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Whole Home Efficiency and Comfort Study – Evaluation Summary

July 25, 2013

As part of the 2009/2010 Demand-Side Management (DSM) Settlement Agreement, the Energy Efficient Business Coalition (EEBC) proposed that Public Service Company of Colorado ("Public Service" or the "Company") conduct a Whole House Energy Efficiency and Comfort (WHEC) Study to investigate holistic approaches to residential energy savings. EEBC suggested that a DSM product similar to the Standard Offer Program for business customers be made available for residential customers. A description of the pilot effort and a summary of the results are described herein.

Description

As stated in the Company's 2011 DSM Plan[1] the WHEC Study was designed to evaluate the savings that could result from implementing a comprehensive package of energy saving technologies, through coordinated design and installation, to optimize the energy efficiency of residential homes. The stated objectives of the pilot included:

- Evaluating the "house as a system" approach to energy efficiency retrofits and upgrades;
- Providing a comprehensive energy efficiency retrofit to ten homes in the Denver area; and
- Deploying additional "emerging technologies" (e.g. air source heat pumps, ground source heat pumps, sealed combustion water heaters, etc.) to 8 of the homes participating in the pilot.

Public Service contracted with EEBC to implement the study. The analysis of results was conducted by Mesa Point Energy consultants.

Implementation

First, EEBC assembled a list of standards and specifications to determine which energy retrofits would be made to each home in the pilot. A third-party certified Home Energy Auditor consulted with EEBC and the project coordinator to determine best practices for each pilot participant. Homes selected for the program were of typical size for the local residential area, and had inefficient features such as poor attic and wall insulation. At the outset a homeowner survey was conducted to determine typical energy use patterns, along with a more detailed energy audit. The energy retrofits deployed included the following:

[1] Docket No. 10A-471EG, Indirect Products & Services, A. Product Development, 2. Product Development for Energy Efficiency, c. Colorado Whole House Energy Efficiency and Comfort Study, pg. 195.

- Insulation and air sealing;
- HVAC – properly sized, energy-efficient furnace and air conditioning, air duct sealing, proper ventilation, commissioning, and home owner training/education; and
- Emerging technologies such as solar-powered, tankless, sealed combustion or heat pump water heaters; ground source heat pump (GSHP); indirect evaporative cooling; and/or energy-efficient windows.

The ten pilot homes were selected in the fall of 2010; and the energy efficiency measures were installed in the last quarter of 2010.

Evaluation
Mesa Point Energy evaluated the energy savings that could be attributed to this pilot activity based on the data provided from EEBC, as well as data collected from the Company's billing system for each home both pre- and post-retrofit. Energy usage was compared with, and without, correction for differences in weather. Additionally, to further assess the performance of the energy efficiency measures, an estimation of expected savings for each home retrofit was calculated using methods presented in the Technical Reference Manual of the 2011 DSM Plan.

The evaluation concludes that the efficiency measures were not cost effective as deployed, having a lengthy payback period. Table 1 below summarizes the results:

TABLE 1: PROJECT SAVINGS SUMMARY

	kWh		Therm		Total			Financials	
House	Energy	$ Dollar	Energy	$ Dollar	Total kBTU	$ Total	CO_2 Savings, lbs	Project Cost	Simple Payback (years)
1	652	$70	167	$144	18,879	$215	2,992	$18,500	86
2	584	$66	288	$215	30,753	$281	4,300	$18,500	66
3	-2,270	($266)	731	$881	65,385	$615	4,922	$40,500	66
4	-394	($48)	195	$193	18,179	$145	1,654	$29,000	200
5	-1,011	($108)	503	$418	46,822	$310	4,263	$27,000	87
6	-	$0	-	$0	-	$0	0	$27,000	0
7	-1,564	($181)	188	$159	13,478	($22)	-303	$23,500	no payback
8	-1,549	($180)	386	$367	33,346	$187	2,039	$24,000	128
9	-7,878	($908)	548	$472	27,954	($436)	-6,197	$20,300	no payback
10	-1,007	($114)	589	$471	55,459	$357	5,278	$19,800	55
Sum	**-14,438**	**($1,669)**	**3,595**	**$3,323**	**310,255**	**$1,653**	**18,948**	$248,100	150
EEBC Administration Costs								$61,297	
						Grand total		$309,397	**187**

Several key factors influenced the outcomes of the pilot:

- *Unanticipated Impacts of Fuel Switching* – Several efficiency measures were deployed to address natural gas consumption. In many cases natural gas using devices, such as water heaters were converted to electrically-powered appliances. During the initial development phase of the pilot, natural gas prices were higher than they are today and had been projected to increase significantly in the future. Since that time, market forces have driven natural gas prices down, which impacted the economic benefits of conservation.

- *Non-Standard Baseline* – Initial audit data indicates that several of the participants' HVAC systems were either inadequate for the space or in disrepair (not functioning) at the outset of the pilot. Thus, the baseline (pre-retrofit) usage was lower than expected; and the addition of cooling load resulted in an increase in electrical usage, leading to negative savings impacts.
- *Sample Anomalies* – Greater energy savings could have been realized had the efficiency measures been compared against different baselines. (For example, indirect evaporative cooling equipment was installed where a direct evaporative cooling system was already in place, meaning that the baseline usage for cooling was less than the usage after the retrofit).
- *High First Costs* – Some of the efficiency measures, notably GSHP and window replacement, have high "first costs." These technologies would need to be valued beyond their energy savings in order to have a positive net economic impact (at current energy prices).
- *Offsetting the Entire Purchase Price of Efficiency Upgrades* – Energy savings resulting from the pilot period were compared against the full cost of deploying the energy efficiency measures. This approach yielded unacceptable payback periods.

The study results validate Public Service's current approach to residential DSM programs which are designed to offset only the *incremental* cost between energy-efficient equipment and baseline equipment options, rather than attempting to offset the entire purchase price. Furthermore, our prescriptive rebates for existing homes offer cost-effective energy savings that are beneficial to our customers; whereas a "whole-home" incentive has been shown, through evaluation of this pilot, to be economically infeasible given the extensive variability in the energy use baseline across residential customers.

Public Service will continue to collaborate with the EEBC in efforts to grow strong energy efficiency programs, educate the building community on the benefits of energy efficiency, and engage with the various stakeholders within the energy efficiency industry.

The pilot evaluation study prepared by Mesa Point Energy is attached; and has been posted to our website, available at:
http://www.xcelenergy.com/About_Us/Rates_&_Regulations/Regulatory_Filings/CO_DSM.

Impact Evaluation of the Colorado Whole House Energy Efficiency and Comfort Study

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EXECUTIVE SUMMARY

Mesa Point Energy was retained by Xcel Energy to conduct an evaluation of the Colorado Whole House Energy Efficiency & Comfort Study (WHEC) Pilot program, in accordance with the 2009/2010 Demand-Side Management (DSM) Settlement Agreement between Public Service Company of Colorado ("Public Service" or the "Company" – a subsidiary of Xcel Energy Inc.) and the Colorado Public Utility Commission. The WHEC Pilot was proposed by an industry stakeholder, the Energy Efficient Business Coalition (EEBC); and as a result of the Settlement, was implemented during the fourth quarter of 2010. The project involved the installation of several energy efficiency measures within 10 homes in the greater Denver metropolitan area. All 10 houses were both natural gas and electricity customers of Xcel Energy.

A utility bill analysis of energy savings was conducted as a part of the program evaluation. Table 1 shows the costs and savings associated with the project.

TABLE 1: PROJECT SAVINGS SUMMARY

House	kWh Savings	$ kWh Savings	Therm Savings	$ Therm Savings	Total $ Savings	Project Cost	Simple Payback (years)
1	651.62	$70	166.56	$144	$215	$18,500	86
2	583.87	$66	287.60	$215	$281	$18,500	66
3	(2,269.96)	-$266	731.31	$881	$615	$40,500	66
4	(393.86)	-$48	195.22	$193	$145	$29,000	200
5	(1,011.08)	-$108	502.72	$418	$310	$27,000	87
6	-	$0	-	$0	$0	$27,000	0
7	(1,563.94)	-$181	188.15	$159	-$22	$23,500	no payback
8	(1,549.44)	-$180	386.33	$367	$187	$24,000	128
9	(7,877.83)	-$908	548.34	$472	-$436	$20,300	no payback
10	(1,007.46)	-$114	588.97	$471	$357	$19,800	55
Sum	(14,438.07)	-$1,669	3,595.20	$3,323	$1,653	$248,100	150
					EEBC Admin costs	*$61,297*	
					Admin as % of total	***25%***	
					GT	$309,397	**187**

As a result of the program, it is estimated that annual CO_2 emissions were reduced by 18,948 lbs per year. Customer kWh usage increased by approximately 17% as a result of the projects, while gas therm usage decreased by approximately 45%. The increase in kWh was primarily, due to the installation of a ground-source heat pump (GSHP) in test home 3 and the replacement of gas-fired domestic hot water (DHW) heaters with air source heat pump DHW heaters in test homes 9 and 10. Additionally, the increase in electric energy use may have resulted from changes in the energy use patterns of the home occupants.

Subsequent to completing energy efficiency retrofits associated with the pilot, the owners of test house 6 opted to install a photovoltaic (PV) system, which essentially eliminated the need to purchase any electricity from Xcel Energy. The costs of the PV system were not included in the high-level portion of the analysis, and therefore any energy impacts resulting from house 6 energy were removed.

An analysis of each of the energy efficiency measures implemented and the whole-house impacts is included in the body of this report.

INTRODUCTION

This report is an evaluation of the Colorado Whole House Energy Efficiency & Comfort (WHEC) Study, which was a pilot demand-side management (DSM) program undertaken in 2010 by Xcel Energy and the program implementer, the Energy Efficiency Business Coalition (EEBC).

Documents reviewed and referenced during this evaluation include:

1. Project description (see footnote 1)
2. Monthly utility bills provided by Xcel Energy (with customer-identifiable data concealed)
3. A pre-installation energy audit on each home
4. Limited project contract reporting and documentation files received from EEBC
5. The Technical Reference Manual (TRM) which is an appendix to the Company's 2011 DSM Plan
6. Equipment technical specifications
7. TRM Documents from other utilities
8. Actual weather data from Centennial Airport and typical meteorological year (TMY) 3 data for Denver

WHEC STUDY DESCRIPTION

The purpose of the program was to study the impact of implementing a comprehensive package of energy saving technologies, through coordinated design and installation to optimize energy efficiency, in individual homes.

The WHEC Study treats the house as a system and was intended to acquire energy savings and payback data from homes that have undergone a comprehensive energy efficiency retrofit. Because the homes were occupied by Xcel Energy customers, the WHEC pilot provided an opportunity to study the effects of installing an array of energy-saving measures under live conditions, evaluating the true costs of the "house as a system" concept.

As presented in the project scope of work document,[1] the WHEC Study objectives included:

- Evaluating the "house as a system" approach to energy efficiency retrofits and upgrades;
- Providing a comprehensive energy efficiency retrofit to ten homes in the Denver area; and
- Deploying additional "emerging technologies" (e.g. air source heat pumps, ground source heat pumps, sealed combustion water heaters, etc.) to 8 of the homes participating in the pilot.

Ideal homes selected for the program included homes of typical size for the area, with inefficient features such as poor attic and wall insulation. The energy efficiency retrofits included the following stated objectives:

1. Determine typical energy use patterns via a homeowner survey;
2. Detail initial energy use baseline results for the participating homes;
3. Retrofit insulation and air sealing;

[1] Scope of work found in "Colorado 2011 WHEC-Study.docx" provided by Xcel Energy.

4. Properly size and install energy-efficient furnaces and air conditioning units; provide air duct sealing; ensure proper ventilation; and conduct commissioning and home owner training / education; and
5. Deploy emerging technologies which included solar, tank less, sealed combustion or air source heat pump water heaters; ground source heat pumps; indirect evaporative cooling; air source space conditioning heat pumps; and/or energy efficient windows.

The EEBC's primary role was to assemble a list of standards and specifications to determine to what extent retrofits should be made to each home in the program. Since each home is unique, each of the home's project coordinators was expected to consult with EEBC to determine best practices.

Xcel Energy's role was to coordinate the measurement of actual energy savings through billing data shared with EEBC for evaluation and verification.

The analysis and installation phase of the project was conducted, largely, during the fourth quarter of 2010.

DATA SUMMARY

This section provides summary performance data for the WHEC Pilot program participants. Table 2 shows the calculated energy, dollar and CO_2 emissions savings for each home.[2]

TABLE 2: SUMMARY OF SAVINGS FOR EACH HOUSE

	kWh		Therm		Total		
House	Energy	$ Dollar	Energy	$ Dollar	Total kBTU	$ Total	CO_2 Savings, lbs
1	652	$70	167	$144	18,879	$215	2,992
2	584	$66	288	$215	30,753	$281	4,300
3	(2,270)	-$266	731	$881	65,385	$615	4,922
4	(394)	-$48	195	$193	18,179	$145	1,654
5	(1,011)	-$108	503	$418	46,822	$310	4,263
6	-	$0	-	$0	-	$0	0
7	(1,564)	-$181	188	$159	13,478	-$22	(303)
8	(1,549)	-$180	386	$367	33,346	$187	2,039
9	(7,878)	-$908	548	$472	27,954	-$436	(6,197)
10	(1,007)	-$114	589	$471	55,459	$357	5,278
Sum	**(14,438)**	**-$1,669**	**3,595**	**$3,323**	**310,255**	**$1,653**	**18,948**

Consideration of the project costs incurred by Xcel Energy provides the program economics on a home by home basis, as shown in Table 3. Also shown is the estimated incremental cost of the efficient equipment over standard equipment, and the accompanying payback. Note that consideration of estimated incremental costs only improves payback by a factor of 3.6.

[2] Home 6 data outputs were removed due to installation of a PV system that was outside of the scope of the project, but heavily impacted the project results.

TABLE 3: SUMMARY OF COST, PAYBACK, AND CO2 SAVINGS PER HOUSE

House	Project Cost	Simple Payback (years)	Estimated Incremental Cost	Simple Payback Incremental (years)
1	$18,500	86	$5,691	27
2	$18,500	66	$5,691	20
3	$40,500	66	$14,529	24
4	$29,000	200	$7,691	53
5	$27,000	87	$12,941	42
6	$27,000	0	$12,941	0
7	$23,500	no payback	$8,287	no payback
8	$24,000	128	$7,892	42
9	$20,300	no payback	$4,742	no payback
10	$19,800	55	$5,492	15
Sum	$248,100	150	$85,900	52
Admin	$61,297			
Admin as % total	**25%**			
GT	$309,397	**187**		**89**

Savings were calculated based on the Company's TRM, and raw savings (with and without corrections for weather). Figure 1 compares the savings estimated under each of the three approaches.

FIGURE 1: COMPARISON OF SAVINGS BY THREE METHODS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings	(14,224)	3,682	(22,773)	43,074	20,301
Regressed Savings	(14,438)	3,595	(23,115)	42,064	18,948
TRM savings	(7,911)	6,499	(12,666)	76,041	63,375

The difference in savings between the regressed / utility bill analysis and the TRM analysis is attributable to a number of factors including:

- Rebound, wherein the homeowner uses more energy;
- Undocumented changes in occupant energy use (for example, the addition of new TVs or more family members to the home); and/or
- Variation between assumptions and actual site conditions regarding project scope, baseline efficiencies, and overall building characteristics.

Comparison of the three approaches applied to each house can be found in Appendix A.

Overview of Homes

All of the homes in the study were in the Denver metropolitan area, with qualitative indications that they were viable candidates for building envelope, HVAC and DHW improvements. Table 4: Summary of Program Test HomesTable 4 identifies the location, size, and age of the houses that participated in the pilot.

TABLE 4: SUMMARY OF PROGRAM TEST HOMES

Test Home	Town	Square footage	Year built
1	Denver	2,214	1984
2	Centennial	1,755	1982
3	Westminster	2,000	1973
4	Boulder	1,315	1968
5	Highlands Ranch	1,800	2000
6	Arvada	2,500	1999
7	Westminster	1,600	1979
8	Arvada	1,680	1942
9	Denver	2,400	1960
10	Lakewood	4,000	1995

Overview of Measures

The following core measures were applied to all of the participating houses:

- Attic and wall insulation;
- Air sealing;
- Duct sealing;
- Lighting; and
- A "Poor Man's HRV"[3]

[3] A rigid galvanized duct leading with sealed seams, from an intake opening to a grille in the wall. When air pressure indoors falls significantly below that of the outdoors, the required make-up air flows into the house through the duct; a manufactured backdraft damper at the rim-joist end of the duct prevents heated indoor air from passing out of the house when the interior is under positive pressure.

The extent of implementation of the measures was not clear, only the total equipment / installation charge to the Company was provided. For example, it is not known how many CFLs were actually replaced, the configuration and benefits of the "Poor Man's HRV" was not delineated; insulation levels and areas before and after installation were not well documented and so on.

In addition to the aforementioned measures, several of the homes received additional retrofits such as:

- GSHP (replacing a natural gas furnace)
- Air source heat pumps (for DHW and space heating)
- Installation of solar thermal DHW heating
- High-efficiency windows
- Coolerado brand evaporative air conditioners
- Tankless DHW heater
- Sealed combustion DHW heater

Table 5 summarizes the retrofits implemented within each home.

TABLE 5: MATRIX OF MEASURES INSTALLED IN EACH HOME

Measure	Type	Home 1	Home 2	Home 3	Home 4	Home 5	Home 6	Home 7	Home 8	Home 9	Home 10
Insulation	Attic and Walls	x	x	x	x	x	x	x	x	x	x
	Air Sealing	x	x	x	x	x	x	x	x	x	x
Duct Sealing	Standard	x	x	x	x	x	x	x	x	x	x
Ventilation	"Poor Man's" HRV	x	x	x	x	x	x	x	x	x	x
Lighting	CFL 100%	x	x	x	x	x	x	x	x	x	x
Heating System	ES 95% 2stage Gas	x	x		x	x	x	x	x	x	x
	GSHP			x							
Air Conditioning	Central A/C 14 SEER	x	x		x	x	x				
	Air Source Heat Pump									x	x
	Evap - Coolerado							x	x		
Water Heating	Gas Tankless			x	x			x			x
	SolarWH w Elec Tank					x	x				
	Sealed Combustion	x	x								
	ASHP Water Heater								x	x	
Windows	High Efficiency Windows				x						

To analyze the performance of the pilot, each house was evaluated separately. A discussion of the analysis methods used in the evaluation of both the measures' and test homes' performance follows.

POINTS OF REFERENCE

The evaluation included several analysis components. Specifically:

- Savings estimation using "Option C, Whole Building" measurement and verification (M&V) approach[4]; algorithms used in the Company's TRM; and common engineering analysis techniques and methods; and

[4] International Performance Measurement and Verification Protocol (IPMVP).

- Incremental cost estimation using values from the Company's TRM and other publicly available sources such as TRMs from other utilities.

Utility bill analysis is used to evaluate energy consumption before and after implementation of the retrofits. To support this analysis, the Company provided monthly electricity and gas billing data of participating homes from October 29, 2008 through January 28, 2013. This data covered two years "pre-installation" and two years "post-installation" which was the basis for the analysis.

Comparison of pre- and post-installation consumption was done in two ways. First, usage was compared without any corrections for differences in weather. Second, a weather corrected regression was developed and then savings were calculated assuming a TMY.

To the extent possible, preconditions were determined from audit documentation, whereas post conditions were determined from contractor documentation. Full details of the results are presented in Appendix B: Full Calculation Spreadsheet.

To further assess measure performance, an estimation of expected savings for each home and retrofit was calculated using calculation methods presented in the Company's TRM. Specific sections of the TRM that were used for the analysis are shown in TABLE 6. Where the TRM calculations were not appropriate or possible, the TRM algorithms are augmented with standard engineering energy calculation methods and assumptions.

Table 6: TRM References

Page	Measure Description
568	Attic insulation and bypass sealing natural gas savings
568	Attic insulation and bypass sealing electric savings
568	Attic insulation and bypass sealing savings
568	Air sealing and weather-stripping natural gas savings
568	Air sealing and weather-stripping savings - (heating/cooling)
568	Wall insulation natural gas savings
568	Wall insulation savings (heating and cooling)
544	Furnace from AFUE 78% to 94% (Tier 2): NG savings
555	New HE furnace or boiler natural gas savings
546	New Equipment Electrical energy Savings
577	Electric storage water heater baseline energy consumption
577	High efficiency heat pump storage tank consumption
577	Standard tank water heater 0.67 EF
577	Water heater electric Savings
555	CFL savings

Measure-by-Measure Evaluation

The measure-by-measure assessment relied on available baseline data and project documentation. By considering each house's energy performance, and by reviewing equipment documentation, observations on each measure were made. These measure-by-measure observations are as follows:

Attic and wall insulation

Attic and wall insulation can be an economically attractive measure. However, it was not possible to determine the appropriateness and energy performance of this measure because pre- and post-insulation values, specific configuration, and areas covered were not fully provided in the project documentation.

Total Cost of Materials & Installation, Per Home: $4,000

Savings M&V: Energy savings are variable and unknown. While the walkthrough audits gave a preliminary estimation of insulation levels, the values in many cases were only assumptions based on age of the home and known construction practices. Post-retrofit insulation values were not well documented. For analysis it was assumed insulation values were increased to commonly recommended levels that could be reached for the allotted cost.

Insulation retrofits can have a good payback, but as the pre-retrofit level of insulation increases, the performance of the retrofit diminishes.

Air Sealing

It is assumed that the air sealing portion of the project involved weather-stripping, caulking, and other methods to reduce air infiltration. The result of these measures was well documented through blower door tests completed pre- and post-retrofit.

Total Cost of Equipment & Installation, Per Home: $800

Savings M&V: Pre- and post-retrofit blower door tests were well documented for this measure.

Duct Sealing

Duct sealing results in the reduction of leakage from HVAC supply ducts, using either foil duct tape, brush on sealing mastic, or an aerosol duct sealing method. While this measure can reduce energy use and increase comfort, it is difficult to assign definitive energy savings, particularly when the ducts are located in conditioned space (because the conditioned air ultimately goes into the conditioned space, therefore offsetting heating and cooling loads).

Total Cost of Equipment & Installation, Per Home: $400

Savings M&V: Unknown

Lighting

Efficient lighting is a well-established and widely adopted energy conservation measure. It is expected that proper implementation of a lighting project will produce an economically viable retrofit. However, baseline lamp system, operating hours, and quantity of lamp retrofits were not well documented.

Total Cost of Equipment & Installation, Per Home: $800

Savings M&V: Unknown

POOR MAN'S HRV

The poor man's HRV is a rigid galvanized duct leading with sealed seams, from an intake opening to a grille in the wall. When air pressure indoors falls significantly below that of the outdoors, the required make-up air flows into the house through the duct; a manufactured backdraft damper at the rim-joist end of the duct prevents heated indoor air from passing out of the house when the interior is under positive pressure This project may improve occupant comfort, but measurable energy benefits are hard to quantify.

Total Cost of Equipment & Installation, Per Home: $500

Savings M&V: Unknown (assumed no energy savings).

ENERGY STAR® RATED FURNACE

Several test homes received a 95% efficiency rated furnace which reduces natural gas use by increasing the heading system's annual fuel utilization efficiency (AFUE).

Total Cost of Equipment & Installation, Per Home: $4,500[5]

Savings M&V: It can be assumed that the scope would include the removal of the old furnace, installation of a PVC combustion air intake and exhaust system, installation of a good thermostat, and equipment startup. There can be significant variation in the actual work scope depending on site conditions.[6]

DOMESTIC HOT WATER

The hot water configurations installed were of several types including: sealed combustion, tankless, air source heat pump, and solar thermal with electric or natural gas back-up. This saves energy by increasing the energy factor (EF).

Total Cost of Equipment & Installation, Per Home:

- Natural gas tankless DHW heater: $4,000 (4 homes)
- Solar water heating with electric or natural gas back-up: $12,000 (2 homes)
- Sealed combustion tanked DHW heater: $3,500 (2 homes)
- Air source heat pump DHW heater: $4,500 (2 homes)

Savings M&V: In most cases, savings likely occurred as a result of retrofits. However, in some cases, for example, in the case of installation of an air source heat pump system, a detailed analysis would be helpful in understanding the effect of changing from natural gas to electricity as the energy source.[7] Given the average likely energy performance, it may be difficult to justify the costs for these more advanced systems.

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[5] This amount may be representative of the installed costs for a high efficiency furnace.
[6] The actual site conditions were not well documented for the pilot.
[7] The actual site conditions were not well documented for the pilot.

Air Conditioning

Various air conditioning systems were installed in the test homes.

Total Cost of Equipment & Installation, Per Home:

- Central air conditioning, 14 SEER: $4,000 (5 homes)
- Air source heat pump: $4,800 per home (2 homes)
- Coolerado brand air conditioner: $8,000 per home (2 homes)

Savings M&V: Some of the retrofits were adding air conditioning to homes that were previously not air conditioned, and others were replacing evaporative cooling systems with refrigerated A/C systems or more complex evaporative systems. In many cases, it is likely that energy use would significantly increase. In these cases, the retrofits were not advantageous from an energy conservation standpoint.

Ground Source heat pump

Test House 3 received a ground source heat pump.

Total Cost of Equipment & Installation, Per Home: $30,000

Savings M&V: The advantages of a GSHP compared to more conventional heating and air conditioning systems may be hard to justify because of the high first cost and the uncertainty of increased energy performance. The actual site conditions were not well documented for the pilot.

Windows

Test House 4 received high efficiency windows.

Total Cost of Equipment & Installation, Per Home: $10,000

Savings M&V: Given the high cost of windows, this measure is not economically attractive from an energy standpoint, however, the actual site conditions were not well documented for the pilot. It's possible that a smaller incremental cost between standard windows and high performance windows could provide attractive energy economics.

Summary of Findings

From a simple payback perspective, and with the limited data available, the pilot did not provide economics that would justify further operation in a utility-sponsored DSM program context, nor would it, on energy merits alone, provide compelling economics to the homeowner if they had to bear most of the cost of the measure's installation. Table 7 shows the summary results of the program.

TABLE 7: SUMMARY PROGRAM ECONOMIC RESULTS

House	Project Cost	Simple Payback (years)	Estimated Incremental Cost	Simple Payback Incremental (years)
1	$18,500	86	$5,691	27
2	$18,500	66	$5,691	20
3	$40,500	66	$14,529	24
4	$29,000	200	$7,691	53
5	$27,000	87	$12,941	42
6	$27,000	0	$12,941	0
7	$23,500	no payback	$8,287	no payback
8	$24,000	128	$7,892	42
9	$20,300	no payback	$4,742	no payback
10	$19,800	55	$5,492	15
Sum	$248,100	150	$85,900	52
Admin	$61,297			
Admin as % total	25%			
GT	$309,397	187	GT	52

IMPACT

As shown in Table 8, the savings from the project totaled 310,255 kBTU per year, resulting in a reduction of utility bill costs to the homeowner of approximately $1,653. The CO_2 emission reduction is estimated at 18,948 pounds per year using the Company's carbon emissions calculation values of 1.601 lbs/kWh for electricity, and 117 lbs/MMBTU for natural gas. .

TABLE 8: ENERGY, DOLLAR, AND CO2 REDUCTION IMPACT

	kWh		Therm		Total		
House	Energy	$ Dollar	Energy	$ Dollar	Total kBTU	$ Total	CO_2 savings, lbs
1	652	$70	167	$144	18,879	$215	2,992
2	584	$66	288	$215	30,753	$281	4,300
3	(2,270)	-$266	731	$881	65,385	$615	4,922
4	(394)	-$48	195	$193	18,179	$145	1,654
5	(1,011)	-$108	503	$418	46,822	$310	4,263
6	-	$0	-	$0	-	$0	0
7	(1,564)	-$181	188	$159	13,478	-$22	(303)
8	(1,549)	-$180	386	$367	33,346	$187	2,039
9	(7,878)	-$908	548	$472	27,954	-$436	(6,197)
10	(1,007)	-$114	589	$471	55,459	$357	5,278
Sum	**(14,438)**	**-$1,669**	**3,595**	**$3,323**	**310,255**	**$1,653**	**18,948**

Appendix A: House-by-House Analysis

This appendix contains detailed information and findings for each home in the WHEC program. The analysis of each house contains the following information:

- Table of measures and cost to install
- Table illustrating energy usage
- Weather and cost by year table
- Monthly Kwh by year and month
- Therm used by Year Graphics
- Therm and kwh regressions tables
- Therm per HDD with regression graphs
- KWh per CDD with regression graph
- Annual kWh and therm Savings graph and tables

House 1

Characteristics

House 1 is a 2,214 square foot, two-story home that was constructed in 1984. According to project documentation, the owner reported comfort issues.

Data

Table 6: Test House 1: Measure and Cost List

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
High efficiency furnace	$4,500	$505
14 SEER central AC	$4,000	$999
Sealed Combustion DHW	$3,500	$750
CFL lighting	$800	$27
Poor man’s HRV	$500	$0
Total	$18,500	$5,691

Table 7: Test House 1: Usage, Weather and Cost by Year

Annualized Usage and Weather by Year									
Cal Year	Therms	HDD	Th/HDD	Therm Cost	kWh	CDD	kWh/CDD	kWh Cost	Summer Therm
2009	625	6597	0.09	$526.14	10187	715	14.25	$966.88	63
2010	573	6213	0.09	$476.63	10042	1026	9.79	$1,133.58	61
2011	460	6527	0.07	$416.43	9436	1002	9.41	$1,075.09	52
2012	368	5522	0.07	$342.51	10901	1288	8.47	$1,221.92	51
2013	78	1127	0.07	$54.42	797	0	0.00	$84.94	0

TMY pre	607	6403	0.09	$526.09	10189	788	12.92	$1,097.79	38
TMY post	440	6405	0.07	$381.66	9538	788	12.10	$1,027.58	38

TABLE 8: TEST HOUSE 1: USAGE BY MONTH

	kWh						**Therms**					
Month	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**
1	933	887	684	680	733	667	94	101	87	59	81.8	62.9
2	810	819	631	714	733	667	67	105	86	69	90.4	54.6
3	656	584	596	633	742	676	57	59	47	30	77.8	35.8
4	639	652	595	800	761	697	55	34	29	23	49.3	30.2
5	667	656	547	785	806	747	25	26	21	17	40.8	14.2
6	832	1130	921	1197	1018	982	22	21	20	17	16.6	11.0
7	1230	1074	1157	1496	1078	1049	21	19	16	17	11.7	9.9
8	1151	1282	1196	1287	1120	1095	20	21	16	17	10.1	16.8
9	1001	975	978	1053	955	913	22	22	16	17	20.6	31.5
10	680	608	723	775	771	709	42	20	16	18	42.8	46.4
11	710	627	777	768	736	669	66	56	39	32	65.5	68.7
12	878	748	631	713	734	667	134	89	67	52	99.3	58.2
Total	10187	10042	9436	10901	10189	9538	625	573	460	368	606.7	440.1
Average	10114.5		10168.5				599		414			
Savings				-54		651.6				185		166.6
% Savings						**6%**						**27%**

FIGURE 1: TEST HOUSE 1 THERM USAGE

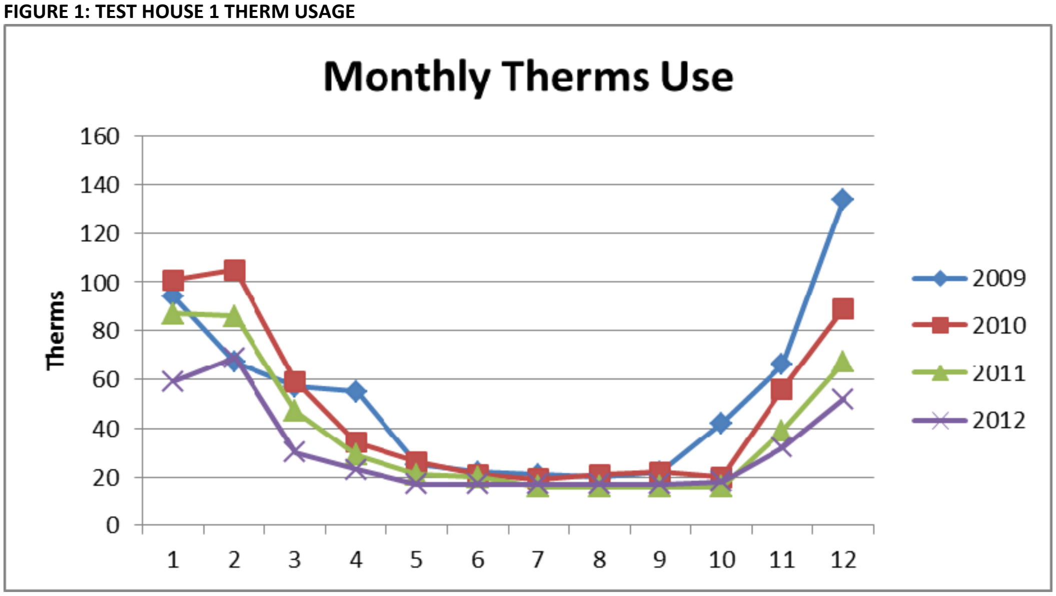


FIGURE 2: TEST HOUSE 1 KWH USAGE

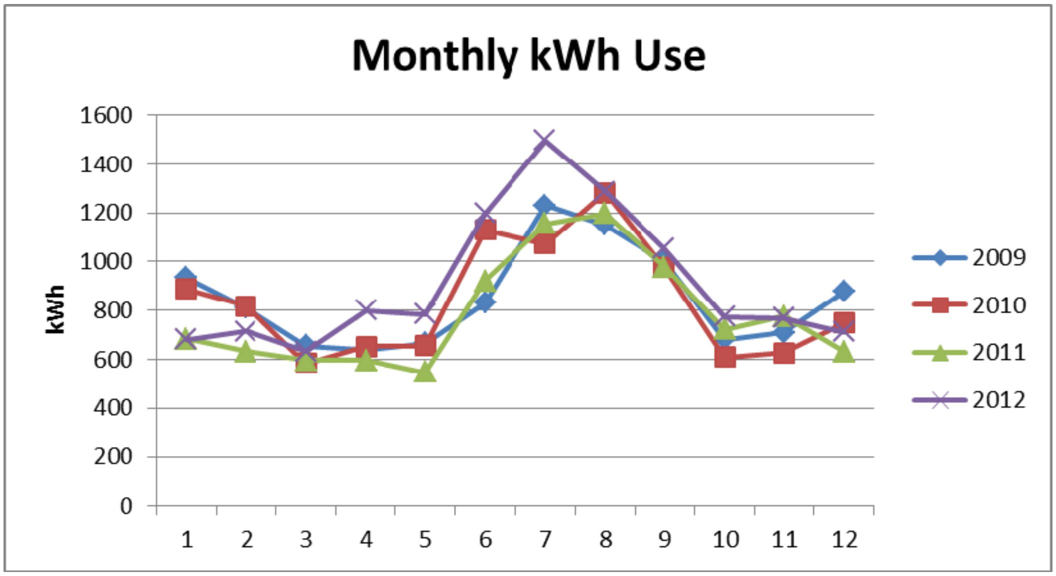


TABLE 9: TEST HOUSE 1: THERM AND KWH REGRESSIONS

		slope	intercept	R square
Therms per HDD	pre	0.0829	6.30	0.96
	post	0.0547	7.42	0.92
kWh per CDD	pre	1.7606	733.42	0.81
	post	1.9525	666.51	0.95

FIGURE 2: TEST HOUSE 1 THERM PER HDD WITH REGRESSION

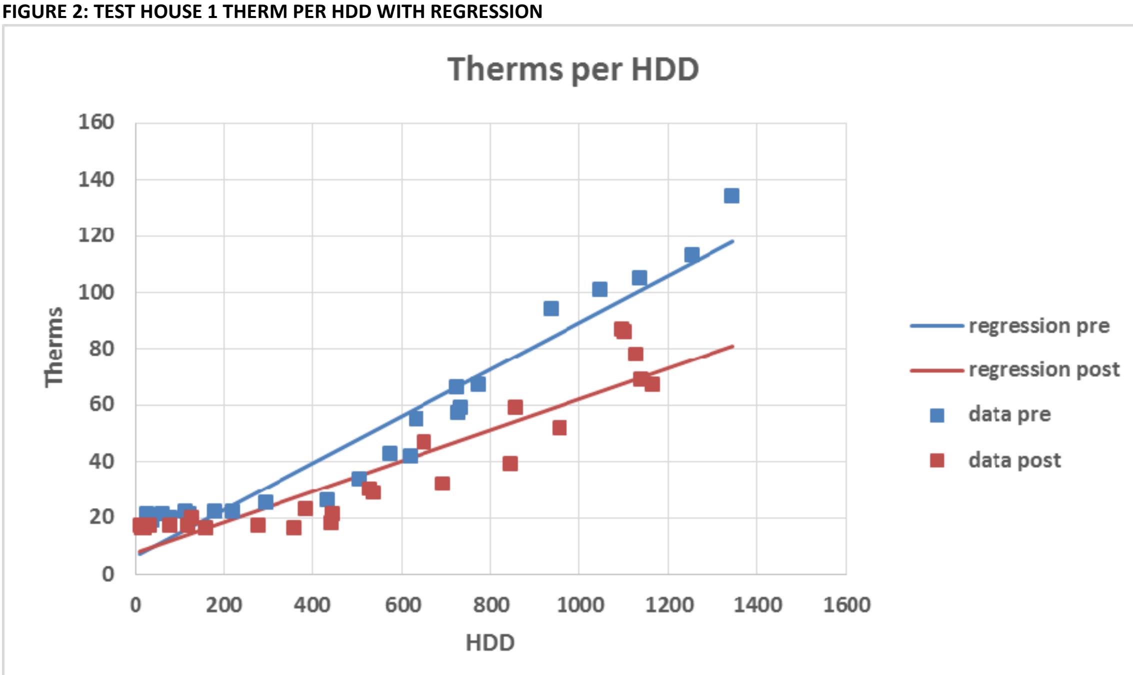


FIGURE 4: TEST HOUSE 1 KWH PER CDD WITH REGRESSION

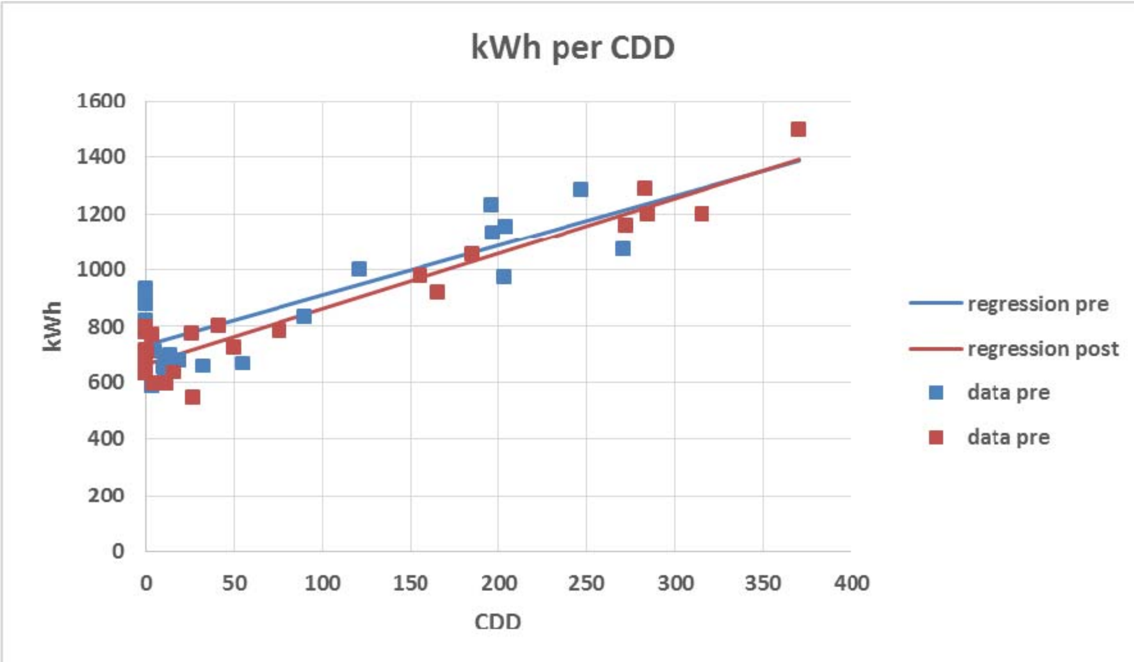
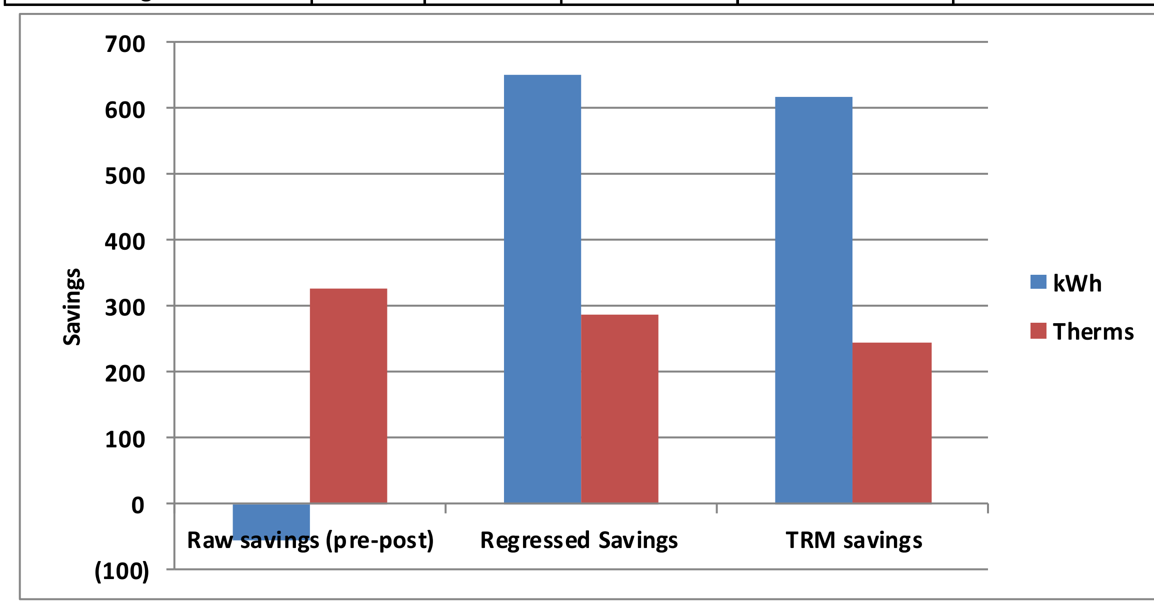


FIGURE 5: TEST HOUSE 1 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	(54)	185	(86)	2,165	2,078
Regressed Savings	652	167	1,043	1,949	2,992
TRM savings	617	365	987	4,271	5,258



DISCUSSION

As a base-case, test house 1 had standard improvements, which saved 6% kWh and 27% therms via regression analysis. The regressed and TRM analysis are in good agreement, but the raw kWh savings are conversely negative. The discrepancy could be caused by unusual electrical use in 2012 due to unusual warm summer weather. The raw CO_2 savings totaled 2,078 lbs. Note that the auditor could not access insulation so estimated based mostly on vintage, but also considered cavity depth for vaulted ceiling.

House 2

Characteristics:

House 2 is a 1,755 square foot, tri-level home that was constructed in 1982. Owners reported “house needs EE improvements.”

Data

TABLE 10: TEST HOUSE 2: MEASURE AND COST LIST

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
High efficiency furnace	$4,500	$505
14 SEER central AC	$4,000	$999
Sealed Combustion DHW	$3,500	$750
CFL lighting	$800	$27
Poor man’s HRV	$500	$0
Total	$18,500	$5,691

TABLE 11: TEST HOUSE 2: USAGE, WEATHER AND COST BY YEAR

Annualized Usage and Weather by Year									
Cal Year	Therms	HDD	Th/HDD	Therm Cost	kWh	CDD	kWh/CDD	kWh Cost	Summer Therm
2009	1221	6627	0.18	$941.44	10826	715	15.14	$1,043.33	83
2010	1180	6239	0.19	$874.95	11490	1026	11.20	$1,311.31	85
2011	938	6540	0.14	$733.77	10704	1002	10.68	$1,215.35	76
2012	812	5515	0.15	$605.38	10877	1288	8.45	$1,222.64	79
2013	137	1175	0.12	$89.19	1094	0	0.00	$117.03	0
TMY pre	1201	6437	0.19	$899.65	11230	788	14.24	$1,266.47	60
TMY post	914	6404	0.14	$684.24	10647	788	13.50	$1,200.62	76

TABLE 12: TEST HOUSE 2: USAGE BY MONTH

	kWh						Therms					
Month	2009	2010	2011	2012	Pre	Post	2009	2010	2011	2012	Pre	Post
1	1124	981	941	890	876	837	194	206	157	121	165.7	128.8

2	890	934	830	980	876	837	147	193	134	149	182.5	113.3
3	990	814	732	731	881	841	127	140	85	81	158.3	80.9
4	673	729	886	826	885	845	109	91	76	71	107.4	63.6
5	797	704	691	658	908	864	56	71	60	40	80.2	30.5
6	785	1134	813	1036	1000	941	35	34	28	28	28.3	23.2
7	1059	1274	1160	1212	1082	1010	25	26	27	26	16.8	21.9
8	891	1302	1050	1110	1061	992	23	25	21	25	14.7	31.1
9	843	945	955	907	1010	950	33	24	34	28	29.2	63.9
10	692	683	775	825	897	854	91	42	50	52	80.6	95.4
11	924	859	787	718	878	838	134	133	98	70	130.1	144.7
12	1158	1131	1084	984	876	837	247	195	168	121	207.4	116.2
Total	10826	11490	10704	10877	11230	10647	1221	1180	938	812	1201.2	913.6
Average	11158		10790.5				1200.5		875			
Savings				367.5		583.9				325.5		287.6
% Savings						**5%**						**24%**

FIGURE 6: TEST HOUSE 2 THERM USAGE

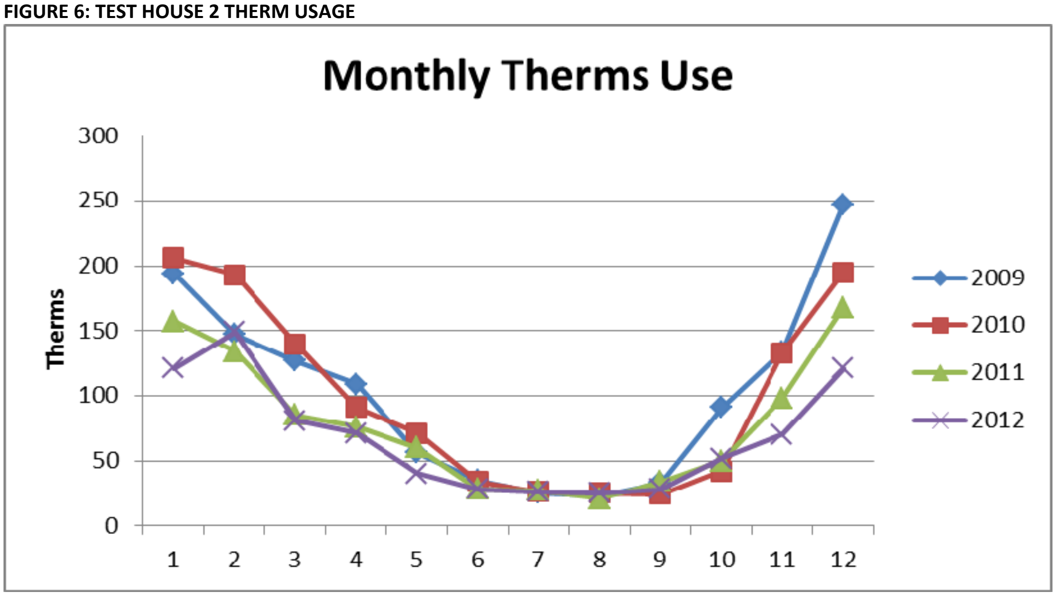


FIGURE 7: TEST HOUSE 2 KWH USAGE

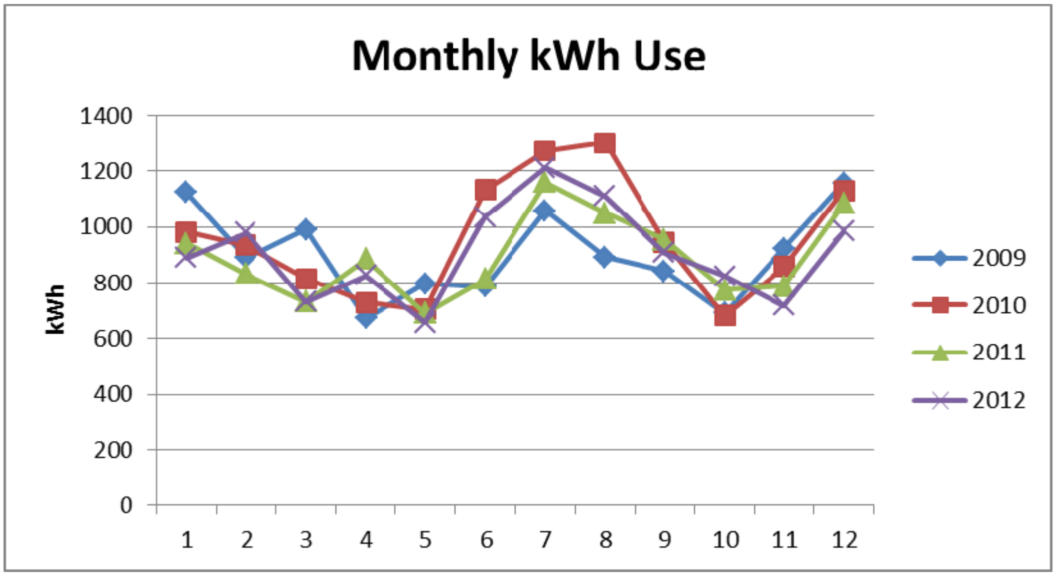


TABLE 13: TEST HOUSE 2: THERM AND KWH REGRESSIONS

		slope	intercept	R square
Therms per HDD	pre	0.1752	6.09	0.99
	post	0.1116	16.40	0.98
kWh per CDD	pre	0.9077	876.24	0.47
	post	0.7639	837.03	0.60

FIGURE 8: TEST HOUSE 2 THERM PER HDD WITH REGRESSIONS

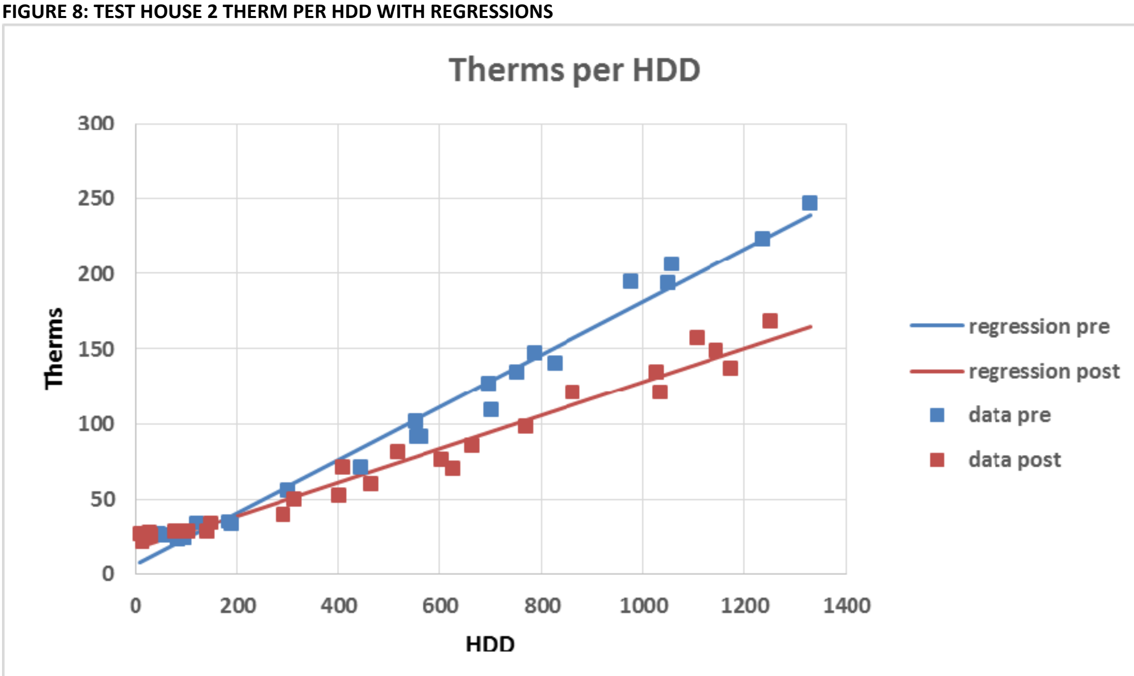


FIGURE 9: TEST HOUSE 2 KWH PER CDD WITH REGRESSIONS

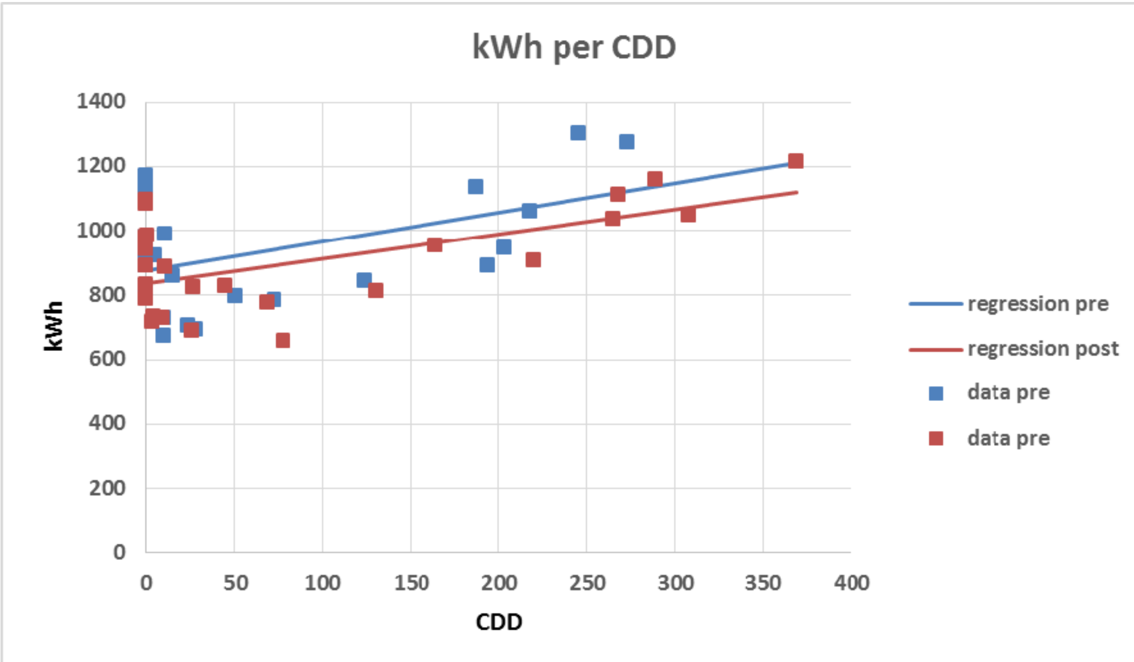
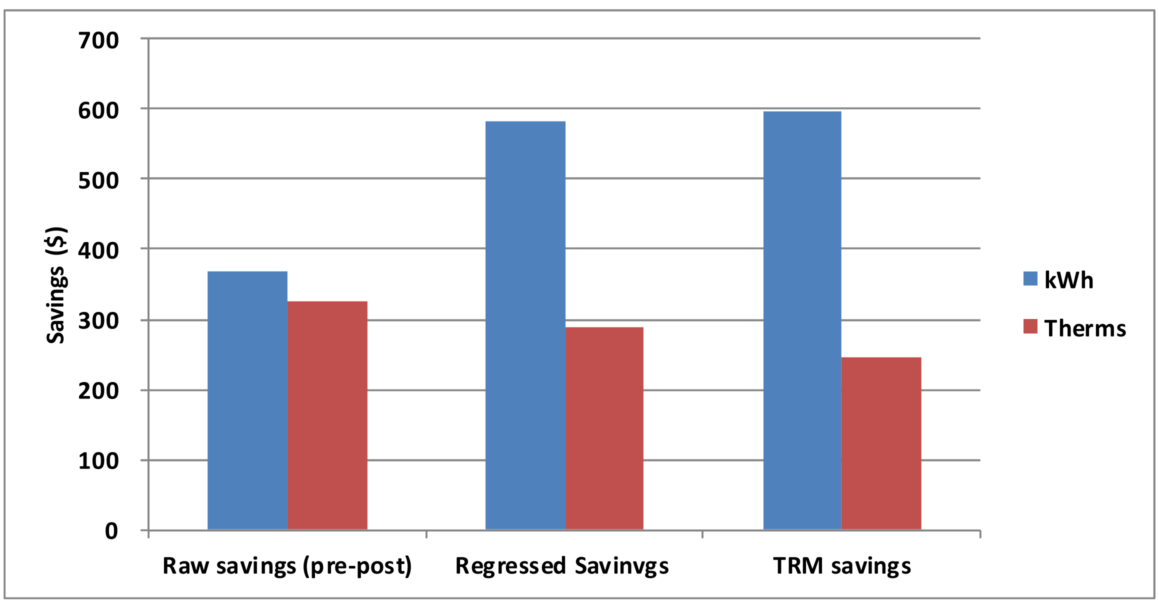


FIGURE 10: TEST HOUSE 2 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	368	326	588	3,808	4,397
Regressed Savinvgs	584	288	935	3,365	4,300
TRM savings	596	246	954	2,881	3,835



Discussion

Also as a base-case, test house 2 had standard improvements similar to house 1. Overall, resulting regressed savings were 5% kWh and 24% therms. The raw, regressed, and TRM analysis are in good agreement. The raw CO_2 savings totaled 4,397 lbs.

House 3

Characteristics:

House 3 is a 2,000 square foot, ranch-style home that was constructed in 1973. Owners reported “house is drafty, high energy bills.”

Data

Table 14: Test House 3: Measure and Cost List

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
GSHP	$30,000	$10,342
Gas Tankless	$4,000	$750
CFL lighting	$800	$27
Poor man’s HRV	$500	$0
Total	$40,500	$14,529

Table 15: Test House 3: Usage, Weather and Cost by Year

Annualized Usage and Weather by Year									
Cal Year	Therms	HDD	Th/HDD	Therm Cost	kWh	CDD	kWh/CDD	kWh Cost	Summer Therm
2009	16	0	0.00	$15.55	64	0	0.00	$17.96	0
2010	701	6198	0.11	$601.09	6607	1026	6.44	$790.59	32
2011	47	6582	0.01	$169.52	8682	1002	8.66	$1,003.31	9
2012	41	5522	0.01	$173.29	8923	1288	6.93	$1,031.32	11
2013	4	1127	0.00	$15.12	896	0	0.00	$101.05	0
TMY pre	776	6382	0.12	$934.23	6510	788	8.26	$761.42	28
TMY post	44	6382	0.01	$53.26	8780	788	11.14	$1,026.92	9

Table 16: Test House 3: Usage by Month

	kWh						Therms					
Month	2010	2011	2012	2013	Pre	Post	2010	2011	2012	2013	Pre	Post
1	509	521	800	896	482	710	136	7	3	4	110.7	4.3
2	516	741	955		482	710	132	4	3		122.3	4.4
3	522	909	657		487	712	96	6	3		106.5	4.2
4	509	784	571		491	714	56	3	3		65.7	3.7
5	454	491	584		511	721	48	2	4		50.8	3.5

6	595	735	864		610	756	12	4	4		15.4	3.0
7	854	764	1068		690	784	11	2	5		7.0	2.9
8	769	760	762		668	776	9	3	2		5.5	2.9
9	477	617	769		614	757	8	3	3		14.8	3.0
10	445	545	480		507	719	27	3	3		55.9	3.6
11	454	709	542		484	711	72	3	4		82.7	3.9
12	503	1106	871		483	710	94	7	4		138.2	4.6
Total	6607	8682	8923	896	6510	8780	701	47	41	4	775.5	44.2
Average	6607	8802.5					701	44				
Savings				-2195.5		-2270.0				657		731.3
% Savings						**-35%**						**94%**

FIGURE 11: TEST HOUSE 3 THERM USAGE

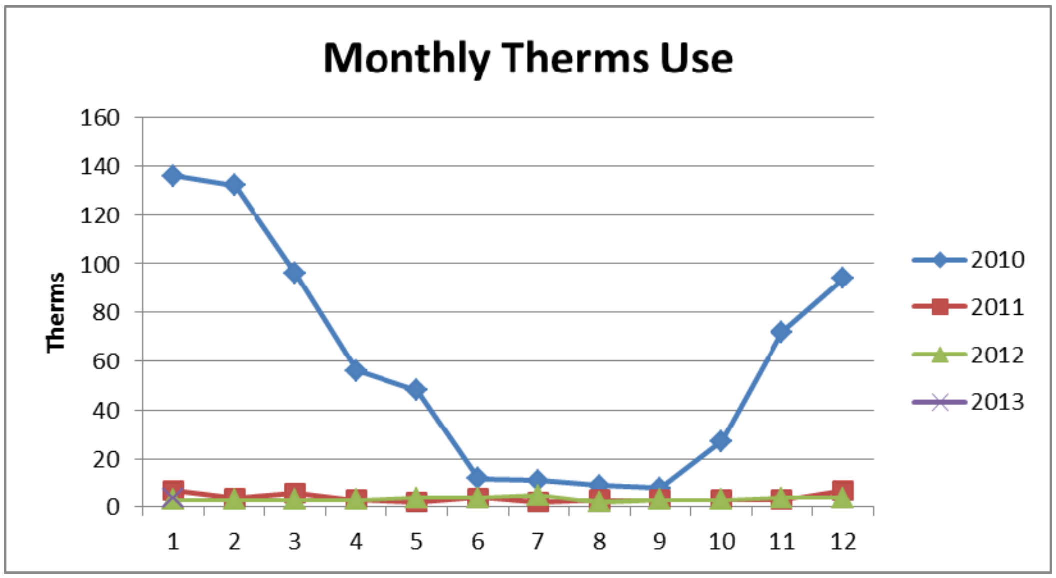


FIGURE 12: TEST HOUSE 3 KWH USAGE

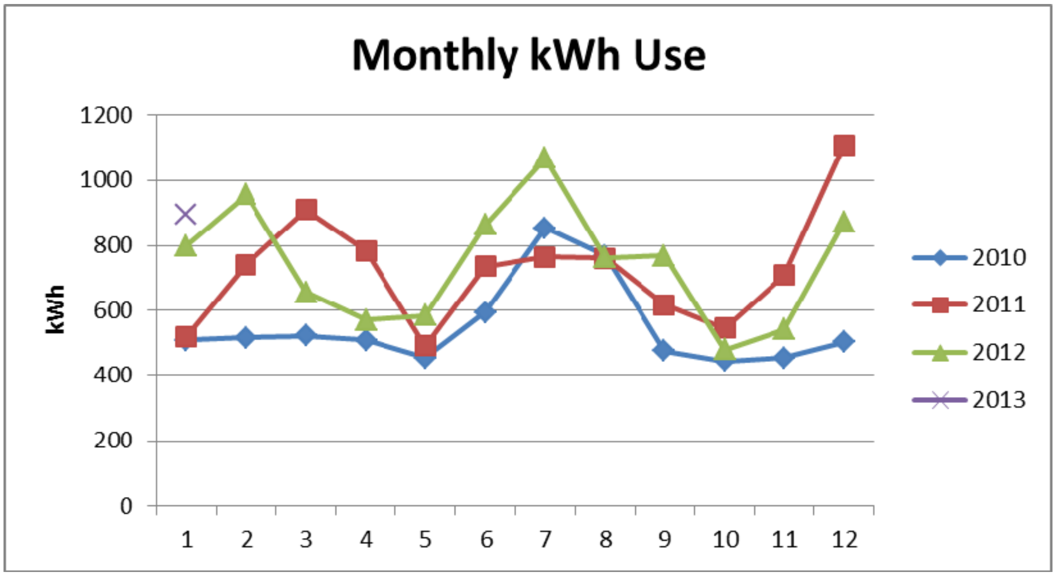


TABLE 17: TEST HOUSE 3: THERM AND KWH REGRESSIONS

		slope	intercept	R square
Therms per HDD	pre	0.1225	-0.53	1.00
	post	0.0016	2.84	0.49
kWh per CDD	pre	0.9143	482.42	0.78
	post	0.3240	710.36	0.23

FIGURE 13: TEST HOUSE 3 THERM PER HDD WITH REGRESSIONS

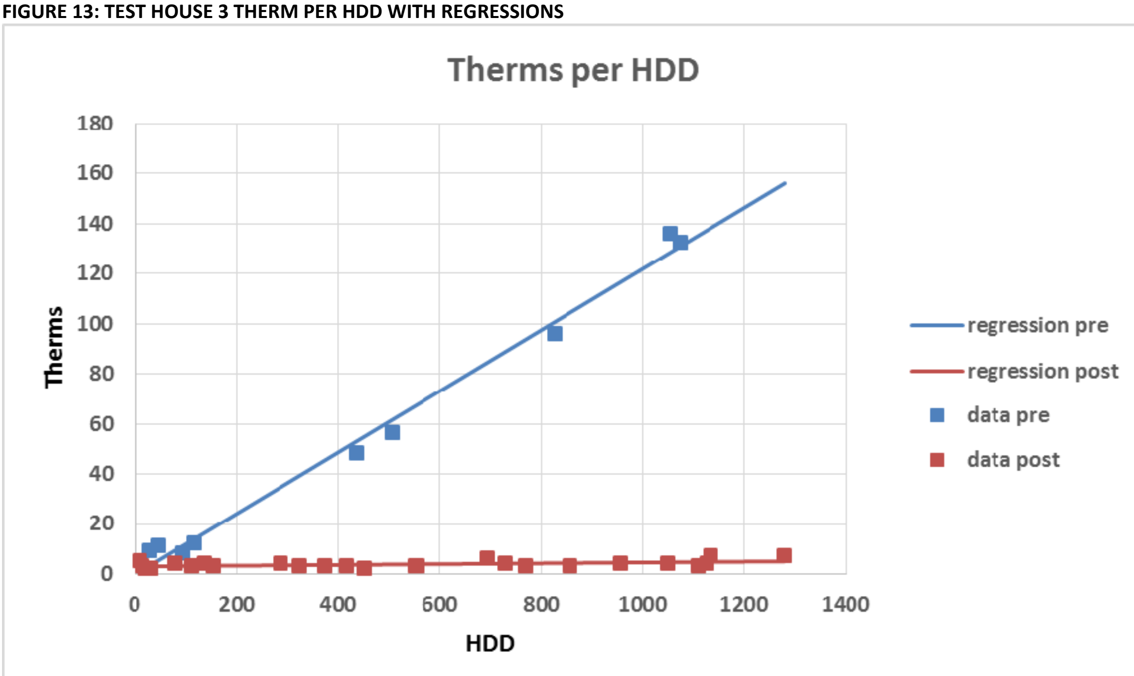


FIGURE 14: TEST HOUSE 3 KWH PER CDD WITH REGRESSIONS

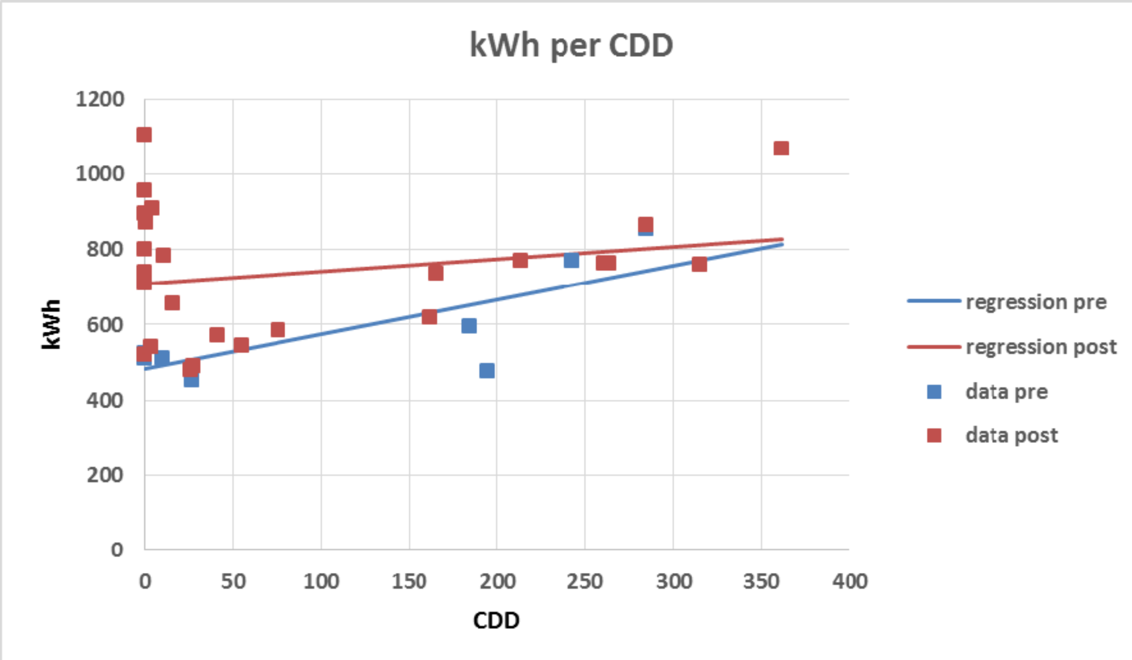
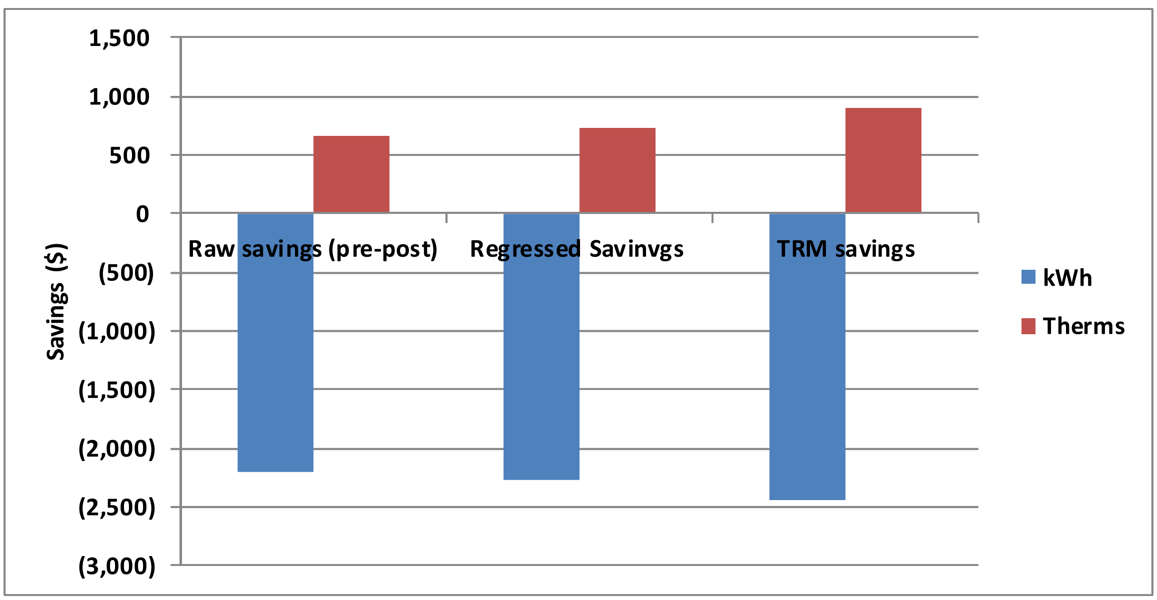


FIGURE 15: TEST HOUSE 3 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	(2,196)	657	(3,515)	7,687	4,172
Regressed Savinvgs	(2,270)	731	(3,634)	8,556	4,922
TRM savings	(2,443)	900	(3,911)	10,530	6,618



DISCUSSION

Overall, resulting regressed savings were -35% kWh and 94% therms. The raw, regressed, and TRM analysis are in good agreement. The raw CO_2 savings totaled 4,172 lbs.

A major retrofit of test house 3 was the replacement of the A/C system and natural gas furnace with a ground-source heat pump system. Significant savings in natural gas use by elimination of gas heating led to excellent natural gas savings, but comes at the cost of increased electrical usage.

According to project documentation the A/C system in the pre-retrofit case was "disconnected," further reducing the baseline energy use. While there may have been good and predicable A/C energy savings (as shown in the TRM estimate in Figure 15) if the baseline A/C was operational, the retrofit resulted in negative energy savings.

House 4

Characteristics

House 4 is a 1315 square foot, two-story home that was constructed in 1968. According to project documentation, the owner's reason for participating is that the house is "not energy-efficient, needs upgrades (and) better IAQ [indoor air quality]."

Data

TABLE 18: TEST HOUSE 4: MEASURE AND COST LIST

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
High efficiency furnace	$4,500	$505
14 SEER central AC	$4,000	$999
Gas Tankless	$4,000	$750
CFL lighting	$800	$27
High Efficiency Windows	$10,000	$2,000
Poor man's HRV	$500	$0
Total	$29,000	$7,691

TABLE 19: TEST HOUSE 4: USAGE, WEATHER AND COST BY YEAR

Annualized Usage and Weather by Year									
Cal Year	Therms	HDD	Th/HDD	Therm Cost	kWh	CDD	kWh/CDD	kWh Cost	Summer Therm
2009	556	6680	0.08	$521.92	4655	715	6.51	$529.75	56
2010	518	6315	0.08	$473.86	5232	1026	5.10	$642.70	57
2011	354	6427	0.06	$372.41	4660	1002	4.65	$572.13	22
2012	303	5612	0.05	$338.99	5997	1288	4.66	$715.26	19
2013	66	1180	0.06	$51.61	619	0	0.00	$74.91	0
TMY pre	534	6406	0.08	$527.16	4978	788	6.31	$604.71	45
TMY post	338	6409	0.05	$334.28	5372	788	6.81	$652.56	16

TABLE 20: TEST HOUSE 4: USAGE BY MONTH

	kWh						Therms					
Month	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**
1	578	640	572	517	432	451	114	107	92	65	84.5	59.2
2	566	482	435	654	432	451	67	74	66	59	74.4	51.4
3	290	431	427	568	432	451	63	75	44	56	79.3	55.1
4	364	407	460	370	430	451	58	49	23	12	53.7	35.4
5	359	407	420	356	427	450	37	32	21	8	40.8	25.4
6	340	374	348	444	412	447	21	22	13	8	23.6	12.1
7	381	449	269	617	372	439	20	19	4	6	10.8	2.1
8	378	440	363	500	379	440	15	16	5	5	10.5	1.9
9	320	357	328	560	377	440	18	14	6	6	9.0	0.8
10	321	359	278	362	422	449	25	14	9	12	27.7	15.2
11	330	423	342	410	429	451	40	22	26	23	46.3	29.6
12	428	463	418	639	432	451	78	74	45	43	72.9	50.2
Total	4655	5232	4660	5997	4978	5372	556	518	354	303	533.6	338.3
Average	4943.5		5328.5				537		328.5			
Savings				-385		-393.9				208.5		195.2
% Savings						**-8%**						**37%**

FIGURE 16: TEST HOUSE 4 THERM USAGE

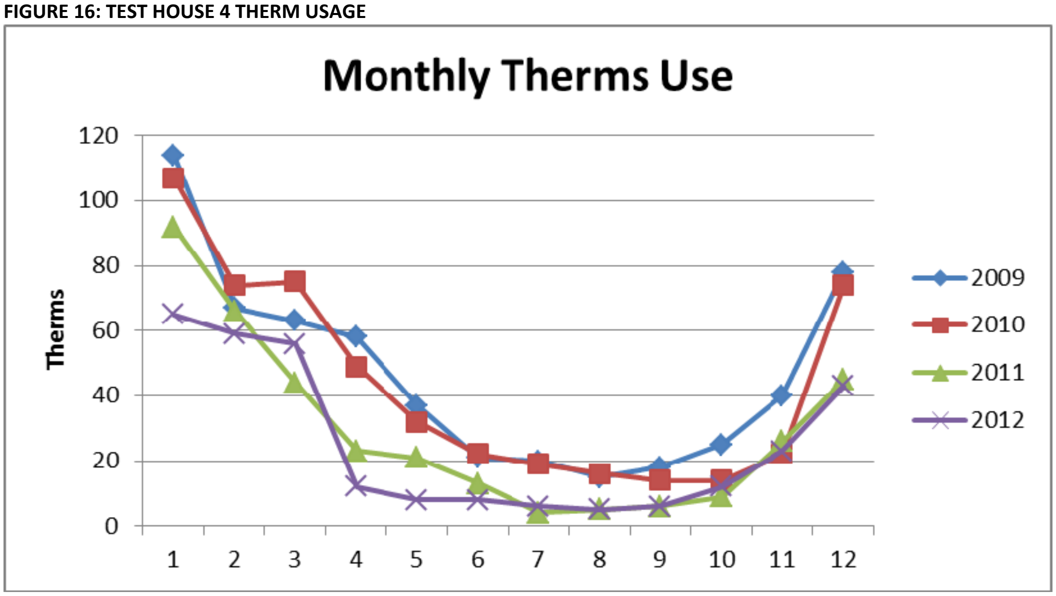


FIGURE 17: TEST HOUSE 4 KWH USAGE

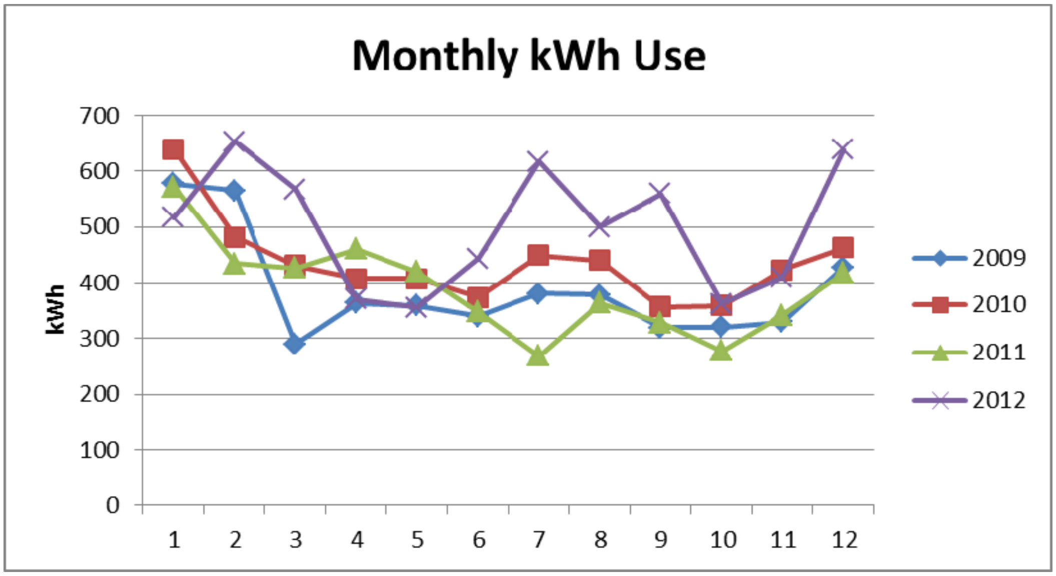


TABLE 21: TEST HOUSE 4: THERM AND KWH REGRESSIONS

		slope	intercept	R square
Therms per HDD	pre	0.0723	5.85	0.96
	post	0.0560	(1.68)	0.97
kWh per CDD	pre	(0.2680)	432.47	(0.28)
	post	(0.0566)	451.40	(0.06)

FIGURE 18: TEST HOUSE 4 THERM PER HDD WITH REGRESSIONS

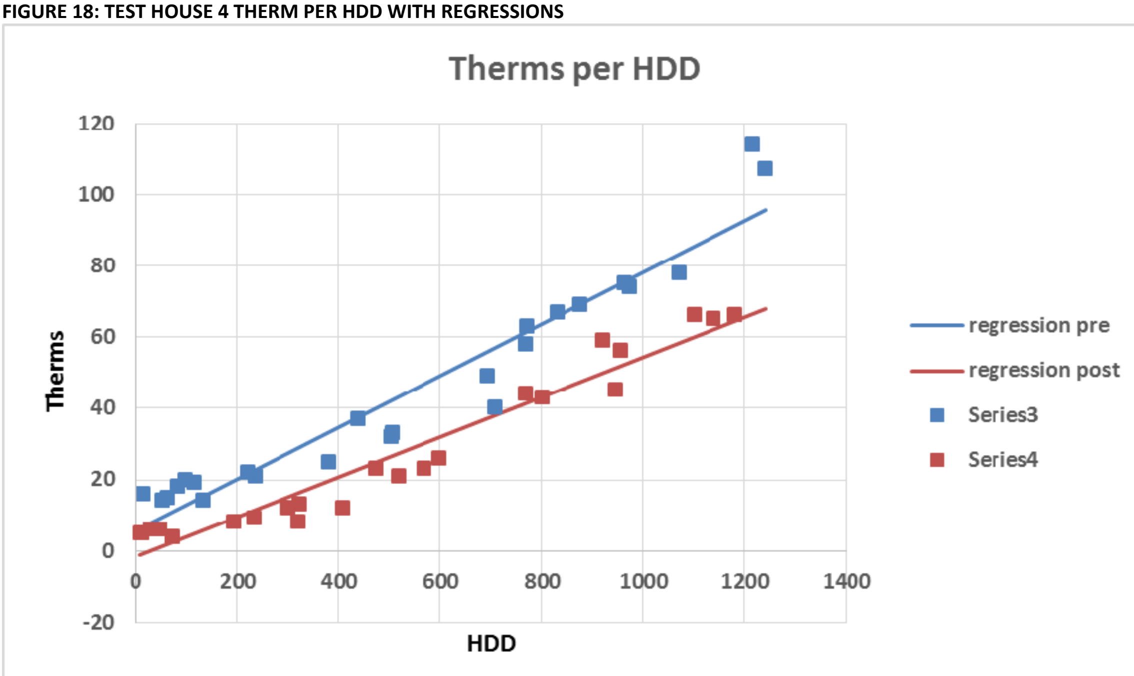


FIGURE 19: TEST HOUSE 4 KWH PER CDD WITH REGRESSIONS

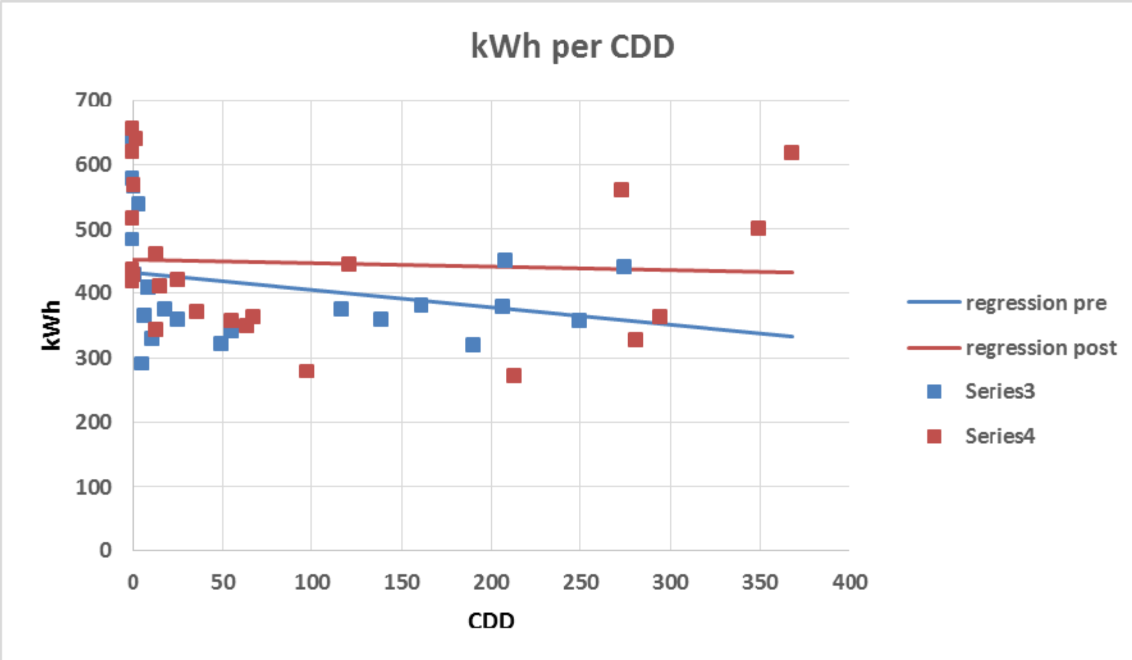
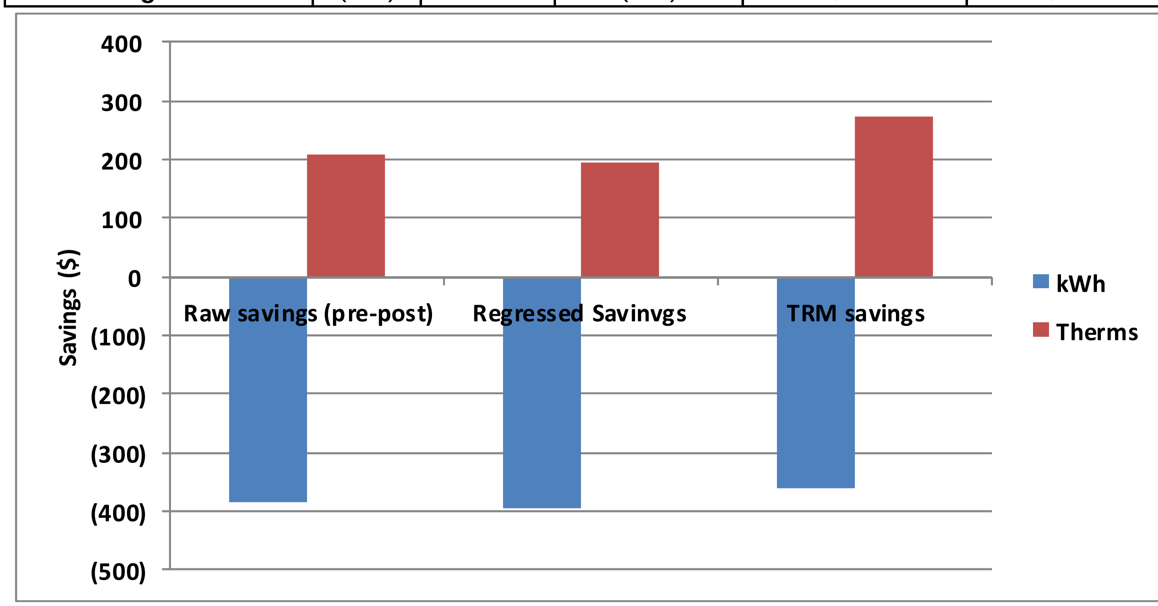


FIGURE 20: TEST HOUSE 4 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	(385)	209	(616)	2,439	1,823
Regressed Savinvgs	(394)	195	(631)	2,284	1,654
TRM savings	(361)	274	(577)	3,205	2,628



Discussion

Test house 4, in addition to receiving the standard array of measures also received new windows at a cost of $30,000 and in a tankless DHW heating system. Overall, resulting regressed savings were -8%

kWh and 37% therms. The raw, regressed, and TRM analysis are in good agreement. The raw CO_2 savings totaled 1,823 lbs.

Project documentation indicates that this home in its pre-retrofit condition only had “window” air conditioning. The reason that home 4 shows significant negative energy savings is because in its baseline configuration, it only had window air conditioning. We take this to mean that it had a small (perhaps 1/3 or 1/2 ton) AC unit, which was replaced by a central unit. The project undoubtedly increased the comfort in the home, but it also created extra electric energy use. It is assumed in the TRM savings analysis that 25% the baseline home was air conditioned.

It is possible that only a small portion of the house was cooled prior to the retrofits, while the entire house was air conditioned in the post case. This change resulted in a lower than expected savings.

House 5

Characteristics

House 5 is an 1800 square foot, two-story home that was constructed in 2000. According to project documentation, the owner’s reason for participating is “wants to lower utility bills, interested in EE, IAQ.”
In addition to the standard array of measures, test home 5, a newer home built in 2000, received a solar DHW heater with gas DHW heat backup.

Data

TABLE 22: TEST HOUSE 5: MEASURE AND COST LIST

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
High efficiency furnace	$4,500	$505
14 SEER central AC	$4,000	$999
SolarWH w Natural Gas backup	$12,000	$8,000
CFL lighting	$800	$27
Poor man’s HRV	$500	$0
Total	$27,000	$12,941

TABLE 23: TEST HOUSE 5: USAGE, WEATHER AND COST BY YEAR

Annualized Usage and Weather by Year									
Cal Year	Therms	HDD	Th/HDD	Therm Cost	kWh	CDD	kWh/CDD	kWh Cost	Summer Therm
2009	979	6772	0.14	$760.02	12220	715	17.09	$1,147.81	96
2010	784	6182	0.13	$600.73	13888	1026	13.54	$1,603.68	96
2011	443	6587	0.07	$407.33	14334	1002	14.30	$1,584.84	7
2012	285	5494	0.05	$311.39	14336	1288	11.13	$1,572.64	2
2013	95	1351	0.07	$63.85	1410	0	0.00	$142.85	0

TMY pre	887	6480	0.14	$738.34	12926	788	16.39	$1,385.32	80
TMY post	384	6306	0.06	$319.90	13937	788	17.68	$1,493.68	-4

TABLE 24: TEST HOUSE 5: USAGE BY MONTH

	kWh						**Therms**					
Month	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**
1	932	943	1235	1305	801	1072	170	141	117	84	136.0	76.0
2	666	781	1422	1063	801	1072	125	117	98	71	121.7	65.9
3	666	1086	1017	955	801	1072	104	124	53	52	122.5	66.5
4	812	895	990	989	837	1084	112	74	35	9	87.9	42.0
5	675	725	929	1023	901	1104	63	57	22	16	67.2	27.2
6	1010	1399	1243	1289	1163	1189	37	39	7	2	40.5	8.3
7	1640	1801	1274	1546	1794	1394	31	31	0	0	19.1	-6.8
8	1626	1868	1507	1646	1580	1325	28	26	0	0	20.7	-5.7
9	1632	1941	1552	1362	1640	1344	32	32	0	0	21.1	-5.4
10	921	1034	1042	1009	977	1129	52	16	0	3	49.9	15.0
11	771	666	910	989	829	1081	70	32	32	9	74.8	32.7
12	869	749	1213	1160	802	1072	155	95	79	39	125.7	68.7
Total	12220	13888	14334	14336	12926	13937	979	784	443	285	887.0	384.3
Average	13054		14335				881.5		364			
Savings				-1281		-1011.1				517.5		502.7
% Savings						**-8%**						**57%**

FIGURE 21: TEST HOUSE 5 THERM USAGE

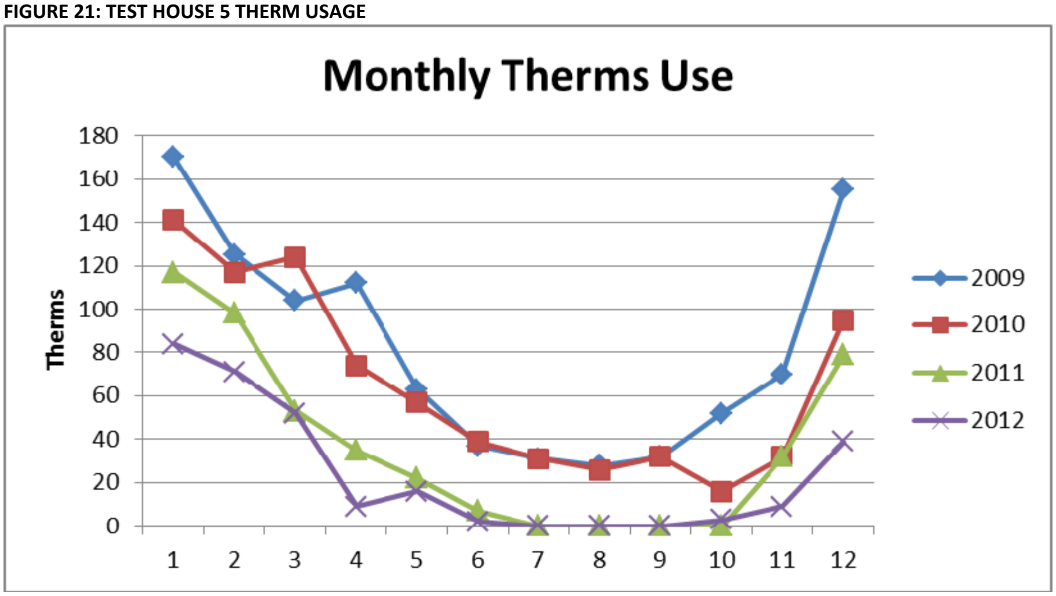


FIGURE 22: TEST HOUSE 5 KWH USAGE

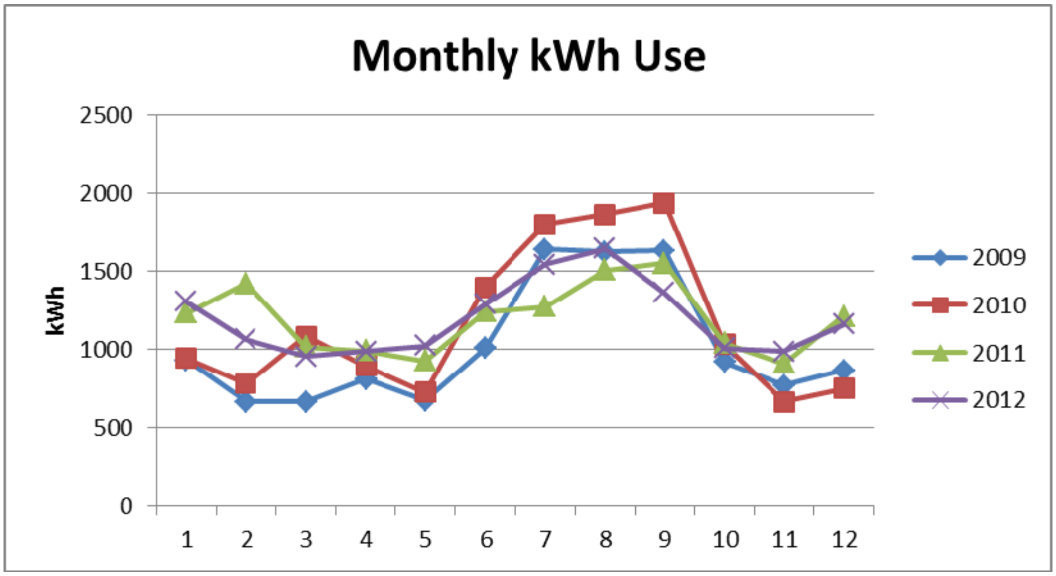


TABLE 25: TEST HOUSE 5: THERM AND KWH REGRESSIONS

		slope	intercept	R square
Therms per HDD	pre	0.1123	13.27	0.96
	post	0.0796	(10.97)	0.96
kWh per CDD	pre	4.2003	801.20	0.95
	post	1.3614	1071.98	0.75

FIGURE 23: TEST HOUSE 5 THERM PER HDD WITH REGRESSIONS

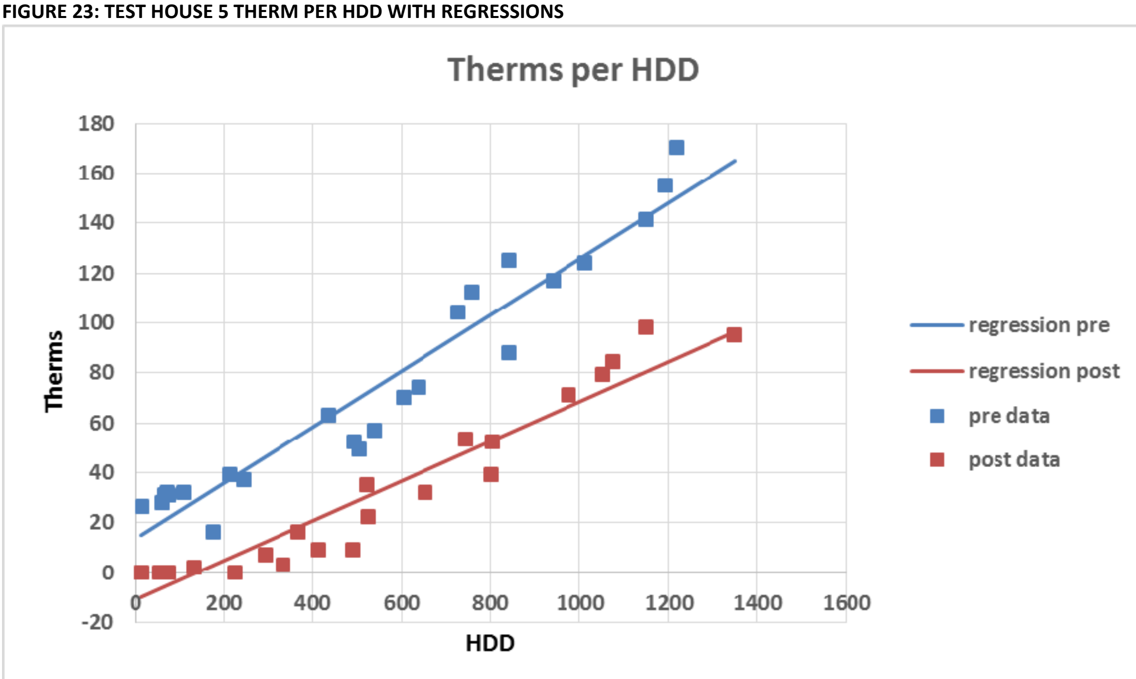


FIGURE 24: TEST HOUSE 5 KWH PER CDD WITH REGRESSIONS

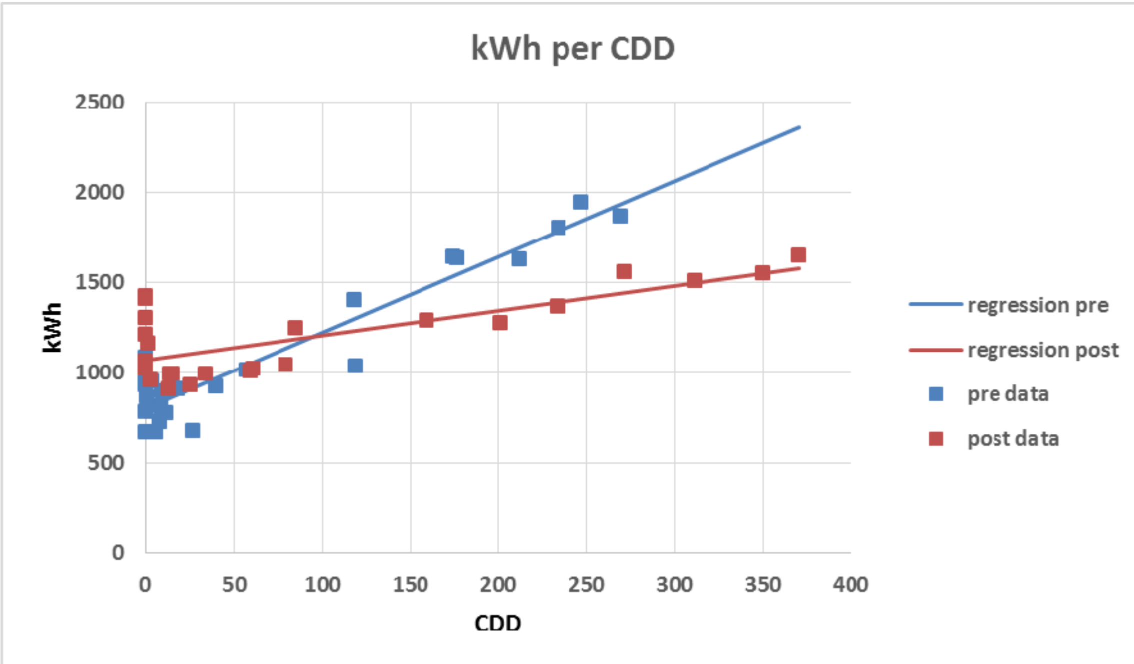


FIGURE 25: TEST HOUSE 5 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	(1,281)	518	(2,051)	6,055	4,004
Regressed Savinvgs	(1,011)	503	(1,619)	5,882	4,263
TRM savings	441	711	706	8,322	9,028

Discussion

Overall, resulting regressed savings were -8% kWh and 57% therms. The raw and regressed savings analysis are in reasonable agreement, the TRM analysis shows positive kWh savings. The raw CO_2 savings totaled 4,004 lbs.

House 5 shows an increase in electric energy use. Given the array of measures, this increase is not explained by the data. There several plausible reasons for the electrical energy use increase, such as running the air conditioner more, or changes in occupancy usage patterns and characteristics. The actual reason cannot be identified without more investigation and analysis.

House 6

Characteristics

House 6 is a 2500 square foot, two-story home that was constructed in 1999. According to project documentation, the owner's reason for participating is they wanted to "improve energy efficiency, less drafts."
In addition to the standard array of measures, test home 6, a newer home built in 1999, received a solar DHW heater with electric DHW heat backup. A photovoltaic (PV) system was also installed on the house, but not within the scope of the WHEC study. Overall, resulting regressed savings were 83% kWh and 48% therms. The raw, regressed, and TRM savings analysis are in reasonable agreement. The raw CO_2 savings totaled 11,278 lbs.

Note that the benefits of the PV system are seen both in the utility bill based savings calculations and the TRM based calculations. Depending on operation of the collector, they may have used a significant amount of electricity for water heating.

Data

TABLE 26: TEST HOUSE 6: MEASURE AND COST LIST

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
High efficiency furnace	$4,500	$505
14 SEER central AC	$4,000	$999
SolarWH w electric Backup	$12,000	$8,000
CFL lighting	$800	$27
Poor man's HRV	$500	$0
Total	$27,000	$12,941

TABLE 27: TEST HOUSE 6: USAGE, WEATHER AND COST BY YEAR

Annualized Usage and Weather by Year									
Cal	Therms	HDD	Th/HDD	Therm	kWh	CDD	kWh/CDD	kWh	Summer

Year				Cost				Cost	Therm
2009	296	2265	0.13	$263.54	4043	480	8.42	$409.78	37
2010	746	6154	0.12	$636.40	9297	1025	9.07	$997.36	50
2011	447	6555	0.07	$442.95	2958	1003	2.95	$401.90	15
2012	325	5576	0.06	$360.41	0	1288	0.00	$616.88	2
2013	106	1264	0.08	$74.94	1079	0	0.00	$118.67	0
TMY pre	792	1886	0.42	$730.28	10082	493	20.44	$1,570.37	14
TMY post	409	6179	0.07	$376.79	1738	788	2.20	$270.67	-20

TABLE 28: TEST HOUSE 6: USAGE BY MONTH

	kWh						Therms					
Month	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**
1		923	836	0	968	195		137	103	74	123.1	72.0
2		994	530	0	968	195		114	56	72	122.7	71.7
3		958	319	0	952	189		81	27	14	75.5	40.4
4		801	163	0	926	179		51	23	3	69.8	36.6
5		581	0	0	832	142		27	15	2	32.9	12.1
6	385	551	0	0	602	51	26	12	0	0	7.1	-5.1
7	414	787	0	0	514	16	11	11	0	0	5.1	-6.4
8	502	514	0	0	563	35	12	8	0	0	2.2	-8.3
9	634	483	0	0	886	163	35	11	0	6	35.4	13.7
10	963	455	0	0	937	183	80	30	28	26	64.4	33.0
11	1145	870	0	0	965	194	132	97	63	43	90.8	50.5
12	1380	1110	0	1079	968	195	167	132	85	106	162.9	98.5
Total	5423	9027	1848	1079	10082	1738	463	711	400	346	791.9	408.6
Average	7225		1463.5				587		373			
Savings				5761.5		8344.3				214		383.3
% Savings						**83%**						**48%**

FIGURE 26: TEST HOUSE 6 THERM USAGE

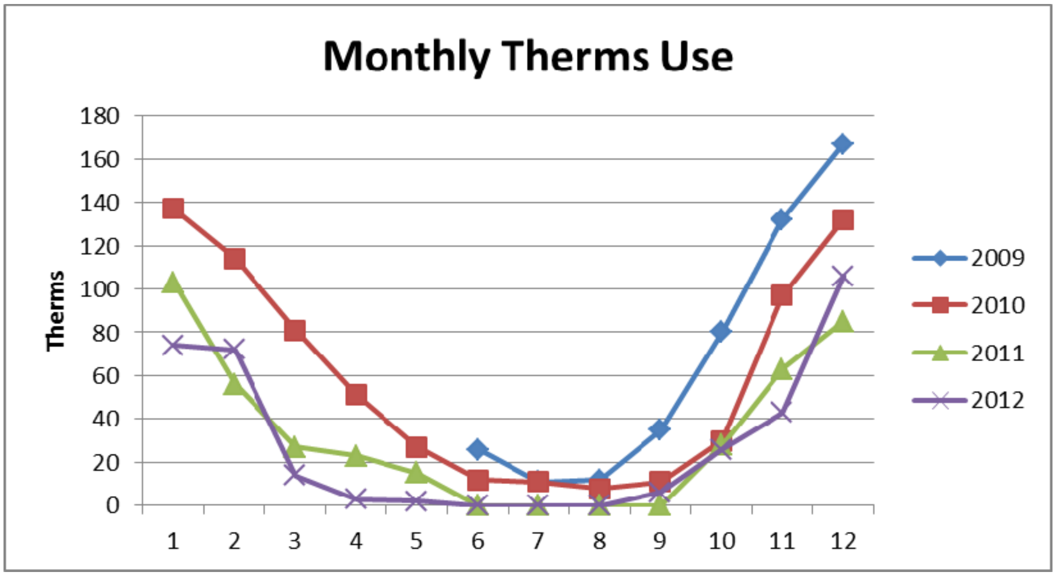


FIGURE 27: TEST HOUSE 6 KWH USAGE

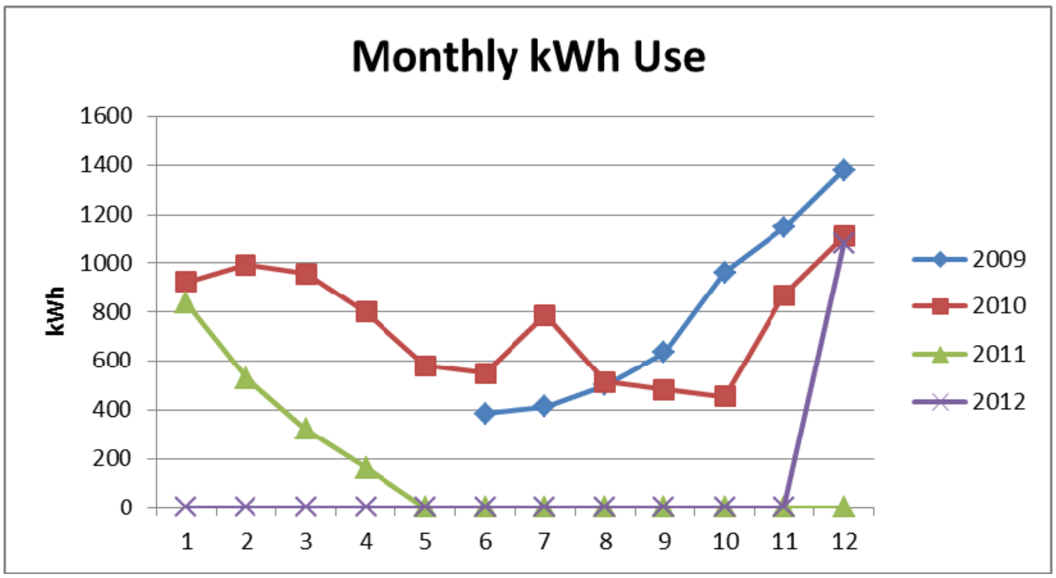


TABLE 29: TEST HOUSE 6: THERM AND KWH REGRESSIONS

		slope	intercept	R square
Therms per HDD	pre	0.1282	(2.61)	0.99
	post	0.0852	(11.55)	0.97
kWh per CDD	pre	(1.9456)	968.00	(0.73)
	post	(0.7691)	195.34	(0.33)

FIGURE 28: TEST HOUSE 6 THERM PER HDD WITH REGRESSIONS

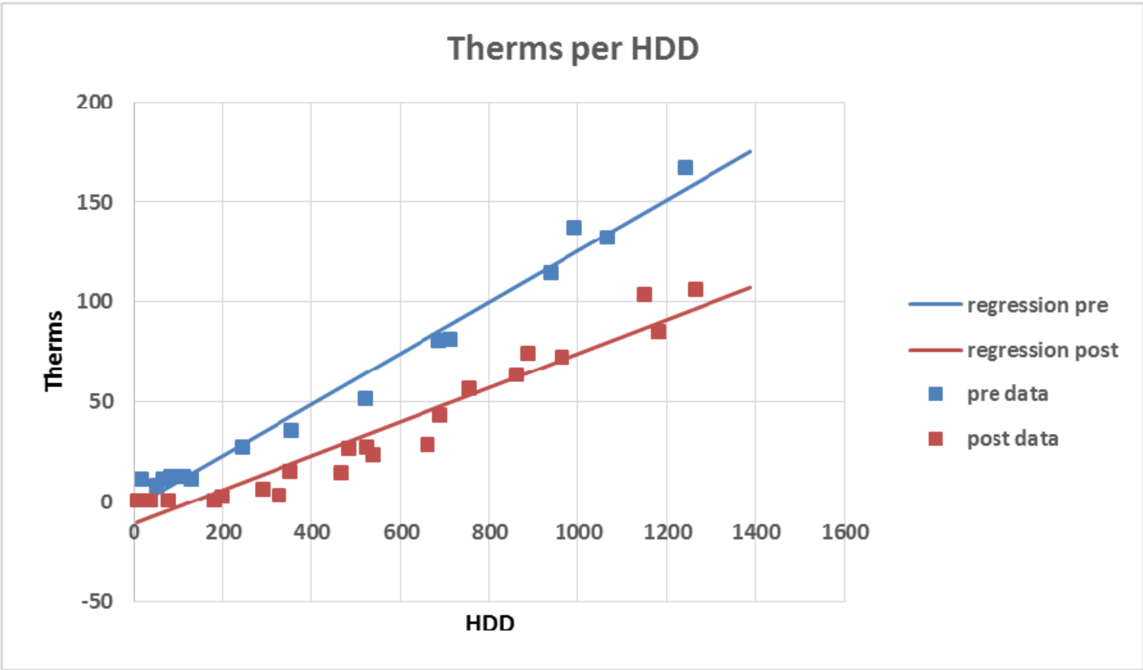


FIGURE 29: TEST HOUSE 6 KWH PER CDD WITH REGRESSIONS

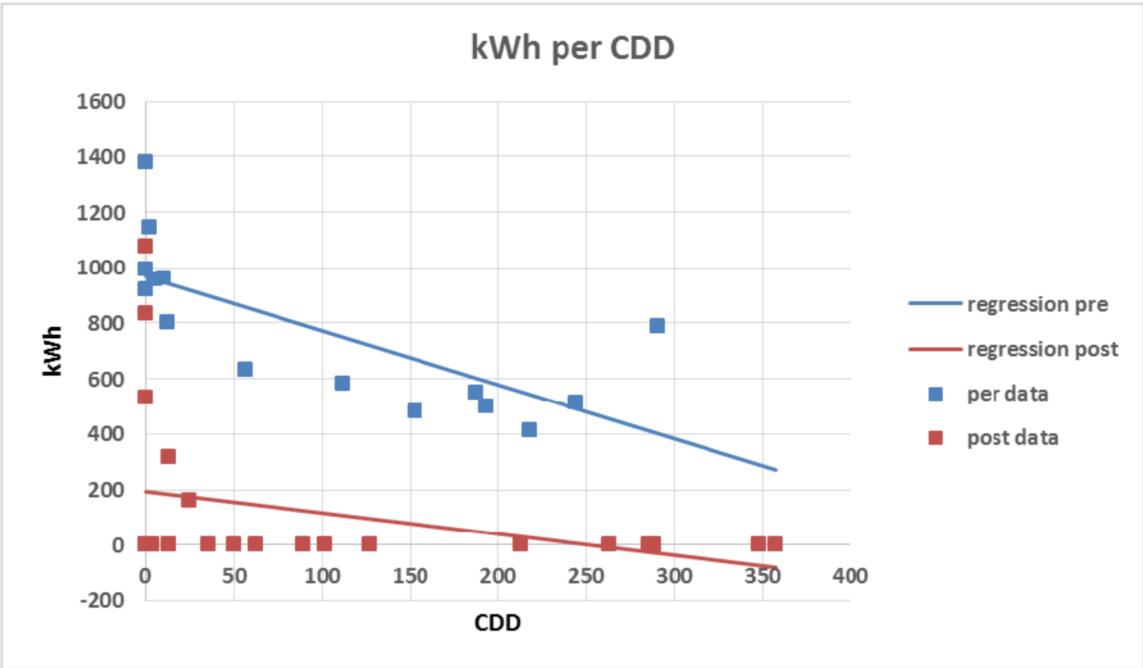
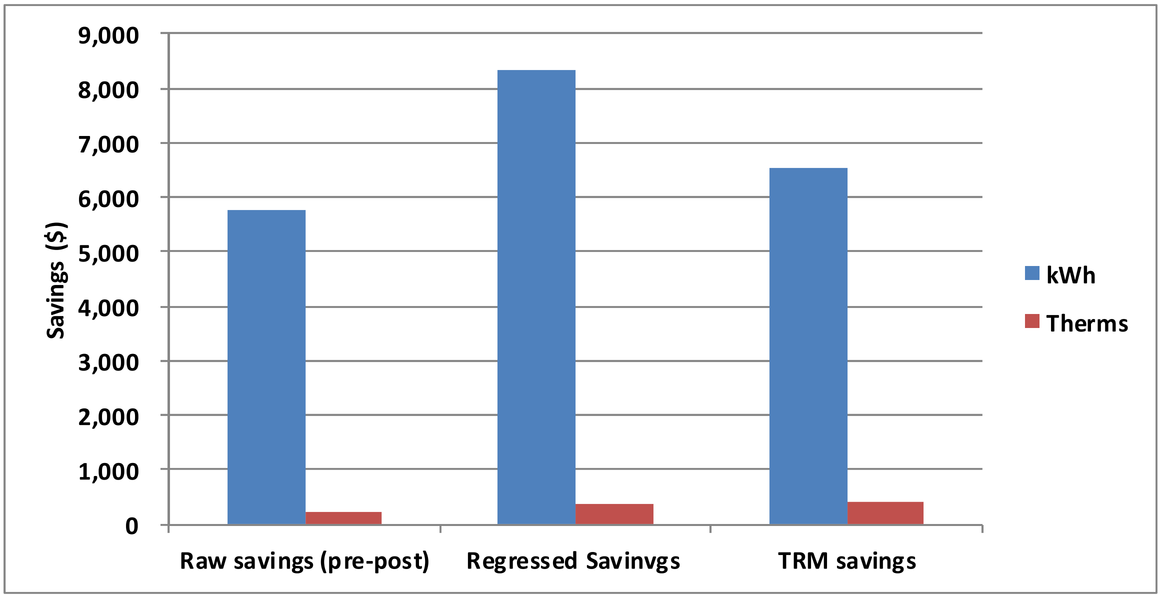


FIGURE 30: TEST HOUSE 6 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	5,762	214	9,224	2,504	11,728
Regressed Savinvgs	8,344	383	13,359	4,485	17,844
TRM savings	6,553	406	10,492	4,747	15,238



Discussion

Home 6 savings was not included in the analysis because of the installation of a PV system subsequent to the installation of the project measures. The PV system has appeared to perform well; however, reducing purchased electrical use to zero.

House 7

Characteristics

House 7 is a 1600 square foot, two-story home that was constructed in 1979. According to project documentation, the owner's reported a "…want to lower utility bills…Concerns about air-tightness, drafts."

Data

TABLE 30: TEST HOUSE 7: MEASURE AND COST LIST

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
High efficiency furnace	$4,500	$505
Evap - Coolerado	$8,500	$3,595
Gas Tankless	$4,000	$750
CFL lighting	$800	$27
Poor man's HRV	$500	$0

Total	$23,500	$8,287

TABLE 31: TEST HOUSE 7: USAGE, WEATHER AND COST BY YEAR

Annualized Usage and Weather by Year

Cal Year	Therms	HDD	Th/HDD	Therm Cost	kWh	CDD	kWh/CDD	kWh Cost	Summer Therm
2009	802	6609	0.12	$693.62	5993	715	8.38	$646.51	50
2010	860	6213	0.14	$707.63	6517	1026	6.35	$765.25	53
2011	702	6506	0.11	$609.96	7159	1002	7.14	$855.48	38
2012	395	4590	0.09	$381.20	7053	1287	5.48	$782.68	23
2013	215	2118	0.10	$151.87	1406	1	1757.50	$161.75	0
TMY pre	824	6406	0.13	$697.70	6345	788	8.05	$734.60	22
TMY post	636	6403	0.10	$538.45	7909	788	10.03	$915.67	19

TABLE 32: TEST HOUSE 7: USAGE BY MONTH

	kWh						Therms					
Month	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**
1	602	701	0	855	522	677	121	163	148	86	121.1	93.1
2	591	535	583	869	522	677	102	161	142	91	143.4	110.1
3	542	488	587	681	522	676	75	95	70	47	101.2	77.9
4	397	499	598	629	523	673	65	60	43	30	66.7	51.5
5	369	510	626	486	529	660	24	45	42	17	50.8	39.3
6	401	589	691	535	538	636	18	22	17	9	12.5	10.0
7	517	620	678	628	543	624	16	16	12	7	6.7	5.7
8	447	622	672	529	546	615	16	15	9	7	3.3	3.0
9	452	618	591	551	535	644	22	17	12	8	21.3	16.8
10	497	607	607	584	524	672	72	37	29	39	60.2	46.5
11	556	728	698	706	522	677	98	111	74	54	112.7	86.7
12	622	0	828	785	522	677	173	118	104	110	124.4	95.6
Total	5993	6517	7159	7838	6345	7909	802	860	702	505	824.3	636.2
Average	6255		7498.5				831		603.5			
Savings				-1243.5		-1563.9				227.5		188.1
% Savings						**-25%**						**23%**

FIGURE 31: TEST HOUSE 7 THERM USAGE

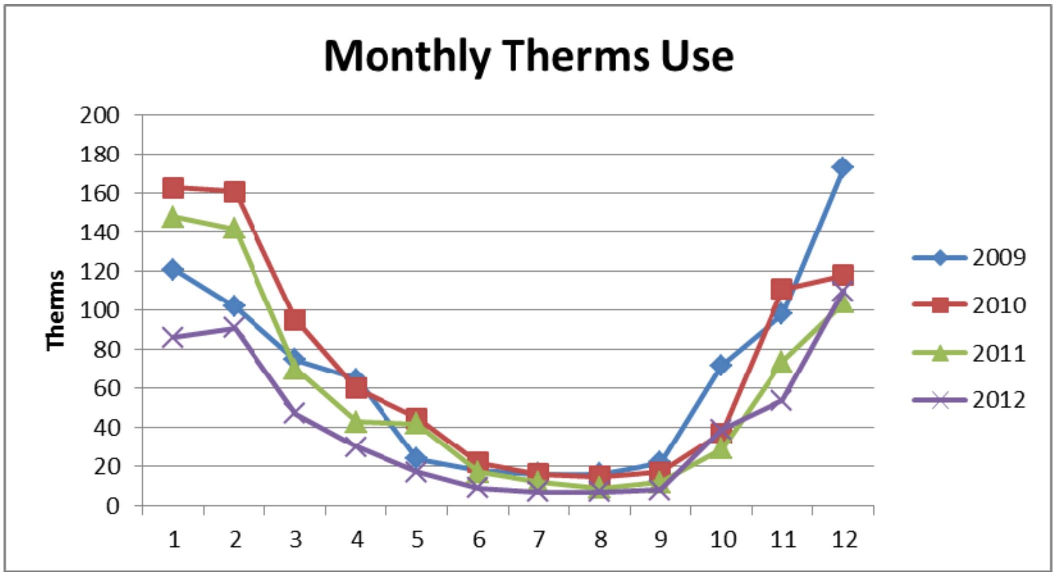


FIGURE 32: TEST HOUSE 7 KWH USAGE

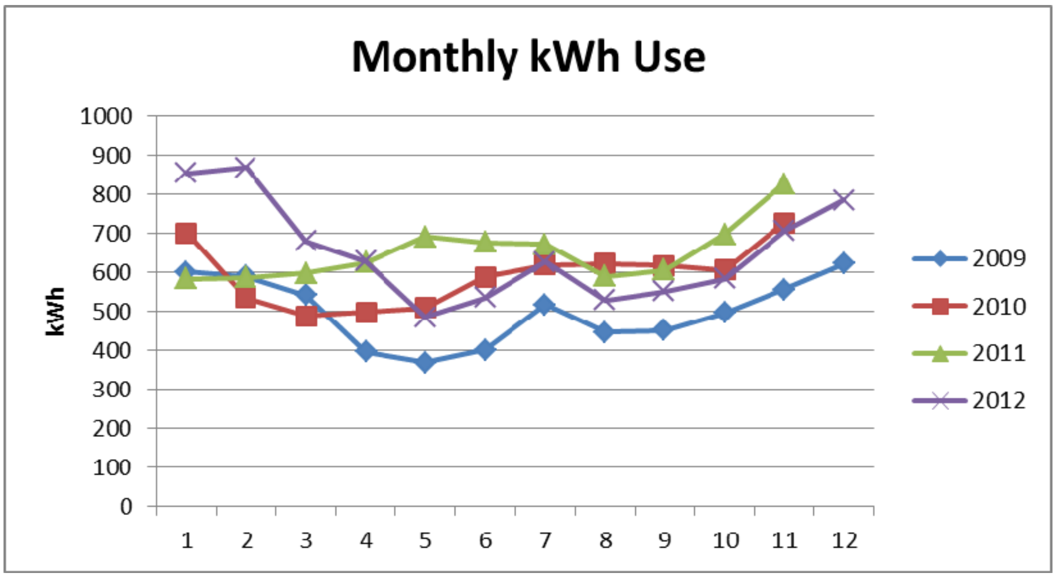


TABLE 33: TEST HOUSE 7: THERM AND KWH REGRESSIONS

		slope	intercept	R square
Therms per HDD	Pre	0.1331	(2.35)	0.98
	Post	0.1017	(1.28)	0.95
kWh per CDD	Pre	0.1093	521.57	0.12
	Post	(0.2803)	677.49	(0.34)

FIGURE 33: TEST HOUSE 7 THERM PER HDD WITH REGRESSIONS

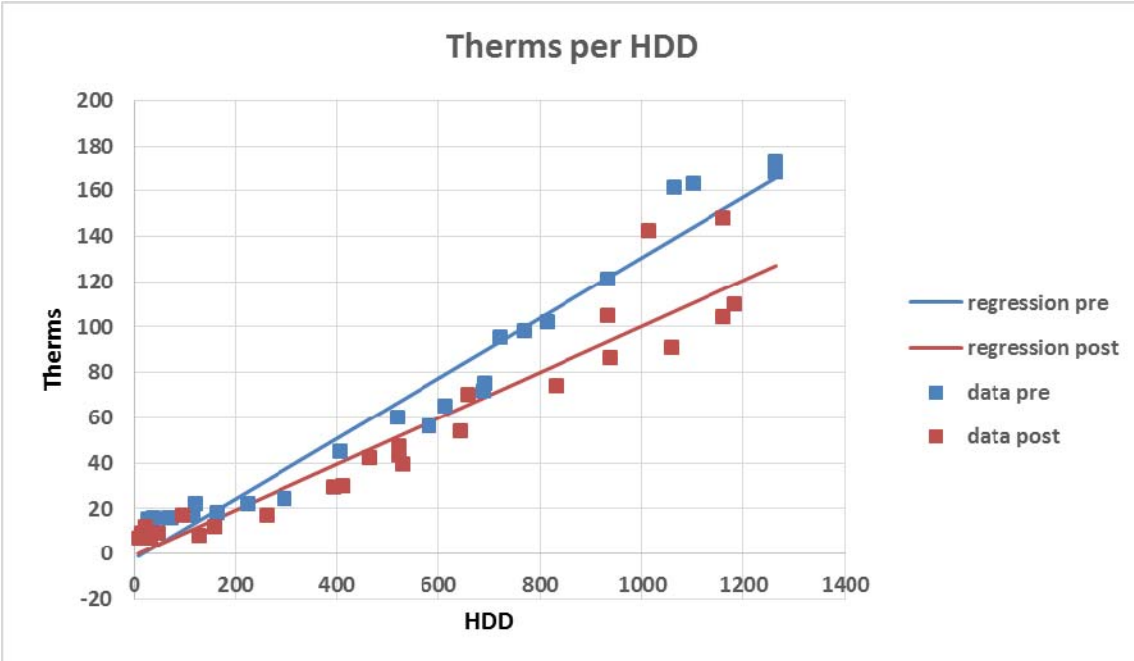


FIGURE 34: TEST HOUSE 7 KWH PER CDD WITH REGRESSIONS

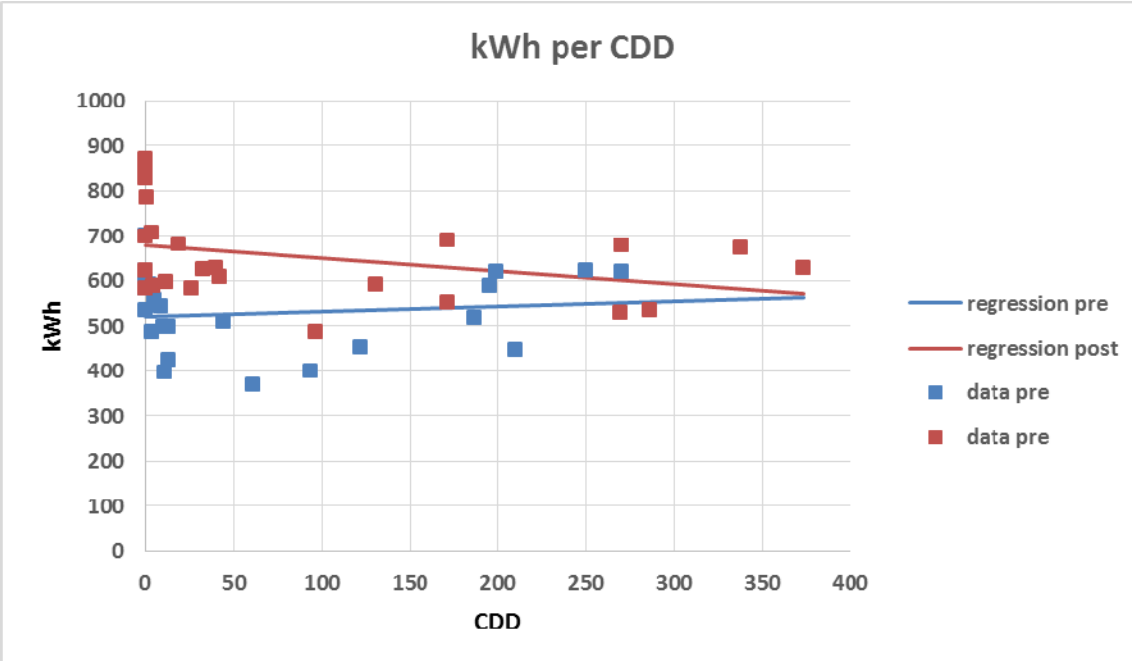
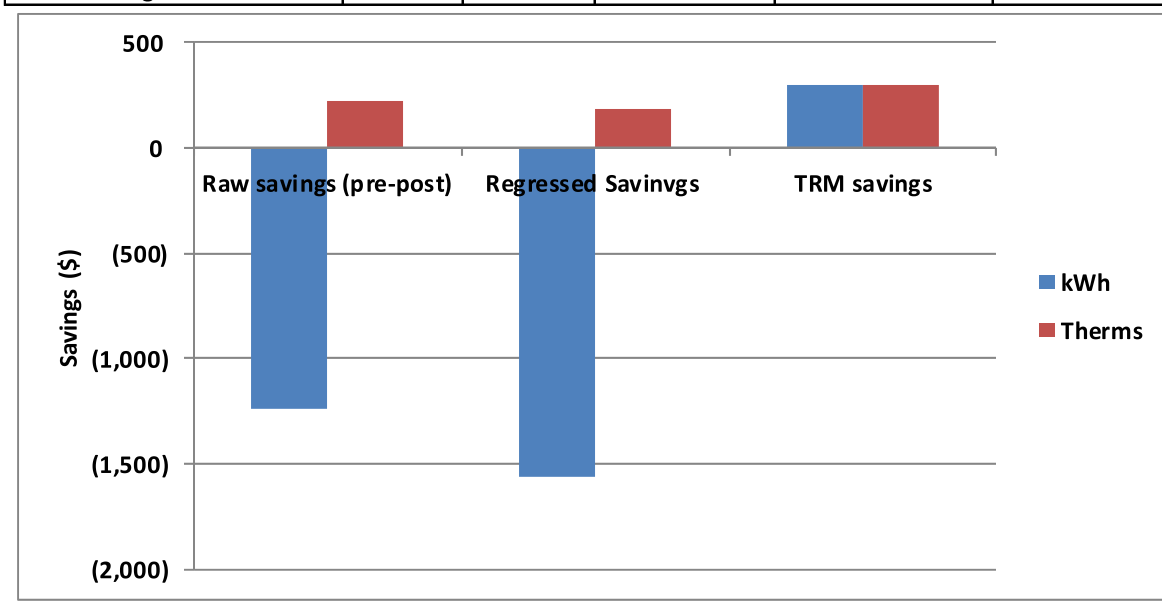


FIGURE 35: TEST HOUSE 7 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	(1,244)	228	(1,991)	2,662	671
Regressed Savinvgs	(1,564)	188	(2,504)	2,201	(303)
TRM savings	301	295	481	3,456	3,937



Discussion

In addition to the standard array of measures, test home 7 also received a Coolerado brand evaporative cooler. Overall, resulting regressed savings were -25% kWh and 23% therms. The raw and regressed savings analysis are in reasonable agreement, the TRM analysis shows positive kWh savings. The raw CO_2 savings totaled 671 lbs.

Project documentation indicates that in its pre-retrofit condition it was cooled by an evaporative cooler and possibly a whole-house exhaust fan. The SEER values of a swamp cooler and the Coolerado are similar. While the indoor comfort of the home may have increased significantly, more energy was consumed. This increase could have been because the owner ran the air conditioner more often during the year, or from changes in occupancy characteristics.

HOUSE 8

CHARACTERISTICS

House 8 is a 1680 square foot, two-story home that was constructed in 1942. According to project documentation, the owner's reported "older Home needs EE improvements."

In addition to the standard array of measures, test home 8 also received a Coolerado brand evaporative cooler which replaced a 12 seer vapor compression central air conditioner. This is a fairly efficient baseline air conditioner, and so the savings is, obviously, less than if the baseline unit was very inefficient.

Air source heat DHW heat pump included in scope to replace natural gas DHW heating. To calculate this savings, the non-weather dependent gas use was converted to electric equivalent usage of an air-source domestic hot water heater.

DATA

TABLE 34: TEST HOUSE 8: MEASURE AND COST LIST

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
High efficiency furnace	$4,500	$505
Evap - Coolerado	$8,500	$3,950
ASHP Water Heater	$4,500	$0
CFL lighting	$800	$27
Poor man's HRV	$500	$0
Total	$24,000	$7,892

TABLE 35: TEST HOUSE 8: USAGE, WEATHER AND COST BY YEAR

Annualized Usage and Weather by Year									
Cal	Therms	HDD	Th/HDD	Therm	kWh	CDD	kWh/CDD	kWh	Summer

Year				Cost				Cost	Therm
2009	797	6475	0.12	$699.46	6955	715	9.72	$726.93	71
2010	762	7450	0.10	$662.48	5944	1026	5.80	$698.94	36
2011	298	5331	0.06	$321.25	4809	101	47.71	$551.16	0
2012	258	4607	0.06	$293.39	6644	1287	5.16	$763.46	21
2013	110	2131	0.05	$89.94	1507	1	1883.75	$171.39	0
TMY pre	769	6393	0.12	$731.11	6362	788	8.07	$740.55	29
TMY post	382	7313	0.05	$363.64	7912	789	10.03	$920.89	62

TABLE 36: TEST HOUSE 8: USAGE BY MONTH

	kWh						**Therms**					
Month	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**
1	634	432	846	604	534	673	133	122	67	51	110.7	41.4
2	559	491		650	534	673	95	121		65	119.2	43.1
3	544	395	527	572	534	672	78	70	15	26	88.3	36.8
4	586	473	618	515	533	669	72	37	0	8	68.2	32.7
5	613	533	717	456	530	659	35	32	0	5	41.6	27.3
6	575	462	818	545	525	643	26	14	0	1	13.0	21.4
7	705	510	749	627	522	632	23	13	0	0	9.4	20.7
8	704	386	705	692	519	626	22	9	107	20	6.4	20.1
9	476	367	616	793	528	651	23	11	0	27	22.0	23.3
10	391	333	556	613	533	669	50	22	3	15	55.0	30.0
11	493	360	780	577	534	672	83	86	41	40	106.2	40.5
12	482	720	779	879	534	673	160	65	65	56	128.7	45.1
Total	6762	5462	7711	7523	6362	7912	800	602	298	314	768.6	382.3
Average	6112		7617				701		306			
Savings				-1505		-1549.4				395		386.3
% Savings						**-24%**						**50%**

FIGURE 36: TEST HOUSE 8 THERM USAGE

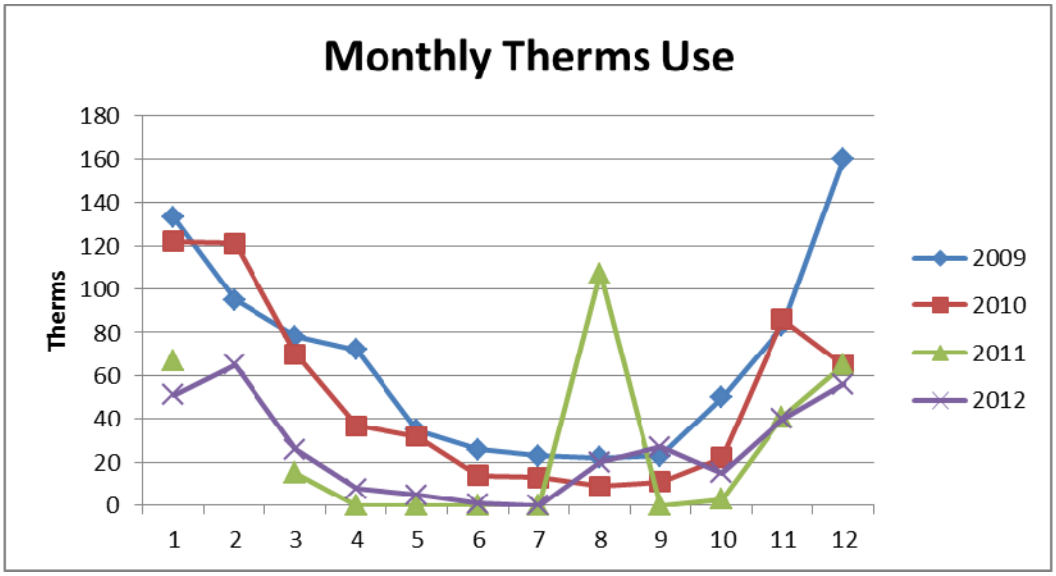


FIGURE 37: TEST HOUSE 8 KWH USAGE

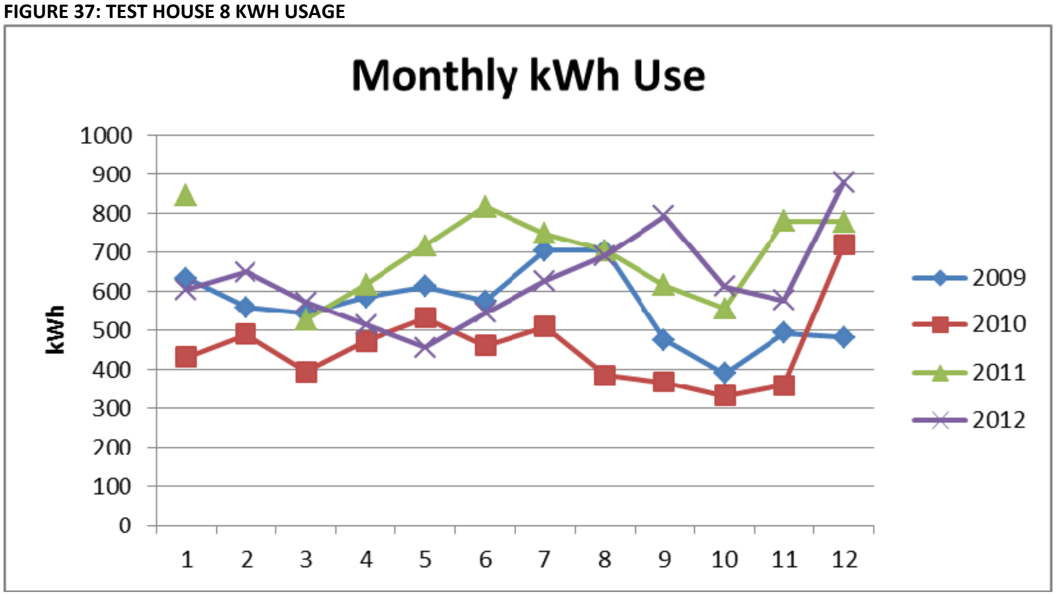


TABLE 37: TEST HOUSE 8: THERM AND KWH REGRESSIONS

		slope	intercept	R square
Therms per HDD	pre	0.1159	1.20	0.96
	post	0.0237	19.02	0.39
kWh per CDD	pre	(0.0652)	534.49	(0.06)
	post	(0.2031)	672.66	(0.19)

FIGURE 38: TEST HOUSE 8 THERM PER HDD WITH REGRESSIONS

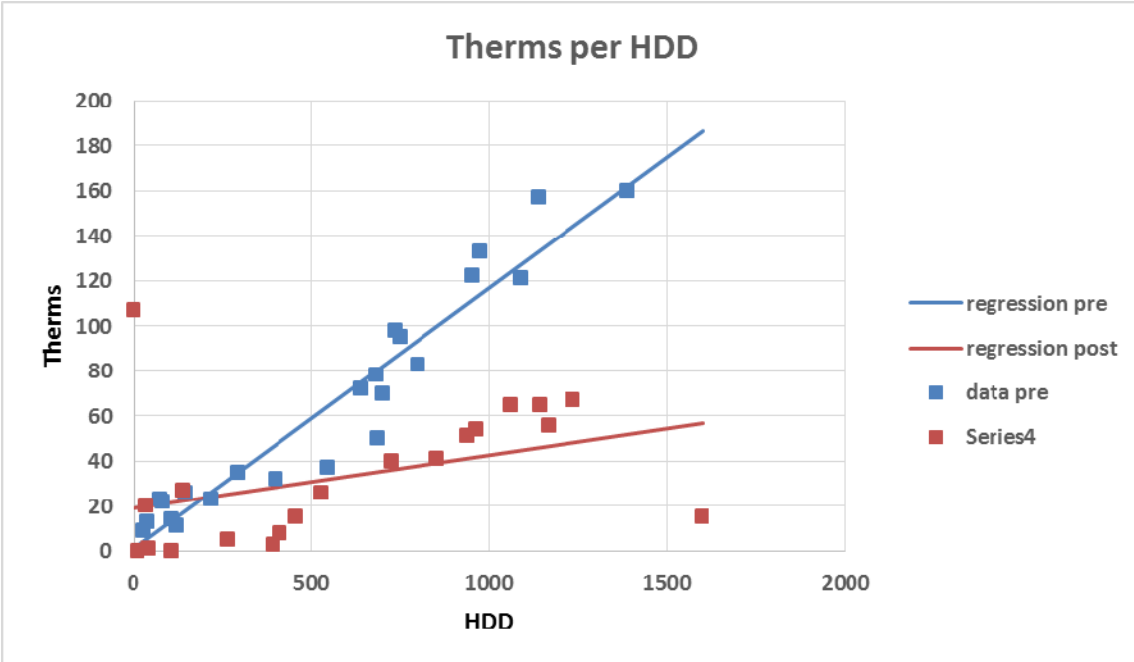


FIGURE 39: TEST HOUSE 8 KWH PER CDD WITH REGRESSIONS

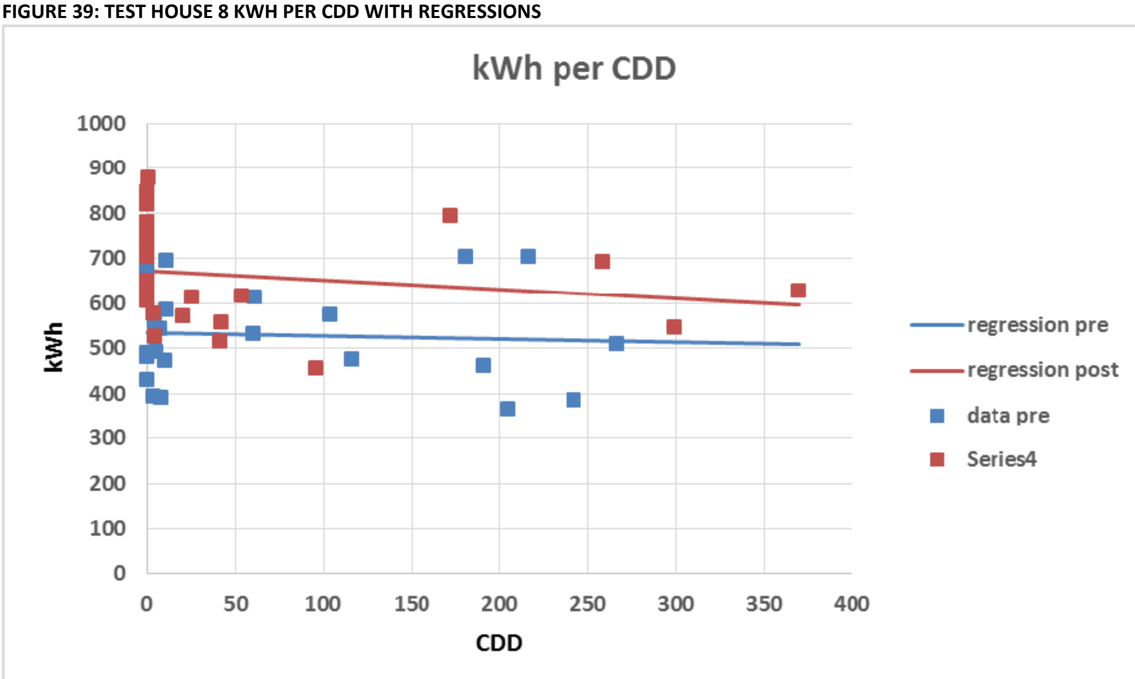
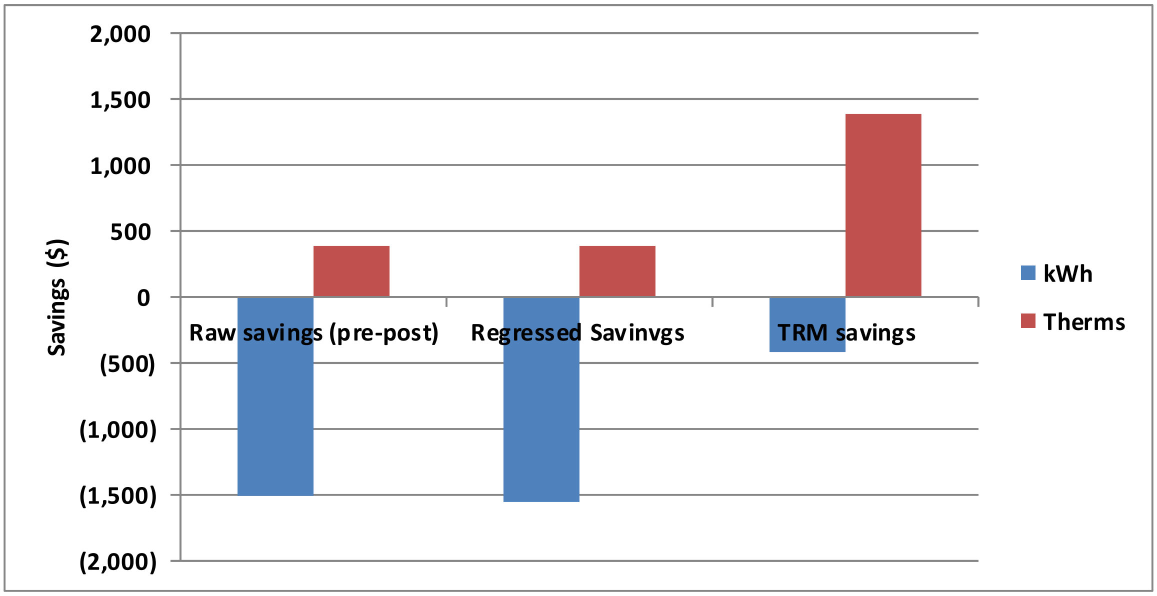


FIGURE 40: TEST HOUSE 8 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	(1,505)	395	(2,410)	4,622	2,212
Regressed Savinvgs	(1,549)	386	(2,481)	4,520	2,039
TRM savings	(407)	1,393	(652)	16,294	15,643



Discussion

In addition to the standard array of measures, test home 8 also received a Coolerado brand evaporative cooler which replaced a 12 seer vapor compression central air conditioner. Overall, resulting regressed savings were -24% kWh and 50% therms. The raw and regressed savings analysis are in good agreement, the TRM analysis has similar trends. The raw CO_2 savings totaled 2,212 lbs.

The replaced air conditioner was a fairly efficient baseline, and so the savings is, obviously, less than if the baseline unit was very inefficient. An air source heat DHW heat pump replaced natural gas DHW heating. To calculate this savings, the non-weather dependent gas use was converted to electric equivalent usage of an air-source domestic hot water heater. Given that the equations are fairly clear and should provide reasonable estimates, the greater than expected electric energy use, and less than expected gas savings is difficult to explain. There could be a number of reasons including occupant behavior changes.

House 9

Characteristics

House 9 is a 2400 square foot, two-story home that was constructed in 1960. According to project documentation, the owners reported wanting to “reduce energy bills, house is drafty.”

There was no AC initially, but perhaps a whole house fan. It would appear that two, air source heat pumps were implemented; both a DHW air source heat pump and an house heating and AC heat pump.

The ASHP for AC is in addition to an energy star rated high efficiency furnace. It seems redundant and cost-inefficient to install both an ASHP and a furnace.

DHW heater was only 2 years old, but was replaced with air source HP DHW.

Utility costs went up by nearly $1000 per year, which is not what the owner likely had in mind.

DATA

TABLE 38: TEST HOUSE 9: MEASURE AND COST LIST

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
High efficiency furnace	$4,500	$505
Air Source Heat Pump AC	$4,800	$800
ASHP Water Heater	$4,500	$0
CFL lighting	$800	$27
Poor man's HRV	$500	$0
Total	$20,300	$4,742

TABLE 39: TEST HOUSE 9: USAGE, WEATHER AND COST BY YEAR

Annualized Usage and Weather by Year									
Cal Year	Therms	HDD	Th/HDD	Therm Cost	kWh	CDD	kWh/CDD	kWh Cost	Summer Therm
2009	1111	6743	0.16	$923.44	14276	715	19.96	$1,409.08	52
2010	1003	6211	0.16	$805.47	13722	1026	13.38	$1,662.77	62
2011	467	6513	0.07	$451.18	21352	1002	21.30	$2,462.25	5
2012	410	5568	0.07	$414.20	21850	1288	16.97	$2,500.09	4
2013	149	1303	0.11	$99.69	3380	0	0.00	$353.60	0
TMY pre	1035	6444	0.16	$891.63	13633	788	17.29	$1,571.76	4
TMY post	487	6343	0.08	$419.29	21511	788	27.28	$2,480.01	-16

TABLE 40: TEST HOUSE 9: USAGE BY MONTH

	kWh						Therms					
Month	2009	2010	2011	2012	Pre	Post	2009	2010	2011	2012	Pre	Post
1	839	683	1719	1593	944	1772	144	172	102	107	164.0	101.9
2	783	683	1716	1548	944	1772	122	157	50	67	177.5	87.8
3	885	464	1230	1174	968	1775	102	73	13	13	97.8	96.0
4	943	421	1404	1819	1013	1779	58	59	10	4	76.6	47.2
5	1254	1056	1516	2107	1196	1799	23	27	3	2	33.8	34.3
6	1458	1654	1852	2155	1636	1846	15	21	1	2	-0.4	8.0
7	1530	1777	1743	1946	1487	1830	14	14	1	0	2.1	-12.9
8	1493	1831	2119	1557	1529	1835	16	17	2	2	2.8	-11.4
9	939	1130	1251	1414	1058	1784	62	18	3	6	46.9	-11.0

10	858	773	1556	1432	971	1775	95	63	36	14	90.9	16.0
11	1935	1523	1910	2658	944	1772	217	179	101	66	163.9	43.0
12	1727	3336	2447	3380	944	1772	203	145	127	149	179.2	87.8
Total	14644	15331	20463	22783	13633	21511	1071	945	449	432	1035.1	486.7
Average	14987.5		21623				1008		441			
Savings				-6635.5		-7877.8				567.5		548.3
% Savings						**-58%**						**53%**

FIGURE 41: TEST HOUSE 9 THERM USAGE

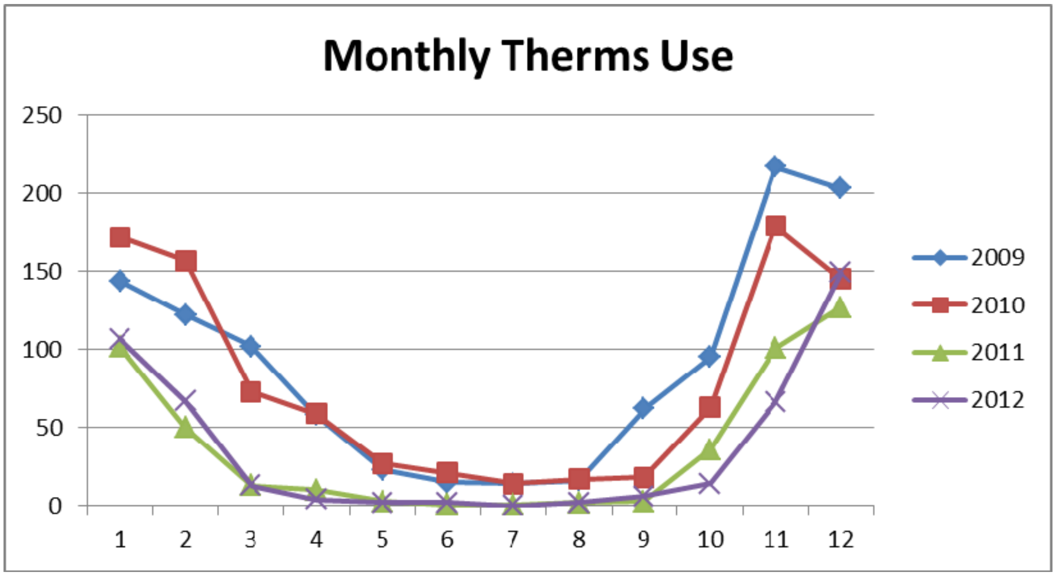


FIGURE 42: TEST HOUSE 9 KWH USAGE

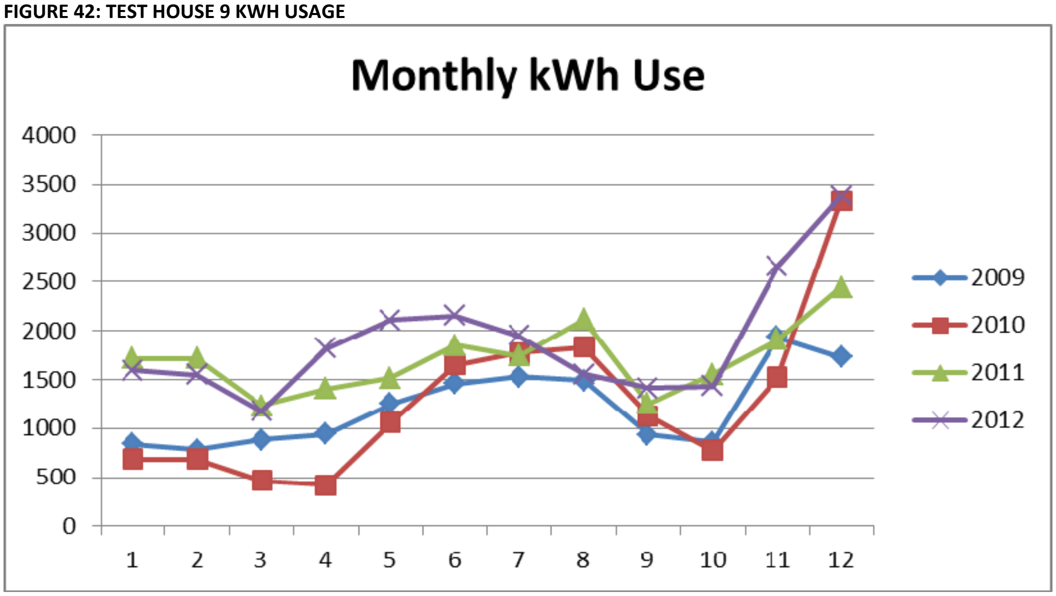


TABLE 41: TEST HOUSE 9: THERM AND KWH REGRESSIONS

	slope	intercept	R square

Therms per HDD	pre	0.1802	(9.86)	0.98
	post	0.1104	(18.71)	0.94
kWh per CDD	pre	2.9304	943.54	0.63
	post	0.3151	1771.85	0.08

FIGURE 43: TEST HOUSE 9 THERM PER HDD WITH REGRESSIONS

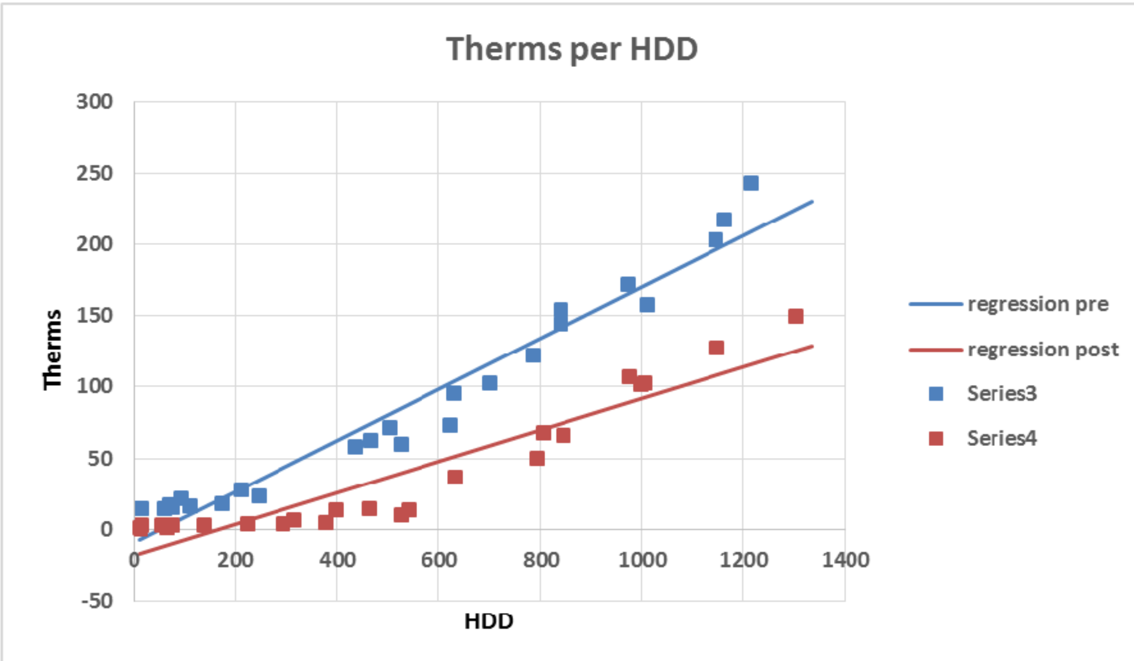


FIGURE 44: TEST HOUSE 9 KWH PER CDD WITH REGRESSIONS

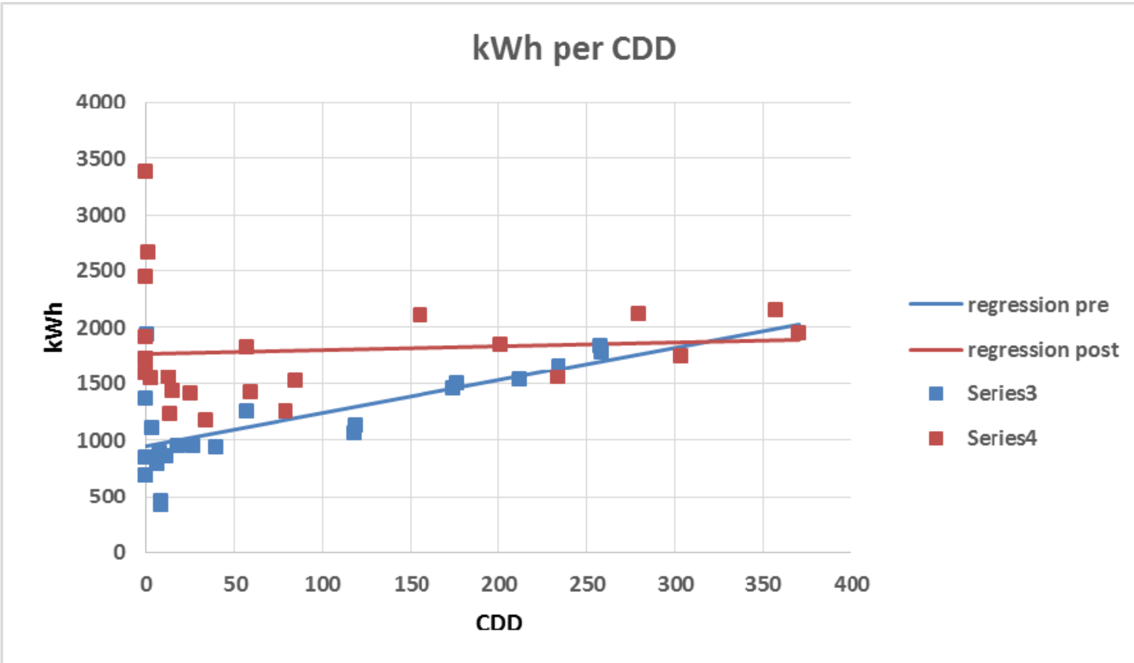


FIGURE 45: TEST HOUSE 9 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	(6,636)	568	(10,623)	6,640	(3,984)
Regressed Savinvgs	(7,878)	548	(12,612)	6,416	(6,197)
TRM savings	(5,644)	1,675	(9,037)	19,599	10,563

Discussion

There was no AC initially, but perhaps a whole house fan. It would appear that two, air source heat pumps were implemented; both a DHW air source heat pump and an house heating and AC heat pump. Overall, resulting regressed savings were -58% kWh and 53% therms. The raw, regressed, and TRM savings analysis are in good agreement. The raw CO_2 savings totaled were negative 3,984 lbs.

The ASHP for AC is in addition to an energy star rated high efficiency furnace. It seems redundant and cost-inefficient to install both an ASHP and a furnace. DHW heater was only 2 years old, but was replaced with air source HP DHW. Utility costs went up by nearly $1000 per year, which is not what the owner likely had in mind. It is hard to explain why the costs when up as much as they did.

House 10

Characteristics

House 10 is a 4000 square foot, two-story home that was constructed in 1995. According to project documentation, the owners reported “house needs energy efficient improvements.”
This house received both an air source heat pump and a 95% efficient furnace. This is an odd installation practice. It is possible that the homeowner has been using the air-source heat pump instead of the furnace as the primary heating source. This would explain the increase in electric use.

Data

TABLE 42: TEST HOUSE 10: MEASURE AND COST LIST

Measure	Cost	Estimated Incremental Cost
Attic and Walls	$4,000	$2,738
Air Sealing	$800	$272
Duct Sealing	$400	$400
High efficiency furnace	$4,500	$505
Air Source Heat Pump AC	$4,800	$800
Gas Tankless	$4,000	$750
CFL lighting	$800	$27
Poor man’s HRV	$500	$0
Total	$19,800	$5,492

TABLE 43: TEST HOUSE 10: USAGE, WEATHER AND COST BY YEAR

Annualized Usage and Weather by Year									
Cal Year	Therms	HDD	Th/HDD	Therm Cost	kWh	CDD	kWh/CDD	kWh Cost	Summer Therm
2009	1303	6641	0.20	$1,045.80	11702	715	16.36	$1,117.32	107
2010	1283	6425	0.20	$973.20	13146	1026	12.82	$1,516.39	128
2011	644	6376	0.10	$568.11	13335	1002	13.30	$1,501.31	53
2012	626	5561	0.11	$529.05	13876	1288	10.78	$1,563.64	66
2013	160	1267	0.13	$106.16	1283	0	0.00	$138.71	0
TMY pre	1273	6452	0.20	$1,018.99	12328	788	15.64	$1,396.09	59

TMY post	684	6389	0.11	$547.64	13335	788	16.91	$1,510.18	52

TABLE 44: TEST HOUSE 10: USAGE BY MONTH

	kWh						**Therms**					
Month	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**	**2009**	**2010**	**2011**	**2012**	**Pre**	**Post**
1	1015	920	1308	1131	927	1057	169	199	138	109	165.0	110.4
2	1016	900	1093	1093	927	1057	157	205	93	123	215.6	90.1
3	775	841	838	1011	940	1064	150	142	35	45	119.3	118.7
4	807	745	1143	1072	960	1075	94	92	33	31	108.6	64.2
5	703	1164	1058	1013	1030	1113	44	64	24	25	67.8	58.2
6	998	1252	902	1418	1198	1204	33	35	14	20	23.2	35.1
7	1273	1380	1299	1419	1270	1243	30	29	15	21	18.8	9.9
8	1185	1425	1445	1417	1224	1218	29	27	17	21	16.7	7.3
9	897	1204	876	963	1041	1119	55	31	16	22	60.6	6.2
10	815	805	960	1055	953	1071	132	64	36	40	101.7	31.0
11	810	1140	1178	1099	930	1058	172	154	84	49	180.7	54.3
12	1370	1235	1185	1283	927	1057	241	139	120	160	195.3	99.0
Total	11664	13011	13285	13974	12328	13335	1306	1181	625	666	1273.2	684.3
Average	12337.5		13629.5				1243.5		645.5			
Savings				-1292		-1007.5				598		589.0
% Savings						**-8%**						**46%**

FIGURE 46: TEST HOUSE 10 THERM USAGE

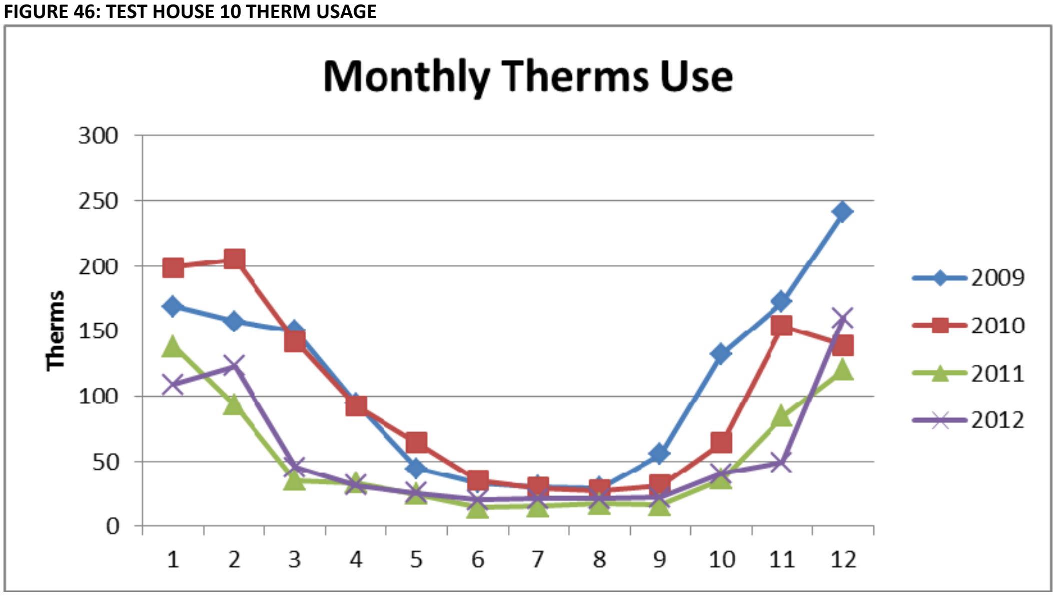


FIGURE 42: TEST HOUSE 10 KWH USAGE

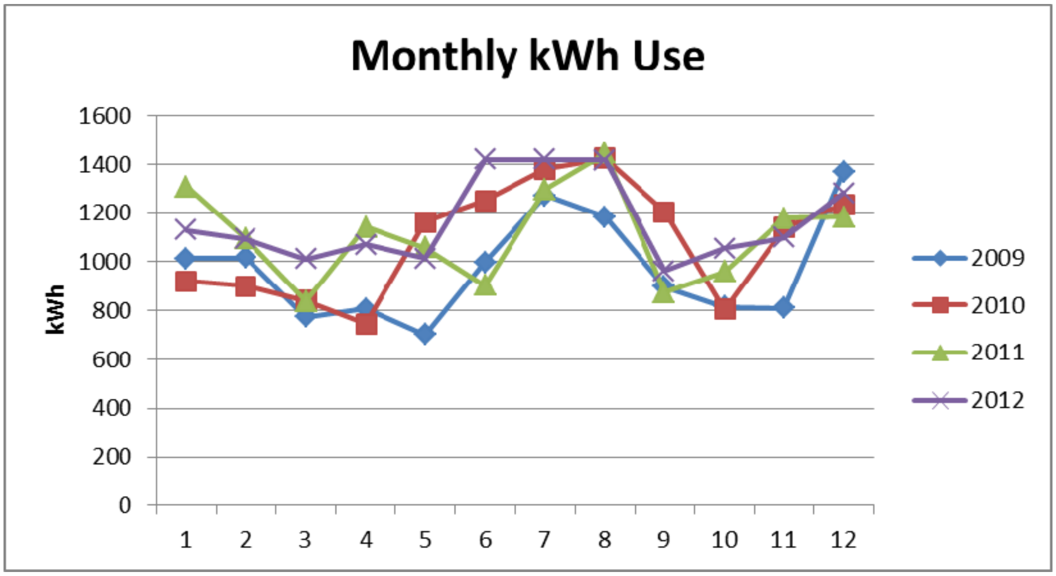


TABLE 47: TEST HOUSE 10: THERM AND KWH REGRESSIONS

		slope	intercept	R square
Therms per HDD	pre	0.1817	8.90	0.99
	post	0.1028	1.75	0.93
kWh per CDD	pre	1.5216	927.34	0.59
	post	0.8253	1057.04	0.58

FIGURE 48: TEST HOUSE 10 THERM PER HDD WITH REGRESSIONS

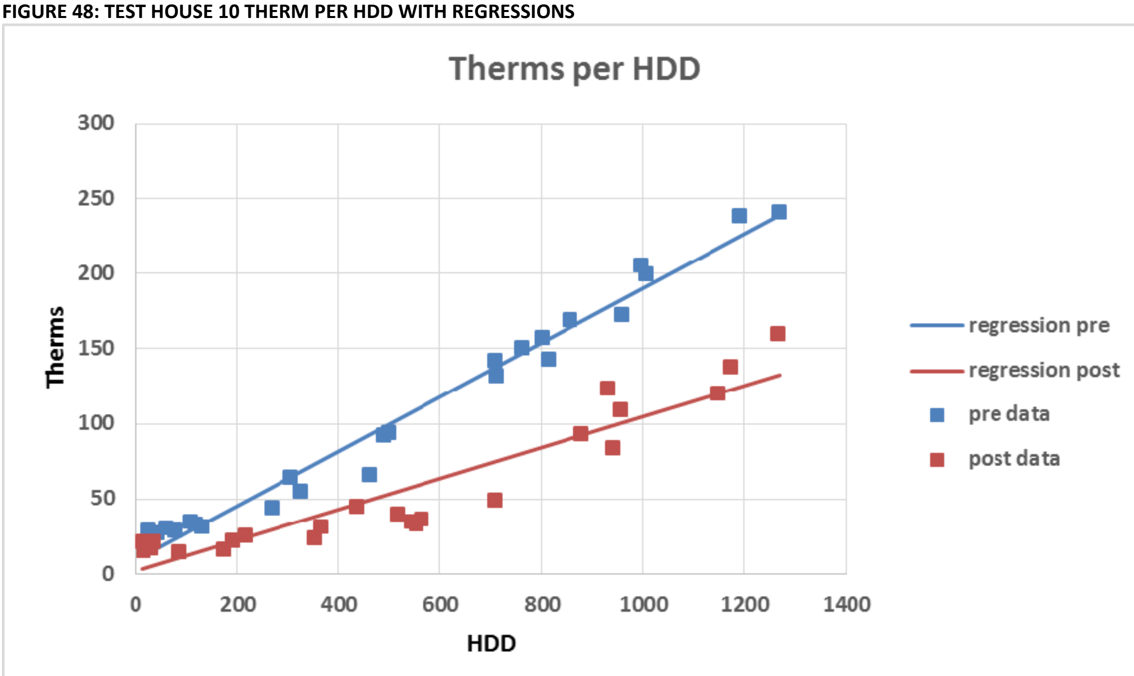


FIGURE 49: TEST HOUSE 10 KWH PER CDD WITH REGRESSIONS

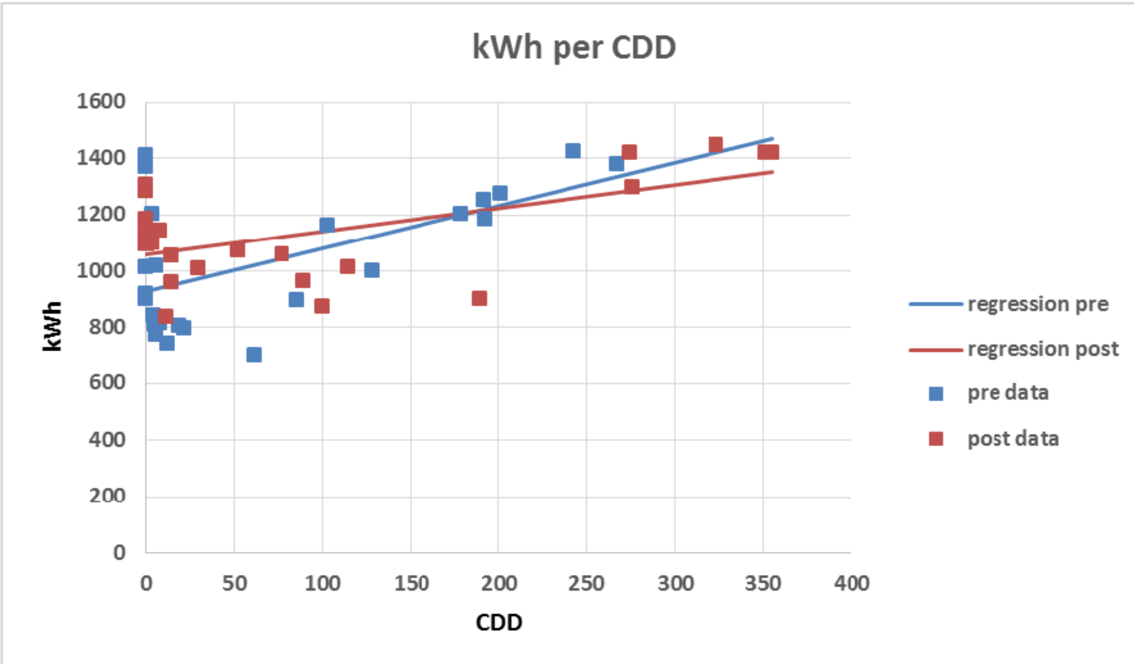
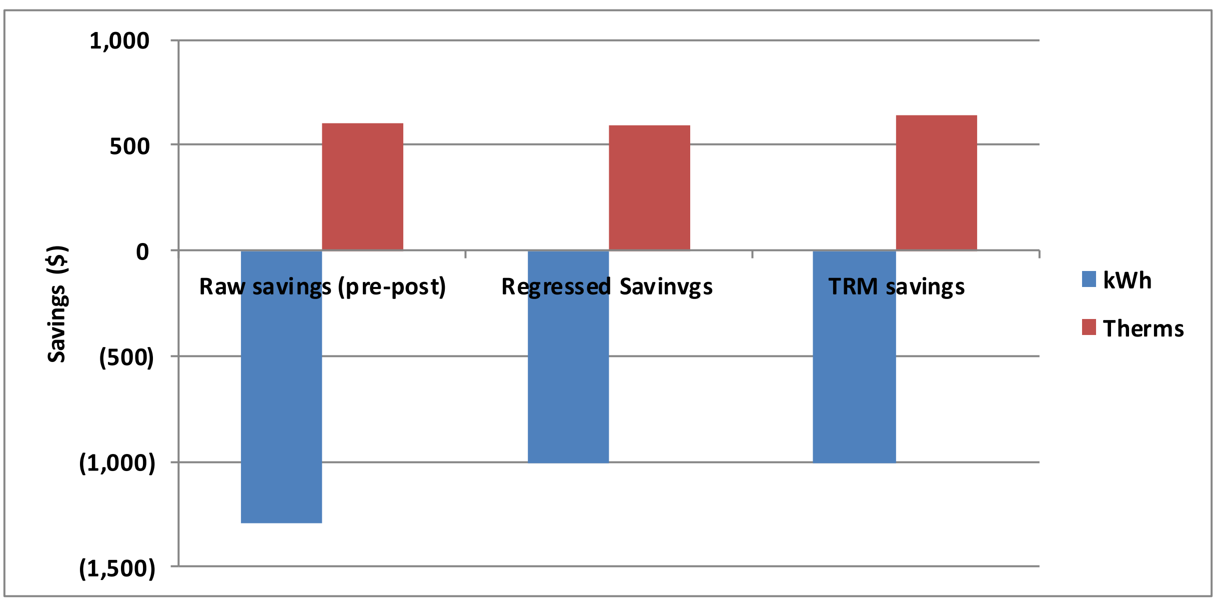


FIGURE 50: TEST HOUSE 10 ANNUAL KWH AND THERM SAVINGS

	kWh	Therms	CO_2 electric	CO_2 natural gas	CO_2 (lbs) total
Raw savings (pre-post)	(1,292)	598	(2,068)	6,997	4,928
Regressed Savinvgs	(1,007)	589	(1,613)	6,891	5,278
TRM savings	(1,011)	640	(1,618)	7,482	5,864



Discussion

This house received both an air source heat pump and a 95% efficient furnace. Overall, resulting regressed savings were -8% kWh and 46% therms. The raw, regressed, and TRM savings analysis are in reasonable agreement. The raw CO_2 savings totaled were 4,928 lbs.

An air source heat pump and furnace together is an odd installation practice. It is possible that the homeowner has been using the air-source heat pump instead of the furnace as the primary heating source. This would explain the increase in electric use.

APPENDIX B: FULL CALCULATION SPREADSHEET

A detailed spreadsheet in electronic format is on file and available upon request from Xcel Energy.

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