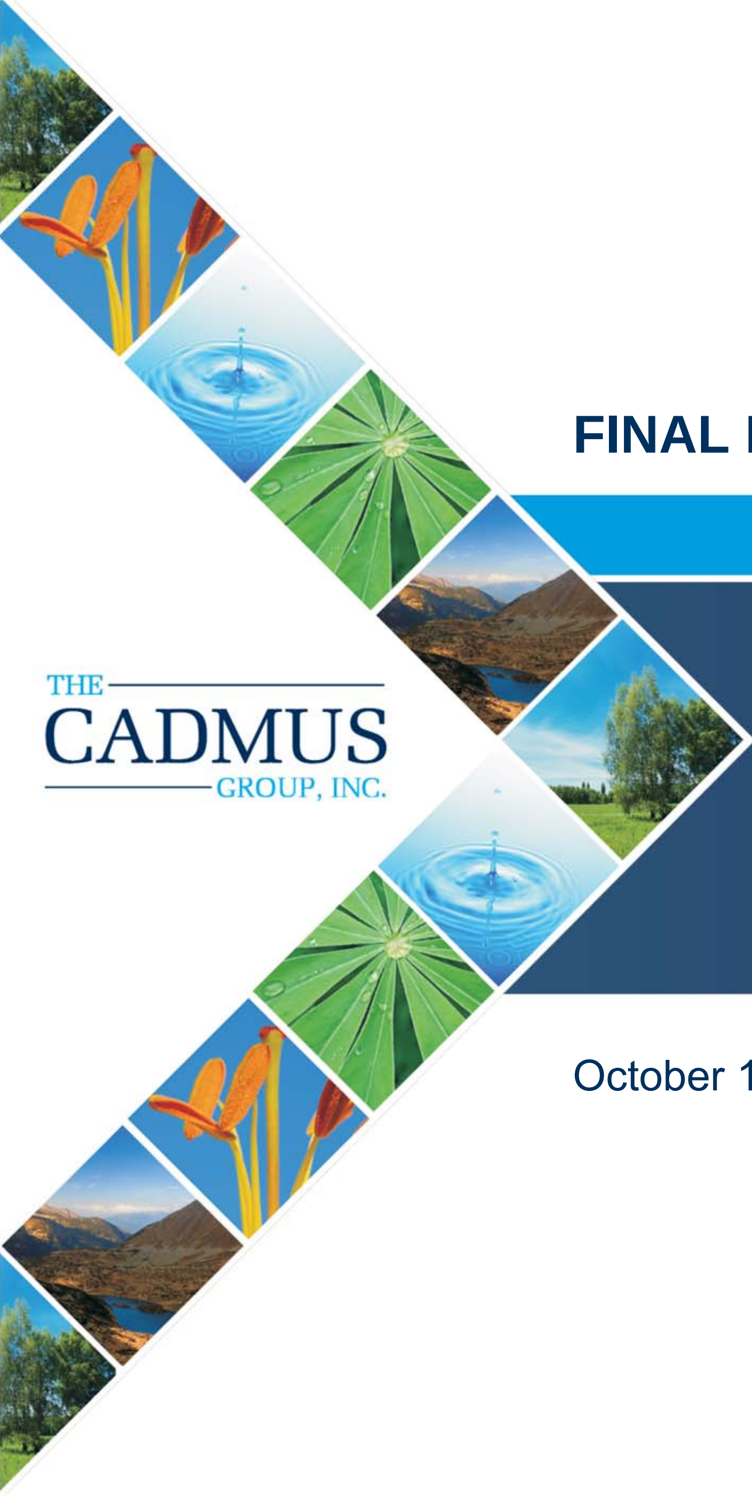

THE CADMUS GROUP, INC.

FINAL REPORT

2010 New Buildings Program Impact Evaluation

October 18, 2012

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EXECUTIVE SUMMARY

Energy Trust of Oregon (ETO) retained the Cadmus Group, Inc., (Cadmus) to complete an impact evaluation of the 2010 New Buildings Program, a comprehensive effort to assist owners of newly constructed or substantially renovated commercial and industrial buildings to achieve energy savings through four different tracks: Standard, Custom, ENERGY STAR, and LEED. A third-party program management contractor—Portland Energy Conservation, Inc.—implemented the 2010 New Buildings Program.

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.
- The ENERGY STAR Track assists participants in certifying their buildings through the Environmental Protection Agency's national energy performance rating system.
- LEED Track projects receive incentives for achieving energy savings as part of certification by the U.S. Green Building Council.

Cadmus sampled 41 projects for evaluation, matching the evaluation level requested by ETO. The sample included: 26 of the largest savings projects (all with reported savings greater than 2,000 MBtu[1]); and a random sample of 15 smaller projects. The sample experienced attrition, however, due to two participants' refusal to respond to repeated contact requests. As shown in Table 1, the final sample contained 39 projects, consisting of 239 measures, representing 62% of the program's total reported, combined savings.

Table 1. 2010 Program and Sample Total Quantities and Reported Savings

	Total Number of Projects	Total Number of Measures	Reported Electricity Savings (kWh)	Reported Gas Savings (therms)	Reported Combined Energy Savings (MBtu)
Program Total	244	1,245	26,044,322	1,134,551	202,318
Sample Total	39	239	14,544,714	749,757	124,602

Cadmus evaluated the program through site visits and reviews of engineering calculations and building simulation models. Site visits validated proper installation and functioning of incented equipment, and provided operational characteristics data to support engineering analysis. Cadmus evaluated Standard Track measures primarily using industry-standard algorithms. Custom measures were analyzed through algorithms, detailed calculation spreadsheet reviews, simulation modeling, and/or energy management system trend data. Cadmus engineers analyzed

[1] MBtu is used throughout this report to represent million Btu.

differences between baseline and as-built simulation models for LEED projects. Cadmus analyzed ENERGY STAR Benchmarking projects by examining differences between baseline and as-built energy use intensities (EUI) using utility billing data. Through the impact evaluation, Cadmus identified a variety of factors reducing the overall program realization rate (the ratio of evaluated to reported savings), as shown in Table 2. Total combined reported energy savings (electricity and gas) represented 202,318 MBtu. Cadmus calculated the total combined evaluated energy savings as 195,386 MBtu, for a 97% overall realization rate.

Table 2. Overall 2010 Program Realization Rates and Energy Savings

Measure Category	Total Number of Measures	Reported Electricity Savings (kWh)	Reported Gas Savings (therms)	Evaluated Electricity Savings (kWh)	Evaluated Gas Savings (therms)	Electricity Savings Realization Rate	Gas Savings Realization Rate
Standard Food Service	97	1,136,661	9,803	1,196,648	9,803	105%	100%
Standard HVAC	249	1,115,482	152,015	1,185,284	121,962	106%	80%
Standard Lighting	595	6,152,260	0	7,190,608	0	121%	N/A
Standard Motors	79	291,191	0	290,467	0	100%	N/A
Standard Water Heating	80	145,225	136,602	145,225	85,900	100%	63%
Custom	71	3,320,331	166,251	3,247,121	233,685	98%	141%
Custom Food Service	23	1,565,119	32,103	1,644,268	31,934	105%	99%
ENERGY STAR	1	1,041,218	4,687	1,248,104	7,913	120%	169%
LEED	50	11,276,835	633,091	8,487,972	622,094	75%	98%
Total 2010 Sample	1,245	26,044,322	1,134,551	24,635,698	1,113,291	95%	98%

* Savings values listed in the impact evaluation are gross values. Calculation of a net-to-gross ratio fell outside the scope of this evaluation.

Primary factors affecting realization rates included:

- Actual operating conditions differed from deemed assumptions for lighting operating hours;
- Actual equipment operation differed from expected patterns;
- Observed equipment quantities differed from reported quantities; and
- Building simulation models did not accurately reflect as-built conditions or operating parameters.

The 2010 program savings realization rate of 97% exceeds the 2009 program evaluation value of 96%. Most measure types achieved high realization rates. The primary factors that lowered the overall realization rate included:

- Significant variation between proposed and as-built equipment types, building operation, and performance in LEED buildings;
- Applying the same deemed savings in the original savings estimates for gas-fired boilers regardless of whether they serve as primary or backup units; and

- Not accounting for lower consumption for condensing water heaters installed in conjunction with refrigeration heat recovery systems in grocery stores.

The issues were balanced out to a degree by higher savings resulting from:

- Longer actual lighting operating hours than deemed;
- Lower than expected as-built energy use intensity in one ENERGY STAR building; and
- Better than expected performance for Custom HVAC projects.

Overall, the 2010 program implementer performed a reasonable level of review and quality control to achieve high average project savings realization rates.

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MEMO

Date: October 18, 2012
To: Board of Directors
From: Sarah Castor, Evaluation Sr. Project Manager
Jessica Rose, Business Sector Manager, New Buildings Program
Subject: Staff Response to the 2010 New Buildings Program Impact Evaluation

The 2010 program year was a year of significant change for the New Buildings program. In addition to continued weak economic conditions, the Oregon energy codes for new commercial construction became much more stringent. Despite these challenges, the results of the 2010 New Buildings Impact Evaluation show that the program's overall realization rates remained about the same as 2009.

Since the transition to PECI as the program management contactor (PMC) in late 2009, the program has instituted several changes, many of which are not apparent in projects for a year or more given the long lead times in new construction. The changes implemented include:

- Program redesign and launch in October 2010 with the goal of simplifying overall structure, providing tiered incentives that increase with savings achieved and motivate customers to incorporate even more energy efficiency
- Quarterly coordination with planning and evaluation to address changing codes and standards
- Requirement of two reviews on all project submittals to ensure incentive requirements have been met
- Introduction of a required lighting calculator for 2010 code projects that calculates savings and incentives based on lighting power density compared to code
- Introduction of a simplified HVAC calculator for 2010 code projects that calculates savings and incentives for a number of HVAC measures, including demand control ventilation, unitary HVAC equipment, VFDs, fan power, air-to-air heat exchangers, and economizers
- Review of all models and calculations for modeled projects
- Review of model input/output files for LEED projects and correcting the calculation of savings as needed

The evaluator made several specific recommendations for program improvements based on 2010 project findings (in italics), many of which we have already addressed as part of the 2010 program redesign, or will address as follows:

- *Apply savings more appropriately to back-up boilers and condensing water heaters*
  For standard measures, the program does not currently distinguish the load usage of boilers and condensing water heaters for the purposes of determining savings or eligibility for incentives. Non-primary usage could incorporate a range

of situations, from peaking boilers that help make geothermal systems cost-effective, to water heaters that are installed to meet future loads, to purely redundant equipment. The program team will revisit this issue and make a recommendation to Energy Trust to account for secondary, backup boilers and condensing water heaters by either: 1) reducing the average standard savings claimed; 2) creating measure(s) for secondary equipment with lower savings and incentives; or 3) requiring equipment to be primary and meet certain load requirements or submit load calculations to verify equipment sizing to be eligible for incentives.

For custom projects, the program ensures the correct savings are calculated based on the expected load of each boiler and water heater. No savings are claimed for redundant boilers that have no expected load.

- *Account for reduced consumption through heat recovery*
  The program agrees with this recommendation, and has addressed this issue for modeled or custom measures in the program technical guidelines that were updated in December 2010. The guidelines outline and require that:
  - All interactions between standard measures (e.g. water heaters) and modeled measures are accounted for in the modeled measure savings by including the standard measures in the baseline model assumptions
  - All interactions between solar thermal collectors and water heating measures are accounted
  - Grocery stores larger than 50,000 square feet must include heat reclaim off the refrigeration system in the baseline model, as a recent NEEA market study indicated that heat reclaim has become standard practice in larger stores.

  Adjusting the standard gas measures to account for interactions with custom or modeled savings measures is more challenging as these savings numbers are deemed based on a variety of operating assumptions and cannot be easily overridden in FastTrack.

  One alternative approach would be to consider creating a separate standard water heater measure for grocery stores to discount savings for stores that also install heat reclaim. However, since the savings associated with this standard measure are based on estimated run times and water heating loads for a variety of applications, the program may find that the savings claimed in grocery applications (even with heat recovery) will vary minimally from the existing standard measure savings assumptions.

- *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, PECI 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.

- *Provide more detail on exceptional calculations*
  The program currently, as a process step, does place all exceptional calculation workbooks, simulations, and associated documentation in the project files. It was unfortunate that one of the selected projects did not have this information in the project files; only an earlier version of the calculation (not the final version) was in the electronic project file. As a part of the updated documentation processes described in the bullet above, PECI will ensure the final version of each exceptional calculation is included in the project file.

INTRODUCTION

Energy Trust of Oregon (ETO) retained the Cadmus Group, Inc., (Cadmus) to complete an impact evaluation of the 2010 New Buildings Program (the program's process evaluation will be completed by another firm).

The New Buildings Program comprehensively seeks to assist owners of newly constructed or substantially renovated commercial and industrial buildings in achieving energy savings through the following, four 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 ENERGY STAR Track assists participants in certifying their buildings through the Environmental Protection Agency's national energy performance rating system.
- The LEED Track projects receive incentives for achieving energy savings as part of certification by the U.S. Green Building Council.

Portland Energy Conservation, Inc., (PECI), a third-party program management contractor (PMC), managed the 2010 program. PECI replaced Science Applications International Corporation (SAIC) at the beginning of the 2009 program year.

During the 2010 program year, 244 projects received incentives through the Standard, Custom, ENERGY STAR, 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 numbers of measures and first-year reported energy savings for each track for the 2010 program year. The Standard and Custom Tracks have been further divided into subcategories, based on measure categories.

Table 3. 2010 Standard Track Total Measures and Reported Savings

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
Standard Food Service	97	1,136,661	9,803
Standard HVAC	249	1,115,482	152,015
Standard Lighting	595	6,152,260	0
Standard Motors	79	291,191	0
Standard Water Heating	80	145,225	136,602
Standard Track Total	1,100	8,840,819	298,420

Table 4. 2010 Custom Track Total Measures and Reported Savings

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
Custom	71	3,320,331	166,251
Custom Food Service	23	1,565,119	32,103
Custom Track Total	94	4,885,450	198,354

Table 5. 2010 ENERGY STAR Track Total Buildings and Reported Savings

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
ENERGY STAR	1	1,041,218	4,687

Table 6. 2010 LEED Track Buildings and Reported Savings

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
LEED	50	11,276,835	633,091

Table 7. 2010 Total Program Measures and Reported Savings

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
Total 2010 Program	1,245	26,044,322	1,134,551

The following section presents Cadmus' methodology for evaluating the 2010 program.

METHODOLOGY

The impact evaluation, designed to verify reported program participation and estimate gross energy savings, measured gross energy changes using: data collected on site; program tracking data; and engineering models.

The impact evaluation included the following approaches for determining gross energy savings attributable to the program:

- Sample development
- Data collection
- Engineering analysis

Savings were calculated based on changes between baseline and installed efficiency measures. Cadmus used program tracking data, assessed for assumptions and accuracy, in the calculations.

Sampling Methodology

Previously, Cadmus evaluated the New Buildings Program for both 2008 and 2009. At the 2010 study's beginning, Cadmus met with ETO staff to develop a sampling plan, review appropriate evaluation methods, and discuss specific program details. ETO staff, noting the program's top 40 projects represented nearly three-quarters of its 2010 savings, suggested these might represent a reasonable sample of measures. However, ETO staff also expressed interest in the performance of small business projects, which present a growing market segment for the program.

Cadmus converted energy and natural gas savings into millions of British thermal units (MBtu), providing a standard metric for comparing projects. Most projects contained a range of measures, with varying savings levels. Cadmus selected a census of 26 projects with more than 2,000 MBtu in energy savings, meeting ETO's request to evaluate a large portion of program savings. ETO provided Cadmus with a list of small buildings (defined as less than 50,000 square feet in area). From the list, Cadmus selected a random sample of 15 projects.

To acquire the necessary documentation, Cadmus provided the list of sample projects to ETO staff. Cadmus also reviewed Standard projects to ensure the sample contained all major measure types as well as a representative quantity of standard practice measure types. ETO and the PMC noted several measures of interest during the evaluation kickoff meeting. The measures represented either emerging technologies or ones which are expected to make up a significant portion of program savings in future years. Upon review, Cadmus determined the sample represented all measure categories of interest, as shown in Table 8.

Table 8. 2010 Evaluation Measures of Interest

Measure	Relevant Projects in Sample
Tankless water heaters in restaurants	2
Variable refrigerant flow system	1
Mixed use buildings	3
Demand controlled ventilation	3
Grocery refrigeration	6
Condensing boilers	2

Throughout the evaluation, attrition occurred for two projects. As shown in Table 9, attrition occurred when participants could not be reached for site visits.

Table 9. Sample Attrition Details

Participant	Project Type	Building Type	Reported Savings (MBtu)	Reason for Attrition
ETONB1002	NBE LEED-NC	Multifamily residential	4,151	Participant could not be reached for site visit, despite repeated attempts.
ETONB1011	NBE Standard	Multifamily residential	57	Participant could not be reached for site visit, despite repeated attempts.

After attrition, the final evaluation sample included 39 projects, representing 62% of reported program savings. Table 10 shows sample and population details for 2010 projects. Cadmus conducted verification and analysis on all measures for each project in the sample.

Table 10. 2010 Reported Program Evaluation Sample Details

	Total Number of Projects	Total Number of Measures	Reported Electricity Savings (kWh)	Reported Gas Savings (therms)	Reported Combined Energy Savings (MBtu)
Program Total	244	1,245	26,044,322	1,134,551	202,318
Sample Total	39	239	14,544,714	749,757	124,602
Sample Portion of Program Total	16%	19%	56%	66%	62%

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

Table 11. Sample Reported Energy Savings by Measure Category

Measure Category	Total Number of Measures	Total Electricity Savings (kWh)	Total Gas Savings (therms)
Standard Food Service	37	803,433	2,915
Standard HVAC	35	58,793	81,426
Standard Lighting	73	652,971	0
Standard Motors	29	89,333	0
Standard Water Heating	11	26,553	6,485
Custom	14	1,534,719	121,004
Custom Food Service	22	1,350,245	32,103
ENERGY STAR	1	1,041,218	4,687
LEED	17	8,987,449	501,137
Total 2010 Sample	239	14,544,714	749,757

Cadmus calculated the sampling precision[2] to determine whether it was acceptable, based on standard statistical levels of rigor to extrapolate sample energy savings to the overall program population. For each of the four tracks, Cadmus determined the confidence interval (precision) for a 90% confidence level, and found the sample exceeded a 90/10 level, as shown in Table 12.

Table 12. 2010 Sample Precision

Track	Confidence Level	Confidence Interval
Standard	90	±7.9%
Custom	90	±3.4%
ENERGY STAR	90	0%*
LEED	90	±11.2%
Total	90	±9.0%

* Cadmus sampled the only measure in the ENERGY STAR Track, so the confidence interval is 0%.

For comparison purposes, Table 13 shows distributions of measure savings in the overall program and sample population. Though the sample distribution remained very consistent with the overall program project savings distribution, the sample featured less prescriptive lighting and water heating savings, and a larger proportion of the more complex LEED measures, which generally involved greater energy savings and required more analysis. These distribution differences remained consistent with the process used for selecting projects that saved more energy.

2 The confidence level and interval determine precision. Values for Standard projects, for example, indicate Cadmus can be 90% certain, based on sampling error, the correct answer falls within ±7.9% of evaluated savings.

Table 13. Total and Sample Measure Portions of Energy Savings

Measure Category	Population Measure Energy Savings (MBtu)	Portion of Total Measure Savings	Sample Measure Energy Savings (MBtu)	Portion of Sample Measure Savings
Standard Food Service	4,860	2%	3,034	2%
Standard HVAC	19,009	9%	8,343	7%
Standard Lighting	20,998	10%	2,229	2%
Standard Motors	994	0%	305	0%
Standard Water Heating	14,156	7%	739	1%
Custom	27,954	14%	17,337	14%
Custom Food Service	8,550	4%	7,817	6%
ENERGY STAR	4,022	2%	4,022	3%
LEED	101,797	50%	80,788	65%
Total	202,318	100%	124,617	100%

As shown in Table 14, the evaluation sample and program population represented a mix of building types, with offices making up the predominant sample building type. This was a change from 2008, when the most common sample building type involved grocery stores, and 2009, when the most common sampled building type was education. The sample's “other” building types were an airport terminal and an aquatic center.

The sample distribution of building types roughly matched the program population, except for grocery and office buildings (which were slightly oversampled, due to the disproportionate savings level they represented).

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%	7	3%
Auto Services	0	0%	3	1%
Church	0	0%	2	1%
College/University	2	5%	11	5%
Grocery	4	10%	6	2%
Gym/Athletic Club	1	3%	5	2%
Hi Rise Residential	1	3%	5	2%
Hospital	1	3%	2	1%
Infrastructure	1	3%	2	1%
Institution/Government	1	3%	9	4%
Laundry/Dry Cleaners	0	0%	2	1%
Lodging/Hotel/Motel	1	3%	5	2%
Manufacturing	0	0%	7	3%
Multifamily Residential	2	5%	9	4%
Office	11	28%	49	20%
Other	2	5%	20	8%
Other Health	0	0%	11	5%
Other Residential	1	3%	3	1%
Parking structure/Garage	0	0%	3	1%
Religious/Spiritual	0	0%	2	1%
Restaurant	4	10%	18	7%
Retail	2	5%	21	9%
Retirement/Assisted Facilities	0	0%	1	0%
Schools K-12	3	8%	17	7%
Warehouse	2	5%	24	10%
Total	39	100%	244	100%

Data Collection

Cadmus reviewed 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. Cadmus reviewed analyses originally used to calculate expected savings, and verified operating and structural parameters. Site visits verified installations and determined changes to operating parameters following measure installation.

In some cases, Cadmus 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 Cadmus to develop recommendations for future studies.

Document Review

The evaluation began by reviewing relevant documentation and other program materials from the PMC. In several cases, Cadmus could not identify calculation spreadsheets or relevant data for measure savings calculations. Cadmus usually could 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 in obtaining energy simulation models for Custom and LEED projects. The PMC's project documentation only included eleven of the 20 simulation models required for Custom and LEED projects. Many projects included simulation models that did not match the LEED EAc1 form or the final version of the design. Cadmus and the PMC obtained most remaining models from simulation modeling firms and program participants. In some cases, the PMC modified the model prior to approving savings, and Cadmus obtained the final models. Cadmus 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.

During documentation review, Cadmus paid particular attention to calculation procedures and documentation of savings estimates. Information reviewed for all sample sites included: 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 whole-building simulation model projects (included as Appendix B). Field staff used streamlined versions of the form, focusing on specific end uses when verifying individual measures at a site.

Site visits sought to accomplish the following, with field engineers focusing on three primary tasks:

1. Verifying installation of all measures for which participants received incentives: To the extent possible, field engineers verified energy-efficiency measures remained in place, had been correctly installed, and functioned properly, based on spot measurements, energy management system trend data, visual inspections, or facility staff experience, as appropriate. Field engineers also verified operating parameters for installed equipment.
2. 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. Data required proved unique to each measure.
3. 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, field engineers noted equipment counts differing from those incented. When finding fewer measures in place, Cadmus accordingly reduced realization rates. Cadmus noted 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 the following, major measure groups:

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

The following sections describe the focus of site visits, and the procedures used to verify savings from different types of measures installed through the program. In previous program evaluations, Cadmus applied more in-depth analysis to prescriptive HVAC and motor measures, quantifying “equivalent full load hours” (EFLHs) affected equipment, and then adjusting energy savings.

For the 2010 evaluation, Cadmus focused analysis resources on the complex LEED and Custom projects, which constituted a larger portion of the program and sample energy savings.

Standard Food Service

For many Northwest utility clients, the PMC implements the EnergySmart Grocer program on the Bonneville Power Administration’s behalf. Prior to the 2010 program year, the New Buildings Program utilized the Custom Track to incent many food service measures, such as anti-sweat heat controls and floating head pressure controls. Beginning with the 2010 program year, the PMC provided many of these as prescriptive measures with deemed savings. The program also incented 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 units met program efficiency requirements.

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

Standard Lighting Measures

The analysis included two 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.
- 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.

Analyzing lighting measure savings required documentation regarding fixture wattages, quantities, and operation hours, reviewed within each file prior to conducting on-site inspections.

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 buildings’ occupants within the relevant spaces.

We evaluated lighting control systems specifically by 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 whether lights turned off. Lighting automation systems were visually inspected for scheduled operation hour set points, and then were verified against claims used in submitted calculations.

In addition to parameters listed above, Cadmus conducted on-site 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 numbers 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 units met the program’s efficiency requirements. Cadmus performed more detailed calculations and analysis on several measures, including boilers and demand controlled ventilation (DCV). Site inspections included interviews with facility personnel, which enabled Cadmus to verify operation hours, temperature set points, and proper installation of energy-efficient equipment.

For boilers, Cadmus attempted to quantify heating loads through utility billing data and by determining whether 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. Cadmus developed a new DCV calculation workbook to account for these factors, and to evaluate energy savings, based on building types, HVAC types, occupancy patterns, and typical meteorological year (TMY) data.

Standard Motors and Variable Speed Drives

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

Standard Water Heating

Cadmus developed a separate category for water heaters and measures significantly influencing water heating loads, such as dishwashers and showerheads.

Dishwashers were rated through ENERGY STAR, with Cadmus verifying equipment counts and confirming the units met the program's efficiency requirements. The evaluation sample did not include showerhead measures.

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.[3] 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 lighting power density reductions to more complex chiller heat recovery systems. The diversity of projects required a variety of calculation methods used to estimate energy savings. Primarily, these included 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 whether 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, confirmed through site visits and interviews with facility operations staff.

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[3] *ASHRAE Handbook.* 2004. HVAC Systems and Equipment.

ENERGY STAR

The 2010 program approved one project through the ENERGY STAR Track. Cadmus performed a site visit for this project to confirm the energy-efficiency measure's installation and building operating characteristics. Cadmus then used as-built and occupied utility billing data to calculate a new ENERGY STAR benchmarking score (using the Portfolio Manager tool).[4]

LEED Building and Custom Track Simulation Models

For the 2010 program evaluation sample, all 15 LEED Track buildings and five 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; and
- Employed well-developed and sophisticated engineering analysis tools, such as DOE-2 or TRACE.

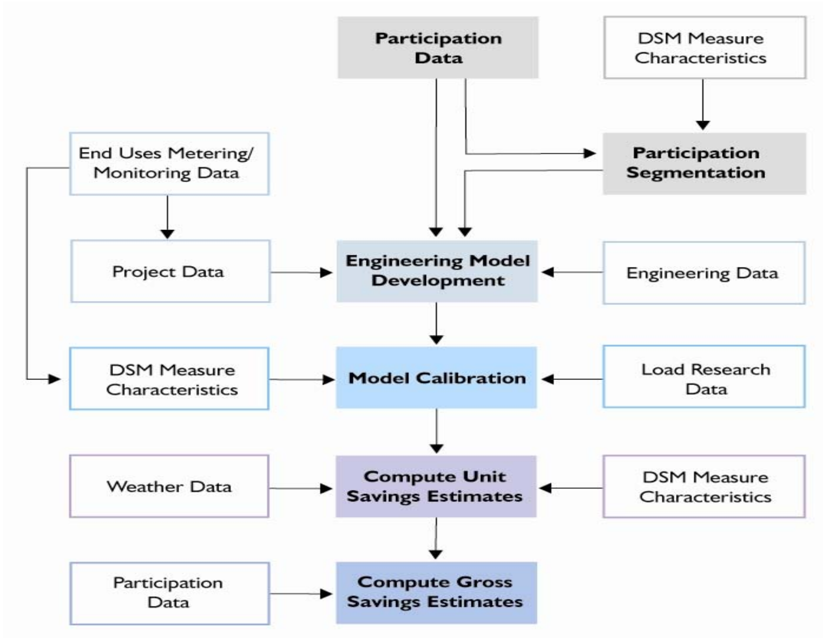
The analysis focused on the following issues:

- 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 for creating the baseline model by removing the energy-efficient measures in the simulation.
- Comparing calibrated, as-built model energy use results with the baseline model to determine individual building annual energy savings.
- 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.

4 http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

Figure 1 depicts the MCEM approach.

Figure 1. Measurement-Based Calibrated Engineering Method Flowchart



Model Calibration

Being this was a new construction program, the only model that could be used for calibration purposes was the model for the as-built building. This represented Cadmus' starting point, and we obtained as-built models for all building measure projects in the final sample.

As-built models 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; and schedules. This information was confirmed using project files and detailed data collection reports from site visits. Through site interviews, Cadmus determined occupancy levels 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. Minor discrepancies resulted from use of typical meteorological year (TMY3) data in DOE-2, rather than actual historical weather data for the calibration period. It is difficult to develop actual historical weather data files due to the variety of parameters required by DOE-2, particularly hourly solar radiation values. Cadmus found National Oceanic and Atmospheric Administration (NOAA) weather conditions for the Portland Metro area (the location of 14 of 20 buildings modeled) were reasonably close to the averages used in TMY3 weather files, as shown in Table 15. Four other modeled projects were located in the Willamette Valley, with weather conditions similar to that in the Portland Metro area. Cadmus looked at recent weather data for comparisons, using a full year of NOAA data from April 2011 through March 2012.

Table 15. Average Weather Data vs. Actual Conditions*

	Heating Degree Days	Cooling Degree Days
Average	4,548	222
2011-2012	4,775	273
Difference	5%	23%

* www7.ncdc.noaa.gov/CDO/cdoselect.cmd?datasetabbv=GSOD&countryabbv=&georegionabbv=

Cadmus notes cooling energy usage is less dependent on weather conditions in buildings with constant internal heat gains from sources such as process, lighting, and plug loads constituting a relatively large percentage of overall cooling loads. As weather-sensitive cooling loads were relatively small, Cadmus chose to calibrate the building to 30-year average data, as opposed to modeling actual climatic conditions found in the 2011–2012 data.

ANALYSIS AND FINDINGS

This section presents: results of engineering analysis, applied to the sample; adjustments to reported values; calculation of realization rates; and extrapolation to the full 2010 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 16. The overall sample had an 87% electric realization rate, with a 103% natural gas realization rate. Cadmus adjusted electricity and gas savings resulting from the measure-specific reasons outlined in the sections below.

Table 16. Sample Reported and Evaluated Savings and Realization Rates

Measure Category	Total Number of Measures	Reported Electricity Savings (kWh)	Reported Gas Savings (therms)	Evaluated Electricity Savings (kWh)	Evaluated Gas Savings (therms)	Electricity Savings Realization Rate	Gas Savings Realization Rate
Standard Food Service	37	803,433	2,915	845,834	2,915	105%	100%
Standard HVAC	35	58,793	81,426	62,472	65,328	106%	80%
Standard Lighting	73	652,971	0	763,176	0	117%	N/A
Standard Motors	29	89,333	0	89,111	0	100%	N/A
Standard Water Heating	11	26,553	6,485	26,553	4,078	100%	63%
Custom	14	1,534,719	121,004	1,500,880	170,085	98%	141%
Custom Food Service	22	1,350,245	32,103	1,418,528	31,934	105%	99%
ENERGY STAR	1	1,041,218	4,687	1,248,104	7,913	120%	169%
LEED	17	8,987,449	501,137	6,764,772	492,433	75%	98%
Total 2010 Sample	239	14,544,714	749,757	12,719,431	774,686	87%	103%

Standard Food Service

The Standard Food Service category represented refrigeration, cooking, and grocery measures, which had a 105% 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 types, efficiencies, and end uses.

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 equipment counts at each site matched reported values, and equipment met ENERGY STAR specifications. These measures achieved a 100% realization rate.

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.

For ECM motors, the PMC applied deemed savings estimates, based on a weighted average for walk-ins and display cases across motor sizes and refrigeration temperatures. Cadmus used PMC data, supplied to the Regional Technical Forum (RTF) to recalculate savings, with specific weighted averages across motor sizes for low- and medium-temperature refrigeration cases. The sample included a higher proportion of low temperature cases, which increased overall energy savings. These measures had a realization rate of 112%.

Cadmus applied benchmarking from secondary sources to examine savings of controls measures, such as anti-sweat heater controls, evaporator fan controls, and floating head and suction pressure controls. Reported savings were deemed reasonable in all cases (and occasionally conservative), resulting in a 100% realization rate for these measures.

For LED case lighting, Cadmus verified fixture counts and energy consumption, based on manufacturer specification sheets. Cadmus calculated energy savings relative to a linear T8 fluorescent baseline, applying the appropriate refrigeration factor, based on whether it was in a low or medium temperature case. These measures had a 116% calculated realization rate.

Cadmus benchmarked night-cover savings, based on ASHRAE calculations for savings relative to overall compressor loads. One of two projects appeared to overstate energy savings, hence savings were adjusted accordingly. The realization rate for these two measures was 75%.

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, demand-controlled ventilation (DCV), and air-to-air heat exchangers. These measures had an overall realization rate of 81%. Energy savings adjustments for four measures in the sample were influenced by Cadmus' calculations on boiler loads and DCV savings as well as by differences in observed equipment and efficiency ratings. HVAC evaluation adjustments are detailed below.

Electric HVAC Measures

Cadmus calculated a 100.4% realization rate for purely electric HVAC measures, including packaged air conditioning and air source heat pumps, with field engineers observing accurate equipment counts. Two measures involved units with size and efficiency differing from the reported values, that overall, led to a realization rate slightly greater than 100%.

Gas HVAC Measures

Gas HVAC measures included heating methods, such as direct-fired radiant, condensing boilers and furnaces, and unit heaters. Cadmus reviewed the calculation methodology for direct-fired radiant heating 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 radiant heating measures.

Cadmus reviewed project assumptions, manufacturer's specifications, and heating operation characteristics to support calculations for condensing boilers. The program assigned equal savings for each equivalent boiler. In one of two evaluated facilities, Cadmus noted, however, two boilers served as backup units and had low utilization rates. The project reported energy savings of 25,980 therms for the three boilers, in addition to 2,586 therms in savings for three condensing tank water heaters. Based on billing data, however, the entire facility had average annual gas consumption of only 40,066 therms. Given the billing data and low consumption, Cadmus reexamined the estimates. We applied the utility billing data and ASHRAE calculations to estimate the average annual heating load, then determined gas consumption required for the code baseline and as-built efficient boilers to meet that load. The difference between the two values represented energy savings, which were 40% of the reported value.

Demand Controlled Ventilation

Cadmus calculated slight variations from Standard HVAC deemed savings for DCV projects, with a 91% overall realization rate for this measure. DCV systems use CO_2 sensors to indirectly determine occupancy in building spaces, and adjust ventilation, heating, and cooling requirements accordingly. Typically, these measures produce both electricity and gas savings. DCV calculations involve a significant number of variables, including:

- Ventilation system air exchange rate;
- Specific heating and cooling equipment details;
- EFLH for all HVAC equipment; and
- Occupancy fractions for controlled spaces.

However, the ETO incentive was based solely on the ventilation system air exchange rate, a value not always providing adequate information to accurately quantify measure savings.

Cadmus calculated DCV measure savings using an Excel worksheet, accounting for the operational parameters, noted above, as well as for a building's expected heating and cooling loads in response to TMY data. Resulting savings were reasonably close to deemed savings.

Standard Lighting

Standard Lighting measures included efficient lighting fixtures, and controls such as occupancy sensors and daylight dimming. Lighting measures achieved a 117% realization rate, compared with reported savings. Cadmus noted Standard Lighting savings were based on deemed values per fixture, regardless of building types and actual operation hours. However, building code requirements for new construction require buildings to meet a set lighting power density (LPD). The program's method of applying savings by individual fixtures instead of overall lighting power may not achieve savings beyond the required LPD.

Some measure savings were based on a deemed average for a range of fixture sizes (such as "CFL 18 to 26 Watt"). Cadmus evaluated measures based on actual wattages, ballast factors, and operation hours, determined through site visits and reviews of invoices and manufacturer specification sheets.

Other primary factors influencing the realization rate included:

- LED exit sign deemed savings;
- Alterations in fixture quantities.
- Higher average operating hours in the sample than those used to develop deemed savings estimates; and

LED Exit Signs

After January 1, 2005, the Energy Policy Act of 2005 (EPAct 2005) prohibited manufacture of exit signs with usage higher than 5 watts per face. Though, presumably, older signs could be found in inventories or through foreign vendors, EPAct 2005 resulted in LED exit signs as the standard practice for new construction. The 2010 New Buildings Program incented LED exit signs,[5] although PECI indicated these installations only involved legacy projects from the previous implementer.

For the evaluation, Cadmus set the baseline at the maximum allowed value of 5 watts per face, or 10 watts total for double-faced signs. In manufacturers' specifications, many LED exit signs listed ratings ranging from of 1 to 3 watts per face. This provided some savings over the baseline value, and Cadmus calculated the energy savings as the difference between the code value and actual wattage, multiplied by 8,760 hours of operation per year. The evaluated savings were 18,878 kWh (or 84%) less than reported savings. Though this represented a substantial reduction, it was relatively small (2%) compared to overall evaluated Standard Lighting energy savings of 758,852 kWh.

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 adjusted fixture counts accordingly. For savings calculation purposes, baseline and as-built fixture counts were adjusted to match observed quantities.

Sample Lighting Fixture Average Operating Hours

Evaluated sample project lighting fixture measures (e.g., CFLs, T8, and T5 lamps) operated for longer periods than values used in deemed energy savings estimates, which increased the realization rate. For example, Cadmus back-calculated values ranging from 2,800 to 4,167 operating hours from deemed savings for T8 fixtures. Cadmus examined average operating hours in the evaluated T8 fixture sample, weighted by their total reported lighting energy savings. The sample average of 5,124 operating hours per year resulted in substantially higher savings than the deemed savings values. Higher evaluated operating hours resulted from the sample including

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[5] ETO eliminated this measure from the program in mid-2009.

several large savings projects at facilities operating for long periods per day, such as grocery stores. Applying the following equation resulted in a 140% lighting fixture sample realization rate:

$$RR_{sample} = \frac{kW_{evaluated} * OPHRS_{wght-sample}}{kWh_{reported}}$$

Where:

RR_{sample} = sample realization rate

$kW_{evaluated}$ = total evaluated demand reduction

$OPHRS_{wght\text{-}sample}$ = sample weighted average operating hours

$kWh_{reported}$ = total reported lighting energy savings

Lighting Controls

Deemed lighting control measures included daylight dimming and occupancy sensors. As with lighting fixtures, Cadmus field engineers adjusted savings for these measures based on equipment counts and lighting operating hours. Cadmus also adjusted savings based on the actual fixture wattage controlled by each measure. The validated results indicated reported savings were accurate, with a 100.2% realization rate.

Standard Motors

The Standard Motor category included premium-efficiency motors and VSDs. The realization rate for this subset was 100%. Cadmus found the observed equipment counts matched the reported values, and all but one installed measure met or exceeded program minimum requirements. Cadmus found all VSDs operational.

Code Minimum Requirements

Cadmus noted one 77% efficient motor did not meet code minimum efficiency. In this case, no energy savings could be assigned. However, this issue occurred on one small motor measure, with a total reduction in the savings of 222 kWh, equaling less than 1% of total reported sample savings for this measure category.

Standard Water Heating

The Standard Water Heating category represented remaining measures with deemed savings, including water heaters and measures significantly influencing water heating loads, such as dishwashers and showerheads. The realization rate for these measures was 67%. Cadmus adjusted energy savings downward for water heater issues, such as assigning appropriate loads and impacts from refrigeration heat recovery systems.

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

Primary Versus Back-up Units

One school project, described in the Standard HVAC subsection, installed three condensing water heaters. The school did not operate all three as primary units, and deemed savings overestimated consumption. 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 student and staff member, which accounted for use from washrooms, showers, cooking, and dishwashing. Energy savings represented the difference in consumption, based on the code and as-built efficiency.

Heat Reclaim from Grocery

Participants in two grocery projects installed water heaters above code efficiency, and installed custom heat recovery systems, which used a heat exchange system to draw excess heat from the refrigerant loop to pre-heat the domestic hot water system. This reduced consumption of the standard water heaters. ETO assigned deemed savings for these water heaters, but those savings did not account for reduced heating load due to the heat recovery system. The heat recovery allowed the water heaters to use less energy; however, this also reduced the savings they could achieve based on deemed energy consumption.

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 heat recovery systems. Custom Projects had a 120% energy savings realization rate.

Custom Measure Calculations

Cadmus evaluated Custom measure energy savings through a review of available data and calculation spreadsheets, supported by on-site verification, energy management system trend data, energy simulation models, and utility billing data. As a prescriptive methodology was not appropriate for most of these measures, Cadmus relied heavily on models and calculation spreadsheets developed by contractors, participants, and the PMC. Cadmus reviewed program documentation, determining calculation sources for each measure, and contacting the sources, where necessary, to obtain original calculation spreadsheets or models. Cadmus compared inputs and methodologies against available data to confirm methodologies and results, or adjusted values, as necessary. In most cases, Cadmus determined the methodology and reported savings values were reasonable, although slight adjustments occasionally were required.

Custom Food Service

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 103% realization rate for all Custom Food Service measures.

Cadmus determined the methodology and operating parameters were correct for most of these measures. However, four Custom Lighting Controls projects did not account for reduced heat load when the refrigeration case lights were turned off. The reduced heat load resulted in lower refrigeration compressor energy, which is often accounted for in calculations. Cadmus calculated the energy savings increased for all four measures, for a 127% realization rate.

Cadmus used actual site conditions and temperature differences to analyze two domestic hot water heat reclaim measures. These values resulted in a slight decrease in energy savings, for a 98% realization rate. Cadmus found an error in the original analysis for one hot gas defrost measure. Correcting the error increased savings and the measure achieved a 104% realization rate.

Custom Gas

Cadmus evaluated two Custom Gas measures for a recreational center. The measures provided custom incentives for high efficiency boilers and water heaters. A building simulation model estimated the project savings. Cadmus revised the model based on site verification findings and utility billing data. The main gas end-use adjustment involved enabling the pool dehumidifier unit heat recovery to satisfy space heating loads. This decreased the natural gas consumption to match the recorded utility data. Cadmus also made adjustments to the domestic water heating setpoint, the occupied heating setpoint for the spaces other than the pool, and the process load that characterized the pool heating. These adjustments increased the gas savings for both measures, resulting in a realization rate of 129%.

Custom HVAC

Custom HVAC measures represented a variety of applications, including: displacement ventilation; radiant heating; demand controlled ventilation; pool heat recovery; 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 133%.

One measure primarily impacted the Custom HVAC realization rate. Cadmus calibrated a simulation model with displacement ventilation and radiant heating using EMS trend data, coupled with utility billing data. The original model did not effectively reflect the building performance, particularly in regard to the radiant heating system, which resulted in significantly higher evaluated gas savings.

Custom Lighting

One Custom Lighting project in the sample involved reductions in LPD over code or standard practice. For this project, Cadmus determined claimed space identifications were reasonable, and fixture counts and operating hours were close to reported values. Cadmus noted variations, however, in fixture wattages, operating hours, and square footage, which reduced savings. This measure achieved an 83% realization rate.

Two Custom Lighting Control projects involved reductions in lighting energy by controlling the operating schedules. For these projects, Cadmus determined the programmed schedule and baseline were reasonable, and fixture counts matched reported values, with the measures resulting in a 100% realization rate.

Custom Shell

Custom Shell measures included a variety of strategies to improve thermal resistance of building envelopes, including energy-efficient windows and wall and ceiling insulation. Overall, Cadmus calculated a 116% realization rate for these measures.

Cadmus used simulation modeling, calibrated to utility billing data, to calculate savings for two of the four measures, due to interactive effects with HVAC equipment, process loads, and lighting. Cadmus modified the simulation model for a high efficiency window project with the largest energy savings based on site visit verification. The changes included elimination of the overnight setback thermostat setpoints and more accurate occupied thermostat setpoints. This increased the project's energy savings, resulting in a 115% realization rate. Cadmus made slight alterations to the simulation model for another, smaller high efficiency window project that also increased savings.

Cadmus determined savings on two smaller measures, using a spreadsheet insulation savings calculator, calibrated to utility billing data. This method indicated savings estimates were reasonable, and Cadmus accepted reported values for the project.

ENERGY STAR Benchmarking

In 2010, one participant completed an ENERGY STAR Benchmarking project. These buildings involved an array of energy-efficiency measures, serving to bring down the site's overall energy use intensity, relative to a baseline established for each building type by ENERGY STAR.

Cadmus conducted site visits for the projects, verifying energy-efficiency measures had been correctly installed and the resulting energy-use intensities (EUIs) accurately represented the building's expected performance. Cadmus then recalculated the building's ENERGY STAR score, using the Portfolio Manager tool, determining energy savings between as-built and baseline building types. Cadmus assigned savings to electricity and natural gas, based on ratios estimated by the PMC.

Based on the Portfolio Manager results, the building's EUI achieved more energy savings than reported. The electricity realization rate was 120% and natural gas realization rate was 169%.

LEED Buildings

Cadmus conducted site visits for 15 LEED-certified buildings in the evaluation sample, and this track's projects had the highest variation from reported savings. The LEED sample projects achieved an overall realization rate of 90%. 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. Where possible, Cadmus also calibrated models to actual electricity and gas billing data.

Table 17 shows resulting realization rates. The following two subsections discuss Cadmus' adjustments for calculating evaluated energy savings.

Table 17. LEED Building Realization Rates

Project	Building Type	Reported Electricity Savings (kWh)	Reported Gas Savings (therms)	Calculated Electricity Savings (kWh)	Calculated Gas Savings (therms)	Electricity Savings Realization Rate	Gas Savings Realization Rate
ETONB1001	Multifamily Residential	221,042	60,420	623,705	61,050	282%	101%
ETONB1004	Hi Rise Residential	347,621	9,619	519,593	8,132	149%	85%
ETONB1007	Institution/Government	176,912	2,849	13,215	1,879	7%	66%
ETONB1008	Office	497,043	3,943	497,043	3,943	100%	100%
ETONB1010	Other	0	59,945	0	32,927	N/A	55%
ETONB1012	Office	479,665	518	373,373	0	78%	0%
ETONB1012	Office	479,665	518	373,373	0	78%	0%
ETONB1015	Lodging/Hotel/Motel	689,656	9,466	256,655	24,956	37%	264%
ETONB1017	Multifamily Residential	1,649,507	102,753	1,084,150	82,025	66%	80%
ETONB1019	Office	0	35,075	0	44,025	N/A	126%
ETONB1023	Office	21,174	1,105	12,797	1,105	60%	100%
ETONB1023	Office	21,174	1,105	12,797	1,105	60%	100%
ETONB1027	College/University	389,474	10,840	356,846	25,176	92%	232%
ETONB1028	Infrastructure	3,301,360	0	2,492,437	0	75%	N/A
ETONB1030	Office	507,110	78,996	0	110,428	0%	140%
ETONB1031	College/University	0	105,753	0	69,390	N/A	66%
ETONB1036	Schools K-12	206,046	18,232	148,789	26,292	72%	144%
Total		8,987,449	501,137	6,704,627	492,433	75%	98%

Note: ETONB1012 and ETONB1023 installed two projects each under the LEED Core and Shell program.

Calculation Methodologies

Energy savings for LEED projects were calculated as the difference in annual energy use between baseline and counterfactual 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. The program implementer degraded estimated energy savings by 5% to convert from an ASHRAE 90.1-2004 baseline to the 2007 Oregon Structural Specialty Code. Cadmus determined the 5% differential was reasonable, confirming the value by interpolating research performed by Architecture 2030,[6] which estimated the “2030 Challenge Code” would save: 30% more energy than ASHRAE 90.1-2004; and 25% more energy than Oregon code. The difference between the two codes resulted in a 5% reduction from ASHRAE 90.1-2004.

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. One significant weakness with LEED NC v2.2 (and the prior LEED versions) has been a lack of accountability for construction of energy-efficient measures. A developer could design a highly energy-efficient building, and receive the appropriate number of EAc1 credits, but not be required to actually construct the green features

[6] Architecture 2030. June 20, 2009. “Meeting the 2030 Challenge Through Building Codes.”

and systems. No mechanism existed for tracking as-built energy use to confirm buildings continued to meet LEED specifications.

Cadmus noted a variety of project-specific issues, resulting in variations between reported and achieved savings, but no overarching concerns. Generally, variations occurred due to calibration to actual utility bills and as-built conditions, confirmed through site visits. These enabled Cadmus to determine how equipment actually operated, relative to the initial simulation model.

On average, the electric realization rate was low due to higher levels of electric heating than predicted on several large projects. As an example, one project did not account for electric heating coils in a pedestrian tunnel. In another case, the project provided heating through gas boilers for guest rooms rather than the proposed variable refrigerant volume system. This reduced the electric load and associated savings, while increasing gas consumption and savings. A separate appendix documents, in greater detail, specific issues with model calibration and reasons for variances.

Extrapolation to the Program Population

Lighting Fixture Population Realization Rate

Cadmus determined the overall realization rate for the lighting fixture population as a first step in extrapolating evaluated savings to the overall program lighting fixture population. The sample realization rate was adjusted to compensate for differences in sample and overall lighting population operating hours.

Cadmus determined the overall lighting fixture population operating hours by building type, using weighted average operating hours by energy savings for each lighting project in the sample. Cadmus determined the results were fairly consistent with the weighted operating hours by building type calculated in the 2009 program evaluation. Cadmus then assigned the 2010 operating hours for each project with the same building type, identified through the Fast Track database extract. For building types not included in the sample, Cadmus applied weighted operating hours from the 2009 and 2010 evaluations, or applied savings from the “Other” building type.

The weighted average operating hours for the sample were 5,124. Weighted average annual operating hours for the overall lighting fixture population were 4,528. Cadmus calculated the final 124% lighting fixture realization rate as follows:

$$RR_{population} = RR_{sample} * \frac{OPHRS_{wght-pop}}{OPHRS_{wght-sample}}$$

Where:

RR_{sample} = sample realization rate

$RR_{population}$ = final lighting realization rate for population

$OPHRS_{wght-sample}$ = sample weighted average operating hours

$OPHRS_{wght\text{-}pop}$ = population weighted average operating hours

Cadmus calculated the evaluated savings for other lighting measure types, such as LED exit signs and occupancy sensors, using the methodology in the following section.

Extrapolation to Population

As described earlier, the measurement and verification process involved sampling 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:

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

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

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

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

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. The team 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 18 and Table 19 show final evaluated savings by measure, fuel, and program levels.

Table 18. Program Level Electricity and Gas Savings

Measure Category	Total Number of Measures	Reported Electricity Savings (kWh)	Reported Gas Savings (therms)	Evaluated Electricity Savings (kWh)	Evaluated Gas Savings (therms)	Electricity Savings Realization Rate	Gas Savings Realization Rate
Standard Food Service	97	1,136,661	9,803	1,196,648	9,803	105%	100%
Standard HVAC	249	1,115,482	152,015	1,185,284	121,962	106%	80%
Standard Lighting	595	6,152,260	0	7,190,608	0	121%	N/A
Standard Motors	79	291,191	0	290,467	0	100%	N/A
Standard Water Heating	80	145,225	136,602	145,225	85,900	100%	63%
Custom	71	3,320,331	166,251	3,247,121	233,685	98%	141%
Custom Food Service	23	1,565,119	32,103	1,644,268	31,934	105%	99%
ENERGY STAR	1	1,041,218	4,687	1,248,104	7,913	120%	169%
LEED	50	11,276,835	633,091	8,487,972	622,094	75%	98%
Total 2010 Sample	1,245	26,044,322	1,134,551	24,635,698	1,113,291	95%	98%

Table 19. Program Level Realization Rates

Fuel Type	Realization Rate
Electricity (kWh)	95%
Gas (therms)	98%
Total Energy (MBtu)	97%

Energy Use Intensity of Sampled Projects

Cadmus also calculated the sampled projects' EUI by examining building floor area in square feet and utility billing data for gas and electricity usage. Two projects were not examined, as they constituted a portion of a much larger facility. Four other projects had one fuel type served by utilities other than those providing funding to the Energy Trust, and utility billing data could not be obtained.

Table 20 shows EUI data for the 33 remaining projects.

Table 20. EUIs for 2010 Evaluation Sample Buildings

Project	Building Type	Area (sf)	Electricity EUI (kWh/sf)	Gas EUI (therms/sf)	Total Energy EUI (kBtu/sf)
ETONB1001	Mixed use Residential	231,709	3.9	0.17	30
ETONB1004	Mixed use Residential	397,481	5.2	0.12	29
ETONB1005	Office	3,820	8.1	0.51	79
ETONB1006	Office	128,260	14.2	0.06	54
ETONB1007	Public Order and Safety	68,200	14.4	0.15	64
ETONB1008	Office	182,115	9.1	0.01	32
ETONB1009	Mercantile (Retail Other Than Mall)	134,000	27.7	0.43	137
ETONB1012	Office	504,583	8.2	0.00	28
ETONB1013	Education	7,500	58.5	0.00	200
ETONB1014	Office	4,200	13.6	0.07	53
ETONB1015	Lodging	144,151	19.5	0.66	132
ETONB1017	Mixed use Residential	505,000	8.4	0.26	55
ETONB1018	Gym/Athletic Club	46,260	23.0	1.07	186
ETONB1020	Food Sales	17,000	75.9	1.81	440
ETONB1021	Warehouse and Storage	29,440	4.9	0.12	29
ETONB1022	Education	129,000	2.0	0.27	34
ETONB1023	Office	18,283	11.4	0.00	39
ETONB1024	Mixed use Residential	800	40.5	0.00	138
ETONB1025	Food Service	2,940	193.1	9.0	1,564
ETONB1027	Education	95,308	7.0	0.19	43
ETONB1028	Office / Other	1,285,970	3.5	0.13	25
ETONB1029	Warehouse and Storage	415,000	0.5	0.25	27
ETONB1030	Office	309,012	12.6	0.16	59
ETONB1031	Education	193,017	10.7	0.24	60
ETONB1032	Restaurant	3,816	60.8	3.16	523
ETONB1033	Food Service	45,000	38.0	0.49	179
ETONB1034	Other	142,000	25.0	0.20	105
ETONB1035	Food Sales	41,313	43.9	1.46	296
ETONB1036	Education	140,000	11.0	0.28	65
ETONB1038	Office	10,800	6.6	0.87	109
ETONB1039	Food Service	2,500	79.2	2.08	479
ETONB1040	Mercantile (Retail Other Than Mall)	154,564	21.4	0.33	106
ETONB1041	Food Sales	37,720	53.1	0.85	266

Table 21 shows performance of 2010 sample building energy use intensity, relative to two other studies that previously have been used to benchmark the performance of new construction buildings in Oregon.[7] [8] Appendix A highlights data from these studies in greater detail. For many building types, sample sizes were too small to draw definitive conclusions.

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[7] ETO FY2009 program savings calculation spreadsheet, "2005398 01 18 2009 River East Center Form 520L 540L Final.xls"

Table 21. Comparison of EUI Data with Other Studies

Building Type	2010 New Buildings Evaluation		PGE EUI Data for Post-1985 Buildings (kBtu/sf)	Ecotope New Construction EUI 2002-2004 (kBtu/sf)
	Buildings in Sample	Average EUI (kBtu/sf)		
Colleges	2	54.4	89.8	65.9
Department Stores	2	120.7	61.2	76.8
Elementary	1	65.3	43.2	48.5
Fast Food	1	523.0	587.8	512.7
Full Service Restaurant	2	1,065.2	587.8	512.7
High Rise Apt	3	40.8	66	58.5
High Schools	1	199.5	73.1	48.5
Hotel	1	132.0	88.3	58.5
Institution	1	63.5	N/A	102.8
Low Rise Apt	1	138.3	58.4	58.5
Middle Schools	1	33.6	55.8	48.5
Office	8	41.0	85.3	81.9
Other	3	37.4	N/A	96.3
Supermarket	4	267.8	198.7	202.8
Warehouse	2	26.7	32.1	31.8

In general, sample buildings used less energy per square foot than buildings in either comparison study. In particular, high-rise apartments and offices had significantly smaller EUIs than the averages from prior studies. These were mostly LEED buildings with aggressive energy saving targets.

Highest EUI building types in the sample (full service restaurants and supermarkets) used significantly more energy per square foot than similar buildings in the other studies. One full-service restaurant had an EUI much higher than the other, which brought up the average for that building type. That one site may be an outlier, and may not be typical of new construction full service restaurants.

The four supermarkets in the sample had a higher EUI than the supermarkets in either study. Neither of the other two studies reported average floor area for buildings. Cadmus reviewed secondary literature[9] to determine that the 2010 sample supermarket projects likely had a smaller average area than those in either study (35,258 square feet versus 45,561 square feet). Participants built the 2010 sample supermarkets in relatively dense urban or suburban areas, but still had to provide the same deli and refrigerated case options as larger stores in order to be competitive. In particular, one urban supermarket featured many of the same options as a larger competitor up the street, but occupied only 17,000 square feet. The increased density for these projects resulted in a larger EUI. In terms of average energy consumption (multiplying square feet by the EUI), the 2010 sample supermarkets were nearly equivalent to those in the Ecotope study (9,444 MBtu per year versus 9,240 MBtu per year).

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[8] Ecotope. December 2009. “Baseline Energy Use Index of the 2002-2004 Nonresidential Sector: Idaho, Montana, Oregon, and Washington.” Table A-11

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

One of the most significant differences involved department store building types. These two projects used considerably more energy than similar buildings in the comparison studies. Both projects predominantly featured retail space, but also included a grocery. The comparison studies did not include grocery space.

Schools also 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.

CONCLUSIONS AND RECOMMENDATIONS

Cadmus conducted an impact evaluation of the 2010 ETO New Buildings Program by analyzing energy savings for 239 measures implemented in 39 projects. The measures belonged to four different program tracks (Standard, Custom, ENERGY STAR, and LEED), and represented a variety of subcategories. Cadmus performed verification site visits for each project, 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.

ETO applied appropriate methodologies and assumptions for many measures, although, on average, 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 97% program-level realization rate.

Cadmus identified a number of areas for program improvements. The most significant would involve the PMC reviewing and revising deemed savings methodologies, particularly for gas boilers and condensing tank water heaters. Cadmus also noted changes in energy simulation model reporting methods that could improve future evaluation efforts; the following recommendations reflect potential improvements.

Calculate Lighting Savings Through Lighting Power Density

Oregon code requires new construction and substantial renovation projects achieve a lighting power density below a prescribed value, based on the building type. The 2010 New Buildings Program provided incentives for lighting measures, based on fixture types instead. The PMC indicated they revised the program to calculate savings based on LPD beginning with the 2011 program year. Cadmus supports this program revision.

Apply Savings More Appropriately to Back-up Boilers and Condensing Water Heaters

On several projects, participants installed multiple condensing boilers and water heaters. In general, one unit would be designated as the primary unit, and participants used additional units as back-ups for peak conditions. However, the program applied identical energy savings values to each unit. Cadmus recommends the program obtain more information on how participants plan to use boilers and water heaters, and apply prorated savings to back-up units.

Account for Reduced Consumption Through Heat Recovery

Two grocery projects installed above-code efficiency water heaters, in conjunction with heat recovery from the refrigeration loop. Deemed savings estimates for water heaters did not account for reduced consumption from heat recovery pre-heating. Cadmus recommends the PMC consider including water heater savings in the Custom heat recovery measures to account for appropriate consumption.

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 PMC obtained the correct models for 11 of 20 simulation modeling projects. To obtain the remainder, Cadmus and the PMC contacted participants and building simulation model contractors for the appropriate models used to calculate savings. Though a time-consuming task, all modeling contractors complied.

Cadmus recommends the PMC obtain energy simulation models for review during the program year or require building simulation model developers sign a consent form, releasing models for evaluation purposes. This step should be a requirement for LEED Track incentives and any Custom incentives using model-estimated savings, thus improving the likelihood a project can be evaluated. The PMC 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 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 PMC 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 what information they support. We recommend the PMC verify the models match the energy consumption output on a gross savings level.

Provide More Detail on Exceptional Calculations

Cadmus determined the exceptional calculations were problematic on one building. The PMC included savings associated with custom measures for pool equipment without proper justification of the reported savings. Cadmus recommends all exceptional calculation workbooks, simulations, and associated documentation be provided in the project files.

APPENDIX A. COMPARISON ENERGY USE INTENSITY DATA

EUI data for the FY 2010 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

* ETO 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

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

APPENDIX B. DATA COLLECTION FORM

Commercial Data Collection Form

ETO New Buildings

General Info (Complete before visit if possible, and finish on-site):

Company Name:	______	Utility Account #:	______
Contact Name:	______	No. Electric Meters:	______
Contact Phone Number:	______	No. Gas Meters:	______
Address:	______	Annual kWh:	______
City, State, Zip:	______	Annual therms:	______

		Record Electric Meter Numbers:	Record Gas Meter Numbers:
Engineer:	______	______	______
Site Visit Date:	______	______	______
Site Visit Time:	______	______	______
Notes:	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______

Survey Key

N/A= Not Applicable NX= Not Available

General Info

1. Do you have any other energy service providers? If yes, please check which services apply to this business:

Electric		Gas		Propane	

2. When is this building occupied? [Check appropriate season and corresponding months]

All Year						Other Seasonal (check months)					
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

3. What is the weekly occupancy schedule of this building?

Day	Business Hours	Closed All Day?	Open 24 Hours?
Sunday	From: ____ To: ____	□	□
Monday	From: ____ To: ____	□	□
Tuesday	From: ____ To: ____	□	□
Wednesday	From: ____ To: ____	□	□
Thursday	From: ____ To: ____	□	□
Friday	From: ____ To: ____	□	□
Saturday	From: ____ To: ____	□	□

4. How many people, on average, occupy this building? ______________

Building Information

5. When was the building first occupied? ____________

6. What is the percentage of full occupancy today? ____________

7. How long has the building maintained this level of occupancy? ____________

8. How large is the building's conditioned space in square feet? ____________ft²

9. How large is the total building (excluding garage) in square feet? __________ft²

10. If the building has an unconditioned parking garage, how large is it? ________ft²

11. What percent of the total building square footage from Question 8 is unconditioned?

__________ %

__

12. What is the square footage by primary use of your building? [complete appropriate space]

Education	Grocery	Health	Lodging	Office	Restaurant	Retail	Warehouse	Other

13. If Other: Please describe: ____

14. If High-Rise Residential: How many units? ____________

15. Average residential unit size? ____________

16. A) How many floors is this business above ground? ____________

B) How many floors is this building above ground? ____________

C) How many floors is this business below ground? ____________

D) How many floors is this building below ground? ____________

17. When was the last time this building was commissioned? ____________

18. Is this a LEED Building? Please indicate certification system and level.____________

Envelope

19. Answer all questions as they relate to the **entire building**

Building Envelope		
Walls		
Framing Type	*1= Metal 3=Concrete* *2=Wood 4=Masonry*	
Insulation Type	*1= Batt /Blown* *2=Rigid* *3= None* *4=Unknown*	
Estimated R-Value		
Windows		
% of Total Wall Area (i.e. window to wall ratio)	*(%)*	
Layers of Glazing	*(1,2,3)*	
Glazing Type	*1= Clear* *2=Reflective* *3= Tinted* *4= low E* *5=Gas Filled*	
Frame Type	*1= Metal* *2=Wood* *3=Vinyl*	
Roofs		
Total Roof Area	(Ft²)	
Roof Type	*1=Flat 2=Pitched*	
Surface Material	*1= Built - up* *2=Cool Roof* *3=Membrane* *4=Metal* *5=Shingles/Flat* *6=Green Roof*	
Estimated R-Value		
Floors		
Floor Type	*1= Basement (conditioned)* *2=Basement (unconditioned)* *3= Slab (conditioned)* *4= Slab (unconditioned)*	
Estimated R-Value		

HVAC System

20.

Packaged HVAC System				
		System 1	System 2	System 3
HVAC System Type	*(see Table Below)*			
Number of Identical Units				
Regular Maintenance?	*(Circle One)*	Y / N	Y / N	Y / N
Percent of Business	*(%)*			
Age	*(Years)*			
Temperature Control Type	*(See Table Below)*			
Manufacturer				
Model name				
Model number				
Rated Cooling Capacity	*(Tons)*			
Rated Heating Capacity	*(Btu/hr)*			
Performance Rating	*(Circle One)*	EER SEER	EER SEER	EER SEER
Performance Rating Value				
Primary Heat:				
Fuel Type	*(see Table Below)*			
Efficiency	*(%)*			
Supplemental Heat:				
Fuel Type	*(see Table Below)*			
Efficiency	*(%)*			
Terminal Reheat Type	*(see Table Below)*			
Insulated Duct	*(Circle One)*	Y / N	Y / N	Y / N
Air-to-Air Heat Recovery	*(Circle One)*	Y / N	Y / N	Y / N
Economizer	*(Circle One)*	Y / N	Y / N	Y / N

Packaged HVAC System Types		
1=Packaged Single Zone-A/C Only	6=Heat Pump, Air Source	11=Unit Ventilator
2=Packaged Single Zone-A/C w/ Heat	7=Heat Pump, Ground Source	12=Window/ Wall A/C Unit
3=Packaged Multi Zone	8=Heat Pump, Water Source	13=Window/ Wall Heat Pump
4=Packaged VAV	9=Split System	
5=Evaporative Cooler	10=Unit Heater	

Temperature Control Types
1=Thermostat-Programmable
2=Thermostat-Manual
3=EMS
4=Always on
5=Manual on/off
6=Time Clock

Fuel Types	
1=Electric	5=Purchase HW or Steam
2=Natural Gas	6=Wood
3=Fuel Oil	7=Other (Make Note)
4=LPG	

21.

Terminal Reheat Types
1=Electric
2=Hot Water
3=Steam
4=Other

Central HVAC System -Air Handler				
		System 1	System 2	System 3
HVAC System Type	(*see Table Below*)			
Temperature Control Type	(*See Table Below*)			
Percent of total business sq.ft.	(%)			
Does this system serve more than this business?	(Y/N)			
Manufacturer				
Model name				
Model number				
Cooling Coils	(*Circle One*)	Y / N	Y / N	Y / N
Heating Coils	(*Circle One*)	Y / N	Y / N	Y / N
Supply Fans:				
Volume Control	VFD	Y / N	Y / N	Y / N
Quantity				
Total Motor HP				
Motor Efficiency	*(S, PE)*			
Return Fans:				
Volume Control	VFD	Y / N	Y / N	Y / N
Quantity				
Total Motor HP				
Motor Efficiency	*(S, PE)*			

HVAC System Type			Temperature Control Types
1=CV-Single Zone	7=VAV-Cooling Only	13=Hydronic Heat Pump	1=Thermostat-Programmable
2=CV-Multi Zone	8=VAV-Terminal Reheat	14=Induction	2=Thermostat-Manual
3=CV-Dual Duct	9=VAV-Dual Duct	15= Radiant Slab Heat	3=EMS
4=CV-Terminal Reheat	10=Fan Coil	16=PTAC	4=Always on
5=FPS-Fan Powered VAV-Series	11=Baseboard	17=Unit Ventilators	5=Manual on/off
6=FPP-Fan Powered VAV-Parallel	12=Heat & Vent	18=Radiators	6=Time Clock

22.

Central HVAC System- Boiler				
		System 1	System 2	System 3
Fuel Type	*(see Table Below)*			
Regular Maintenance	*(Circle One)*	Y / N	Y / N	Y / N
Percent of business	*(%)*			
Does this system serve more than this business?	*(Y/N)*			
Age	*(Years)*			
Temperature Control Type	*(See Table Below)*			
Manufacturer				
Model name/ Number				
Input Capacity	*(Btu/h)*			
Efficiency	*(%)*			
Number of Identical Boilers				
Number of Units on Standby				
Hot Water Pumps				
Quantity				
Total Motor HP				
Motor Efficiency	*(S, PE)*			
Temperature Control Type				
Capacity Control Type	*1= Constant Speed* *2=Variable Speed*			
Heating Pipes Insulated	*(Circle One)*	Y / N	Y / N	Y / N
Number of Units on Standby				

Fuel Types	
1=Electric	5=Purchase HW or Steam
2=Natural Gas	6=Wood
3=Fuel Oil	7=Other (Make Note)
4=LPG 23.	

Temperature Control Types
1=Thermostat-Programmable
2=Thermostat-Manual
3=EMS
4=Always on
5=Manual on/off
6=Time Clock

Central HVAC System- Chiller				
		System 1	System 2	System 3
Chiller Type	*(see Table Below)*			
Regular Maintenance	*(Circle One)*	Y / N	Y / N	Y / N
Percent of business	*(%)*			
Does this system serve more than this business?	*(Y/N)*			
Age	*(Years)*			
Temperature Control Type	*(See Table Below)*			
Manufacturer				
Model name/ Number				
Rated Cooling Capacity	*(Tons)*			
Performance Rating	*(Circle One)*	EER - IPLV - kW/ton	EER - IPLV - kW/ton	EER - IPLV - kW/ton
Performance Rating Value				
Compressor:				
Design Full load KW				
Number of Identical Chillers				
Number of Units on Standby				
Heat Rejection System				
Condenser Type	*(See Table Below)*			
Capacity Control Type	*1= Fixed Temp* *2=Floating Temp* *3= Head Pressure*			
Fan Control	*1= Constant* *2=Cycle* *3= Pony Motor* *4=Two Speed* *5=Variable Speed*			
Water Side Economizer	*(Circle One)*	Y / N	Y / N	Y / N
Temperature Control Type	*(See Table Below)*			
Total Fan Horsepower	*(HP)*			

Chiller Types	
1=Centrifugal	5=Absorption, Hot Water
2=Reciprocating	6=Absorption, Natural Gas
3=Rotary	7=Absorption, Steam
4=Scroll	

Condenser Types
1=Air Cooled Condenser
2=Cooling Tower (Open)
3=Evaporative Cooler

Temperature Control Types
1=Thermostat-Programmable
2=Thermostat-Manual
3=EMS
4=Always on
5=Manual on/off
6=Time Clock

Chilled Water Pumps				
		System 1	System 2	System 3
Pump Use	*1= Primary* *2=Secondary*			
Quantity				
Total Motor Horsepower	*(HP)*			
Motor Efficiency	*(S, PE)*			
Capacity Control	*1= Constant Speed* *2=Variable Speed*			
Temperature Control Type	(See Table Below)			
Number of Units on Standby				
Condenser Water Pumps				
Quantity				
Total Motor HP	*(HP)*			
Motor Efficiency	*(S, PE)*			
Capacity Control	*1= Constant Speed* *2=Variable Speed*			
Temperature Control Type	(See Table Below)			
Number of Units on Standby				

Temperature Control Types
1=Thermostat-Programmable
2=Thermostat-Manual
3=EMS
4=Always on
5=Manual on/off
6=Time Clock

HVAC Controls

24. Does the heating system employ temperature reset controls? Y / N

25. If 'Lodging' type facility: Is a key card energy control system used? Y / N

Ventilation

26. Is an indoor parking garage with ventilation present? Y / N

27. If yes, is the garage ventilation system controlled with CO sensors? Y / N / DK

28. For interior spaces, is any demand-controlled ventilation system employed?Y / N / DK

			Number of Identical Hoods
29.	Are ventilation hoods used?	Y/N/DK	
30.	Demand based controls (DCV Controls)?	Y/N/DK	
31.	Variable Volume?	Y/N/DK	
32.	Is make up air provided direct to ventilation hood?	Y/N/DK	

Domestic Hot Water

33.

Domestic Hot Water				
		System 1	System 2	System 3
Water Heat type	*(see Table Below)*			
Fuel Type	*(see Table Below)*			
Age	*(Years)*			
Location	*(Conditioned or Unconditioned*			
Tank Wrap	*(Circle One)*	Y / N	Y / N	Y / N
Pipe Wrap	*(Circle One)*	Y / N	Y / N	Y / N
Circulation Pump	*(Circle One)*	Y / N	Y / N	Y / N
Continuously Circulating	*(Circle One)*	Y / N	Y / N	Y / N
Set-Point	*(^{0}F)*			
Is a Setback Used	*(Circle One)*	Y / N / DK	Y / N / DK	Y / N / DK
Manufacturer				
Model Name/ Number				
Tank Capacity	(Gal)			
Input Capacity	(KW or Btu/hr)			
Recovery	(Gal/hr)			
Efficiency	*(EF)*			
Is Drain Water heat Recovery Used	*(Circle One)*	Y / N	Y / N	Y / N

Water Heater Types
1=Heat Pump
2=Heat Recovery
3=Instantaneous (Tankless)
4=Self-Contained
5=Storage Tank (Central Boiler)
6=Self-Contained Storage
7=Other (Make Note)

Fuel Types	
1=Electric	5=Purchase HW or Steam
2=Natural Gas	6=Wood
3=Fuel Oil	7=Other (Make Note)
4=LPG	

34. Number of faucets with given flow rate:

	<0.5 GPM	0.5 to 1.5 GPM	1.5 to 2.5 GPM	>2.5 GPM
Number				
Motion Controllers?				

Lighting

35. What percent of floor space is served by the following lighting application?

Standard Interior Lighting___________%
High-bay Lighting _________________%
Should sum to 100%

36. What is the estimated interior, conditioned lighting power density for the building[s]? ______________ W/ft^2

37. What is the estimated interior, unconditioned lighting power density for the building[s]? ______________ W/ft^2

(Can estimate LPD after completing lighting worksheet/lighting counts if needed.)

Please fill out the tables below, using the summary tab of the lighting input spreadsheet:

38. **Lighting Type**		
Total Watts: ______________	Percent of total lamp count	
Total # Lamps: ___________		
	Interior	Exterior
Linear Fluorescent		
Compact Fluorescent		
Incandescent		
Metal Halide		
High Pressure Sodium		
Mercury Vapor		
LED		
Neon (Cold Cathode)		
Other		

39. **Fluorescent Lamp Types**		
Total Watts: _______	Percent of total fluorescent lamp count	
Total # Lamps: ____	Interior	Exterior
T12		
T8		
T10		
T8 Plus (25W/28W)		
T5		
T5HO		
40. **Ballast Types**		
Magnetic-Standard		
Magnetic-ES		
Electronic		
Electronic Dimming		
Emergency		

41. **Control Type**		
	Percent of total lamp count	
	Interior	Exterior
Manual:		
Switch		
Circuit Breaker		
Dual Level Switch		
Dimmer Switch		
Timer		
Occupancy Sensor		
Daylighting Controls		
Energy Management System		

39a. Are there skylights in the building? Y / N

39b. Are skylights used as a light source in the building? Y / N

42. Are bi-level lighting controls used in stairways? Y / N

43. What type of exit signs does this building have – see table below?_____________

Type	Count
Incandescent	
Compact fluorescent	
LED	
Other (note type)_	
Don't Know	

44. Has the lighting system been updated in the last 5 years? Y / N / DK

Plug Loads

Appliances: If there is more than one type of appliance in the building, note the average age, frequency of use, and Energy Star rating

45.				
46.				
47.				
48.				
49.				
50.				
51.				
52.				
53.				
54.				
55.				
56.				
57.				
58.				

59. Is a network computer energy management system used? Y / N / DK

60. Are power supplies 80% efficiency (80 Plus)? ___________% if DK enter "-99"

61. Are any vending machine controllers used? Y / N / DK

62. If either a residential or commercial clothes washer and/or dryer is present, please complete the table below:

	Washers		Dryer
	Front Load	Top Load	
Number of Similar Efficiencies/Types			
Ozonating Cycle?	Y / N		--
Age (years)			
Loads per week			
% EnergyStar? Enter %, if DK enter "-99"			
Dryer fuel type (1=electric, 2=natural gas, 3=propane)	--	--	
Efficiency (MEF)			

63. Does this building have residential style dishwashers? Y / N

	Type 1	Type 2	Type 3
Number of Identical Units			
Age (years)			
Manufacturer			
Model Name/Number			
Loads per week			
Energy Star?	Y / N		
Efficiency (EF)			

64. Are commercial dishwashers used? Y / N

65. Is the dishwasher a low-temp system? Y / N

66. Does the dishwasher have a booster heater? Y / N

   a. If yes, what is the fuel of the booster heater? Elect

   ric / Gas

Cooking

67. Does this building have any commercial kitchen equipment? Y / N

Which equipment is present? If there is more than one type used in the building, note the most common fuel, average age, frequency of use, and EnergyStar rating

	Fuel	Number	Age (years)	Frequency of Use (hrs/wk)	EnergyStar ?
68. Standard Oven	E / G				Y / N / DK
69. Convection Oven	E / G				Y / N / DK
70. Range	E / G				Y / N / DK
71. Fryer	E / G				Y / N / DK
72. Hot food holding cabinet	E / G				Y / N / DK
73. Steam Cooker	E / G				Y / N / DK
74. Griddle	E / G				Y / N / DK
75. Microwave Oven	E				
76. Conveyor Oven	E / G				Y / N / DK

Refrigeration

77. Does this building have any commercial refrigeration equipment? Y / N

(Non-residential-style refrigerators)

a. Total Refrigeration System capacity:____Tons

Refrigeration equipment details for stand alone :

	Total Size (ft^3)	Qty	Stand alone?	Age (years)	Energy-Star?
1. Solid door refrigerator/freezer					Y / N / DK
2. Glass door refrigerator/ freezer					Y / N / DK

Refrigeration equipment details:
(Types: 3=Open Medium Temp Display Case, 4=Open Low Temp Display Case, 5=Display case with doors)

	Total linear ft
3. Open medium temp display case	
4. Open low temp display case	
5. Display case with doors	

Refrigerated space details:
(Types: 1=Walk-in Refrigerator, 2=Walk-in Freezer, 3=Refrigerated Warehouse, 4=Freezer Warehouse)

	Type	Size (ft^2)	Age (years)	Lighting (Fluorescent, LED, None)	Compressor (hp)
System 1					
System 2					
System 3					
System 4					
System 5					
System 6					
System 7					
System 8					
System 9					
System 10					

b. Are there multiplex compressor systems used? Y / N

78. Are anti-sweat heater controls used on display case doors? Y / N

79. What type of lights do display cases have? ____________

(1=fluorescent, 2=LED)

80. Are VFDs used on compressors? Y / N

81. Are demand defrost controls used? Y / N

82. Are floating head pressure controllers used? Y / N

83. Are high-efficiency evaporator fans used? Y / N

84. Are night covers used on open display cases? Y / N

85. Are evaporator fan controls used? Y / N

86. Has this refrigeration system been commissioned? Y / N / DK

87. Is a heat recovery system used? Y / N

88. Do any display cases have special doors that don't require anti-sweat heat?Y / N

89. Does this building have any ice makers? Y / N

Ice maker details:

	Capacity (lbs/hr)	Qty	Stand alone?	Age (years)	Energy-Star?
Ice Maker 1					Y / N / DK
Ice Maker 2					Y / N / DK
Ice Maker 3					Y / N / DK

Water

90. Does this building have a pool? Y / N

91. What type of fuel is used to heat the pool? [Check one]

Electricity	
Natural Gas	
Propane	
Other	

92. When is the pool used?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Pool pump details:

	Pump 1	Pump 2	Pump 3	Pump 4
Age (years)				
Manufacturer				
Model Number				
Size (hp)				
RPM				
Enclosure Type (1=ODP, 2=TEFC)				
Efficiency (%)				

93. How are the pool pumps controlled?

	Pump 1	Pump 2	Pump 3	Pump 4
Runs continuously				
Timer				
VSD				
Other				

Other Process Loads

94. Does this building have a compressed air system? Y / N
    a. If Yes, total HP of air compressor system: _____

Renewable Energy

95. Does this building have any renewable energy systems? Y / N
96. If so what type? (e.g. solar, wind) _____________
97. What is the capacity of the system? (MWh, Annual kWh, max kW)_____________

Server Rooms

98. Does this building have server rooms? Y / N
    a. Total Floor Area _____________
    b. Description of Server Room
       ____
    c. Number of processors _____________
    d. Does space have its own conditioning system? Y / N
    e. If yes, provide more detail on system units and types__________________________
       - ____
       ____
    f. Cooling capacity _____________
    g. UPS electrical capacity _____________
    h. UPS current load _____________