City of Worcester, Massachusetts

LESSONS FROM THE RESIDENTIAL REBATE PILOT

Comparison of two single-family homes in Worcester - Energy Efficiency Case Study

The Residential Rebate Pilot (RRP), Worcester Energy's principal residential efficiency program, ran from 2012 to 2014 and was funded by the Green Community Grant. The goal of the Pilot was to provide a financial incentive to encourage investments in energy efficient building improvements and to use lessons learned to market energy efficiency to the Worcester community. The Pilot funded 168 energy efficiency projects which included 208 dwelling units for 1-4 family homes.

This case study compares energy efficiency improvements and cost savings of two single-family homes that participated in the Pilot.

On average, 59% of Massachusetts residential energy expenditures are attributed to space heating costs[1], making improved home insulation and investments in heating equipment (HVACs) clear targets for energy saving measures. Not surprisingly, 49% of the Pilot participants completed an energy efficiency HVAC project and 55% completed a home insulation (aka weatherization) project.

The two participants' main motive was the replacement of inefficient heating systems nearing the their end of useful life. In addition to HVAC replacements, both participants purchased an indirect hot water heater and completed weatherization projects. Single-Family A participant added a ductless mini-split as a supplemental source of heat and air conditioning for two bedrooms. Read on to learn more about the home energy efficiency measures taken, and see how each home's energy use and utility bill changed as a result.

Table 1:		**Single-Family A (SF A)**	**Single-Family B (SF B)**
Characteristics of the Participating Home and Residents	Year Built	1963	1922
	Number of Residents	1	2
	Living Space Area	1112 ft^2	1464 ft^2
	Energy Scoring System	Energy Performance Scorecard (EPS)	Home Energy Rating System (HERS)
Home Projects (Projects) done through Residential Rebate Pilot	Original HVAC	30-year-old natural gas boiler	50-year-old oil boiler
	Heating Fuel after the Project	Natural Gas	Conversion: Heating Oil to Natural Gas
	Heating System	Hot water	Hot water
	Energy Efficiency Project:	*Combination Boiler & Hot Water Heater:* 95% efficient (AFUE) natural gas boiler (86,000 BTU) with 14-gallon indirect fired water heater	*Combination Boiler & Hot Water Heater:* 97.3% efficient (AFUE) natural gas boiler (70K BTU) with a 40-gallon indirect fired water heater and 4 circulator pumps
		Weatherization: Insulation (Attic insulation through Mass Save) and Air sealing	*Weatherization:* Insulation (Attic and bedroom insulation through Mass Save) and Air sealing (DIY project)
		Ductless Mini-Split Heat Pump with 2 indoor units (for the two bedrooms)	n/a (use two portable Air Conditioners ~10 days a year, during the hottest, most humid days)

[1] Executive Office of Energy and Environmental Affairs. Department of Energy Resources. Accessed 17 Nov. 2015. http://www.mass.gov/eea/energy-utilities-clean-tech/misc/household-heating-costs.html

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Single-Family A Project Summary:

- *Picture to the left* - 95% efficient **natural gas boiler** with 14-gallon indirect **water heater** (replaced a 30-yr old natural gas boiler).
- *Bottom picture* – excerpts from the **insulation/weatherization** contract for the work that was done on the house.

  The largest items are the cellulose **insulation** (7" and 12" thickness) blown into the attic floor.

  Air sealing, door sweep and door weather stripping was covered 100% by Mass Save ($1,332.79 in value) !

Continued

1. DESCRIPTION OF WORK TO BE PERFORMED

NSL will perform or cause to be performed the following work on the customer's address above, in a professional manner and in accordance with the terms of this Contract, including the attached recommendations/work order describing the work in detail (the "Work") which are incorporated herein by reference:

Description	Quantity	Location	
Install 2" Thermal Barrier Polyiso On Kneewall	60	Living Space	$264.00
Attic Floor Open Blow Cellulose 12"	1,600	Living Space	$2,976.00
Damming	66	N/A	$144.54
12" Mushroom Vent	5	Attic	$689.85
Vent bath fan to roof flapper	2	Attic	$258.42
Attic Floor Open Blow Cellulose 7"	384	Living Space	$587.52
		Sub Total:	$4,920.33
		Utility Incentive Share	$2,000.00
		Customer Contribution	$2,920.33

1. DESCRIPTION OF WORK TO BE PERFORMED

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Description	Quantity	Location	
Perform Air Sealing at Estimated 62.5 CFM50 Per Hour	14	Living Space	$1,180.48
Door Sweep	3	N/A	$69.54
Exterior Door Weather Stripping	3	N/A	$82.77
		Sub Total:	$1,332.79
		Utility Incentive Share	$1,332.79
		Customer Contribution	$0.00

Single-Family A Project Summary:

Continued from the previous page:

- *Picture on the left:* **Ductless Mini-Split Heat Pump** (providing supplemental heating and air conditioning).
- *Picture on the bottom:* Ductless Mini-Split Heat Pump's indoor unit in one of the two bedrooms.

Single-Family A Project Summary:

As a result of the project, the Energy Performance Score (EPS) of this home fell from **243 to 87!** (million British thermal units of energy per year)

The owner is spending a lot less on energy and the home's carbon footprint is much smaller (read on to learn more).

The owner reported to be very happy with all the improvements to the home which resulted in lower energy bills and increased comfort – both in winter time and during the summer.

Read on to learn more.

Single-Family B Project Summary:

- **Air-sealing**
- Blown-in cellulose **insulation** in the attic, on top of the pre-existing fiberglass insulation.
- Already had fiberglass insulation in the walls.

Continued

Single-Family B Project Summary:

- 97.3% efficient natural gas **boiler** with a 40-gallon indirect fired water heater (replaced a 50-yr old oil boiler).

Single-Family B Project Summary:

As a result of the project, the Home Energy Rating Score (HERS) fell from **96 to 71!** By comparison, a standard new home has a HERS of 100. The lower the HERS score, the more energy efficient the building is.

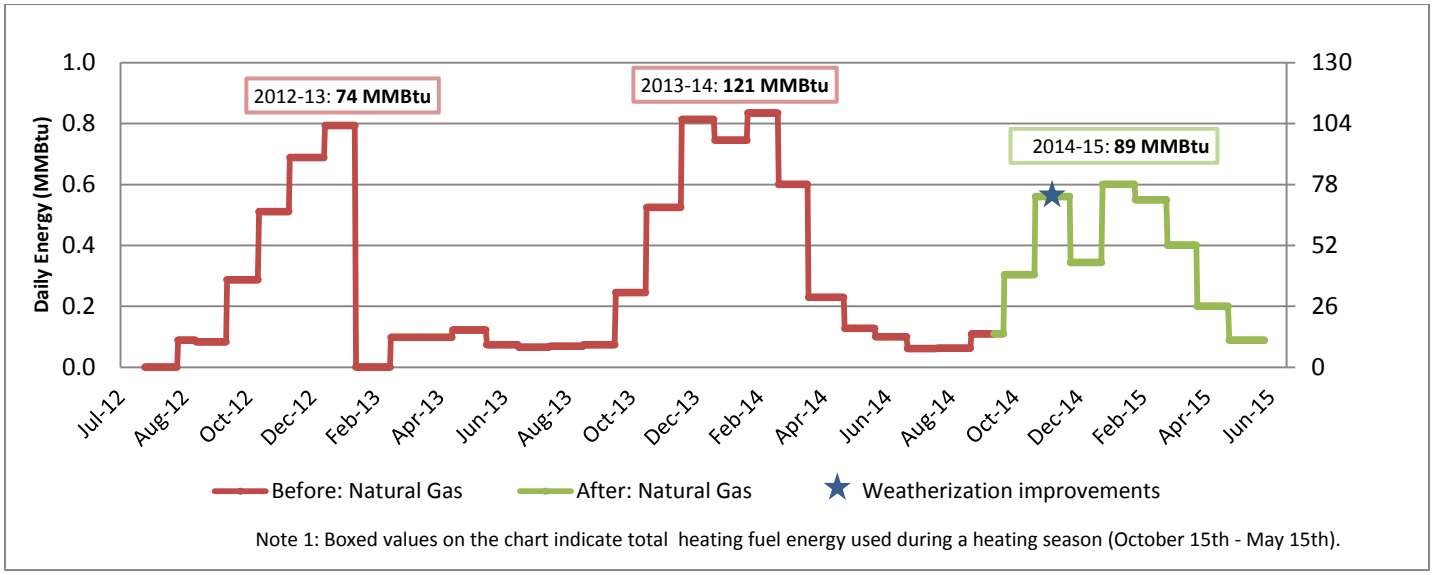
The two owners are now spending a lot less on energy and their carbon footprint is much smaller.

Additionally, the owners noted increase in overall comfort due to reduced air infiltration and an optimized efficient heating system: "*We find for the same thermostat setting now, we are more comfortable*."

Read on to learn more.

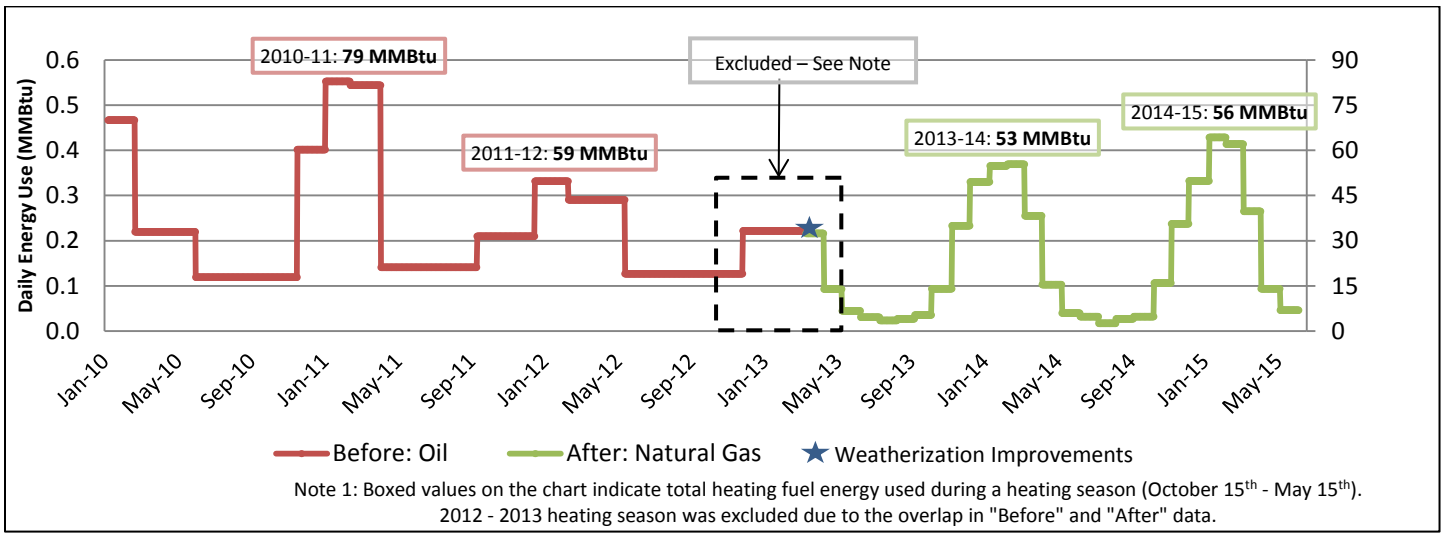
I. Use of Heating Fuel Before and After the Project – Overall Trends

Chart 1 - SF A: Single-Family A's heating fuel use before (in red) and after (in green) the Project (7/24/2012 - 6/10/2015):



Note 1: Boxed values on the chart indicate total heating fuel energy used during a heating season (October 15th - May 15th).

Chart 1 - SF B: Single-Family B's heating fuel use before (in red) and after (in green) the Project (1/8/2010 - 6/11/2015):



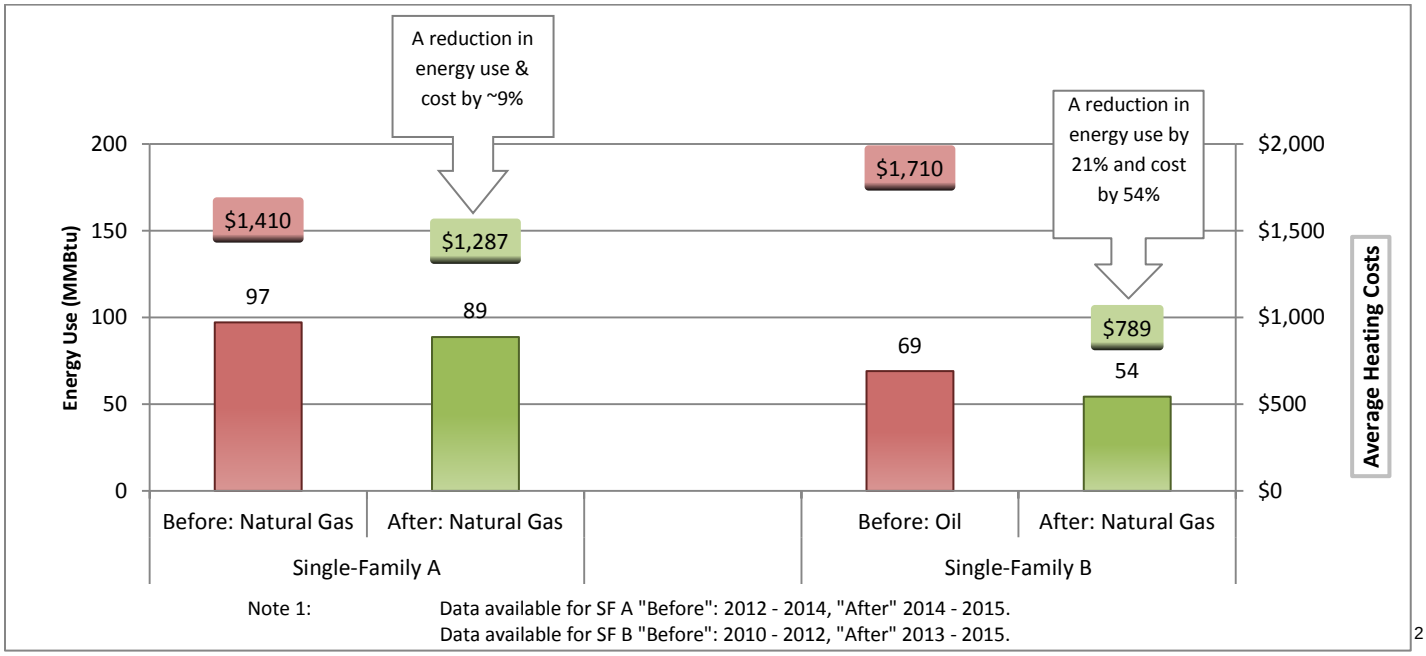
Note 1: Boxed values on the chart indicate total heating fuel energy used during a heating season (October 15th - May 15th).
2012 - 2013 heating season was excluded due to the overlap in "Before" and "After" data.

Observations: Average heating fuel use decreased after the completion of energy efficiency projects for both homes.

- *1 therm of natural gas = 100,000 Btu = 0.10 MMBtu (million British thermal units)*
- *1 gallon of heating oil = 138,500 Btu = 0.139 MMBtu (million British thermal units)*

II. Use, Cost, and Emissions from the Heating Fuel During Heating Season

Chart 2 - Heating fuel use and costs Before and After the Project - Comparison of Averages During Heating Seasons (October 15th – May 15th):



[2]

Observations:

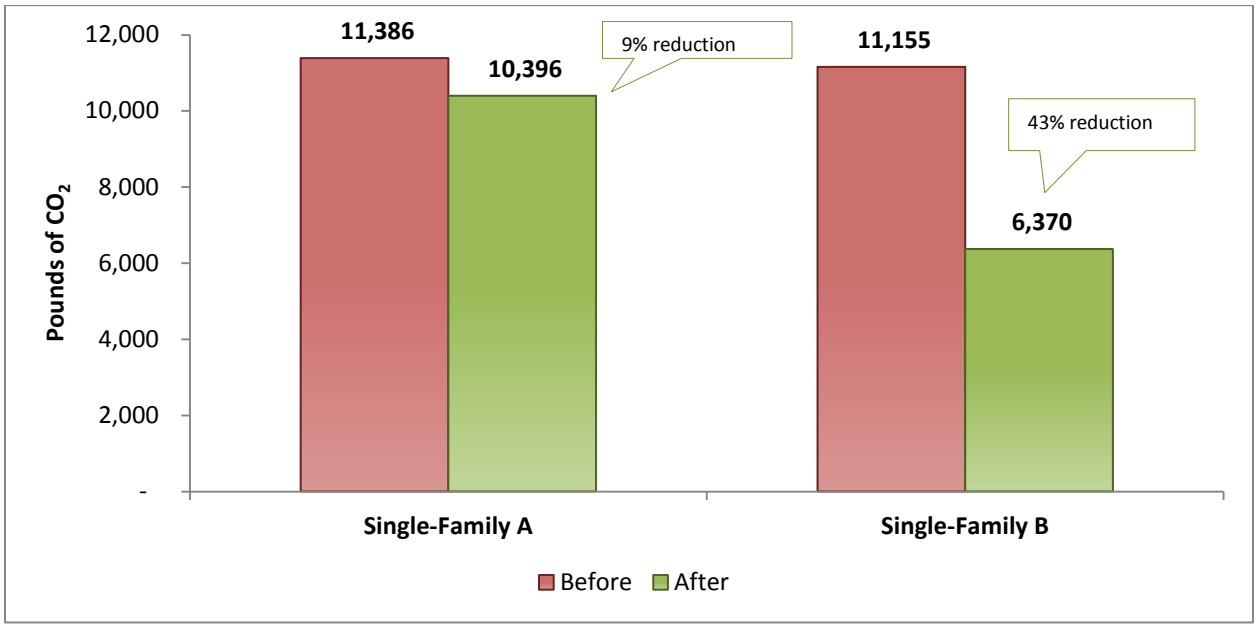
Energy Use. After the Project, both families saw a noticeable reduction in energy use and cost - 8 MMBTu for Single-Family A and 15 MMBTus for Single-Family B. For comparison, just one MMBTu is the equivalent of energy consumed by a car traveling 315 miles! SF B showed a much larger decrease in energy use and cost. This difference can be attributed in large part to upgrading to a boiler that is more than twice as efficient as the old one and the switch from an oil to a natural gas burning boiler (current oil prices are 1.7 times greater than natural gas). Additionally, SF A home has an additional energy consumption source – a ductless mini-split heat pump, which is more efficient than other heat pumps on the market, but not as efficient as using two portable ACs on a minimal basis (SF B).

Comfort. Interestingly, while SF A has a smaller living area, smaller number of residents, and is relatively newer construction as compared to SF B, it consumes more energy. Some factors that are difficult to measure, but are real nevertheless, are each resident's use of home (some work from home and therefore use more energy), types of residents (e.g. guests, small children and elderly may be less tolerant of less-than-optimal ambient temperatures), and comfort/lifestyle choices. For example, the SF A homeowner, who frequently works from home, expressed strong preference for cooler temperatures during the summer at nights, but did not mind heat during the day. One of the benefits of the new HVAC system, as stated by the SF B owner, were the zone controls for different floors of the house, contributing to even higher efficiencies and better comfort - "*..following the energy interventions… we find for the same thermostat setting now, we are more comfortable*" (SF B home owner).

Project and Program Satisfaction. Both homeowners reported that they were very satisfied with having done the project. SF A owner stated: "*I was grateful to have a new boiler, because … when they had told me that my old furnace might not last the winter, obviously that was frightening… I had peace of mind knowing that I had heat" and "this program… is wonderful and really makes energy efficiency affordable to residents who want to do better, but don't have the cash on hand to do."* SF B owner stated: "*It made sense… from a financial point of view, not only to replace [the old oil boiler] but try to get the best energy efficient boiler I could get.*"

[2] 1 therm of natural gas = 100,000 Btu = 0.10 MMBtu
1 gallon of heating oil = 138,500 Btu = 0.139 MMBtu

Chart 3 – Carbon Dioxide Emissions (lbs) Before and After the Project - Comparison of Averages During Heating Seasons (October 15th – May 15th):

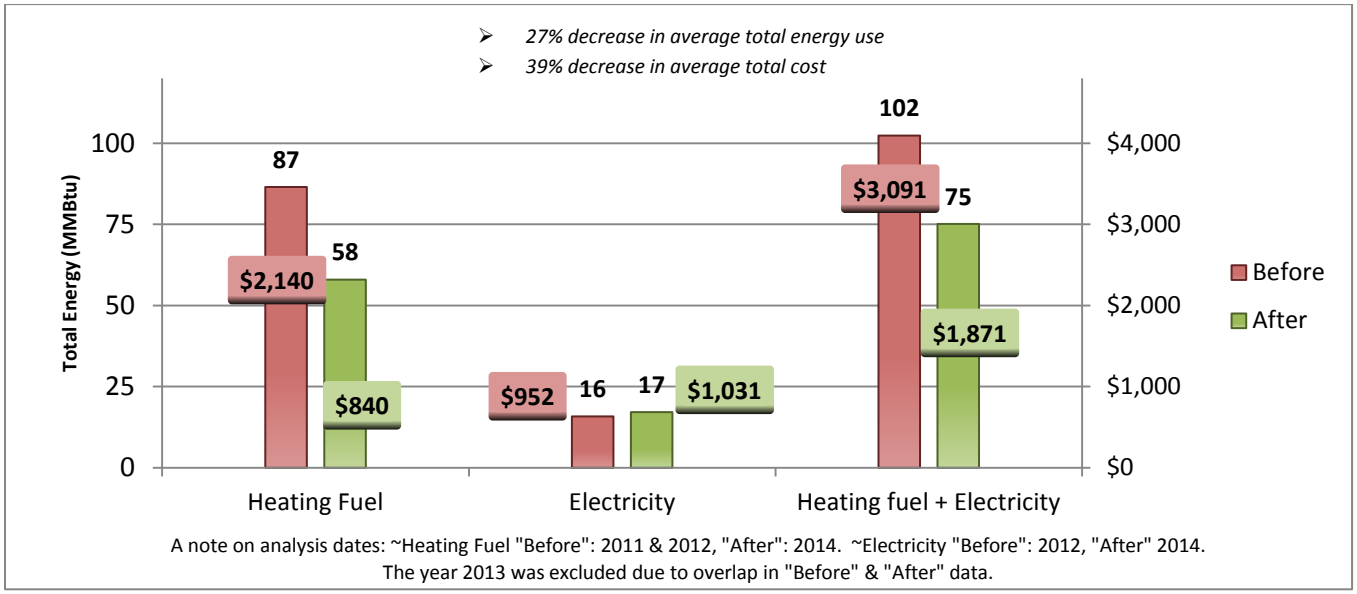


Observations: Both families decreased their carbon emissions. Single-Family B shows a relatively larger change, which can be attributed to the conversion of their boiler from oil to natural gas; the burning of #2 fuel oil emits about 38% more carbon dioxide than natural gas[3].

III. Annual Total Energy Use and Cost

Chart 4 – SF B - Single-Family B's total energy use and costs (January – December):

(Note that there is not currently enough data available to perform a similar analysis of Single-Family A on a yearly basis)



[4]*Observations:* Total energy use decreased by 27% saving the homeowner on average an impressive $1,200 a year. Interestingly, electrical usage increased slightly (~6%), but more data is needed to see if this represents a trend and to investigate reasons for such an increase.

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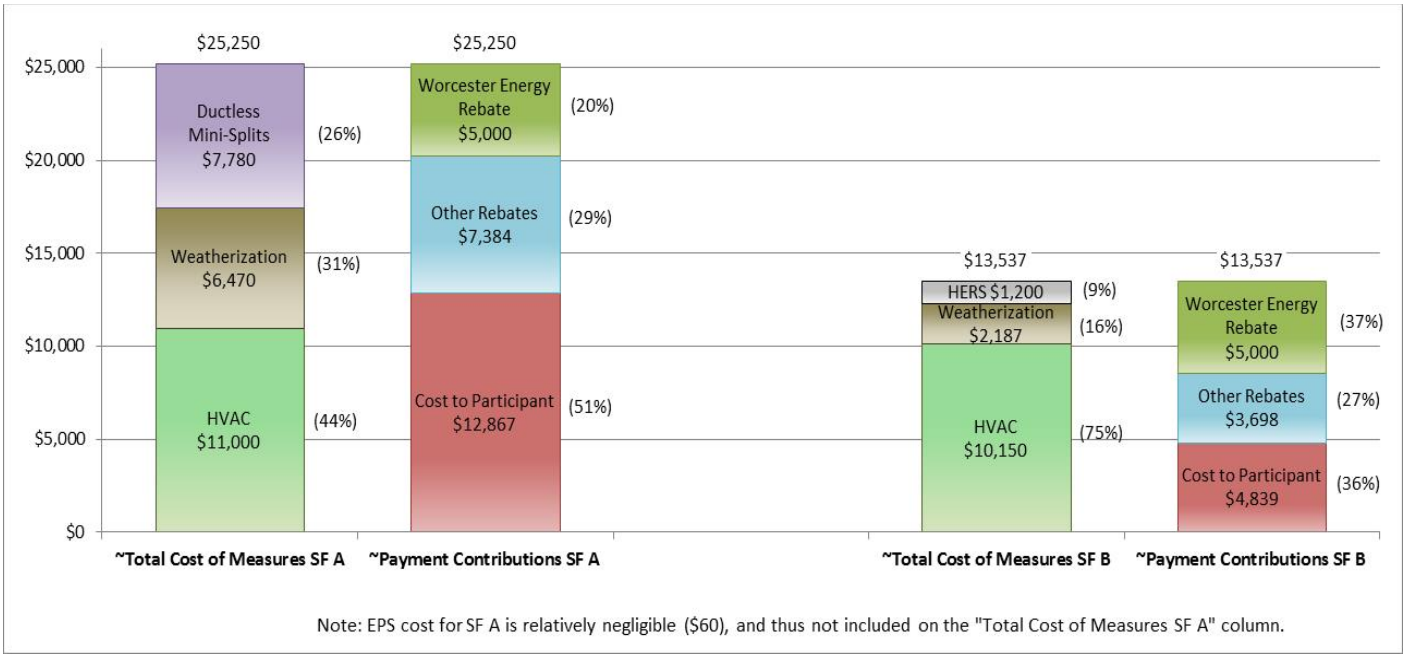
[3] https://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11

[4] 1 therm of natural gas = 100,000 Btu = 0.10 MMBtu
1 gallon of heating oil = 138,500 Btu = 0.139 MMBtu
1 kilowatthour of electricity = 3,412 Btu = 0.0034 MMBtu

IV. Project Costs

Chart 5 - Comparison of Project Costs by Energy Efficiency Measures and by Payment Contributions:



Observations: The relationship between the cost of an energy efficiency project and cost savings is not always a simple one. As can be seen here, the cost of the HVAC project was similar, but weatherization costs were significantly different. Additionally, the Single-Family A included ductless mini-splits which affected the total costs of the project and cost to the participant significantly.

Notes on data analysis methods:

1. Electricity and Natural Gas: Raw data was obtained directly from the utility providers (via Consent Forms obtained as part of the Residential Rebate Pilot application and agreement). The data was provided in kilowatt-hours (kWh) for electricity and in therms for natural gas, roughly every month.
2. Oil: Raw data (gallons of oil and delivery dates) was obtained directly from the participants in compliance with the Residential Rebate Pilot agreement. It was assumed that the starting date of Natural Gas data was the end date of the oil usage for oil to natural gas conversion projects.
3. Consumption data was divided by the number of days in the period to view trends and calculate heating season and annual averages.
4. Conversion Factors:

   Energy to Million British thermal Units conversion factors (using site energy, consistent with MEI methodology):

   Electric = 0.003412 MMBtu/kWh **Oil** = 0.13869 MMBtu/gal **Natural Gas** = 0.1 MMBtu/therm

   CO_2 emissions conversion factors (source: Department of Energy Resources):

   Electric = 0.96 lb CO_2/kWh **Oil** = 22.38 lb CO_2/gal **Natural Gas** = 11.71 lb CO_2/therm **Estimated**

   Energy costs (based on current available Massachusetts averages):

   Electric = $0.205/kWh (supply & delivery) **Oil =** $3.43/gal **Natural Gas =** $0.0145/$ft^3$

   Electric = $60.08/MMBtu (supply & delivery) **Oil =** $24.73/MMBtu **Natural Gas =** $14.50/MMBtu

   Sources:

   - Electric: National Grid Basic Service Rate. 17 Jun. 2015.
   - Oil: Executive Office of Energy and Environmental Affairs. Department of Energy Resources. Accessed 17 Nov. 2015. 2014/2015 Average Price per Gallon of Heating Oil. http://www.mass.gov/eea/energy-utilities-clean-tech/home-auto-fuel-price-info/historical-heating-oil-prices.pdf.
   - Natural Gas: U.S. Energy Information Administration. Residential Natural Gas Prices by State. Massachusetts, 2014. Accessed 17 Nov. 2015. http://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PRS_DMcf_a.htm