FINAL REPORT - IMPACT EVALUATION OF THE PATH TO NET ZERO PILOT PROGRAM FOR NEW BUILDINGS

Submitted to

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ENERGY + WATER + EFFICIENCY

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We want to acknowledge the support of Energy Trust staff, the program management contractor (CLEAResult), and end users to support this study. Many hours were spent reviewing plans and draft work products along with time spent gathering documentation and trend data, answering questions, and escorting the evaluation team during its inspections. This study could not have been completed without these contributions to our efforts.

EXECUTIVE SUMMARY

This report describes the results of the impact evaluation of Energy Trust of Oregon's Path to Net Zero (PTNZ) pilot. The primary goal of the pilot was to understand if net zero energy could be achieved and to understand the process required by design teams to make decisions that lead to a net zero outcome or are critical to creating a path to net zero program approach in commercial buildings. Increased technical and financial support was provided to support decision-making in pursuit of the goals. A process evaluation was conducted alongside the program's implementation of the pilot and concluded in 2012.[1] With all pilot buildings now complete, and enough post-occupancy data available, this impact evaluation was conducted to characterize the effectiveness of many measures pursued through the New Buildings program (the program)'s Path to Net Zero Pilot.

From the separate process evaluation, we know that the pilot was met with great interest from owners and the design community, providing information to the program. A white paper was also published through ACEEE that describes the early energy use of the buildings along with major energy efficiency features and measures selected, and the program's assessment of major net zero design strategies.[2] This evaluation builds on extensive information gained by program staff, design teams, and building owners; and provides a final assessment of savings impact.

Background

The pilot was designed to significantly advance major renovation and new construction projects beyond energy code. It referenced the 2007 Oregon Structural Specialty code and applied program requirements about building layout to determine baseline. Pilot requirements included a commitment to target 50% energy savings in design, but allowed projects to pursue 60% energy savings if using a combination of efficiency and on-site renewable energy generation, which provided the program with a learning opportunity as far as incorporating renewable energy measures.

To achieve these high energy savings targets, the pilot focused on early decision making and was geared to provide technical support to assess various energy-savings considerations in the very early stages. With early design assistance, the program engaged with building owners and teams to discuss energy-savings strategies; the program also provided technical support for studies and energy modeling, and later addressed installation and commissioning, as well as providing optional monitoring and reporting support. By 2014, eight projects completed the pilot.

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[1] http://assets.energytrust.org/api/assets/reports/121204_PTNZ_Report.pdf

[2] B. Walker, E. Rowe, S. Truax and J. Rose, "Notes from the Trail: Checking in on the Path to Net Zero", 2012 ACEEE Summer Study on Energy Efficiency in Buildings. http://aceee.org/files/proceedings/2012/start.htm.

Energy Trust's New Buildings program incorporated early lessons learned into the standard program, such as early design assistance, and then launched Path to Net Zero in 2014 as a standard offering with updated requirements and reference energy code, making the requirement a target of 40% energy savings. The impact evaluation summarized in this report aims to provide important information to program staff about the performance of this highest tier of energy efficient building design.

Due to the unique nature of PTNZ pilot project, the more extensive commissioning, monitoring and reporting and post-occupancy engagement that was required, the eight pilot projects had not been included in previous impact evaluations of the NB program. Most PTNZ projects were evaluated with two years of post-occupancy data compared to the regular program's one-year timeline.

The goals of this impact evaluation were to:

1. **Measure actual savings compared to program estimated savings** for these projects by determining the gas and electric energy savings associated with each measure implemented at six sampled sites. Energy Trust uses this information for program savings projections and budget developments, and incorporates it into their annual true-up of program savings.
2. **Report observations and make recommendations** to help Energy Trust improve the effectiveness of future engineering studies and impact evaluations of its commercial new construction projects, particularly buildings designed for the highest energy performance targets. These include findings that help explain substantial deviations from the claimed savings, and recommendations for changes to gross savings calculation methods and/or other program processes that will enhance future realization rates.

Methodology

The three primary steps of this evaluation included a review of previous engineering estimates, site data collection, model review, and an impact analysis. Energy Trust provided project files for each site, which the evaluation team reviewed and examined to assess the reasonableness of modelling assumptions, such as hours of operation and equipment specification. In particular, we examined the baseline model definition to determine if the baseline methodology complied with code requirements. The 2007 Oregon Structural Specialty Code was applicable to five sites, with ASHRAE 90.1-2007 applied to one site.

Following this, we performed site visits and collected trend data to inform revisions to the simulation models for each site. The revised simulation models were in turn used to analyze energy savings impacts.

Findings

Findings are presented to answer three questions:

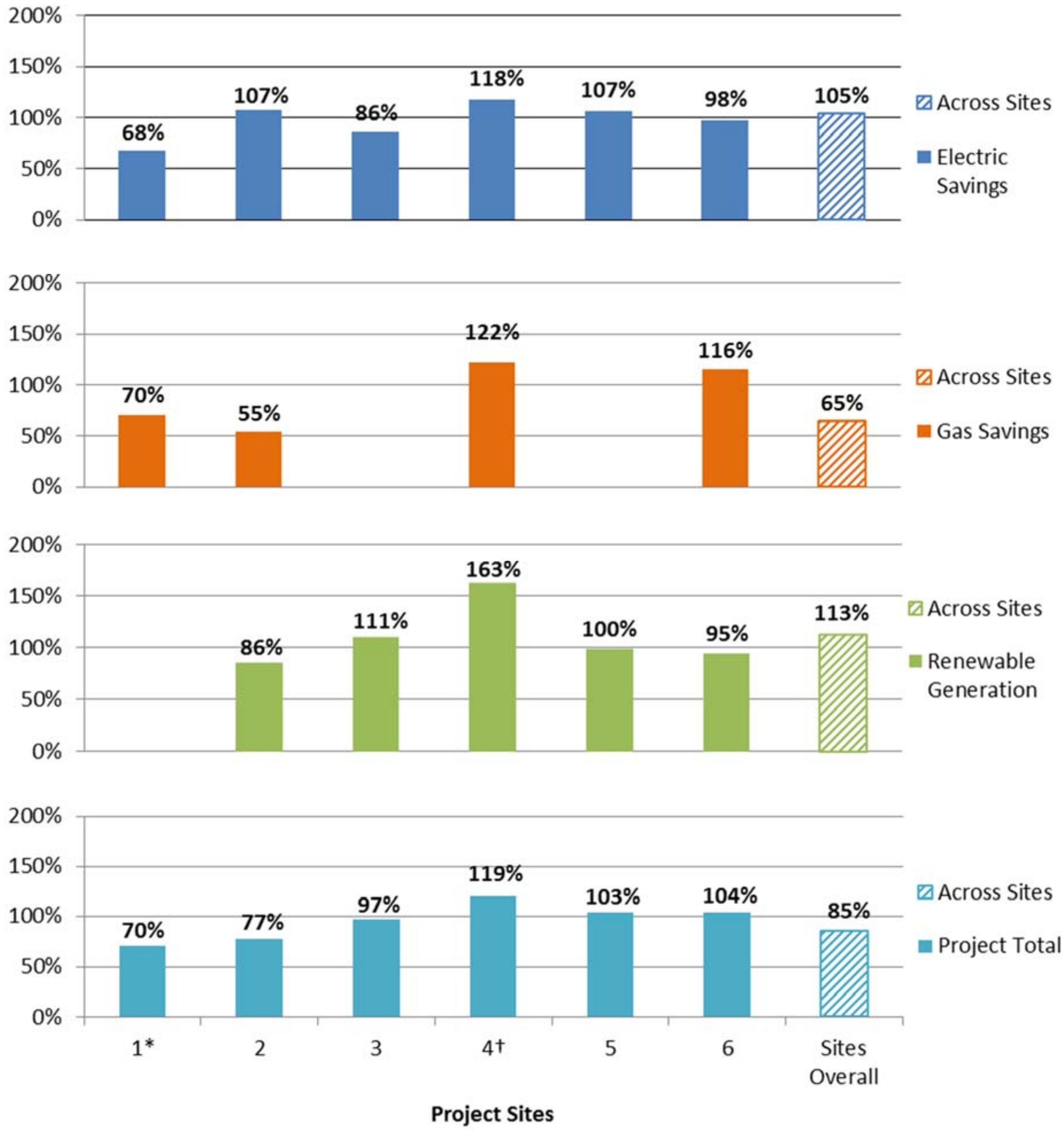
1. How well did the pilot program predict savings for each project?
2. How well did the PTNZ pilot program meet its goals of percent savings over code?

3. What program-wide observations were made and what issues were uncovered during the course of the evaluation?

Prediction of Savings

Four projects were well within their estimated electric savings goals (100% realized savings) or exceeding them; one project was slightly lower than the target, only realizing 86% of original savings estimated; and one saved far less than expected, realizing only 68% of the original electric savings estimate. Gas realization rates varied more widely compared to electric energy savings; in two of the four projects with gas savings measures, the gas savings were around 20% higher than predicted, and two projects saved 30-50% less gas energy than their target. Renewable generation, in the form of photovoltaic (PV) arrays, was incorporated into five projects. Four of the five projects with solar PV installed were within range of original generation estimates and one large project exceeded its goal with additional investments made to extend its PV system.

Figure 1 displays the impact evaluation findings as percent realization rates, indicating what percent of the original savings estimates were actually achieved. Savings realization rates are broken out among the three main sources--electric and natural gas savings, and also renewable energy generation--followed by the total site-level savings realization rates presented at the bottom of the chart. Across all evaluated sites, the electric realization rate was 105%, the gas realization rate was 65%, and the renewable generation realization rate was 113%. When considering all fuels savings and renewable energy generation, the realization rate across the evaluated sites was 85%.



*This site did not have renewable generation installed

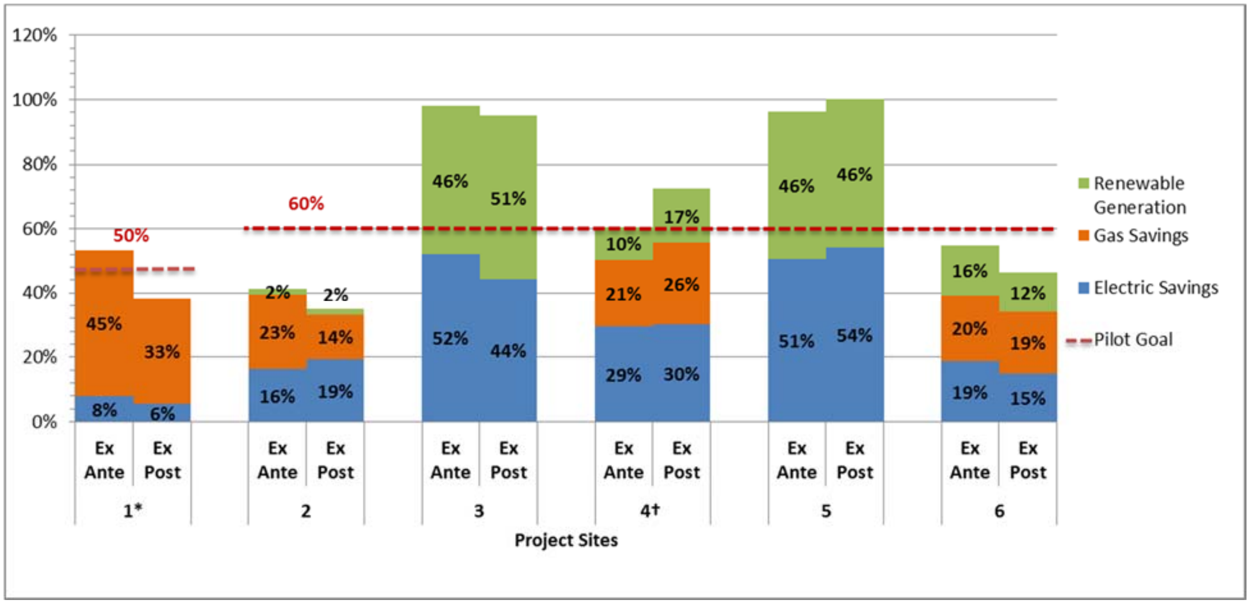
†Photovoltaic generation at this site was not incentivized under the PTNZ pilot but PV generation was still claimed based on specified minimum of 112,000 kWh for the project

Figure 1: PTNZ Project Realization Rates by Site, Type of Savings and Generation

Percent Savings Over Code

Six of the eight pilot projects completed by 2014 were evaluated, three of which are meeting their Path to Net Zero energy savings goals.

Figure 2 below presents the site-level evaluation estimates of percent savings over the 2007 Oregon Structural Specialty Code (ASHRAE 90.1-2007 for Site 2) broken down by savings component. The percent savings goal for each site is shown as a dotted red line. Ex ante and ex post savings are presented side-by-side to illustrate changes between the original pilot estimate and the evaluated estimate. It should be noted that the PTNZ pilot sought to achieve 50% savings over code with projects that utilized only energy efficiency measures and 60% savings over code for projects that utilized efficiency and renewable energy measures. With exception of Site 1, all of the projects evaluated in this study installed renewable generation, in the form of solar PV.



*This site did not have renewable generation installed.

†Photovoltaic generation at this site was not incentivized under the PTNZ pilot but PV generation was still claimed based on specified minimum of 112,000 kWh for the project.

Figure 2: PTNZ Project Percent Savings over 2007 Oregon Structural Specialty Code

Overall Observations/Issues

The following observations and issues were encountered during the course of the evaluation:

PTNZ Program Issues/Observations

- Data integrity issues were encountered at each site. These included the following:
    - Lack of historical trends
    - Historical trends set to record for too short a term (typically less than a week)
    - Large chronological gaps in data
    - Issues with intermediate data handling, especially for sites with web “dashboards” that import data from control systems

  - At all sites we visited, we found that the Monitoring and Reporting (M&R) system was either inactive or experienced data issues. Sites that indicated a high level of involvement in site energy monitoring demonstrated better savings realization rates. The one site with an inactive M&R system exhibited the lowest realization rate.

- In addition to the energy impact analysis presented above, SBW surveyed site building management staff to improve understanding of their energy management and monitoring behaviors. The results of the survey are shown in the appendices provided with the internal version of this report.

Savings-Related Issues/Observations

- Electric measures are generally performing well, with a few exceptions performing slightly below expectations.
- There appears to be much more variability amongst the gas measures. Some of these measures are performing well against code, while others are demonstrating significantly lower realization rates. Actual gas usage was found to be higher than expected.
- Renewables are generally performing better than expected, and at some sites are offsetting under-performance by the electric efficiency measures.
- Energy models were found to be well-developed and of excellent quality. Although we did find modeling errors which impacted savings, the relative number of errors we found was small. We believe that the high level of technical review required for the models was a major reason for success in this area.

Recommendations

This section describes recommendations developed as a result of the issues encountered during the engineering review and impact analysis processes.

Data Integrity

Data plays a critical part in meeting the goals of any energy efficiency program. It is especially important for net zero programs. PTNZ program energy savings goals are far more aggressive than for conventional programs, and even a small increase in energy can significantly impact whether or not these goals are met. Data allows building owners to quickly detect rises in energy, identify the causes, and ensure that applied solutions are working.

Data issues were discovered at each of the six evaluated sites. The following recommendations are meant to improve how the program handles both M&R data (which pertains to whole building and end use energy such as lighting, HVAC, etc.) and control system trend data (which pertains to detailed system operation such as fan speeds, temperature setpoints, daylighting, control, etc.).

- Currently, although the program requires periodic checks (sometimes quarterly) of M&R data throughout the 18 month reporting period, data quality issues were encountered with data stored during this period. We recommend improving the methodology used to check

M&R data during this period. This could include more frequent checks to ensure that valid data is being stored, a closer examination of the reasonableness of the data, or comparison of accumulated M&R data with concurrent utility billing data. These activities could also be incorporated into the site commissioning plan in order to facilitate implementation.

- We also recommend strongly encouraging customers to keep the M&R system active and functioning beyond the current 18 month requirement in order to facilitate the maintenance of energy savings. This could be encouraged by educating customers about the advantage in energy savings of maintaining the system. The same methodology used by Energy Trust to ensure data validity during the 18 month period (with the improvements noted above) could be adopted by the customer.
- In general, sites should be encouraged to regularly check all historical trend system data (M&R and otherwise) to ensure continued integrity. Sites should also be encouraged to maintain historical control system trends of 15-minute interval data for at least a year in order to capture building operation during all conditions. Sites should be educated as to why this is important, and the benefits of monitoring their historical trend systems regularly (as well as the negative impacts of not doing so).
- M&R does not extend to natural gas. Due to underperformance of gas measures and data issues at many of the sites, consider offering an M&R option for gas, which would install gas meters on major equipment such as boilers and domestic hot water heaters, and would record gas usage at 15 minute intervals similar to how electric M&R is currently being accomplished.

Integrated Building Management System Practices

Discussions with site property management personnel and the survey given to site personnel demonstrated a wide range of building management practices and engagement levels that inherently affect the persistence of savings measures. At one site, the controls contractor and building management worked closely together to maintain system performance, while at another site, the building management was not fully aware of typical system controls, resulting in unnecessary summer boiler operation. Additionally, some features of these advanced buildings provide unusual challenges for maintenance staff in their day-to-day work, resulting in specialized vendors having to be called in to facilitate standard maintenance.

We recommend developing measures and resources that support building management in sustaining building performance, including the following:

- Identify and support advanced system maintenance trainings specifically tailored to new technologies for building maintenance staff to ensure sufficient site expertise throughout the life of the measures installed. This is especially important for sites that experience building management changeover.
- Encourage site staff to conduct periodic walkthroughs that check on key measures; this ensures that tenants continue to use best practices. Some of the projects have involved

measures whose effectiveness relies on good tenant education and regular communication with building management staff.

- Encourage site staff to collaborate with their controls contractors in actively managing building performance. This may include the controls contractor directly monitoring performance and reporting regularly to site staff, or setting up a system that alerts staff to abnormally high energy usage and other performance indicator abnormalities. Enlisting the help of controls contractors is important because in most cases they are more familiar with the complexities of building operation than the site staff.
- Support and encourage building design teams to minimize building maintenance complexity and requirements. One important design feature would be maintenance accessibility to key systems. In one site in particular, maintenance of system performance was inhibited by a building design that made the system difficult to physically access, resulting in costly and time-consuming maintenance that required specialized vendors.

Maintenance of Effective Practices

This recommendation is based on which practices evaluators identified as being the most effective during the PTNZ pilot. We recommend that these practices be maintained in the future to help ensure the success of the program going forward.

- Technical reviews were found to be a thorough review of energy calculation methods, inputs, and assumptions. The reviews ensured that pre-occupancy energy models and calculations were of good quality. The format and layout of the technical review memos presented information clearly and helped in isolating specific issues and responses.

Energy Modeling Methodology

Energy modeling methodologies employed by the pilot were found to be sound. The one area for potential improvement relates to calculation of both project level and measure level savings. The pilot used a rolling baseline method to determine measure level savings, in which measures are added one at a time to the baseline model, and savings are calculated in steps as each measure is added.

This could be improved upon by using the full interactive model (all measures included) to calculate both total project and individual measure savings. Savings by measure can be accomplished with the interactive model using a “last in” approach in which the measure of interest is removed from the full interactive model to create the baseline condition for the measure. This ensures that interaction with all other measures is accounted for. Note that this method could potentially impact measure cost-effectiveness.

MEMO

Date: July 12, 2016
To: Board of Directors
From: Jessica Rose Iplikci, Program Manager, New Buildings Program
Sarah Castor, Evaluation Sr. Project Manager
Subject: Staff Response to New Buildings Path to Net Zero Pilot Impact Evaluation

Summary

Energy Trust New Buildings launched the nation's first Net Zero Energy pilot in 2009, called Path to Net Zero, designed to work closely with commercial building owners and their design and construction teams targeting design performance 50% above energy code. As documented in a process evaluation, completed in 2012, the pilot focused on the process to design and construct net zero buildings, identifying strategies and design features that save energy and understanding for how available technologies can be designed to achieve greater energy savings and benefits for building owners. This pilot impact evaluation found the program's early engagement and technical support resulted in significant energy saved.

Savings Results

The impact evaluation provides a snapshot of savings after approximately two years of occupancy, lending a unique perspective on the relationship between as-designed savings estimates and building occupancy.

- Energy Trust's pilot evaluations found that engaging owners in energy target setting and identifying energy savings goals and strategies early in the design process drives building design and construction practices that can result in 50% better than energy codes, or depending on the building owner's goals, a net zero energy building.

- Evaluators found that "the high level of technical review required for the models was a major reason for success." Total electric and gas savings were modeled correctly, with few issues or errors found by evaluators.

- Overall pilot realization rates were 105% electric, 65% gas, and 113% for solar PV generation. Operating decisions at one large site led to greatly reduced gas realization.

- Three of the six projects evaluated exceeded the pilot goal of 50% energy savings beyond code through energy efficiency or 60% savings through efficiency and renewables, the primary objective of Path to Net Zero.

Discussion

The pilot included several building types in various sectors, providing early insights to potential designs and decision making. Each project had a unique set of design goals and constraints they worked through, and pilot results cannot be generalized until the program has more implementation experience across a wider range of projects pursuing similar goals and technologies. It was important for program staff to understand the overall design decisions, the process to design a better building and approaches to equipment selection – the central goal of the pilot.

Recognizing that the building construction industry's design and construction practice has multiple phases (schematic design, design development, construction development) followed by building occupancy, the pilot aimed to influence decisions early in design. By working directly with building owners, energy efficiency became part of how they approach design decisions. By also working closely with design teams, the program was able to understand how to assess design-related decisions and factor those into modeled energy savings estimates.

Energy use is expected to fluctuate during occupancy for various reasons which are hard to predict. One of the early challenges is with assessing how to factor in occupancy strategies or operational related assumptions in net zero buildings.

Some building owners dialed in their building energy use on all levels, resulting in steadily meeting annual estimated savings ranges, and the final savings estimates were very close to program estimates. Others may be operating the building to a different use case and varied from what we know they are capable of achieving; the building may require some adjustments, but there are no major issues with the actual design of the buildings (further discussion below). Program staff have a good basis for what worked well with some customers and how to close this gap in the market.

Having well-defined occupant needs will help inform design strategies (deciding between a simple or complex building depending on occupant characteristics and needs, for example) and are needed to advance building design practice. It's important to note how the program assesses energy savings estimates in this context currently: design decisions take into consideration operations and occupancy then energy savings estimates are derived. Designers are asking for more post-occupancy information to guide decisions and Energy Trust will work to close these market gaps.

Staff Observations
Staff have the following observations of the evaluation report and recommendations for future evaluations.

Modeling measure interactivity was a challenge to evaluate because it is difficult to identify savings at the measure level for whole building projects that model multiple, often complex, inter-dependent measures. For the evaluation report, the final, calibrated model is used to estimate the whole building savings, which are then compared to the program estimate of whole building energy savings, without actually considering measure-level savings. The program does provide multiple methods of modeling energy savings associated with each measure. Given that there are pros and cons for each, the program has continued to offer all three methods.

Due to the interactivity of many building design features and systems integration, evaluators were not able to attribute actual savings to specific measures documented by the program, and to do so would require extensive building sub-system metering that is not typically done and would increase costs. Evaluators also noted that using a full interactive modeling process produces more accurate estimates of whole building energy savings than the way the program is currently required to estimate these savings. Staff also understand the full interactive effects can provide a more accurate picture of energy considerations than what the program is currently allowed to do.

To make improvements in savings estimates, in future evaluations, program staff need to see a detailed list from evaluators of all adjustments evaluators made to building energy simulation models for each site, including adjustments in baseline, HVAC schedule, occupancy and load, along with the basis for these changes.

Evaluation efforts focused recommendations on energy management and information system (EMIS) data though the focus of the pilot was on main contributors of success and challenges to designing to this high standard. There is an outstanding question of whether better data integrity would lead to better savings realization and what the costs would be, or whether it would just make evaluation easier.

Conclusions

New Buildings will continue to advance design practices to enable progress through Path to Net Zero. The program's Path to Net Zero offering aligns with the Architecture 2030 Challenge and references Oregon energy efficiency code which has been expanded and enhanced. Additional market transformation strategies and tactics are also being deployed to support the design and construction community.

TABLE OF CONTENTS

1. INTRODUCTION

The Path to Net Zero (PTNZ) Pilot was launched in 2009 and provided increased support and incentives to new commercial and multifamily projects intended to achieve exceptional energy performance of at least 50% energy savings compared to 2007 Oregon Structural Specialty Code if using energy efficiency alone, or a minimum of 60% energy savings compared to 2007 code if using a combination of energy efficiency and renewable (solar) energy.

Projects were provided with support in the form of early design assistance, technical assistance, installation and commissioning incentives, and incentives for monitoring and reporting (M&R) performance to the New Buildings (NB) program after project completion. By 2014, eight projects had been completed under the pilot. The NB program has recently launched a new generation of PTNZ offerings to the market, built off of the learnings from the 2009 pilot. This impact evaluation aims to provide important information to program staff and prospective customers about the performance of this highest tier of energy efficient buildings.

While a process evaluation of the Path to Net Zero Pilot was completed in late 2012[3], because of the unique nature of PTNZ projects, the more extensive commissioning, monitoring, and reporting of buildings after construction they required, the eight pilot projects have not been included in previous impact evaluations of the NB program. The goals of this impact evaluation were to:

1. **Develop reliable estimates of actual savings** for these projects. Determine the gas and electric energy savings associated with each measure implemented at six sampled sites[4]. This information will be used for program savings projections and budget developments and will be incorporated into Energy Trust's annual true-up of program savings.
2. **Report observations and make recommendations** to help Energy Trust improve the effectiveness of future engineering studies and impact evaluations of its commercial new construction projects, particularly buildings designed for the highest energy performance targets. These may include findings that help explain substantial deviations from the claimed savings, and recommendations for changes to gross savings calculation methods and/or other program processes that will enhance future realization rates and program cost effectiveness.

[3] http://assets.energytrust.org/api/assets/reports/121204_PTNZ_Report.pdf

[4] See Section 2 for information on why two sites were not included in the impact analysis

2. METHODOLOGY

This section presents and describes the methods the evaluation team used to carry out this study. The three primary steps of this evaluation included a review of previous engineering estimates, site data collection and model formulation, and an impact analysis. Each step is described in more detail below.

2.1. Review of Engineering Estimates

We performed a review of the original engineering estimates on the population of eight pilot projects. Table 1 summarizes the eight participating projects. Projects are identified by a project site number in order to preserve site anonymity. During the kickoff meeting, Energy Trust and Program Management Contractor (PMC) staff laid out the rationale for excluding two projects. The first (project ID 7) was an early, atypical project that was grandfathered into the pilot. The second (project ID 8) had low occupancy and malfunctioning HVAC equipment. We reviewed program materials to confirm the bases for these exclusions and concurred with the program recommendations. Given that the results of this evaluation are meant to provide reliable estimates for future planning, excluding these two projects from the study was considered appropriate.

Table 1: Projects in Sample Frame

		Program	
Project Site	Year Completed	Electric Savings (kWh)	Natural Gas Savings (Therms)
1	2013	54,055	10,601
2	2014	1,117,207	56,833
3	2013	78,990	0
4	2012	322,524	4,756
5	2012	120,087	0
6	2011	47,429	2,118
7*	2010	6,578	0
8*	2013	44,339	0

*Not included in sample.

Energy Trust provided project files for each site, which we reviewed and examined for reasonableness of modeling assumptions, such as hours of operation and equipment specification. We modified any unreasonable assumptions as needed and estimated their impact on savings. This review was focused on the version of the program models that were developed after program verification of each project. We assumed that this version was the basis for the program's savings claim and had the greatest likelihood of utilizing as-operated data from the completed projects.

For each site, baseline models had been developed by the program to represent building energy use designed to meet but not exceed code minimum requirements. We examined the baseline models to determine compliance with the baseline methodology, which called for meeting the 2007 Oregon Structural Specialty Code[5]. The baseline models played a critical role in the technical approach used in this evaluation, since the program energy use targets were reductions from 2007 code.

The evaluation team developed initial M&V strategies, based on a review of the energy savings estimates for each building, and focused on end uses and measures that accounted for significant portions of total savings. Table 2 shows program estimates of savings by end use, aggregated across all six sampled sites. The tracking data suggested that HVAC and lighting measures, since they account for the vast majority of savings, deserved the closest scrutiny.

Table 2: End Use Distribution Across Sampled Sites

End Use	No. of Measures	kWh Savings	Therm Savings	kWh % of Total	Therm % of Total
Domestic Hot Water	4	169	1,404	0.0%	1.9%
HVAC	19	676,250	71,416	38.8%	96.1%
Kitchen	5	27,071	426	1.6%	0.6%
Lighting	10	890,290	-	51.1%	0.0%
Other	12	131,559	1,061	7.6%	1.4%
Plug Loads	4	15,954	-	0.9%	0.0%
Totals	**54**	**1,741,293**	**74,307**	**100.0%**	**100.0%**

We discussed the following with Energy Trust program staff and PMC engineers in preparation for conducting the site visits and surveys with site building management staff, and we modified our plans based on their feedback:

- Practical modeling and data collection strategies for parameters of interest.
- Energy monitoring system capabilities. These systems provided critical data used in calibrating the evaluation energy performance models.
- Facility operator survey guides, customized to reflect the technologies deployed at each site, the available energy monitoring systems and methods used by the program to estimate savings. They also reflected our assessment of the information available from the project files.

We provided a detailed spreadsheet documenting these M&V strategies to Energy Trust and PMC staff for their comments and suggestions. This spreadsheet and associated discussions led to agreement on the preferred approach for data collection and analysis.

[5] 2007 Oregon Structural Specialty Code was used for all sites except for project 2, which used ASHRAE 90.1-2007.

2.2. Site Data Collection and Interviews

Once an agreement with Energy Trust was reached on plans for data collection and M&V strategies, program personnel contacted each sampled site to explain the evaluation to the facility contact, and notified them of evaluator contact. Shortly afterwards, the evaluation team arranged for a site visit and collected a facility operator survey. During this initial contact, we sought to determine the best way to obtain the needed information, if this had not already been established, and got valuable details from the site contact concerning the configuration of the measures, measure performance, and the specific capabilities of any customer control and monitoring systems that could provide data needed for the evaluation. We made every effort to develop a site visit plan that minimized disruption to site personnel and made the best use of available data collection systems. During this call, we also determined whether there were any safety or site access procedures that needed to be followed by our engineers.

During the site inspection, we observed and asked about the effect of the measures on schedules of operation and set points for important building systems, so we could estimate what those would have been in the baseline building. These buildings also installed advanced Monitoring and Reporting (M&R) equipment. Some operators have been using these data to optimize building performance. Such metering would not have been present in the baseline building. In cases where M&R data was operating and being used, it is likely that savings are being generated as a result. While it is difficult to say with certainty what contribution these systems are making to savings, sites where the system is still active seem to be performing better. This is explained further in the Findings section of this report.

We completed the site visits and collected the information called for in the data collection plan, making allowances for modifications after further discussion with the site contact. This included obtaining trend logs from customer control and monitoring systems or billing data, as needed, for model inputs or calibration. In many cases, trend data was available via online portals, but the continuity of the data varied greatly from one site to the next.

2.3. Impact Analysis

We started the analysis with the adjusted program model for the whole building developed in the review of engineering estimates task. We established calibration targets for this model based on the metered whole building energy use, as well as any separate metering of sub-systems and renewables that was available from the advanced monitoring system at each site. Our calibration goal was +/-10% of whole building utility bills annually, with an attempt to match monthly profiles as close as reasonably possible. We used control system trend data, construction plans, sequences of operations, site observations, and insights gained from the building operator surveys to refine the efficient case model inputs. We used the evaluation year weather file in the calibration model. We did not attempt to normalize renewable generation data to weather, but rather reported renewable generation for the evaluation year as being representative of a typical year.

Based on program documentation and site data collection, we assigned measures to the following categories:

- Photovoltaic (PV)
- Conventional incentivized measures
- Conventional non-incentivized measures
- Behavioral measures

The next step was to ensure that the baseline model was accurate. The original intent of this model was to meet, but not exceed the applicable code which was defined as the 2007 Oregon Structural Specialty Code for all sites except Site 2, which applied ASHRAE 90.1-2007. Importantly, these codes do not specify the utilization of the plant and equipment. The calibrated efficient case model had schedules of operation and control settings for all building systems, but had to be calibrated to the performance of the efficiency measures, many of which modified operations such as daylighting controls. Where appropriate, we adjusted the baseline model to reflect these settings.

The baseline and efficient case models were used to estimate savings. We ran the models on the Typical Meteorological Year (TMY) weather file used for the program models in order to provide the savings estimate for a typical year. Savings were calculated as the difference in annual energy use estimated by both models. We combined this with monitored data from any renewables and determined whether each building met the goals of 50% or 60% decrease in energy use compared to the applicable code. We then calculated savings realization rates as the ratio of the evaluation savings (ex post) to the program estimate of savings (ex ante).

During the course of our investigation for each site, starting with the preliminary file review prior to the kick-off meeting and continuing through the final estimation of savings, we documented observations that would help us make recommendations for improving the accuracy of the expected savings in future program years.

At a minimum, we made observations and recommendations concerning the following topics:

- The structure of the models used by the program.
- Any substantial errors in assumptions used to model energy savings analyses, either in the original program estimates or in the program's verification of energy savings.
- Reasons for differences – an understanding of why the evaluation savings estimates were different than the program estimates (in cases where there were differences), e.g., assumptions too conservative, incorrect hours of operation, or loads differ from expectations.
- Energy savings analysis approaches and assumptions, or customer behavior or decision-making that would be helpful to Energy Trust in designing, implementing, or evaluating its programs in the future.

The final product of these observations is presented as a listing of specific recommendations that come from this work regarding analysis approaches and assumptions as well as customer behavior or decision-making that will be of value to Energy Trust in developing, implementing and evaluating future program cycles.

3. Findings

This section presents and discusses the energy impact results for the Path to Net Zero Pilot projects. It begins with a discussion of overall pilot savings and seeks to answer three questions:

1. How well did the pilot program predict savings for each project?
2. How well did the PTNZ pilot program meet its goals for percent savings over code?
3. What program-wide observations were made and what issues were uncovered during the course of the evaluation?

Following this summary are descriptions of the savings for each evaluated site, along with site-specific issues/observations.

3.1. Program Findings Summary

3.1.1. Prediction of Savings

Table 3 shows impact evaluation percent realization rates and total kBtu savings for each site and for the pilot overall.

Table 3: Project Realization Rates and Savings

	Realization Rate			
Project Site	**Electric Savings**	**Gas Savings**	**Renewable Generation**	**Overall**
1*	68%	70%	-	70%
2	107%	55%	86%	77%
3	86%	-	111%	97%
4†	118%	122%	163%	119%
5	107%	-	100%	103%
6	98%	116%	95%	104%
7††	-	-	-	-
8††	-	-	-	-
Sites Overall	**105%**	**65%**	**113%**	**85%**

	Realized Savings (kBtu)				
Project Site	**Electric Savings**	**Gas Savings**	**Renewable Generation**	**Total**	**% Savings Over Code**
1*	125,971	745,700	-	871,671	38%
2	4,123,358	2,962,407	385,819	7,471,584	35%
3	121,382	-	138,473	259,855	95%

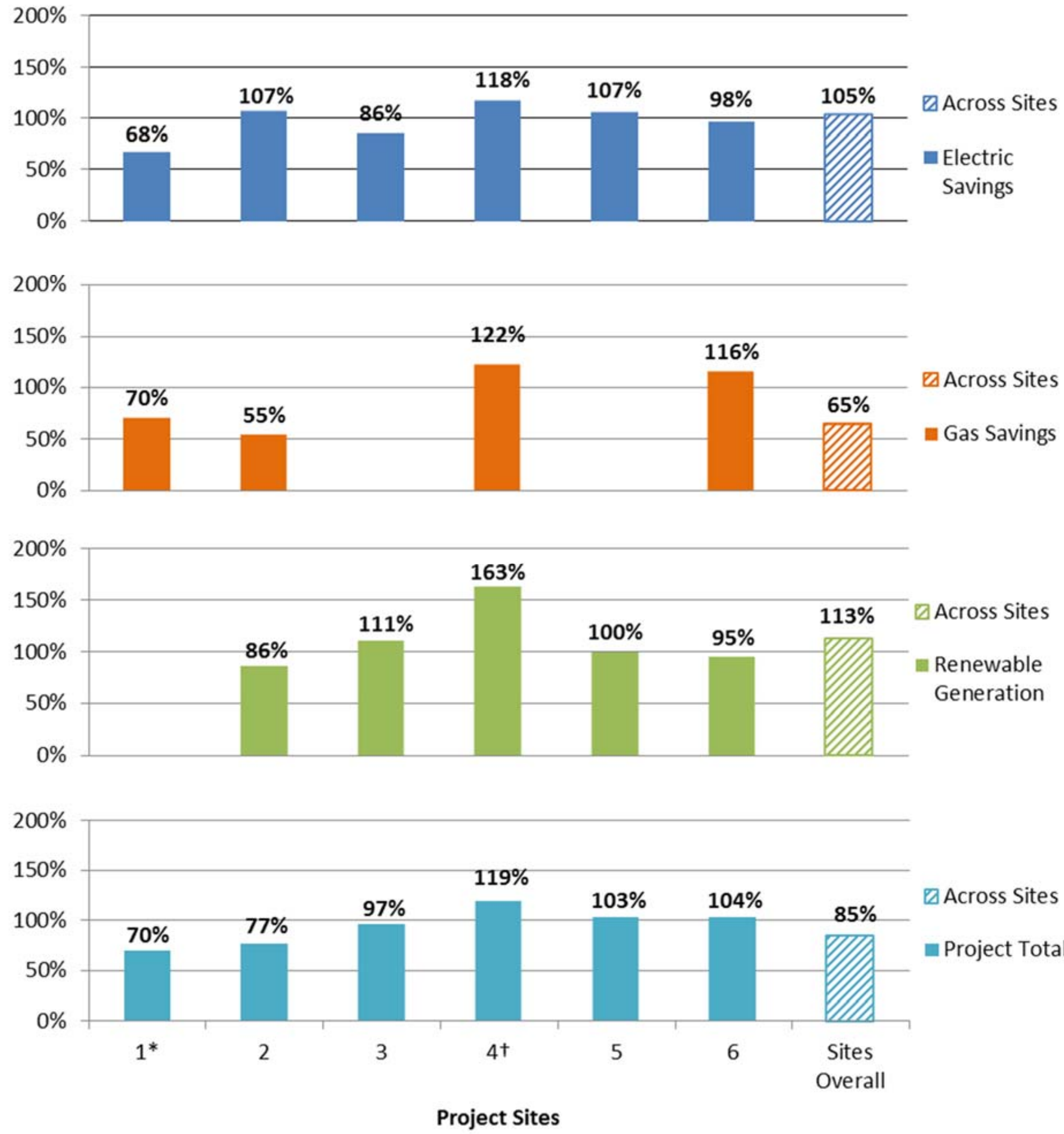
	Realized Savings (kBtu)				
Project Site	Electric Savings	Gas Savings	Renewable Generation	Total	% Savings Over Code
4†	1,127,792	955,445	623,983	2,707,220	72%
5	436,520	-	370,707	807,227	100%
6	158,689	205,394	128,595	492,678	46%
7††	-	-	-	-	-
8††	-	-	-	-	-
Sites Overall	**6,093,712**	**4,868,946**	**1,647,577**	**12,610,235**	**65%**

* This site did not have renewable generation installed.

†Photovoltaic generation at this site was not incentivized under the PTNZ pilot but PV generation was still claimed and based on specified minimum of 112,000 kWh for the project.

††These sites were not included in the study; see Methodology section for further explanation.

Figure 3 displays the impact evaluation findings as percent realization rates, indicating what percent of the original savings estimates were actually achieved. Savings realization rates are broken out among the three main sources--electric and natural gas savings, and also renewable energy generation--followed by the total site-level savings realization rates presented at the bottom of the chart. Across all evaluated sites, the electric realization rate was 105%, the gas realization rate was 65%, and the renewable generation realization rate was 113%. When considering all fuels savings and renewable energy generation, the realization rate across the evaluated sites was 85%.



*This site did not have renewable generation installed.

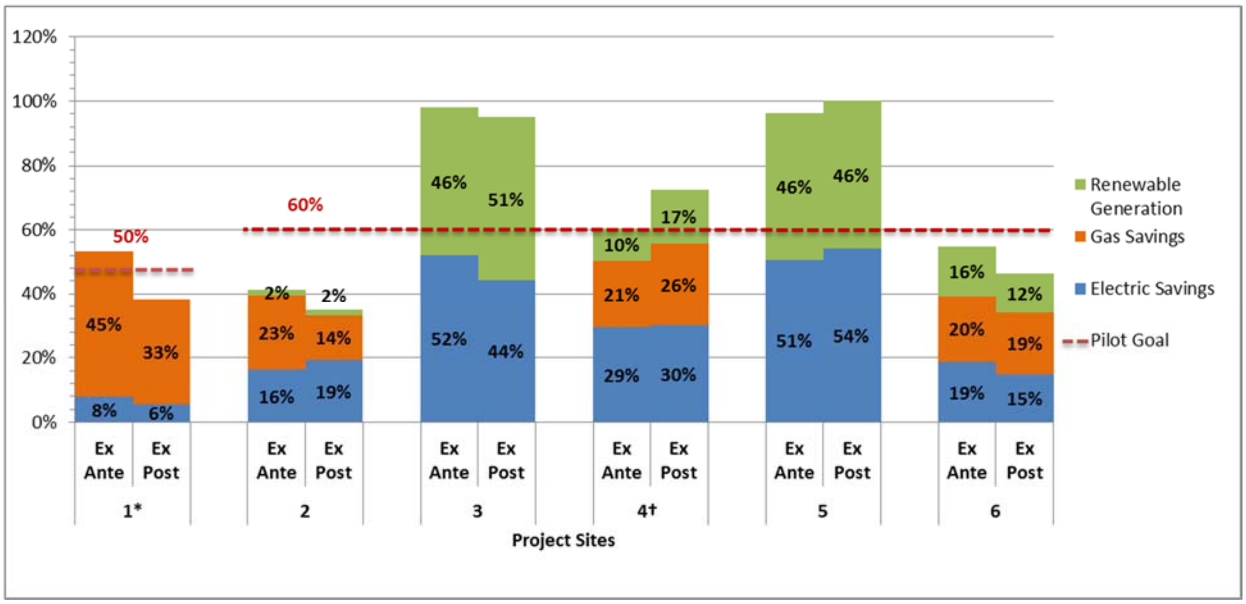
†Photovoltaic generation at this site was not incentivized under the PTNZ pilot but PV generation was still claimed and based on specified minimum of 112,000 kWh for the project.

Figure 3: PTNZ Project Realizaiton Rates by Site and Type of Savings

In Figure 3, we can see that electric measures are generally performing well with a few exceptions performing below expectations. There appears to be much more variability amongst the gas measures. Some of these measures are performing well, while others are demonstrating significantly lower realization rates. Actual gas usage was found to be higher than expected due to a variety of reasons which are covered in more detail in the site findings below.

3.1.2. Percent Savings Over Code

Figure 4 below presents the site-level evaluation estimates of percent savings over the 2007 Oregon Structural Specialty Code (ASHRAE 90.1-2007 for Site 2) broken down by savings component. The percent savings goal for each site is shown as a dotted red line. Ex ante and ex post savings are presented side-by-side to illustrate changes between the original pilot estimate and the evaluated estimate. It should be noted that the PTNZ pilot sought to achieve 50% savings over code with projects that utilized only energy efficiency measures and 60% savings over code for projects that utilized efficiency and renewable energy measures. With exception of Site 1, all of the projects evaluated in this study installed solar PV for renewable generation.



*This site did not have renewable generation installed.

†Photovoltaic generation at this site was not incentivized under the PTNZ pilot but PV generation was still claimed based on specified minimum of 112,000 kWh for the project.

Figure 4: PTZN Project Percent Savings Over Energy Code

3.1.3. Overall Observations/Issues

The following observations and issues were encountered during the course of the evaluation:

PTNZ Program Issues/Observations

- Data integrity issues were encountered at each site. These included the following:
  - Lack of a historical trend system
  - Historical trends set to record for too short a term (typically less than a week)
  - Large chronological gaps in data
  - Issues with intermediate data handling, especially for sites with web "dashboards" that import data from control systems

- At all sites we visited, we found that the M&R system was either inactive or experienced data issues. Sites that indicated a high level of involvement in site energy monitoring demonstrated better savings realization rates. In particular, we found that sites with active M&R systems performed better. M&R system status for each site is shown in Table 4.

Table 4: M&R System Status by Project

Project Site	Status	Notes
1	Inactive	
2	Active, issues encountered	Subpanel meter and historical trend data was available, but with significant issues.
3	Active, issues encountered	Significant holes in M&R data were encountered.
4	Active, issues encountered	Issues were encountered with the gas submeter.
5	Active, issues encountered	Electric meters were incorrectly calibrated.
6	Active, issues encountered	Significant holes in M&R data were encountered.
7*	N/A	
8*	N/A	

*Not included in sample

Savings Related Issues/Observations

- Electric measures are generally performing well with a few exceptions performing slightly below expectations.
- There appears to be much more variability amongst the gas measures. Some of these measures are performing well against code, while others are demonstrating significantly lower realization rates. Actual gas usage was found to be higher than expected.
- Electric renewables are generally performing better than expected, and at some sites are offsetting under-performance by the electric efficiency measures.
- Energy models were found to be well-developed and of excellent quality. Although we did find modeling errors which impacted savings, the relative number of errors we found was small. We believe that the high level of technical review required for the models was a major reason for success in this area.

4. Site Specific Findings

4.1. Project Site 1

4.1.1. Site Description

This facility was built to accomplish LEED Platinum certification and Living Building Challenge requirements through a number of efficiency measures. The following measures were proposed by the program:

Table 5: Project Site 1 Measures

Measure	Measure Type	Status	Notes
High Performance Envelope	Incentivized	Installed	HVAC
Service Water Heating with Solar	Incentivized	Not installed	HVAC
High Efficiency Boilers	Incentivized	Installed	HVAC
Heat Wheel	Incentivized	Installed	HVAC
Manually Lower Room Temperature Setpoints	Behavioral	Not installed	HVAC
Custom Refrigerator, Solid Door	Incentivized	Installed as a freezer	Kitchen
Electric Convection Oven	Incentivized	Installed	Kitchen
Hot Food Holding Cabinet	Incentivized	Installed	Kitchen
Electric Steam Cooker	Incentivized	Installed	Kitchen
Commercial Vent Hood Gas Heat	Incentivized	Installed	Kitchen
Residential Lighting	Incentivized	Installed	Lighting
Dining/Lounge/Boardroom Lighting	Incentivized	Installed	Lighting
Other Lighting	Incentivized	Installed	Lighting
Residential Lighting Manual Reduction Strategy	Behavioral	Installed	Lighting
Monitoring and Reporting	Incentivized	Installed but no longer operating	Other
Plug Load Reduction	Behavioral	Installed	Plug Loads

4.1.2. Impact Analysis Results

Current evaluation savings can be seen in the following table, with the largest reason for savings difference being higher gas usage due to updated model inputs and higher-than-anticipated domestic hot water (DHW) usage. Note that the deemed vent hood kitchen measure was removed from the kitchen portion of the savings and added to the eQUEST model ("model" in the table below) in order to capture the interactivity between the vent hood and other related building systems; hence the zero gas savings and reduced electric savings in the kitchen savings components.

Table 6: Project Site 1 Impact Analysis Results

	Ex Ante Savings		Ex Post Savings		
Savings Component	**(kWh, Thm)**	**(kBtu)**	**(kWh, Thm)**	**(kBtu)**	**Realization Rates**
Model Electric (kWh)	27,984	95,481	17,154	58,529	61%
Kitchen Electric (kWh)	26,071	88,954	19,766	67,442	76%
Total Electric (kWh)	54,055	184,436	36,920	125,971	68%
Model Gas (Thm)	10,175	1,017,500	7,457	745,700	73%
Kitchen Gas (Thm)	426	42,600	-	-	0%
Total Gas (Thm)	10,601	1,060,100	7,457	745,700	70%
Grand Total (kBtus)		1,244,536		871,671	70%
% Savings over Code		53%		38%	

As Table 6 above shows, gas is the primary source of energy use. The unexpectedly high gas usage at the site, however, did not impact savings as much because the sources identified as causing high gas usage increased baseline gas usage as well. Electric savings dropped considerably due to model changes that resulted in a decrease in baseline electricity usage and an increase in proposed electricity usage.

We observed the following during the course of the evaluation:

- The M&R system, which can provide valuable information about site energy usage, was disabled.
- The control trend system was not set up to record historical data over the long term. This can also provide valuable energy related information.
- The site management is very energy conscious. They regularly perform walk-throughs to ensure that windows are closed when needed, lights are operating correctly, etc. This likely has a large impact on maintaining energy savings.
- Residential areas are not mechanically cooled. This resulted in uncomfortable conditions during the summer. This was mitigated somewhat by installing electric ceiling fans in each residential space, resulting in a small increased in energy use.

Overall, gas was by far the largest contributor to total energy at the site, and therefore had the greatest effect on overall savings.

4.2. Project Site 2

4.2.1. Site Description

This building was completely modernized to achieve a LEED Platinum certification. Building improvements included efficient lighting, building envelope, HVAC, and domestic hot water systems, as well as the installation of PV. Measures were distributed into the following bundles as proposed by the program:

Table 7: Project Site 2 Building Measures

Measure Bundle	Measure Type	Status	Notes
Lighting	Incentivized	Installed	Lighting
Interactive Envelope	Not Incentivized	Installed	HVAC
HVAC	Incentivized	Installed	HVAC
Domestic Hot Water	Incentivized	Installed	Domestic Hot Water
Regenerative Elevators	Incentivized	Installed	Other
Decentralized Server Room with Heat Recovery Chiller	Not Incentivized	Installed	HVAC
Photovoltaic Array	Photovoltaic	Installed	Other
Monitoring and Reporting	Incentivized	Installed	Other

4.2.2. Impact Analysis Results

TMY weather was used for the final model to provide a representative comparison. Results of the impact analysis are shown in Table 8.

Table 8: Project Site 2 Impact Analysis Results

	Ex Ante Savings		Ex Post Savings		
Savings Component	(kWh, Thm)	(kBtu)	(kWh, Thm)	(kBtu)	Realization Rates
Model Electric (kWh)	1,127,521	3,847,102	1,208,487	4,123,358	107%
Photovoltaic (kWh)	131,215	447,706	113,077	385,819	86%
Model Gas (Thm)	54,348	5,434,800	29,624	2,962,407	55%
Total kBtu		9,729,608		7,471,584	77%
% Savings over Code	41%		35%		

Electric savings showed an increase because of better-than-expected performance in lighting measures. Gas savings was lower because savings had been overestimated due to a modeling error. Additionally, the reduced lighting energy in the installed model increased heating energy due to HVAC interactions.

The following observations were made during the course of the evaluation:

- Light reflecting from an adjacent building is causing significant overheating in some zones. The site is looking into installing chilled beams in the overheated zones. This may increase energy use in the future.
- Although overall usage data was available, M&R subsystem data was not. We were able to get data from lighting subpanels and boiler/DHW gas meters, but no data was available for HVAC or other end uses. Additionally, issues were present with the historical trend system. We recommend that these systems be repaired and maintained to provide for better energy monitoring and management in the future.
- The central plant equipment at this building was not updated during the project, resulting in oversized equipment. Although issues from this have generally been mitigated, it makes it difficult to operate the building as efficiently as would be the case with properly sized equipment. Note that this is a design issue and did not impact evaluation savings.
- The building is complex and had many operational issues at the outset, but most of these issues have now been resolved, and the building appears to be operating well. The staff indicated that overall they are happy with the results of the project, and that occupants are satisfied as well.

In summary, increased electric energy savings served to only partially mitigate the significantly lower evaluated gas savings and lower–than-expected renewable energy generation at the site.

4.3. Project Site 3

4.3.1. Site Description

This facility was designed to achieve LEED Platinum certification. Incorporated into this structure's design were a number of efficiency measures. The following measures were proposed by the program:

Table 9: Project Site 3 Measures

Measure	Measure Type	Status	Notes
DHW Savings	Not Incentivized	Not verified	Domestic Hot Water
Envelope	Incentivized	Installed	HVAC
HVAC	Incentivized	Installed	HVAC
Efficient Motors (HRV)	Incentivized	Installed	HVAC
Demand Control Ventilation	Incentivized	Installed	HVAC
Solarduct - OSA Preheat	Incentivized	Installed	HVAC
Irrigation Water Cooling	Incentivized	Installed	HVAC

Measure	Measure Type	Status	Notes
Lighting	Incentivized	Installed	Lighting
Daylighting	Incentivized	Installed	Lighting
Photovoltaic Array	Photovoltaic	Installed	Other
Custom Track Assistance Grant: Model Calibration	Incentivized	Completed	Other
Monitoring and Reporting	Incentivized	Installed	Other
Informational Kiosk	Behavioral	Not verified	Other
Energy Usage Education	Behavioral	Not verified	Other
Reduced Plug Loads	Incentivized	Installed	Plug Loads

4.3.2. Impact Analysis Results

The ex-ante model was calibrated to actual conditions shortly after occupancy under a Custom Track Assistance grant for Model Calibration. This model was re-calibrated by the evaluators and represents the ex post model. We used TMY weather for the final model to provide a representative comparison. Results are shown in Table 10.

Table 10: Project Site 3 Impact Analysis Results

	Ex Ante Savings		Program-Post-Occ. Calibration	Ex Post Savings		
Savings Component	(kWh)	(kBtu)	(kWh)	(kWh)	(kBtu)	Realization Rates
Model Electric (kWh)	41,571	141,840	28,172	35,575	121,382	86%
Photovoltaic (kWh)	36,584	124,825	42,418	40,584	138,473	111%
Total (kWh)	78,155	266,665	70,590	76,159	259,855	97%
% Savings over Code	108%		98%	95%		

Note that the primary reason for reduced savings over the ex-ante estimate was the post-occupancy calibration activities completed prior to this evaluation, which reduced program savings by 32% and found an increase in PV generation of 14%. Reasons for differences are detailed in a calibration report commissioned by the Energy Trust. These reasons include:

- Under-prediction of ground source heat pump energy
- Over-prediction of lighting and plug load energy
- Under-prediction of PV generation

Further changes made as part of this evaluation increased overall savings from the calibrated program model.

The following observations were made during the course of the evaluation:

- The site contact indicated that there were no issues with how the building is running. However, due to the unconventional nature of many of the systems, specialized maintenance personnel are required to maintain building operation. Additionally, the contact indicated that the layout of the mechanical room makes maintenance very difficult. Equipment access for valves and HVAC units is particularly challenging.
- Although the M&R system is operating and collecting data, intermittent issues are apparent (e.g., a large data gap in 2014 data). The data collection system needs regular maintenance in order to ensure data validity in the future.

While electric savings measures did not perform as expected in the program analysis, PV generation was higher than expected, leading to an overall evaluation realization rate close to 100%.

4.4. Project Site 4

4.4.1. Site Description

This new complex integrated a number of cutting-edge efficiency measures to accomplish net zero operation. The following measures were proposed by the program:

Table 11: Project Site 4 Measures

Measure	Measure Type	Status	Notes
High Efficiency Chiller	Incentivized	Installed	HVAC
Passive Cooling w/ Heat	Incentivized	Installed	HVAC
Improved Building Envelope	Not Incentivized	Installed	HVAC
Improved Interior Lighting	Incentivized	Installed	Lighting
Low Flow Plumbing	Incentivized	Installed	Other
Monitoring and Reporting	Incentivized	Installed	Other
Photovoltaic Array	Photovoltaic	Installed	Other

4.4.2. Impact Analysis Results

Baseline model adjustments were made to comply with code minimum requirements, and the 2014 weather file was replaced with the TMY3 file from the closest weather station to provide an average year simulation of savings. Table 12 shows evaluation savings compared to program savings, as well as percent savings compared to code.

Table 12: Project Site 4 Impact Analysis Results

	Ex Ante Savings		Ex Post Savings		
Savings Component	**(kWh, Thm)**	**(kBtu)**	**(kWh, Thm)**	**(kBtu)**	**Realization Rates**
Model Electric (kWh)	322,884	1,101,681	330,537	1,127,792	102%
Photovoltaic† (kWh)	112,000	382,144	182,879	623,983	163%
Total Electric (kWh)	434,884	1,483,825	513,416	1,751,775	118%
Model Gas (Thm)	7,835	783,530	9,554	955,445	122%
Grand Total (kBtu)		2,267,355		2,707,220	119%
% Savings over Code		61%		72%	

†Photovoltaic generation was not incentivized under the PTNZ pilot but PV generation was still claimed based on specified minimum of 112,000 kWh for the project.

Savings increased over what was reported by the program due to the following:

- Changes made to the baseline model, which increased baseline electric energy and gas use. This had the effect of increasing both electric savings and gas savings.
- The installed photovoltaic system was much more extensive than originally planned and resulted in increased electricity generation. PV modules were installed on the roof of the building as well as the roof of an adjacent building.

The following observations were made during the course of the evaluation:

- We encountered problems obtaining gas data due to data issues with the controls system. We recommend that these problems be corrected. In most buildings, gas billing data can be obtained, but that is not the case here as hot water comes from the central plant. Therefore, it is critical that there is a valid method in place for determining gas usage.
- The site contact indicated that during summer, the building can overheat somewhat, but that it is not a problem for occupants.
- Phase change bags were added to exposed-ceiling areas of naturally ventilated corridor spaces to mitigate building overheating. Since these spaces have no mechanical cooling, this did not affect energy usage. This appears to be a relatively new technology, at least in this form. As is common with new technology, issues remain—the facility is currently addressing problems with many of the bags leaking.
- According to the site, a major reason for the success of the building is the controls system, along with a very experienced controls contractor who is familiar with new technologies. The controls system measures thousands of points (conventional parameters, as well as slab temperatures, solar gain, etc.). This allows for a full diagnosis of issues down to the room level. The potential downside is that the building does require very experienced personnel to operate systems correctly.
- Electrochromatic windows in the classrooms, which darken with increasing sunlight or upon a signal from the HVAC system, take 15 minutes to fully change. This presents problems for

professors who want to darken/lighten the room quickly for multimedia presentations. There is currently no solution for this, and it may lead to more conventional lighting fixture usage energy than originally intended.

Overall, this site performed quite well, with all measure providing significantly more evaluated savings than the program estimates.

4.5. Project Site 5

4.5.1. Site Description

This new facility incorporated a number of efficiency measures into its design and operation. The design featured efficient HVAC measures, building envelope improvements, efficient lighting, and monitoring and reporting systems designed to bring significant savings. The building had recently undergone a major renovation and recommissioning to correct issues with the original project. The following measures were proposed by the program:

Table 13: Project Site 5 Measures

Measure	Measure Type	Status	Notes
HVAC - Heat Pump Domestic Hot Water Heater	Incentivized	Installed	Domestic Hot Water
Envelope - SIP	Incentivized	Removed due to issues	Envelope
Envelope - Improved Vertical Glazing and Daylighting	Incentivized	Installed	Envelope
HVAC - Heat Recovery Ventilation and Air-to-Water Heat Pump with Radiant System	Incentivized	Installed	HVAC
Natural Ventilation	Not Incentivized	Installed	HVAC
Lighting - Reduced Interior LPD	Incentivized	Installed	Lighting
Lighting - Reduced Exterior LPD	Incentivized	Installed	Lighting
Monitoring and Reporting	Incentivized	Installed, but with issues	Other
Informational Kiosk	Behavioral	Installed	Other
Laptop Computers vs Desktops	Incentivized	Installed	Plug Loads
Photovoltaic Array	Photovoltaic	Installed	Other

4.5.2. Impact Analysis Results

Savings are based on the calendar year 2014 and TMY3 weather data from the nearest weather station. Table 14 shows evaluation savings compared to program savings, as well a percent savings compared to code.

Table 14: Project Site 5 Impact Analysis Results

	Ex Ante Savings		Ex Post Savings		
Savings Component	**(kWh)**	**(kBtu)**	**(kWh)**	**(kBtu)**	**Realization Rates**
Model Electric (kWh)	120,087	409,737	127,937	436,520	107%
Photovoltaic† (kWh)	108,648	370,707	108,648	370,707	100%
Total Electric (kWh)	228,735	780,444	236,585	807,227	103%
% Savings over Code		96%		100%	

†Due to the recent renovation, data for PV generation was not available. Since the PV modules were observed to be operation, the program estimate of PV modules was accepted for the evaluation.

The evaluation shows this site consistently performing at or above program expectations with electric measures performing significantly better than program estimates.

The following observations were made over the course of the evaluation:

- The M&R lighting and plug load submeters were working well, but the HVAC end use submeter was not recording. This issue was being addressed at the time of our site visit.
- Structurally insulated panels (SIPs) developed water damage over time and had to be replaced with conventional roofing.
- The PV modules were cleaned for the first time during the recent recommissioning. The site reported that cleaning the modules boosted the PV generation by 8% for standard modules and 20% for bi-facial modules. This illustrates the importance of regularly cleaning PV arrays to maintain optimum energy generation.
- The site is currently experimenting with a weather forecast system that predicts outside conditions days ahead of time. This is necessary to optimize the slab heating/cooling system controls, which require days of advance notice in order to change slab temperatures. Once the slabs are at temperature, they work very well in maintaining occupant comfort. The site is also moving away from using airside systems to warm up the building in mornings and cool it down at night—the more efficient slab system will be the primary stage system, with airside systems operating as a second stage. Once implemented, these changes are expected to improve building comfort and increase energy savings.

4.6. Project Site 6

4.6.1. Site Description

This building was designed to meet LEED Gold requirements through a series of measures including, but not limited to, efficient envelope design, high efficiency lighting, photovoltaics, and high efficiency appliances. The following measures were proposed by the program:

Table 15: Project Site 6 Measures

Measure	Measure Type	Status	Notes
HE DHW Heater	Incentivized	Installed	Domestic Hot Water
Glazing Upgrade, Envelope, HE Boiler, Radiant Heating	Incentivized	Installed	HVAC
Exterior Walkways	Behavioral	Installed	HVAC
HE Lighting Common Area	Incentivized	Installed	Lighting
Low Flow Fixtures	Incentivized	Installed	Other
Photovoltaic Array	Photovoltaic	Installed	Other
Monitoring and Reporting	Incentivized	Installed, but data gaps exist	Other
HE Appliances	Incentivized	Installed	Plug Loads
Narrow Windows (to avoid installation of plug-in air conditioners)	Behavioral	Ineffective, but residents do not use plug-in air conditioners	Plug Loads

4.6.2. Impact Analysis Results

Results of the impact analysis are shown in the table below. Generation from the solar PV array was higher than expected. Gas savings were higher due to unnecessary summer boiler use, which increased both baseline and proposed energy and offset reduced solar thermal generation.

Because baseline boiler efficiency is lower than proposed boiler efficiency, the summer boiler usage actually generates additional savings. This is not a positive result, however, as the boiler was still operating unnecessarily due to inappropriate system set points when the heating load could have instead been met with the solar thermal system that was also installed as a part of this project. The summer boiler use increased model gas savings by 16%.

Table 16: Project Site 6 Impact Analysis Results

	Ex Ante Savings		Ex Post Savings		
Savings Component	(kWh, Thm)	(kBtu)	(kWh, Thm)	(kBtu)	Realization Rates
Model Electric (kWh)	47,483	162,012	46,509	158,689	98%
Photovoltaic (kWh)	15,000	51,180	19,066	65,053	127%
Total Electric (kWh)	62,483	213,192	65,575	223,742	105%
Model Gas (Thm)	1,774	177,406	2,054	205,394	116%
Solar Thermal (Thm)	843	84,300	635	63,542	75%

	Ex Ante Savings		Ex Post Savings		
Savings Component	**(kWh, Thm)**	**(kBtu)**	**(kWh, Thm)**	**(kBtu)**	**Realization Rates**
Total Gas (Thm)	2,617	261,706	2,689	268,935	103%
Grand Total (kBtu)		474,898		492,677	104%
% Savings over Code		55%		46%	

Note: The ex post analysis saw an increase in the code baseline energy consumption that decreased the relative size of the savings over code.

The following observations were made during the course of the evaluation:

- Building ownership has changed multiple times since project completion. New owners are not nearly as familiar with building operation as the original owners. A direct result of this is suboptimal summer boiler operation. New ownership left the boilers running because they didn't understand the controls sequence. Approximately 40% of the annual gas use could have been avoided by using the solar thermal array in place of the boiler to meet summer heating loads.
- The manager, who lives on site, stated that there is no need for heating during winter due to the tightness of the building envelope. In summer however, the building overheats, even though it is designed with cross breeze ventilation when operable windows are opened.
- A display in the lobby of the building shows each occupant's weekly energy usage compared to the target energy use. The manager stated that this has a direct impact on how much occupants use. Although there is a likely benefit, this impact could not be quantified.
- Large gaps exist in historical data for the building. This should be corrected as it is critical to understanding long-term energy trends at the building.
- A measure that changed the size of operable windows to avoid installation of plug-in air conditioners appears ineffective, because of advances in air conditioner offerings in the marketplace. Newer air conditioners often contain a small exhaust hose that can be installed in almost any size window. Regardless, residents are strongly encouraged by management not to use these devices, and no resident is currently using them.

This project performed well, with the only significant reduction in evaluated savings coming from less-than-expected solar hot water energy, which was offset by the better-than-expected performance of PV and gas measures. However, gas use could have been greatly reduced by monitoring the boiler control sequence.

5. Recommendations

This section describes recommendations developed as a result of the issues encountered during the engineering review and impact analysis processes.

5.1. Data Integrity

Data plays a critical part in meeting the goals of any energy efficiency program. It is especially important for net zero programs. PTNZ program energy savings goals are far more aggressive than for conventional programs, and even a small increase in energy can significantly impact whether or not these goals are met. Data allows building owners to quickly detect rises in energy, identify the causes, and ensure that applied solutions are working.

Data issues were discovered at each of the six evaluated sites. The following recommendations are meant to improve how the program handles both M&R data (which pertains to whole building and end use energy such as lighting, HVAC, etc.) and control system trend data (which pertains to detailed system operation such as fan speeds, temperature setpoints, daylighting, control, etc.).

- Currently, although the program requires periodic checks (sometimes quarterly) of M&R data throughout the 18 month reporting period, data quality issues were encountered with data stored during this period. We recommend improving the methodology used to check M&R data during this period. This could include more frequent checks to ensure that valid data is being stored, a closer examination of the reasonableness of the data, or comparison of accumulated M&R data with concurrent utility billing data. These activities could also be incorporated into the site commissioning plan in order to facilitate implementation.
- We also recommend strongly encouraging customers to keep the M&R system active and functioning beyond the current 18 month requirement in order to facilitate the maintenance of energy savings. This could be encouraged by educating customers about the advantage in energy savings of maintaining the system. The same methodology used by Energy Trust to ensure data validity during the 18 month period (with the improvements noted above) could be adopted by the customer.
- In general, sites should be encouraged to regularly check all historical trend system data (M&R and otherwise) to ensure continued integrity. Sites should also be encouraged to maintain historical control system trends of 15-minute interval data for at least a year in order to capture building operation during all conditions. Sites should be educated as to why this is important, and the benefits of monitoring their historical trend systems regularly (as well as the negative impacts of not doing so).
- M&R did not extend to natural gas. Due to underperformance of gas measures and data issues at many of the sites, consider offering an M&R option for gas, which would install gas meters on major equipment such as boilers and domestic hot water heaters, and would record gas usage at 15 minute intervals similar to how electric M&R is currently being accomplished.

5.2. Integrated Building Management System Practices

Discussions with site property management personnel and the survey given to site personnel demonstrated a wide range of building management practices and engagement levels that inherently affect the persistence of savings measures. At one site, the controls contractor and building management worked closely together to maintain system performance, while at another site, the building management was not fully aware of typical system controls, resulting in unnecessary summer boiler operation. Additionally, some features of these advanced buildings provide unusual challenges for maintenance staff in their day-to-day work, resulting in specialized vendors having to be called in to facilitate standard maintenance.

We recommend developing measures and resources that support building management in sustaining building performance, including the following:

- Identify and support advanced system maintenance trainings specifically tailored to new technologies for building maintenance staff to ensure sufficient site expertise throughout the life of the measures installed. This is especially important for sites that experience building management changeover.
- Encourage site staff to conduct periodic walkthroughs that check on key measures; this ensures that tenants continue to use best practices. Some of the projects have involved measures whose effectiveness relies on good tenant education and regular communication with building management staff.
- Encourage site staff to collaborate with their controls contractors in actively managing building performance. This may include the controls contractor directly monitoring performance and reporting regularly to site staff, or setting up a system that alerts staff to abnormally high energy usage and other performance indicator abnormalities. Enlisting the help of controls contractors is important because in most cases they are more familiar with the complexities of building operation than the site staff.
- Support and encourage building design teams to minimize building maintenance complexity and requirements. One important design feature would be maintenance accessibility to key systems. In one site in particular, maintenance of system performance was inhibited by a building design that made the system difficult to physically access resulting in costly and time consuming maintenance that required specialized vendors.

5.3. Maintenance of Effective Practices

This recommendation is based on which practices evaluators identified as being the most effective during the PTNZ pilot. We recommend that these practices be maintained in the future to help ensure the success of the program going forward.

- Technical reviews were found to be a thorough review of energy calculation methods, inputs, and assumptions. The reviews ensured that pre-occupancy energy models and calculations were of good quality. The format and layout of the technical review memos presented information clearly and helped in isolating specific issues and responses.

5.4. Energy Modeling Methodology

Energy modeling methodologies employed by the pilot were found to be sound. The one area for potential improvement relates to calculation of both project level and measure level savings. The pilot used a rolling baseline method to determine measure level savings, in which measures are added one at a time to the baseline model, and savings calculated in steps as each measure is added.

This could be improved upon by using the full interactive model (all measures included) to calculate both total project and individual measure savings. Savings by measure can be accomplished with the interactive model using a "last in" approach in which the measure of interest is removed from the full interactive model to create the baseline condition for the measure. This ensures that interaction with all other measures is accounted for. Note that this method could potentially impact measure cost-effectiveness.