Con Ed Multifamily Program One-Pipe Steam Expanded Literature Review Findings

West Hill Energy and Computing

Executive Summary

ES.1 Objective & Scope

The purpose of this study is to provide recommendations for modifications to the program approach and guidelines to improve the efficiency of one-pipe steam systems.

Con Edison's current suite of steam energy efficiency measures (EEM's) are all well-established methods of achieving savings in one-pipe steam buildings[1].

However, realizing savings has been challenging. The results of WHEC's billing analysis performed on one-pipe steam measures for Program Years 2017 and 2018 indicated virtually no savings, despite significant cost and effort.

This study builds on the previous data and literature review and adds greater specificity to the recommendations.

Tasks included the following:

- **Performing a more in-depth literature review** of studies, papers and best practices including interviews with subject matter experts.
- **Researching similar programs and/or sector strategies** including NYSERDA's MF program, NYC's Green Housing Preservation Program (GHPP) and Accelerated Conservation & Efficiency Program (ACE), and other state EE programs with similar buildings and heating systems.
- **Develop guidelines** to improve outcomes for Con Edison's One-pipe steam program

1. See References at end of Report

ES.2 Findings

The overall approach of Con Ed's One-Pipe Steam program needs to change in order to have a chance at success.

Findings

- The literature review and interviews with industry experts indicate that Con Ed is generally targeting what are regarded as the correct one-pipe steam (1PS) measures.
- One-pipe steam systems are a special area of expertise. Each system must be assessed and treated comprehensively, and improvements need to be implemented in the correct order, to ensure success.
- While there are many elements in the current program that align with our findings, the current structure incentivizes hardware installation, discourages comprehensiveness, and lacks controls for follow-through.

Conclusion: The literature review and interviews with industry experts indicate that the current prescriptive approach will not be effective for one-pipe steam systems.

Possible Paths Forward

Change approach to assure comprehensiveness and modify incentives/processes accordingly:

- Have pre-qualified steam experts perform assessments, with Willdan documenting.
- Make easy-to-do changes during assessment.
- Keep steam expert involved to oversee other contractors as needed (adding vents/TRVs/EMS).
- Ensure rigorous close-out process by the steam expert who performed the assessment.
- Incentivize all parties to persist and complete the job.
- Use deemed savings (vs. building by building), developed via pilot program.

ES.3 Overview of Comprehensive Approach

The literature review and interviews with experts identified the following steps that need to be implemented, in order:

1. Lower steam pressure if it is too high (per multiple sources, including Willdan's assessments, 0.5 to 1.5 psig is the ideal range; higher pressures will not allow TRVs to operate)
2. Add boiler control systems where required – boiler controls should be installed at the same time as other measures, so that the systems function properly together
3. Calculate the required venting, assess what is present, and provide more vents only if needed; check that all vents are operating correctly
4. Correct near-boiler piping configuration, as needed
5. Tune the burner; clean the boiler (annually), flush the pipes
6. Balance the system, from the boiler to the radiators vents
7. Provide TRVs for overheated apartments after balancing the system and *only if needed*
8. Relay the changes that were made and their importance to the super and tenants to ensure they produce persistent results; otherwise, tenants or the super may turn settings back to where they were or disable or remove devices

Improving steam heating efficiency requires expertise, access, good communication from implementer to tenants, time, and a comprehensive understanding of the building's heating issues. *" You need a caliper, charts, skill and time".*

Interview with , October 16, 2019

ES.4 Summary of Recommended Program Changes

Program Component	Current	Proposed	Comments
Recruitment	Unknown	See recommendations on slide 4.2	There is substantial, effective experience nationally that can be drawn upon.
Site Assessment	Detailed data collection	Expert will evaluate, make some changes immediately and develop SOW as needed. Willdan could accompany and document; go straight to installation based on SOW.	Eliminate step in which a separate contractor needs to visit; faster implementation, fewer players, possibly fewer site visits, lower costs
Data Collection	Good, but lack of in-unit access hampers key data collection	Focus on in-unit access	While in-unit access is an acknowledged challenge, there are successful experiences to draw upon.
Savings Estimation	Highly detailed, time consuming, inaccurate	Use billing analysis to estimate deemed savings	Saves time, improves accuracy
3rd Party Desk Reviews	Desk reviews are done; results not always used	Eliminate desk reviews	Reduces costs
Installation	EEMs are reasonable but need to be comprehensive and have EEMs installed in the correct order.	After initial visit's adjustments, vents, TRVs, and/or EMS can be installed if needed by current contractors *under expert's oversight*. Ensure FULL implementation of SOW.	Identity root issues to ensure that upgrades will be effective
Inspection	Conducted, but follow up is unclear. In unit access is limited.	More rigorous, use expert; wider in-unit access needed; set up specific protocols for inspection follow up	Verify system is working, not just that EEMs were installed.
Incentives	Per measure	Not-to-exceed limit on direct action; could have initial incentive based on SOW with bonus for installing everything	Substantial incentives were paid in 2017/2018 for uncertain savings. Revise approach to encourage comprehensive installations.

Introduction

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This study builds on the previous data and literature review and adds greater specificity to the recommendations.

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Tasks included the following:

- **Performing a more in-depth literature review** of studies, papers and best practices including interviews with subject matter experts.
- **Researching similar programs and/or sector strategies** including NYSERDA's MF program, NYC's Green Housing Preservation Program (GHPP) and Accelerated Conservation & Efficiency Program (ACE), and other state EE programs with similar buildings and heating systems.
- **Develop guidelines** to improve outcomes for Con Edison's One-pipe steam program

1.2 Background

The Con Ed one-pipe steam program targets an historically inefficient component of multifamily buildings where there is potential for large reductions in gas use.

Currently, one-pipe steam systems are present in half of New York City's residential floor area.[1]

- A large proportion of multifamily buildings in New York City were built in the early 1900's.
- These buildings were commonly heated with one-pipe steam systems and coal-fired boilers.
- Gradually coal-fired boilers were replaced with oil or natural gas boilers. However, these newer boilers react to demand much more quickly and existing distribution piping was often not modified to accommodate the new equipment[2].
- Mismatch between boiler and the distribution system can cause wet steam, uneven heat, short cycling and/or water hammering.
- In addition, modern boilers are built differently, and this can also cause or contribute to these problems.
- Typically systems were modified numerous times over the years to try and address these problems, often with incomplete success[2].

Con Ed's 1PS initiative packages a number of measures together with an in-depth initial assessment in order to address this potential.

However, finding savings has been challenging. The billing analysis for PY2017-2019 found that *ex post* savings are 3% +/-3% of pre-install use.

Substantial incentives were disbursed in order to achieve this level of savings for the 145 projects analyzed.

The MF building sector in New York City is unique and possesses significant challenges that other EE programs do not. Success will require a similarly unique approach.

1. "Demystifying Steam Report", Urban Green Council, 2-12-2019
2. Numerous sources, see References at end of Report.

1.3 Comments on the Prescriptive Approach

The literature review and interviews with industry experts indicate that *the prescriptive approach will not be effective for one-pipe steam systems.*

- Steam systems are not complex, but they are a special area of expertise.
- Each system must be assessed and treated *comprehensively.*
- Improvements need to be implemented in the *correct order*, to ensure success.
- Each building's system is different.

Therefore, a custom, comprehensive approach is needed *for each building.*

A prescriptive approach with multiple players of limited experience and limited authority, based on incentives per device installed, will not be effective as it does not address the whole system. However, a change in approach need not be costly.

According to steam expert , fixing a decades-old steam system is often less about putting in new equipment than it is about removing items added over the years, in order to return the system to its original, working state.

The initial assessment by a reputable steam expert (which should include immediate pressure adjustment and burner tuning) generally requires 2-3 hours, possibly up to 6 hours in a building with particularly hard-to-access areas or complex piping. Recommended venting or EMS would be an additional cost.

1.4 Recommended ECMs for One-Pipe Steam Systems

The literature and interviews with industry experts indicate the following measures are recommended for one-pipe steam systems, in combination as needed, and installed in a specific order.

Recommended Measure	Description
Boiler Control System (EMS)	Upgrading the boiler control system to include both in-unit and outdoor air temperature sensors at the same time as other measures are installed.
Correcting "near-boiler" outlets and headers; ensure piping is properly insulated	This measure ensures that steam entering distribution piping is always "dry" (no entrained water due to undersized piping, inadequate elevation, etc.) Insulation is also critical to save energy and ensure the steam reaches the destination before condensing. The industry norm of 1" insulation thickness is not adequate.
System Balancing	This term always includes ensuring adequate main, riser, and radiator venting, and often includes a recommendation to reduce system operating pressures to 0.5 – 1.5 psig. It can also include correcting near-boiler piping and adjusting burner settings.
Thermostatic radiator valves (TRV's)	This measure is the addition of TRV's to individual radiators in overheated rooms as determined after the system is balanced.
Domestic Hot Water: Adjust or replace mixing valves or add separate domestic hot water heating	If hot water is supplied by the boiler, non-winter operation is at very low efficiency. This can be compounded if the mixing valve has failed or its temperature setpoint is too high. The mixing valve can be adjusted or replaced to save energy. A more expensive alternative is to add a separate domestic hot water heating system that will operate at higher efficiency year-round, allowing the boiler to be shut down during the summer.

REFERENCES:

1. Holohan, Dan. (2010). Greening Steam: How to Bring 19th-Century Heating Systems into the 21st Century.
2. Measure Guideline: Steam System Balancing and Tuning for Multifamily Residential Buildings, Jayne Choi, Peter Ludwig, and Larry Brand, Partnership for Advanced Residential Retrofit, US DOE, April 2013
3. Improving Steam Performance, US DOE OIT
4. Demystifying Steam Report, Urban Green Council, 2-12-2019

Current Program

2.1 Overall Review of Con Ed 1PS Program

Con Ed is generally targeting what are regarded as the correct one-pipe steam (1PS) measures. Some of the recommended measures are already in the MF Program.

Recommended Measure	Currently in CE MF Program[1]	Notes
Boiler Control System (EMS)	#10. Energy Management System	Separate measure rather than installed as part of 1PS package
System Balancing & TRVs	#2. Master & Riser Air Venting #5. One-Pipe Steam Radiators (includes master & riser vents, TRVs, boiler clean & tune)	Venting is part of system balancing, but system balancing also involves additional work, such as ensuring that all radiator vents are operating properly.
TRVs	#5. (above) and #4. Thermostatic Radiator Valves	In-unit access can be difficult but is necessary to achieve a comprehensive upgrade.

In addition, these Willdan audit activities and recommendations are supported by our research:

- Checking for near-boiler piping waterline-to-header minimum distance
- Calculating distribution system volume in order to correctly specify venting
- Checking and adjusting system operating pressures
- Boiler "Clean and Tune"
- Checking for adequate pipe insulation[2]

However, measures are installed individually and do not appear to be recommended, installed, or adjusted to address the system holistically. For example, radiator venting do not appear to be comprehensively addressed. While it is relatively straightforward to clean a boiler, tuning a burner appears to require some skill. Its unclear if burners are properly tuned and there is no documentation of specific actions.

In general, there do not appear to be incentives or other protocols in place to assure that settings are adjusted properly, to verify that the building is performing as intended, or to follow-up on recommended capital projects (such as new boilers or EMS) with owner/managers.

1. https://www.coned.com/en/save-money/rebates-incentives-tax-credits/rebates-incentives-for-multifamily-customers/equipment-rebates-for-multifamily-buildings
2. Though we would recommend greater thickness of insulation

2.2 Review of Program Process Flow

Based on our review of the program materials submitted to the SMART database, a broad outline of the steps in the 1PS program are as follows.

1 Site Assessment

Customer is identified and agrees to consider a proposal. → Willdan conducts a site assessment which focuses on the program's measures. → A contractor visits the site. Savings are estimated using the Willdan 1PS tool.

2 Desk Review

A Desk Review of the projected savings is performed by a 3rd party engineer. → If the estimated savings meet a certain threshold, incentives are offered on a per-measure basis. → If the customer agrees to proceed, a contract is signed.

3 Inspection

The measures recommended in the site assessment report are installed. → A post inspection is conducted. → An incentive is issued.

2.3 Review of Current Program Steps

While we recommend using a comprehensive implementation approach, we reviewed the current program to identify areas that may be causing lower savings and found a few possibilities.

Program Step	Advantages	Disadvantages
Site Assessment	Follows good general engineering practice. Collects key information needed for thorough assessment.	Details can be confusing, and template may not be understood by implementers.
Calculation of Savings	Provides an estimate of savings	Time consuming. Many inputs are collected, but the keys savings calculation is based on meeting a constant setpoint of 72°F in all unit. Very few units are accessed to determine which are overheated (and may need TRVs).
Desk Review	Desk reviews highlight some critical issues.	Desk Review comments and concerns do not appear to be addressed consistently.
Installation	Seems adequate for those measures installed	Sometimes key recommended measures are not installed or performed, such as pressure setting adjustments. It does not appear that radiator vents are being assessed and/or replaced to complete system balancing.
Inspection	Seems adequate for those measures inspected	Very few units are accessed to verify TRV installation, effectiveness.
Follow-up	Unknown	Consequences for measures not installed or not properly installed are apparent.

The above steps are the main areas with issues. The following pages review each program step in detail.

2.4 Review of Site Assessments

Overall, the Willdan site assessments appear to be set up with a good framework for collecting information, but information is not being captured in a clear and consistent way.

The form is set up correctly to capture near-boiler piping, insulation levels, quantity of radiators, and pressure control levels. Pipe volume and ventilation calculations are also performed. These are the correct items to consider, as mentioned in the literature and our interviews.

However, there is significant variation in the way items are documented between reports. For example, labelling and description of setpoint controls on pressure control devices can be particularly confusing. It sometimes appears the site assessor may not understand the intent of the controls, as shown in the table from a 1PS report below. For future program work, all settings and controls should be well documented to understand what is working.

Pressure Control	Type	Control	Setting (psi)	Diff.	Differential (psi)
1	Vaporstat	Operational Range	N/A	Subtractive	N/A
2	Pressuretrol	Operational Range	2	Subtractive	Min
3	Pressuretrol	Operational Range	6	Subtractive	2
4	Pressuretrol	Manual High Pressure Reset	10	N/A	N/A

This table does not show how the control strategies and setpoints interact, whether the control mode is recorded correctly[1], or if some controls are redundant. The report does not make any recommendations for adjusting settings or the criteria that should be used to select the most appropriate settings beyond a standard comment in the Incentive Recommendations table. Providing setpoint recommendations with an explanation is a key component to resolving steam heating system issues. Also, photos are sometimes too out-of-focus or dark to determine the settings or make and model information.

[1]It does not appear to be as there should be a modulating burner control.

2.5 Review of Savings Calculation

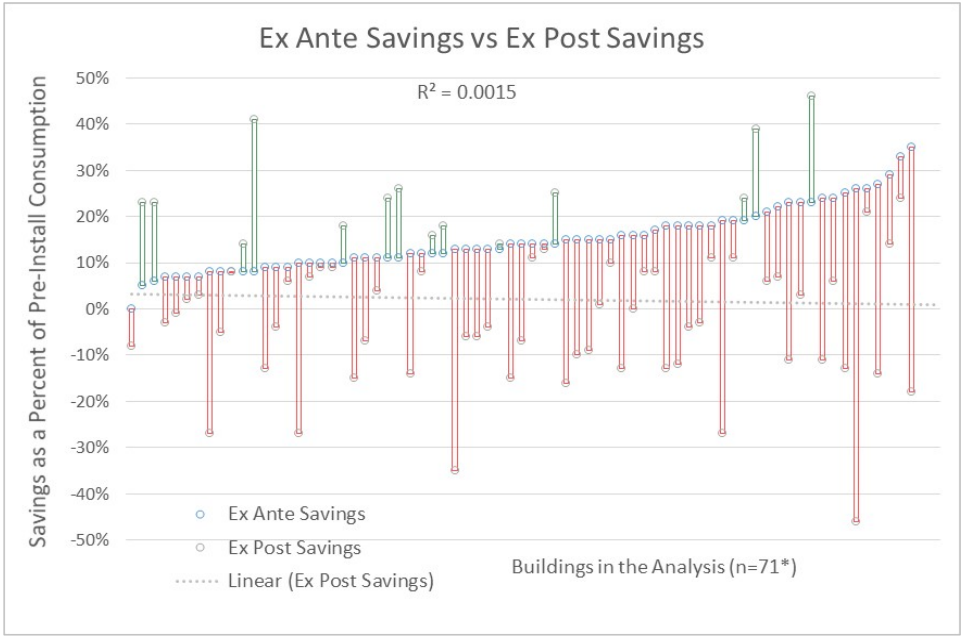
The Willdan 1PS tool is detailed and has over 100 inputs, information gathered during an extensive site assessment. However, the calculation of savings is driven by **one central assumption**:

The building is overheating and will be restored to 72°F after the measures are put in place.

This is a flawed assumption. The graph below, based on the billing analysis, shows no clear correlation between ex ante savings and evaluated ex post savings in the current program. The blue markers on the graph represent ex ante savings sorted from lowest to highest, and the grey markers represent the associated ex post savings for each ID from the billing analysis. The red line indicates ex post savings were lower than ex ante savings and the green line indicates they were higher.

There is no way of knowing if improving each system will have energy savings or improved comfort.

As it is difficult to accurately estimate savings in individual buildings, we recommend using billing analysis to develop savings for the 1PS package as a whole and developing deemed savings from this analysis.



*One building was removed from this graph for visibility as the savings were more than 100% greater than the *ex ante* savings as a percent of pre- consumption

> "No two systems are alike, and many hands have touched them over the years."
>
> Interview with , October 16, 2019

2.6 Review of Third-Party Desk Reviews

The 3rd party desk reviews provides a high-level check on a flawed savings calculation method. Also, the recommendations in the report do not appear to be used by the program.

In an extract from one review[1], shown below, the reviewer explicitly stated that savings should not be considered acceptable, but the project went ahead using these savings. Additional detail on the assumptions used in the savings methodology are also shown in the screenshot of the report below.

Since each system is different and reliably predicting savings per site is not feasible, significant effort could be saved by eliminating this step.

3. SUMMARY

- The proposed calculations and estimated savings should be not considered acceptable due to the calculation baseline exceeding the utility baseline.
- The Master Venting measure accounts for most of the project savings and is heavily dependent on the observed space temperature of 79°F.
- The calculation spreadsheet file provided was consistent with the savings calculation guidelines.
- The savings in the analysis are based on returning the building to near-optimal temperature control. The measure is "Master Venting and TRV" and implies that both aspects must be

Sample size of 2 with high variability (shown in image

Assumes building will return to 72F in all cases.

The total savings are a significant percentage of the baseline. The project is intended to lead to a large improvement in the heating conditions. The savings percentage *is unreasonable* due to the lower calculated baseline.

Apartments			
Apartment	Type	Floor	Temperature (°F)
6K	2 Bedroom	6	73
6A	1 Bedroom	6	85
Average			79

1. In this extract of the review, notes and underlines were added in red to draw attention to portions of the report.

Technical Details of a Comprehensive Approach

3.1 Overview of Comprehensive Approach

The literature review and interviews with experts identified the following steps that need to be implemented in order:

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Interview with , October 16, 2019

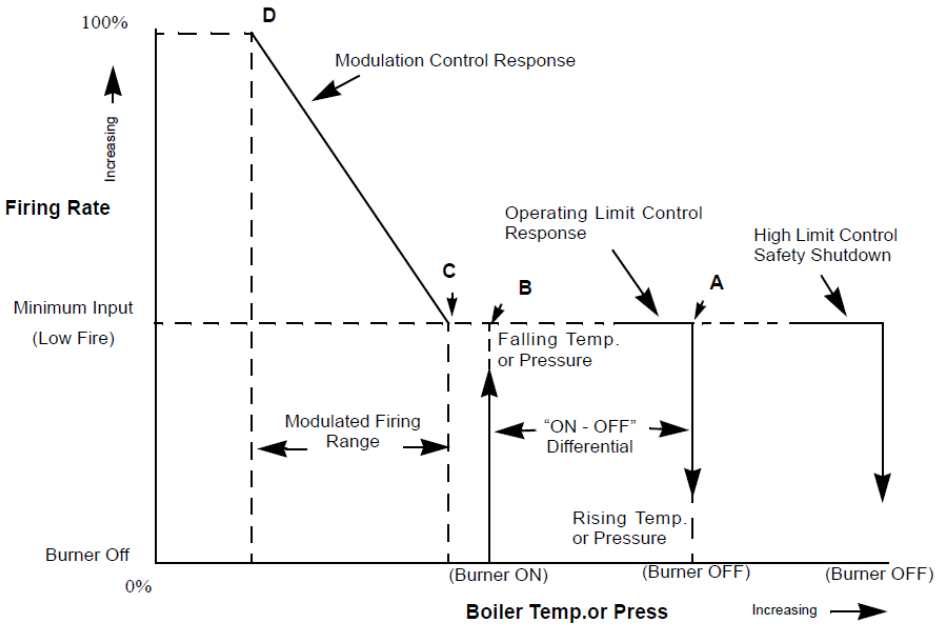
3.2 Setting the Correct Steam Pressure and Boiler Modulation

When three pressuretrol controllers are present, they usually control in the following manner and should be adjusted as described below. It should be verified this is the intended control before adjustments are made.

1. **Operating Limit Pressuretrol** –Turns the burner on and off based on pressure (points A and B on the control diagram). Typically set to turn the burner on at 0.5 PSI (Point B) and off at 1.5 PSI (Point A).

2. **Modulating Pressuretrol** – Modulates the output of the burner between points C and D of the control diagram. Typically set to be in low fire when the operating limit control turns the burner on and off[1]. Using the example operating limit pressures above, point C should be at about 0.4 psi and D should be set to the lowest pressure available.

3. **High Pressure Reset** - Turns burner off in the event the operating limit controller fails (far right of graph). The reset should be set to a pressure slightly above the operating limit controller and below 90% of safety valve rating.

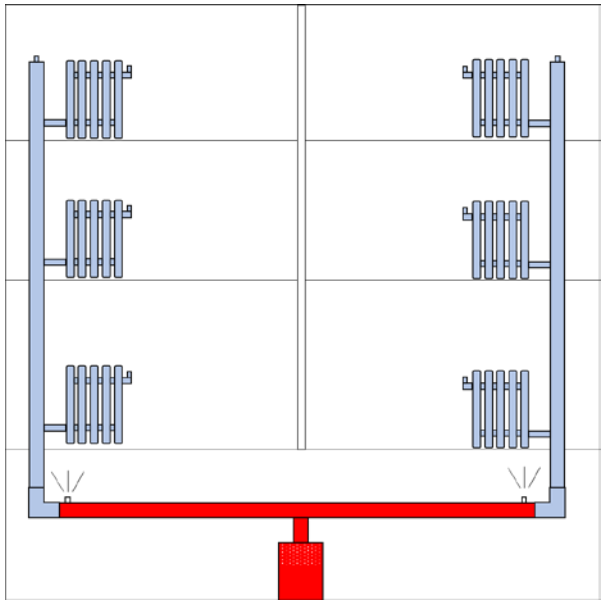


From: Cleaver Brooks Operations Manual, http://cleaverbrooks.com/products-and-solutions/boilers/firetube/icb/ICB%20Operating%20and%20Maintenance%20Guide.pdf, page 84

1 The modulating range should not overlap with the operating limit range as shown by distance between B and C

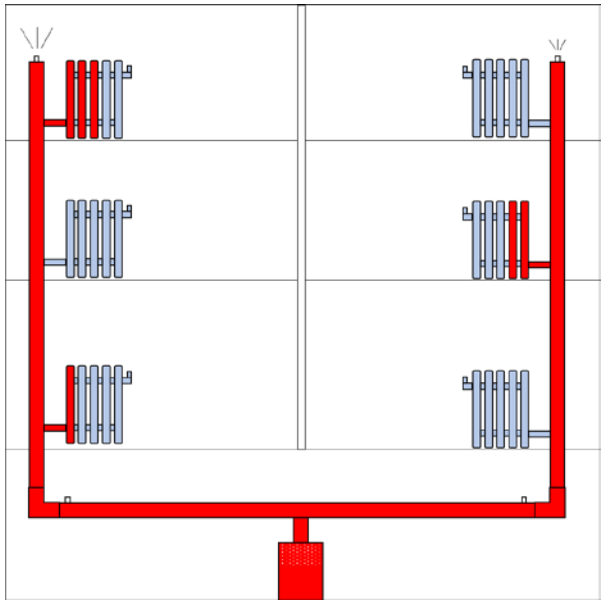
3.3 Balancing a Steam System

Balancing is a multistage process. A thorough assessment must first be conducted. For example, insufficient venting, large differences in steam arrival times, excessively short boiler cycles, lack of zone control or temperature averaging, lack of pipe insulation, and variable steam main lengths can all contribute to uneven heating in a building.



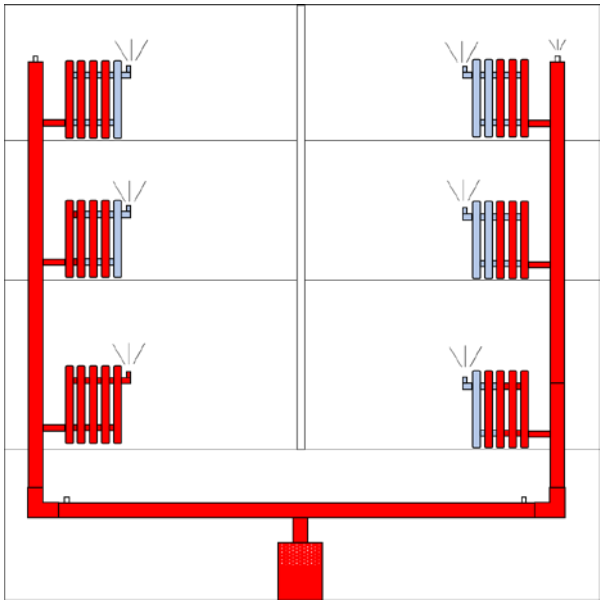
Near-Boiler Piping & Main Vents

If near-boiler piping is run correctly, pipe insulation exists, and main venting is adequate, steam will fill the main steam lines, but will not move up risers if riser vents are non-functional



Riser Vents

If riser venting is adequate, steam fills the riser lines. If it is not adequate, the steam will stop or arrive slower.



Radiator Vents

If radiator vents are non-functional, living spaces still get little or no heat

Only when main, risers and radiator vents all function correctly will the system bring balanced heat throughout the building.

Right-Sizing Near-Boiler Piping

The quality of steam exiting the boiler is crucial to improving overall system efficiency. If the steam is too wet, *i.e.*, contains water droplets, it leads to noisy pipes, spitting air vents and wasted fuel.

The boiler's steam outlet is critical to making dry steam. Modern boilers are so much smaller and faster acting than the old coal boilers that many steam distribution systems in older NYC buildings were built for.

In particular, the stock outlets on larger,[1] modern boilers should never be used to size the riser/header, as that will cause steam to flow too quickly out of the boiler and suck water with it. When these boilers run at full fire, wet steam carries so much water that they shut down and then cycle, with uneven heating, spitting vents and water hammering as the result.

These steps are required to avoid this situation:

- Correct boiler riser sizing
- Correct header sizing
- Correct header and takeoff configuration
- Correct distance from boiler water line to lowest horizontal steam line

The scope and cost of making these corrections will vary widely from site to site.

From: Holohan, Dan. (2010). Greening Steam: How to Bring 19th-Century Heating Systems into the 21st Century.

[1] Over 100 boiler horsepower

TRVs

- System pressure must be in the 1psi range or TRVs will not work.
- The system must be balanced first: main, riser and radiator vents must be properly sized and operating or TRVs will not work and may make any existing problems worse (uneven heating, water hammering) [1].
- TRVs must have a built-in vacuum breaker.
- Straight shank air vents (usually a new one) should be screwed into the TRV valve body.
- Inlet stem packing should be checked to ensure it is not leaking; otherwise, air enters the radiator and the TRV malfunctions.
- Only install TRVs in rooms without EMS in-unit temperature sensors. Installing TRVs in rooms with temperature sensors can cause a controls conflict.

Modulating Burners

- The incremental up-front costs of better burners can usually be paid for with a single season's worth of fuel savings, and tenants' comfort will be improved because steam systems work better with modulating burners. They need to be properly tuned on an annual basis.
- It takes time and skill to adjust a modulating burner correctly.

1. Master vents sized for the distribution system risers can be added to top floor radiators located off of each building riser; see https://heatinghelp.com/systems-help-center/rethinking-trvs-for-steam-systems/
2. "Demystifying Steam Report", Urban Green Council, 2-12-2019, page 9

Implementation Recommendations

4.1 Comprehensive Implementation Approach

A comprehensive implementation approach is needed to garner savings. A full understanding of these unique systems is critical to achieve savings.

1. **Identify heating system contractors experienced with steam** to perform comprehensive system audits:
    a. HeatingHelp.com List of NYC-area Contractors
    b. Comprehensive site assessment
    c. Develop scope of work

Authorize them to implement upgrades at the time of the site assessment up to a not-to-exceed cost (such as $6,000).

2. **Heating system contractor does oversight of work.** Existing contractors could be used for some tasks, such as installing vents and EMS, as authorized by and under the supervision of the heating system contractor.

3. **Inspection is needed to verify system is working correctly.** A different heating system contractor should conduct the inspection. The inspection should cover verifying that the system is balanced, running at low pressure and distributing heat evening throughout the building. Protocols for follow up from inspections should be developed and enforced.

4. **Coordinate closely with building owners to get tenants onboard to access apartments.** Access is required to balance the system and achieve savings.

5. **Per-item incentives should be eliminated.** Savings are achieved when the system functions as a whole. Installing more items could result in lower or no savings. Program costs could be lowered from the current approach by targeting the appropriate devices to install (or simply adjust) to improve the system, and higher savings should be realized on average.

Review incentive structure to make incentives based on comprehensive approach. Develop incentive structure to promote comprehensiveness, such as an initial incentive based on the SOW and a bonus for installing all measures.

6. **Develop deemed savings from pilot redesign.** No two steam systems are alike, and there is tremendous variability between buildings. A billing analysis should be conducted using all buildings in the pilot and deemed savings should be developed as a percent of pre-install heating use. This approach will save a substantial amount of time and effort.

4.2 Outreach – Broader Approach to Owners/Managers

Streamlining access to program and services has been shown to reduce market confusion and perceived high transaction costs. A single point of contact can be assigned for owners/managers to enroll and as an on-going resource throughout each project from beginning to end. Suggestions from other programs are provided below.

Leverage established networks of state and local housing organizations to market and deliver programs.

Partner with trade allies, such as associations of apartment owners and property managers; these groups are familiar with the multifamily housing stock and its ownership and investment structures.

Partner with Owner/Managers of multiple properties for early and visible successes that encourage imitation

Deliver effective messages that demonstrate clear value with actionable guidance. Investments and changes to properties must yield benefits to owners and residents that ***they*** value.

*The primary objective of property management is to ensure that the multifamily building is sufficiently marketable in order to maintain a high level of occupancy. As such, energy savings is not the sole or even primary driver…**

*….of many of the multifamily renovation/rehabilitation projects the MPP has funded." from Multifamily Performance Program Impact Evaluation (2009–2011), by ERS for NYSERDA

Non-energy Benefits to Owners/Managers

- Reduced maintenance costs
- Improved equipment performance and lifespan
- Greater property value
- Increased building durability
- Increased resident comfort, health, and safety
- Increased tenant retention
- Competitive advantages in real estate markets from low energy costs and associated green building attributes
- Preparation for future changes such as economic fluctuations, volatile fuel prices, and new building codes

REFERENCES:

Reaching More Residents: Opportunities for Increasing Participation in Multifamily Energy Efficiency Programs, May 2016;) and More Savings for More Residents: Progress in Multifamily Housing Energy Efficiency, February 2017; American Council for an Energy-Efficient Economy (ACEEE)

Engaging as Partners in Energy Efficiency: Multifamily Housing and Utilities, January 2012, Center for Neighborhood Technology (CNT)-Energy and ACEEE

4.3 Outreach – Accessing Tenant Units

Accessing all apartments is crucial to the success of balancing and saving energy, requiring working closely with landlords to coordinate visits and promoting the rewards to all tenants by improving the system (lower fuel use, less over- or under-heating, greater comfort). Some insights from other programs and steam experts are discussed below.

- **Unit locations and building layout are important** to consider when assessing and balancing a building. Each building will have different hot and cold spots and will require different venting configurations and placement of control sensors. In-unit access is necessary both during the assessment stage and during implementation.

- **Tenants and building managers need to be informed about the balancing process and that its success will require time and cooperation.** Tenants should be educated to not throttle their radiator valves (this will undo balancing), that the boiler is triggered by an averaging of space temperatures, and balancing work will require their cooperation and occasional access to their units. Building managers should be properly instructed about how to use the newly installed controls.

- **Tenant outreach should be carefully planned.** Allow enough notice to reach all tenants and ensure that outreach materials are in the appropriate languages. Use various venues to reach tenants, including electronic and hard copy notices. Dispense with the need for signatures. Ensure explanatory materials are left with tenants.

- **Educating owners and building operations staff** is essential. Relay the changes that were made and their importance to the super and tenants to ensure persistence of results so that tenants or super will not turn settings back to where they were or disable/remove devices.

Effective outreach to owners/managers paves the way for in-unit access.

4.4 Inspection

The main issues with inspections appear to be a lack of adequate protocols to follow up on issues.

Lack of access to units

Without access to units, temperatures cannot be sampled, venting cannot be verified, and the installation or effectiveness of TRVs cannot be evaluated.

Lack of adequate controls/protocols

If certain key measures are not implemented, or implemented incorrectly, then other measures may not be effective.

- Some approved recommendations were not implemented or not done as directed, but there does not appear to be a clear path to correction, completion, or follow-up.
- TRVs and main vents seemed the most consistently installed measures but installing TRVs without proper (low) pressure settings means they will not operate.
- Pressure adjustments as documented in inspection reports seemed particularly opaque and confusing.
- Its unclear what if any follow up is done to ensure measures are completed and/or corrected.

Steam system upgrades are fundamentally different from prescriptive ECMs such as lighting, in which a missed fixture in one area will not negate savings elsewhere. A much more rigorous close-out process is required.

4.5 Summary of Program Changes

Program Component	Current	Proposed	Comments
Recruitment	Unknown	See recommendations in 4.2	There is substantial, effective experience nationally that can be drawn upon.
Site Assessment	Detailed data collection	Expert will evaluate, make some changes immediately and develop SOW as needed. Willdan could accompany and document; go straight to installation based on SOW.	Eliminate step in which a separate contractor needs to visit; faster implementation, fewer players, possibly fewer site visits, reduces costs
Data Collection	Good, but lack of in-unit access hampers key data collection	Focus on in-unit access	While in-unit access is an acknowledged challenge, there are successful experiences to draw upon.
Savings Estimation	Highly detailed, time consuming, inaccurate	Use billing analysis to estimate deemed savings	Saves time, improves accuracy
3rd Party Desk Reviews	Desk reviews are done; results not always used	Eliminate desk reviews	Reduces costs
Installation	EEMs are reasonable but need to be comprehensive and have EEMs installed in the correct order.	After initial visit's adjustments, vents, TRVs, and/or EMS can be installed if needed by current contractors *under expert's oversight*. Ensure FULL implementation of SOW.	Identity root issues to ensure that upgrades will be effective
Inspection	Conducted, but follow up is unclear. In unit access is limited.	More rigorous, use expert; wider in-unit access needed; set up specific protocols for inspection follow up	Verify system is working, not just that EEMs were installed.
Incentives	Per measure	Not-to-exceed limit on direct action; could have initial incentive based on SOW with bonus for installing everything	Substantial incentives were paid in 2017/2018 for uncertain savings. Revise approach to encourage comprehensive installations.

GLOSSARY

Pressuretrol – A boiler pressure control device that initiates firing based on steam pressure. This term is that of a particular manufacturer's model which is so prevalent as to be the term commonly used to define all boiler pressure control devices.

Master Riser – The main vertical steam lines branching off the main boiler steam header

EMS – Energy Management System; usually a Building Energy Management system with multiple inputs, outputs and monitoring capabilities. In this case it is used as defined by the Con Ed gas measures program and refers to boiler controls that use in-unit temperature sensors in addition to outside air sensing to control boiler operation.

Boiler Controls – All devices and sensors that control boiler operation, including the burner and its controls as well as in-unit controls such as TRVs

Thermostatic Radiator Valve (TRV) –a self-regulating valve that controls the temperature of a room by changing the flow of steam or hot water into a radiator. When the room temperature rises and reaches setpoint, a capsule in the valve head expands and causes the valve to close. When closed, air cannot be vented from the radiator therefore more steam cannot enter it, preventing overheating. TRVs do not balance systems, but they can prevent overheating in specific rooms.

Header – This usually refers to the main horizontal distribution line in the boiler room. It is part of "Near-Boiler Piping".

Near-Boiler Piping, or Take off Configuration – This refers to the steam piping arrangement connected to the boiler steam outlet. Proper layout is critical to safe and efficient boiler operation, and certain elevations and distances must be maintained. Modern boilers are much smaller than older boilers and there have been issues with wet steam, boiler cycling and water hammer when proper design is not followed. This is also referred to as "Near-boiler piping".

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Con Ed Multifamily Program
One Pipe Steam
Billing Analysis Report

West Hill Energy and Computing

1-Pipe Steam Billing Analysis Table of Contents

1 Objectives and Methods Overview (1.1)

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1 Objectives and Methods Overview

1.1 Objectives and Methods Overview

The purpose of the 1-pipe steam billing analysis was to evaluate natural gas energy savings for the 2017 and 2018 program year activities.

An additional objective of the analysis was to determine realization rates based on the *ex ante* and *ex post* savings

Each project reported by the program consisted of a variety of 1-pipe steam measures including boiler clean and tune, master venting, riser vents, and TRVs.

An overview of the steps used in the billing analysis is provided in the table to the right. Additional detail on each of these steps is provided on the following slides, in the order shown in the table.

Step	Purpose	Method
Results	Compare verified savings to *ex ante* savings	Ratio estimation
Data Preparation	Develop a complete data set with key fields from various sources	Data manipulation
Data Cleaning/ Account Removal	Prepare the billing data and remove buildings with incomplete or poor quality data	Apply criteria for inclusion in model
Billing Model	Conduct modeling and determine characteristics of sample	Building-by-building, 2-stage regression
Verification of Results	Review the results, identify sources of uncertainty, and assess the impacts	*Post hoc* stratification, review of outliers and influential data points, sensitivity analyses

2 Results

2.1 Results – Energy Savings Overview

The realization rate is 20% and the *ex post* energy savings, as a percent of pre-install use, are 3% for all projects in the one-pipe steam billing analysis.

The final results of the billing analysis for the one-pipe steam measures are shown in the table below.

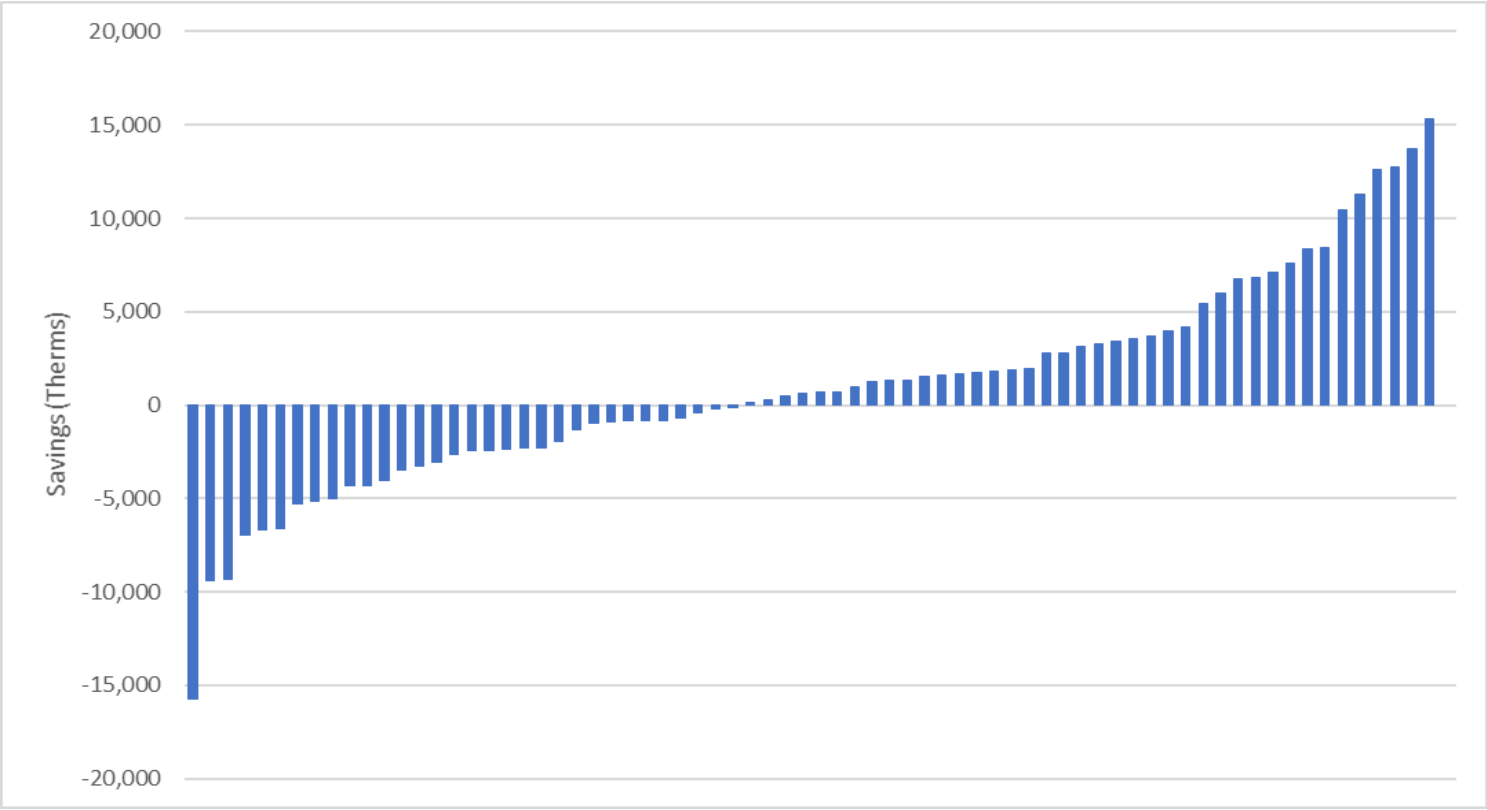
Number of Buildings in the Model	Mean *Ex Ante* Savings	Mean *Ex Post* Savings	*Ex Ante* Savings as a Percent of Pre- Heating Use[1]	*Ex Post* Savings as a Percent of Pre-Heating Use	Realization Rate
72	458.4 Dth	93.5 Dth	15%	3% +/- 3%	20% +/- 24%

1. Pre-use is heating only. *Ex ante* savings as a percent of total pre-install use are 9.1%.

2.2 Results – Savings by Building

The distribution of energy savings for buildings in the final energy model is almost even between those that are using more energy and those that are saving energy.

Although some buildings are showing substantial savings, these savings are being offset by an almost equal number of buildings that are showing substantially more energy usage. The graph below shows all buildings in the final billing analysis and sorts them by savings.



3 Data Preparation

3.1 Data Preparation – Data Sources

To conduct the billing analysis, data from several sources was combined, as shown in the following table. The preparation of this data into the final analysis is outlined on the following slides.

Source	Data Used
Program Data	Measures installed, install date, ex ante savings, account number, address
Billing Data	Consumption, read date, read code, service class code, part supplied code, account number, address, borough, block, lot
NOAA weather data	Hourly outside air temperature, date, hour, station location

3.2 Data Preparation - Program Data

The key variables from the program data were the *ex ante* savings and the installation date of the measure. The way they were used is described below.

The *ex ante* savings were used as the denominator in the realization rate (RR) calculation.

The pre- and post-install periods in the billing data were defined using the install date in the program data and the following definitions:

- Pre-install – The period including billing cycles completed prior to the period 30 days before the first efficiency measure was installed
- Post-install – The period including billing cycles starting approximately 30 days after the last efficiency measure was installed
- Install Period – The period between the pre- and post-install period

Once the pre- and post-install period was defined, two other modifications were made:

1. The install period was dropped from the billing analysis as it contained a mixture of pre- and post-installation data.
2. The billing period was trimmed, if necessary, to approximately one year prior to the installation and one year after the installation.

3.3 Data Preparation – Initial Data Cleaning

The initial data cleaning addressed overlapping reads and incorrect meter types for the measure received. The procedure to identify and resolve each of these issues is described in the table below.

Step	Procedure
Remove overlapping reads (Billing Data)	1. The Con Edison meter read code and key identify whether the meter reading is an estimated reading or a verified reading. 2. If an estimated reading was followed by a verified reading, the estimated reads were deemed to be of lower quality and therefore dropped. 3. If the overlapping readings were of the same quality, the earlier reading was dropped.
Identify the area served by the meter data (Billing Data)	Natural Gas – a thorough review of natural gas usage was assessed to ensure the savings and the billed consumption related to the same buildings and spaces. • A cutoff of < 3,000 therms/year was used to verify the meters were not apartment meters. • The natural gas only EUI of buildings was used to flag buildings in the 2nd or the 98th percentile of EUIs. These were reviewed further during the account removal process with other selection criteria.

3.4 Data Preparation – Resolving Weather Data Issues

The Central Park, NY NOAA weather station was used for the analysis to maintain consistency with other Con Edison projects. This weather station had several missing hours in the data. The process for obtaining and cleaning this data is described in the table below.

Step	Procedure	Finding
Download Relevant Weather Data	Six years of hourly weather data for Central Park, NYC was downloaded from the National Oceanographic and Atmospheric Administration (NOAA).	-
Identify Missing Hours	The weather data was crosschecked with all of the hours that should be in the weather data.	784 missing hours (<1% of all hours)
Interpolate to Fill in Missing Hours	The missing hours were interpolated between the non-missing hours for up to 4 missing hours in a row.	642 missing hours remain (<1% of all hours)
Fill in Remaining Missing Hours with the Next Closest Weather Station	Remaining gaps were filled in with weather data from the LaGuardia Airport weather station.[1]	0 missing hours remain

[1] Using JFK airport weather data to fill in the gaps was investigated, but it was found that this resulted in less than a 0.01% difference in the overall HDD from LaGuardia. and Con Ed agreed that using LaGuardia data to fill in the gaps would be acceptable.

3.5 Data Preparation – Degree Day Calculation Procedure

Heating and cooling degree days were calculated for each day in the weather file and summed over each delivery period.

HDD base 62°F and CDD base 57.5°F were used per correspondence with Con Edison.

The sum of the heating degree days (HDD) and cooling degree days (CDD) for each delivery period were calculated from the processed hourly weather data.

Normalizing Degree Days

The weather-dependent use was normalized to account for differences between the pre- and post-periods. The normalized HDD and CDD were taken as the average HDD and CDD from 2012 to 2018.

4 Data Cleaning



4.1 Data Cleaning – Account Removal Description

Accounts were removed from the billing model due to lack of data, erratic data, or if the meter type did not align with the measure installed. These reasons are detailed in the table below.

Account Removal Category	Description
Insufficient Bills	At least 180 days of billing data in both the pre- and post-periods were required. Additional criteria were applied for both the pre- and post-periods: at least two deep winter months (December through March) or a total HDD of 60% of the normalized annual HDD.
Erratic Bills	Buildings were removed for the following reasons: 1. The account had more than three overlapping reads in a row 2. The R^2 was less than 0.70, heating estimator was not statistically significant or less than 0.15 therms per HDD 3. The intercept changed more than 60% between the pre- and post-install periods or more than 40% and the R^2 was less than 0.8.
Apartment Meters	No potential apartment meters were identified, and no accounts were dropped at this step.

4.2 Data Cleaning – Account Removal Numbers

Of the 145 accounts in the billing analysis, 50% were included in the final model. The number that dropped out at each stage is detailed in the table below.

	Number of Accounts	Number Removed	% of Total
Total Buildings	145	-	100%
Insufficient Bills	107	38	74%
Erratic Bills	72	35	50%
Apartment Meters	72	0	50%
Buildings in Final Model	**72**	-	**50%**

5 Billing Model

5.1 Billing Model – Overview of Method

The analysis method involved conducting a building-by-building regression of the weather on consumption for the pre- and post-installation periods.

An overview of the steps taken for the billing model are described in the table below.

Component	Step
Objective	Determine weather-dependent heating consumption
Measures	Master Vents, Riser Vents, Thermostatic Radiator Valves (remote sensor and standard), Burner Tuning Measures, and Aerators and Showerheads
Model	Building-by-building regression, separate for pre- and post-periods
Bills	Monthly bills from Con Edison
Purpose of Model Comparison	Assess whether building has natural gas base use (such as DHW)
Models Compared	Intercept v non-intercept
Model Selection Criteria	Intercept model is the default if the intercept > 0; choose non-intercept model if intercept < 0 or (R^2 of the no intercept model > 0.05 higher than the intercept model)

5.2 Billing Model – Regression and Consumption Equations

The regression equation and how annual consumption was calculated are shown below.

Regression Equation

$$C_t = \alpha + HDD_t \beta + \varepsilon$$

Where

C_t is the daily consumption per day (therms) during billing cycle *t*

α is the intercept, designating the base (non-weather-dependent) use

HDD is the daily heating degree days for billing cycle *t*

β is the heating slope (therms/HDD)

ε is the error term

Natural Gas Annual Heating Consumption

$$Therms_{heating} = \beta \; x \; AHDD_{norm}$$

Where

$Therms_{heating}$ is the natural gas annual heating consumption

β is the heating slope (therms/HDD) from the regression equation

$AHDD_{norm}$ is the normalized, annual heating degree days

5.3 Billing Model

The purpose of the natural gas analysis was to isolate the heating consumption during the pre- and post-install periods. The steps in the natural gas billing analysis are discussed below.

The steps involved in the natural gas billing analysis were:

1. Regress average daily HDD on average daily consumption (Therms/day) during each billing cycle, separately for the pre- and post-periods.

2. Identify the best regression model (intercept or non-intercept) to determine the heating use (see criteria on 4.5.1).

3. Review each account for erratic or inexplicable results and remove buildings with problematic data or regression results (see criteria on 4.4.1).

4. Conduct verification and sensitivity analyses to assess the validity of the results.

5. Calculate final savings, as described to the right.

The savings were determined by comparing the heating use in the pre- and post-installation period.

The heating use per degree day was calculated separately for the pre- and post-install period and multiplied by the 6-year annual average HDD. The equation below was used to calculate savings.

$$Therms_{savings} = Therms_{heating,pre} - Therms_{heating,,post}$$

Where

$Therms_{savings}$ is the annualized heating savings for each building

$Therms_{heating,pre}$ is the annualized heating use during the pre-period

$Therms_{heating,post}$ is the annualized heating use during the post-period

6 Verification of Results

6.1 Verification of Results

A series of checks were performed on the model to verify the results.

The table below outlines the additional analysis we conducted to verify the results.

Description	Procedure	Finding	Change to Model
Influential data	Participating buildings were removed one by one and the overall realization rate was recorded. One record was found to have the most significant change in the overall results, too close to the change in intercept and R^2 cutoffs (>40% change and <80%, respectively). One additional record that was fringe on these same cutoffs was also removed.	3% increase in savings as a percent of pre use	Model updated, final results reflect this increase
Adjust for variations in base use	An average of the pre and post intercept was used when the intercept (base use) varied by more than 50% pre to post. (Base use is typically small in comparison to heating use.)	3% decrease in savings as a percent of pre use	No change
	Accounts with less than 2 spring, summer, or fall months (April to November) in either the pre or post and significant swings in the intercept pre to post (>40%) were dropped. Two accounts met these criteria.	<0.1% increase in savings as a percent of pre use	No change

7 Conclusions and Recommendations

7.1 Conclusions and Recommendations

Our analysis indicates that *ex post* savings are approximately 3% of pre-install heating use and *ex ante* savings are currently overstated at 15%.

Conclusions

- The billing analysis shows *ex post* savings as a percent of pre-install heating use between -3% to 3% based on which attrition criteria are applied to the final model as seen in section 6.1.
- There is wide variation in savings on an individual building level.
- An almost equal number of buildings are showing substantial savings and substantially more use.
- The Willdan steam savings analysis tool seems to be substantially overstating savings.

Recommendations

- An expanded literature review would help us identify more specific recommendations.