.
- Obtain energy simulation models during program year.
- Maintain consistent documentation on simulation model files.
- Ensure simulation models match approved savings.
- Encourage participants to enable energy management system trends.
- Obtain calculation sheets for exceptional calculations.
- Require energy metering for project not directly served by utility services.
- Ensure that incentives correctly account for all utility types.

Overall, the 2011 program implementer performed a reasonable level of review and quality control to achieve high average project savings realization rates. The measure types with lower evaluated savings represented large, complex measures whose final operating patterns can be difficult to predict, particularly in a new construction application. The implementer has continually worked to streamline and improve the program’s delivery mechanisms, and we believe their work has been effective.

MEMO

Date: February 28, 2014
To: Board of Directors
From: Sarah Castor, Evaluation Sr. Project Manager
Jessica Rose, Business Sector Manager, New Buildings Program
Subject: Staff Response to the 2011 New Buildings Program Impact Evaluation

The results of the 2011 New Buildings Impact Evaluation show that the program's overall realization rates remained close to those from 2009 and 2010, and the program management contractor (PMC), PECI, is doing a good job of estimating savings on average.

Energy Trust worked with Cadmus to further investigate the case of a large central utility plant project that had a very low realization rate due to lower-than-assumed load on its chillers. The conclusion that we reached was that the program did everything in its power to correctly estimate the plant load and in fact more load may have been added since the evaluation site visit. Program staff are following up with the participant to ascertain the current planned load and another site visit will be conducted by Cadmus in 2014 to gather additional data and information on plant loading and potentially revise the 2011 program realization rates. Energy Trust intends to explore alternative ways to claim savings for phased projects, as well as processes for evaluating those projects to avoid having to visit a site multiple times. We appreciate the excellent help from both PECI and Cadmus in understanding the reasons for the low initial realization rate for this project.

The evaluator made several specific recommendations for program improvements based on 2011 project findings (in italics), many of which the program has already addressed, or will address as follows:

- *Develop "sanity checks"*
  The program will discuss sanity checks to identify potentially problematic projects before they submit applications for prescriptive incentives.

- *Obtain energy simulation models during program year*
  Since receiving this recommendation in late 2010 through the 2008 Impact Evaluation report, the program began collecting model files for all LEED and modeled projects. Starting in October 2010, the LEED application terms and conditions required project owners to provide Energy Trust with the energy simulation models and inputs. The program has collected modeling files for all projects that applied for LEED incentives after October 2010.

  The program has always collected and reviewed modeling files and spreadsheet calculations for Custom and Modeled Savings projects.

- *Maintain consistent documentation on simulation model files*
  For LEED projects, the program keeps each version of model files in separate folders

each with the date of submission. Additionally, the program has updated the review memo template for both LEED and modeled savings projects that are submitted by the project representative or energy analyst. The LEED review memo specifies the names of all final documentation. For modeled savings, the review memo details the final savings for each measure, which are checked against the savings in the approved Savings Summary Worksheet. Going forward, the basis of the final incentive, supporting documentation, final incentive amount, and simulation models will be categorized consistently and clearly labeled for each projects in the program.

- *Ensure simulation models match approved savings for LEED projects*
  Currently the program reviews model input/output files but does not run the models unless there is a significant reason due to discrepancies. The program could re-run each model to verify that the models match the energy consumption output on a gross savings level. If a discrepancy is found, the program would most likely need to make any adjustments without support from the design team, since most LEED projects are reviewed after construction and certification and the energy analyst does not receive technical assistance incentives. PECI will review the benefits and drawbacks to this approach with Energy Trust and document the final agreed-upon process in the Program Implementation Manual.

  The program agrees that the models should be clearly labeled with what information they support. If the program opens and runs each model in the process described above, the team will ensure that models are labeled appropriately.

- *Encourage participants to enable energy management system trends*
  Given the usefulness to evaluation as well as participant energy performance monitoring, the program will suggest that energy management systems have trending enabled at the end of the project.

- *Obtain calculation sheets for exceptional calculations*
  The program currently, as a process step, does place all exceptional calculation workbooks, simulations, and associated documentation in the project files. PECI will ensure the final version of each exceptional calculation, including methodology and source, is included in the project file.

- *Require energy metering for projects not directly served by utility services*
  Recognizing the value to the evaluation and participant, the program will recommend that campus buildings with multiple fuel sources submeter each fuel source. The program will not require it for incentive eligibility.

- *Ensure that incentives correctly account for all utility types*
  For buildings connected to central steam plants that are eligible for incentives, the program will include central plant steam savings when calculating savings for that building.

Introduction

Energy Trust of Oregon retained Cadmus to complete an impact evaluation of the 2011 New Buildings Program. Cadmus worked with a subcontractor for this evaluation, SBW (collectively referred to as the Cadmus team).

The New Buildings Program comprehensively seeks to assist owners of newly constructed or substantially renovated commercial and industrial buildings in achieving energy savings through these three different tracks:

- The Standard Track supports prescriptive equipment measures, such as lighting, motors, HVAC, and others, typically through deemed savings and rebate values.
- The Custom Track provides incentives to reduce a building's energy use below the code-compliant minimum value. Included measures typically involve more complex energy savings analyses than prescriptive measures.
- The LEED Track projects receive incentives for achieving energy savings as part of certification by the U.S. Green Building Council.

For the 2011 program year, the implementer also included a category for "retired measures." These measures were typically ones for which the Regional Technical Forum revised the measure's savings methodology. One example, for which Cadmus evaluated three measures, involved LED case lighting. In the retired measure, savings were quantified by linear feet of refrigerated case doors, while the new methodology required savings to be quantified by linear feet of lamps.

Portland Energy Conservation, Inc., (PECI), a third-party program management contractor, managed the 2011 program. During the 2011 program year, 291 projects received incentives through the Standard, Custom, and LEED Tracks. Cadmus engineers analyzed differences between baseline and as-built simulation models for LEED projects.

Table 3 through Table 7 show the total number of measures and first-year reported energy savings for each track for the 2011 program year. The Standard and Custom Tracks have been further divided into subcategories, based on measure categories.

Table 3. 2011 Standard Track Total Measures and Reported Savings

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
Standard Food Service	174	2,002,170	39,461
Standard HVAC	186	512,989	97,883
Standard Lighting	469	3,717,814	0
Standard Motors	79	497,527	0
Standard Water Heating	143	365,385	42,257
Standard Track Total	1,051	7,095,885	179,601

Table 4. 2011 Custom Track Total Measures and Reported Savings

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
Custom	103	25,632,151	218,370
Custom Food Service	42	1,739,329	71,626
Custom Track Total	145	27,371,480	289,996

Table 5. 2011 LEED Track Buildings and Reported Savings

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
LEED	33	5,409,556	308,900

Table 6. 2011 Retired Measures

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
Retired Measures	6	103,649	9,805

Table 7. 2011 Total Program Measures and Reported Savings

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
Total 2011 Program	1,235	39,980,570	788,302

The 2010 Oregon Energy Efficiency Specialty Code (OEESC) took effect on October 1, 2010. The new code applied to some completed projects in the 2011 program year. Table 8 below lists the 2011 program population by prevailing energy code. The prevailing energy code is indicated by the year ("07" or "10") preceding the program track.

Table 8. Measure Population of 2007 and 2010 Energy Code Measures

Program Track	Quantity of Measures	Reported Electric Savings (kWh)	Reported Gas Savings (therms)
07 Custom	38	18,969,066	4,706
07 LEED	32	5,383,489	308,900
07 Standard	645	3,116,357	109,574
07 Standard / Custom	233	9,508,686	273,705
07 Standard / ESTAR	5	6,286	368
10 Analysis Only	7	119,846	842
10 LEED	1	26,067	0
10 Prescriptive & Analysis	50	818,747	25,557
10 Prescriptive Only	176	1,248,065	47,745
Core Performance Pilot	12	206,857	9,879
LRM ESTAR	6	37,970	152
Net Zero Pilot	30	539,134	6,874
Total	**1,235**	**39,980,570**	**788,302**

PECI did not list the prevailing energy code for the 11 projects in the Core Performance Pilot, Low-Rise Multifamily ENERGYSTAR (LRM ESTAR), and Net Zero Pilot tracks, so Cadmus could not specify the breakout by energy code for those projects. Measures permitted under the 2010 code represented 20% of the total remaining population, indicating the program has begun the transition from the older code. Cadmus anticipates the process will take several years due to the long timelines associated with new construction projects.

The following section presents Cadmus' methodology for evaluating the 2011 program.

Methodology

To verify reported program participation and estimate gross energy savings in the impact evaluation, Cadmus estimated changes in gross energy consumption using data collected on site, program tracking data, and engineering models.

We used the following approaches to determine the gross energy savings attributable to the program:

- Sample development
- Data collection
- Engineering analysis
- Calibrated simulation 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.

Sampling Methodology

Cadmus has evaluated the New Buildings Program for 2008, 2009, and 2010. Energy Trust and Cadmus agreed at the beginning of the 2010 evaluation process that a mix of large and small projects with a sample size of approximately 40 sites per year should be sufficient to capture a sufficiently accurate assessment of program performance.

Cadmus converted energy and natural gas savings into millions of British thermal units (MMBtu), providing a standard metric for comparing projects. Most projects contained a range of measures, with varying savings levels. We selected a census of 16 projects with more than 2,000 MMBtu in energy savings, meeting Energy Trust's request to evaluate a large portion of program savings. We selected a random sample of 24 projects from a list of smaller saving projects.

To acquire the necessary documentation, Cadmus provided the list of sample projects to Energy Trust staff. Cadmus also reviewed Standard track projects to ensure the sample contained all major measure types as well as a representative quantity of standard practice measure types. Energy Trust and the implementer noted several measures of interest during the 2010 evaluation kickoff meeting. These measures represented either emerging technologies or ones that are expected to make up a significant portion of program savings in future years.

Cadmus determined, in conjunction with Energy Trust, to sample almost all measure categories of interest, as shown in Table 9. One exception was tankless water heaters in restaurants because there were only two such projects in the program population, and both sites reported relatively low energy savings.

Table 9. Evaluation Measures of Interest

Measure	Relevant Projects in Sample
Tankless water heaters in restaurants	0
Variable refrigerant flow system	1
Mixed use buildings	4
Demand controlled ventilation	3
Grocery refrigeration	6
Condensing boilers	1

One project in the initial sample declined to participate, citing the potential disruption to the facility's residents. Cadmus selected an appropriate replacement site with similar measures to maintain the sample of 40 projects. The final sample represented 71% of reported program savings.

At Energy Trust's request, Cadmus did not conduct site verification for the largest project in the sample. Energy Trust staff noted this participant had already received multiple verifications and would likely be the subject of a post-occupancy study by a third-party firm. Cadmus agreed to review the results of the post-occupancy study and use the findings to evaluate the facility's energy saving performance, if that information is made available before the end of 2013.

Table 10 shows sample and population details for 2011 projects. Cadmus conducted verification and analysis on all measures for each project in the sample, except the largest project.

Table 10. 2011 Reported Program Evaluation Sample Details

	Total Projects	Total Measures	Reported Electricity Savings (kWh)	Reported Gas Savings (therms)	Reported Combined Energy Savings (MMBtu)
Program Total	298	1,235	39,980,570	788,302	215,244
Sample Total	40	228	30,167,347	506,823	153,613
Sample Portion of Program Total	13%	18%	75%	64%	71%

As shown in Table 11, the final evaluation sample represented a cross-section of major measure categories and types, with Custom measures representing the largest category of energy savings.

Table 11. Sample Reported Energy Savings by Measure Category

Measure Category	Total Measures	Reported Electricity Savings (kWh)	Reported Gas Savings (therms)
Standard Food Service	45	1,242,642	11,107
Standard HVAC	28	322,667	22,018
Standard Lighting	49	872,320	0
Standard Motors	30	298,026	0
Standard Water Heating	25	37,629	8,880
Custom	18	23,169,989	188,734
Custom Food Service	20	1,430,049	50,377
LEED	10	2,697,006	225,708
Retired Measures	3	97,019	0
Total 2011 Sample	**228**	**30,167,347**	**506,823**

Cadmus calculated the sampling precision to determine whether it was acceptable, based on standard statistical levels of rigor to extrapolate sample energy savings to the overall program population.[2] For each of the three tracks, Cadmus determined the confidence interval (precision) for a 90% confidence level, and we found the sample exceeded a 90/10 level, as shown in Table 12. The sample precision estimate excludes the one large site that is yet to be evaluated.

Table 12. 2011 Sample Precision

Track	Confidence Level	Confidence Interval
Standard	90	±4.1%
Custom	90	±6.4%
LEED	90	±7.5%
Total	90	±3.0%

For comparison purposes, Table 13 shows distributions of measure savings in the overall program and sample population, minus the one project still to be evaluated. Though the sample distribution was very consistent with the overall program project savings distribution, the sample featured less prescriptive savings and a larger proportion of the more complex Custom measures, which generally involved greater energy savings and required more analysis. These distribution differences were consistent with the process used for selecting projects that saved more energy.

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2 The confidence level and interval determine precision. Values for Standard track projects, for example, indicate Cadmus can be 90% certain, based on sampling error, the population value falls within ±4.1% of evaluated savings.

Table 13. Total and Sample Measure Portions of Energy Savings

Measure Category	Population Measure Energy Savings (MMBtu)	Portion of Total Measure Savings	Sample Measure Energy Savings (MMBtu)	Portion of Sample Measure Savings
Standard Food Service	10,778	7%	5,351	5%
Standard HVAC	11,539	7%	3,303	3%
Standard Lighting	12,685	8%	2,976	3%
Standard Motors	1,698	1%	1,017	1%
Standard Water Heating	5,472	3%	1,016	1%
Custom	54,787	34%	43,423	44%
Custom Food Service	13,097	8%	9,917	10%
LEED	49,347	31%	31,773	32%
Retired Measures	1,334	1%	331	0%
Total	160,737	100%	99,106	100%

As shown in Table 14, the evaluation sample and program population represented a mix of building types, with colleges/universities, restaurants, and warehouses predominating in the sample. This was a change from previous evaluation years, when the most common sample building types were:

- 2008: grocery stores
- 2009: education
- 2010: offices

The sample's "other" building types were a fruit packing plant and university science building.

The sample distribution of building types (NAICS codes) roughly matched the program population, with a few exceptions. College/university and data centers were slightly oversampled, due to the disproportionate level of savings they represented. Warehouses were a higher than expected portion of the random sample. Offices and schools represented a slightly lower portion of the sample, but these two building types have been extensively studied in prior program years.

Table 14. Building Types Represented in Evaluation Sample and Population

Building Type	Sample Quantity	Portion of Total Sample	Population Quantity	Portion of Total Population
Assembly	0	0%	4	1%
Auto Services	0	0%	4	1%
Church	0	0%	1	0%
College/University	6	15%	24	8%
Data Center	3	8%	4	1%
Grocery	2	5%	9	3%
Gym/Athletic Club	0	0%	2	1%
Hi Rise Residential	1	3%	3	1%
Hospital	2	5%	5	2%
Infrastructure	0	0%	2	1%
Institution/Government	1	3%	5	2%
Laundry/Dry Cleaners	0	0%	1	0%
Lodging/Hotel/Motel	1	3%	4	1%
Manufacturing	0	0%	1	0%
Multifamily Residential	3	8%	17	6%
Office	2	5%	35	12%
Other	2	5%	27	9%
Other Health	1	3%	22	8%
Other Residential	0	0%	1	0%
Parking structure/Garage	0	0%	3	1%
Religious/Spiritual	0	0%	3	1%
Restaurant	5	13%	28	10%
Retail	3	8%	30	10%
Retirement/Assisted Facilities	0	0%	1	0%
Schools K-12	1	3%	31	11%
Warehouse	7	18%	24	8%
Total	**40**	**100%**	**291**	**100%**

Data Collection

Cadmus reviewed the available documentation (e.g., audit reports, savings calculation work papers) for the sample sites, paying particular attention to the calculation procedures and documentation for savings estimates. We reviewed analyses originally used to calculate expected savings and verified operating and structural parameters. During site visits, we verified installations and determined changes to operating parameters following measure installation.

For Custom and LEED track projects, Cadmus frequently obtained trend data from energy management systems (EMS), including energy demand, lighting, or temperature details. Site visit and trend data informed savings impact calculations. Individual measure savings, aggregated into measure categories, allowed calculations of measure-level realization rates (the ratio of evaluated to reported savings). We then applied these rates to program-level reported savings associated with the respective measure types and summed total adjusted savings to determine the overall, program-level, energy savings realization rate. Site visit data and analysis also provided information enabling us to develop recommendations for future studies.

Document Review

The evaluation began by reviewing relevant documentation and other program materials from the implementer. In several cases, Cadmus could not identify calculation spreadsheets or relevant data for custom measure savings calculations. In these cases, we could usually contact the participant or relevant contractor to obtain and update original calculation sheets, based on site visit data, utility billing information, or other sources.

Cadmus also experienced difficulty obtaining energy simulation models for Custom and LEED track projects because PMC's project documentation included six of the 13 simulation models required. Also, five projects included simulation models that did not match the LEED EAc1 form or the final version of the design. Cadmus and PECI obtained most remaining models from PECI's archives and simulation modeling firms. In some cases, PECI staff or their subcontractor, Nexant, modified the model prior to approving savings, and Cadmus obtained the final models. We also found inconsistencies in project files, which increased the difficulty in determining the basis of the final incentive, correct supporting documentation, and appropriate simulation models.

We reviewed information for all sample 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:
  - Descriptions
  - Schematics
  - Performance data
  - Other supporting information
- Information about savings calculation methodologies, including:
  - Methodologies used
  - Assumption specifications and the sources for these specifications
  - Calculation accuracy

Site Verification Visits

Cadmus developed a comprehensive data collection form for LEED and Custom track whole-building simulation model projects.[3] 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 energy-efficiency measures had been correctly installed, remained in place, and functioned properly. They conducted spot measurements, collected energy management system 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 determined pertinent data for collection from each site using in-depth reviews of project files.
- **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 differed from those for which incentives had been provided. When we found fewer measures in place, we reduced the realization rates accordingly. We noted that the as-built equipment quantities could vary from design counts due to changes in building structures or space usage.

Engineering Analysis

Procedures used to verify savings through engineering analysis depended on the type of measure analyzed. The program included these major measure groups:

- Standard Food Service
- Standard HVAC
- Standard Lighting
- Standard Motors and Variable Speed Drives
- Standard Water Heating
- Custom
- LEED

[3] The data collection form can be found as Appendix B in the 2010 New Buildings Impact Evaluation report <http://energytrust.org/library/reports/ETO_NBE_2010_Impact_Evaluation_Report.pdf>

The following sections describe the focus of site visits and the procedures Cadmus used to verify savings from different types of measures installed through the program. For the 2011 evaluation, we focused analysis resources on the complex Custom and LEED track projects, which constituted a larger portion of the program and sample energy savings.

Standard Food Service

Prior to the 2010 program year, the New Buildings Program used the Custom track to provide incentives for many food service measures, such as anti-sweat heat controls and floating head pressure controls. Beginning with the 2010 program year, the implementer provided many of these as prescriptive measures with deemed savings.

The program also provides incentives for high-efficiency food service appliances, such as refrigerators and cooking equipment. Much of the cooking and refrigeration equipment had ENERGY STAR ratings. Cadmus verified equipment counts and confirmed that these units met program efficiency requirements.

Cadmus analyzed grocery measures using a variety of methods. Where applicable (such as with LED case lighting), we recalculated energy savings using equipment counts, manufacturer specification data, and estimated refrigeration load reduction. In other cases (such as floating head pressure controls), we benchmarked deemed savings estimates against secondary sources to confirm reported values were reasonable.

Standard Lighting Measures

The analysis included three types of Standard Lighting projects:

- **Installation of high-efficiency lamps, ballasts, and/or fixtures**, expected to reduce lighting power densities below code-required values. These measure types reduced demand and energy consumption without affecting operation hours between baseline and as-built conditions. These measures were incented on a measure-by-measure basis, rather than on a whole-building level.
- **Lighting control strategies, including occupancy sensors, daylight dimming controls, and automated lighting control systems.** These measure types typically involved operation-hour reductions to more closely match building occupancy.
- **Lighting power density reductions** for the entire facility below the values prescribed by the 2010 Oregon OEESC.

Analyzing lighting measure savings required documentation regarding fixture wattages, quantities, and operation hours. We also verified space types and areas for lighting power density calculations.

Cadmus verified energy-efficient replacement input wattages using several sources, including the manufacturer industry lamp and ballast product catalogs. The investigation also evaluated operation hours for each site, based on activities of the buildings’ occupants within the relevant spaces.

We evaluated lighting control systems by specifically focusing on functionality and operation hours. Occupancy sensors were checked twice per site visit: initially to trigger the sensor activating the lights and again to determine if the lights turned off. We visually inspected lighting automation systems for scheduled operation hour setpoints, which we then verified against claims used in submitted calculations.

In addition to parameters listed above, we conducted onsite interviews with building operators and facility staff, verifying operation hours and areas where fixtures had been installed. The field engineer documented lamp and ballast information for each fixture, counting the number of fixtures installed and organizing fixtures affected by lighting controls systems.

Standard HVAC Measures

For most sites with HVAC measures, Cadmus focused on equipment counts, verifying that the units met the program's efficiency requirements. We performed more detailed calculations and analysis on several measures, such as boilers and demand-controlled ventilation (DCV). Our site inspections included interviews with facility personnel, which enabled us to verify operation hours, temperature setpoints, and proper installation of energy-efficient equipment.

For boilers, we attempted to quantify heating loads through utility billing data and by determining if the deemed savings adequately represented actual savings. DCV measures required more complex calculations, accounting for all HVAC and ventilation parameters as well as occupancy patterns within the buildings. We obtained PECI's DCV calculator and modified inputs as necessary to recalculate energy savings.

Standard Motors and Variable Speed Drives

For high-efficiency motor and variable speed drive (VSD) installation measures, Cadmus focused on equipment counts, verifying that the units met the program's efficiency requirements. For verification purposes, we confirmed motors met or exceeded program requirements by motor type, speed, and horsepower rating. Field engineers also reviewed VSD operation to confirm if the drives were active and that they had not been manually overridden to operate at 100% speed.

Standard Water Heating

Cadmus developed a separate category for water heaters and any other measures that significantly influenced water heating loads, such as dishwashers and showerheads. Dishwashers were rated through ENERGY STAR; we verified equipment counts and confirmed that the units met the program's efficiency requirements.

Cadmus calculated condensing water heater savings by comparing manufacturers' specified efficiencies with code requirements. Each unit's annual energy consumption was calculated using ASHRAE guidelines for average daily hot water use per person, hotel room, or meal.[4] Energy savings were the difference in consumption, based on the code and as-built efficiency.

Custom Measures

Custom Track projects included a range of measures, from window upgrades to more complex chiller systems. The diversity of projects required a variety of calculation methods to estimate energy savings, primarily calculation spreadsheets and building simulation modeling.

For each project, Cadmus performed a site visit to verify correct installation of incented equipment and to confirm quantities and operating characteristics, thus determining if the initial analysis approach was reasonable, and, if necessary, applying a revised calculation approach. Calculations and simulation models were adjusted to reflect as-built parameters, which we confirmed through site visits and interviews with facility operations staff.

LEED Building and Custom Track Simulation Models

For the 2011 program evaluation sample, all 10 LEED track buildings and three Custom track projects reported savings calculated using building energy simulation models. Cadmus' used a Measurement-Based Calibrated Engineering Method (MCEM) to evaluate savings for these projects. This approach was:

- Based on *in situ* measurements and observations
- Calibrated to best available energy use indices
- Employed well-developed and sophisticated engineering analysis tools, such as DOE-2 or TRACE

The analysis focused on the following issues:

- Quantifying as-built building construction characteristics, energy systems operational characteristics, and energy-efficient measure characteristics (such as quantities, capacities, and efficiencies) and calibrating models to the best available consumption indices (including billing records).
- Reviewing energy-efficient measure assumptions and performance variables for each building to develop input data revisions to the calibrated, as-built model. We then created the baseline model by removing the energy-efficient measures in the simulation.
- Comparing the results of calibrated, as-built model energy use with the baseline model to determine the annual energy savings for individual buildings.
- Summarizing energy savings for each building and, for Custom measures, each individual incented measure. Along with participation data, these values were extrapolated to the population to estimate gross savings for the program.

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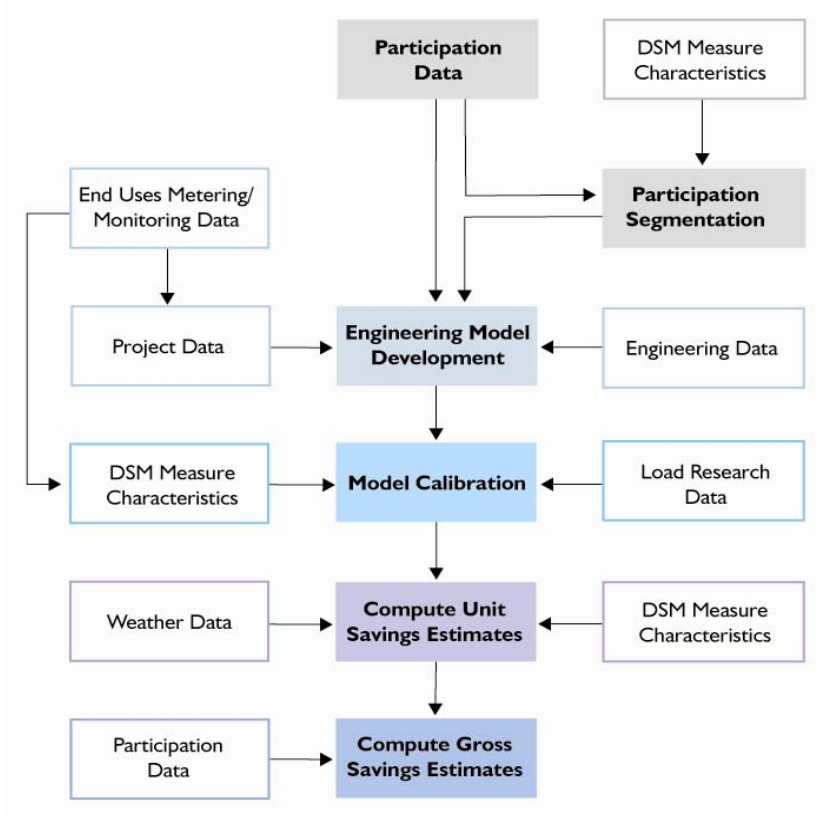
4 *ASHRAE Handbook.* 2004. HVAC Systems and Equipment.

Figure 1 depicts the MCEM approach.

Figure 1. Measurement-Based Calibrated Engineering Method Flowchart



Model Calibration

Because this is a new construction program, the model for the as-built building was the only one that could be used for calibration purposes and this was Cadmus' starting point. We obtained as-built models for all building measure projects in the final sample, which were based on:

- Building sizes and configurations
- Shell characteristics (such as window-shading coefficients and wall insulation values)
- HVAC equipment specifications
- Lighting densities and control methods
- Occupancies
- Schedules

We confirmed this information through project files and detailed data collection reports from site visits. Through site interviews, we determined occupancy levels that had been achieved during the previous year and adjusted equipment operating characteristics for the spaces modeled.

The models were calibrated primarily to annual electricity and gas consumption, and we reviewed monthly variation for discrepancies. We also obtained actual historical weather data for the calibration period on each project.

Analysis and Findings

This section presents the results of engineering analysis, as applied to the sample; adjustments to reported values; calculation of realization rates; and extrapolation to the full 2011 program population. It also includes general observations regarding discrepancies and other factors influencing measure-level realization rates. Finally, it examines energy-use intensity data derived from the sample.

Sample Evaluated Savings

Reported and evaluated energy savings values were compared through measure-level realization rates, as shown in Table 15. The evaluated sample had a 92% electric realization rate, with a 90% natural gas realization rate. Cadmus adjusted electricity and gas savings based on the measure-specific reasons described in the sections below.

Table 15. Sample Reported and Evaluated Savings and Realization Rates

Measure Category	Total Measures	Electricity Savings		Gas Savings		Realization Rate	
		Reported (kWh)	Evaluated (kWh)	Reported (therms)	Evaluated (therms)	Electricity Savings	Gas Savings
Standard Food Service	45	1,242,642	1,239,802	11,107	11,422	100%	103%
Standard HVAC	28	322,667	320,339	22,018	23,085	99%	105%
Standard Lighting	49	872,320	847,058	0	0	97%	N/A
Standard Motors	30	298,026	199,518	0	0	67%	N/A
Standard Water Heating	25	37,629	43,869	8,880	8,854	117%	100%
Custom	15	7,194,940	6,309,117	188,734	157,991	88%	84%
Custom Food Service	20	1,430,049	1,424,403	50,377	49,511	100%	98%
LEED	10	2,697,006	2,544,690	225,708	202,954	94%	90%
Retired Measures	3	97,019	97,019	0	0	100%	N/A
Total 2011 Sample	225	14,192,298	13,025,814	506,823	453,817	92%	90%

Standard Food Service

The Standard Food Service category represented refrigeration, cooking, and grocery measures, which had a 100% overall realization rate. For refrigeration and cooking measures, Cadmus verified equipment counts and ENERGY STAR eligibility. For grocery measures, energy savings adjustments resulted from revised calculations, based on verified equipment quantities.

Refrigeration and Cooking Measures

Incented refrigeration equipment involved ENERGY STAR appliances, such as refrigerators and ice-making machines. Cooking measures covered electric and gas equipment, including convection ovens

and electric hot food cabinets. ENERGY STAR also rated most cooking appliances. Convection oven calculations relied on a methodology developed by the Food Service Technology Center.

Cadmus verified that equipment counts at each site matched reported values and that equipment met ENERGY STAR specifications. We found that one refrigerator did not meet the ENERGY STAR requirement, as specified by the program. The point of contact for another facility claimed one of the incented freezers had been borrowed and was at another school. We could not visit the other facility to verify the operation, and assigned no savings to this measure. We also found one gas fryer measure that we evaluated to have more savings than reported due to longer operating hours.

The realization rate for refrigeration and cooking measures was 102%.

Grocery Measures

Grocery measures featured a variety of efficiency improvements to grocery refrigeration systems, such as electrically commutated motors (ECMs), LED case lighting, controls, and night covers. Cadmus reviewed deemed savings estimates and recalculated savings based on verified equipment details or secondary source data. In general, we found participants had installed these measures as reported, and the measures achieved the reported savings. In one case, we found that an anti-sweat heater control measure had achieved less than the reported savings because the onsite verification found there were fewer case doors with anti-sweat heater controls than reported.

The realization rate for grocery measures was 99.9%.

Standard HVAC

Standard HVAC projects covered a range of electric and gas measures, including high-efficiency air conditioners, heat pumps, chillers, boilers, direct-fired radiant heating, DCV, and economizers. These measures had an overall realization rate of 103%.

Energy savings adjustments were made for four measures in the sample based on Cadmus' calculations on heating loads, differences in observed equipment quantities, and one calculation error. Electric HVAC, gas HVAC, and DCV adjustments are explained in the next sections.

Electric HVAC Measures

Cadmus calculated a 99.3% realization rate for purely electric HVAC measures, including packaged air conditioning and air source heat pumps. Field engineers observed mostly accurate equipment counts. One site reported installing two 12.5-ton HVAC units and nine 15-ton HVAC units; however, in the onsite verification, we found three 12.5-ton units and eight 15-ton units.

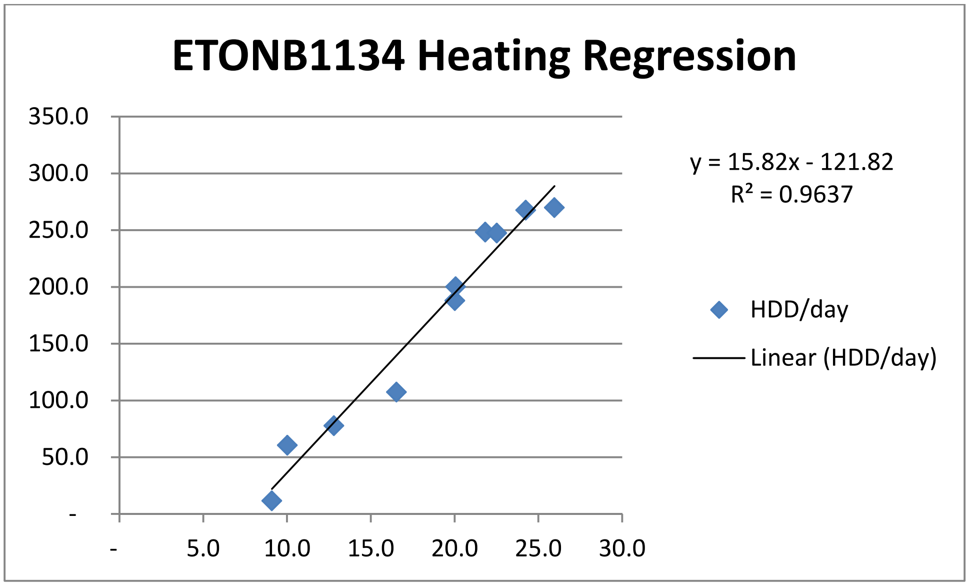
Cadmus also identified an error in the calculation spreadsheet PECI used to determine 2010 code economizer savings. The spreadsheet identifies the design minimum outside air flow as a percent of total air flow. The spreadsheet mistakenly divides this value by 100, even though it is already represented as a percentage. The result is an artificially low setting for minimum outside air flow that overstates economizer savings. We calculated an 84% realization rate for the three measures we evaluated that had this error.

Gas HVAC Measures

Gas HVAC measures included heating technologies, such as condensing boilers and unit heaters. Cadmus reviewed the calculation methodology for boiler projects in the sample and applied a revised engineering calculation to determine the resulting reductions in heating energy. In each case, reported values proved reasonable, and we applied a 100% realization rate for boiler measures.

We evaluated a high-efficiency condensing unit heater measure at one facility where these unit heaters represented the facility's only natural gas load. Cadmus performed a linear regression analysis, as shown in Figure 2, to correlate heating degree days to natural gas consumption. We calculated the facility's average annual consumption using the resulting regression equation and typical meteorological year (TMY) 3 estimates of heating degree days. We then calculated the expected difference in consumption between the high-efficiency unit heater and a code baseline heating system with 80% efficiency. This method found higher than deemed gas savings, resulting in a 114% realization rate.

Figure 2. Linear Regression Analysis for High-Efficiency Unit Heater



Demand Controlled Ventilation

Cadmus evaluated nine demand-controlled ventilation (DCV) measures that reported electric and/or gas savings. In each case, we verified equipment nameplate information and operational characteristics at the site. We reviewed PECI's spreadsheet calculation tool for DCV savings and determined that the methodology estimated energy savings accurately. We compared PECI inputs to values observed on site and found the results matched. We assigned a 100% realization rate to these DCV measures.

Standard Lighting

Standard Lighting measures included lighting power density reductions, efficient lighting fixtures, and controls such as occupancy sensors and daylight dimming. Lighting measures achieved a 97% realization rate compared with reported savings. For previous program years, Cadmus noted Standard Lighting savings were based on deemed values per fixture, regardless of building types and actual operation hours. In 2011, the program made the transition to using a lighting power density approach for site-level lighting savings, as required by energy code.

The implementer based lighting measure savings for projects initiated in previous program years on a deemed average for a range of fixture sizes (such as "CFL 18 to 26 Watt"). To evaluate savings, however, Cadmus analyzed measures based on actual wattages, ballast factors, and operation hours, which were determined through site visits and reviews of invoices and manufacturer specification sheets.

Other primary factors influencing the realization rate were:

- Alterations in fixture quantities and wattages
- Different operating hours in the sample than those used to develop deemed savings estimates
- Incorrect lighting power density (LPD) assumptions

Fixture Count Adjustments

Cadmus field engineers occasionally noted discrepancies between reported and observed fixture counts. During the construction phase, participants reevaluated their lighting needs and sometimes adjusted fixture counts accordingly. For savings evaluation purposes, we adjusted baseline and as-built fixture counts to match observed quantities.

Sample Lighting Fixture Average Operating Hours

Evaluated sample project lighting fixture measures (e.g., CFLs, T8, and T5 lamps) 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. The average evaluated operating hours, in conjunction with fixture count adjustments, resulted in reduced energy savings.

Lighting Power Density Baseline Error

Cadmus identified one error in a 2010 code calculation for lighting power density in a warehouse. The implementer's calculation reported a code baseline of 1.16 watts per square foot. The appropriate baseline from the 2010 OEESC is 1.24 watts per square foot. Cadmus verified the as-built lighting power density was also higher than reported. The project achieved a realization rate of 92%.

Standard Motors

The Standard Motor category included premium-efficiency motors and VSDs. The realization rate for Standard Motors was 67%. Cadmus adjusted savings based on as-verified equipment efficiencies and counts.

Code Minimum Requirements

Cadmus found one facility that installed several 60 HP, 100 HP, and 150 HP motors. The participant reported that these motors exceeded the minimum program requirements. During the onsite verification, we found that all motors met only the code baseline requirement. In this case, no energy savings could be assigned for the motor measures at this facility. Although we evaluated 20 different premium efficiency motor measures, the relatively large size and quantity of motors at this facility reduced the evaluated savings considerably, resulting in a realization rate of 38% for this measure category.

Variable Speed Drives

Cadmus confirmed VSD quantities and operational characteristics. In the case of one school, the site's point of contact could identify only four of the six reported VSDs on 7.5 HP motors. We prorated the savings accordingly. We found the remaining VSD measures installed at other sites at the appropriate quantities and controlling the expected loads, so we assigned those measures a 100% realization rate. The combined realization rate for VSDs was 91%.

Standard Water Heating

The Standard Water Heating category represented the remaining measures with deemed savings, including water heaters and measures significantly influencing water heating loads, such as dishwashers and showerheads. Cadmus adjusted energy savings to account for energy consumption, non-standard applications, and correct fuel type. The realization rate for all measures in this category was 102%.

For dishwashers, Cadmus verified equipment counts and confirmed that units met ENERGY STAR specifications. These measures achieved a 100% realization rate.

Condensing Tank Consumption Adjustments

Cadmus evaluated nine condensing water heater tank measures using utility billing data and benchmarking through ASHRAE and CBECS consumption estimates.[5,6] On average, we found the deemed savings value was either the same or slightly less than evaluated consumption and gas savings. The resulting realization rate for these measures was 116%. The calculated consumption difference also increased the evaluated savings on a bathroom aerator measure at a school.

Tankless Water Heater Consumption Adjustments

Cadmus found reduced consumption for two tankless water heater projects installed on non-standard applications. The program's deemed savings estimates appeared to adequately characterize energy savings for tankless water heaters serving primary domestic water heating loads.

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5 2011 ASHRAE Handbook – HVAC Applications, Chapter 50: Service Water Heating.

6 Commercial Buildings Energy Consumption Survey (CBECS), http://www.eia.gov/consumption/commercial.

In one case, a grocery store installed a tankless water heater on a domestic hot water recirculation loop in which condensing storage water heaters provided primary heating. We determined that the water loop needed to be brought back up to the temperature setpoint after losses from the distribution loop, rather than from groundwater temperature; the tankless water heater's load requirements were thereby reduced. Energy savings are calculated as the difference between code baseline and as-built consumption. The heating load for both cases was reduced below deemed savings estimates, which further meant the difference between the baseline and efficient case (the energy savings) was also reduced. We calculated the resulting realization rate at 59%.

Another non-standard application involved five tankless water heaters installed at a residence in Central Oregon. Two provided domestic hot water (DHW), while the other three provided backup heat for a ground source heat pump system (GSHP). The HVAC contractor offset gas consumption for both the DHW and GSHP loops using a solar water heating system. This participant received commercial incentives because the HVAC contractor submitted a project enrollment form claiming the property type was office, residential, and "show/retreat." Cadmus spoke with the homeowner, and he noted he occasionally uses the property to demonstrate the installed sustainable technologies, which represented the "showroom" and "retreat" use cited in the application form. However, Cadmus' discussions with the property owner and review of online aerial photographs[7] of the property confirmed it was a private residence. This project should not have qualified for the New Buildings program because it was residential and a non-standard backup application for the tankless water heaters.[8] Neither Cadmus nor Energy Trust could obtain utility billing data for the home; consequently, we recalculated the energy savings by benchmarking gas consumption on a square footage basis from RECS data,[9] supplemented by assumptions on the portion of water and space heating loads provided by the GSHP and solar water heating system. The evaluated savings for this project provided a 29% realization rate. Although the measures were installed at a residence, we included the savings in the evaluated total because we are trying to capture the impact of all measures installed through the program.

Incorrect Water Heating Fuel

In one case, a shower wand measure reported using gas water heating. During the onsite verification, Cadmus found that water heating was supplied by an electric storage water heater. We also calculated the water heating energy load was lower than the deemed savings reported. These two issues combined to reduce the measure's energy savings realization rate to 69%.

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[7] Obtained through the public domain from GoogleMaps (maps.google.com)

[8] Because of the volume of small projects, 10% of projects receiving incentives under $10,000 are randomly sampled for site visits to verify measure installation and other project information. This site was not selected for a site visit.

[9] Residential Energy Consumption Survey (http://www.eia.gov/consumption/residential)

Custom Projects

Custom projects represented a “catch all” subcategory of non-prescriptive measures with gas and electricity savings and involved controls systems, specialty refrigeration measures, and data center HVAC systems. Custom projects had an 89% energy savings realization rate.

Custom Measure Calculations

Cadmus evaluated Custom measure energy savings by reviewing available data and calculation spreadsheets, supported by onsite verification, EMS trend data, energy simulation models, and utility billing data. Because a prescriptive methodology was not appropriate for most of these measures, we relied heavily on models and calculation spreadsheets developed by contractors, participants, and the implementer.

We reviewed program documentation, determining calculation sources for each measure and contacting the sources, where necessary, to obtain original calculation spreadsheets or models. We compared inputs and methodologies with available data to confirm methodologies and results, or adjusted values, as necessary. In most cases, we determined the methodology and reported savings values were reasonable, although slight adjustments were required occasionally.

Custom Grocery

Custom Food Service measures involved more complex measures, improving refrigeration efficiencies not easily accounted for in deemed savings estimates. Examples included heat recovery from refrigeration systems, high-efficiency refrigeration cases, and case lighting controls. Cadmus’ adjustments, based on actual equipment operation and site verification parameters, resulted in a 99% realization rate for all Custom Food Service measures.

Cadmus determined the methodology and operating parameters were correct for most of these measures. We found a calculation error for a domestic hot water heat reclaim measure in a grocery store. The calculation method assumed a baseline water heater at 78% efficiency, but the installed water heater was 95% efficient. This adjustment resulted in a decrease in energy savings, since a more efficient water heater would waste less heat that needed to be reclaimed. Correcting the error resulted in an 82% realization rate for that project.

Data Centers

Cadmus evaluated two data center projects with large custom HVAC measures. One project was operating as reported. We determined its energy-efficiency measures reduced consumption to the expected level and achieved the full reported energy savings. On the other project, the participant increased the server load from 880 to 1,010 kW, which increased the demand for space conditioning and required additional HVAC energy consumption. The project saved more energy than reported because the incentivized HVAC measures to meet the additional load were more efficient than code requirements. This project had a 109% realization rate.

Custom HVAC

Custom HVAC measures represented a variety of applications, including chiller upgrades, natural ventilation, high-efficiency boilers, water side economizers, and other innovative HVAC technologies. Cadmus evaluated these projects through EMS trend data on system parameters, utility billing data, reviews of design engineers' calculations, and building simulation models, for a resulting realization rate of 89%.

The second largest project in the 2011 program year (identified by Cadmus as ETONB1127) was a major renovation with multiple energy-efficiency measures bundled together as one SEED project[10]. These included HVAC and controls measures such as VSD chillers, condenser water reset controls, and variable speed condenser water pumps. Cadmus obtained a large quantity of EMS trend data on the various systems and used this information to update the simulation model. We included the full model calibration details in Appendix B due to the project's large size and complexity, even though it was not a LEED project. The required modifications and calibration indicated that the facility saved more electricity than reported, but the natural gas savings were overestimated. We made adjustments that decreased gas savings, including reducing exhaust airflow to match verified conditions, lowering heating setpoints in some spaces, and reducing the domestic water heating load to match the utility billing profile. The overall realization rate for this project was 97%.

The third largest 2011 project was a new central utility plant for a hospital complex (identified by Cadmus as ETONB1119). This project featured custom measures for high-efficiency chillers, cooling tower, and boilers. However, Cadmus found the actual HVAC loads at this facility were less than anticipated, which resulted in reduced energy savings. The combined realization rate for the three custom measures was 47%. The participant estimated that the cooling loads were based on 2008 chiller trends, which we consider a reasonable approach. However, the analysis also set the minimum load to 20%, which would have been 500 tons of cooling load for 4,631 hours of the year. The EMS data showed an average cold weather load of 100 tons. In addition, the designers based the load profile on nameplate capacity and assumed the chillers would be fully loaded (2,500 tons) at peak facility load. The EMS data showed a maximum cooling load of 2,200 tons, with an average during hot hours closer to 1,800 tons. The estimated and evaluated cooling load by temperature bin is shown in Figure 3. We also show a graphical representation of the number of hours during the year for each temperature bin.

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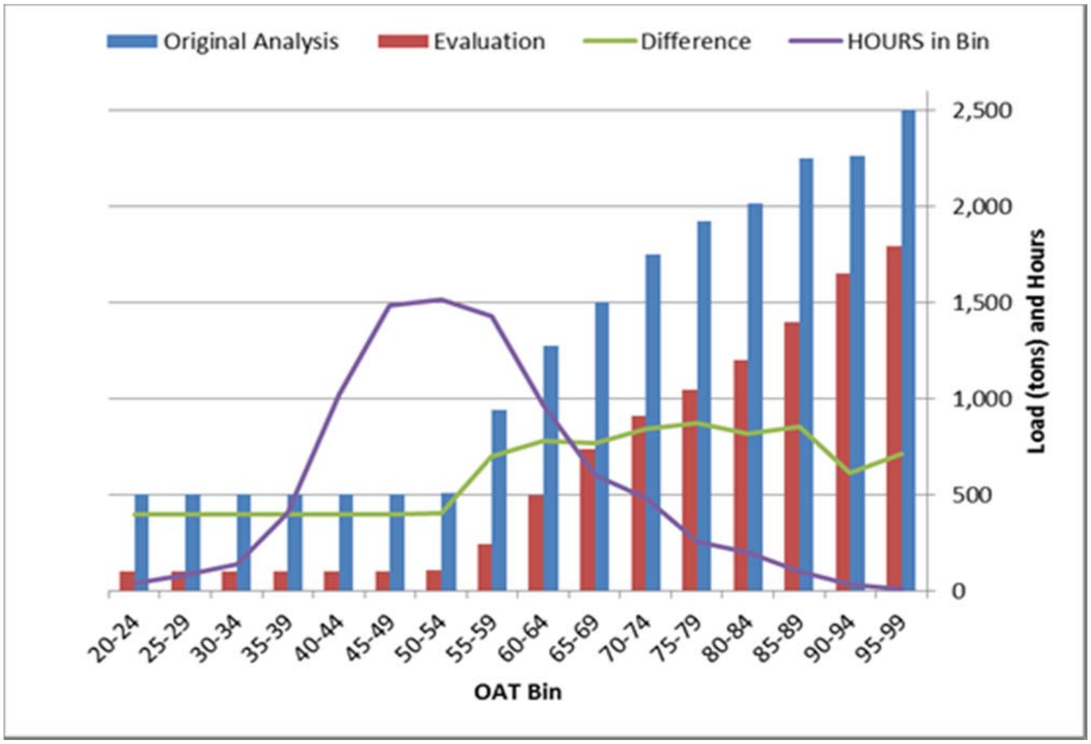
[10] Oregon Department of Energy State Energy Efficiency Design program: http://www.oregon.gov/ENERGY/CONS/SEED/Pages/index.aspx

Figure 3. Comparison of ETONB1119 Estimated versus Evaluation Cooling Loads



In another case, a participant reported 25,547 kWh in savings for a natural ventilation system at a new university building. However, the commissioning agent confirmed the system was not implemented. No savings could be attributed to this measure.

Custom Lighting

One Custom Lighting project in the sample involved reductions in lighting power density over code requirements. For this project, Cadmus determined claimed space identifications were reasonable and fixture counts were close to reported values. We found lower operating hours than reported, which reduced savings. This measure achieved a 52% realization rate.

LEED Buildings

Cadmus conducted site visits for 10 LEED-certified buildings in the evaluation sample and found that this track's projects had relatively large variations from reported savings. The LEED sample projects achieved an overall realization rate of 91%. The Cadmus team's field engineers completed an extensive data collection form, accurately characterizing as-built parameters for mechanical equipment, lighting power densities, and plug load densities. Field engineers also interviewed facility operations staff to gain a detailed understanding of building operations, occupied hours, and setpoints.

Cadmus compared as-built building characteristics to values specified in the DOE-2 or TRACE simulation model submitted for the project. Where possible, Cadmus also calibrated models to actual electricity and gas billing data using historical weather data.

Table 16 shows resulting realization rates. The following two subsections discuss Cadmus' adjustments for calculating evaluated energy savings.

Table 16. LEED Building Realization Rates

Project	Building Type	Reported Electricity Savings (kWh)	Calculated Electricity Savings (kWh)	Reported Gas Savings (therms)	Calculated Gas Savings (therms)	Electricity Savings Realization Rate	Gas Savings Realization Rate
ETONB1101	Multifamily Residential	1,149,530	853,887	6,305	4,181	74%	66%
ETONB1102	College/University	29,499	31,116	20,653	4,214	105%	20%
ETONB1103	Multifamily Residential	169,685	236,458	0	0	139%	N/A
ETONB1104	College/University	45,868	45,955	7,761	8,014	100%	103%
ETONB1105	College/University	496,445	576,090	55,680	78,718	116%	141%
ETONB1111	Institution/Government	0	0	34,783	30,723	N/A	88%
ETONB1118	Multifamily Residential	191,053	165,025	22,335	11,258	86%	50%
ETONB1124	Office	588,859	610,092	44,408	37,509	104%	84%
ETONB1132	Warehouse	26,067	26,067	0	0	100%	N/A
ETONB1138	College/University	0	0	33,783	28,336	N/A	84%
Total		2,697,006	2,544,690	225,708	202,954	94%	90%

Calculation Methodologies

Energy savings for LEED projects were calculated as the difference in annual energy use between baseline and as-built models, with energy savings calculated relative to the ASHRAE 90.1-2004 standard, the required standard for establishing LEED Energy & Atmosphere credit 1 (EAc1) points. PECI degraded the baseline energy consumption by 5% in order to convert from an ASHRAE 90.1-2004 baseline to the 2007 Oregon Structural Specialty Code. Cadmus agreed that the 5% differential was reasonable, confirming the value by interpolating research performed by Architecture 2030,[11] which estimated the "2030 Challenge Code" would save 30% more energy than ASHRAE 90.1-2004 and 25% more energy than Oregon code.

Project ETONB1132 was a 2010 code project, which required the LEED baseline consumption to be derated by 15% to be consistent with the new 2010 OEESC.

Discrepancies Between the Modeled and As-Built Projects

Cadmus also adjusted energy savings due to differences in equipment and operational parameters between simulation models and as-built structures. We noted a variety of project-specific issues, resulting in variations between reported and achieved savings but no overarching concerns. Generally,

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11 Architecture 2030. June 20, 2009. "Meeting the 2030 Challenge Through Building Codes."

differences resulted due to calibration to actual utility bills and as-built conditions, which we confirmed through site visits. During these site visits, we determined how equipment actually operated, compared to the initial simulation model. A summary of the major impacts are outlined below.

ETONB1101 highlighted the difficulties with modeling variable refrigerant flow (VRF) systems. For this building, the modeling results suggested substantially higher energy consumption than actual utility meter data showed. The resulting evaluated savings were less than the reported value. eQUEST does not accurately model VRF systems as well as modeling software such as EnergyPlus does. Further research may better predict the actual energy consumption of the VRF equipment in order to improve modeling techniques for this technology.

Cadmus identified a number of issues with the analysis for ETONB1102. The as-built facility differed significantly from the program's simulation model in terms of building operation. In particular, the original model significantly overestimated natural gas consumption relative to the post-occupancy utility billing data. Based on these discrepancies, Cadmus put in significant effort to modify the LEED model to reflect the as-built operation, and then calculate the energy savings.

We evaluated higher than reported energy savings for ETONB1103, a multifamily facility. The major source of savings involved a reduction in equipment power density. Cadmus updated the baseline model to reflect an appropriate residential lighting power density of 0.5 W/sf. The developer installed ENERGY STAR® appliances in all of the units, which decreased the equipment power density and increased energy savings. In addition, we extended the air handling unit schedules and lowered the occupied cooling set point for meeting rooms based on the on-site verification findings. These adjustments increased electric consumption for ventilation fans and the cooling system. This increased energy savings since the increased load was provided by high efficiency equipment.

Analysis of ETONB1104, a university science building, led to an increase in both electric and gas savings due to differences between the reported and as-built operating schedules. The initial model assumed laboratory ventilation would operate on a schedule. The on-site verification, however, confirmed the laboratory's air handling units operated 24 hours per day, seven days per week, as would be expected in this type of application. The adjustment increased energy consumption for ventilation, heating, and cooling. The energy savings also increased since these loads were provided by equipment that was more efficient than code requirements. The savings for this project were difficult to evaluate because the building was not on an individual utility meter. The participant performed limited sub-metering on some of the systems (electricity, gas, and steam), which provided some guidance for model calibration. Cadmus found a similar issue on project ETONB1138, which relied on district heating system. Without submetering, Cadmus had to rely more heavily on the participant's assumptions and engineering judgment in these two cases since actual heating data was not available. The original analysis for ETONB1104 did not account for the steam boiler efficiency. We incorporated an assumption of 80% steam plant efficiency, which increased savings since the reported value did not account for thermal losses in burning natural gas to create steam.

Cadmus evaluated lower than reported savings for ETONB1118. On this project we determined savings may have been overestimated for the demand controlled ventilation measure. We believe it is likely the demand controls are overriding the minimum outside air flow settings assumed in the model, requiring more gas consumption for heating than expected. This project installed a solar water heating system that was based on LEED exceptional calculations. The implementer did not include the calculation with the project files. Cadmus estimated the solar water heating savings based on the system size, local seasonal irradiance variation, and projected hot water consumption. We then subtracted this savings estimate from the modeled consumption to determine the expected heating load the facility's boiler system would need to meet.

Extrapolation to the Program Population

As described earlier, the measurement and verification process involved analyzing projects with a sample large enough to provide 90/10 confidence and precision for each program track. Cadmus calculated realization rates to apply to each measure type (e.g., Standard HVAC, Custom Food Service) at the remaining, non-sampled sites. Realization rates were calculated as weighted averages, based on the evaluation sample, where:

$$RR_{ij} = \frac{Evaluated_{ij}}{Reported_{ij}};\ for\ measure\ j\ at\ site\ i \quad (1)$$

$$RR_{j} = \frac{\sum_i Evaluated_{i}}{\sum_i Reported_{i}};\ for\ measure\ j\ across\ all\ sample\ sites \quad (2)$$

$$\sum_k Evaluated_{k} = RR_{j}\, x \sum_j Reported_{j};\ for\ measure\ j\ across\ all\ sites\ in\ measure\ population \quad (3)$$

$$RR_{l} = \frac{\sum_k Evaluated_{k}}{\sum_k Reported_{k}};\ for\ the\ population\ (all\ sites\ and\ measures) \quad (4)$$

Where:

RR is the realization rate

i is the sample site

j is the measure type

k is the total population for measure type j

l is the total program population

Realization rates were calculated for each individual site in the sample, based on Equation 1. Cadmus calculated realization rates for measure types using the ratio between the sum of evaluated savings and the sum of reported savings from the sample for each measure type (Equation 2). Total population evaluated savings were calculated by multiplying the measure type realization rate from the sample by total reported savings for the population of each measure type (Equation 3). The program realization rate was the ratio of total evaluated savings to total reported savings (Equation 4).

Table 17 and Table 19 show final evaluated savings by measure, fuel, and at the program level.

Table 17. Program Level Electricity and Gas Savings

Measure Category	Total Measures	Reported Savings		Evaluated Savings		Realization Rate	
		Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
Standard Food Service	174	2,002,170	39,461	1,997,594	40,580	100%	103%
Standard HVAC	186	512,989	97,883	509,288	102,628	99%	105%
Standard Lighting	469	3,717,814	0	3,610,147	0	97%	N/A
Standard Motors	79	497,527	0	333,077	0	67%	N/A
Standard Water Heating	143	365,385	42,257	425,977	42,135	117%	100%
Custom	100	9,657,102	218,370	8,468,144	182,800	88%	84%
Custom Food Service	42	1,739,329	71,626	1,732,462	70,395	100%	98%
LEED	33	5,409,556	308,900	5,104,045	277,759	94%	90%
Retired Measures	6	103,649	9,805	103,649	9,805	100%	100%
Total 2011 Population	**1,232**	**24,005,521**	**788,302**	**22,284,382**	**726,100**	**93%**	**92%**

When combining all measure categories, the Standard Track population achieved an overall realization rate of 99.6%. The Custom Track population achieved an overall realization rate of 89%. The realization rates by track are shown in Table 18.

Table 18. Track Reported and Evaluated Savings and Realization Rates

Track	Reported Electricity Savings (kWh)	Evaluated Electricity Savings (kWh)	Reported Gas Savings (therms)	Evaluated Gas Savings (therms)	Electricity Savings Realization Rate	Gas Savings Realization Rate
Standard	7,095,885	6,876,082	179,601	185,343	97%	103%
Custom	11,396,431	10,200,606	289,996	253,194	90%	87%
LEED	5,409,556	308,900	5,104,045	277,759	94%	90%

Table 19. Program Level Realization Rates

Fuel Type	Realization Rate
Electricity (kWh)	93%
Gas (therms)	92%
Total Energy (MMBtu)	92%

Energy Use Intensity of Sampled Projects

Cadmus also calculated the sampled projects' energy use intensity (EUI) by examining building floor area in square feet and utility billing data for gas and electricity usage. Three university projects, one hospital central plant project, and a warehouse expansion were not examined, as they constituted a portion of a larger facility. Three other projects had one fuel type served by utilities other than those providing funding to Energy Trust, and utility billing data could not be obtained. One project has yet to be evaluated, so we could not yet ascertain if all billing data was provided and accurate. Also, one other project was a residential home and Energy Trust could not obtain the data for this site.

Table 20 shows EUI data for the 30 remaining projects.

Table 20. Energy Use Intensities for 2011 Evaluation Sample Buildings

Project	Building Type	Area (sf)	Electricity EUI (kWh/sf)	Gas EUI (therms/sf)	Total Energy EUI (kBtu/sf)
ETONB1102	Education	57,945	30.3	0.76	179
ETONB1104	Education	27,000	32.7	1.17	229
ETONB1108	Education	9,535	7.2	0.00	25
ETONB1130	Education	67,485	6.3	0.34	55
ETONB1123	Food Sales	42,000	36.6	1.45	270
ETONB1114	Food Service	3,781	43.5	4.30	579
ETONB1115	Food Service	1,525	22.0	3.01	376
ETONB1122	Food Service	6,247	27.4	6.51	744
ETONB1128	Food Service	6,350	68.5	4.06	640
ETONB1131	Food Service	5,500	83.9	6.41	928
ETONB1127	Health Care (Inpatient)	838,415	2.1	0.34	42
ETONB1121	Lodging	101,555	11.6	0.62	101
ETONB1116	Mercantile (Retail Other Than Mall)	145,000	22.7	0.34	111
ETONB1120	Mercantile (Retail Other Than Mall)	65,808	35.8	0.71	193
ETONB1137	Mercantile (Retail Other Than Mall)	18,038	13.7	0.15	61
ETONB1101	Mixed use Residential	394,000	4.5	0.11	26
ETONB1103	Mixed use Residential	40,500	7.0	0.06	30
ETONB1118	Mixed use Residential	106,655	3.9	0.29	42
ETONB1140	Mixed use Residential	62,493	3.7	0.03	16

ETONB1124	Office	260,000	0.5	0.64	65
ETONB1112	Other	21,200	521.0	0.78	1,856
ETONB1117	Other	14,600	18.0	3.61	422
ETONB1133	Other	30,000	69.6	0.31	268
ETONB1111	Public Order and Safety	33,200	24.1	0.66	148
ETONB1113	Warehouse and Storage	30,767	4.5	0.18	34
ETONB1125	Warehouse and Storage	40,000	7.3	0.17	41
ETONB1129	Warehouse and Storage	23,758	11.3	0.21	60
ETONB1132	Warehouse and Storage	20,653	6.9	0.01	25
ETONB1134	Warehouse and Storage	413,700	1.9	0.09	16
ETONB1139	Warehouse and Storage	7,180	18.8	0.00	64

Table 21 shows performance of buildings in the 2011 sample in terms of energy use intensity, relative to two other studies that previously have been used to benchmark the performance of new construction buildings in Oregon.[12,13] Appendix A highlights data from these studies in greater detail.

Table 21. Comparison of EUI Data with Other Studies

Building Type	Buildings in Sample	Average EUI (kBtu/sf)	PGE EUI Data for Post-1985 Buildings (kBtu/sf)	Ecotope New Construction EUI 2002-2004 (kBtu/sf)
Colleges	2	195	89.8	65.9
Department Stores	2	137	61.2	76.8
Elementary School	1	55	43.2	48.5
Full Service Restaurant	5	708.3	587.8	512.7
High Rise Apartment	4	28.3	58.4	58.5
High Schools	1	24.5	73.1	48.5
Medical Clinic	1	41.6	77.3	91.8
Office	1	65.5	85.3	81.9
Other	6	319.7	N/A	96.3
Supermarket	1	269.9	198.7	202.8
Warehouse	6	21.5	32.1	31.8

12 Energy Trust of Oregon FY2009 program savings calculation spreadsheet, "2005398 01 18 2009 River East Center Form 520L 540L Final.xls"

13 Ecotope. December 2009. "Baseline Energy Use Index of the 2002-2004 Nonresidential Sector: Idaho, Montana, Oregon, and Washington." Table A-11.

Unlike the results of previous program years, many of the sample buildings used more energy per square foot than buildings in the comparison studies. In most cases, this was due to limitations of those studies' building type designation. For example:

- The two sampled college buildings actually represent laboratory and science buildings, which are significantly more energy intensive than a building that houses only classrooms or administrative functions.
- The two department stores both include a large grocery component, which increased the energy intensity relative to the conventional department stores referenced in the comparison studies. However, these uses were less than half of the overall area, so they could not be considered supermarkets.
- Finally, the other category included several data centers with very high energy use intensity. These types of facilities were less prevalent during the time period of the Ecotope comparison study, so it is reasonable for the evaluated sample to have a higher EUI.

Cadmus noted that the supermarket building type had higher average EUIs than the comparison studies. We found the same result for supermarkets during the 2009 and 2010 program evaluations. The average 2010 supermarket EUI was 268 kBtu/sf, almost identical to the 270 kBtu/sf found for the 2011 supermarket. Neither of the other two comparison studies reported average floor area for buildings. Cadmus reviewed secondary literature to determine that the 2011 sample supermarket projects likely had an area relatively similar to those in either study (42,000 square feet versus 45,561 square feet).[14] This differs from the 2010 supermarkets, which had a slightly smaller average area.

We found similar issues for restaurant building types. The fast food restaurant building type in 2009 and full service restaurant building type in 2010 and 2011 also had consistently higher average EUIs than the comparison studies. The increased EUI for supermarkets and restaurants, despite higher efficiency equipment, could represent an area for further study by either Energy Trust or PECI.

Schools demonstrated a varied range, with respect to reference studies, both above and below reference EUIs. However, the small sample size precluded drawing any conclusions about trends or factors accounting for the differences.

The medical clinic project was ETONB1127, which was actually a mental health facility which was extensively retrofit. The reference studies don't provide a clear comparison based on building type, although the project's EUI is below the reference study values for either medical clinic or hospital. Regardless, the facility has a relatively low EUI compared to most other building types in the sample, which demonstrates the significant energy efficiency improvements made during the renovation project.

[14] < http://www.fmi.org/research-resources/supermarket-facts/median-total-store-size-square-feet >

Cadmus found the four high-rise apartments and six warehouses in the sample achieved lower average EUI than the comparison studies. These results are consistent with the 2009 and 2010 results. The warehouse savings were primarily driven by reductions in lighting power density, indicating the program is consistently driving warehouse EUIs below the average values from the reference studies. The apartment savings often involved LEED or comprehensive HVAC measures. The lower EUIs for these buildings over multiple years also indicate successful efforts by the program to reduce energy consumption compared with the reference study data.

Conclusions and Recommendations

Cadmus conducted an impact evaluation of the 2011 Energy Trust of Oregon New Buildings Program by analyzing energy savings for 228 measures implemented in 40 projects. The measures belonged to three different program tracks (Standard, Custom, and LEED) and represented a variety of subcategories.

A third-party firm is in the process of conducting a post-occupancy evaluation on one large data center project with the highest energy savings in the 2011 program year. Cadmus will not evaluate this project's energy savings until the post-occupancy evaluation is complete.

We performed verification site visits for each remaining project in the sample and evaluated 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 algorithms, calculation spreadsheets, and building simulation models.

Energy Trust and its implementer, PECI, applied appropriate methodologies and assumptions for many measures, although, overall, Cadmus' evaluated savings differed from reported energy savings. Many measures included variations between assumptions used to estimate reported savings and evaluated values. Cadmus also noted revisions to calculation methodologies, equipment counts, and variations between expected and achieved simulation model performance. These combined factors led to a 92% program-level realization rate.

Overall, the 2011 program implementer performed a reasonable level of review and quality control to achieve high average project savings realization rates. The measure types with lower evaluated savings represented large, complex measures whose final operating patterns can be difficult to predict, particularly in a new construction application. The implementer has continually worked to streamline and improve the program's delivery mechanisms, and we believe their work has been effective.

Cadmus identified several areas for program improvements. The most significant would involve the changes in energy simulation model energy tracking and reporting methods that could improve future evaluation efforts. There are also steps the implementer could take to obtain a better sense of appropriate measure installations and encourage participants to collect data useful for ongoing commissioning and future evaluation efforts. The following recommendations reflect potential improvements.

Develop "Sanity Checks" to Approve Projects

Cadmus found one project that received prescriptive incentives for installing tankless water heaters. The site was actually a private residence, and should not have qualified for incentives through the New Buildings program. While program implementation guidelines were correctly followed in this instance, we recommend the implementer consider additional scrutiny of projects that claim to use part of the facility for a residence, unless it is clearly a multifamily project. One tool may be working with the relevant utility company to see if the site is given a residential or commercial billing account.

In addition, the implementer may consider developing "sanity checks" to approve incentives for prescriptive water heating and HVAC equipment. For example, the implementer could develop rules of thumb for the appropriate quantity of each type of equipment for a certain area for various building types. In this case, the participant installed five tankless water heaters at a 4,600-square foot site. Unless the site was clearly designated multifamily, it's unlikely that an equipment density at this level would meet the requirements for a prescriptive application.

Obtain Energy Simulation Models During Program Year

Cadmus used DOE-2 and Trane TRACE software to evaluate energy simulation models for LEED buildings and a subset of Custom projects. The implementer obtained the correct models for six of 13 simulation modeling projects. PECI searched through their archives again to identify the correct modeling files on several of the projects. In other cases, Cadmus contacted building simulation model contractors for the appropriate models used to calculate savings. Though a time-consuming task, all modeling contractors complied. In one case Cadmus made significant adjustments to the simulation model to match the as-built structure.

Cadmus recommends the implementer obtain energy simulation models for review during the program year or require building simulation model developers sign a consent form that releases models for evaluation purposes. This step should be a requirement for LEED track incentives and any Custom track incentives using model-estimated savings, thus improving the likelihood a project can be evaluated. The implementer indicated they would require simulation models to be submitted starting with the 2012 program year.

Maintain Consistent Documentation on Simulation Model Files

Cadmus found the project documentation for simulation projects was inconsistent from one project to the next, which made it difficult to determine the appropriate savings and relevant material to support energy savings. The basis of final incentive, supporting documentation, final incentive amount, and simulation models should be categorized consistently, and clearly labeled, across all projects. Cadmus also recommends the implementer list any changes made to the simulation models and document why those changes were made.

Ensure Simulation Models Match Approved Savings

Many project files included simulation models that did not match LEED EAc1 forms or the final approved building performance. The models should be clearly labeled with the exact information they support. We recommend the implementer verify that the models match the energy consumption output on a gross savings level.

Encourage Participants to Enable Energy Management System Trends

Cadmus has found that, in general, new construction facilities have energy management systems. In most cases the sites evaluated for this program year had enabled trending on major equipment and controls systems. This data was critical to our evaluation effort, and can also provide important

information for the participant about how their facility is operating. In a couple of cases, systems were not trended, although the participant was willing to enable trends at our request. The resulting data was limited, but sufficient to make necessary adjustments to simulation models or calculation spreadsheets. We believe it would be helpful for participants and future evaluation efforts for the program to encourage participants to enable EMS trends during the commissioning process.

Obtain Calculation Sheets for Exceptional Calculations

If the savings claimed under EAc1 include any exceptional calculations, the implementer should document the spreadsheets or source of these calculations. For example, if the participant claims gas savings from installing a solar hot water array under EAc1 and these savings are included in the incented amount, the implementer should document the methodology and source of the stated savings or exclude them from the incented savings.

Require Energy Metering for Projects Not Directly Served by Utility Services

For projects that do not have dedicated energy meters, such as individual buildings on a campus, Energy Trust should consider requiring that the participant sub-meter the energy sources in order to be incented for a given utility. For example, if a building is served by electricity, gas, and steam, require that electrical power, gas therm, and steam Btu meters be installed if incentives are paid for all utility types. The data from the submeter should provide long-term benefit to the participant by providing more granularity on energy consumption for the relevant building. The implementer should consider establishing an energy-savings threshold above which such projects would still potentially meet cost-effectiveness criteria with submeter installation.

Ensure that Incentives Correctly Account for All Utility Types

Projects where district steam savings are claimed that are being paid a gas incentive should be certain to include the steam plant efficiency in calculating the therms saved. LEED defines the project boundary at the building, but a comprehensive utility savings approach commonly allows for a building's steam energy savings to include the upstream savings at the central plant.

Appendix A. Comparison Energy Use Intensity Data

EUI data for the FY 2011 sample, shown in Table 20, can be compared with other available data to determine the relative performance of new construction projects. The following tables provide two example data sets.

Table 22. PGE Data for Post-1985 Buildings

Building Type	Bldg. w/Elec Heat (kBtu/sf)	Bldg. w/Fossil Fuel (kBtu/sf)
Auditoriums	77.1	93.7
Banks	56.1	62.9
Churches	45.3	56.2
Colleges	78.3	89.8
Department Stores	58.0	61.2
Dormitories	55.0	72.0
Elementary School	35.5	43.2
Fast Food Restaurant	527.8	587.8
Full Service Restaurant	111.8	116.6
General Office	73.2	85.3
High Rise Apartment	55.6	66.0
High Rise Office Building	65.6	73.7
High Schools	60.1	73.1
Hospitals	184.0	230.4
Hotels	78.2	88.3
Low Rise Apartment	48.7	58.4
Medical Clinic	71.4	77.3
Middle Schools	45.8	55.8
Motels	51.6	65.3
Strip Malls	67.4	72.3
Supermarkets	196.1	198.7
Warehouse	28.1	32.1

Source: Energy Trust FY2009 program savings calculation spreadsheet: "2005398 01 18 2009 River East Center Form 520L 540L Final.xls"

Table 23. Ecotope Mean EUI Data for Buildings with Majority New Construction in Oregon, 2002–2004

Building Type	Mean EUI (kBtu/sf)
Assembly	76.3
College	65.9
Education	48.5
Grocery	202.8
Health Services	91.8
Hospital	123.1
Institution	102.8
Office	81.9
Other	96.3
Residential / Lodging	58.5
Restaurant / Bar	512.7
Retail	76.8
Warehouse	31.8

Source: Ecotope: "Baseline Energy Use Index of the 2002-2004 Nonresidential Sector: Idaho, Montana, Oregon, and Washington," Table A-11, December 2009.