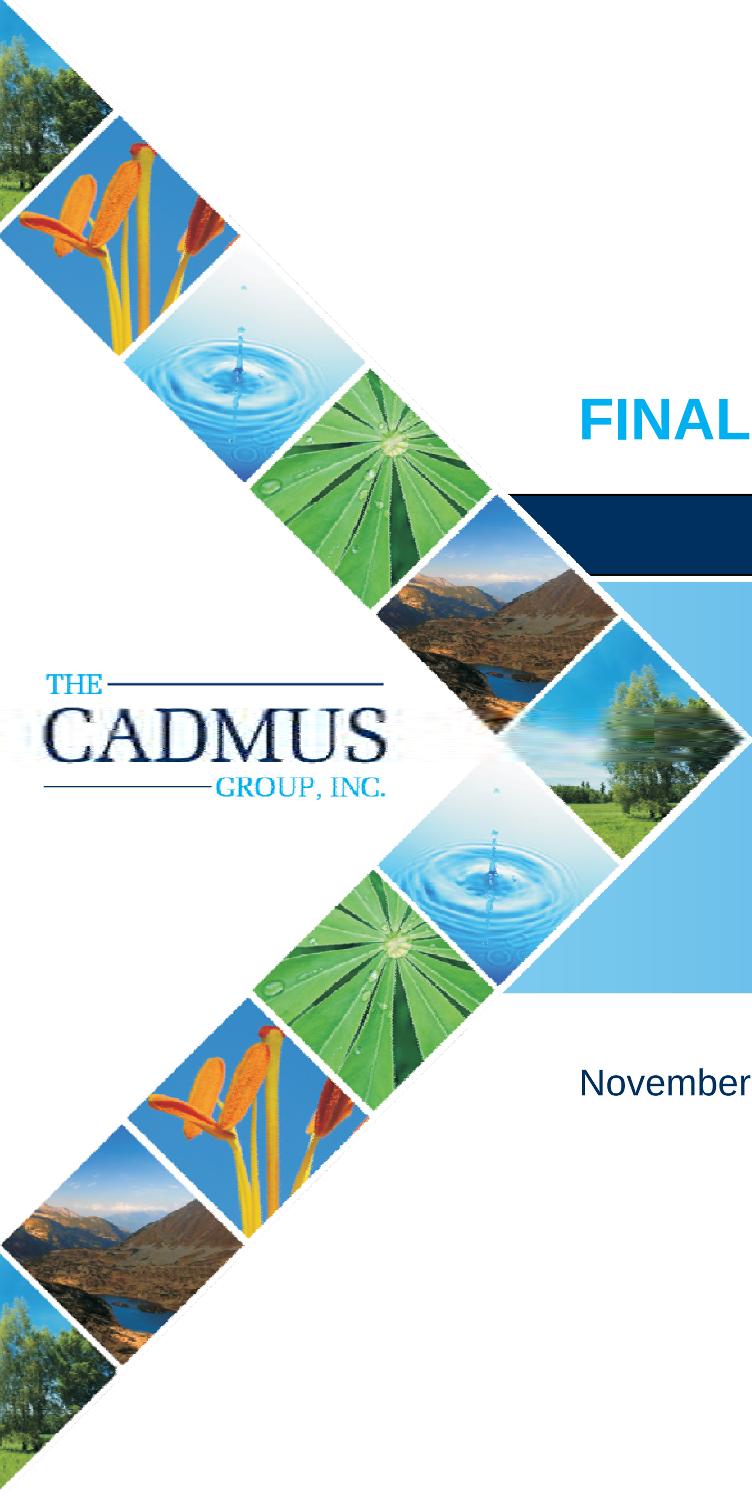

FINAL REPORT

2009 New Buildings Program Impact Evaluation

November 4, 2011

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Executive Summary

The Energy Trust of Oregon (ETO) retained the Cadmus Group, Inc., (Cadmus) to complete an impact evaluation of the 2009 New Buildings Program, a comprehensive effort to assist owners of newly constructed or substantially renovated commercial and industrial buildings to achieve energy savings through differing tracks. The program's four tracks include: Standard Track, Custom, ENERGY STAR, and LEED. These tracks are described as follows:

- The Standard Track supports prescriptive equipment measures, such as lighting, motors, HVAC, and others, through deemed savings.
- The Custom Track provides incentives to reduce a building's energy use below the 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.

The 2009 New Buildings Program was implemented by a third-party program management contractor (PMC), Portland Energy Conservation, Inc. (PECI). Participants also initiated a portion of completed projects under a previous implementer, Science Applications International Corporation (SAIC). ETO changed management contractors beginning with the 2009 program year.

Cadmus developed a sample of the 31 largest savings projects for evaluation to match the evaluation level achieved for 2008 projects. The sample experienced attrition, however, primarily due to participant refusals and issues related to simulation modeling. The sample attrition details are shown in Table 7. Where possible, projects removed from the sample were replaced with similar projects, and Cadmus added or replaced projects to maintain the same level of total evaluated savings. The final sample contained 34 projects, consisting of 316 measures, which represent 68 percent of the total program reported combined savings, as shown in Table 1.

Table 1. 2009 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)[1]
Program Total	189	1,071	20,715,091	640,716	134,751
Sample Total	34	316	14,406,517	423,636	91,519

Cadmus evaluated the program through site visits and reviews of engineering calculations and models. Site visits validated proper installation and functioning of incented equipment, and provided operational characteristics data to support engineering analysis. Cadmus evaluated

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

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 and a subcontractor, SBW Consulting, analyzed 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, as shown in Table 2. The total combined reported energy savings (electric and gas) represented 134,751 MBtu. Cadmus calculated the total combined evaluated energy savings to be 129,201 MBtu, for a 96 percent overall realization rate (see Table 21).

Table 2. Overall 2009 Program Realization Rates and Energy Savings

Measure Category	Total Number of Measures	Reported Electric Savings (kWh)	Reported Gas Savings (therms)	Evaluated Electric Savings (kWh)	Evaluated Gas Savings (therms)	Electric Savings Realization Rate	Gas Savings Realization Rate
Standard Lighting	521	7,059,897	0	7,117,845	-	101%	N/A
Standard Motors	165	894,512	0	709,732	-	79%	N/A
Standard HVAC	250	501,223	181,551	498,784	198,372	100%	109%
Standard Other	61	189,609	18,205	216,298	22,749	114%	125%
Standard Census[2]	4	228,000	108,675	91,981	3,038	40%	3%
Custom	10	618,792	18,629	616,498	18,476	100%	99%
Custom Shell	10	181,717	75,942	40,076	84,008	22%	111%
Custom HVAC	9	3,688,784	40,213	4,133,523	20,768	112%	52%
Custom Lighting	16	1,271,887	0	1,117,040	-	88%	N/A
Custom Motor	4	125,768	0	141,955	-	113%	N/A
ESTAR	2	245,680	21,813	0	27,402	0%	126%
LEED	19	5,709,222	175,688	5,374,037	233,344	94%	133%
Total	1,071	20,715,091	640,716	20,029,136	608,621	97%	95%

* All savings values listed in the impact evaluation are gross values. The calculation of a net-to-gross ratio was outside the scope of this evaluation.

Primary factors affecting realization rates included:

- Actual operating conditions differed from deemed prescriptive assumptions for operating hours.
- Actual equipment operation patterns differed from expected patterns.
- Incented measures just met building code requirements.
- Equipment quantities observed differed from reported quantities.

[2] Cadmus evaluated the census of package terminal heat pump and tankless water heater measures in the program population. Since the census was evaluated, the achieved results were not extrapolated to the remaining program population.

The 2009 program realization rate of 96 percent represents an improvement over the 2008 program realization rate of 86 percent. Factors contributing to the higher realization rate included longer actual lighting operating hours than deemed, better performance from LEED buildings, and conservative assumptions in some deemed savings estimates. However, Cadmus also noted problematic issues with deemed savings estimates and the savings methodology for Standard Track measures, particularly package terminal heat pumps, tankless water heaters, and demand controlled ventilation. We also determined that one facility inappropriately received incentives through both the Standard and ENERGY STAR Tracks; removing the duplicative savings reduced the realization rate. Overall, the 2009 implementer performed a reasonable level of review and quality control to achieve high average project savings realization rates.

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MEMO

Date: September 30, 2011
To: Board of Directors
From: Sarah Castor, Evaluation Sr. Project Manager
Jessica Rose, Business Sector Manager, New Buildings Program
Subject: Staff Response to the 2009 New Buildings Program Impact Evaluation

The 2009 program year was one of significant change for New Buildings. In addition to the change in Program Management Contractor (PMC), the commercial new construction market experienced a significant slowdown as a result of economic conditions. Despite these challenges, the results of the 2009 New Buildings Impact Evaluation show that the program increased its electric and gas realization rates over 2008.

Since the transition to the new PMC, the program has instituted several changes, including:

- a redesign of the participation process, program tracks and incentive structures, with the goals of simplifying the program experience for participants and motivating them to make their buildings even more energy efficient
- conducting routine evaluation of measures available
- coordinating with planning and evaluation on a bi-monthly basis to make updates due to changing standards and new codes
- instituting simplified calculators that streamline a number of HVAC measures, including demand control ventilation, unitary HVAC equipment, VFDs, fan power, air-to-air heat exchangers, and economizers, to insure that savings calculations are performed correctly
- completing two reviews on all project submittals for compliance with program requirements
- reviewing all models and calculations for modeled projects
- correcting the calculation of savings for LEED projects
- modifying the ENERGY STAR offer.

The evaluator made several specific recommendations for program improvements based on 2009 project findings (in italics) which we have already addressed, many as part of the 2010 program redesign, or will address as follows:

- *Remove incentives for LED exit signs*
  LED Exit signs were removed from the program in the second quarter of 2009.

- *Calculate lighting savings through lighting power density*
  An LPD based lighting tool was deployed with the program redesign beginning in the third quarter 2010. Projects under the 2010 code and/or after the program redesign must use the LPD calculator tool, while projects under the 2007 code can use standard measures.

- *Move demand control ventilation (DCV) projects to the Custom track*
  The program adopted a calculated savings approach to standard HVAC measures with the program redesign and deployed a comprehensive HVAC calculator (much like the lighting calculator the program has seen success with). This calculator includes DCV measures that replace the standard ones.

- *Review and revise deemed estimates for package terminal heat pumps (PTHPs), tankless water heaters, condensing tank water heaters, VSDs, and occupancy sensors*
  Energy Trust will review condensing tank water heater measures for the program. Actions have already been taken for the following measures:
    - PTHPs – savings were lowered to 1,000 kWh in December 2010.
    - Tankless water heaters – savings were updated in October 2010 which corrected an error in the incentive calculation that caused the unreasonably high savings estimate.
    - VSDs – savings and incentives are now calculated through the HVAC calculator
    - Occupancy sensors – fixture-mounted occupancy sensors were added in February 2010; the 2010 lighting calculator tool calculates savings for occupancy sensors based on the number of fixtures controlled, whereas the prior calculator did not account for all fixtures controlled leading to under-claimed savings

- *Obtain energy simulation models during program year*
  Since the last evaluation report in late 2010, the program began collecting model files for all LEED and modeled projects. The application terms and conditions were updated to specify that project owners agree to provide Energy Trust with the energy simulation models and inputs as a condition of incentive payment.

- *Avoid combining ENERGY STAR buildings with other tracks*
  During the time the 2009 ENERGY STAR offer was available, it was limited to standard customers only. The reason was that savings opportunities were available beyond what was achieved though the installation of standard measures that could be captured through

ENERGY STAR requirements and review by a professional engineer. With the 2010 program redesign, ENERGY STAR was significantly modified: savings are no longer claimed through this track because they are difficult to verify, and incentives were significantly reduced from the original $25,000 potential to the revised $1,000 - $3,000 depending a building's score. The intent of the revised ENERGY STAR offer is to provide modest support for post-occupancy monitoring and behavior change while the program develops new approaches that serve a broad market and are verifiable. New opportunities through commissioning, acceptance testing, metering and reporting are now developing with program experience and the Path To Net Zero pilot.

Introduction

The Energy Trust of Oregon (ETO) retained the Cadmus Group, Inc., (Cadmus) to complete an impact evaluation of the 2009 New Buildings Program. The program's process evaluation will be completed by another firm. The New Buildings Program is a comprehensive effort to assist owners of newly constructed or substantially renovated commercial and industrial buildings to achieve energy savings through four differing tracks: Standard, Custom, ENERGY STAR, and LEED.

- 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. Measures included typically involved more complex energy savings analyses than did 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.

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

During the 2009 program year, 189 projects received incentives through the Standard, Custom, ENERGY STAR, and LEED Tracks. Cadmus engineers and a subcontractor, SBW Consulting, analyzed differences between baseline and as-built simulation models for LEED projects.

The following tables show total quantities of measures and first-year reported energy savings for each track in the 2009 program year. The Standard and Custom Tracks were further divided into subcategories based on measure categories.

Table 3. 2009 Standard Track Total Measures and Reported Savings

Measure Category	Total Number of Measures	Total Electric Savings (kWh)	Total Gas Savings (therms)
Standard Lighting	521	7,059,897	0
Standard Motors	165	894,512	0
Standard HVAC	251	729,223	181,551
Standard Other	64	189,609	126,880
Standard Track Total	1,001	8,873,241	308,431

Table 4. 2009 Custom Track Total Measures and Reported Savings

Measure Category	Total Number of Measures	Total Electric Savings (kWh)	Total Gas Savings (therms)
Custom	10	618,792	18,629
Custom Shell	10	181,717	75,942
Custom HVAC	9	3,688,784	40,213
Custom Lighting	16	1,271,887	0
Custom Motor	4	125,768	0
Custom Track Total	49	5,886,948	134,784

Table 5. ENERGY STAR Track Total Buildings and Reported Savings

Measure Category	Total Number of Measures	Total Electric Savings (kWh)	Total Gas Savings (therms)
ENERGY STAR	2	245,680	21,813

Table 6. 2009 LEED Track Buildings and Reported Savings

Measure Category	Total Number of Measures	Total Electric Savings (kWh)	Total Gas Savings (therms)
LEED	19	5,709,222	175,688

Table 7. 2009 Total Program Measures and Reported Savings

Measure Category	Total Number of Measures	Total Electric Savings (kWh)	Total Gas Savings (therms)
Total 2009 Program	1,071	20,715,091	640,716

The following section presents Cadmus' methodology for evaluating the 2009 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 to determine the gross energy savings attributable to the program:

- Sample Development
- Data Collection
- Engineering Analysis

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

Sampling Methodology

Cadmus evaluated the New Buildings Program for both 2008 and 2009. At the study's beginning in 2010, Cadmus met with ETO staff to develop a sampling plan, review appropriate evaluation methods, and discuss specific program details. ETO staff, noting the top 50 projects represented more than half of 2008 program savings, suggested these might represent a reasonable sample of measures. Cadmus converted energy and natural gas savings into units of millions of British thermal units (MBtu) to have a standard metric for comparing projects. Most projects contained a range of measures with varying levels of savings, so Cadmus selected a census of the 50 top-saving projects and attempted to evaluate as many as possible. This methodology allowed Cadmus to evaluate a large quantity of individual measures with various savings, rather than select a random set of projects with different levels of savings. Due to attrition and project replacement, Cadmus evaluated 48 projects for the 2008 program year, representing 67 percent of total 2008 program savings.

For 2009, Cadmus attempted to evaluate an equal or higher portion of program savings than in 2008. Appendix B outlines the details of the 2009 impact evaluation sampling methodology, which identified an initial sample of 31 projects.

Cadmus provided the sample projects list to ETO staff to supply documentation. Cadmus reviewed Standard projects to ensure the final sample contained all major measure types as well as a representative quantity of standard practice measure types. Upon review, Cadmus determined all major measure categories previously outlined were represented in the sample.

Some attrition occurred throughout the evaluation. Reasons for attrition are outlined in Table 8, with the predominant reasons being: the participant could not be reached for a site visit, and the simulation modeling firm would not provide the model.

Despite repeated requests and without an adequate rationale, three simulation modeling firms refused to release simulation models for 2009 projects. The final attrition issue involved one project, which had never been occupied. As actual occupant usage patterns could not be evaluated through the simulation model, Cadmus removed the project from the sample.

Table 8. Sample Attrition Details

Participant	Project Type	Building Type	Reported Savings (MBtu)	Reason for Attrition
ETONB0905	NBE LEED-NC	Lodging	7,576	Simulation modeling firm refused to release model.
ETONB0907	NBE LEED-NC	Education	3,766	Simulation modeling firm refused to release model.
ETONB0908	NBE Standard	Education	3,410	Participant could not be reached for site visit despite repeated attempts.
ETONB0910	NBE LEED-NC	Office	2,760	Simulation modeling firm refused to release model.
ETONB0929	NBE Standard-Custom	Health Care (Inpatient)	739	Simulation modeling firm refused to release model.
ETONB0940	NBE Standard	Education	571	Participant could not be reached for site visit despite repeated attempts.
ETONB0941	NBE Standard	Office	552	Participant could not be reached for site visit despite repeated attempts.
ETONB0942	NBE LEED-NC	Office	912	Building never occupied.

In general, projects were replaced by the next-highest energy-saving project outside of the original sample. Given attrition and project additions, the final evaluation sample included 34 projects. The final sample represented 68 percent of reported program savings, slightly exceeding the proportion of evaluated sample to total program savings in the 2008 evaluation. Table 9 shows sample and population details for 2009 projects. Cadmus conducted verification and analysis on all measures for each project in the sample.

Table 9. 2009 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	189	1,071	20,715,091	640,716	134,751
Sample Total	34	316	14,406,517	423,636	91,519
Sample Portion of Program Total	18%	30%	70%	66%	68%

The final evaluation sample represented a cross-section of major measure categories and types, as shown in Table 10. In the sample, Standard measures represented both the largest category of energy savings and the most frequent type of measure installed (as part of 22 projects). Custom measures were second in terms of savings and frequency (as part of 12 projects).

Table 10. Sample Reported Energy Savings by Measure Category

Measure Category	Total Number of Measures	Total Energy Savings (kWh)	Total Gas Savings (therms)	Total Energy Savings (MBtu)
Standard Lighting	125	3,983,257	0	13,591
Standard HVAC	68	401,575	78,245	9,195
Standard Motors	57	214,511	0	732
Standard Other	29	80,946	134,778	13,754
Custom	28	5,362,377	127,470	31,043
ENERGY STAR	2	245,680	21,813	3,020
LEED	7	4,118,171	61,330	20,184
Total	316	14,406,517	423,636	91,519

Cadmus calculated the sampling precision[3] 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 11.

Table 11. 2009 Sample Precision

Track	Confidence Level	Confidence Interval
Standard	90	±9.1%
Custom	90	±8.2%
ENERGY STAR	90	0%[4]
LEED	90	±7.2%

For comparison, Table 12 shows the distribution of measures in the overall program and sample population. The sample distribution was very consistent with the overall program project distribution. However, the sample featured less prescriptive lighting and a larger proportion of the more complex Custom measures, which generally involved more energy savings and required significantly more analysis. These differences in distribution were consistent with our process of selecting projects that saved more energy.

Table 12. Reported and Evaluated Measure Portions of Population

Measure Type	Reported Measure Quantity	Portion of Total Measures	Evaluated Measure Quantity	Portion of Sample Measures
Standard Lighting	521	49%	125	40%
Standard HVAC	165	15%	68	22%
Standard Motors	251	23%	57	18%
Standard Other	64	6%	29	9%
Custom	49	5%	28	9%
ENERGY STAR	2	0%	2	1%
LEED	19	2%	7	2%
Total	1,071	100%	316	100%

[3] The precision is the confidence level and interval. These values for Standard projects, for example, indicate that Cadmus is 90 percent certain the correct answer is with ±9.1 percent of the evaluated savings.

[4] Cadmus sampled the census of measures in the ENERGY STAR Track, so the confidence interval is 0%.

The evaluation sample and program population also represented a mix of building types, as shown in Table 12. The predominant sample building type was Education, a significant change from 2008 when the most common sample building type involved grocery stores. The "Other" building types in the sample involved a range of activities, including manufacturing, storage, warehouses, a parking garage, and an aquatic center.

The sample distribution roughly matches that of the program population, except for Education and Retail buildings. Cadmus sampled the top saving projects from the program population. Education buildings typically represented the highest savings, with a wide range of measures. The retail project with the highest savings only represented 522 MBtu, while the lowest saving project in the final sample represented 648 MBtu. As a result, the Education building segment represented one third of the sample, while Retail buildings were not included.

Table 13. Building Types Represented in Evaluation Sample and Population

Building Type	Sample Quantity	Portion of Total Sample	Population Quantity	Portion of Total Population
Education	11	32%	35	18%
Food Sales	1	3%	4	2%
Food Service	1	3%	8	4%
Health Care (Inpatient)	2	6%	5	3%
Health Care (Outpatient)	-	-	4	2%
Laundry/Dry Cleaners	-	-	1	1%
Lodging	1	3%	3	2%
Mercantile (Retail Other Than Mall)	-	-	22	11%
Mixed use Residential	2	6%	5	3%
No listing	-	-	6	3%
Office	4	12%	37	19%
Other	6	18%	32	17%
Public Assembly	1	3%	2	1%
Public Order and Safety	1	3%	1	1%
Religious Worship	1	3%	2	1%
Service	-	-	2	1%
Warehouse and Storage	3	9%	23	12%
Total	34	100%	192	100%

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Data Collection

We reviewed available documentation (e.g., audit reports, savings calculation work papers, etc.) for a sample of sites, with particular attention paid to the calculation procedures and documentation for savings estimates. Cadmus reviewed the analyses originally used to calculate expected savings, and verified operating and structural parameters. We conducted site visits to verify installations and determine any changes to operating parameters following the measures' installation. In some cases, Cadmus obtained trend data from energy management systems (EMS) for energy demand, lighting, or temperature details. Site visit and trend data informed savings impact calculations. Individual measure savings, aggregated into measure categories, were used to calculate measure-level realization rates. We then applied these rates to program-level reported savings associated with the respective measure type and summed total adjusted savings to determine the overall, program-level, energy savings realization rate. The site visit data and analysis also provided information that enabled Cadmus to develop recommendations for future studies.

Document Review

The evaluation began with a review of relevant documentation and other program materials. In the 2009, the New Buildings Program was managed by a third-party PMC, PECI. ETO changed PMCs for the 2009 program. As part of the changeover, SAIC staff provided PECI with program documentation, including forms, emails, calculations, invoices, and specification sheets.

In several cases, Cadmus could not find calculation spreadsheets or relevant data for measure savings calculations. In most cases Cadmus was able to contact the participant or relevant contractor to obtain and update the original calculation sheet, based on site visit data, utility billing information, or other sources.

Cadmus also experienced difficulty obtaining energy simulation models for Custom and LEED projects. The project documentation received from the PMC included only four of the 16 simulation models required for Custom and LEED projects. Most simulation modeling firms readily provided the necessary models, but Cadmus could not obtain models for four projects.

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).

We reviewed each project file for the following information:

- Documentation on equipment installed, including: (1) descriptions; (2) schematics; (3) performance data; and (4) other supporting information.
- Information about savings calculation methodologies, including: (1) what methodology was used; (2) assumption specifications, and the sources for these specifications; and (3) calculation accuracy.

Site Verification Visits

Site visits were used to: verify measure installations; collect primary data to calculate savings impacts; and interview facility contacts. Cadmus developed a comprehensive building measure data collection form for LEED and whole building simulation model projects, included as Appendix C. Field staff used streamlined versions of the form focused on specific end uses when individual measures were verified at a site.

During site visits, field engineers focused on three primary tasks:

1. Verified installation of all measures for which participants received incentives: To the extent possible, field engineers verified energy-efficiency measures were in place,

installed correctly, and properly functioning based on spot measurement, energy management system trend data, visual inspection, or facility staff experience, as appropriate. Field engineers also verified operating parameters for installed equipment.

2. Collected physical data required to analyze energy savings realized from installed measures: Field engineers determined the pertinent data to collect from each site using in-depth reviews of project files. Data required were unique to each measure.
3. Conducted interviews with the facility operations staff to confirm project documentation's accuracy and obtain additional data on operating characteristics for the installed systems.

During several site visits, field engineers noted when equipment counts differed from those incented, with either less or more measures in place. In cases with fewer measures in place, Cadmus reduced realization rates accordingly. 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 being analyzed. The following major measure groups were included in this program:

- Standard Lighting
- Standard HVAC
- Standard Motors and Variable Speed Drives
- Standard Other (prescriptive water heating, cooking, and refrigeration equipment)
- 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.

Standard Lighting Measures

Two types of projects were included in the Standard Lighting ones we analyzed:

- Installation of high-efficiency lamps, ballasts, and/or fixtures expected to reduce lighting power densities below the code-required value: 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 occupancies.

Analyzing savings for lighting measures required documentation of the fixture wattage, quantity, and operation hours, which we reviewed within each file prior to conducting on-site inspections.

Cadmus verified the energy-efficient replacement input wattage using several sources, including the manufacturer industry lamp and ballast product catalogs. We 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 the lights were turned off. Lighting automation systems were visually inspected for scheduled operation hour set points, and then verified against claims used in submitted calculations.

In addition to parameters listed above, we conducted on-site interviews with building operators and facility staff to verify the operation hours and areas where fixtures were installed. The field engineer calculated lamp and ballast information for each fixture, counting the number of fixtures installed, and organizing fixtures affected by lighting controls systems.

Standard HVAC Measures

For sites with HVAC measures, Cadmus focused on equipment operating characteristics and "equivalent full load hours" (EFLHs) of affected equipment, based on applications, geographical locations, and operation types. Site inspections included interviews with facility personnel, which enabled Cadmus to verify operation hours and proper installation of energy-efficient equipment.

Cadmus generally calculated savings based on differences between code-minimums and installed equipment efficiencies (rated in SEER, EER, IPLV, COP, or HSPF), and multiplied by the EFLH for the specific building types and applications. Some measures, such as demand-controlled ventilation, involved more complex calculations, accounting for all HVAC and ventilation parameters as well as occupancy patterns within the buildings.

Standard Motors and Variable Speed Drives

For high-efficiency motor and VSD installation measures, savings parameters included efficiency of the code baseline motor, efficiency of the installed motor, the load factor, and operation hours. Cadmus collected nameplate information for motors during on-site inspections as well as other technical information provided by facility contacts. In this case, field verification focused on proper installation of rebated equipment and verification of operating parameters. Field engineers also observed VSD operation to verify motors were operating below 100 percent, if they were active.

Cadmus applied VSD energy saving factors, based on end-use and system operating characteristics, such as constant or variable volume air flows. Energy savings factors were derived from values cited in secondary sources.[5]

Standard Other Measures

Cadmus noted a subset of Standard Track measures did not fit into the primary categories. Largely, these included cooking, refrigeration, and water heating equipment. During site visits,

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[5] Mid-Atlantic Technical Reference Manual, May 2010 <http://neep.org/uploads/EMV%20Forum/EMV%20Products/Mid%20Atlantic%20TRM_V1d_FINAL.pdf>

Cadmus collected data on number of units, sizes, model numbers, and other pertinent information, and then verified these data against program documentation. Much of the cooking and refrigeration equipment was rated through ENERGY STAR. Cadmus verified energy savings for these measures through on-line ENERGY STAR calculators. Condensing water heater savings were calculated by comparing manufacturers' specified efficiencies with code requirements. Each unit's EFLH was calculated using ASHRAE guidelines for average daily hot water use per person, hotel room, or meal.[6]

Custom Measures

Custom Track projects represented a range of measures, from lighting power density reductions to more complex chiller heat recovery systems. The diversity of projects was matched by the 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 confirm quantities and operating characteristics. We then determined whether the initial analysis approach was reasonable, and applied a revised calculation approach, if necessary. Calculations and simulation models were adjusted to reflect as-built parameters confirmed through site visits and interviews with facility operations staff.

ENERGY STAR

The 2009 program approved two projects through the ENERGY STAR Track. Cadmus performed site visits for both projects to confirm energy-efficiency measure installations 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[7]).

LEED Building and Custom Track Simulation Models

In the 2009 program evaluation sample, all six LEED Track buildings and ten Custom Track projects reported savings calculated using building energy simulation models. Cadmus' Measurement-Based Calibrated Engineering Method (MCEM) was the methodology used to evaluate savings for these projects. This approach was: (1) based on *in situ* measurements and observations; (2) calibrated to best available energy use indices; and (3) 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.

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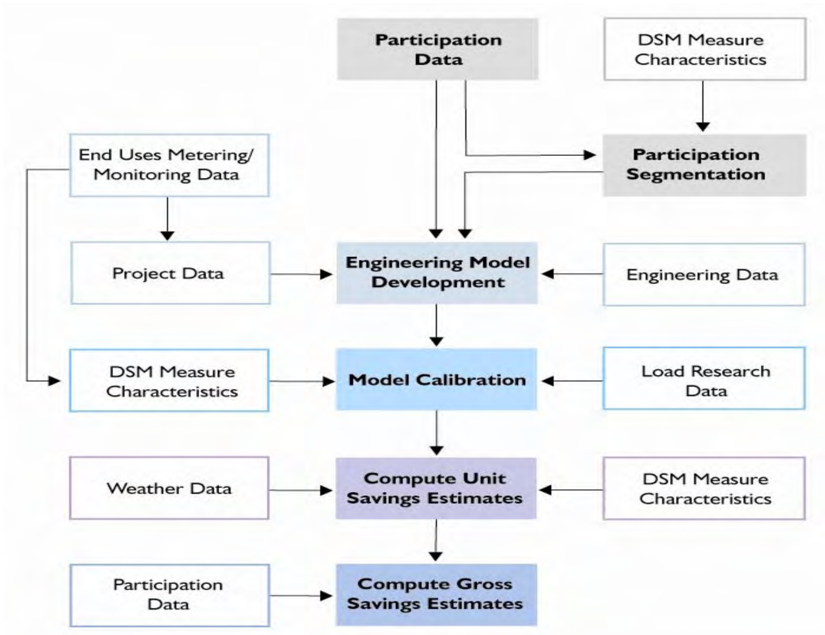
[6] *ASHRAE Handbook*, 2004 HVAC Systems and Equipment.
[7] < http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager >

- 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.

Figure 1 graphically describes the MCEM approach.

Figure 1. Measurement-Based Calibrated Engineering Method Flowchart



Model Calibration

As this was a new construction program, the only model to calibrate was the as-built model. Thus, this represented our starting point. We obtained almost all as-built models for building measure projects in the sample. However, the mechanical design firm for several of the highest-saving LEED projects refused to release the DOE-2 simulation models; those were removed from the sample and replaced by the next largest ones from the program population.

The as-built models were based on the building size and configuration, 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, we determined occupancy levels achieved during the previous year, and adjusted the equipment operating characteristics for spaces modeled.

The models primarily were calibrated 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 noted 2009 heating weather conditions for the Portland Metro area (the location of 24 out of 34 sites visited) were reasonably close to the averages used in TMY3 weather files, as shown in Table 14 below.

Table 14. Average Weather Data vs. Actual 2009 Conditions[8]

	Heating Degree Days	Cooling Degree Days
Average	4,169	467
2009	4,782	707
Difference	1%	51%

Cadmus notes cooling energy usage is less dependent on weather conditions in buildings where constant internal heat gains from sources such as process, lighting and plug loads constitute a relatively large percentage of the overall cooling loads. Since weather-sensitive cooling loads were relatively small, Cadmus chose to calibrate the building to 30 year average data as opposed to modeling the actual climatic conditions found in the 2009 data.

[8] < www.degreedays.net >

Analysis and Findings

This section presents the results of engineering analysis applied to the sample, adjustments to reported values, calculation of realization rates, and extrapolation to the full 2009 program population. It also includes general observations regarding discrepancies and other factors influencing measure-level realization rates. Finally, we examine energy use intensity data derived from the sample.

Sample Evaluated Savings

Reported and evaluated energy savings values were compared through measure-level realization rates, as shown in Table 15. The overall sample electric realization rate was 111 percent, and the natural gas realization rate was 81 percent. Cadmus adjusted electric and gas savings due to measure-specific reasons outlined below.

Table 15. Sample Reported and Evaluated Savings and Realization Rates

Measures Type	Reported Electric Savings (kWh)	Reported Gas Savings (therms)	Evaluated Electric Savings (kWh)	Evaluated Gas Savings (therms)	Electric Savings Realization Rate	Gas Savings Realization Rate
Standard Lighting	3,983,257	0	6,157,863	0	155%	N/A
Standard Motor	214,511	0	170,199	0	79%	N/A
Standard HVAC	401,575	93,834	184,874	102,528	46%	109%
Standard Other	80,946	119,189	75,238	15,675	93%	13%
Custom	577,827	18,327	575,685	18,176	100%	99%
Custom Shell	118,998	68,930	26,244	76,251	22%	111%
Custom HVAC	3,639,276	40,213	4,078,046	20,768	112%	52%
Custom Lighting	915,069	0	803,663	0	88%	N/A
Custom Motor	111,207	0	125,520	0	113%	N/A
ENERGY STAR	245,680	21,813	0	27,402	0%	126%
LEED	4,118,171	61,330	3,855,741	81,457	94%	133%
Total	14,406,517	423,636	16,053,073	342,257	111%	81%

Standard Lighting

Standard Lighting measures involved efficient lighting fixtures, and controls such as occupancy sensors and daylight dimming. Lighting measures achieved a 155 percent realization rate compared with reported savings. Cadmus noted Standard Lighting savings were based on deemed values per fixture, regardless of building type and actual hours of operation. However, building code requirements for new construction and substantial renovation require buildings to meet a set lighting power density (LPD). The program method of applying savings by fixture 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 review of invoices and manufacturer specification sheets.

The other primary factors influencing the realization rate included: LED exit sign deemed savings; occupancy sensor deemed savings; higher average operating hours in the sample; alterations in fixture quantities; and addition of HVAC interaction factors.

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. Older signs presumably could be found in inventories or from foreign vendors. However, EPAct 2005 resulted in LED exit signs as the standard practice for new construction.

The 2009 New Buildings Program incented LED Exit Signs[9], although PECI indicated these installations only involved legacy projects from the previous implementer. In 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 the manufacturer's specification sets, many LED exit signs listed ratings ranging from of 1 to 3 Watts per face. This provided some savings over the baseline value, but evaluated savings were 198,377 kWh (or 89 percent) less than the reported savings. This represented a substantial reduction, but was relatively small (3 percent) compared to the overall evaluated Standard Lighting energy savings of 6,157,863 kWh.

Occupancy Sensors

In the 2009 program evaluation, Cadmus noted many wall and ceiling occupancy sensors controlled significantly more fixtures than those accounted for by the deemed savings estimates. When this was taken into account, these measures had a 292 percent overall realization rate.

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 calculation purposes, both the baseline and as-built fixture counts were adjusted to match observed quantities.

HVAC Interaction Factors

Though the interactive effect of installing more efficient lighting fixtures and controls reduces cooling requirements, it can result in requiring additional heating. Cadmus accounted for HVAC interactions in our calculations. Values were obtained from the Northwest Power and Conservation Council's Commercial Sector Deemed Savings Calculation Methodology.[10] On average, inclusion of interactive factors for both heating and cooling resulted in a slight increase in evaluated lighting savings.

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

[10] <http://www.nwcouncil.org/energy/rtf/supportingdata/APPENDIXM2.XLS>

Sample Average Operating Hours

The evaluated sample project lighting measures operated for longer periods than the values used in deemed energy savings estimates, which increased the realization rate. For example, Cadmus back-calculated 3,800 operating hours from deemed savings for T8 fixtures. Cadmus examined average operating hours in the evaluated sample, weighted by their total reported lighting energy savings. The sample average was 7,521 operating hours per year, which resulted in substantially higher savings. Evaluated operating hours were higher because the sample included several large saving projects at facilities operating 24 hours per day (including a hospital, manufacturing facility, and hotel). The lighting sample realization rate of 155 percent was determined using the following equation:

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

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

Standard Motors

The Standard Motor category included premium-efficiency motors and variable speed drives (VSDs). The realization rate for this subset was 79 percent. Energy savings adjustments were influenced by actual observed equipment counts; Cadmus assumptions for energy savings factors, equivalent full-load hours (EFLH); and whether installed measure exceeded code minimum requirements.

Cadmus Assumptions

Cadmus noted reported measure savings appeared to have been based on end use, such as ventilation fans or HVAC pumps. Cadmus adjusted measure savings using projected EFLHs according to the building type and end use. For premium efficiency motors, Cadmus' assumptions resulted in a 111 percent average realization rate.

For VSDs, Cadmus applied EFLH assumptions identical to those used in motor calculations, as well as parameters based on specific end-use, fan type, and facility operating hours verified on-site. Energy savings factors were derived from values cited in secondary sources.[11] The resulting realization rate for VSDs was 68 percent.

Code Minimum Requirements

For several measures, Cadmus noted an incented measure either just met the code's minimum efficiency or was required by code. In these cases, no energy savings could be assigned. For example, on project ETONB0937, the installed 2 hp motor had 84 percent efficiency, as required

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[11] Mid-Atlantic Technical Reference Manual, May 2010 <http://neep.org/uploads/EMV%20Forum/EMV%20Products/Mid%20Atlantic%20TRM_V1d_FINAL.pdf>

by code. However, these issues occurred on three small motor measures, with a total savings reduction resulting of 434 kWh, equaling less than 1 percent of total reported sample savings for this measure category.

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. The overall realization rate for these measures was 101 percent. Energy savings adjustments in the evaluation were primarily influenced by Cadmus' assumptions for EFLH, observed equipment counts, and efficiency ratings from manufacturer specification sheets.

Overall, the evaluated savings were comparable to the reported savings, so the realization rates were high. However, Cadmus noted significant issues that affected evaluated savings for chillers, package terminal heat pumps and DCV systems. Details of the HVAC evaluation adjustments are presented below.

Electric HVAC Measures

Cadmus calculated a 65 percent realization rate for purely electric HVAC measures, including packaged air conditioning, air source heat pumps, and air cooled chillers. Cadmus field engineers observed equipment counts were accurate. Primary factors influencing the realization rate included variations between Cadmus and PMC assumptions for EFLH and the actual versus deemed differences between the baseline and installed efficiencies.

The realization rate for most electric HVAC measures was greater than 100%. One large chiller measure had a 30% realization rate, however, which drove down the overall realization rate for these measures. Two other chillers measures achieved realization rates greater than 100% using similar assumptions for EFLH as the chiller which achieved a low realization rate. Cadmus believes the actual efficiency for this particular unit may have been less than that factored into the deemed savings assumption.

The most significant discrepancy involved a measure for 114 half-ton package terminal heat pumps (PTHP) at project ETONB0915. Reported savings were 228,000 kWh, equal to 2,000 kWh per half-ton PTHP. Cadmus calculated a revised energy savings of 807 kWh per unit after ETO clarified the PTHP baseline as a code-minimum package terminal air conditioner with electric resistance heating. ETO reported the PTHP deemed savings estimates had been updated in subsequent program years to approximately 800 kWh per unit, which represents close agreement with the Cadmus value. As this project was the only one in the program population to install PTHPs, Cadmus segregated the evaluated savings, and did not factor the results into the realization rate applied to the entire program population. The revised Standard HVAC electric realization rate without PTHPs (including dual fuel measures such as DCV) increased from 46 to 100 percent.

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 two direct-fired radiant heating projects in the sample, and applied a revised engineering calculation for comparison to determine the resulting reductions in heating energy. We determined the reported values were reasonable in each case, and applied a 100 percent realization rate to these 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. However, Cadmus noted in several facilities that one boiler served as a backup unit with low utilization. Cadmus modified the savings analyses accordingly, and determined a realization rate of 77 percent for boiler measures.

The sample included one measure for a condensing, high-efficiency unit heater to condition an office located within a warehouse. The office space operated 24 hours per day, was lightly insulated, and was exposed to ambient conditions for much of the time. Cadmus calculated significantly higher annual savings of 1,718 therms for this measure, based on the manufacturer's specification sheet and assumed EFLHs, compared with reported savings of 489 therms.

In addition, Cadmus noted variation on the only sample project that installed air to air heat exchangers. The facility's only HVAC system was a variable refrigerant flow heat pump system, but 97 percent of the deemed savings were attributed to therm savings. The deemed savings estimate represented a dual fuel measure, and did not appropriately address the project's HVAC fuel source. Without gas heating, the gas savings realization rate was 0 percent. However, the overall realization rate for these measures on an MBtu basis was 119 percent due to the large electric savings.

Demand Controlled Ventilation

Cadmus calculated the highest variation from Standard HVAC deemed savings with DCV projects, with an overall realization rate of 230% for this measure. DCV systems use CO_2 sensors to indirectly determine the amount of occupancy in building spaces and adjust the ventilation, heating, and cooling requirements accordingly. These measures typically achieve both electric and gas savings. DCV calculations involve a significant number of variables, including specific details of heating and cooling equipment; equivalent full-load hours for all HVAC equipment; fractions of occupancy for controlled spaces; and whether the system included heat recovery. However, the ETO rebate was based solely on the ventilation system CFM, and this value does not provide adequate information to accurately quantify measure savings.

The energy savings methodology for DCV involves highly variable assumptions for parameters such as occupancy patterns and HVAC equipment schedules throughout the year, as well as differences in HVAC system design for similar building types. Some secondary data are available, as referenced, but more complex calculation methods, such as simulation modeling, are necessary for accurate savings estimates but were outside the scope of this evaluation.

Cadmus calculated savings for DCV measures through a deemed savings methodology developed for the California Energy Commission[12]. The methodology required Cadmus to match Oregon site climatic conditions to California climate zones. The calculations assumed energy

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[12] < http://www.energy.ca.gov/title24/2005standards/archive/documents/2002-04-23_workshop/2002-04-23_WORKSHOP_REPORT.PDF >

savings per square foot of occupied space, based on several levels of occupant density. The resulting savings were higher than the ETO deemed savings, as shown in Table 16 for the five DCV projects. The magnitude of realization rates indicate that the ETO deemed methodology and savings values may have been too conservative.

Table 16. Comparison of Reported and Evaluated Savings for DCV Measures

Project	Reported Electric Savings (kWh)	Reported Gas Savings (therms)	Evaluated Electric Savings (kWh)	Evaluated Gas Savings (therms)	Electric Savings Realization Rate	Gas Savings Realization Rate	Energy Savings Realization Rate
ETONB0909	2,124	2,680	4,718	3,932	222%	147%	149%
ETONB0912	5,771	7,283	11,580	9,650	201%	133%	134%
ETONB0913	1,452	1,832	6,480	5,400	446%	295%	299%
ETONB0918	2,597	3,277	3,600	16,800	139%	513%	503%
ETONB0938	1,153	1,453	2,700	2,250	234%	155%	157%

Standard Other

The Standard Other category represented the remaining measures with deemed savings, and included water heating, refrigeration, and cooking measures. Cadmus obtained the original ENERGY STAR calculators or other calculation methodologies used to determine savings, and revised the calculations based on site verification data.

Water Heating Measures

The water heating measures primarily involved condensing water heaters and tankless water heaters, along with showerhead gas and dishwasher measures. Cadmus calculated condensing water heater and showerhead gas savings by comparing the manufacturer's specified efficiency with the code requirement. Each unit's EFLH was calculated using ASHRAE guidelines for average daily hot water use per student or hotel room.[13] The showerhead gas measure for a lodging facility had an 82 percent realization rate. Condensing water heaters had a 160 percent overall realization rate. The high realization rate may result from usage patterns Cadmus assumed for Education facilities, which were 86 percent of the condensing tank evaluation sample. Education facilities represented 83 percent of the program population for condensing tank measures, so Cadmus determined it was reasonable to apply this sample realization rate to the program population.

Cadmus applied a similar calculation for tankless water heating measures, and found a much lower 3 percent realization rate. This realization rate had the largest impact on the overall program gas realization rate. In each case, Cadmus found reported tankless water heater savings significantly exceeded the project's actual gas utility usage, as shown in

We calculated the efficiency difference between a tankless water heater and code baseline water heater could be as much as 40 percent. Cadmus assessed the reasonableness of the PMC's deemed savings estimates by assuming that at the extreme all of a facility's annual gas use

[13] *ASHRAE Handbook*, 2004 HVAC Systems and Equipment.

involved water heating, although space heating is typically a more predominant load. Using project ETONB0922 as an example, a 40 percent increase in efficiency would yield a baseline gas usage of 8,957 therms and a maximum possible savings of 3,583 therms. This savings value is substantially less than the reported savings of 14,925 therms. These calculations confirmed the reported savings estimates were not reasonable, and the evaluated savings should be more representative of the actual energy savings.

Table 17.

We calculated the efficiency difference between a tankless water heater and code baseline water heater could be as much as 40 percent. Cadmus assessed the reasonableness of the PMC's deemed savings estimates by assuming that at the extreme all of a facility's annual gas use involved water heating, although space heating is typically a more predominant load. Using project ETONB0922 as an example, a 40 percent increase in efficiency would yield a baseline gas usage of 8,957 therms and a maximum possible savings of 3,583 therms. This savings value is substantially less than the reported savings of 14,925 therms. These calculations confirmed the reported savings estimates were not reasonable, and the evaluated savings should be more representative of the actual energy savings.

Table 17. Tankless Water Heater Savings and Utility Billing Data

Project	Reported Gas Savings (therms)	Total Annual Gas Use (therms)	Evaluated Gas Savings (therms)
ETONB0904	78,750	10,574	2,241
ETONB0920	15,000	1,026	308
ETONB0922	14,925	5,374	489

The remaining water heating measure involved two ENERGY STAR dishwashers with both gas and electric savings. Cadmus used the measure's 2008 ENERGY STAR calculator to determine the reported savings. The measure's evaluated realization rate was 106 percent.

Refrigeration Measures

The incented refrigeration equipment involved ENERGY STAR appliances, such as refrigerators and ice-making machines. Cadmus determined savings through the applicable 2008 ENERGY STAR calculators. The resulting realization rate was 144 percent.

Cooking Measures

These measures involved both electric and gas equipment, including convection ovens and electric hot food cabinets. The electric hot food cabinets were also rated through ENERGY STAR, and Cadmus determined savings through the applicable 2008 calculators. The convection oven calculations relied on a methodology developed by the Food Service Technology Center. Cadmus reviewed the methodology and made adjustments as necessary to reflect site verification parameters, such as daily operating hours. Cadmus calculated the convection oven realization rate at 65 percent and the hot food holding cabinet realization rate at 85 percent, indicating deemed values may have been too high.

Custom Projects

Custom Projects represent a "catch all" subcategory of nonprescriptive measures with both gas and electric savings. These involved controls systems, specialty refrigeration measures, and heat recovery systems. The Custom measure realization rate was 99 percent.

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. Since 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 the program documentation to determine calculation sources for each measure, and contacted the sources, where necessary, to obtain the original calculation spreadsheets or models. Cadmus compared the inputs and methodology against available data to confirm the methodology and results, or adjusted values as necessary. In most cases, Cadmus determined the methodology and reported savings values were reasonable, although slight adjustments were occasionally required.

Custom Lighting

Two Custom Lighting projects in the sample involved reductions in lighting power density (LPD) over code or standard practice. For these projects, Cadmus determined the claimed space identifications were reasonable, and fixture counts and operating hours were close to the reported values. Cadmus noted variations in fixture wattages, operating hours, and square footage, which adjusted savings slightly.

The remaining projects included CFL measures, which normally would have been incented through the Standard Track. The implementer reported including these measures in the Custom Track to maintain the integrity of savings after CFL savings calculations had been altered significantly from an earlier version of the incentive workbook. The overall realization rate for Custom Lighting measures was 88 percent.

Custom Motors

Custom Motors measures involved ECM motors for refrigeration measures, high-efficiency exhaust fan motors, and VSDs for cooling towers. Cadmus reviewed the methodology, calculation sheets, and data provided by participants and contractors. Cadmus made adjustments based on actual equipment operation and site verification parameters, calculating a 113 percent realization rate.

Custom HVAC

The Custom HVAC measures represented a variety of applications, including: displacement ventilation, boiler economizers, heat recovery chillers, and other innovative HVAC technologies. Cadmus evaluated these projects through energy management system (EMS) trend data on system parameters, review of the design engineer's calculations, and/or building simulation models. The resulting realization rate was 97 percent.

Two measures primarily impacted the Custom HVAC realization rate. Cadmus calibrated the displacement ventilation simulation model using EMS trend data coupled with utility billing data and calculated significantly higher electricity savings. For the boiler economizer project, Cadmus determined the facility staff shut down the relevant boilers during the summer and allowed two smaller boilers to maintain steam levels. We also determined a slightly lower boiler load factor based on the facility staff interview, boiler logs, and utility billing data. These two factors reduced the expected therm savings.

Custom Shell

Custom Shell measures included a variety of strategies to improve the thermal resistance of the building envelope including energy efficient windows and wall and ceiling insulation. Cadmus used simulation modeling calibrated to utility billing data to calculate savings on nearly all of these measures, due to interactive effects with HVAC equipment, process loads, and lighting. Cadmus determined savings on one smaller measure through a spreadsheet roof insulation savings calculator, calibrated to utility billing data. This method indicated savings estimates were reasonable, and Cadmus accepted the reported values for that project. Overall, Cadmus calculated the realization rate for these measures at 104 percent.

On one project, the participant installed low-emissivity windows on a hospital facility. Due to high internal loads, the new windows reduced gas consumption by 6,008 MBtu. However, this required additional cooling capacity to offset the internal loads, resulting in an electric penalty of 1,877 MBtu. ETO maintains a policy to not report as “reduced energy savings” the negative energy savings from one fuel (in this case electricity) from measures exclusively funded to save another fuel (in this case gas). This policy was put in place because the increased load is not a consequence of the program funded by providers of that fuel (in this case the electric providers). ETO does use the dual fuel impacts to determine measure cost-effectiveness. On the basis of ETO’s policy, Cadmus did not include the electric cooling penalty in the evaluated savings or program realization rate.

ENERGY STAR Benchmarking

In 2009, participants completed two ENERGY STAR Benchmarking projects. 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 both projects to verify energy-efficiency measures had been correctly installed and the resulting EUI accurately represented the building’s expected performance. Cadmus then recalculated each building’s ENERGY STAR score using the Portfolio Manager tool, and determined energy savings between the as-built and baseline building types. Cadmus assigned savings to electric and natural gas based on ratios estimated by the PMC.

Based on the Portfolio Manager results, one building’s EUI achieved higher energy savings than reported. However, the building received electric service through Eugene Water and Electric Board, which is not a utility contributing to ETO. Electric savings for this project were not reported in the original database, and Cadmus agreed this was appropriate. The gas savings were appropriately counted, however.

The other building had a large number of measures installed through the Standard Track. Cadmus calculated aggregate savings for Standard Track measures, and determined these savings exceeded savings calculated through Portfolio Manager. Consequently, Cadmus determined all reported ENERGY STAR Benchmarking savings represented savings already reported through the Standard Track, and no savings could be assigned to the project through the ENERGY STAR Track. Table 18 shows reported and evaluated savings by project.

Table 18. ENERGY STAR Realization Rates

Project	Building Type	Reported Electric Savings (kWh)	Reported Gas Savings (therms)	Calculated Electric Savings (kWh)	Calculated Gas Savings (therms)	Electric Savings Realization Rate	Gas Savings Realization Rate
ETONB0916	Public Order and Safety	N/A	19,019	N/A	27,402	N/A	144%
ETONB0925	Education	245,680	2,794	0*	0	0%	0%
Total		245,680	21,813	0	27,402	0	126%

* Project ETONB09025 also received incentives thorugh the Standard Track, and Cadmus determined the Standard Track measures represented all of the facility's savings.

LEED Buildings

Cadmus conducted site visits for the six LEED-certified buildings in the evaluation sample. The field engineers completed an extensive data collection form to accurately characterize as-built parameters for mechanical equipment, lighting power density, and plug load density. The field engineers also interviewed the facility operations staff to gain a detailed understanding of building operations, occupied hours, and set points.

Cadmus and SBW compared as-built building characteristics to values specified in the DOE-2 or TRACE simulation model. Where possible, the Cadmus team also calibrated the models to actual electric and gas billing data. Project ETONB0921 was intended to provide gas heat through air handling units as well as through electric resistance terminal units for backup. The HVAC contractor experienced difficulty setting up the system for proper operation, and the electric resistance units provided the overwhelming majority of the building's heat until late Spring 2011. As a result, the utility billing data were distorted from the expected operational parameters. Therefore, this project could not be calibrated to billing data, and the original inputs were evaluated for reasonableness. Cadmus modified model parameters to reflect actual construction and operation, but accepted inputs that could not be clarified except through calibration.

Table 19 shows the resulting realization rates. The adjustments Cadmus made to calculate the evaluated energy savings are discussed in the next two subsections.

Table 19. LEED Building Realization Rates

Project	Building Type	Reported Electric Savings (kWh)	Reported Gas Savings (therms)	Calculated Electric Savings (kWh)	Calculated Gas Savings (therms)	Electric Savings Realization Rate	Gas Savings Realization Rate
ETONB0902	Mixed use Residential	2,703,425	48,324	2,692,947	72,271	100%	150%
ETONB0921	Office	419,756	2,223	304,090	0	72%	0%
ETONB0923	Office	126,136	10,783	108,879	9,186	86%	85%
ETONB0926	Other	322,889	0	328,732	0	102%	N/A
ETONB0933	Mixed use Residential	239,637	0	194,096	0	81%	N/A
ETONB0934	Education	306,328	0	226,996	0	74%	N/A
Total		4,118,171	61,330	3,855,741	81,457	94%	133%

Calculation Methodologies

For LEED projects, energy savings were calculated as the difference in annual energy use between the baseline and counterfactual models. These energy savings were relative to the ASHRAE 90.1-2004 standard, the required standard for establishing LEED EAc1 points. The program implementer degraded baseline energy savings by 5 percent to convert from a baseline of ASHRAE 90.1-2004 to the 2007 Oregon Structural Specialty Code. Cadmus determined the 5 percent conversion factor was a reasonable value. Cadmus confirmed the value by interpolating research performed by Architecture 2030,[14] which estimated the “2030 Challenge Code” would save 30 percent more energy than ASHRAE 90.1-2004 and 25 percent more energy than Oregon code. The difference between the two codes results in a 5 percent reduction from ASHRAE 90.1-2004.

Discrepancies Between the Modeled and As-Built Project

Energy savings were also adjusted due to differences in equipment and operational parameters between the simulation model and as-built structure. One significant weakness with LEED NC v2.2 (and the prior LEED versions) was 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 and systems. There was no mechanism for tracking as-built energy use to confirm a building continued to meet LEED specifications.

Cadmus noted a variety of project-specific issues that resulted in variation between reported and achieved savings, but no overarching concerns. In general, variation occurred due to calibration to actual utility bills and as-built conditions confirmed through the site visits. These enabled Cadmus to determine how equipment actually operated relative to the initial simulation model. The most notable variance involved two projects that did not include gas equipment use in the initial design model. The simulation model developers did not expect gas heating to be installed on certain equipment types, such as packaged HVAC units. The design models included the as-built gas equipment and therefore used significant gas relative to the baseline models. However, Cadmus did not treat the additional gas usage as a factor to reduce savings estimates. In both cases, Cadmus reported only realization rates for electric savings.

Extrapolation to the Program Population

Lighting Population Realization Rate

Cadmus determined the overall realization rate for the lighting population as the first step in extrapolating evaluated savings to the overall program population. We adjusted the sample realization rate to compensate for differences in sample and overall lighting population operating hours. Cadmus determined the overall lighting population operating hours by building type through weighted average operating hours by energy savings for each lighting project in the sample. We then assigned those operating hours for each project with the same building type identified in the Fast Track database extract. For building types not included in the sample,

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

Cadmus either searched on-line for reported operating hours at the particular facility or applied savings from the "Other" building type.

The sample weighted average operating hours were 7,521. The weighted average annual operating hours for the overall lighting population were 4,925. Cadmus calculated the final lighting realization rate of 101 percent in this manner:

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

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

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

Standard Census

Because our sample included all package terminal heat pumps (PTHP) and tankless water heaters in the program populations, there was no need to extrapolate to the population of these measures. should not be extrapolated to the overall program population. Since the sample included the census of these measures, Cadmus segregated these measure savings (identified in Table 20 as "Standard Census"), and applied their reported and evaluated savings without extrapolation.

Extrapolation to Population

The measurement and verification process involved a minority of sites with projects incented through the 2009 program. Cadmus selected a large enough sample to achieve at least 90/10 precision for each track, in order to apply statistically significant realization rates to the overall program population.

Cadmus calculated realization rates (the ratio of evaluated to reported savings) to apply to each measure types (i.e., Standard HVAC, Custom Lighting) at the remaining, non-sample sites. Realization rates were calculated as weighted averages, based on the evaluation sample, where

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

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

$$\sum_k Evaluated_k = RR_j \, x \sum_j Reported_j; \text{ for measure } j \text{ across all sites in measure population}$$

(3)

$$RR_l = \frac{\sum_k Evaluated_{k}}{\sum_k Reported_{k}}; \text{ for the population (all sites and measures)}$$

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 measure (Equation 1). The team calculated the realization rates for the 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). The total population evaluated savings were calculated by multiplying the measure type realization rate from the sample by the total reported savings for the population of each measure type (Equation 3). The program realization rate is the ratio of all evaluated to all reported savings. (Equation 4).

Table 20 and Table 21 show the final evaluated savings by measure, fuel, and at the program level.

Table 20. Program Level Electric and Gas Savings

Measure Category	Total Number of Measures	Reported Electric Savings (kWh)	Reported Gas Savings (therms)	Evaluated Electric Savings	Evaluated Gas Savings	Electric Savings Realization Rate	Gas Savings Realization Rate
Standard Lighting	521	7,059,897	0	7,117,845	-	101%	N/A
Standard Motors	165	894,512	0	709,732	-	79%	N/A
Standard HVAC	250	501,223	181,551	498,784	198,372	100%	109%
Standard Other	61	189,609	18,205	216,298	22,749	114%	125%
Standard Census	4	228,000	108,675	91,981	3,038	40%	3%
Custom	10	618,792	18,629	616,498	18,476	100%	99%
Custom Shell	10	181,717	75,942	40,076	84,008	22%	111%
Custom HVAC	9	3,688,784	40,213	4,133,523	20,768	112%	52%
Custom Lighting	16	1,271,887	0	1,117,040	-	88%	N/A
Custom Motor	4	125,768	0	141,955	-	113%	N/A
ESTAR	2	245,680	21,813	0	27,402	0%	126%
LEED	19	5,709,222	175,688	5,374,037	233,344	94%	133%
Total	1,071	20,715,091	640,716	20,029,136	608,621	97%	95%

Table 21. Program Level Realization Rates

Fuel Type	Realization Rate
Electric (kWh)	97%
Gas (therms)	95%
Total Energy (MBtu)	96%

Energy Use Intensity of Sampled Projects

Cadmus also examined the sampled projects' EUI by examining buildings' area in square feet and utility billing data for gas and electric usage. Three projects were not examined as they constituted a portion of a much larger facility or Cadmus could not obtain a signed utility billing data release form from the participant.

Table 22 shows EUI data for the 31 remaining projects.

Table 22. EUIs for Evaluation Sample Buildings

Code	Building Type	Area (sf)	Electric EUI (kWh/sf)	Gas EUI (therms/sf)	Total Energy EUI (kBtu/sf)
ETONB0909	Education	78,635	5.0	0.23	40
ETONB0912	Education	193,000	3.8	0.21	34
ETONB0913	Education	108,000	4.1	0.16	30
ETONB0914	Education	71,247	5.8	0.17	37
ETONB0925	Education	106,046	3.7	0.20	33
ETONB0932	Education	106,046	3.7	0.20	33
ETONB0934	Education	68,709	11.5	0.23	62
ETONB0935	Education	71,000	7.3	0.17	42
ETONB0937	Education	31,000	12.9	0.36	80
ETONB0938	Education	45,000	14.3	0.33	81
ETONB0917	Food Sales	33,572	46.7	1.33	293
ETONB0922	Food Service	1,200	51.3	4.48	623
ETONB0906	Health Care (Inpatient)	592,000	29.1	0.89	188
ETONB0915	Lodging	93,653	7.5	0.26	52
ETONB0902	Mixed use Residential	401,000	5.4	0.13	31
ETONB0933	Mixed use Residential	35,190	18.3	0.42	105
ETONB0918	Office	120,000	26.7	0.17	108
ETONB0919	Office	97,000	29.8	0.71	173
ETONB0923	Office	18,645	8.8	0.54	84
ETONB0921	Office / Other	280,000	9.3	0.00	32
ETONB0903	Other	212,000	41.5	0.00	142
ETONB0911	Other	100,000	12.5	0.17	60
ETONB0926	Other	70,305	10.2	0.01	35
ETONB0927	Other	27,089	27.2	2.42	334
ETONB0930	Other	35,000	6.9	0.21	45
ETONB0939	Public Assembly	41,000	13.4	0.00	46

ETONB0916	Public Order and Safety	308,299	7.1	0.13	37
ETONB0920	Religious Worship	7,169	5.1	0.14	32
ETONB0904	Warehouse and Storage	72,000	1.3	0.15	19
ETONB0924	Warehouse and Storage	65,000	0.4	0.05	7
ETONB0928	Warehouse and Storage	246,000	1.1	0.04	8

Table 23 shows the performance of the 2009 sample building energy use intensity relative to two other studies[15][16]. The data from these studies are highlighted in more detail in Appendix A. The sample size for many building types was too small to draw definitive conclusions.

Table 23. Comparison of EUI Data with Other Studies

Building Type	Buildings in Sample	Average EUI (kBtu/sf)	PGE EUI Data for Post-1985 Buildings (kBtu/sf)	Ecotope New Construction EUI 2002-2004 (kBtu/sf)
Elementary	8	36.7	43.2	48.5
Other	6	80.2	N/A	96.3
Office	3	132.7	85.3	81.9
Warehouse	3	9.5	32.1	31.8
Colleges	2	69.9	89.8	65.9
Assembly	1	45.9	N/A	76.3
Church	1	31.6	56.2	N/A
Fast Food	1	622.9	587.8	512.7
High Rise Apt	1	31.5	66.0	58.5
Hospital	1	188.0	230.4	123.1
Hotel	1	51.9	88.3	58.5
Institution	1	36.9	N/A	102.8
Low Rise Apt	1	104.7	58.4	58.5
Supermarket	1	292.7	198.7	202.8

In general, the sample buildings used less energy per square foot than buildings in either reference study. In particular, new construction elementary schools and warehouses experienced a large reduction in energy use compared to the reference buildings. The highest energy use intensity building types in the sample (fast-food restaurants and supermarkets) used more energy than in the reference studies, but were in approximately the same range of EUI.

The most significant difference involved the office building type. On average, these projects used considerably more energy than the reference buildings. Only one project had an EUI of 84.3 kBtu per square foot, which brought it into the range of the reference buildings. Another project

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

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

involved the restoration of a large, historic building with an EUI of 173 kBtu/sf. The building envelope efficiency measures were not sufficient to reduce the EUI into the range of typical new construction office buildings.

Cadmus notes both of the office buildings with larger EUIs also had server rooms. Due to the significant growth in computing power requirements over the last decade, it is unlikely the average office building in either reference study consumed as much energy for server loads. Therefore, a portion of the larger EUIs for the office buildings in the 2009 New Buildings study may be attributable to increased server power requirements.

Conclusions and Recommendations

Cadmus conducted an impact evaluation of the 2009 ETO New Buildings Program by analyzing energy savings for 316 measures in 34 projects. The measures belonged to four different program tracks (Standard, Custom, ENERGY STAR and LEED) and represented a wide variety of subcategories. Cadmus performed verification site visits for each project. Cadmus 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 the reported energy savings. Many measures included variations between the 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. All these factors combined led to a program-level realization rate of 96 percent.

Cadmus identified a number of areas for program improvements. The most significant factor would involve the PMC reviewing and revising deemed savings estimates, particularly for package terminal heat pumps and tankless water heaters. We determined adjustments should be made to various Standard Track measure methodologies, particularly demand controlled ventilation, lighting LPD, and LED exit signs. Cadmus also noted process issues that could improve future evaluation efforts. These potential improvements are reflected in the following recommendations.

Remove Incentives for LED Exit Signs

As noted in the Standard Lighting results section, LED Exit Signs became standard practice after EPAct 2005 eliminated the U.S. manufacture of exit signs with usage exceeding 5 Watts per face. Though this measure remains viable for existing buildings, it is not appropriate for a new construction program. In the 2008 program evaluation, Cadmus recommended ETO no longer provide incentives for this measure. PECI indicated this measure was removed from the program.

Calculate Lighting Savings Through Lighting Power Density

Oregon code requires new construction and substantial renovation projects to achieve a lighting power density below a prescribed value based on building type. The 2009 New Buildings Program provided incentives for lighting measures based on fixture types. PECI indicated the program was revised to calculate savings based on LPD beginning with the 2011 program year. Cadmus supports this program revision.

Move DCV Projects to the Custom Track

DCV projects currently are treated as prescriptive measures through the Standard Track, with the incentive based on ventilation system CFM. However, DCV calculations involve a significant number of variables, including: specific details of heating and cooling equipment; ventilation fan size; equivalent full load hours for all HVAC equipment; fractions of occupancy for controlled spaces; and whether systems include heat recovery.

DCV measures Cadmus evaluated in the sample revealed reported savings significantly understated evaluated savings. Cadmus calculated realization rates in the range of 134 percent to 503 percent, which indicates significant issues with the methodology the Standard Track used to define savings. Cadmus recommends treating each DCV measure as a Custom project, with savings based on appropriate variables unique to each system. PECI claimed a more complex calculator for DCV measures was in development and would replace the current Standard Track measure in a future program year.

Review and Revise Specific Deemed Estimates

Cadmus noted deemed savings estimates for package terminal heat pumps and tankless water heaters, in particular, were unrealistic. For tankless water heater measures, the deemed savings estimates significantly exceeded the total annual gas usage for each building, indicating a significant discrepancy with reasonable values. The realization rates for these measures were low due to these discrepancies. Cadmus also noted concerns with realization rates for other deemed measures, such as condensing water tanks, VSDs, and occupancy sensors. Cadmus recommends PECI examine these measures' deemed savings estimates to determine if there are more reasonable values to apply. Cadmus also determined the PTHP deemed savings estimates were too large, and ETO reported these values have been updated to more appropriate estimates for subsequent program years.

Apply Savings More Appropriately to Back-up Boilers

Participants installed multiple condensing boilers on several projects. In general, one unit was designated as the primary boiler and participants used any additional units as back-ups for morning warm-up and peak heating conditions. However, the program applied identical energy savings values to each boiler. Cadmus recommends the program obtain more information on how boilers will be used by the participant and apply prorated savings to back-up boilers.

Obtain Energy Simulation Models During Program Year

Cadmus and its subcontractor, SBW, used DOE-2 and Trane TRACE software to evaluate energy simulation models for LEED buildings and a subset of the Custom projects. In most cases, this required Cadmus to contact participants and building simulation model contractors to obtain the original models used to calculate savings. Though a time-consuming task, most modeling contractors complied. However, the firms that developed models for several of the highest saving LEED projects refused to comply, without citing any reasonable justification.

Cadmus recommends the PMC either obtain energy simulation models for review during the program year or require building simulation model developers sign a consent form, releasing the model for evaluation purposes. Cadmus recommends this step be a requirement for LEED Track incentives and any Custom incentives through which models estimated savings. This will improve the likelihood that a project can be evaluated.

Avoid Combining ENERGY STAR Buildings with Other Tracks

Cadmus noted one site installed a large number of measures through the Standard Track and received incentives for the ENERGY STAR Track as a separate project. After analysis, Cadmus determined the Standard Track measure energy savings exceeded the difference in energy use intensity used to calculate ENERGY STAR savings. Therefore, no savings could be attributed to the ENERGY STAR project. Cadmus recommends ETO not combine the ENERGY STAR Track with any other track due to EUI impacts.

Appendix A: Comparison Energy Use Intensity Data

The EUI data for the FY 2009 sample from Table 22 can be compared with other available data to determine the relative performance of these new constructions projects. Several example data sets are presented in the tables below.

Table 24. PGE Data for Post-1985 Buildings[17]

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

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

Table 25. Ecotope Mean EUI Data for Buildings with Majority New Construction in Oregon, 2002-2004[18]

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

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

Appendix B: 2009 Proposed Sample Development

For the 2009 impact evaluation, Cadmus submitted a memo to Energy Trust, outlining a proposed methodology. The ETO accepted the proposed methodology, and Cadmus attempted to meet the outlined objectives despite sample attrition. The memo is as follows:

Cadmus is submitting a proposed evaluation sample for 2009 New Buildings projects for the Energy Trust of Oregon to review and approve. The proposed sample includes 31 projects in the 2009 population (the 26 projects with the largest energy savings, based on combined electricity and natural gas savings, plus five additional ones selected because they include measures of special interest). Although this represents a reduction from the 48 sites sampled for the 2008 projects, a comparison between Table 26 and Table 27 indicates the 2009 sample will include approximately the same quantity of measures and total reported energy savings as the 2008 evaluation. Moreover, the proposed 2009 sample will evaluate projects totaling 76% of combined program savings, compared with 67% for the 2008 sample.

Table 26. 2009 Program and Proposed 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	189	1,117	20,715,091	640,716	134,698
Sample Total	31	294	14,719,799	519,315	102,155

Table 27. 2008 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	224	1,073	33,138,094	464,905	159,591
Sample Total	48	330	21,680,726	335,236	107,498

The 2009 project population and total reported savings declined from 2008, although the total number of measures increased slightly. This was due to an increase in the number of relatively small prescriptive measures approved in the program. The proposed 2009 sample includes seven LEED projects, slightly more than the six LEED projects evaluated in the final 2008 sample. The proposed sample also includes two ENERGY STAR Benchmarking projects.

Cadmus performed an analysis to determine how the proposed sample matched the overall program population. Cadmus reviewed the top 50 projects approved in 2009, and determined the top 30 projects reported approximately the same quantity of measures and savings as the 2008 sample relative to each program year's population.

The initial sample of 30 projects included nine schools with a large number of prescriptive measures. The schools, therefore, represented 30% of the sample population, although schools only represented 12% of the total program population. To reduce overrepresentation of schools, we removed the four schools with the lowest savings from the sample, for a final ratio of 17% of the sample population.

Next, Cadmus selected replacement projects to include measures of significant interest, such as Custom HVAC, and those underrepresented in the original sample compared with the population. The resulting comparisons by portion of total measures and total savings are indicated in Table 28.

Table 28. Comparison between Proposed 2009 Sample and Population

Measure Type	Portion of Total Measures		Portion of Total Savings	
	Sample	Population	Sample	Population
Motors	18%	15%	1%	2%
HVAC	13%	18%	3%	5%
Custom	11%	5%	30%	25%
Kitchen/Refrigeration	5%	3%	1%	1%
Gas Heating	10%	9%	18%	19%
LEED / ENERGY STAR	4%	2%	35%	30%
Lighting	39%	48%	13%	18%

In general, Custom and LEED measures are slightly overrepresented in the sample. Cadmus included a larger sample of these measures because their analysis involves a higher level of uncertainty, and they are generally of more interest to the Energy Trust. Lighting projects are slightly underrepresented in the sample. These measures represent a significant portion of total measures in both the sample and program population, but a smaller portion of savings. They are also prescriptive and fairly straightforward, with a lower level of uncertainty. Cadmus chose to focus on measures with a higher level of uncertainty.

The full list of proposed projects, with identifying information and energy savings, is shown on the following page. Cadmus has already received project files on the seven LEED projects through the implementer, and these are highlighted in the proposed sample for easier reference.

Appendix C: 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	(Ft^2)	
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	

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

21.

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 T ype	*(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	

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

23.

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	*(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

	Number	Age (years)	Frequency of Use (hrs/wk)	EnergyStar? (In percent of total number of units)
45. Personal Computers				
46. Laptops				
47. Secondary Monitors				
48. Servers				
49. Combination printer/scanner/ copier/fax				
50. Printers				
51. Scanners				
52. Photocopiers				
53. Fax Machine				
54. Water coolers				
55. Battery Chargers				
56. Snack Machines				
57. Beverage Machines				
58. Residential Style Refrigerators				

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 _____________