2012 Energy Trust of Oregon Production Efficiency Impact Evaluation Report

January 25, 2018

Energy Trust of Oregon
421 SW Oak Street, Suite 300
Portland, OR 97204

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Prepared by:
Jeff Cropp
Jennifer Huckett
Cadmus: Energy Services Division

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Executive Summary

Energy Trust of Oregon retained Cadmus to complete an impact evaluation of the 2012 Production Efficiency (PE) program. This program provides technical services and incentives for agricultural and industrial energy efficiency measures in the following seven tracks:

- Custom Capital
- Custom Operations and Maintenance (O&M)
- Green Rewind
- Lighting
- Prescriptive
- Strategic Energy Management (SEM)
- Streamlined

The PE program is managed in-house by Energy Trust staff. For the 2012 program, six third-party Program Delivery Contractors (PDCs) provided program delivery. Four PDCs delivered savings from custom projects by serving customers in assigned geographic regions or target markets throughout the state and two PDCs delivered high volume, simpler prescriptive and calculated savings measures across Energy Trust's service territory through contractor channels.

For the impact evaluation of the 2012 program, Cadmus sampled 122 projects at 68 sites to provide a mix of measure types and to achieve 90/10 confidence and precision for the population of gas and electric savings claimed in 2012. The sample included the 12 largest savings projects, defined as those with total reported energy savings (electric and gas combined) greater than 5,000 MMBtus.[1] Cadmus divided the remaining projects into various strata, based on track and reported energy savings.

SEM projects were originally included in this impact evaluation, and were part of the sample that was drawn. A separate project sought to leverage the SEM projects sampled for this evaluation; in addition to evaluating the reported savings of the SEM projects selected for this impact evaluation, this separate project sought to evaluate the reported savings of an oversample of SEM projects, and included in-depth interviews with site contacts. The timeline for this project has lagged behind this impact evaluation. For this reason, this report does not cover the evaluation of SEM projects; evaluated savings will be reported in a separate report. The SEM projects reported additional savings of 36,738,204 kWh and 116,000 therms.

We randomly identified the remaining sample of projects from within those strata. As shown in Table 1, the final sample represented 49% of the total electric savings and 67% of the program's gas savings; it represented 52% of the program's total, reported, combined savings, excluding SEM projects.

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

Table 1. 2012 Program and Sample Total Quantities and Reported Savings

	Total Sites	Total Projects	Reported Savings		
			Electricity (kWh)	Gas (therms)	Combined Energy (MMBtu)
Program Total	716	946	91,787,279	721,118	385,290
Sample Total	68	122	44,550,746	480,007	200,008
Sample Portion of Total	9%	16%	49%	67%	52%

For the 2012 impact evaluation, Cadmus partnered with IRZ Consulting, a leading agricultural energy efficiency firm. The Cadmus and IRZ team evaluated the program through on-site measurement and verification (M&V), engineering calculations, and statistical regression models. During site visits, we observed the current status and operating parameters for energy efficiency measures receiving Energy Trust incentives. We measured or recorded operational characteristics to support our engineering analysis. The evaluation addressed lighting, prescriptive, and streamlined measures, primarily using industry-standard algorithms. Cadmus analyzed custom measures using algorithms, detailed calculation spreadsheet reviews, power metering, and/or energy management system (EMS) trend data.

In Table 2, we show reported and evaluated savings and the realization rate (RR),[2] the ratio of evaluated to reported savings, at the program and overall levels for electricity and gas for all tracks except SEM. Savings values listed in the impact evaluation represent gross values. Calculation of a net-to-gross ratio fell outside the scope of this evaluation.

Table 2. Overall 2012 Program RRs and Energy Savings for Electricity and Gas[3]

Track	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
Custom Capital	48,409,104	349,945	45,534,612	290,796	94%	83%
Custom O&M	4,354,464	97,878	3,085,324	77,568	71%	79%
Green Rewind	258,658	-	247,042	-	96%	N/A
Lighting	29,278,534	-	28,205,775	-	96%	N/A
Prescriptive	3,418,567	222,050	3,360,097	211,530	98%	95%
Streamlined	6,067,952	51,245	5,678,908	49,619	94%	97%
Total	**91,787,279**	**721,118**	**86,111,758**	**629,513**	**94%**	**87%**

2 The ratio of evaluated to reported savings.

3 Energy Trust excluded custom greenhouse measures from the 2012 impact evaluation population, as issues arose with evaluating these measures for the prior evaluation (2009–2011). The impact evaluation also excluded mega-projects from the evaluation population, as these projects are evaluated separately.

Table 3 shows the combined energy savings in MMBtus. The SEM projects reported an additional savings of 137,185 MMBtu.

Table 3. Combined 2012 Program RR and Energy Savings in MMBtu

Track	Reported Energy Savings (MMBtu)	Evaluated Energy Savings (MMBtu)	Realization Rate
Custom Capital	200,166	184,444	92%
Custom O&M	24,645	18,284	74%
Green Rewind	883	843	96%
Lighting	99,898	96,238	96%
Prescriptive	33,869	32,618	96%
Streamlined	25,828	24,338	94%
Total	**385,290**	**356,765**	**93%**

The program achieved high realization rates for most measure types and fuels. Cadmus found comparatively lower realization rates for both gas and electric Custom O&M track projects and for gas Custom Capital track projects. The following factors impacted the overall realization rate:

- Some participants determined that energy efficiency measures did not operate to their satisfaction, and removed the measure or adjusted the operational parameters that had allowed them to be more efficient. This reduced energy savings.
- Some facilities' production levels and operating hours declined from the original time of installation, particularly for wood products facilities. This had a mixed impact on project realization rates by increasing energy savings on some project but decreasing savings on others.
- In some cases, PDCs and Allied Technical Assistance Contractors did not adequately account for how measures would actually operate and overestimated energy savings.
- For some sites, the PDCs verified energy savings without collecting trend data, or they collected trend data for less than one week.
- Natural gas billing data for two sites indicated overestimation of prescriptive deemed measure savings. These sites installed prescriptive greenhouse and HVAC tune up measures.

Cadmus' other findings included the following:

- The program saved substantial energy, and the realization rates for the 2012 PE program were consistent with other custom and industrial programs Cadmus has evaluated.
- In 2013, Energy Trust transitioned to new custom PDCs and adjusted PDC service territories. In some cases, PDCs deleted all analysis files and data associated with facilities it no longer represented. Energy Trust did not retain a copy of those files and data, resulting in a loss of documentation used to estimate energy savings for custom projects. This presented difficulties

for Cadmus in examining baseline operating parameters and accurately evaluating program savings.

- The program provided incentives for high-efficiency data center server replacements, treating these as early replacement calculations. This allowed existing servers to be used as the baseline. In one case, the participant installed the new servers as part of their normal, four-year server refresh cycle, indicating they considered the existing servers to be at the end of their effective useful life. This implies that early replacement is not the most appropriate approach to calculate energy savings for this type of measure. Cadmus notes that server technology evolves at a rapid pace, and older servers quickly become obsolete.
- PDCs often proved extremely knowledgeable about the facilities with which they worked, and they were generally receptive to supporting evaluation efforts. Due to early recruitment and documentation issues, Cadmus often had to work directly with PDCs to contact facilities and acquire analysis files and data. We found most PDCs quickly provided any documentation they could access, supplied appropriate facility contacts, and went out of their way to assist with recruitment efforts.
- Energy Trust implementation staff maintained a thorough understanding of project details and participant sensibilities. Cadmus developed a large number of M&V plans for Energy Trust's staff review. Even though PDCs were more directly involved with project review and approval, senior Energy Trust program staff had a strong knowledge of project and analysis details and provided significant feedback on the M&V plans to improve M&V efforts.

Cadmus recommends the following opportunities for improving Energy Trust's Production Efficiency program:

- The program should maintain a repository for all workbooks, analysis models, and data used to estimate energy savings on completed projects. Establishing such a repository may enable Energy Trust to achieve more consistency in applying data for projects at a given site. In addition, this would improve the accuracy and efficiency of evaluation efforts.
- PDCs should consider collecting trend data, where available, for at least two weeks of retrofit energy efficiency measure operations, enabling better characterization of operating parameters.
- The program should consider re-examining deemed savings for some measures, particularly those associated with greenhouses and HVAC tune ups.
- Energy Trust should consider revising measure savings calculations for measures with rapid obsolescence (such as servers), from early replacement to replace on burnout.
- The program and the PDCs may want to explore additional options to encourage the persistence of energy efficiency measures, particularly those associated with operations and maintenance. Cadmus found that several Custom O&M track projects with large reported savings reverted back to baseline conditions well before the end of their expected measure life. PDCs may want to conduct greater scrutiny of how the measures would impact production prior to measure approval (to ensure a higher rate of persistence) or allow a trial period of operation prior to

approving incentives. Another option could involve regular PDC follow up on previously incented measures to engage participants in dialogue on measure benefits and on detrimental impacts to forestall a reversion to baseline conditions.

Energy Trust of Oregon

MEMO

Date: January 25, 2018
To: Board of Directors
From: Erika Kociolek, Evaluation Project Manager
Phil Degens, Evaluation Manager
Ray Hawksley, Sr. Technical Manager, Production Efficiency
Subject: Staff Response to 2012 Production Efficiency Impact Evaluation

The 2012 Production Efficiency impact evaluation, conducted by Cadmus, demonstrates that the program generated substantial energy savings, and accurately estimated the majority of these savings, as evidenced by relatively high realization rates. The evaluation identified minor opportunities for improvement in programs operations and estimation; many of the recommendations were focused on specific measures.

The evaluator did find that some PDCs deleted analysis files and data, which appeared to be related to changes to the custom PDCs and customers served by custom PDCs, which occurred in 2012 and 2013. Energy Trust typically does not require PDCs to deliver analysis and files and data for all projects; as a result, the evaluator recommended maintaining a repository for these materials, which the program will consider.

Although strategic energy management (SEM) projects were part of the sample drawn for this impact evaluation, a separate project sought to leverage the SEM projects sampled for the impact evaluation by combining them with additional SEM projects. The timeline for that project lagged behind this impact evaluation. As a result, the realization rates developed for this impact evaluation do not include SEM projects; we will report evaluated savings for SEM projects in a separate report.

For a variety of reasons, finalizing the results from this impact evaluation took some time. Ensuring faster delivery of evaluation results is important because it provides program staff with more useful and timely information that they can use to improve program delivery and allows measures with shorter lifetimes to be evaluated closer to the time they are installed or completed. Energy Trust evaluation staff are continuing to explore options for shortening the time between measure installation and completion and evaluation; one possibility is to evaluate measures with shorter lifetimes (such as operations and maintenance measures) and very large or complex projects outside of the program impact evaluations and through a separate and ongoing process, which is more similar to the evaluation process for mega-projects and the relatively new process for evaluating large New Buildings projects.

Introduction

Energy Trust of Oregon retained Cadmus to complete an impact evaluation of the 2012 Production Efficiency program, which achieves energy savings in the industrial and agricultural sectors through capital, behavioral, and operations and maintenance measures.

Production Efficiency Program

The Production Efficiency program provides incentives for agricultural and industrial energy efficiency measures using the following seven major categories:

- Custom Capital
- Customer O&M
- Green Rewind
- Lighting
- Prescriptive
- Strategic Energy Management (SEM)
- Streamlined

For the 2012 program year, the following six third-party Program Delivery Contractors (PDCs) oversaw program delivery for specific geographic regions or target markets throughout the state, or developed and delivered prescriptive and calculated savings measures through contractors:

- Cascade Energy - Custom
- Nexant - Custom
- Portland General Electric - Custom
- RHT - Custom
- Cascade Energy - Streamlined
- Evergreen Consulting Group - Lighting

Previous Impact Evaluation Results

A third-party evaluation contractor conducted an impact evaluation of the 2009-2011 Production Efficiency program. That evaluation calculated an unadjusted 94% RR for electric projects and an 89% RR for natural gas projects across those three program years. These realization rates were influenced, in part, to closed facilities and low realization rates for custom greenhouse HVAC measures.

The evaluation contractor for the 2009-2011 impact evaluation made the following recommendations to improve the program:

- Include detailed calculation spreadsheets with all project files.

- Work with participants in compressed air leak detection studies to ensure continued, efficient leak detection program implementation.
- O&M impacts should be evaluated soon after implementation, due to these measures' short expected measure life (three years).
- Use billing data to provide "reality checks" for modeled savings on greenhouses and HVAC upgrades.
- Improve variable frequency drive realization rates by avoiding motors that already run close to fully-loaded and take trend data on manually-operated equipment.
- Apply more appropriate energy savings percentages on lighting controls measures based on the specific space type.

The results of the 2009-2011 impact evaluation were not available until December 2013, so Cadmus found several of these issues still prevalent during the 2012 impact evaluation. In particular, Cadmus identified issues with a lack of detailed calculation files, O&M project persistence, and greenhouse and HVAC upgrade savings.

2012 Impact Evaluation

Cadmus' evaluation goals included the following:

- Develop reliable estimates of Production Efficiency program electric and gas savings and realization rates for the 2012 program year.
- Offer recommendations to help Energy Trust understand deviations from claimed savings.
- Provide information to refine *ex ante* savings estimates and to improve the effectiveness of future engineering studies and impact evaluations of industrial efficiency projects.

The Cadmus team also included a subcontractor, IRZ Consulting. IRZ is a leading agricultural energy efficiency consulting firm with strong familiarity with the irrigation measures implemented as part of the Production Efficiency program.

The 2012 Production Efficiency program tracking data included 2,691 records total, 973 unique project IDs, and 727 unique sites.[4] Energy Trust categorizes projects by track; Table 4 summarizes the types and total number of measures in each track.

[4] Energy Trust excluded custom greenhouse measures from the 2012 impact evaluation population, as issues arose with evaluating these measures for the prior evaluation (2009–2011). The impact evaluation also excluded mega-projects from the 2012 impact evaluation population, as these projects are evaluated separately.

Table 4. Population and Sample Sizes by Track

Track	Total Number of Measures	Measure Descriptions
Custom Capital	124	Custom Waste Water; Custom HVAC; Custom Irrigation; Custom Compressed Air; Custom Pumping; Custom Heat Recovery; Custom Refrigeration; Custom Primary Process; Custom Secondary Process; Custom Fan; Custom Air Abatement; Custom Fresh Water; Custom Hydraulics; Custom Welder; Custom Motors; Custom Gas Boiler
Custom O&M	24	Custom O&M
Green Rewind	88	15–2,000 horsepower (hp) Green Motor Rewind
Lighting	1,600	Prescriptive; Custom
Prescriptive	572	**Irrigation**: Gasket Replacement; Rotating Sprinkler for Impact; Pipe Repair; New or Rebuilt Brass Impact Sprinkler; Drain Replacement; Drop Tube or Hose Extension; Gooseneck Elbow; Multi-Configuration Nozzle; Low-Pressure Regulators; Flow Control Nozzle; Rotating Sprinkler for Low-Pressure; Impact Sprinkler Nozzle; Multi-Trajectory for Impact; Wheel Line Leveler; Custom **Greenhouse**: Thermal Curtains for Greenhouses; Greenhouse Controller; Infrared Poly for Greenhouses **Other**: Zero Loss Drain; High-Efficiency Condensing Boiler with Electronic Ignition RTU Tune Up DCV Control; VSD (5 hp controlled, 9 hp controlled, 7.5 hp controlled); Pipe Insulation; Wine Tank Insulation; Cycling Refrigerated Dryer; Heat Pump, Air-to-Air, 15 Ton; Insulation Roof Gas; Direct-Fired Radiant Heating; Wall Insulation (Electric Resistance); NCRAD, Radiant Heating, Modulating; Attic Insulation (Electric Resistance); Insulation Attic Gas. Custom HVAC; 30 hp Green Motor Rewind
SEM	27	Custom O&M; Kaizen Blitz
Streamlined	147	Custom Irrigation; Custom Compressed Air; Custom Refrigeration; Custom HVAC; Custom Welder; Custom Heat Recovery; Custom Hydraulics; Custom Secondary Process; Custom Pumping; Custom Primary Process; Scientific Irrigation Scheduling (per acre) Custom Fan

Table 5 shows the number of projects and first-year reported savings for each track in the 2012 program year. Custom measures represented 45% of the total reported energy savings, while lighting and prescriptive measures represented the largest portion of projects. The SEM projects, however, achieved the largest reported savings per project, at an average of 5,768 MMBtu per project. All of these factors weighed into the sampling considerations, as outlined in the following section.

Table 5. 2012 Total Projects and Reported Savings by Track

Track	Total Number of Projects	Reported Savings (kWh)	Reported Savings (therms)	Reported Savings (MMBtu)
Custom Capital	108	48,409,104	349,945	200,166
Custom O&M	20	4,354,464	97,878	24,645
Green Rewind	82	258,083	-	881
Lighting	315	29,278,534	-	99,898
Prescriptive	285	3,419,142	222,050	33,871
SEM	27	36,738,204	116,000	136,951
Streamlined	136	6,067,952	51,245	25,828
Total	**973**	**128,525,483**	**837,118**	**522,241**

Methodology

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

In the following sub-sections, we summarize the methodologies used for:

- Sampling
- Reviewing program documentation
- On-site measurement and verification
- Capital measure engineering analysis

Sampling

Cadmus developed a sample design to evaluate electric and gas energy savings resulting from Energy Trust's 2012 Production Efficiency program. The design used an iterative process, first summarizing the project population in terms of reported gas and electric savings within tracks[5] and according to different savings levels (high, medium, low). Energy Trust expressed particular interest in evaluating server upgrades, variable frequency drives (VFDs), wastewater treatment plants, and SEM.

Cadmus determined clear savings thresholds to define strata in terms of combined gas and electric savings levels.[6] Cadmus ultimately designed the sample to incorporate the following confidence/precision targets for verified program total savings estimates:

- Program total energy savings with 90/10 confidence/precision
- Program total electric savings with 90/10 confidence/precision
  - Track total electric savings with 90/20 confidence/precision (except for the Streamlined track)
- Program total gas savings with 90/10 confidence/precision

Based on these targets, Cadmus calculated sample sizes within each energy savings stratum (defined by MMBtu). We then reviewed the distribution of measures among the sampled projects to assess whether the confidence/precision targets would be met.

Finally, Cadmus calculated the sampling weights for projects in each stratum and used these to calculate RRs, estimated total savings, standard errors, and precision savings estimates—at the program level, the

5 Tracks included: Custom Capital, Custom O&M, Streamlined, Lighting, Green Motor Rewind, Prescriptive, and SEM.

6 High-savings projects (>5,000 MMBtu), medium-savings projects (<5,000 and >1,000 MMBtu), and low-savings projects (<1,000 MMBtu).

fuel type level, and within measure categories for electric savings. The remainder of this sub-section provides details on the sample design and analysis.

Population Characterization

Cadmus examined the population's total energy savings and variations in reported measure savings within each program track shown in Figure 1, Figure 2, and Figure 3. In the figures, boxplots display the interquartile range of reported electric or gas savings associated with measures in each track.

Table 6 (below) provides statistics of savings to accompany the figures (population total, mean, and standard deviation) within each program track.

Figure 1. Population Reported Electric (MWh) Savings by 2012 Program Track (Measure Level)

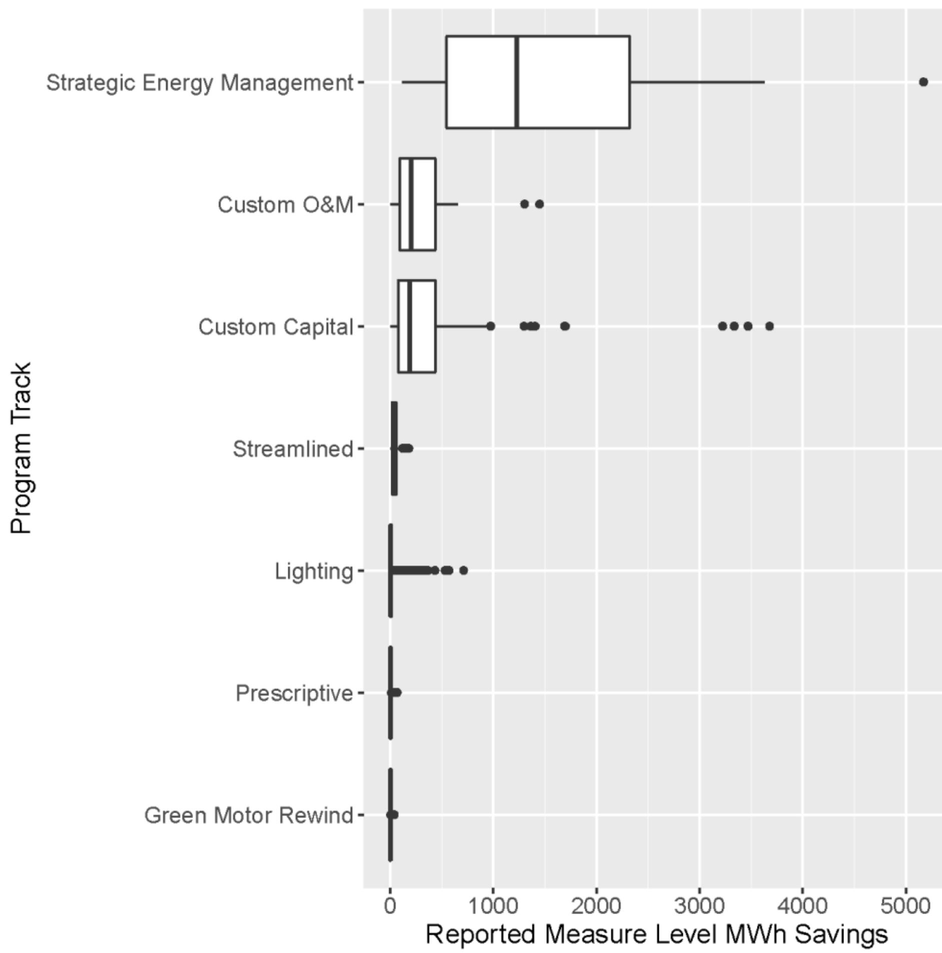


Figure 2. Population Reported Electric (MWh) Savings by 2012 Program Track (Except SEM) (Measure Level)

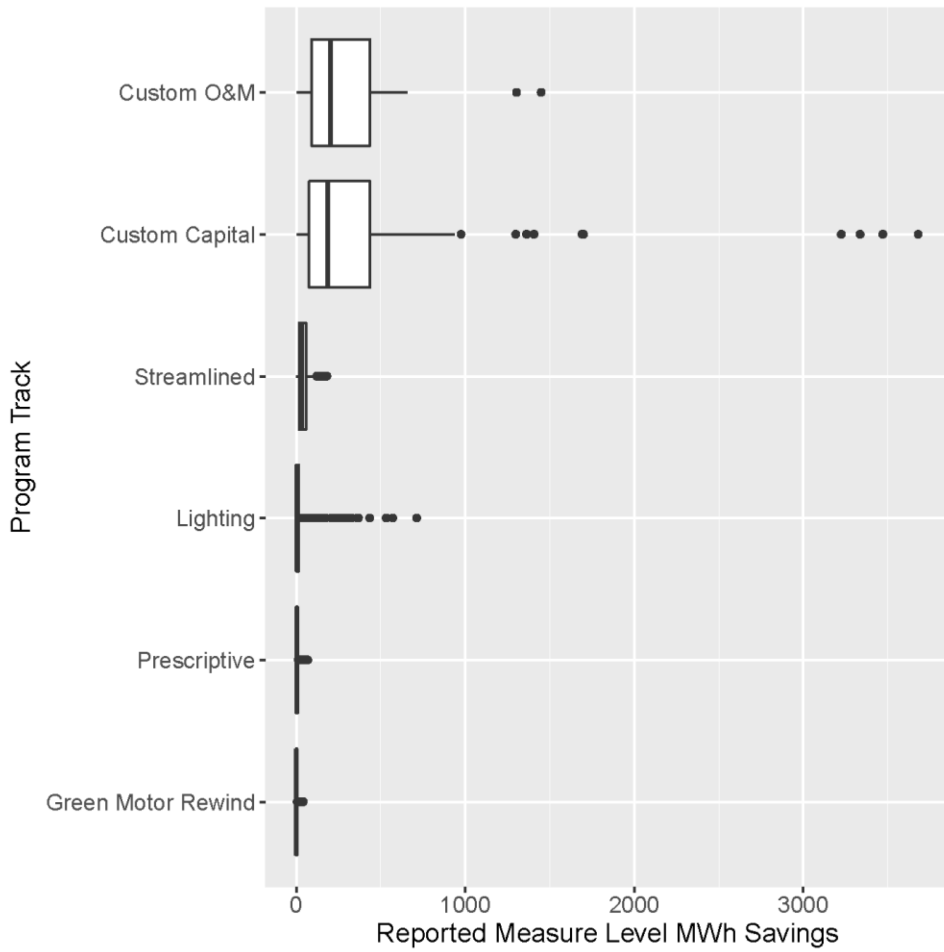


Figure 3. Population Reported Gas (Therms) Savings by 2012 Program Track (Measure Level)

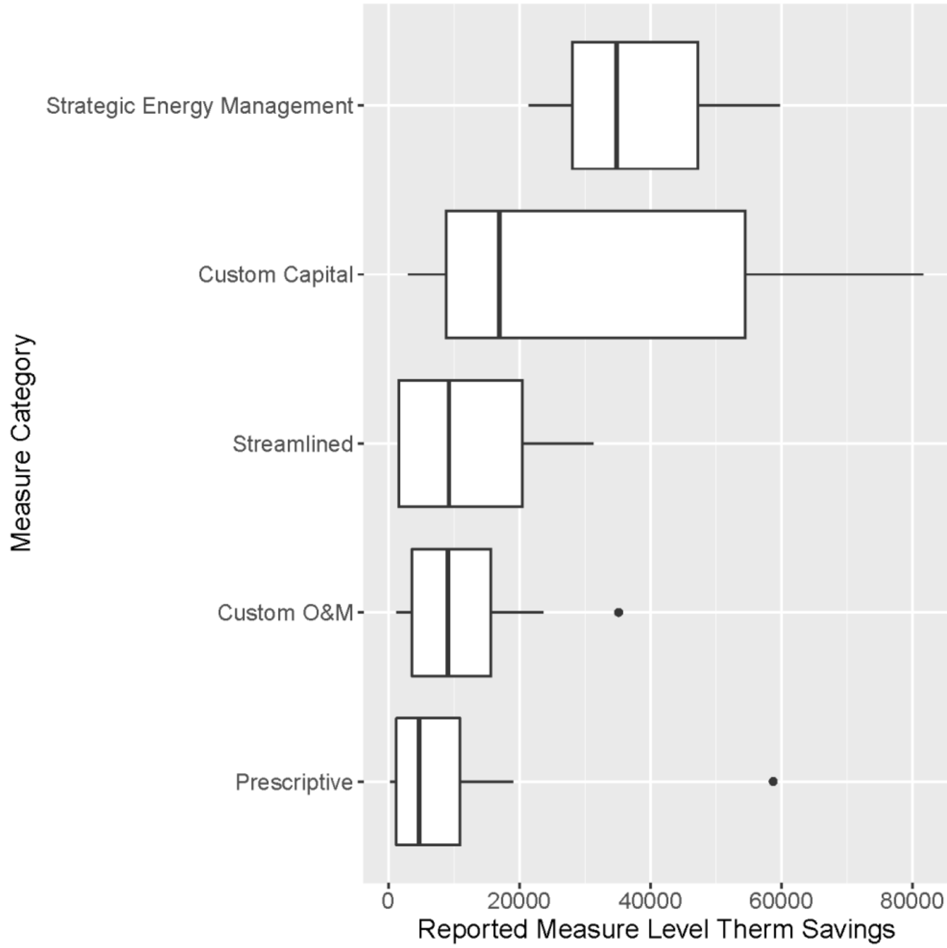


Table 6. Statistics on Reported Measure Level Energy Savings by Track

Track	Total MWh	Mean MWh	Standard Deviation MWh	Total therms	Mean therms	Standard Deviation therms
Custom Capital	48,409.10	390.40	666.51	349,945.00	2,822.14	12,169.01
Custom O&M	4,354.46	251.79	360.45	97,878.00	3,375.10	8,114.12
Green Motor Rewind	258.66	2.91	5.81	-	-	-
Lighting	29,278.53	17.48	48.06	-	-	-
Prescriptive	3,418.57	5.56	10.38	222,049.65	361.06	2,944.60
Streamlined	6,067.95	43.97	40.36	51,245.00	371.34	3,022.67
Strategic Energy Management	36,738.20	1,535.95	1,341.91	116,000.00	5,272.73	14,853.90

The figures indicated the Custom, SEM, and Lighting tracks included measures with the largest total savings. The Custom and SEM tracks also exhibited the highest variation in measure-level energy savings (i.e., longer boxplots indicate high variation and high standard deviation values), but the Lighting track exhibited relatively low variation, despite its large portion of program savings. Based on total savings and variation, Cadmus concluded that sampling a larger portion of projects from the Custom and SEM tracks would prove especially important in achieving program total confidence/precision targets.

Stratification and Sample Sizes

Cadmus summed electric and gas savings within each project to develop a sample frame based on unique projects. We assigned each project to one of three strata based on its total electric and gas savings, combined into MMBtu as follows:

- Large stratum: projects with reported savings greater than 5,000 MMBtu
- Medium stratum: projects with reported savings between 1,000 and 5,000 MMBtu
- Small stratum: projects with reported savings less than 1,000 MMBtu

In the large stratum population, Cadmus selected the census of projects to sample, using simple random sampling (SRS) within each of the medium and small strata to select projects for evaluation. To calculate sample sizes, Cadmus used a 0.5 coefficient of variation and a finite population correction to determine the number of projects required to achieve the targeted confidence/precision levels.

Due to the low variation in lighting projects and because Energy Trust's estimates of lighting savings have remained well understood and stable from year-to-year,[7] Cadmus omitted sites with lighting-only projects from the sample frames for the small and medium strata.

Many sample sites installing multiple measures included lighting projects. Thus, the final sample included 23 lighting projects, despite excluding lighting-only sites. Cadmus considered this an appropriate representation of lighting projects for the final savings estimation.

Table 7 provides the population sizes, sample sizes, and precision targets within each stratum.

Table 7. Population and Sample Sizes by Stratum

Stratum	Sampling Strategy	Stratum Upper Bound (MMBtu)	Population Size (Sites) (N)	Sample Size (Sites) (n)	Precision Target @ 90% Confidence
Large (All)	Census	25,000	24	24	0%
Medium (Excludes Lighting-Only Projects)	SRS	5,000	59	32	10%
Small (Excludes Lighting-Only Projects)	SRS	1,000	410	17	20%
Total	**–**	**–**	**493**	**73**	**10%**

[7] Based on discussions with Energy Trust staff during the impact evaluation kickoff meeting on May 15, 2014.

Review and Approval

Cadmus examined the sampled projects to ensure selecting a sufficient number for each measure category in the sample. Table 8 provides the number of measures in the population and sample, within each stratum and track. As shown, the sample includes all track in the large and medium strata, but only a subset of measures in the small stratum.

To determine whether the combined sample included a sufficient number of measures in each track and for each fuel, Cadmus estimated precision at the track level, as shown in Table 9. Energy Trust approved the resulting sample sizes and the projected precision levels within each track and fuel type.

Table 8. Population and Sample Sizes by Stratum, Track, and Fuel Type

Stratum	Track	Electric		Gas	
		Population Size (Measures)	Sample Size (Measures)	Population Size (Measures)	Sample Size (Measures)
Large	Custom Capital	37	37	6	6
Large	Custom O&M	4	4	1	1
Large	Green Motor Rewind	8	8	-	-
Large	Lighting	55	55	-	-
Large	Prescriptive	3	3	3	3
Large	SEM	12	12	1	1
Large	Streamlined	3	3	-	-
Medium	Custom Capital	45	23	4	2
Medium	Custom O&M	13	4	4	2
Medium	Green Motor Rewind	12	9	-	-
Medium	Lighting	325	66	-	-
Medium	Prescriptive	5	1	6	4
Medium	SEM	9	5	2	2
Medium	Streamlined	3	2	2	-
Small	Custom Capital	34	-	1	-
Small	Custom O&M	6	-	3	-
Small	Green Motor Rewind	69	-	-	-
Small	Lighting	1,286	-	-	-
Small	Prescriptive	588	35	18	-
Small	SEM	-	-	-	-
Small	Streamlined	129	6	2	1
Total		**2,646**	**273**	**53**	**22**

Table 9. Population and Sample Sizes by Track and Fuel Type

Track	Electric			Gas		
	Population Size (Measures)	Sample Size (Measures)	Projected Precision @ 90% Confidence	Population Size (Measures)	Sample Size (Measures)	Projected Precision @ 90% Confidence
Custom Capital	116	60	5%	11	8	8%
Custom O&M	23	8	19%	8	3	30%
Green Motor Rewind	89	17	16%	-	-	N/A
Lighting	1,666	121	7%	-	-	N/A
Prescriptive	596	39	12%	27	7	23%
SEM	21	17	4%	3	3	0%
Streamlined	135	11	23%	4	1	62%
Total	**2,646**	**273**	**4%**	**53**	**22**	**10%**

Cadmus originally included SEM projects in this impact evaluation, and, as described above, they were part of the drawn sample. A separate project sought to leverage the SEM projects sampled for this evaluation; in addition to evaluating the reported savings of the SEM projects selected for this impact evaluation, the separate project sought to evaluate the reported savings of an oversample of SEM projects, and included in-depth interviews with site contacts. The timeline for that project has lagged behind this impact evaluation. As a result, this report does not cover the evaluation of SEM projects; we will report evaluated savings in a separate report.

Review Program Documentation

Cadmus reviewed the available documentation (e.g., verification reports and analysis workbooks) for the sample sites, paying particular attention to the calculation procedures and documentation for savings estimates.

Acquiring Data and Analysis Files

To the extent possible, Cadmus reviewed analyses originally used to calculate reported savings and operating parameters. For capital measures, Energy Trust only retained select documentation for each project. Documents most relevant to the evaluation effort typically included scoping reports or technical assistance studies (TAS), final verification reports, application workbooks, and prescriptive measure application forms. Cadmus required additional files—usually analysis workbooks or raw data files from metering or energy management system (EMS) trends—to update the calculations using on-site measurement and verification (M&V) findings and current operating conditions.

In many cases (though not all), the PDCs maintained a repository of calculation files and data associated with TAS studies and final verification. In 2013, Energy Trust removed one PDC (Cascade Energy) and added a new one (Energy 350). In the process, Energy Trust revised the geographic areas served by each PDC.

Due to these changes, PDCs no longer represented facilities with previously approved projects. In some cases, PDCs deleted all files associated with facilities that the PDC no longer represented. Energy Trust did not obtain these files from the PDCs before they were deleted. Consequently, the PDCs deleted analysis files and raw data for a large portion (41%) of sampled projects in the Custom track, including all Cascade Energy files.

After learning this, Cadmus identified whether projects with deleted files had been analyzed originally by an Allied Technical Assistance Contractor (ATAC) through a TAS. Wherever possible, we reached out to these ATACs to determine if they would provide the original calculations and data used to report energy savings. Energy Trust, however, also had revised its ATAC structure, and most ATACs contacted by Cadmus no longer participated in the program. Still, some ATACs remained receptive to the request and provided files, while others claimed too much time had passed and they would be unable to find the files.

In many other instances, the PDC had acted as the analysis contractor. The relevant project files and data at those sites had been permanently deleted and could not be recovered. To the extent possible, Cadmus attempted to recreate the original calculations and data using any available reports. In total, we could not acquire analysis files and/or data on 13 of 61 Custom track projects in the final sample.

Review Process

The evaluation began by reviewing relevant documentation and other program materials from Energy Trust, the PDCs, and ATACs. Cadmus reviewed information for all sample sites, including program application forms, the tracking database extract, and project reports for each rebated measure (if applicable). The review examined each project file for the following information:

- Documentation on equipment installed or O&M measures performed, including:
    - Descriptions
    - Schematics
    - Performance data
    - Other supporting information
- Information about savings calculation methodologies, including:
    - Methodologies used
    - Assumption on specifications and the sources for these specifications

Cadmus then developed M&V plans for each facility, based on information gleaned from the available documentation. The M&V plan included the following information:

- Status of evaluation and open issues to resolve
- Project summary
- Previous SEM participation
- Review of program documentation and reported savings
- Measurement and verification methodology

Cadmus provided each completed M&V plan to Energy Trust for staff review. Given Energy Trust staff's deep familiarity with the various projects and facilities, they could provide additional guidance regarding M&V methods most viable (or allowable) at the facilities. If necessary, we updated the M&V plans based on this feedback.

On-Site Measurement and Verification

Cadmus conducted on-site M&V to verify energy efficiency measure implementation and to determine changes to operating parameters since measure implementation. Where possible, we obtained trend data from EMS, including energy demand, air flow, or temperature details. Certain cases required installing power meters to log data on equipment energy consumption.

Recruitment and Sample Attrition

The Cadmus-developed sample included 73 sites, which we provided for Energy Trust's review. Energy Trust then requested that the PDCs provide contact information for the most relevant facility staff at each site within their geographic service areas. The PDCs also sent e-mail notifications to facility contacts (assuming contact information was available) to notify them of the evaluation effort.

Cadmus identified a few projects that were unresponsive to our contact attempts. We notified Energy Trust of the issue and requested additional assistance from PDCs. We noted that the PDC staff often visited these facilities, worked closely with the participants, and established close working relationships with them. As such, the PDC staff were in the best position to provide updated or revised contact information for the facility contacts. The PDCs also reached out with e-mails and phone calls to encourage their contacts to participate in the evaluation. Some PDCs and participants noted, however, that they had not yet established strong relationships due to the recent adjustments to PDC service territory, PDC staffing turnover, and participant staff turnover.

Site ETPE201211, a refrigerated warehouse with custom measures, had transferred ownership. The new owner remained in the process of renovating the facility, but planned to continue using it as a refrigerated warehouse. We removed the site from the sample as we could not verify whether the energy efficiency measures would still operate in the new facility.

Cadmus was unable to recruit site ETPE201273. In 2012, this site received incentives for two capital measures. However, the facility subsequently revised operations, with some portions of the plant shut down and others operated by a different company. Cadmus attempted to verify whether the two capital measures were still installed and operational. We learned all of the original staff involved with the capital projects had left the facility. The facility's 2012 PDC had been Cascade Energy. The Cascade staff deleted all analysis files on the projects after leaving the program. The facility's new site personnel met with the new PDC, and the PDC attempted to arrange an evaluation site visit. However, the site contacts reportedly claimed to be too busy with equipment shutdowns. Cadmus made repeated attempts to reach the site contacts by phone and email without success. We ultimately determined we could not evaluate the site and removed it from the sample.

Cadmus eventually recruited all but two sites, for a final total of 66 of the 68 sampled sites being evaluated. While the recruitment effort proved ultimately successful, it took longer than projected due to lack of participant response to contact attempts.

Data Collection

Cadmus developed site-specific data collection forms for each project, given the wide variance in measures and applications. Field staff used streamlined versions of the form for certain types of Prescriptive and Streamlined track projects, particularly those focused on irrigation measures.

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

- **Verifying implementation of all measures for which participants received incentives:** To the extent possible, field engineers verified that energy efficiency measures had been correctly implemented, remained in operation, and functioned properly. They conducted spot measurements, collected EMS trend data, installed power meters, or made visual inspections, as appropriate. Field engineers also verified operating parameters for equipment associated with each energy efficiency measure.
- **Collecting the physical data required to analyze energy savings realized from installed measures:** Field engineers determined pertinent data for collection from each site, based on M&V plans developed from in-depth reviews of project files.
- **Conducting interviews with the facility operations staff:** Field staff confirmed the project documentation's accuracy and obtained additional data on operating characteristics for installed systems. Cadmus and Energy Trust developed a brief on-site interview guide (included in Appendix B) that focused on the following key areas:
    - Changes in operating hours/schedules since project completion
    - Changes in production levels since project completion
    - Operational changes that might impact energy consumption of measures or facilities
    - Qualitative feedback on equipment performance
    - Additional benefits from new equipment

During several site visits, Cadmus field engineers noted equipment counts differed from those which received incentives. When finding fewer measures in place, we reduced the RRs accordingly.

Capital Measure Engineering Analysis

Site visit, metering, and trend data informed savings impact calculations. Individual measure savings, aggregated into sampling strata and tracks, allowed calculations of track-level RRs (the ratio of evaluated to reported savings). Cadmus applied these rates to program-level reported savings associated with the respective strata and tracks, and summed total adjusted savings to determine the overall, program-level, energy savings RR. Site visit data and analysis provided information enabling development of recommendations for future studies.

Procedures used to verify savings for capital measures (and more straightforward O&M projects) through engineering analysis depended on the track chosen. The following sections describe the focus of site visits and the procedures Cadmus used to verify savings from the different program tracks. For the 2012 impact evaluation, we focused analysis resources on complex custom projects, which constituted the largest portion of the program and sample energy savings.

Custom Capital

Custom capital projects represented the most complex projects (and those reported the greatest energy savings). These included a range of measures, from regenerative thermal oxidizers (RTOs) to industrial refrigeration system upgrades. As a prescriptive methodology proved inappropriate for these measures, Cadmus relied heavily on calculation spreadsheets developed by contractors, participants, and the PDCs.

For each project, Cadmus performed a site visit to verify correct installations of incented equipment and to confirm quantities and operating characteristics. In many cases, we also obtained EMS trend data on critical operational parameters or installed power metering equipment. This allowed us to determine if the initial analysis approach proved reasonable, and, if necessary, to apply a revised calculation approach. For projects providing analysis workbooks, Cadmus adjusted calculations to update operating parameters, then confirmed through site visits and interviews with facility operations staff.

Custom Operations and Maintenance

Custom O&M projects represented adjustments to control settings and equipment operating parameters that could be very sensitive to facility changes. The types of O&M projects implemented through the Production Efficiency program lent themselves to calculation spreadsheets developed by the PDCs and contractors, or through on-line software.

As with the Custom Capital track projects, Cadmus performed site visits to verify whether the proposed O&M measures remained in operation. We also interviewed facility operators and reviewed trend data to obtain the current operating parameters for each measure. We updated the calculation workbooks for projects for which those were available.

Green Rewind

For Green Rewind projects, Cadmus field engineers verified the reported quantity and horsepower of incented motors. If a project’s quantity and horsepower matched, we accepted its reported savings.

Lighting

The evaluation's analysis included two types of lighting projects:

- Installation of high-efficiency lamps, ballasts, and/or fixtures, expected to reduce lighting power densities. These measure types reduced demand and energy consumption without affecting operation hours between baseline and as-built conditions. The program incented these measures on a measure-by-measure basis rather than on a whole-building level.
- Lighting control strategies, including occupancy sensors, daylight dimming controls, and automated lighting control systems. These measure types typically involved operation-hour reductions to more closely match building occupancy.

Analyzing lighting measure savings required documentation regarding fixture wattages, quantities, and operation hours. Cadmus also verified space types and areas for lighting power density calculations. We also verified energy-efficient replacement input wattages using several sources, including the manufacturer industry lamp and ballast product catalogs. The investigation further evaluated operation hours for each site, based on activities of buildings' occupants within the relevant spaces.

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

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

Prescriptive

Prior evaluations already examined the veracity of prescriptive measures savings. For most sites with prescriptive measures, Cadmus and IRZ focused on equipment counts, verifying that units met the program's specifications and still operated as intended. The verification methodology particularly was used for irrigation measures, such as sprinklers and wheel line levelers.

For prescriptive measures with large natural gas savings, such as infrared polyethylene for greenhouses and pipe insulation, we attempted to quantify heating loads through utility billing data. In some cases, the billing data analysis provided a relatively efficient method to determine if the deemed savings adequately represented actual savings. Typically, this was not possible for the electric prescriptive measures. These had relatively small energy savings in comparison to annual electricity consumption, and impacts could not be ascertained through a billing analysis.

Streamlined

The streamlined measures often relied on standardized calculation methods, such as the NW Regional Compressed Air Savings Calculator[8] for compressed air systems under 75 hp (as shown in Figure 4). For each project, Cadmus performed site visits and interviews with facility operations staff to verify correct installations of incented equipment and to confirm quantities and operating characteristics. This allowed us to revise the initial analysis approach, if necessary.

Figure 4. NW Regional Compressed Air Savings Calculator Example

	Baseline Compressor		Proposed Upgrade Compressor	
Type of compressor:	Screw		Screw	
Type of part load control:	Inlet Modulation		VFD	
If unloading control, unloaded sump pressure:	Not Applicable		Not Applicable	
Compressor hp:	25	hp	25	hp
Rated flow:	96	acfm	98	acfm
Plant elevation:	50	ft		
Corrected compressor flow (calculated):	97	scfm	99	scfm
If known, compressor shaft bhp:		bhp		bhp
Performance check (calculated):	4.38	acfm/kW	4.47	acfm/kW
Pressure at rated flow:	100	psig	100	psig
Receiver volume:	120		120	gallons
Equipment cost (including optional measure costs):			$ 21,982	
Installation cost, shipping, etc.			$ 1,500	
Estimated annual reduction (increase) in operating or maintenance cost:				$/yr
Estimated annual value of project's non-energy benefits:				$/yr
Cooling fan motor hp:	2	hp	2	hp

INFORMATION ABOUT THE SYSTEM AND ITS OPERATION

Current average operating pressure:	100	psig
Average operating pressure after upgrade:	100	psig
Annual Hours of Operation:	8,712	hours/yr

Profile of Baseline Compressed Air Demand

% time	% flow	hrs/yr	scfm
20%	90%	1,742	88
30%	70%	2,614	68
50%	60%	4,356	58
		0	0
	timed out	0	0
100%		8,712	

Baseline Energy Use

% Load	kW	kWh/yr
90%	21.2	36,967
70%	19.8	51,785
60%	19.1	83,253
0%	14.9	0
0%	0.0	0
	Total:	172,005

Upgrade Energy Use

% Load	kW	kWh/yr
88%	19.9	34,679
69%	15.5	40,459
59%	13.3	57,799
0%	3.3	0
0%	0.0	0
	Total:	132,937

8 https://www.bpa.gov/ee/sectors/agriculture/documents/nw_regional_compressed_air_tool_v2-8_cbv.xls

Analysis and Findings

This section presents the following:

- Engineering analysis results, as applied to the sample;
- Adjustments to reported values;
- Calculation of RRs; and
- Savings estimation for the full 2012 program population, based on sample RRs.

The section also includes general observations regarding discrepancies and other factors influencing measure-level RRs. Cadmus assigned site IDs to each facility to maintain participant anonymity.

Capital Measure Sample Evaluation Savings

Cadmus compared reported and evaluated energy savings values through measure-level RRs, as shown in Table 10. These realization rates are for sample projects only, and do not represent the final population-level realization rates. The evaluated sample produced a 91% electric RR, with an 84% natural gas RR. We adjusted electricity and gas savings based on measure-specific reasons, described in the sections that follow.

Table 10. Sample Reported and Evaluated Savings and RRs

Track	Total Sample Projects	Reported Savings		Evaluated Savings		Realization Rate	
		Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
Custom Capital	52	36,605,092	289,603	34,232,983	228,253	94%	79%
Custom O&M	8	2,609,121	50,758	1,339,981	42,079	51%	83%
Green Rewind	12	117,325	-	112,056	-	96%	N/A
Lighting	17	4,009,349	-	3,893,177	-	97%	N/A
Prescriptive	20	478,436	138,020	429,733	130,734	90%	95%
Streamlined	13	731,423	1,626	684,446	-	94%	0%
Total	**122**	**44,550,746**	**480,007**	**40,692,376**	**401,066**	**91%**	**84%**

Custom Capital

Custom capital projects represented a "catch all" subcategory of nonprescriptive measures with gas and electricity savings, such as high-efficiency compressed air installations, industrial refrigeration measures, and data center server upgrades. Custom capital projects had a 94% energy savings RR.

Cadmus evaluated savings for the Custom Capital track by reviewing available data and calculation spreadsheets, supported by on-site verification, power metering, EMS trend data, and utility billing data. As noted, for 13 projects we could not access original calculation workbooks and models, hence we attempted to reproduce the appropriate calculation methodology to the extent possible within time and budget constraints.

Cadmus compared inputs and methodologies with available data to confirm methodologies and results, or with adjusted values, as necessary. In most cases, we found the methodology and reported savings values reasonable, although slight adjustments were required occasionally.

Custom capital projects included a variety of sub-categories based on the following measure types:

- Air Abatement
- Compressed Air
- Fan
- Heat Recovery
- HVAC
- Irrigation
- Motors
- Primary Process
- Secondary Process
- Pumping
- Refrigeration
- Waste Water

The findings cover specific analysis methods appropriate to each custom category. Cadmus applied the most significant adjustments to projects in the custom air abatement, pumping, secondary process, and wastewater categories.

Custom Air Abatement

Custom air abatement measures remove unwanted particles from the air, including volatile organic compounds and dust in wood products manufacturing facilities. Cadmus evaluated three projects that installed these measures and generally found lower RRs for differing reasons.

The post-installation metering data on dust collection fans showed lower-than-reported fan operating hours at facility ETPE201217. That facility also included an incorrect assumption regarding heating requirements (and resulting gas savings): the facility assumed indoor heating would be required up to an outside air temperature of 68°F. Based on Cadmus' experience, one more appropriately assumes heating needed above 55°F when considering waste heat impacts from production machinery and occupancy.

An RTO retrofitting project at ETPE201204 appeared to apply incorrect assumptions to baseline calculations. Cadmus did not have access to actual calculation workbooks, but the baseline analysis relied on an assumed gas balance of the facility's total gas consumption minus estimates of the facility's boiler gas consumption. These assumptions also relied on calculated equipment efficiencies using the RTO's actual operating parameters. We did not consider the baseline methodology a reasonable representation of system performance; hence we developed a modified calculation that applied the RTO's verified operating parameters from both the baseline and evaluation site visits. This resulted in lower natural gas savings.

The third custom air abatement project experienced the largest reduction in energy savings. The facility installed a new dust collection system that should have dramatically reduced motor consumption on three silos. Cadmus' on-site verification determined that the facility reverted back to the baseline system for two of the three silos. This reduced the evaluated energy savings to 14% of the reported value.

Overall, custom air abatement measures achieved a 75% RR of reported MMBtu savings. Table 11 shows the reported and evaluated savings for each custom air abatement project in the sample.

Table 11. Custom Air Abatement Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
ETPE201204	0	68,388	0	52,038	N/A	76%
ETPE201217	905,556	81,692	808,549	70,607	89%	86%
ETPE201224	698,568	0	95,597	0	14%	N/A
Total Custom Air Abatement	1,604,124	150,080	904,146	122,645	56%	82%

Custom Compressed Air

Cadmus evaluated custom compressed air measures at five facilities, which included new systems and updated control strategies on existing systems. We found several sources of variance for these systems, based on a review of more recent data and further examination of the original calculation methods.

The largest compressed air project at ETPE201235 retrofitted a centrifugal air compressor to improve its efficiency. Cadmus found an error in the verification report's baseline calculations, which overstated energy savings by 50,960 kWh. This error, however, did not appear in the verification calculation file, and it remains unclear how the erroneous value appeared in the final verification report or tracking database. Cadmus also received one year of recent trend data on the compressor's performance. These data indicated the system operated at higher amperage and voltage levels than those obtained during the verification period. This resulted in a slight decrease in energy savings.

Facility ETPE201209 installed new compressors, new dryers, and zero-loss drains as part of a comprehensive compressed air system upgrade. Cadmus obtained compressor performance data from the facility: these confirmed that the average air flow (in cubic feet per minute) dropped significantly during the retrofit period. In turn, this required less compressor power, as shown in Figure 5 and Figure 6. The original calculations incorrectly assumed the baseline dryer would purge air at 15% of the dryer's capacity. Cadmus verified that the dryers would purge at 15% of air compressor flow, which reduced the air flow and power requirements. We also updated the purge requirements for the new dryer. These analysis revisions resulted in electricity savings at 92% of the reported value.

Figure 5. ET2012PE09 Pre-Installation Compressor Operation

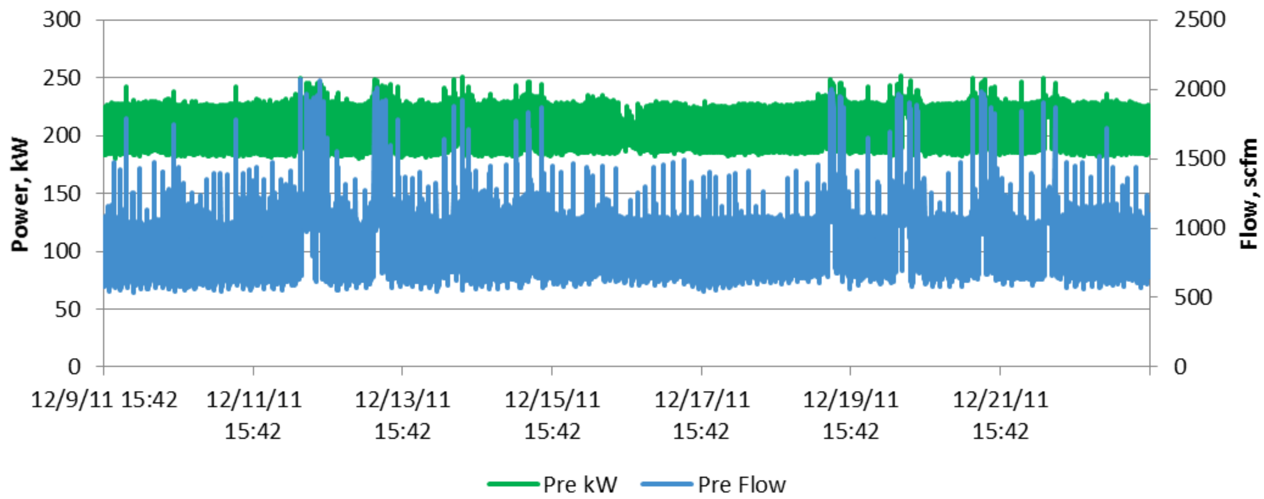
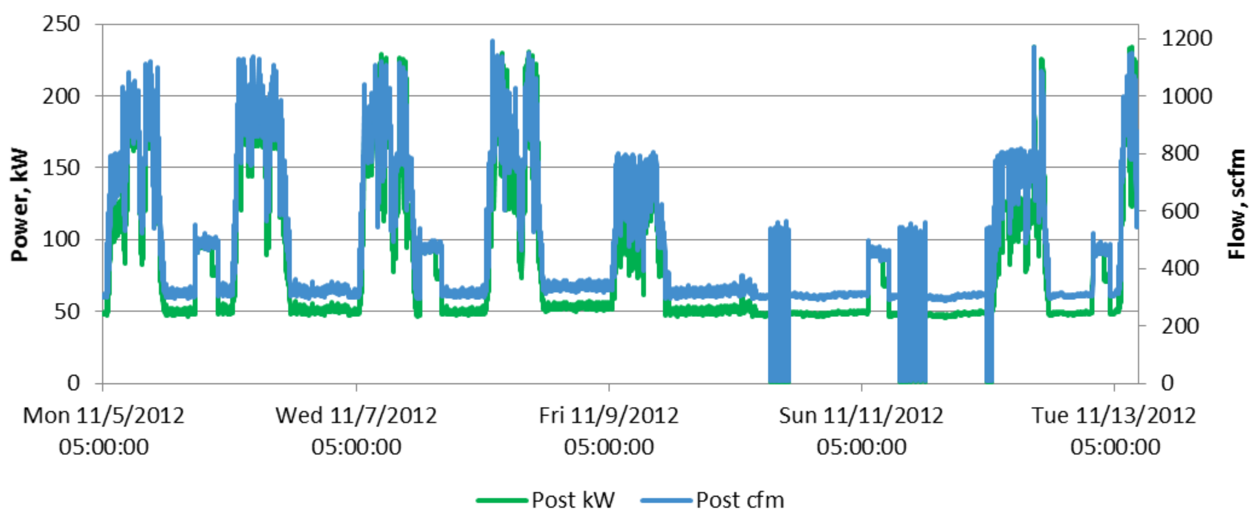


Figure 6. ETPE201209 Post-Installation Compressor Operation



Cadmus determined the remaining custom compressed air projects produced higher or the same energy savings. More recent EMS data indicated significant increases in savings over reported values for a controls upgrade at ETPE201250 (131% RR) and a new compressed air system at ETPE201218 (111% RR). For the final site, the facility contact did not provide revised compressed air system performance data to update the original calculations. Cadmus reviewed the methodology and data used to report original savings estimates and found them reasonable.

Altogether, these custom compressed air projects achieved a 98% RR. Table 12 shows the reported and evaluated savings for each custom compressed air project in the sample.

Table 12. Custom Compressed Air Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings	Evaluated Savings	Realization Rate
	Electricity (kWh)	Electricity (kWh)	Electricity Savings
ETPE201209	1,111,941	1,024,181	92%
ETPE201218	340,708	379,393	111%
ETPE201235	3,681,240	3,486,378	95%
ETPE201250	361,667	472,147	131%
ETPE201256	177,098	177,098	100%
Total Custom Compressed Air	5,672,654	5,539,198	98%

Custom Fan

Cadmus evaluated four custom fan projects on make-up air units and industrial process ventilation fans, three of which relied on VFDs for energy savings. We recalculated the energy savings based on EMS trend data and on-site verification data for these projects. These produced evaluated savings close to the reported values for two of the projects.

For two measures at site ETPE201256, the data showed much wider variance due to much lower production hours than expected. One fan VFD allowed a constantly-running fan to operate on a lower idle setting most of the time, resulting in much larger-than-expected savings. Another fan operated only eight hours per week. Cadmus adjusted the baseline and retrofit consumption calculations accordingly, which reduced energy savings. The overall impact of reduced production hours for both measures at this site reduced energy savings.

Cadmus obtained trend data on the remaining VFD project at ETPE201255. These showed the fan operated at a lower average speed than reported, reducing retrofit energy consumption and resulting in larger overall savings.

Overall, the custom fan projects achieved an energy savings 99% RR of reported MMBtu savings. Table 13 shows the reported and evaluated savings for each custom fan project in the sample.

Table 13. Custom Fan Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
ETPE201206	1,693,992	0	1,628,691	0	96%	N/A
ETPE201255	102,707	0	236,308	0	230%	N/A
ETPE201256 #1	188,441	6,085	242,426	6,862	129%	113%

ETPE201256 #2	185,576	0	12,623	0	7%	N/A
ETPE201268	243,600	0	245,146	0	101%	N/A
Total Custom Fan	2,414,316	6,085	2,365,194	6,862	98%	113%

Custom Heat Recovery

Three sample projects produced estimated savings based on heat recovery methods derived from other processes. Cadmus revised the calculations based on available data to evaluate energy savings, generally finding higher savings than reported.

ETPE201206 replaced their existing compressed air dryer with a heat of compression dryer to reduce electricity consumption. The TAS and verification calculations assumed the baseline dryer purged air at 15% of the instantaneous flow rate. However, the dryer vendor confirmed the baseline purge rate should have been 15% of the dryer's rated capacity at all times. Energy savings increased when Cadmus corrected the calculations.

ETPE201209 installed heat recovery ducting for all air compressors, incented as part of a project described in the custom air compressors subsection. For that project, Cadmus revised the air flow requirements upward as part of normalizing baseline and retrofit consumption. The increased consumption increased heat produced by the air compressor and (consequently) heat available to reduce gas consumption as part of this particular measure. Therefore, natural gas savings for this project increased.

ETPE201254 installed a heat exchanger to recover waste heat from a wood-drying kiln. EMS trend data from the verification period showed that the kiln operated approximately 6,100 hours per year, although the reported energy savings relied on 6,400 hours of operation per year. Cadmus' on-site verification indicated the kiln operated at a higher run-time due to increased sales and customer specifications for dryer products. The participant did not track the amount of product heat treated per year; so we could not accurately revise the energy-savings calculations. Given the increase in sales and consumption, the originally reported 6,400 hours per year likely proved appropriate (if not conservative). Therefore, Cadmus accepted the reported energy savings.

Together, the custom heat recovery projects achieved a 104% RR of reported MMBtu savings. Table 14 shows the reported and evaluated savings for each custom heat recovery project in the sample.

Table 14. Custom Heat Recovery Measure Reported and Evaluated Energy Savings

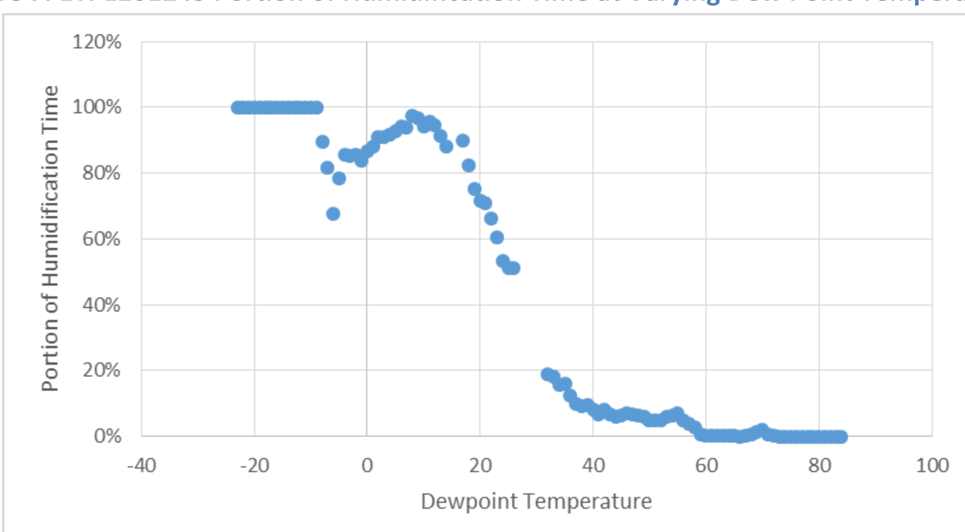
Cadmus Site ID	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
ETPE201206	307,895	0	355,263	0	115%	N/A
ETPE201209	0	11,414	0	13,168	N/A	115%
ETPE201254	0	53,313	0	53,313	N/A	100%

Total Custom Heat Recovery	307,895	64,727	355,263	66,481	115%	103%

Custom HVAC

The custom HVAC projects involved various space conditioning upgrades, with Cadmus evaluating three projects. ETPE201243 replaced an electric boiler used with an adiabatic humidification process. This process humidified the air through a pump and eliminated the need for the electric boiler. The TAS contractor provided us with calculation files used to develop the original analysis, based on assumptions for humidification requirements at different ambient dew point temperatures. These assumed the system would provide humidification at dew point temperatures below 45°F. The participant provided one year of one-minute interval data derived from an EMS system; these included the outside air temperature, humidity, and pump operation. Based on these data, we developed the profile of actual humidification requirements, as shown in Figure 7. This indicated the humidification system did not always operate at dew point temperatures below 45°F, and the system sometimes operated at higher temperatures. Trend data enabled us to better quantify the amount of humidification required on an annual basis and to better characterize the energy consumption reduction from eliminating the electric boiler. The resulting value equaled 87% of reported energy savings.

Figure 7. ETPE201243 Portion of Humidification Time at Varying Dew Point Temperatures



The other two projects involved controls upgrades, although one project added a VFD to a 40-ton air conditioning unit. Based on the scope of both projects (primarily adjustments to controls), Cadmus suggests they may be more appropriately categorized as Custom O&M track projects rather than Custom Capital track projects.

For one project at ETPE201205, Cadmus' on-site verification identified a number of differences with reported occupancy schedules and temperature set points that resulted in lower electricity savings and higher natural gas savings. The participant at the remaining project provided EMS trend data that verified the reported system performance. We accepted the reported savings value for that project.

Overall, the custom HVAC projects achieved slightly lower energy savings, with a 90% RR of reported MMBtu savings. Table 15 shows the reported and evaluated savings for each custom HVAC project in the sample.

Table 15. Custom HVAC Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
ETPE201201	231,380	3,001	171,003	3,820	74%	127%
ETPE201205	244,152	0	244,152	0	100%	N/A
ETPE201243	576,243	0	499,470	0	87%	N/A
Total Custom HVAC	1,051,775	3,001	914,625	3,820	87%	127%

Custom Irrigation

Cadmus evaluated two custom irrigation projects. Facility ETPE201263 implemented pump upgrades, reporting 3,472,001 kWh in electricity savings—the second-largest for non-SEM projects in the 2012 program year. We conducted on-site verification for this project and attempted to acquire additional data from the facility's extensive data trending system. The facility contacts, however, did not prove receptive to working with Cadmus due to concerns regarding Energy Trust incentive payment issues on a previous project. As such, we could not acquire additional data after 2012 with which to evaluate the energy savings.

We found the PDC's methodology insufficiently rigorous for calculating energy savings. The PDC compared pre- and post-installation electricity consumption and pumpage in acre-feet of water per month. Post-installation data from 2012 indicated much higher water consumption rates at much lower electricity consumption rates. The PDC reported energy savings as the difference between 2011 and 2012 utility billing data consumption.

Cadmus noted variances in water and electricity consumption did not justify the PDC's calculation methodology. We developed regressions between pre- and post-installation water and electricity consumption that produced a strong correlation, as shown in Figure 8 and Figure 9. We have successfully applied this methodology in other impact evaluations on projects for which the facility's predominant function involves pumping water (e.g., irrigation and municipal water pumping stations).

Figure 8. ETPE201263 Baseline Water and Electricity Consumption

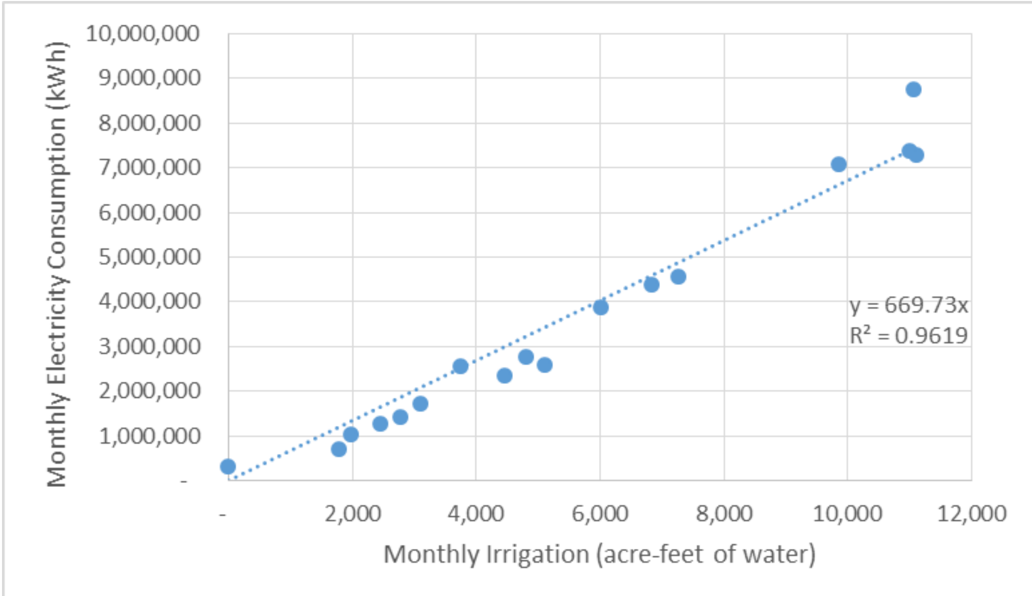
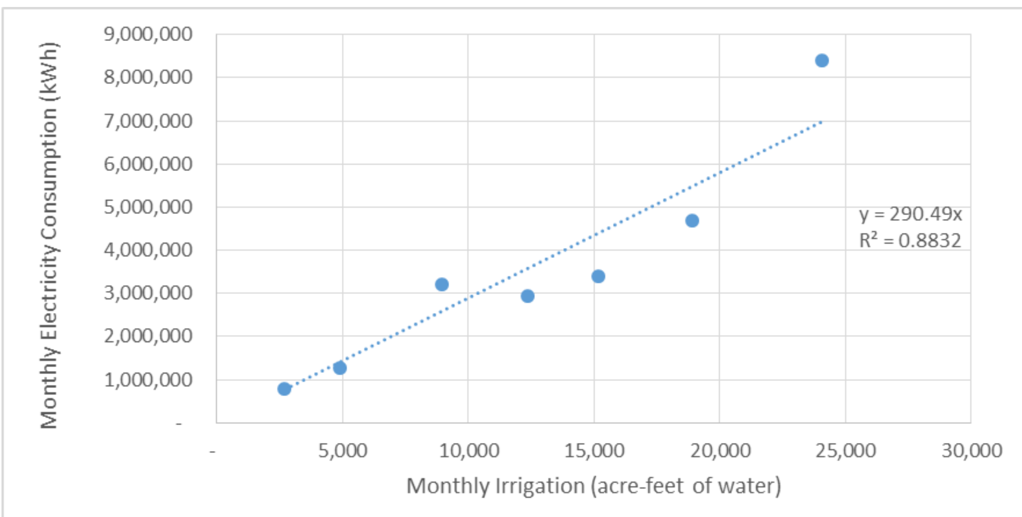


Figure 9. ETPE201263 Retrofit Water and Electricity Consumption



Cadmus applied these correlations to historic annual water consumption and calculated much larger energy savings than the amount reported. We noted, however, that 2012 water consumption data were much higher than in previous years and could represent an anomaly. We determined obtaining additional years' consumption data would helpful in calculating the long-term energy savings, given the magnitude of potential savings. As noted, the participant did not feel compelled to provide us with additional data. Our attempt to work through the facility's new PDC also was unsuccessful. Cadmus evaluated the energy savings for this site at the reported value of 3,472,001 kWh per year, which represented a reasonable value in the absence of supporting data to update the analysis.

The other custom irrigation project for site ETPE201207 reported much lower energy savings after replacing several existing pumps with one large, VFD-controlled pump. IRZ—Cadmus' subcontractor—analyzed the project based on reported values and on-site verification, determining that reported energy savings were appropriate.

The custom irrigation projects achieved a 100% RR. Table 16 shows the reported and evaluated savings for each custom irrigation project in the sample.

Table 16. Custom Irrigation Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings	Evaluated Savings	Realization Rate
	Electricity (kWh)	Electricity (kWh)	Electricity Savings
ETPE201263	3,472,001	3,472,001	100%
ETPE201207	203,916	203,916	100%
Total Custom Irrigation	3,675,917	3,675,917	100%

Custom Motor and Hydraulics

Cadmus evaluated three projects related to custom motor and hydraulic applications. The ATAC contractor provided the calculation workbook for the custom hydraulics project, and we could reconstitute energy-savings calculations from the verification reports for the other two projects.

In each case, Cadmus verified operational parameters on site and found the inputs reasonably accurate. For ETPE201245, the Cadmus field engineer revised operating hours downward to account for holidays, maintenance, and downtime. Despite this, the custom motors and hydraulics projects achieved a 100% RR. Table 17 shows the reported and evaluated savings for each custom motor and hydraulic measure in the sample.

Table 17. Custom Motor and Hydraulic Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings	Evaluated Savings	Realization Rate
	Electricity (kWh)	Electricity (kWh)	Electricity Savings
ETPE201208	576,061	576,061	100%
ETPE201228	117,001	117,001	100%
ETPE201245	61,630	58,199	94%
Total Custom Motor and Hydraulic	754,692	751,261	100%

Custom Primary Process

Cadmus evaluated 12 primary process projects that represented a wide range of applications. Seven projects involved server replacement or upgrade projects at large data centers. These were all for the same participant at multiple locations: ETPE201232, 33, and 34. These projects received an incentive based on energy savings calculated using early replacement methodology, in which the baseline represents the performance of the existing equipment. Cadmus worked closely with participants to obtain detailed data on baseline and retrofit server specifications as well as cooling system information. In each case, Cadmus determined the projects achieved reported savings, for a 100% RR.

Still, our experience with server and data center projects suggests the participant—without a program incentive—likely would have replaced all of these servers with the same efficiency upgrades. In general, data centers replace servers on a “server refresh cycle.” According to the participant, the facilities performed these seven server replacement projects as part of their normal server refresh cycle of four years. The participant significantly reduced the numbers of servers needed to be used by taking advantage of advances in server performance in the previous four years. The participant determined the number of servers purchased was sufficient to provide the same performance as a much larger number of existing servers based on the metric of server output in millions of instructions per second (MIPS). The existing server performance was roughly two to six MIPS, while the new servers performed at 20 to 25 MIPS. Cadmus noted the existing servers still functioned adequately, which supports using the early replacement calculation. However, we believe the advances in technology, coupled with the participant’s corporate policy on the server refresh cycle, likely would have resulted in the same project without the Production Efficiency program’s influence. We believe these factors, particularly the corporate policy on server refresh cycle, support the program applying the “replace on burnout” calculation methodology for server replacement measures. In this calculation methodology, the baseline represents either code efficiency (where available and specified) or an industry standard practice, as defined by the program, rather than the existing equipment. We believe the appropriate baseline for this measure would represent a standard efficiency server with the same MIPS as the replacement server.

Four of the five remaining projects achieved savings higher or reasonably close to reported savings. A project at ETPE201270 experienced a slight decrease in savings due to lower site production following project completion in 2012. A project at ETPE201260 experienced a 35% increase in energy savings due to longer production hours after 2012.

A project at ETPE201252 focused on improving the energy intensity associated with a particular production line by reducing electricity consumption per unit of production. Cadmus reviewed submetered data for the production line along with production data by month, finding that the energy intensity declined even more than expected. This project achieved a 144% RR.

The project at ETPE201238 anticipated achieving a large reduction in natural gas consumption by adding a new, more efficient process line. The PDC estimated the consumption and production rate for the existing and new process lines. Cadmus analyzed the site’s utility billing data to determine the actual reduction in consumption. We used the PDC’s reported values for the production rate as the participant did not respond to data requests from both Cadmus and the PDC. On site, the participant confirmed to Cadmus’ field engineer that, for years, the facility had worked at full production capacity. We determined the reported production rate values seemed appropriate and consistent. After adjusting for changes in operating hours between the baseline and retrofit periods, it appeared the PDC likely overestimated the new line's efficiency. This project achieved a 38% RR.

Overall, the custom primary process projects achieved a 95% RR of reported MMBtu savings. Table 18 shows the reported and evaluated savings for each custom primary process project in the sample.

Table 18. Custom Primary Process Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
ETPE201232 #1	19,253	0	19,253	0	100%	N/A
ETPE201232 #2	117,545	0	117,545	0	100%	N/A
ETPE201232 #3	259,469	0	259,469	0	100%	N/A
ETPE201232 #4	3,226,233	0	3,226,233	0	100%	N/A
ETPE201232 #5	3,337,918	0	3,337,918	0	100%	N/A
ETPE201233	1,692,697	0	1,692,697	0	100%	N/A
ETPE201234	521,910	0	521,926	0	100%	N/A
ETPE201238	0	55,720	0	21,262	N/A	38%
ETPE201252	786,983	0	1,134,221	0	144%	N/A
ETPE201260	185,220	0	250,195	0	135%	N/A
ETPE201269	1,300,226	0	1,320,737	0	102%	N/A
ETPE201270	934,670	0	841,203	0	90%	N/A
Total Custom Primary Process	12,382,124	55,720	12,721,397	21,262	103%	38%

Custom Pumping

Cadmus evaluated 10 custom pumping measures, applied as part of eight individual projects. These projects primarily involved adjustments to control settings or VFD installations. The Cadmus field engineer for each project obtained as much relevant data as possible on site as well as any available trend data. Though we could obtain calculation workbooks for only two of the eight projects (covering four of the 10 measures), we effectively reconstituted the energy-savings methodology for all of the projects, based on conventional engineering algorithms and verification report data.

One-half of the measures achieved RRs within the range of +/- 10% of reported energy savings. The other half either did not achieve energy savings or the evaluation engineer found savings much lower than reported.

For the custom pumping project at ETPE201245, Cadmus reviewed motor on/off data from the facility's supervisory control and data acquisition (SCADA) system, as included in TAS and verification reports. For several pumps, these data indicated that actual operating hours were less than the reported values,

operating 8,400 hours per year instead of the reported 8,760 hours due to maintenance downtime. Though we requested more recent data from the participant to confirm current operations, they did not provide these. Consequently, we adjusted the baseline and retrofit operating hours, an adjustment that reduced energy savings by 16%.

On two custom pumping projects at ETPE201228, the PDC reported the pumps operated constantly. The on-site verification, however, found the pumps operating roughly 4,748 hours per year. Adjusting for operating hours reduced energy savings by 44%.

Two other pumping projects installed VFDs. In both cases, participants adjusted system operation so the VFD proved unnecessary and pumps operated at 100% power. These projects did not achieve any energy savings.

Altogether, the custom pumping projects achieved a 73% RR. Table 19 shows the reported and evaluated savings for each custom pumping project in the sample.

Table 19. Custom Pumping Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings Electricity (kWh)	Evaluated Savings Electricity (kWh)	Realization Rate Electricity Savings
ETPE201228 #1	40,789	25,728	63%
ETPE201228 #2	195,230	200,438	103%
ETPE201228 #3	840,650	469,528	56%
ETPE201245 #1	64,000	0	0%
ETPE201245 #2	1,700,973	1,436,373	84%
ETPE201251	109,530	109,530	100%
ETPE201255	34,536	35,376	102%
ETPE201256 #1	19,736	18,284	93%
ETPE201256 #2	235,703	0	0%
ETPE201256 #3	263,307	264,095	100%
Total Custom Pumping	3,504,454	2,559,352	73%

Custom Refrigeration

Cadmus evaluated four custom refrigeration projects. The same PDC implemented three of these and developed the refrigeration calculation models used to report energy savings. All refrigeration models and data used to inform the models were deleted. Cadmus field engineers verified the current operating characteristics of the refrigeration systems, confirming they reasonably reflected the reported operating characteristics. Developing new refrigeration calculation models for this project type fell outside of the scope of this evaluation. Thus, we accepted the reported savings as reasonably accurate, based on the on-site verification findings.

For the project at ETPE201227, Cadmus verified the measure installation on-site. A review of the calculation workbook provided by the PDC confirmed it provided a reasonable representation of system performance.

The custom refrigeration projects achieved a 100% RR. Table 20 shows the reported and evaluated savings for each custom refrigeration project in the sample.

Table 20. Custom Refrigeration Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings	Evaluated Savings	Realization Rate
	Electricity (kWh)	Electricity (kWh)	Electricity Savings
ETPE201222	435,759	435,759	100%
ETPE201227	87,827	87,827	100%
ETPE201264 #1	274,960	274,960	100%
ETPE201264 #2	180,541	180,541	100%
Total Custom Refrigeration	979,087	979,087	100%

Custom Secondary Process

Cadmus evaluated six secondary process measures at five facilities. One involved server replacements at ETPE201232, similar to those noted for primary processes, and achieved the full reported savings. We adjusted operating hours on two projects (one up, one down) based on on-site verification; the impacts canceled out.

A project at ETPE201256 installed a new VSD chiller with a waterside economizer as two individual measures. Given the facility did not actually use the waterside economizer, the measure did not achieve savings. In addition, the facility operated a lower-than-expected production level. The site contact would not provide updated chiller operating data from the facility's EMS, so Cadmus could not adjust the chiller savings based on current operations. The PDC, however, provided chiller trend data from the original calculation process: these data indicated the chiller consistently performed at lower load levels than in the PDC's 8,760 chiller load calculator. The PDC may have expected loads to increase with production, but this production increase did not occur. As a result, we revised the calculator to better reflect the chiller load data. This reduced energy savings.

The secondary process project at ETPE201231 installed insulation on water tanks and piping for the facility's steam system. Cadmus confirmed the critical operational characteristics on site, supporting the reported savings methodology. The reported savings calculation overstated the boiler efficiency (based on the TAS report). The change in boiler efficiency reduced energy savings.

For a welder replacement project at ETPE201229, we found that operating hours had increased over the reported baseline hours. Cadmus could not definitively determine that the new operating hours would continue indefinitely. We calculated operating hours as the average of reported baseline and verified operating hours. This project achieved a 112% RR.

Altogether the secondary process measures achieved a 79% RR of reported MMBtu savings. Table 21 shows the reported and evaluated savings for each custom secondary process project in the sample.

Table 21. Custom Secondary Process Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
ETPE201229	539,695	0	603,635	0	112%	N/A
ETPE201231	0	9,990	0	8,937	N/A	89%
ETPE201232	54,398	0	54,398	0	100%	N/A
ETPE201256 #1	210,388	0	0	0	0%	N/A
ETPE201256 #2	517,502	0	315,364	0	61%	N/A
ETPE201258	524,637	0	451,604	0	86%	N/A
Total Custom Secondary Process	1,846,620	9,990	1,425,001	8,937	77%	89%

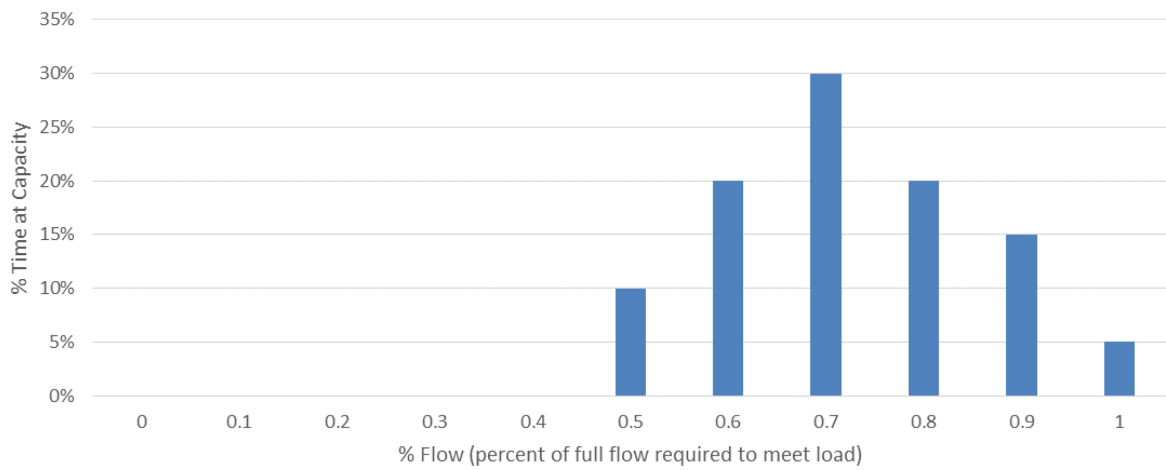
Custom Wastewater

Cadmus evaluated four wastewater projects at two different facilities. For facility ETPE201214, we primarily adjusted energy savings on three measures due to revised operating hours. The reported savings assumed all process equipment would operate 8,760 hours per year. Discussions with facility contacts indicated 8,400 hours per year as a more reasonable estimate, incorporating equipment maintenance, repair, and plant shutdowns.

The contractor also calculated the pumps operated with a 1.0 power factor. This is not a reasonable assumption because nearly all inductive loads, such as pump motors, experience a phase difference between voltage and current waveforms, resulting in a power factor lower than 1. Cadmus updated the savings using a generous assumption of 0.95 power factor and applied the manufacturer's reported amperage values for the retrofit equipment (slightly higher than the values used in the reported savings methodology).

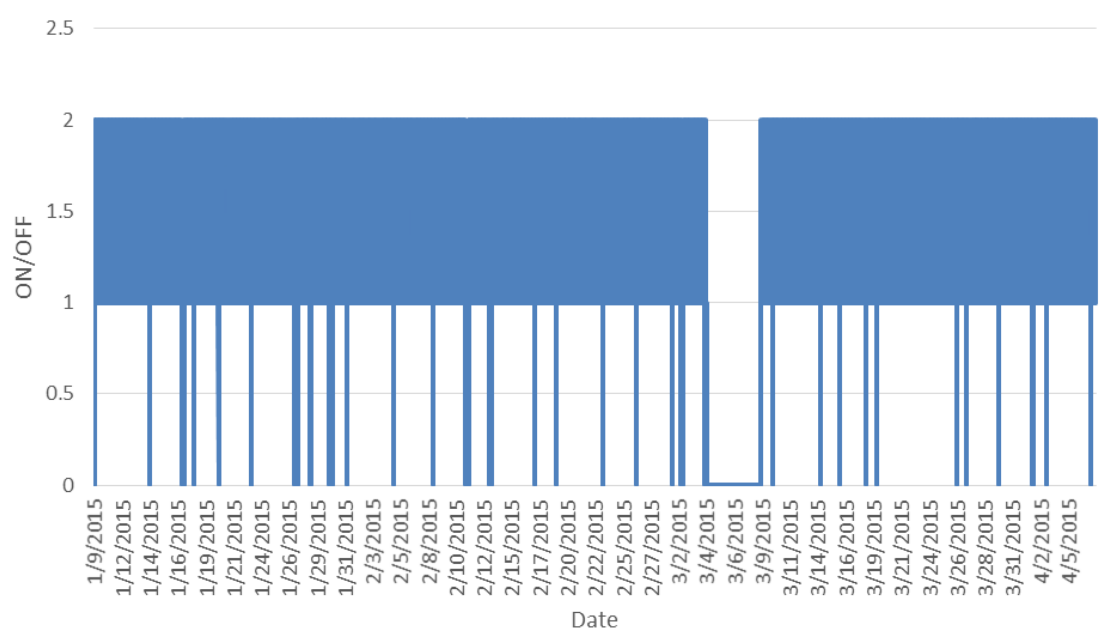
For one project at ETPE201214, Cadmus obtained trend data to establish a load profile for several pumps, as shown in Figure 10. We applied the updated load profile to the savings calculations, which reduced savings slightly.

Figure 10. Annual Load Profile of ETPE201214 Pumps



For the remaining project at ETPE201212, Cadmus installed motor on/off loggers on mixers to better assess their operating parameters. The resulting data, shown in Figure 11, allowed us to better estimate retrofit operations and adjust savings accordingly. We also reduced the baseline operating hours (reported at 8,760 hours) to 8,400 hours to account for equipment maintenance, repair, and plant shutdowns, based on discussions with plant personnel. These adjustments reduced energy savings.

Figure 11. ETPE201212 Digester Mixer #2 On/Off Operation



Overall, the custom wastewater projects achieved an 84% RR. Table 22 shows the reported and evaluated savings for each custom wastewater project in the sample.

Table 22. Custom Wastewater Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings	Evaluated Savings	Realization Rate
	Electricity (kWh)	Electricity (kWh)	Electricity Savings
ETPE201212	875,182	757,214	87%
ETPE201214 #1	977,000	761,166	78%
ETPE201214 #2	376,855	358,552	95%
ETPE201214 #3	182,397	166,362	91%
Total Custom Wastewater	1,536,252	1,286,080	84%

Custom O&M

Custom O&M measures represented a variety of applications, including HVAC system retrocommissioning, boiler controls adjustments, and revisions to motor operating parameters. Cadmus evaluated eight of these projects using EMS trend data on system parameters, utility billing data, reviews of spreadsheet calculations, and on-site verification, producing a 56% RR of reported MMBtu savings.

While Cadmus found that one-half of these projects achieved the reported savings, two larger projects experienced issues with energy-savings persistence. The project at ETPE201228 (reported to save 1,305,401 kWh) simply involved shutting down two 125 hp motors that the facility and PDC determined no longer remained necessary due to other equipment that could help maintain adequate material quality. An on-site verification conducted at the facility found both motors back in operation. The facility contact reported they operated on the same parameters as before the project. Cadmus prorated the project's energy savings by calculating the amount of verifiable time the participant turned off the motors relative to the three-year measure life. The PDC reported the participant shut down the motors on October 5, 2011 and then verified the measure on November 5, 2011 (one month). Therefore, we evaluated the project savings at 1/36 of the reported energy savings.

The O&M project at ETPE201221 involved tuning up an 800 hp boiler with a rated input of 32,659,000 BTU/hour. This project reported relatively large natural gas savings. The facility, however, rebuilt the boiler approximately one year after the tune-up, which eliminated the project's impact. Cadmus prorated the project's energy savings by calculating the amount of time the tune up was in effect (one year) relative to the three-year measure life. Therefore, we evaluated the project savings at one-third of the reported energy savings.

Cadmus found minor variances from reported operational characteristics on two smaller custom O&M projects (ETPE201205 and ETPE201246), which reduced the evaluated energy savings. However, Cadmus conducted the site visits for these two projects over three years after measure installation. This is outside the expected measure life for O&M projects, and we could not say with certainty when the measures were removed from service. Therefore, we evaluated these two projects at their full reported energy savings.

Table 23 shows the reported and evaluated savings for each custom O&M project in the sample.

Table 23. Custom O&M Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
ETPE201205	169,700	0	169,700	0	100%	N/A
ETPE201213	438,000	0	438,000	0	100%	N/A
ETPE201221	0	13,019	0	4,340	N/A	33%
ETPE201228	1,305,401	0	36,261	0	3%	N/A
ETPE201231	0	2,532	0	2,532	N/A	100%
ETPE201246	208,440	0	208,440	0	100%	N/A
ETPE201255	487,580	0	487,580	0	100%	N/A
ETPE201262	0	35,207	0	35,207	N/A	100%
Total Custom O&M	2,609,121	50,758	1,339,981	42,079	51%	83%

Green Motor Rewind

Cadmus evaluated 15 Green Motor Rewind measures at five different sites. As-verified motor sizes and quantities resulted in adjusted savings. In one case, we worked with the participant to locate a reportedly rewound, 300 hp motor, but this could not be found on site; Cadmus found zero savings. In the other cases, we confirmed the reported sizes and quantities. The Green Motor Rewind projects produced a 96% RR. Table 24 shows the reported and evaluated savings for each green motor rewind project in the sample.

Table 24. Green Motor Rewind Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings	Evaluated Savings	Realization Rate
	Electricity (kWh)	Electricity (kWh)	Electricity Savings
ETPE201205	5,269	0	0%
ETPE201230 #1	274	274	100%
ETPE201230 #2	274	274	100%
ETPE201230 #3	274	274	100%
ETPE201230 #4	363	363	100%
ETPE201255	14,682	14,682	100%
ETPE201258 #1	63,109	63,109	100%
ETPE201258 #2	20,754	20,754	100%

ETPE201268 #1	809	809	100%
ETPE201268 #2	274	274	100%
ETPE201268 #3	8,256	8,256	100%
ETPE201268 #4	2,987	2,987	100%
Total Green Motor Rewind	117,325	112,056	96%

Lighting

Lighting measures included efficient lighting fixtures and controls, such as occupancy sensors and daylight dimming. The lighting measures achieved a 97% RR compared with reported savings.

The program based lighting measure savings on projects initiated during previous program years, for a deemed average applying to a range of fixture sizes (e.g., “T5HO 4-lamp fixture”). To evaluate savings, Cadmus analyzed measures based on actual wattages, ballast factors, and operation hours, determined through site visits, invoice reviews, and manufacturer specification sheets.

Other primary factors influencing the RR included the following:

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

Fixture Count Adjustments

Cadmus field engineers occasionally noted discrepancies between reported and observed fixture counts. For savings evaluation purposes, we adjusted the baseline and as-built fixture counts to match observed quantities.

Sample Lighting Fixture Average Operating Hours

Evaluated sample project lighting fixture measures (e.g., CFLs, T8, and T5 lamps) sometimes operated for different periods than values used in deemed energy-savings estimates.

Table 25 shows the reported and evaluated savings for each lighting project in the sample.

Table 25. Lighting Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings	Evaluated Savings	Realization Rate
	Electricity (kWh)	Electricity (kWh)	Electricity Savings
ETPE201205	175,159	175,159	100%
ETPE201206 #1	137,474	143,190	104%
ETPE201206 #2	24,465	24,465	100%
ETPE201206 #3	123,895	89,429	72%
ETPE201208 #1	84,039	82,394	98%
ETPE201208 #2	84,039	82,394	98%

ETPE201226	570,101	565,255	99%
ETPE201227	56,738	56,738	100%
ETPE201229 #1	41,434	45,577	110%
ETPE201229 #2	228,603	251,463	110%
ETPE201245	52,156	52,156	100%
ETPE201250 #1	100,845	100,845	100%
ETPE201250 #2	994,206	994,206	100%
ETPE201252	13,152	13,152	100%
ETPE201261	1,102,324	1,102,324	100%
ETPE201263	220,719	114,429	52%
Total Lighting	4,009,349	3,893,177	97%

Prescriptive

Prescriptive track measures included many different types of agricultural irrigation measures as well as pipe insulation, greenhouse, compressed air, and HVAC measures. Cadmus found three custom HVAC measures and one custom irrigation measure mislabeled as prescriptive projects.

The primary reduction in prescriptive measure savings came from two larger natural gas savings projects (ETPE201202 and ETPE201239) that Cadmus evaluated using utility billing data. One involved a site that installed an infrared polyethylene greenhouse cover, while another facility tuned up its HVAC system and implemented demand-controlled ventilation. Cadmus reviewed each facility's baseline and retrofit natural gas consumption relative to heating degree days and found a reasonable correlation, as shown in Figure 12 and Figure 13. The regression analyses indicated overestimated deemed savings estimates for these projects.

Figure 12. Site ETPE201239 Baseline Daily Therms vs. HDDs

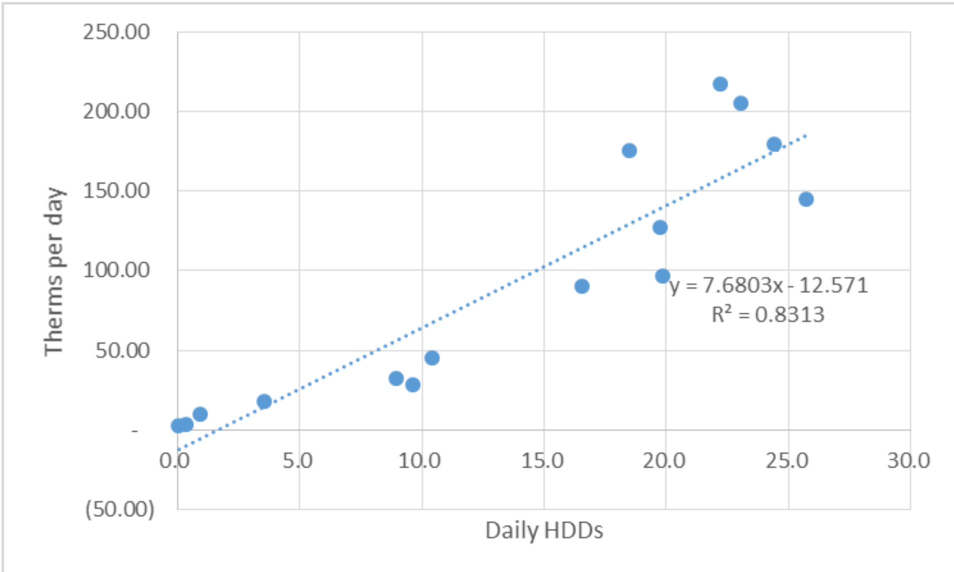
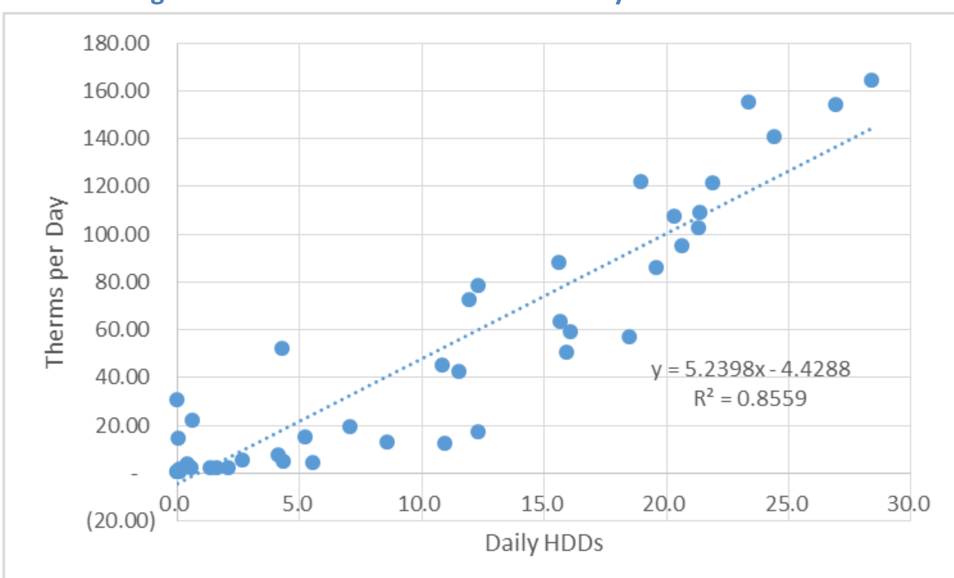


Figure 13. Site ETPE201239 Retrofit Daily Therms vs. HDDs



IRZ evaluated 30 prescriptive irrigation measures, finding nearly all had been implemented and operated as reported. The evaluation team determined these measures should still achieve the reported savings. However, two projects had issues:

- Site ETPE201236 reported installing 50 wheel line levelers. At the on-site verification, the facility contact claimed they only replaced the baseline levelers as needed and had only replaced one-half to date. The evaluation team adjusted energy savings accordingly.

- Site ETPE201240 reported two measures to install 30 impact sprinkler nozzles on 30 new or rebuilt brass impact sprinklers. IRZ found the site had to replace all sprinklers within 1.5 years. Such projects have a reported measure life of five years; so this produced an unexpected failure level. Given the early failure of all measures at this site, Cadmus determined this project did not achieve energy savings.

Prescriptive measures achieved a 94% RR of reported MMBtu savings. This included a 90% RR for electric savings and 95% RR for gas savings, as shown in Table 26.

Table 26. Prescriptive Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
ETPE201202	0	16,527	0	10,416	N/A	63%
ETPE201223	21,930	0	21,930	0	100%	N/A
ETPE201236	68,525	0	68,488	0	100%	N/A
ETPE201239	69,255	8,667	21,888	7,491	32%	86%
ETPE201240	1,299	0	0	0	0%	N/A
ETPE201242	1,924	0	1,924	0	100%	N/A
ETPE201244 #1	30,100	0	30,100	0	100%	N/A
ETPE201244 #2	49,966	0	49,966	0	100%	N/A
ETPE201244 #3	84,556	0	84,556	0	100%	N/A
ETPE201244 #4	30,545	0	30,545	0	100%	N/A
ETPE201246	1,794	0	1,794	0	100%	N/A
ETPE201253 #1	14,000	0	14,000	0	100%	N/A
ETPE201253 #2	3,217	0	3,217	0	100%	N/A
ETPE201257	0	32,148	0	32,148	N/A	100%
ETPE201259	2,804	0	2,804	0	100%	N/A
ETPE201261 #1	7,000	10,820	7,000	10,820	100%	100%
ETPE201261 #2	0	11,052	0	11,052	N/A	100%
ETPE201265	45,412	0	45,412	0	100%	N/A
ETPE201271	46,109	0	46,109	0	100%	N/A
ETPE201272	0	58,806	0	58,806	N/A	100%
Total Prescriptive	478,436	138,020	429,733	130,734	90%	95%

Streamlined

Streamlined track measures included many that rely on well-developed algorithms and standardized spreadsheet tools, such as pump VFDs, compressed air, and efficient welding measures. Cadmus evaluated 14 streamlined measures at 12 sites, finding this track's measures achieved a 94% RR of reported MMBtu savings. This included a 94% RR for electric savings and 97% RR for gas savings.

Cadmus and IRZ conducted on-site M&V at all sites, in most cases finding the measures installed and operating as reported. We verified the inputs associated with the standardized tools used to estimate savings and concluded that most measures achieved the reported savings.

Cadmus adjusted savings for four projects; these all had key operating parameters changed by the participant after project completion. In one case, ETPE201225 installed a solar collector for a chicken breeding area to reduce natural gas consumption. After installation, the participant removed the solar collector altogether, and the project did not achieve savings.

Three other projects experienced more minor reductions in savings:

- For a scientific irrigation scheduling measure at ETPE201216, we obtained actual irrigation data, showing expected demand was lower than reported.
- ETPE201261 installed an efficient air dryer for a system with two 150 hp modulating air compressors. The participant replaced the two air compressors with a 300 hp VSD compressor. This slightly altered the compressed air profile and air dryer demand, resulting in a minor decrease in energy savings.
- At ETPE201267, the compressed air system operated fewer hours after the measure installation; Cadmus applied a blended rate of baseline and retrofit operating hours to evaluate the energy savings.

This track's measures achieved a 88% RR of reported MMBtu savings. This included a 94% RR for electric savings and 0% RR for gas savings, as shown in Table 27.

Table 27. Streamlined Measure Reported and Evaluated Energy Savings

Cadmus Site ID	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
ETPE201203	15,384	0	15,384	0	100%	N/A
ETPE201207	94,674	0	94,674	0	100%	N/A
ETPE201210	42,096	0	42,096	0	100%	N/A
ETPE201216	175,970	0	140,287	0	80%	N/A
ETPE201225	0	1,626	0	0	N/A	0%
ETPE201226	140,663	0	140,663	0	100%	N/A
ETPE201227	56,945	0	56,945	0	100%	N/A

ETPE201247	47,137	0	47,137	0	100%	N/A
ETPE201249	20,689	0	20,689	0	100%	N/A
ETPE201253	14,030	0	14,030	0	100%	N/A
ETPE201261	37,294	0	36,041	0	97%	N/A
ETPE201263	44,632	0	44,632	0	100%	N/A
ETPE201267	41,909	0	31,868	0	76%	N/A
Total Streamlined	731,423	1,626	684,446	0	94%	0%

Estimation of Program Population Energy Savings

Sampling Weights and Estimation

Cadmus calculated the sampling weights for each project by dividing the population size by the sample size within the stratum (h) from which the project was sampled (sampling weight=N_{hi}/n_{hi}), where i denotes project i within stratum h. We then applied the sampling weight to each project's reported and evaluated savings to estimate RRs, total savings, and precision. Table 28 provides the sampling weights for each stratum in the PE sample.

Table 28. Sampling Weights

Stratum (h)[9]	N_{hi}	n_{hi}	Sampling Weights (N_{hi}/n_{hi})
Large	24	24	1.00
Medium	59	32	1.84
Small	410	17	24.12

Cadmus assigned the sampling weights, based on strata, to each project (and the measures within it), regardless of the "reporting category." This category can represent the stratum itself or the measure category (reporting categories: A=Custom Capital, B= Custom O&M, C=Green Motor Rewind, etc.), fuel type (reporting categories: A=electric, B=gas), or any other category Energy Trust chooses to use for summarizing the results.

To estimate verified savings in the project population, based on the sample, Cadmus used a ratio estimator (the RR), calculated by dividing the sample verified savings by the sample reported savings in sampled projects. Multiplying the population-reported savings by the realization rate provided estimates of population-verified savings.

In greater detail, sample reported and verified savings in a category represent the weighted sum of savings over measures or projects in that category (weights equal the sampling weights). Population-

9 Large projects (>5,000 MMBtu), medium projects (<5,000 and >1,000 MMBtu), and small projects (<1,000 MMBtu).

reported savings in the category simply represent the sum of reported savings over all measures or projects in the population in that category.

Reporting category RRs are sample verified savings, divided by the sample reported savings; the estimated population-verified savings are population-reported savings, multiplied by the RR within the category. Cadmus calculated standard errors within each category by applying the sampling weights and finite population correction to the sum of squared errors within the category. We determined the relative precision by multiplying the standard errors by the t-statistic (with degrees of freedom based on the category sample size) and dividing by the category population total verified savings estimates.

Table 29 and Table 30 provide details on the evaluation's use of sampling weights to calculate population estimates within each reporting category.

Table 29. Savings and RR Estimates

Reporting Category	Population Total Reported Savings	Sample Total Reported Savings	Sample Total Verified Savings	RR	Population Estimated Total Verified Savings
A	$X_{A\_pop} = \sum_{h=1}^{3}\sum_{i=1}^{N_{Ah}} x_{Ahi}$	$X_{A\_sam} = \sum_{h=1}^{3}\sum_{i=1}^{n_{Ah}} \frac{N_{hi}}{n_{hi}} x_{Ahi}$	$Y_{A\_sam} = \sum_{h=1}^{3}\sum_{i=1}^{n_{Ch}} \frac{N_{hi}}{n_{hi}} y_{Ahi}$	$RR_A = \frac{Y_{A\_sam}}{X_{A\_sam}}$	$\hat{Y}_{A\_pop} = RR_A \times X_{A\_pop}$
B	$X_{B\_pop} = \sum_{h=1}^{3}\sum_{i=1}^{N_{Bh}} x_{Bhi}$	$X_{B\_sam} = \sum_{h=1}^{3}\sum_{i=1}^{n_{Bh}} \frac{N_{hi}}{n_{hi}} x_{Bhi}$	$Y_{B\_sam} = \sum_{h=1}^{3}\sum_{i=1}^{n_{Bh}} \frac{N_{hi}}{n_{hi}} y_{Bhi}$	$RR_B = \frac{Y_{B\_sam}}{X_{B\_sam}}$	$\hat{Y}_{B\_pop} = RR_B \times X_{B\_pop}$
C	$X_{C\_pop} = \sum_{h=1}^{3}\sum_{i=1}^{N_{Ch}} x_{Chi}$	$X_{C\_sam} = \sum_{h=1}^{3}\sum_{i=1}^{n_{Ch}} \frac{N_{hi}}{n_{hi}} x_{Chi}$	$Y_{C\_sam} = \sum_{h=1}^{3}\sum_{i=1}^{n_{Ch}} \frac{N_{hi}}{n_{hi}} y_{Chi}$	$RR_C = \frac{Y_{C\_sam}}{X_{C\_sam}}$	$\hat{Y}_{C\_pop} = RR_C \times X_{C\_pop}$
Total	$\boldsymbol{X_{pop} = X_{A\_pop} + X_{B\_pop} + X_{C\_pop}}$	$\boldsymbol{X_{sam} = X_{A\_sam} + X_{B\_sam} + X_{C\_sam}}$	$\boldsymbol{Y_{sam} = Y_{A\_sam} + Y_{B\_sam} + Y_{C\_sam}}$	$\boldsymbol{RR_{pop} = \frac{\hat{Y}_{pop}}{X_{pop}}}$	$\boldsymbol{\hat{Y}_{pop} = \hat{Y}_{A\_pop} + \hat{Y}_{B\_pop} + \hat{Y}_{C\_pop}}$

Table 30. Standard Error and Precision Estimates

Reporting Category	Standard Error (SE)	Precision
A	$SE_A^2 = \sum_{h=1}^{3} \frac{N_h^2}{n_h}\left(1-\frac{n_h}{N_h}\right)\sum_{i=1}^{n_{Ah}} \frac{(y_{Ahi} - RR \times x_{Ahi})^2}{n_{Ah}-1}$	$\frac{SE_A \times t.stat_{n_{Ah}-1}}{\hat{Y}_{A\_pop}}$
B	$SE_B^2 = \sum_{h=1}^{3} \frac{N_h^2}{n_h}\left(1-\frac{n_h}{N_h}\right)\sum_{i=1}^{n_{Bh}} \frac{(y_{Bhi} - RR \times x_{Bhi})^2}{n_{Bh}-1}$	$\frac{SE_B \times t.stat_{n_{Bh}-1}}{\hat{Y}_{B\_pop}}$
C	$SE_A^2 = \sum_{h=1}^{3} \frac{N_h^2}{n_h}\left(1-\frac{n_h}{N_h}\right)\sum_{i=1}^{n_{Ch}} \frac{(y_{Chi} - RR \times x_{Chi})^2}{n_{Ch}-1}$	$\frac{SE_C \times t.stat_{n_{Ch}-1}}{\hat{Y}_{C\_pop}}$
Total	$SE_{Total} = \sqrt{SE_A^2 + SE_B^2 + SE_C^2}$	$\frac{SE_{Total} \times t.stat_{n_{Ah}+n_{BH}+n_{CH}-3}}{\hat{Y}_{pop}}$

Table 31 and Table 32 show final evaluated savings by measure, fuel, and program level.

Table 31. Program Level Electricity and Gas Savings and RRs

Track	Reported Savings		Evaluated Savings		Realization Rate	
	Electricity (kWh)	Gas (therms)	Electricity (kWh)	Gas (therms)	Electricity Savings	Gas Savings
Custom Capital	48,409,104	349,945	45,534,612	290,796	94%	83%
Custom O&M	4,354,464	97,878	3,085,324	77,568	71%	79%
Green Rewind	258,658	-	247,042	-	96%	N/A
Lighting	29,278,534	-	28,205,775	-	96%	N/A
Prescriptive	3,418,567	222,050	3,360,097	211,530	98%	95%
Streamlined	6,067,952	51,245	5,678,908	49,619	94%	97%
Total	**91,787,279**	**721,118**	**86,111,758**	**629,513**	**94%**	**87%**

Table 32. Program Level Energy Savings and RRs

Track	Reported Energy Savings (MMBtu)	Evaluated Energy Savings (MMBtu)	Realization Rate
Custom Capital	200,166	184,444	92%
Custom O&M	24,645	18,284	74%
Green Rewind	883	843	96%
Lighting	99,898	96,238	96%
Prescriptive	33,869	32,618	96%
Streamlined	25,828	24,338	94%
Total	**385,290**	**356,765**	**93%**

Cadmus calculated the sampling precision to determine whether it was acceptable, based on standard statistical levels of rigor, to extrapolate sample energy savings to the overall program population.[10] For each track, Cadmus determined the confidence interval (precision) for a 90% confidence level. As shown in Table 33, the sample exceeded a 90/10 level. The sample precision estimates exclude the SEM track.

Table 33. 2012 Sample Precision

Track	Confidence Level	90% Confidence Interval (kWh)	90% Confidence Interval (therms)	90% Confidence Interval (MMBtu)
Custom Capital	90	±4%	±1%	±3%
Custom O&M	90	±62%	±19%	±40%
Green Rewind	90	±26%	N/A	±26%
Lighting	90	±13%	N/A	±13%
Prescriptive	90	±1%	±5%	±3%
Streamlined	90	±8%	±0%	±16%
Total	**90**	**±5%**	**±3%**	**±4%**

[10] The confidence level and interval determine precision. Values for Prescriptive track projects, for example, indicate Cadmus can be 90% certain, based on sampling error, that the population value falls within ±3% of evaluated savings.

Conclusions and Recommendations

Cadmus conducted an impact evaluation of the Energy Trust of Oregon's 2012 Production Efficiency program by originally sampling 273 measures implemented at 73 sites. We evaluated measures at five of these sites through a separate evaluation of SEM projects. Cadmus ended up analyzing energy savings for 230 capital and O&M measures implemented at 68 sites.

Cadmus performed verification site visits for each project in the sample and evaluated energy savings based on verified equipment counts, operating parameters, metering data, EMS trend data, and assumptions derived from engineering experience and secondary sources. For each measure, these data informed prescriptive algorithms and calculation spreadsheets.

Energy Trust's PDCs generally applied appropriate methodologies and assumptions. Overall, Cadmus' evaluated savings differed from reported energy savings. In some cases, participants discontinued measures that received incentives through the program. Many measures included variations between assumptions used to estimate reported savings and evaluated values. Cadmus also noted revisions to calculation methodologies, equipment counts, and variations between expected and achieved equipment performance. These combined factors led to a 94% program electric realization rate and an 87% program gas realization rate, which exclude the SEM track.

Overall, the 2012 PDCs performed a reasonable level of review and quality control to achieve high average project savings RRs. The measure types with lower evaluated savings represented large, complex measures, with final operating patterns often difficult to predict, particularly in industrial settings. Cadmus evaluated many measures two to three years after installation. Persistence of savings became an issue in some cases, particularly for projects involving control settings.

Most prescriptive and streamlined measure types achieved high realization rates. Cadmus primarily reduced overall program energy savings through adjustments to custom project energy savings, particularly O&M projects. The following factors impacted the overall realization rate:

- Some participants determined that energy efficiency measures did not operate to their satisfaction, and removed the measure or adjusted the operational parameters that had allowed them to be more efficient.
- Some facilities' production levels and operating hours declined from the original time of installation, particularly for wood products facilities.
- A PDC applied an incorrect analysis methodology for one large Custom Capital track project (labeled by Cadmus as ETPE201263) aimed at improving water pumping efficiency. The PDC's methodology produced a potentially conservative electricity savings estimate.
- In some cases, PDCs and Allied Technical Assistance Contractors did not adequately account for measure operations and overestimated energy savings.

- For some sites, the PDCs verified energy savings without collecting trend data, or they collected trend data for less than one week.
- Natural gas billing data for two sites indicated overestimates of prescriptive deemed measure savings. These sites installed prescriptive greenhouse and HVAC tune up measures.

Cadmus' other findings included the following:

- The program saved substantial energy, and the realization rates for the 2012 PE program were consistent with other custom and industrial programs Cadmus has evaluated.
- In 2013, Energy Trust transitioned to new custom PDCs and adjusted PDC service territories. In some cases, PDCs deleted all analysis files and data associated with facilities it no longer represented. Energy Trust did not retain a copy of those files and data, resulting in a loss of documentation used to estimate energy savings for custom projects. This presented difficulties for Cadmus in examining baseline operating parameters and accurately evaluating program savings.
- The program provided incentives for high-efficiency data center server replacements, treating these as early replacement calculations. This allowed existing servers to be used as the baseline. In one case, the participant installed the new servers as part of their normal, four-year server refresh cycle, indicating they considered the existing servers to be at the end of their effective useful life. This implies that early replacement is not the most appropriate approach to calculate energy savings for this type of measure. Cadmus notes that server technology evolves at a rapid pace, and older servers quickly become obsolete.
- PDCs often proved extremely knowledgeable about the facilities with which they worked, and they were generally receptive to supporting evaluation efforts. Due to early recruitment and documentation issues, Cadmus often had to work directly with PDCs to contact facilities and acquire analysis files and data. We found most PDCs quickly provided any documentation they could access, supplied appropriate facility contacts, and went out of their way to assist with recruitment efforts.
- Energy Trust implementation staff maintained a thorough understanding of project details and participant sensibilities. Cadmus developed a large number of M&V plans for Energy Trust's staff review. Even though PDCs were more directly involved with project review and approval, senior Energy Trust program staff had a strong knowledge of project and analysis details and provided significant feedback on the M&V plans to improve M&V efforts.

Due to the evaluation, Cadmus recommends the following opportunities for Energy Trust to consider program improvements:

- Energy Trust should maintain a repository for all workbooks, analysis models, and data used to estimate energy savings on completed projects. Though contractors occasionally use proprietary models that would render this inappropriate, establishing such a repository may enable Energy

Trust to achieve more consistency in applying data for projects at a given site. Further, this resource would improve the accuracy and efficiency of evaluation efforts.

- PDCs should consider collecting trend data, where available, for at least two weeks of retrofit energy efficiency measure operations to better characterize operating parameters.
- PDCs should consider examining correlations between energy consumption and the volume of water pumped for pumping efficiency projects. Cadmus has generally found strong linear correlations between monthly electricity billing consumption and pumpage (in volume of water per month) at facilities for which pumping represents the primary electricity load (e.g., irrigation and municipal water pumping stations). Using baseline and retrofit data, PDCs could more effectively calculate the energy savings despite variance in water flow between the two data sets.
- Energy Trust should consider re-examining deemed savings for some measures, particularly those associated with greenhouses and HVAC tune ups.
- Energy Trust should consider revising measure savings calculations for measures with rapid obsolescence (such as servers), from early replacement to replace on burnout.
- Energy Trust and PDCs may want to explore additional options to encourage the persistence of energy efficiency measures, particularly those associated with operations and maintenance measures. Cadmus found that two projects with relatively large reported savings (ETPE201221 and ETPE201228) reverted back to baseline conditions well before the end of their expected measure life. The PDCs may want to conduct greater scrutiny of how the measures would impact production prior to measure approval to ensure a higher rate of persistence or to allow a trial period of operation prior to approving incentives. Another option could involve regular PDC follow up on previously-incented measures to engage participants in dialogue regarding measure benefits and detrimental impacts, forestalling a reversion to baseline conditions.

Appendix A. Confidential Site-Specific Reports

[This documentation is supplied separately from the main report and only for Energy Trust's reference.]

Appendix B. On-Site Interview Guide

1.) Has there been any change in operating hours/schedules since the project was completed?
    a. If so, please describe the operating hours/schedules before and after the project was completed.
    b. Why were operating hours/schedules changed? (Please note if project was the cause of the change and if unclear ask, Did the project have any role in this change? If yes, what was its role?)
    c. Are these changes permanent? If no: When do you expect them to change again and to what level?

2.) Has there been any change in production levels since project was completed/equipment was installed?
    a. If so, please provide data showing baseline (before) and post-measure installation production levels.
    b. What was the reason for these production changes? (e.g., does production vary seasonally?)
    c. If the project was the cause of the change or if unclear ask: Did the project have any role in this change? If yes, what was its role? Are these changes permanent? If no, when do you expect them to change again and to what level?

3.) Can you provide any additional information on operational changes that may impact the energy consumption of the installed energy efficiency measures or plant as a whole? (Note: this question will vary depending on the measure and M&V plan)

4.) How is the equipment working? Are there any issues with equipment performance since the installation?

5.) Have you noticed any additional benefits from the new equipment?