SOUTHERN CALIFORNIA GAS COMPANY

EMERGING TECHNOLOGIES PROGRAM

ASSESSMENT REPORT

PROJECT ID E12SCG0018

HIGH EFFICIENCY NATURAL GAS WALL FURNACE FIELD EVALUATION

PREPARED FOR

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7/25/2013

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07/30/2013

This report file, named “2013-07-25 WF Final Report.pdf” and titled “High Efficiency Natural Gas Wall Furnace field evaluation” has been peer reviewed by us. Our comments have been addressed and necessary improvements are made by the author. Based on the information available, we believe that the field evaluation, research and analysis was conducted in a sound and rigorous manner and that the results are accurate and complete as presented.

Sabarish Vinod,

Manager, Integrated Services

Acknowledgements

Southern California Gas Company and the authors of this report would like to acknowledge the assistance and cooperation of our host site and the residents who went out of their way to allow for our onsite testing and interviews. We would also like to thank the furnace manufacturer that we evaluated for their contributions and dedication to energy saving technology.

Disclaimer

While SCG and the authors of this report did their best to come up with sensible results and recommendations, this report is provided as-is. The models, figures, formulas, and recommendations may not be appropriate or accurate for some situations. It is the reader's responsibility to verify this report and apply the findings appropriately when used in other settings or context. Readers are responsible for all decisions and actions taken based on this report and for all consequences, thereof.

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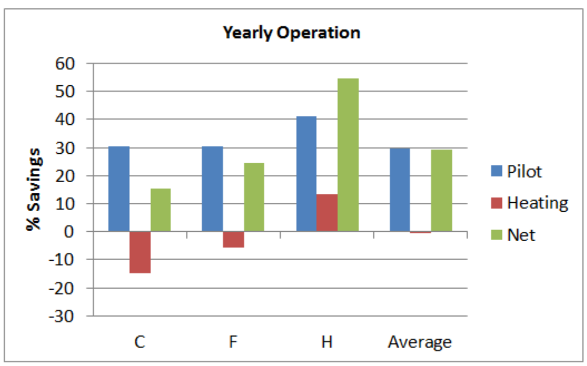
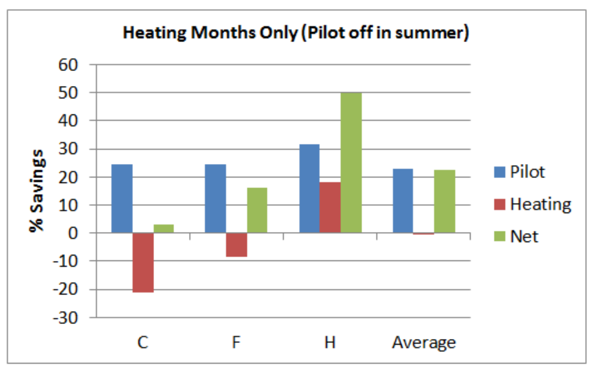
Executive Summary

This study investigates the energy savings capability of high-efficiency, natural gas wall furnace retrofitting. Wall furnaces are common in small residences where complex ductwork is not economically or mechanically appropriate. The study involved a field evaluation of retrofits in studio apartments for the gathering of empirical data. The report discusses factors and variables impacting potential savings along with the mass market applicability in the context of the State of California and major utility regions.

Natural gas wall furnaces are ductless, recessed packaged units that draw air from the living space into a heat exchanger that is heated by a combustion chamber. The airflow can be caused by either forced counterflow blowers or natural convection. Among other choices, natural gas wall furnace options include heating capacity, flow type, and ignition type. The high-efficiency wall furnaces used in this study were rated at 25,000 Btu/hr input with 71% AFUE, had natural convection airflow, and ignited with a standing pilot. They were chosen to be similar to the baseline furnaces.

Gas usage for the baseline and retrofit furnaces was correlated to heating degree days for the purpose of annualization and extrapolation of savings. For the three studios that received replacement furnaces, the % savings of space heating gas consumption varied from 15 to 55% based on year-round operation. Two of the apartments actually increased their heating use due to the added convenience of a new thermostat location. This behavioral change was accounted for in extrapolations to larger populations by use of assumed factors.





Using the assumed correction factors, it was shown that the complex could achieve 7.9% reduction in total yearly consumption of all the studios if all old wall furnaces were replaced. This amounted to a payback time of 82.5 years (of contractor-installed cost), far above the lifespan of a wall furnace.

	Single Studio	All Studios	Complex-wide
Yearly Gas Savings [therms]	35.5	1,571.1	1,571.2
Yearly Cost Savings [$]	$23.2	$1,025.8	$1,025.8
Yearly % Savings of WF Gas Consumption	26.0%	26.0%	Not Calculated
Yearly % Savings of Total Gas	7.9%	7.9%	1.5%
Average Payback Time [years]		82.5	

In order to extrapolate the savings to California and utility territories, estimates of the market size were calculated. Using national, state-wide, and metropolitan census and survey data, the potential wall furnace market size was estimated as the following.

	# of NG Wall Furnace MFR	# of NG Wall Furnace SFR detached	# of NG Wall Furnace SFR attached
SCG Territory	115,075	108,757	13,601
PG&E Territory	52,738	46,405	5,346
SDG&E Territory	19,333	11,952	2,156
California-wide	191,244	170,131	20,272

Using assumed corrective factors relating to usage patterns and behavior, the energy savings for SCG, SDG&E, PG&E, and California regions were estimated using climate zone specifics for each county of each region. The savings presented would be additive over each year. For the cumulative California-wide yearly savings of 611,250 therms/year[2], about 3,250 metric tons of CO_2 emissions per year[2] could be eliminated.

		SCG	PG&E	SDG&E	California
MFR	# target homes reached	2,876.9	1,318.5	483.3	4,781.1
	Gas saved [therms/year[2]]	169,750	100,500	25,500	303,750
	% of total residential gas saved	0.0063%	0.0053%	0.0078%	0.0060%
SFR Detached	# target homes reached	2,718.9	1,160.1	298.8	4,253.3
	Gas saved [therms/year[2]]	162,750	90,250	15,500	274,250
	% of total residential gas saved	0.0060%	0.0048%	0.0048%	0.0053%
Combined MFR and SFR	Gas saved [therms/year[2]]	352,250	201,000	43,750	611,250
	% of total residential gas saved	0.0128%	0.0108%	0.0135%	0.0118%

Pilot light use was the most significant consumer of gas. About half the above savings were due to pilot light consumption reduction. Pilot light elimination would provide added benefit. Utility programs may want to consider the elimination of standing pilots when developing rebate requirements. The elimination of the remaining pilot light consumption would add the following savings to the above values.

	SCG	PG&E	SDG&E	California
Added savings due to removal of pilot light from retrofit model [therms/year[2]]	121,000	53,250	17,000	194,750

In general, it was shown that energy savings due to wall furnace retrofits will not financially payback the consumer. However, there are significant energy savings opportunities in the wall furnace population. Therefore, it seems as though the target market would be consumers who are already planning on purchasing new wall furnaces and could be encouraged to choose a high-AFUE or non-standing pilot light model.

Introduction

Natural gas consumption in the United States has risen in recent years as the price of extraction and delivery has gone down and reliance on the fuel for electricity generation has gone up. Despite this rising trend, natural gas usage in California has remained relatively constant around 2,400,000 MMcf per year (roughly one third of the state's total energy requirements) with commercial sector end-users accounting for about 11% of the demand [1]. Even though California's natural gas demand has not increased, it remains vulnerable to shocks and disruptions in supply due the arrangement of gas pipelines in western North America [2]. California is the last stop in the United States for the pipelines that deliver natural gas from Canada and other states in the Southwest. Even though domestic production is expected to increase due technological and surveying advances, exports will somewhat offset that predicted stability. Mexico is expected to increase its importing of foreign natural gas by 725% from 2008 to 2035 [15].

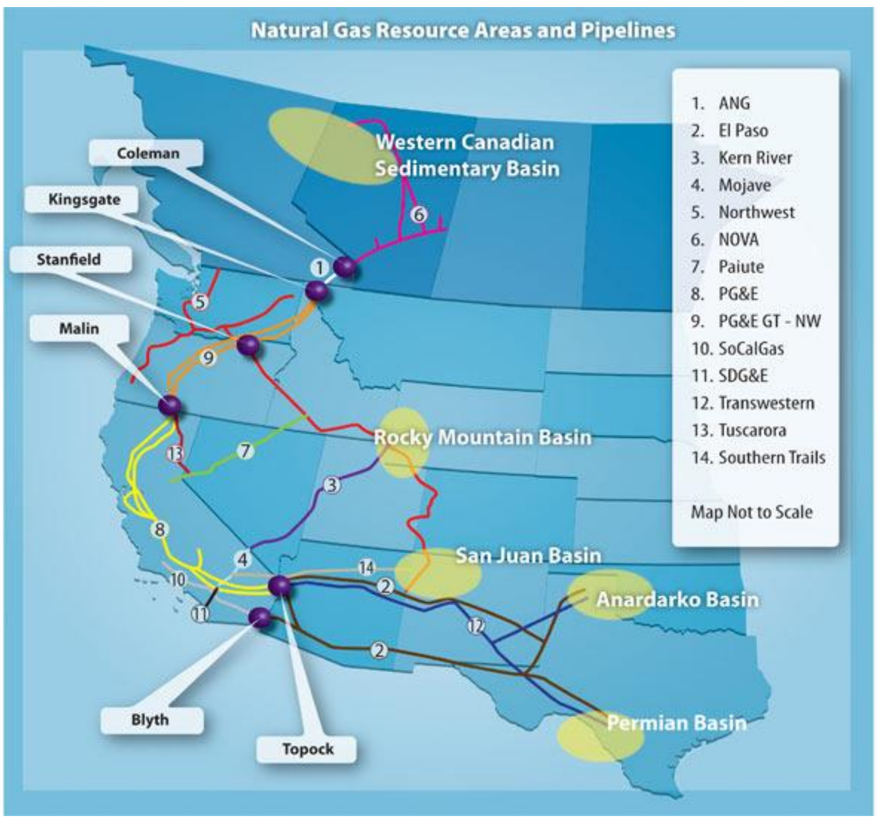


Figure 1 - Western North American gas pipelines [2]

As national demand for the fuel increases, competition for the resource will increase. 86.5% of California's natural gas consumption is sourced from out-of-state. For security and stability concerns, it is advisable to reduce natural gas usage where possible and economical. California's natural gas demand is expected to grow .89% from 2010 to 2020 while rates are expected to rise 19.2% [3]. This slow increase in demand is in part driven by the savings due to changes in California's codes and standards; anticipated changes to commercial building codes and appliances standards will save 291 MMtherms in

2020 [3]. Although U.S. and California consumption is not expected to increase at any more than a slow rate, California is still vulnerable to market shifts and unforeseeable problems.

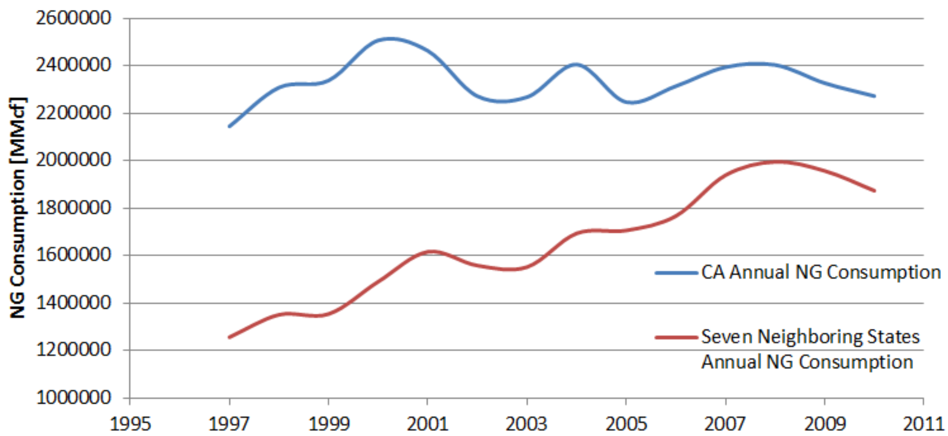


Figure 2 - California and neighboring states annual natural gas consumption [1].

Combustion of natural gas also emits methane and nitrous oxide, two known greenhouse gases. The combustion of natural gas has emission factors of 5 g/MMBtu and .1 g/MMBtu for methane and nitrous oxide, respectively [14]. The residential and commercial burning of natural gas in California in 2010 emitted 4,265 short tons of methane. The extraction and distribution of natural gas is also a significant source of GHG emissions. Reduction of natural gas use is an important aspect of addressing the causes of climate change.

Utilities will therefore benefit from natural gas savings measures in form of increased stability in regards to market shifts, supply, and future resource security. Utilities will also benefit from the ability to service more customers with existing infrastructure and overhead. Customers will benefit from the obvious reduction in costs associated with natural gas purchase.

One energy intensive use of natural gas is wall furnace space heating which occurs in many multi-family residence (MFR) buildings and smaller single family residences (SFR). Wall furnaces are often used when centralized heating is not feasible, economically inadvisable, or does not provide enough individualized control points for each heated space. Therefore, apartment complexes often utilize this type of heating technology. The most common type of wall furnace is convective (as opposed to radiative). These wall furnaces typically use a pilot light (standing or electronic) to ignite a controlled gas flow in a combustion chamber. The gas flow is controlled by a valve in conjunction with a thermostat. Air for both combustion and heating is drawn from the room into the bottom of the furnace by natural convection (“gravity fed”) where it is heated and flows out the furnace at the top vents. Excess gas and combustion products are vented out of the building. Some wall furnaces also use forced convection but those are not studied in this report.

Wall furnaces can last up to 20 years with continued maintenance. Replacing old furnaces with more technically advanced models with more efficient and effective burners, heat exchangers, and flow patterns can be advantageous from a gas consumption point of view. The technologies being reviewed here are high-efficiency, natural gas, gravity wall furnaces with a thermal efficiency of 77% and an AFUE of 71%. AFUE is an annualized fuel efficiency that considers not only steady-state operation like thermal efficiency, but also incorporates transient heating and pilot gas use.

Figure 3 - Typical wall furnace, new control valve, old control valve

The use of the heaters is dependent upon resident comfort levels, number of residents, internal load factors, ambient conditions, floor plans, and other site-specific variables. In order to have a controlled test, studio apartments with the same dimensions and thermal envelope were chosen. The wall furnace usage will be correlated and normalized to heating degree days throughout the evaluation period.

Project Objective

The objective of this study is to evaluate the energy savings potential of high-efficiency wall furnace retrofits and to assess the overall acceptance and opinion via user surveys from a field evaluation. A collection of studio apartments that passed pre-determined selection criteria were chosen for participation in the field study. The energy and cost savings will be quantified along with a qualitative evaluation of the furnaces, themselves. We assess the benefits and potential of the technology as a whole, without regards to manufacturer or model and briefly describe the California market and applicable codes and standards.

Our study has taken place in Southern California Gas Company territory. However, the results should be applicable throughout most of California due to consistent legislation and tariffs. Since the results are presented on a heating degree day basis, the conclusions can be extended to all California climates.

Contents of the report are as follows:

Potential energy savings
We observe energy consumption: by logging aggregate gas flowrate, supply, return, and ambient temperatures, energy consumption can be calculated and normalized. We then project average energy savings on an annual basis for a range of heating degree days.

Customer feedback
We developed a user survey to determine the overall customer reactions to the technology. This was done to help understand the acceptance across different markets and barriers to market implementation and for insight into behavioral changes during the test. Some of the questions included:

- Does the customer like the wall furnace?
- Does the customer appreciate the energy savings?
- Does the replacement furnace affect personal heating patterns in any way?
- Is the replacement furnace better or worse than the old furnace?
- Is the new furnace more convenient and does this affect your usage patterns?

Applicability of SCG incentive and rebate programs
We review various SCG programs with respect to this technology and provide recommendations for where program support may apply.

Concluding remarks and summary
Finally, we conclude our study with a discussion of

- Benefits of energy and savings
- Improvement opportunities
- Considerations for large-scale market implementation
- Potential future study

Project Setting & Methodology

Selected studio apartments of consistent occupancy and thermal envelope were chosen for the three-month evaluation. Baseline data was collected at six apartments for five weeks after which three of the apartments were outfitted with new, high-efficiency wall furnaces. The same high-efficiency furnace model was installed in all three retrofitted apartments. Following that, measurement instrumentation from two of the baseline apartments was moved to two other similar apartments due to the residents not using heating. Full Project and M&V Plans can be found in Appendices A and B, respectively.

The Project Plan (Appendix A) contains detailed information on the following:

- Description of the technology under investigation
- Description of the incumbent technology that is being replaced
- Goals of the assessment project
- Application and/or generalization of project results to similar facilities in other locations
- Generic customer information
- Project milestones (initial tentative timeline)

The M&V Plan (Appendix B) contains detailed information on the following:

- Host sites
- Data collection procedures
    - Data points
    - Data sampling, recording, and collection intervals
    - Instrumentation
- Data analysis procedures
    - Data manipulation and approach
    - Calculation of potential energy savings
    - Calculation of potential cost savings

Host Site Overview

Eight studio apartments in a single building in the Los Angeles greater area were selected for the field evaluation of this report. Each was equipped with an outdated wall furnace of consistent model. Initial baseline data was collected at six apartments prior to installation of the three high-efficiency furnaces in half the units. Following that, two of the non-retrofitted apartment instrumentation setups were relocated to two other apartments because the original two were found not to use their furnaces. Unfortunately, the two new apartments also did not use their furnaces.

In general, wall furnaces are simple, non-problematic devices that require little maintenance until the components begin to break. Due to their age, several of the baseline furnaces had problems such as valve malfunction, pilot light stability problems, and leaking connections. Any anomalous data due to these issues was rejected or treated with exception as described in the Project Error Analysis section.

The original furnaces had dial thermostats inside the lower compartment that housed the valve and pilot light. These thermostats were inaccessible from outside the furnace and also did not have temperature settings, but rather a scale of 1-10. The new furnaces came standard with a more modern thermostat located outside the furnace with temperature settings. This discrepancy is discussed in the Project Error Analysis section.

The apartment characteristics are listed in Table 1. Note that due to the age and possible replacement of components over time, the original thermal efficiency and heating output specifications may not be accurate.

Table 1 – Test site parameters

	Apt B	Apt C	Apt E	Apt F	Apt G	Apt H	Apt J	Apt K
Dates Tested	3/14-4/22	1/18-4/22	1/18-3/14	1/18-4/22	1/18-3/14	1/18-4/22	1/18-4/22	3/14-4/22
CA Climate Zone	8							
Furnace Replaced	No	Yes	No	Yes	No	Yes	No	No
Area [ft^3]	528							
Bd/Bth	1/1							
Occupancy	3	1	2	2	1	1	1	2
Old Furnace Input; Output [Btu/hr]	29,000; 20,300							
Old Furnace η_{th}; AFUE [%]	70%; 63% (estimated AFUE)							
New Furnace Input; Output [Btu/hr]	N/A	25,000; 19,200	N/A	25,000; 19,200	N/A	25,000; 19,200	N/A	N/A
New Furnace η_{th} [%]	N/A	77%	N/A	77%	N/A	77%	N/A	N/A
New Furnace AFUE [%]	N/A	71%	N/A	71%	N/A	71%	N/A	N/A

Measurement & Verification Plan Overview

A measurement and verification plan was developed in order to evaluate furnace operation, cost and cost influencing factors, impact to host site, customer feedback, energy and use reduction, and applicability of existing SCG programs. The full M&V plan can be found in Appendix B. The full M&V plan includes information on host site selection, data collection procedures and instrumentation, and data analysis approach. Further information on data analysis procedures can be found in Appendix C.

Emphasis is placed on the following aspects:

Potential Energy Savings

We calculate energy savings for a variety of conditions and populations. Savings are derived from the gas consumption decrease from the original furnace and are dependent upon behavior. Changes in use time will impact energy savings and payback times. The aggregate gas used each five minutes was recorded to determine consumption on 8-hour, 12-hour, and 24-hours bases. These aggregated values were correlated with to heating degree days. Energy savings are based on the actual improvement (therm/time and therm/HDD) which result in an estimated total therms saved per retrofit over an entire year.

Customer Feedback

Various questions were provided via an online or in-person survey to the residents. Questions such as the following were asked:

Does the customer like the new furnace? Does the new furnace heat as effectively as the original? Do you invoke more control with the different thermostat?

Applicability of SoCal Gas Incentives and National and State Standards

We review all relevant SoCal Gas programs with respect to this technology and provide recommendations for where we believe program support could apply. Alternatively we suggest future custom measures that would be applicable to this type of technology and the most appropriate method of determining potential savings. National and state standards for gas use and wall furnaces are presented.

Finally, we conclude our study with a discussion of

- Benefits of high-efficiency wall furnaces and the replacement of old units
- Barriers to market adoption
- Payback time and savings analysis
- Considerations for large-scale market implementation
- Potential savings for SCG territory and California

Market Overview

Opportunity

The potential market for NG wall furnace retrofits is comprised of existing residences that have Utility natural gas connectivity and have previously established use of a wall furnace. Furthermore, MFR buildings which are greater than 3 stories must be excluded since taller building will often use central heating. Survey data from the US Census Bureau's American Housing Survey (AHS) and the Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS) have data on these topics in county, metropolitan area, and state-wide scales. These data were used to determine the potential market opportunity in California and each major Utility territory. Where available, metropolitan area data on the use of "floor, wall, or other built in hot-air units without ducts" was used for the associated county-wide estimates [4]. Otherwise, the average of all available metropolitan areas was used. The number of MFRs with natural gas wall furnaces in any given county was determined using

$$\# MFR = Total\ Houses * f_{MFR} * f_{1,MFR} * f_{2,MFR} * f_3 * f_4$$

where *Total Houses* is the number of housing units in the county, f_{MFR} is the fraction of residences that are MFRs, $f_{1,MFR}$ is the fraction of MFRs that are connected to Utility piped natural gas, $f_{2,MFR}$ is the fraction of MFRs that use "floor, wall, or other built in hot-air units without ducts", f_3 is the fraction of f_2 that are natural gas wall furnaces, and f_4 is the fraction of MFR buildings that are less than 4 stories. Similarly, the number of target SFRs with wall furnaces in a county are given by

$$\# SFR = Total\ Houses * f_{SFR} * f_{1,SFR} * f_{2,SFR} * f_3$$

For example, according to the AHS, there were approximately 3.45 million residences in Los Angeles County in 2011. Also according to the AHS, 44% of the housing units in the Los Angeles-Long Beach metropolitan area are MFRs and 91.3% of those were connected to Utility natural gas supplies. 31.0% of the MFRs use "floor, wall, or other built in hot-air units without ducts [4]." "Ducts" refers to ductwork delivering supply air to one or more rooms. Wall furnaces are included in the category because they typically draw and supply air directly from and to the space being heated. If 38% of those are natural gas wall or floor furnaces [5] and 50% of *those* are wall furnaces, then there are 75,850 MFRs to target for high-efficiency wall furnace retrofits. Similarly, there are 70,350 target detached SFRs and 9,400 target attached SFRs.

This method was applied for all California counties to determine market sizes. Southern California Gas Company territory includes the counties of Los Angeles, San Bernardino, Riverside, Orange, King, San Luis Obispo, Kern, Santa Barbara, Ventura, Fresno, Imperial, and Tulare [6]. Table 2 lists the potential market sizes in California.

Table 2 - Number of SFR and MFR with wall furnaces in California Utility territories

	# of NG Wall Furnace MFR	# of NG Wall Furnace SFR detached	# of NG Wall Furnace SFR attached
SCG Territory	115,075	108,757	13,601
PG&E Territory	52,738	46,405	5,346
SDG&E Territory	19,333	11,952	2,156
California-wide	191,244	170,131	20,272

This is a significant market size that could potentially contribute to gas consumption reduction in the roadmap towards reduced emissions and increased efficiency. For an average wall furnace lifetime of 20 years, approximately 9,300 wall furnaces are replaced every year in Los Angeles County alone.

It should be noted that RECS reported an average California use of natural gas "floor or wall pipeless furnaces" of 6.6%, *half* of which could be assumed to be wall furnaces [5]. The method used here found average use of NG wall furnaces to be 2.4% and 5.9% in SFR and MFR buildings, respectively. For details on county specific numbers and factors, please contact the authors.

With the number of California residences using wall furnaces, state-wide and Utility territory savings can be predicted. Actual savings across California will vary from the predicted values due to the non-representative nature of the sites selected for field evaluation and the limited testing scope. Wall furnace retrofits across California would include models of different sizes, efficiencies, ignition type, building type, and use patterns. As such, the extrapolated results presented above should be used with a full understanding of the limitations of the project scope.

As described in the Energy Savings section, weighting factors for various types of wall furnace behavior and settings were needed for extrapolation. Using the weighting factors described in the Energy Savings section and Appendix C and the averaged pilot light savings across all tested apartments, the potential energy savings for the three major Utility territories and California were determined using averaged annual heating degree days for each county [12]. These *total* energy savings potentials are listed in Appendix G. Assuming that the average lifespan of a wall furnace is 20 years and 50% could be replaced with models that could be upgraded to high-AFUE, the yearly added savings are 1/40th of the total energy savings potential in a given region. These savings are presented in Table 3.

Table 3 - California and Utility savings potential. Note that the number of target homes is reduced by 10% when calculating energy savings in order to account for residents who choose not to heat in the mild winter climate.

		SCG	PG&E	SDG&E	California
Combined MFR and SFR	Yearly Residential Gas Usage [MMt]	2,736.7	1,883.7	327.0	5,167.8
MFR	# target homes reached	2,876.9	1,318.5	483.3	4,781.1
	Gas saved [therms/year^2]	169,750	100,500	25,500	303,750
	% of total residential gas saved	0.0063%	0.0053%	0.0078%	0.0060%
SFR Detached	# target homes reached	2,718.9	1,160.1	298.8	4,253.3
	Gas saved [therms/year^2]	162,750	90,250	15,500	274,250
	% of total residential gas saved	0.0060%	0.0048%	0.0048%	0.0053%
SFR Attached	# target homes reached	13,601	5,346	2,156	20,272
	Gas saved [therms/year^2]	340	134	54	507
	% of total residential gas saved	0.0013%	0.0010%	0.0013%	0.0013%
Combined MFR and SFR	Gas saved [therms/year^2]	352,250	201,000	43,750	611,250
	% of total residential gas saved	0.0128%	0.0108%	0.0135%	0.0118%

Considering the yearly market penetration, the total energy savings for retrofitting old, standing pilot wall furnaces with new, high-AFUE standing pilot wall furnaces is about 352,250 therms/year^2 for the SCG territory and 611,250 therms/year^2 for California as a whole. These savings would be cumulative over each successive year as additional old wall furnaces are replaced with new high-AFUE models. In other words, for SCG, after one year 352,250 therms/year would be saved, after two years 704,500 therms/year would be saved, after 3 years 1,056,750 therms/year would be saved, and so on. Similarly, after one year .013% of total residential gas would be saved, after two years .026% or total residential gas would be saved, after three years .038% of total residential gas would be saved, and so on.

Since the savings comes largely from the pilot light reduction, it is also worthwhile to consider savings that would be achieved from eliminating standing pilots altogether. A model with similar AFUE and an intermittent spark or hot surface ignition would save additional .124 therms per day per residence over the retrofitted model. This would amount to significant added savings as shown in Table 4.

Table 4 - These savings could be added to the above values if the retrofit furnace was equipped with a non-standing pilot light ignition.

	SCG	PG&E	SDG&E	California
Added savings due to removal of pilot light from retrofit model [therms/year^2]	121,000	53,250	17,000	194,750

Note that these savings calculations used assumed resident behavior and market size based upon intuition and rough estimates. All decisions based upon these findings should include a full understanding of the assumptions used in this study.

Products and Systems

Manufacturers and vendors of wall furnaces include the following.[1]

- Empire Heating Systems [7]
- Louisville Tin & Stove Co. [8]
- Rinnai America Corporation [9]
- Williams Furnace Co. [10]

[1] The list is in alphabetical order, provided as is, not exhaustive, and the selection is arbitrary. The authors of this report do not endorse or guarantee, and disclaim any responsibility for: the content, products or services offered, their performance or suitability, and any consequences or damages, incidental or otherwise, that may result from their consideration or use.

Applicable Codes and Standards

Natural gas wall furnace standards are dictated by California Title 20. The category of wall furnace used in this study has a standard minimum AFUE of 63-64%, well below the utilized replacement model of 71% [11].

Table 5 - Title 20 gas wall furnace, floor furnace, and room heater standards [11]

Standards for Gas Wall Furnaces, Floor Furnaces, and Room Heaters

Appliance	*Design Type*	*Capacity (Btu per hour)*	*Minimum AFUE (%)*
Wall furnace	Fan	≤ 42,000	73
Wall furnace	Fan	> 42,000	74
Wall furnace	Gravity	≤ 10,000	59
Wall furnace	Gravity	> 10,000 ≤ 12,000	60
Wall furnace	Gravity	> 12,000 ≤ 15,000	61
Wall furnace	Gravity	> 15,000 ≤ 19,000	62
Wall furnace	Gravity	> 19,000 ≤ 27,000	63
Wall furnace	Gravity	> 27,000 ≤ 46,000	64
Wall furnace	Gravity	> 46,000	65
Floor furnace	All	≤ 37,000	56
Floor furnace	All	> 37,000	57
Room heater	All	≤ 18,000	57
Room heater	All	> 18,000 and ≤ 20,000	58
Room heater	All	> 20,000 and ≤ 27,000	63
Room heater	All	> 27,000 and ≤ 46,000	64
Room heater	All	> 46,000	65

The standards have not changed since 1992, when AFUE was called "seasonal efficiency." Since furnace manufacturers have made strides in heat delivery efficiency, it would perhaps be advisable to update California new wall furnace standards with regards to today's available models.

In addition to energy consumption standards, wall furnace installation and design must also meet ANSI Z21.86 standards for vented gas fired space heating appliances regarding nitrogen oxide emissions. They must also comply with the safety standards in national electrical and gas code from the NFPA and ANSI, the California Building Code, and any other state or local codes that supplement or supersede the national code.

Project Results and Discussion

Although we are confident in the quality of the data and calculations, the reader should know that results are of limited breadth and may not be statistically representative.

System Cost and Cost-influencing Factors

A wall furnace can cost anywhere between $400 and $3,000 (parts only), depending on the model and size. Optional features such as intermittent spark or hot surface ignition, multiple room, and counterflow blowers add to unit cost. For a unit of similar size as in this study (25,000 Btu/hr), prices vary from $400 to $1,000. Installation and permitting incur additional cost. Typically, a licensed contractor will install a wall furnace since it involves shutting off gas mains, bleeding air from lines, plumbing fittings, venting installation, and possible drywall work.

A total system cost for a single wall furnace is outlined in Table 6.

Table 6 - Single wall furnace and installation costs

Item	Cost
25000 Btu/h Wall Furnace w/ standing - Parts	$772.50
Permit	$360.00
Labor	$766.50
Total Installed Cost	**$1,899.00**

System cost will vary based upon location, wall furnace options, and contractor rates. A typical wall furnace replacement can be expected to have an effective measure life of 20 years.

Customer feedback

The residents in each apartment were given a survey to determine acceptance of both baseline and retrofit furnaces and to screen for possible anomalous situations or confounding behavior. Selected answers are presented here; all answers can be found in Appendix E: Survey Results.

In general, the residents were comfortable with both the baseline and retrofit furnaces. The baseline furnaces received a 3.75 out of 5 rating while the new furnaces received a 4.7 when asked "How happy are you with your furnace?" The residents did like the new furnaces better, however, not necessarily because they were more effective at heating. When asked to rate the statement, "The wall furnace heats the house well," the baseline furnace received a 3.9 and the retrofit received a 4.3. Rather, the increase in furnace happiness could be due to non-heating changes. For instance, the new furnace had an external thermostat which was installed on the side wall while the baseline furnace had a dial of 1-10 inside the baseplate cover next to the gas control valve. This increase in convenience of control had an effect as shown by the following survey results. The residents who did not receive new furnaces anticipated that having a more convenient thermostat would cause them to use and control the furnace at least the same and possibly more.

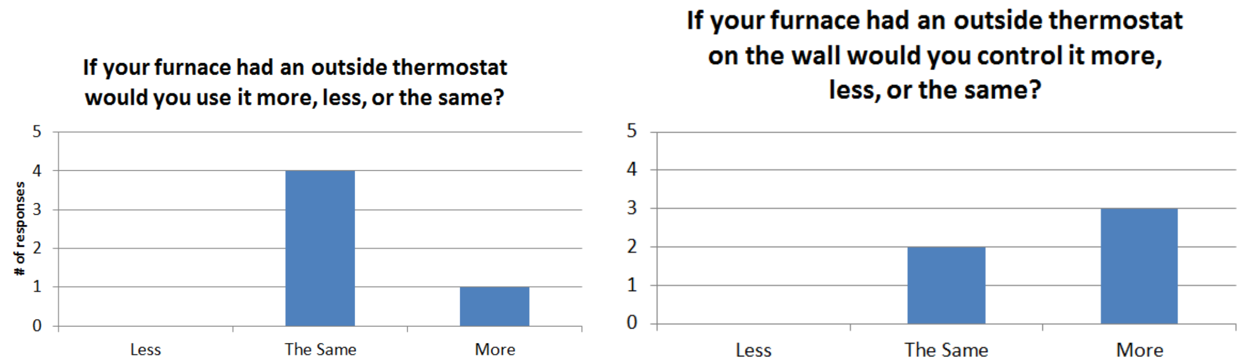


Figure 4 - Non-retrofit apartments' consideration of more convenient thermostat

Similarly, the residents who received a new furnace said that they used the furnaces the same or more than the baseline due to the external thermostat.

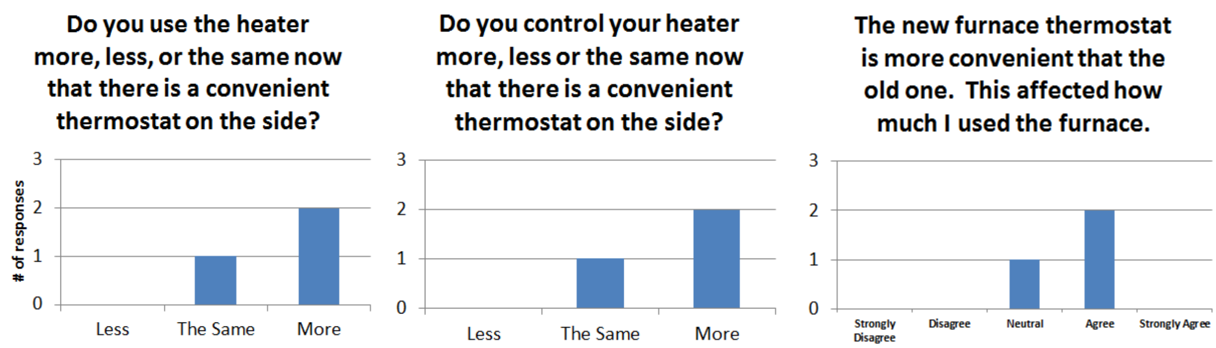


Figure 5 - Retrofit apartments' reaction to having thermostat on outside of new wall furnace.

All residents said that they rarely or never leave their furnace on when not home. This is an important determination for the heating degree day (HDD) correlations in the following section.

Energy Savings

Energy savings were calculated for each apartment that received a retrofitted wall furnace. These results were then used to develop correlations with heating degree days in 12 hour intervals. The treatment allowed for separate consideration of pilot and heating gas usage. Appendix C provides details of the calculations and methods. These correlations were used to extrapolate savings to all applicable buildings in the apartment complex in order to determine site-wide benefits. Finally, the same correlations were used to extrapolate savings across California based on county-specific yearly HDD data.

After correlation to HDD and annualization of savings, percent savings were determined for each apartment as shown in Figure 6. These are savings as a percent of total baseline consumption. Apartments C and F reported that the new thermostat location increased convenience and caused them to use their furnaces more frequently. This is the reason for the negative heating savings. Note the variation in savings from increased heating to no increase in heating and from year-round to heating months only operation.

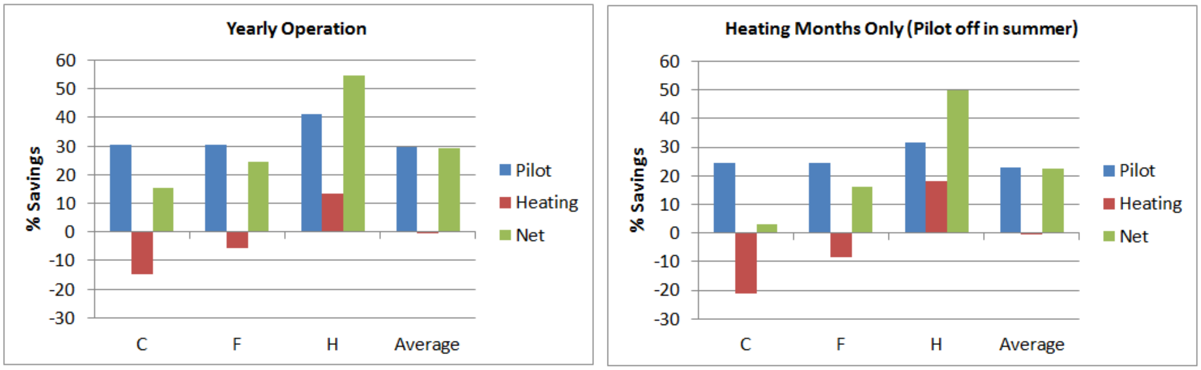


Figure 6 - Pilot, heating, and combined annual savings percentage of total baseline consumption for each retrofitted apartment.

The average pilot light gas consumption across all eight tested apartments was about 7.2 and 3.7 therms per month for baseline and retrofit furnaces, respectively. The baseline pilot amounts to 62% of the total yearly consumption for year-round operation of the baseline furnaces.

In order to extrapolate the results, certain correction factors were applied since the data from the evaluation was limited, varied, and not statistically representative. Weights were necessary for whether or not residents using heating in the winter, whether or not residents would increase their use due to added wall furnace thermostat convenience, whether the residents use their furnaces and leave their pilot lights on year-round or only during heating months, and what type of residences comprise the total number of homes in the wall furnace population considered (studio, 1Bd, 2Bd).

In order to account for variation in home size, which would affect total heating usage, a volumetric ratio was applied in order to calculate heating gas consumption (as opposed to pilot gas) for larger homes. Areas of 693 and 910 ft^2 with heights of 8 feet were used for 1 and 2 bedroom homes using wall furnaces, respectively. The heating consumption for a larger home was calculated using

$$Home\ 2\ Heating\ Gas = \frac{Home\ 2\ Volume}{Home\ 1\ Volume}(Home\ 1\ Heating\ Gas)$$

The chosen factors are shown in Table 7. Further details on their use and assumptions can be found in Appendix C.

Table 7 - Savings extrapolation weights and factors.

	Apartment Complex	California MFR	California SFR
Fraction who do not heat	0.25	0.10	0.10
Increased use weight	0.67	0.20	0.20
Unchanged use weight	0.33	0.80	0.80
Year-round weight	0.75	0.75	0.50
Heating Months only weight	0.25	0.25	0.50
Studio fraction	N/A	0.25	0.10
1 Bd fraction	N/A	0.55	0.30
2 Bd fraction	N/A	0.20	0.60

Using the above weights, the average savings for a single studio and the entire complex are shown in Table 8. The complex was comprised of 59 studio units and other 1 and 2 bedroom residences. Since the 1 and 2 bedroom residences did not use wall furnaces, they cannot contribute to complex-wide wall furnace retrofit energy savings.

Table 8 - Apartment complex yearly gas savings

	Single Studio	All Studios	Complex-wide
Yearly Gas Savings [therms]	35.5	1,571.1	1,571.2
Yearly Cost Savings [$]	$23.2	$1,025.8	$1,025.8
Yearly % Savings of WF Gas Consumption	26.0%	26.0%	NC*
Yearly % Savings of Total Gas Consumption**	7.9%	7.9%	1.5%
Average Payback Time of Installed Cost [years]		82.5	

*Not Calculated because individual unit gas consumption was not available.

**Estimated based on average heating consumption fraction of total residential gas consumption. Not empirical.

Applicability of existing or future rebate and incentive programs

There is currently a rebate program for the replacement of gravity wall furnaces in Southern California Gas Company territory for detached SFRs and apartment MFRs [13]. The program offers a $50 rebate for replacing existing wall furnaces with a new model of 70+% AFUE from participating manufacturers. This rebate, when viewed in the context of total cost and payback time, may be incentive enough for a homeowner to upgrade to a high AFUE furnace if already in the market for a replacement but not enough to entice one to replace an old furnace that has not reached its end-of-life. The current program may often simply piggy-back on customers who are already in the market for a new wall furnace. For this reason, the market opportunity and annual benefit to California is presented in context of the expected replacement frequency of end-of-life furnaces. Appendix G presents the entire market potential of all existing wall furnaces in California without regards to market penetration.

While there are more SFR in SCG territory than MFR (60% to 40% by number of units), the wall furnaces are likely much more prevalent in MFR. Therefore, there is obvious benefit in offering such a program to both SFR and MFR.

It may be valuable to consider extending rebates to floor furnaces. Potential programs could also consider applicability of forced convection and non-standing pilot light ignition, both of which would reduce gas consumption but would require added electricity demand, consumption, and system costs.

Project Error Analysis

Project Plan Deviation

There were several deviations from the original project plan due to unforeseen complications in the evaluation. After the first half of the evaluation, before the retrofit furnaces were installed, it was noticed that two of the baseline apartments (E & G) did not use their heater. In order to capture as much baseline data as possible, the instrumentation from these apartments was moved to two other apartments (B & K).

The contracted plumbers mistakenly installed three of the gas meters backwards on apartments E, H, and J. This matter was rectified as quickly as possible but raised concerns of calibration problems. By comparing the aggregate flow during pilot operation and during similar heating time periods for both forward and backward meters, it was shown that the meter calibration was unaffected in by the incorrect installation at the low flow rates applicable to our project. For details on this calibration check, see Appendix F.

The project scope called for screening apartment occupant behavior in order to minimize uncontrolled or unobserved variables that influence the results. Unfortunately, two of the residents admitted to using the furnace while the windows were open. However, it is the opinion of the authors that study results are still valid since other residents across California who do not pay their own gas bill may do the same. Furthermore, the HDD baseline temperature calculation we employed should level out such uncontrollable variables for the most part.

Ideally, the baseline and retrofit furnaces would be identical in function and user interface in order to ensure no behavioral modification of the users. Unfortunately, the baseline furnaces had an outdated, hidden thermostat that was more inconvenient than the retrofit. This engendered increased use in some of the residences. This was dealt with by incorporating weighting factors in the extrapolation of the complex and county savings estimations. It was assumed that most wall furnaces suitable for retrofitting would not cause increased use resulting in the factors in Table 7.

Finally, the evaluation time was extended in order to capture more data as was needed due to increasing ambient temperatures as the heating season ended.

Anomalous Data and Treatment

Due to the age and of the furnaces and other field circumstances, there were sections of data that were unusable. These sections of data were due to furnace valves malfunctioning, pilot lights not lighting, interrupted gas supply, incorrect thermostat installation, and accidental unplugging of data logger sensors, all of which were remedied as soon as possible. These sections were removed from the data sets, after which analysis took place as normal. After the anomalous data was removed, there was still enough information to develop correlations to HDD; the anomalous data did not render results invalid. For detailed information on the removed data and circumstances, see Appendix C.

Conclusions

Benefits of High-AFUE Wall Furnaces

The high-efficiency wall furnaces of today use the same operating principles as older wall furnaces, but use more advanced components that reduce the amount of gas needed to maintain a comfort level. Therefore the benefits stem entirely from reduced energy consumption. The higher efficiency valve reduces energy needs of the standing pilot light and combustion chamber. The pilot light, as shown above, is the dominant energy consuming component in mild climates such as southern California. The retrofit pilot lights result in reduced standby losses and consumption. Models that use intermittent pilots and hot surface ignition could possible save even more energy. These advanced ignition systems do require an electricity supply, however. Although the data collected was confounded by the uncontrolled thermostat location and convenience, it can be concluded that the retrofit furnaces also use less energy during heating mode.

Derivative benefits of energy savings are GHG emission reductions and reduced Utility costs for the resident. Natural gas has a reported emission factor of 0.00531 metric ton CO_2/therm [14]. The reported potential energy savings across California of 611,250 therms/year[2] would eliminate 3,250 metric tons of CO_2 emissions per year[2].

For a residence that does not turn off the heater and pilot light during summer, the retrofit of old wall furnaces without eliminating the standing pilot light can save about 35% of the wall furnace gas consumption and about 10% of total household gas consumption. Across California, if all existing wall furnaces are old, standing-pilot light models and are replaced with new high-AFUE models at a market penetration rate of 1/40th each year, about 611,250 therms/year[2] could be saved, reducing about .012% of the total residential gas consumption each year. This number is likely an overestimate since many existing models probably are not as inefficient as the baseline models in this field evaluation. However, removing the pilot lights completely can provide added benefit to the savings presented here.

Possible Drawbacks and Risks of High-AFUE Wall Furnaces

There are no added risks of using a high-efficiency wall furnace in place of an older, lower-efficiency model. Wall furnaces are a well-established technology. The expectation of energy savings can be considered risky; this was observed in the field evaluation. If the older model has a "hidden" thermostat, the newer model may engender increased heating use, thereby reducing the energy savings opportunity due to added user comfort. Since the pilot savings outweigh the heating savings by about 50% even when heating use does not increase, relative savings expectations should be higher in mild climates and lower in colder climates.

System & Technology Improvement Opportunities

In milder climates such as southern California that do not have too many yearly heating degree days or heating months, the pilot light gas usage dominates the total usage as seen in Figure 7.

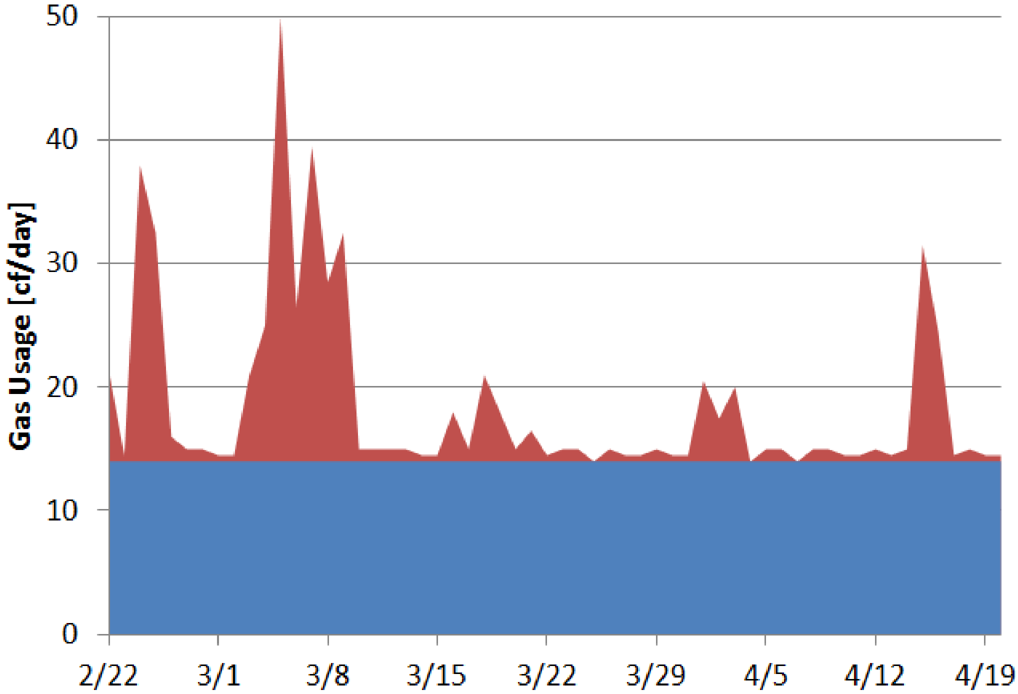


Figure 7 – Daily gas usage for one of the tested studio apartments with the baseline furnace. The blue area is the gas consumed by the pilot light; the red area under the spikes is the heating gas.

The ratio of the pilot usage to heating usage (blue area to red area) is large. Reducing pilot light usage is the obvious target for energy savings. There are models of ductless furnaces that use intermittent spark ignition or hot surface ignition to eliminate standing pilot lights. These pilot options are not universally available and are generally restricted to higher-end and larger models. They were not available in the size of furnace used in this study. Extending these options to all wall furnaces could be very helpful in regards to energy savings. Note that the savings above are mostly due to the more efficient pilot light. Eliminating the standing pilot light entirely would significantly increase savings. It should be kept in mind that hot surface and intermittent pilot lights require more complex components and an electrical connection.

Applicability of Case Study Findings to Other Load Types and Sectors

Other furnaces with higher AFUE than the retrofit model used here exist but they were not similar in size and Btu/hr rating to the baseline furnaces at the evaluation site. The empirical data here are for one particular size of wall furnace with a standing pilot light in a second story MFR studio. The results will be different (although in the same neighborhood) for various other types of ductless furnaces and buildings. Savings in larger apartments and houses was estimated based on a linear extrapolation based on home volume as depicted in the results section. Floor furnaces operate in a similar fashion and could also be a potential program target.

Current rebates are offered to detached SFR and MFR buildings with existing wall furnaces. Future programs might consider extending the rebate to other types of gas furnaces of varying size. The standing pilot versus intermittent or hot surface ignition might also define rebate requirements based on further study.

Considerations for Large-scale and Persistent Market Implementation

The wall furnace market is long-established and this type of heating has widespread use. Today's wall furnaces have standard efficiencies greater than older models. There is little risk that retrofits will not attain higher efficiency than the baseline they replace. Therefore, yearly replacement and Utility benefit can be estimated using the average wall furnace lifetime. These are the results presented in the Market Opportunity section. When compared to the total potential savings of all wall furnaces in California presented in Appendix G, it is obvious that the lifespan and adoption rate of high-efficiency furnaces greatly reduce the achieved savings with respect to the total potential.

The cost savings and current rebate offered do not provide an opportunity for payback of total system cost within the wall furnace lifetime. Therefore, it is expected that the savings and rebate realized by any homeowner may not be enough to encourage replacement of an old furnace that is working satisfactorily. However, the rebate and savings may encourage homeowners who are already in the market for a replacement furnace to seek out a high-efficiency unit over a low-efficiency unit.

With respect to new construction and newer buildings, an update to the California regulatory code could spur the adoption of high-efficiency units. The current wall furnace code has not been updated for 20 years, falling behind the increasing efficiencies of currently available units.

Possible Future Study

This study focused on a single size of wall furnace in a single type of studio apartment. While some extrapolation to larger homes was done, future studies may want to expand to other sizes and types of furnaces and residences. For instance, a future study could perform evaluations in 1-2 bedroom SFR and MFR buildings, floor furnaces, counter-flow forced convection furnaces, furnaces with non-standing pilot lights, and in other climate zones. Tighter control of behavioral variables such as thermostat location and regular work hours should be included. Finally, the savings extrapolations performed required many assumptions regarding larger furnace populations since the data set was limited to three retrofit furnaces. Future studies should include larger sample sizes in order to obtain a more statistically representative dataset.

Glossary and Acronyms

AFUE	annualized fuel utilization efficiency
ANSI	American National Standards Institute
η	thermal efficiency
HDD	heating degree days
MFR	multi-family residence
M&V	measurement and verification
NFPA	National Fire Protection Association
NG	natural gas
SCG	Southern California Gas Company
SFR	single family residence
WF	wall furnace

References

[1] State Energy Data System (SEDS): 1960-2010. U.S. Energy Information Administration. http://www.eia.gov/beta/state/seds/seds-data-complete.cfm?sid=CA#Consumption

[2] Average Per Capita Natural Gas Consumption by State 2006. The California Energy Commission Energy Almanac. http://energyalmanac.ca.gov/naturalgas/per_capita_consumption.html

[3] California Energy Demand 2012-2022 Final Forecast. California Energy Commission. 2012. http://www.energy.ca.gov/2012publications/CEC-200-2012-001/CEC-200-2012-001-CMF-V1.pdf

[4] American Housing Survey 2011. United States Census Bureau. http://www.census.gov/housing/ahs/

[5] Residential Energy Consumption Survey (RECS). U.S. Energy Information Administration. http://www.eia.gov/consumption/residential/

[6] Company Profile. Southern California Gas Company. http://www.socalgas.com/about-us/company-info.shtml

[7] Empire Heating Systems. http://www.empirezoneheat.com/ehs/index.php

[8] Louisville Tin & Stove Co. http://www.cozyheaters.com/

[9] Rinnai. http://www.rinnai.us/

[10] Williams Comfort Products. http://www.williamscomfortprod.com/

[11] California Code of Regulations, Title 20. Public Utilities and Energy. 2012. California Energy Commission. http://www.energy.ca.gov/reports/title20/index.html

[12] BizEE Degree Days. http://www.degreedays.net

[13] Southern California Gas Company Residential Rebates. http://www.socalgas.com/for-your-home/rebates/

[14] Voluntary Reporting of Greenhouse Gasses Program Coefficients. U.S. Energy Information Administration. http://www.eia.gov/oiaf/1605/coefficients.html

[15] International Energy Outlook 2011. U.S. Energy Information Administration. Report Number DOE/EIA-0484(2011). http://www.eia.gov/forecasts/ieo/index.cfm

Appendix A: Project Plan

Description of the technology under investigation

Gas wall furnaces are widely used in apartments, motels, and other group housing in California. There may be significant energy savings potential in the replacement of outdated, old furnaces which have lower AFUE (Annualized Fuel Utilization Efficiency) than current technology. Gas wall furnaces are used for space heating of these dwelling units when a centralized system is inappropriate for meeting individual resident demands and can avoid heating unused spaces. Since an apartment complex or motel often has many units, there could be great return in cost and energy savings from retrofitting with new, more efficient models.

Recent natural gas gravity wall furnaces can have AFUE greater than 70%, far above the Title 20 wall furnace standard minimums of 63% (effective throughout at least v.2012). The new, high efficiency models achieve these levels by incorporating electricity-independent "matchless" pilot igniters, automatic thermostats, reduction of flue gas temperature to minimize heat losses, and improved burners, heat exchangers, and blowers. The objective of these high-efficiency wall furnaces is to reduce the amount of gas usage and thermal waste while maintaining a satisfactory heat output for user comfort. In the event of power outages, the electricity independent designs will still function.

The new technology wall furnaces in question will be 25,000 Btu/hr input units which output 19,200 Btu/hr of heat at an AFUE of 71%. The furnaces can be installed recessed or free-standing next to existing walls if necessary. Fresh air for the furnace combustion must be drawn into the room from crawl space or outside. Within the unit, gas is drawn into a combustion chamber where it releases heat into a concurrent flow, plate heat exchanger after being ignited with a piezoelectric spark. Via natural convection, room air is drawn through the bottom vent, flows past the plate heat exchanger, and exits at the top to heat the room. The units will not use any forced convection despite it being an option. The units are vented, convection heaters which exhaust fumes out of the residence through a top-mounted duct. This design tends to somewhat increase waste of generated heat but is generally safer than ventless units which are typically smaller and less common. Furthermore, ventless units often require electricity in order to monitor oxygen levels in the living space.

Description of incumbent technology (or existing standard practice, etc.)

In general, gas wall furnaces can be categorized as radiant or convective. All models are usually used in hard-to-heat areas or where a centralized system is inadvisable or inconvenient. The furnaces use outside air in order to ensure that harmful fumes do not accumulate in the living space. Radiant heaters use a solid, heated element to radiate heat to objects and people within the line of sight of the heater. Convective heaters use either passive or forced convection over a heat exchanger to provide hot air for circulation through the heated space. In each case, a gas combustion burner is used for the heat production.

Aside from wall furnace heaters, the only small space heating devices are electrical and gas floor furnaces and room heaters and wood-burning units.

Original wall furnace with heat exchanger and pilot light igniter

Furnaces may use different types of blowers, igniters, motors, heat exchangers, materials, and other electrical components. The choice of these components in the design will ultimately affect the unit's reliability and efficiency. In general, they operate through the same principles as described in the Description of Technology under Investigation section. As furnaces age (20 years is an expected lifespan), the reliability can suffer and older models that use pilot lights have significantly lower AFUE than current designs. The furnaces being used as a baseline have an originally rated thermal efficiency (Btu out vs. Btu in) of 70% when first purchased which corresponds to an AFUE of about 63%, i.e. *just* meeting code.

Goals of the assessment project

The goal of the technology evaluation is to assess the extent of gas usage reduction due to the replacement of outdated, old natural gas wall furnaces with a new, higher-efficiency model, to quantify the results, and to provide suggestions for market adoption incentives and impact. This reduction in gas use should not come at the expense of user comfort. To accomplish this, the following will be completed:

1) Describe furnace setup, operations, and functionality; assess whether the systems perform as designed, and how/if they differ from the old models.
2) Obtain and present customer feedback regarding usage and satisfaction.
3) Quantify energy and cost savings potential. This includes:
    a. Calculating annual energy and cost savings for each test site.
    b. Calculating payback time with respect to usage patterns.
    c. Assessing accuracy of vendor- and system- provided reports.
    d. Investigating what types of activities and behaviors are most suitable for the technology.
    e. Extrapolating the findings to other situations and sites.

f. Providing recommendations as to how California Utilities could further support this technology.
g. Sensitivity analysis, and if necessary & possible normalization for variables that may influence the results such as occupancy, demographics, location, residence orientation, internal loads, etc.
h. Correlation with weather patterns

If sufficient background information is available, NegaWatt shall also elaborate on

1. Potential market size and associated market barriers in California and the SoCalGas territory.
2. Likely adoption rate.
3. Discussion of codes and standards.
4. Discussion of possible improvements as well as alternative offerings, technologies, or systems.

Application and/or Generalization of project results to similar facilities in other locations, other types of facilities, etc

The proposed market for this technology is expansive: any residence that uses distributed rather than centralized space heating; most often these are apartments, group housing, offices, motels, etc. Any of these buildings could possibly take advantage of this technology and benefit from gas and electricity savings provided the current heating technology is of lower efficiency.

Upfront, we are able to identify the relevant factors that can vary from site to site:

1) Size and geographical/solar orientation of heated space
2) Internal loads and forced circulation such as fans, portable space heaters, computers, and lights
3) User preferences for thermostat setting
4) Preinstalled wall furnace type (baseline energy use)
5) Weather conditions
6) Users' demographics
7) Occupancy levels
8) Excessive losses due to poor insulation, open windows, open doors, leaks, etc.

All variables will be documented and discussed so that reviewers of the report may individually infer applicability of the results to their own circumstances.

Measurement and Verification Plan

Please see Appendix B.

Generic customer information (e.g., the type and geographic location of the residential homes, user demographics, etc)

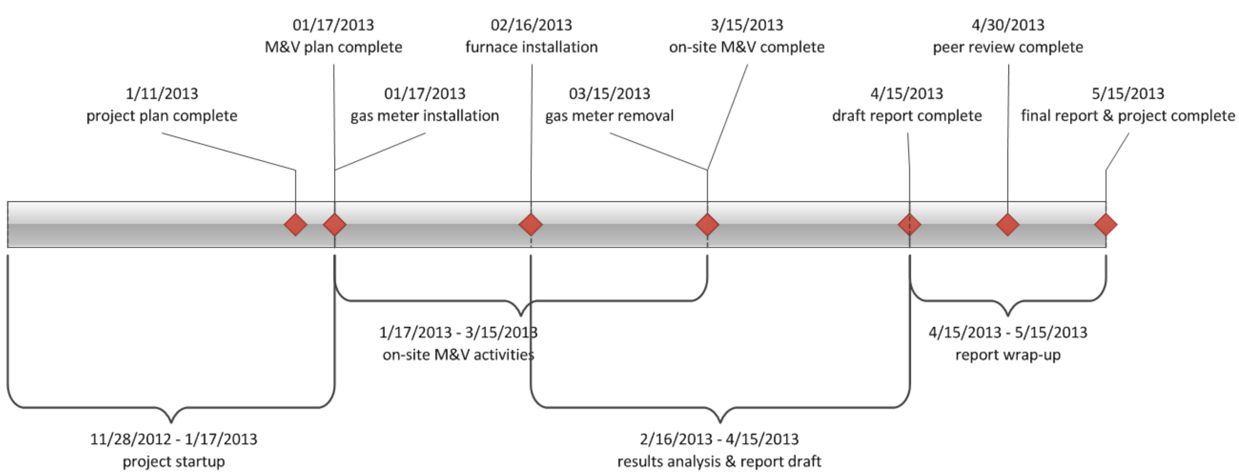
The devices should be installed at group housing sites that are in regular use and at locations that have consistent occupancy and load in the Los Angeles area. Therefore,

- apartments in the Los Angeles area will be selected,
- all apartments will be of similar orientation & envelope,
- wasteful behavior may disqualify data,
- units will have consistent and similar occupancy,
- apartments will be small enough to only require a single wall furnace,
- study will span time in the heating months of the year,
- the installation should simply replace current furnaces while minimizing any visual or living space changes,
- the original setup will be quantitatively and qualitatively characterized,
- selection of users and their demographics will all be documented to the extent possible and permissible with privacy concerns taking priority.

The evaluations will be performed at 6 residential apartments. The initial assessment phase will establish a baseline before the retrofit of 3 furnaces for the measuring of the replacement technology.

Additional details about the test sites will be included in the M&V plan [1].

Project Milestones



Milestones are subject to change as project develops.

Etcetera

This assessment follows the scientific rigor protocol described in [2].

The final report for this project will be made available as [3] on www.etcc-ca.org. Additional references will be contained therein.

This project will be tracked in NegaWatt's project management tools once the project plan has been approved. The document repository for this project is NegaWatt's secure file server. Please contact the authors of this project plan if you need access to these systems or to any of the referenced documents.

References

[1] Gas Wall Furnace Measurement Plan.docx
[2] Draft ETP assessment protocol 061610.docx
[3] Gas Wall Furnace Final Evaluation Report.docx (forthcoming)
[4] Scope of Work_ET12SCG00xx4_Wall Furnace.docx

Appendix B: Measurement & verification plan

Introduction

This measurement plan is an integral part of the project described in "Gas Wall Furnace Field Testing Project Plan" [1] and "Scope of Work_ET12SCG00xx4_Wall Furnace" [3]. If you are not familiar with this project, please read the project plan first for a number of necessary explanations and background information.

It follows the guidelines established in [2].

It has been designed to accurately assess both the baseline performance of the incumbent technology (or standard practice in the absence of an incumbent) and the performance of the technology under study.

It has been designed in compliance with one of the evaluation methods identified in the International Performance Measurement and Verification Protocol (IPVMP) except where site- or technology-specific circumstances dictated a deviation from one of these protocols. The Measurement Plan identifies selected IPMVP method to be used or the justification for any deviations from IPMVP.

All instrumentation under the control of evaluation staff shall be calibrated in accordance with guidelines established in the IPMVP as described in [2].

For field evaluations, all reasonable efforts shall be made to calibrate or replace any customer-owned instrumentation or where this is not possible, to document the calibration status of such instrumentation.

Measurement uncertainty for each monitoring device will be documented. Note that an error analysis evaluating the uncertainty associated with energy and demand savings estimates will be required for the Final Report.

All instrumentation will be commissioned prior to initiating data collection to ensure that measurement and logging systems are functioning properly, to minimize risk of unusable data sets.

Any anomalous data will be investigated and explained. Following investigation, careful consideration will be given to whether such data should be incorporated in the analysis or replaced by additional data collection.

Any events that occur at customer premises during the data collection period that are likely to compromise the validity of the assessment project and that are beyond the control of evaluation staff will be communicated to program management without delay.

Test site description

The test sites for this project are single bedroom studio apartments in the same building in a complex in the Los Angeles metropolitan area. Only internal apartments (Units B-K) on the upper story will be considered in order to maintain a common thermal envelope across all sites (see figure below). Each apartment will be previously equipped with a natural gas gravity wall furnace meant for space heating of the living area. The particular furnace use patterns at each site will be documented upon survey of the residents and apartment managers. Henceforth, these natural gas gravity wall furnaces will simply be called wall furnaces for brevity.

Site building with upper story apartments

Each site will have already established use of a wall furnace prior to the study. Each original furnace is rated at 29,000 Btu/hr input with a thermal efficiency of about 70%. Since the furnaces are old, the ratings and efficiency may no longer be as stated on the identification plaque. After measurement of baseline conditions and furnace use, half of the old models will be replaced with new, closest match, higher efficiency Williams models. The chosen Williams model has a rating of 25,000 Btu/hr input with a thermal efficiency of 77% and AFUE of 71%.

Potential test sites in single apartment building

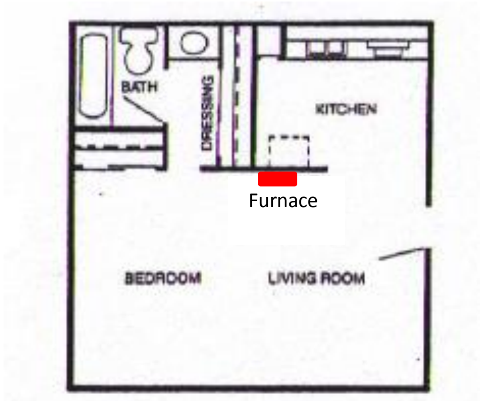
Site	Old Furnace Input; Output [Btu/hr]	Old Furnace η_{th}	Area [ft^2]	Bd/bth	Residents
B-K	29,000; 20,300	70%	528	1/1	1-3

Other sites were evaluated, but were eliminated based on the following necessary criteria for an appropriate set of test sites:

- Similar solar orientation
- No upcoming lease expiration or moving dates
- Consistent occupancy of 1 to 3 residents
- Pre-established use of a natural gas wall furnace with efficiency lower than selected model
- Reliable natural gas wall furnace which has no expectation of malfunction or breakdown

Additionally, although not a prerequisite, each apartment must not practice wasteful behavior such as having open windows and doors or portable electric heaters during measurement and furnace operation. If such excessive internal heat gains or losses are prevalent, data may be rendered unusable or measurement durations may need adjustment. If necessary, measurement will be relocated to other apartments if it is found that data is unusable or if the resident's comfort levels or work patterns are unusual or render data valueless. Similarly, if certain apartments require doable maintenance or repairs to their furnace before the evaluation can begin, exceptions can be made.

Each selected apartment is located above a garage where gas supply lines are situated. The apartments are north-south oriented and each has conjoining neighbors to the east and west.



Studio apartment floorplan with furnace location

Ideally, occupancy patterns and working hours over the measurement duration would be regular and predictable, but that is likely to not be the case. Since there will be no measurement of tenant schedules or time at home, if data is inconsistent and cannot be compared between apartments, normalization may be done via assumptions or behavior survey.

Data collection procedures

The main objective of this project, as specified in [1], is to assess whether the wall furnace technology functionally performs as designed and satisfies user demands, to calculate energy and cost savings due to increased efficiency, to determine the gains of a market-wide implementation, and to advise the client on possible administration of incentives. The data to be measured in this project in order to achieve this goal will be variables from sensors and personal feedback.

Data will be taken in two phases. Phase 1 will be baseline data collection with the original wall furnaces and Phase 2 will be data collection with half the sites using the original furnaces and the other half using new, higher efficiency models of similar size. Instrumentation will be installed at the very onset of Phase 1, three new wall furnaces will be installed before Phase 2, and the instrumentation will be removed at the completion of Phase 2.

There will be no attempt to guide the behavior of the wall furnace users in order to ensure energy savings. The behavioral reactions to the wall furnaces are important metrics of the success of the new technology.

Data points

Data will be taken in two phases with spot testing at the beginning and end of each phase. The first phase of testing will be with the original wall furnace while the second stage will be with half the apartments retro-fitted with the new technology furnace. Prior to the first phase, initial data is necessary from each site in order to capture the operating conditions of the original furnaces. In the case that the original furnaces use electricity, data on electricity usage will be taken. Otherwise, this data may be omitted. Spot measured or surveyed data includes:

1) Building orientation and sun exposure
2) Building internal loads and circulation
3) Wall furnace ratings and specifications
4) Tenant thermostat setting preferences if willing
5) Wall furnace variable spot measurements
    a. Voltage and current of any electrical components

Data that is necessary for the remainder of the project during both phases are:

6) Air temperatures at supply vent, T_H [°F]
7) Air temperature of conditioned space at representative locations, T_L [°F]. This value will also be the assumed return air temperature.
8) Ambient outside air temperatures, T_∞ [°F].
9) Aggregate and time-dependent wall furnace gas usage, *Gas* [ft^3]

Wall furnace temperature measurements. Sensor 1 measures the hot supply air and sensor 2 measures the conditioned space air.

The aggregate gas usage will be presented in total gas used, as a time-dependent rate, and on a heating degree day basis.

Finally, at the end of the measurement plan, surveys given to the users will assess the acceptance, opinion, and usability of each type of furnace. Possible behavioral adjustments to the new furnaces will be included in the survey questions. Additional data that will be collected via final survey includes, but is not limited to:

1) Utility $/therm and $/kWh for the site (gas and electricity)
2) Average gas and electricity bill
3) Average gas and electricity usage
4) Occupancy, schedule patterns, and thermostat settings if tenant willing
5) User demographics
6) Weather conditions and ambient temperatures

Data sampling, recording and collection intervals

The energy calculations use total gas throughput and flow rate from the gas meter. Air temperature values of the furnace supply and return along with the conditioned space will be measured. Temperatures will be recorded for the purpose of normalization, calculation of heating degree days, characterization of the residence heating use, and for determining when the heater is being used. For correlation of gas and temperature data, the loggers should record at similar time intervals.

The gas flow rate is recorded via a pulse signal which generates a frequency of 1 pulse per cubic foot. The new furnaces in question are rated at 25,000 Btu/hr and will therefore use about 1 cubic foot of gas per 2.4 minutes during combustion. Each pulse will last about 3 seconds and will be recorded as a contact closure state change. The state changes will be logged as a time series and averaged over 5 minute intervals since heating and cooling will occur on roughly that time scale. Similarly, the temperatures will be recorded each 10 seconds and averaged over 5 minute intervals.

The total duration of measurement and verification monitoring will be long enough to avoid anomalous schedule variations or weather patterns for extrapolation to to yearly usage patterns and other climate zones. The measurement period will be during the winter heating months and may be modified within reason at the discretion of NegaWatt to ensure high quality results and expedite project execution. The duration may be extended if heating conditions are not pervasive enough to provide sufficient data.

Collection durations

Data collection	Total Time for Data Collection
Initial Data	1 day
Phase 1: Original Furnace	5 weeks
Phase 2: Original and Retrofit Furnaces	7-8 weeks

Instrumentation

Sensors will be used for monitoring air temperature, gas usage, and electricity use if required.

Instruments that will be used in the project to measure the previous stated data points are:

- Electricity Consumption (spot measurements if applicable):
    - A Fluke 1735 Three Phase Power Logger device for energy consumption. The 1735 conducts energy consumption testing by logging most electrical power parameters and captures voltage events. Calibration of the Fluke 1735 was done on 3/30/2011. Measuring range and accuracy for the main variables of the power logger are:
        - Voltage (V-RMS Wye measurement)
          Range (V-RMS Wye): 57 / 66 / 110 / 120 / 127 / 220 / 230/ 240 / 260 / 277 / 347 / 380 / 400 / 417 / 480 V AC
          Range (V-RMS Delta): 100 / 115 / 190 /208 / 220 / 380 / 400 / 415 / 450 / 480 / 600 /660 / 690 / 720 / 830 V AC
          Resolution: 0.1 V
          Intrinsic error: ± (0.2% of measured value + 5 digits)
          Operating error: ± (0.5% of measured value + 10 digits)
        - Current (A-RMS)
          Range: 15 A / 150 A / 3000 A RMS (non-distorted sine wave)
          Resolution: 0.01 A
          For ranges 150 A/3000 A
          Intrinsic error: ± (0.5 % of m. v. + 10 digit)
          Operating error: ± (1 % of m. v. + 10 digit)
          For range 15 A
          Intrinsic error: ± (0.5 % of m. v. + 20 digit)
          Operating error: ± (1 % of m. v. + 20 digit)
        - Energy Measurement (kWh, KVAh, kVARh)
          Intrinsic error: ± (0.7 % of measured value + F variation error* +15 digit)
          Resolution: 1 W to 10 W
          Operating error: ± (1.5 % of measured value + F variation error* + 20 digit)
          * Frequency variation error: ±2 % measured value + 2* (% maximum frequency deviation)
    - DENT instruments Elitepro Recording Poly Phase Power Meter. Last calibration data was September 2011:
        - ELOG 2009 Windows based software package for programming, set-up, communicating, data retrieval and analysis (can export to excel or access)
        - Voltage: 3 channels
          Range: 0-600 V (AC or DC)
          Accuracy: < 1% of reading, exclusive of sensor (0.2% typical)
          Resolution: Better than 0.1% FS – 12 bit A/D
        - Current: 4 channels
          0-6,000 A (with current sensor having 333mVac output, ordered separately)
          Range: 0-600 V (AC or DC)
          Accuracy: < 1% of reading, exclusive of sensor (0.2% typical)
          Resolution: Better than 0.1% FS – 12 bit A/D

- Air Temperature:
    - Onset TMCx-HD for spot temperature measurements at installation events
        - Range: -40 to 212 °F
        - Accuracy: ±.45 °F (32 to 122°F)
        - Resolution: .05 °F
    - Onset Hobo U12-006 data logger with external channels for stereo cable input
        - Range: 0-2.5 VDC with TMCx-HD/HE cable
        - Resolution: .0006 V
        - Operating range: -4 to 158 °F
        - Time accuracy: ±1 minute per month
        - Interval Setting: 1 second

- Gas metering:
    - Itron Metris M250 gas meter
        - Counter resolution: 100 ft^3
        - Dial resolution: .05 ft^3
        - Meter capacity: 250 CFH natural gas @ .5 inch w.c. differential
        - Accuracy: ±1%
    - RIOTronics PulsePoint
        - Temperature range: -40 to 240 °F
        - Contact resistance: .5 Ω
        - Open circuit resistance: >100 MΩ
        - Max 3 sec/contact closure
        - 2 contacts per dial revolution (connected to 2 ft^3/revolution dial)
        - Duty cycle: 10-15% on, balance off

    - Onset Hobo U9-001 state logger with external channel for state logging.
        - Operating range: -4 to 158 °F
        - Time accuracy: ±1 minute per month
        - Resolution: 1 state change (1/2 CF)
        - Solid state switch closure: <15kΩ low, >300kΩ high

Data analysis procedures

As stated in the Introduction, all data will be reviewed before analysis and any anomaly will be investigated and explained. This may include furnace malfunction, loggers becoming unplugged, installation issues, and other events. Anomalous data will be evaluated on a case-by-case basis to determine whether it shall be incorporated in the analysis, corrected, or replaced by additional data collection.

Due to the somewhat limited number of furnaces and sites that are part of the study (with respect to the total population of available models, residence types, and other variables), we do not expect to have statistically representative results in all respects. We will therefore also perform a *sensitivity analysis* of the various factors influencing energy usage. This will help determine which factors to pay particular attention to when estimating energy savings for new installations of this technology, how accurate estimations can be, and where M&V of certain key factors may be advisable.

Data manipulation (aggregation, statistical analysis, etc)

A general and comprehensive analysis of the collected data will be conducted. All data will be collected as comma separated value files and manipulated in Microsoft Excel or Matlab. The raw data returned will be vectors of temperature and cubic feet of gas used over the measurement period in five minute intervals. The gas used will be presented as both total aggregated use over time and gas flow rate as five minute-averaged values. The air temperatures measured at the supply, conditioned space, and ambient will also be presented as five minute-averaged values. If necessary, the data may be aggregated into longer time intervals, such as hourly or daily, in order to have interpretable and understandable results.

The time-dependent gas rate and temperature series will allow for correlation of gas savings and temperature. The time stamp of both the gas usage and air temperatures will be coordinated for this purpose. These data will allow assessment of day-to-day usage patterns and correlation with weather conditions and heating degree days (HDD).

If there exists any high degree of variability associated with operating conditions or changes over the duration, such as vacations, abnormal weather conditions, etcetera, adjustment of data may be done. It is unavoidable that each test site will save differing amounts of energy based upon the original baseline furnace and occupant demands of each. The data may be normalized to this variation of demand and baseline conditions if necessary, but it may be advantageous to view the variability of energy savings in each unique situation for an understanding of variability in the market as a whole.

Calculation of energy and demand savings

The gas meter measures gas flow to the furnace, which is used in the pilot light (if applicable) or combustion chamber with the excess exhausted. Since gas usage is measured directly, energy consumption in therms over a time interval is calculated as,

$$E = \frac{1}{100}\int Gas\,dt$$

where *Gas* is the logged gas flow as a function of time. The energy consumption will be correlated with calculated heating degree days (based upon ambient conditions and a standard or calculated baseline temperature) so that energy consumption can be normalized to units of therm/HDD.

If E_1 is the total normalized energy used with the original furnace E_2 is the total normalized energy used with the higher efficiency furnace, the energy savings is calculated as,

$$E_{saved} = E_1 - E_2$$

The energy saved and total energy used allows comparison of the original and new furnace in each retrofitted apartment or between retrofitted and non-retrofitted apartments. Energy saved over a year with a climate zone based number of heating degree days will be calculated.

Error analysis for these calculations will be based off the resolution and inaccuracies of the pulse logger, gas meter, temperature logger, and temperature sensors. Although not reflected in the above equations, temperature data may be used in the calculation of energy savings, energy delivered to the space, or heating degree days and therefore should be reflected in the error analysis.

Calculation of cost savings

A payback chart will be created in Microsoft Excel which will take all of the measurements and calculations into account. It will return the payback time for choosing a high efficiency model. The money saved for any given month realized from switching to a high efficiency furnace can be determined by

$$CostSavings = E_{saved} * GasRate$$

where *GasRate* is in \$/therm and E_{saved} is the calculated energy savings for the month or year in question.

Since repairs and breakdowns of old furnaces cannot be predicted, these maintenance costs cannot be incorporated accurately. However, the higher cost associated with purchasing a high efficiency furnace instead of a standard furnace can be used to calculate payback time of the extra investment. The table below illustrates a hypothetical calculation of cost savings and payback time of a new high efficiency furnace purchase instead of standard efficiency. It assumes that there is no increase in furnace use time.

Example payback time calculation for 20000 Btu/hr output furnaces with 74% and 77% thermal efficiency

Item	Value	Comments
Cost increase	$50	Example cost increase from standard to high efficiency furnace
Furnace input	27,000 Btu/hr; 26,000 Btu/hr	Gas requirements for each unit
Time on per day	4 hours	Average total runtime per day
Energy saved per day	.04 therms	Total gas energy saved per day
Energy saved per month	1.2 therms	Total gas energy saved per month
Energy cost savings	$1.8/month	Based off rates of $1.5/therm
Payback time of extra cost	27.8 months	Payback time for customer

This scenario is simplified and hypothetical and should not be interpreted as typical of results. Ultimately, the energy and cost savings for a given increase in efficiency will be tabulated and presented along with recommendations for implementation.

References

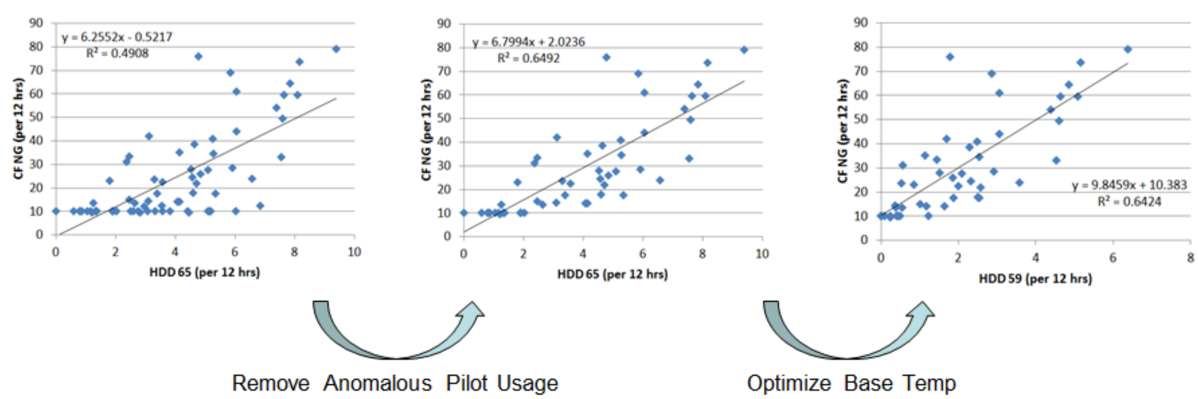
[1] Gas Wall Furnace Project Plan v.1.0.docx
[2] Draft ETP assessment protocol 061610.docx
[3] Scope of Work_ET12SCG00xx4_Wall Furnace.docx

Appendix C: Methods, Correlations, and Apartment-specific Details

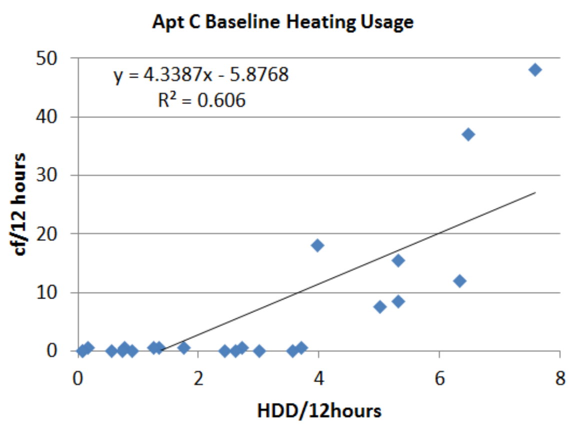
Correlation with HDD values was done separately for each apartment. The steps taken for each individual dataset were as follows:

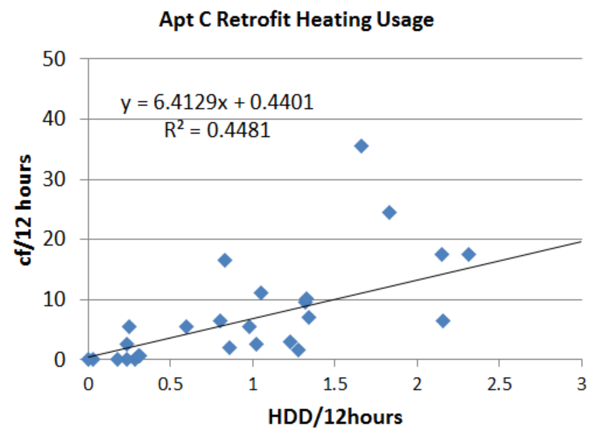
1. Removed anomalous data. Details on anomalous sections of data are given for each apartment below.
2. Data made continuous in time of day although not over dates. In other words, data was removed and shifted such that the dataset began at 000 hours and each 2355 data point was followed by a 000 data point (data was recorded at 5 minute intervals). This was necessary so that aggregated data over the target time intervals contained the same times of day for each date.
3. Aggregated gas usage and total HDD for target time intervals (8, 12, and 24 hours). HDD values were calculated for each 5 minute recorded interval (i.e. heating degree five minutes) for a range of base temperature values of 55 to 75 degrees Fahrenheit before aggregation.
4. A constant value of pilot gas consumption was subtracted from all data points in order to separate pilot and heating consumption. The correlated data is thus for heating gas only.
5. Aggregated data was sorted in order of HDD values. All zero heating gas consumption above the cutoff point was removed. The cutoff point was the HDD value above which the residents would use the wall furnace. The points of higher HDD where no heating was done were assumed to be time intervals during which there were non-trivial HDD and the resident was out-of-house. Note that the removed data had to be accounted for later in prediction of yearly savings by incorporating a reduction in heating usage by a fixed percentage of away time (~8 hours per day).
6. A linear regression was applied and the HDD base temperature was adjusted to an ideal location that maximized the R^2 value and approached the (0,0) point of the cf-HDD space. It was necessary to determine unique HDD base temperatures for each apartment because the dataset was small enough to be significantly coupled to behavioral variables and was not statistically representative of the wall furnace population, in total.

The following figure graphically represents the transformations from aggregated data to correlated data. In this case the y-intercept target was 10 cf/12hours because the pilot light consumption constant had not been removed.



The following are apartment specific correlations and regressions along with the justified sections of data that were removed.

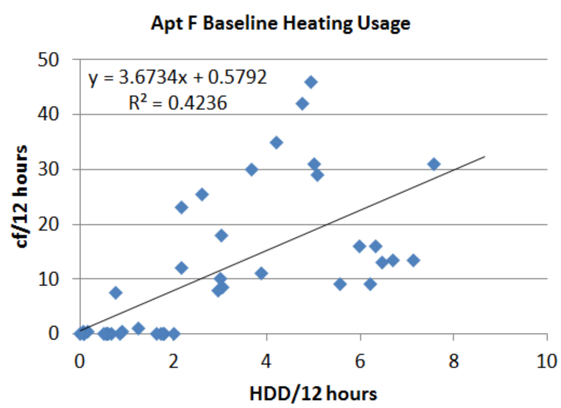


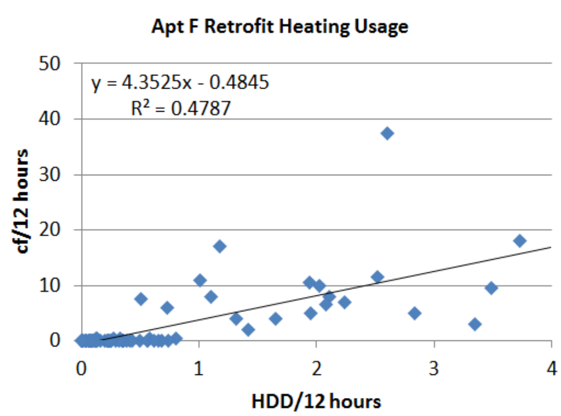


The apartment C baseline correlation is less than ideal because there was a limited amount of data available from the original furnace. The resident did not use the furnace often because he was told that there was a problem with the gas supply. It was fixed but he was not told that it was okay to use again. Therefore there was a long stretch of time where he was unaware that the furnace was usable, reducing the total number of useful data points.

Apt C anomalous data treatment.

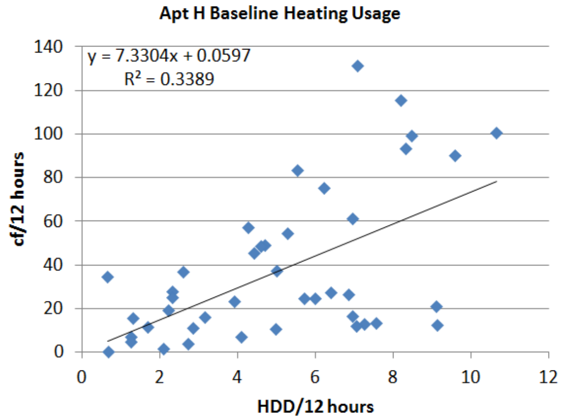
1/31-2/19 (baseline)	Gas supply interrupted and resident not aware that furnace was usable again. Data removed.

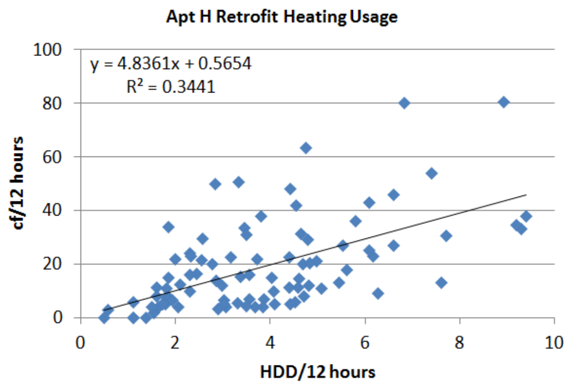




Apt F anomalous data treatment

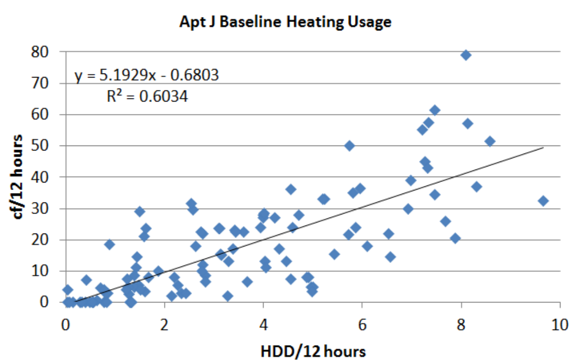
1/19-1/23 (baseline)	Pilot light went out and did not come back on for several days. Unknown cause. Data removed.
2/21-2/25 (retrofit)	Thermostat was improperly installed (and then fixed) and would not allow operation. Data removed.





Apt H anomalous data treatment

2/7-2/14 (baseline)	Pilot light would not stay lit, but residents used furnace as normal by lighting pilot whenever needed. Pilot light usage was added back in manually.
2/14-2/20 (baseline)	Pilot light and combustion chamber would not fire at all. Data removed.



The remaining apartments did not use the wall furnaces for heating and the only gas consumed was for the standing pilot light. The pilot light usage for these apartments is listed in the following table.

Apartment	Pilot Gas Usage [cf/day]
B	25.2
E	23.4
G	16.7
K	24.9

The heating gas correlations are tabulated for all tested time intervals. 12 hour intervals produced the most consistent and average correlations. Again, these correlations are for heating gas only (not pilot light) and do not account for resident away time.

		8 Hour Intervals				12 hour intervals				24 hour intervals			
Apt	Pilot cf/day	Slope	R2	Y-int	Base T	Slope	R2	Y-int	Base T	Slope	R2	Y-int	Base T
C	26.8	4.53	0.672	-2.99	63	4.34	0.606	-6.28	63	4.16	0.88	-10.63	63
C Retro	14.9	6.15	0.422	-0.23	63	6.41	0.448	0.44	63	2.58	0.39	-1.2	63
F	22.4	2.38	0.399	0.6	71	3.67	0.424	0.58	63	1.93	0.221	0.16	67
F Retro	12.4	2.53	0.512	0.05	65	4.35	0.479	-0.48	61	10.38	0.475	0.73	57
H	31.5	5.04	0.251	-0.31	75	7.33	0.339	0.06	67	12.52	0.425	3.08	61
H Retro	10	2.92	0.2	3.53	75	4.84	0.344	0.57	69	7.89	0.409	3.42	63
J	20	5.11	0.537	0.25	65	5.19	0.603	-0.68	65	7.67	0.737	-0.3	61

As described in the Energy Savings section of the Project Results and Discussion chapter, weighting and corrective factors were needed to extrapolate savings to the entire complex and to California Utility territories. These factors were chosen based upon intuition and

	Apartment Complex	California MFR	California SFR
Fraction who do not heat	0.25	0.10	0.10
Increased use weight	0.67	0.20	0.20
Unchanged use weight	0.33	0.80	0.80
Year-round weight	0.75	0.75	0.50
Heating Months only weight	0.25	0.25	0.50
Studio fraction	N/A	0.25	0.10
1 Bd fraction	N/A	0.55	0.30
2 Bd fraction	N/A	0.20	0.60

The potential gas savings per number of particular type of residence (SFR or MFR) are calculated using the following weighted equation based upon the above correlations.

$$\frac{Therms\ Saved}{\#Residences} = w_{yr}\{p_{yr} + HDD_{yr} * w_{increase}[w_{st} * h_{st} + w_{1b} * h_{1b} + w_{2b} * h_{2b}] + HDD_{yr} * w_{constant}[w_{st} * h_{st} + w_{1b} * h_{1b} + w_{2b} * h_{2b}]\} + w_{hm}\left\{p_{yr} * \frac{7}{12} + HDD_{hm} * w_{increase}[w_{st} * h_{st} + w_{1b} * h_{1b} + w_{2b} * h_{2b}] + HDD_{hm} * w_{constant}[w_{st} * h_{st} + w_{1b} * h_{1b} + w_{2b} * h_{2b}]\right\}$$

Where *w* is the weight, p_{yr} is the pilot light gas savings [therms/year], *h* is the heating gas savings [therms/HDD], and *HDD* are the number of heating degree days. The subscripts denote the following:

- *yr*- year-round
- *increase* – increased use of furnace due to change in location of thermostat
- *st* – studio apartment
- *1b* – 1 bedroom apartment
- *2b* – 2 bedroom apartment
- *constant* – no increase in use of furnace due to change in location of thermostat
- *hm* – heating months only operation

Several key assumptions are necessary for the estimation of yearly savings. As an example, the assumptions for the apartment complex were based on the following:

- Fraction of tenants who use space heating: 0.75
    - We found that 2/6 homes did not use their wall furnace despite it functioning normally. This was due to personal preference and night-time work hours. The two apartments that were chosen to replace these also did not use their furnaces but these were not taken into account in the assumption since the meters were moved late in the heating season and one tenant commented that she did not know how to turn on the heater. The fraction was assumed slightly larger than the data suggested, based on intuition.
- Fraction of tenants who would increase their heating use: 0.67
    - The original furnaces had dial thermostats (1-10 rather than in degrees) inside the furnaces baseplate cover. This was inconvenient and perhaps reduced use. The new furnaces had a standard thermostat on the outside of the furnace. Two of three tenants said that this increase in convenience caused them to use their furnace more frequently. This increase in use would decrease savings despite the higher efficiency of the furnace.
- Fraction of tenants who turn off their pilot light during non-heating months: 0.25
    - In the mild SoCal climate, pilot light gas accounts for about 50% of total use. Thus, leaving the pilot light on during summer months accounts for a very significant portion of gas costs. Since tenants do not pay their own gas bills and are likely unconcerned with small amounts of individual gas usage, most probably do not think to turn off their pilot lights during the summer.

Appendix D: SCG bill sample from test site

The Gas Company
A Sempra Energy utility®

DATE MAILED Jan 14, 2013 Page 1 of 4
24 Hour Service
1-800-427-2200 English
1-800-342-4545 Español
1-800-252-0259 TTY
www.socalgas.com

H H

Account Summary

Amount of Last Bill			$5,586.21
Payment Received	01/11/13	THANK YOU	- 5,586.21
Current Charges			+ 6,542.67
Total Amount Due			**$6,542.67**

This bill reflects modified gas charges due to a rate change.

45070

Current Charges

Rate: GM-BE - Residential Climate Zone: 1
Meter Number:
Cycle: 8
Master Meter Livin

Billing Period	Days	Current Reading	- Previous Reading	= Difference	x Pressure Factor	x BTU Factor	= Total Therms
12/10/12 - 01/10/13	31	927518	917674	9844	0.000	1.018	10021

GAS CHARGES		Amount($)
Customer Charge	31 Days x $11.17200	346.33
Gas Service (*Details below*)	10,021 Therms	

	Baseline	
Therms used	10,021	
Rate/Therm	$.49340	
Charge	$4,944.36	= 4,944.36

Total Gas Charges $5,290.69

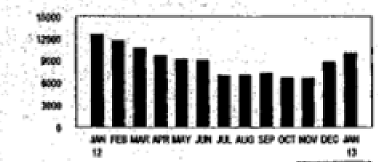
TAXES & FEES ON GAS CHARGES		Amount($)
State Regulatory Fee	10,021 Therms x $.00068	6.81
Public Purpose Surcharge	10,021 Therms x $.08730	874.83
Santa Ana City Users Tax	$6,172.33 x 6.00%	370.34

Total Taxes and Fees on Gas Charges $1,251.98

Total Current Charges $6,542.67

DATE DUE	Feb 4, 2013
AMOUNT DUE	$6,542.67

Gas Usage History *(Total Therms used)*



	Jan 12	Dec 12	Jan 13
Total Therms used	12,598	8,785	10,021
Daily average Therms	370.5	258.4	323.3
Days in billing cycle	34	34	31

Special Discount You may be eligible for the California Alternate Rates for Energy (CARE) program. For more information or to apply online, go to socalgas.com (search "CARE"). Or call 1-800-427-2200 to request an application.

Descuento Especial Usted podría ser elegible para el programa de Tarifas Alternativas para Energía en California (CARE). Para más información o para aplicar, visite socalgas.com/español (busque la palabra clave "CARE") o llame al 1-800-427-2200.

The Gas Company's gas commodity cost per therm for your billing period:
Jan. . . . . $.36809 Dec. . . . . $.40358

PLEASE KEEP THIS PORTION FOR YOUR RECORDS. (FAVOR DE GUARDAR ESTA PARTE PARA SUS REGISTROS.)
PLEASE RETURN THIS PORTION WITH YOUR PAYMENT. (FAVOR DE DEVOLVER ESTA PARTE CON SU PAGO.)

The Gas Company A Sempra Energy utility®

Save Paper & Postage
PAY ONLINE
www.socalgas.com

DATE DUE	Feb 4, 2013
AMOUNT DUE	$6,542.67

Please enter amount enclosed.

CY 08 3927 0614

Appendix E: Survey Results

Which apartment do you live in?	Number of people living in your home.	Do you have regular work hours? If so, what are they?	
B	3	no	
C	1	yes	57 hours
E	2	yes	T-F 10 pm - 8am
F	2	yes	
G	1	yes	9am - 7pm
H	1	yes	N/A
J	1	yes	varies with school
K	2	yes	8:30-5:30

Have you taken any vacations this year? If so, when and how long?		How happy are/were you with your original furnace?	How happy are you with your new furnace?	I received a new furnace.
no		Happy	I did not get a new furnace	No
yes	06/10/2013	Happy	Happy	Yes
no		Happy	I did not get a new furnace	No
no		Happy	Love it	Yes
yes	03/31/2013	Neutral	I did not get a new furnace	No
yes	N/A	Happy	Love it	Yes
yes	sometimes	Neutral	I did not get a new furnace	No
no		Happy	I did not get a new furnace	No

The wall furnace heats the house well.	I use the furnace frequently	If your furnace had an outside thermostat would you use it more, less, or the same?	If your furnace had an outside thermostat on the wall would you control it more, less, or the same?
Strongly Agree	Neutral	The Same	More
Agree	Neutral	The Same	More
Neutral	Neutral	More	More
Agree	Disagree	The Same	The Same
Neutral	Disagree	The Same	The Same

Do you leave your furnace on when you are not home?	How cold does it have to be outside for you to turn on the furnace?	Where there any issues or problems with the furnace over the last several months?
No	55*F and under.	yes, a gas leak.
No	58	No
No	65	no
No	very cold	no
No	No thermostat so can't	No
No	N/A	
No	very cold	no
Rarely	40-50 DEGREES	they haven't explained to me how to turn it on and off

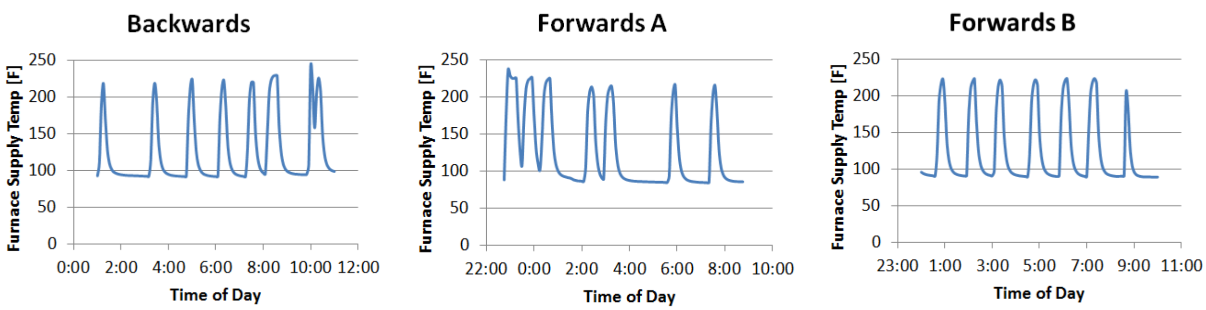
Do you have space heaters that you use? Do you leave the windows or doors open a lot when the furnace is on?	The old wall furnace heated the house well.	The new wall furnace heats the house well.	I used the old furnace frequently
	Agree	Agree	Neutral
Space heaters			
Windows	Agree	Agree	Agree
Windows			
	Agree	Strongly Agree	Neutral

I use the new furnace frequently	Do you use the heater more, less, or the same now that there is a convenient thermostat on the side?	Do you control your heater more, less or the same now that there is a convenient thermostat on the side?
Neutral	More	More
Agree	More	More
Neutral	The Same	The Same

The new furnace thermostat is more convenient that the old one. This affected how much I used the furnace.
Agree
Agree
Neutral

Appendix F: Gas Meter Calibration Check

As described in the Project Error Analysis section, the gas meter calibration required examination since they were improperly installed. The figure below shows the three similar heating curves (supply air temperature from the furnace) from the same meter during which the heater was activated 7 times within a 10 hour period.



Supply air temperature for three different 10 hour heating periods from the same meter attached to Apt J, one taken after incorrect backwards installation and two taken after corrective re-installation.

The heat delivered to the space, *Q*, is proportional to the temperature change of the air across the furnace. In order to check that the calibration was unaffected and both backwards and forwards data was usable, the ratio of the area under the temperature curves, *Θ*, to the 10-hour gas flow was calculated. The table below lists gas consumption, the *cf/Θ* ratios, and the percent error of the three possible comparisons. Note that the comparison between two forwards meter timespans have nearly as much error as a comparison between a forwards and backwards orientation. The small error and intrinsic error due to the applied method suggest that the meter calibration was unaffected by the improper installation.

Comparison of heating gas consumption between forward and backward installation of meter in Apt J

	Backwards	Forwards A	Forwards A
Gas [cf]	86	98	92
Θ	7.89	8.91	7.96
cf/ *Θ*	5.45	5.50	5.78
% Relative Error			
	Backwards	Forwards A	Forwards B
Backwards	0.0%	0.9%	5.7%
Forwards A		0.0%	5.0%
Forwards B			0.0%

The following table shows the pilot consumption for two apartments that had the meter installed backwards. Again, there was no significant effect on the calibration. Thus, both data from backward and forward meters was used in the analysis.

Pilot gas consumption with backward and forward meters, averaged over 3+ days without heating.

	Apt E	Apt J
Backwards Meter – Pilot Gas [cf/day]	23.4	19.9
Forwards Meter – Pilot Gas [cf/day]	23.4	20.0

Appendix G: Total California Wall Furnace Savings Opportunity

The following values represent the total wall furnace retrofit potential across California and the Utility territories. These values result from assuming that all existing furnaces have the same savings potential as the tested baseline furnaces and all these furnaces would be replaced by the 71% AFUE model used in this study. In other words, these results are the same as presented in the Market Opportunity section without being reduced for high-AFUE furnace market penetration and yearly replacement expectations. These results also use the weighting factors tabulated in the Energy Savings section and Appendix C.

Total California and Utility savings potential. Note that the number of target homes is reduced by 10% when calculating energy savings in order to account for residents who choose not to heat in the mild winter climate.

		SCG	PG&E	SDG&E	California
Combined MFR and SFR	Yearly Residential Gas Usage [MMt]	2,736.7	1,883.7	327	5,167.8
MFR	# target homes	115,075	52,738	19,333	191,244
	Gas saved [MMt/year]	6.79	4.02	1.02	12.15
	% of total residential gas saved	0.25%	0.21%	0.31%	0.24%
SFR Detached	# target homes	108,757	46,405	11,952	170,131
	Gas saved [MMt/year]	6.51	3.61	0.62	10.97
	% of total residential gas saved	0.24%	0.19%	0.19%	0.21%
SFR Attached	# target homes	13,601	5,346	2,156	20,272
	Gas saved [MMt/year]	0.79	0.41	0.11	1.33
	% of total residential gas saved	0.05%	0.04%	0.05%	0.05%
Combined MFR and SFR	Gas saved [MMt/year]	14.09	8.04	1.75	24.45
	% of total residential gas saved	0.51%	0.43%	0.54%	0.47%

The total savings potential for retrofitting old standing pilot wall furnaces with new, high-AFUE standing pilot wall furnaces is about 14.09 MMt for the SCG territory and 24.45 MMt for California as a whole. Since the savings comes largely from the pilot light reduction, it is also worthwhile to consider savings that would be achieved from eliminating standing pilots altogether. A model with similar AFUE and an intermittent spark or hot surface ignition would save additional .124 therms per day per residence. This would amount to significant added savings as shown in the following table.

These savings could be added to the above values if the retrofitfurnace was equipped with a non-standing pilot light ignition.

	SCG	PG&E	SDG&E	California
Added savings due to removal of pilot light from retrofit model [MMt/year]	4.84	2.13	.68	7.79

(End of document)