NATURAL RESOURCES DEFENSE COUNCIL

Energy Efficiency Benefits

Heating and Cooling Energy Conservation Case Study

40 W 20th Street, NRDC New York Headquarters

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Executive Summary

NRDC's headquarters is housed in the top 5 floors of a 12-story building dating from 1911[1]. Over the last several years, many energy conservation measures (ECMs) have been implemented to upgrade NRDC's space. Many of these have targeted electricity use, such as installation of occupancy sensors for lighting, reduction of printing energy use, and a major update to NRDC's onsite data center. Some of the ECMs have also impacted heating efficiency, such as installation of new windows throughout the building, and a renovation of the 8th floor to an open plan, which allows heat to circulate more effectively.

With the implementation of NRDC's real-time reporting software (Noveda) we are able to pin-point opportunities for improvement and potential cost savings and report on the effectiveness of ECMs once implemented. This analysis evaluated the aggregate benefits of four measures (set points & timing adjustments, boiler controls, air sealing, and an electric heater) and has found that they have resulted in a 30% reduction in heating energy and a 76% reduction in cooling energy, or roughly 13% of total electricity use, saving enough energy to power around 20 homes[2]. Our cost savings were $34-43k annually[3] on a total investment of $87k, resulting in a roughly 2 year simple payback period, and an IRR of 36%. Excluding the set points & timing adjustments and looking at just those ECMs that required an investment, annual savings were $17-18k, resulting in a roughly 4.5 year simple payback period, with an IRR of 7%.

Heating Efficiency Improvements and Emission Reductions

Four of the most recent ECMs have targeted the building envelope and heating & cooling efficiency.

- Set points for our thermostats were lowered for winter 2012/2013.
- New boiler controls were implemented in July 2013, enabling the building manager to monitor and manage set points and temperatures more granularly via numerous sensors on all floors.

[1] The top 5 floors are owned and occupied by NRDC; the middle two floors are owned by NRDC and leased to a tenant, and the lower five floors are owned and occupied by the Andrew Heiskell New York City Library for the Blind.

[2] 225,000 kWh saved annually, including heating and cooling energy; the equivalent of 20 average US homes at 10,932 kWh. Source: https://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3

[3] The savings range depends on weather and energy cost assumptions used to calculate avoided spending on heating fuel and electricity for cooling. See appendix for details.

- Air sealing was completed throughout the basement, NRDC-owned floors (6-12) and roof between August and October of 2014, and was estimated to have closed the equivalent of a 10 square foot hole in the building envelope[4].
- The water tank on the roof for the fire sprinkler system was switched from boiler heat to electric heat in December 2015, eliminating the need for the boiler to run to keep the water from freezing in the winter, and enabling significantly lower boiler usage on weekends.

In addition, in September 2013, the boiler was switched over to B100 biodiesel, made from recycled cooking oil purchased from Tri-state Biodiesel. This was not an efficiency measure, but using biodiesel dramatically reduces our climate change-contributing greenhouse gas emissions because of its biogenic nature[5].
Similarly, in

Analysis of Improvements in Heating Efficiency

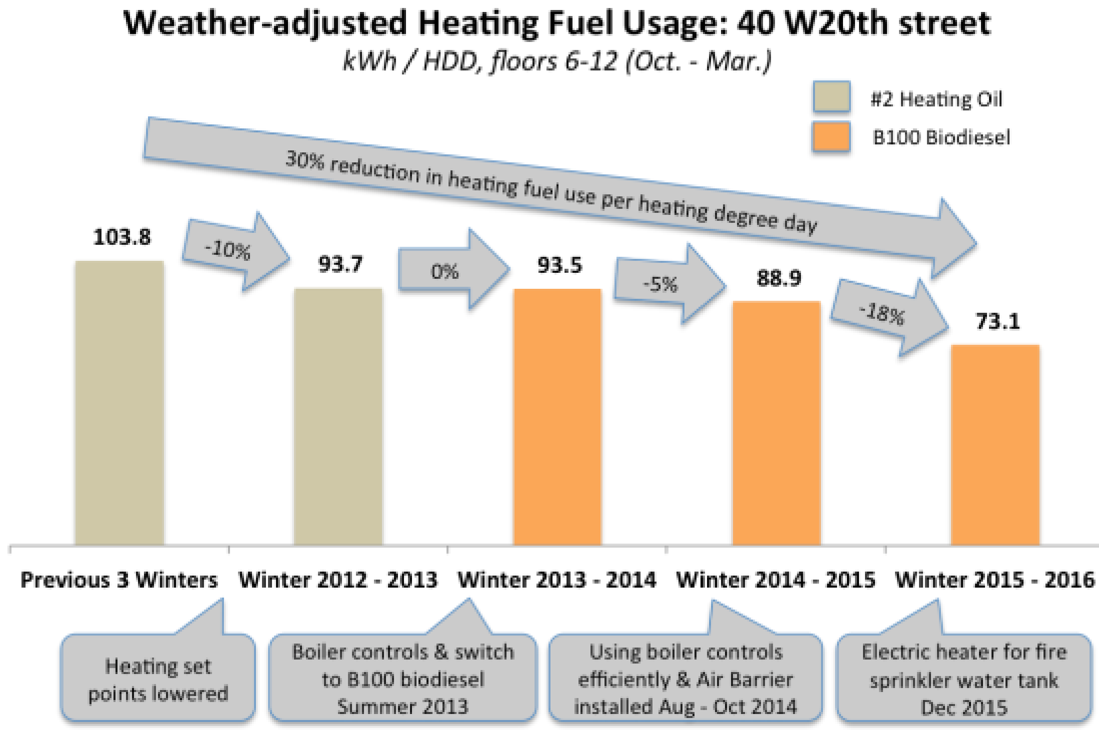
In order to isolate the improvements in heating efficiency, we measured total gallons of heating oil consumed, converted this to kilowatt-hours based on the average heating value for that fuel (biodiesel has a lower energy content per gallon), and adjusted for temperature variance between years (Winter 2014/2015 was around 11% cooler than the 10 year average, and Winter 2015/2016 was 18% warmer).

Heating Efficiency Findings

The combination of all heating efficiency improvements led to a 30% reduction in heating fuel use, after adjusting for weather.

[4] Air sealing materials used were the best available, non-toxic option.

[5] The carbon released when it is burned is from biological, not fossil fuel sources and thus is part of the biogenic carbon cycle; the carbon it contains came from the atmosphere into the plants from which it was harvested. In addition, because our biodiesel comes from recycled cooking oil, it is being put to use twice before its carbon is returned to the atmosphere.



Lowering the heating set points in winter 2012/2013 seemed to reduce heating fuel consumption by ~10% from the average of the previous 3 years. The boiler controls and the switch to biodiesel, both implemented before the 2013/2014 heating season, seemed to have no detectable impact. The air barrier and/or improvements in usage of the boiler controls seem to have improved heating efficiency by around another 5% in Winter 2014/2015 compared to Winter 2013/2014. The Senior Facility Manager noted that the set points were still in flux for the first several months the boiler controls were in place, so it is possible that some of the improvement in Winter 2014/2015 is attributable not to the air barrier, but to those controls being used more effectively. The largest improvement was observed in Winter 2015-2016, as heating efficiency improved by an additional 18% from Winter 2014-2015. Prior to December 2015, the Building Manager noted that the boiler was being used to maintain the rooftop sprinkler system water tower above 40 degrees Fahrenheit, and thus ran more often and used more fuel than was necessary just to warm the building itself. On weekends, set points were left as high as 73 degrees F to ensure the boiler would run, heat the water tank and prevent freezing. Once an electric heater was installed in the tank in Dec. 2015, the weekend set points were lowered to 69 degrees F. Fuel use on weekends from January to April 2016 was nearly 1,000 gallons less than the same period in 2015, and heating efficiency on those weekends improved by 53%.

Methodology

Timing & Scope

Our analysis compared 4 winters (2012/2013, 2013/2014, 2014/2015, and 2015/2016) during heating season (October-March). We analyzed total gallons of heating fuel consumed by the boiler, which heats floors 6-12 and common areas of the building (basement, foyer, elevator).

Heating Oil Consumption

The amount of heating oil consumed was measured in two ways:

- Daily direct measurements of the tank level every morning around 8am by the building manager, using a petrometer.
- Starting in September 2013, a flow meter automatically measured the amount of fuel consumed in one-minute increments, and the data is captured via a web-based sustainability management tool (Noveda).

Where these two measurements overlap, for the winters of 2013/2014 and 2014/2015, they varied by less than 1% overall, so we have high confidence in the petrometer measurements for previous years. We have used the automated meter readings since they have become available.

Average Heating Values

In comparing fuel usage across years where different heating fuels were used, it would not be accurate to directly compare gallons of #2 heating oil against gallons of B100 biodiesel, because they have different heating values, or energy density. Instead we compared energy use in standard units: kilowatt-hours. Biodiesel has 11% less energy content per gallon, so 111 gallons of B100 have the same energy content as 100 gallons of #2 oil. Our analysis used the average gross calorific heating values to compare the energy content of #2 heating oil to that of biodiesel.[6]

Weather normalization

Finally, for comparability across winters, we adjusted the heat usage by dividing kilowatt-hours consumed by the number of heating degree days (HDD) per winter[7]. Winter 2012/2013 (Oct - Mar.) totaled 4,042 HDD. Winter 2013/2014 was much

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[6] The numbers we used were 40.85 kWh/gallon for #2 heating oil and 36.27 kWh/gallon for B100 biodiesel. In both cases we used the midpoint of the higher and lower heating values.
Source for #2 heating oil: Engineering Toolbox, retrieved March 2015
http://www.engineeringtoolbox.com/fuel-oil-combustion-values-d_509.html
Source for B100 biodiesel: Alternative Fuels Data Center, retrieved March 2015
http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf

[7] One heating degree-day is defined as one degree below the average daily temperature of 65 degrees Fahrenheit, for one day. Thus if the temperature was 35 degrees for 10 days, that would total 30 degrees*10 days, or 300 heating degree-days. Heating degree-day data was obtained from Weather Underground, for the KNYC weather station in Central Park.

colder at 4,472 HDD. Winter 2014/2015 was even colder at 4,563 HDD. Winter 2015/2016 was the warmest in over a decade, at 3,248 HDD.

Cooling Efficiency Improvements

At the beginning of 2014, measures were taken to limit use of air conditioning on nights and weekends. The air sealing completed between August and October of 2014 improved cooling efficiency as well as heating efficiency by closing the equivalent of a 10 square foot hole in the building envelope.

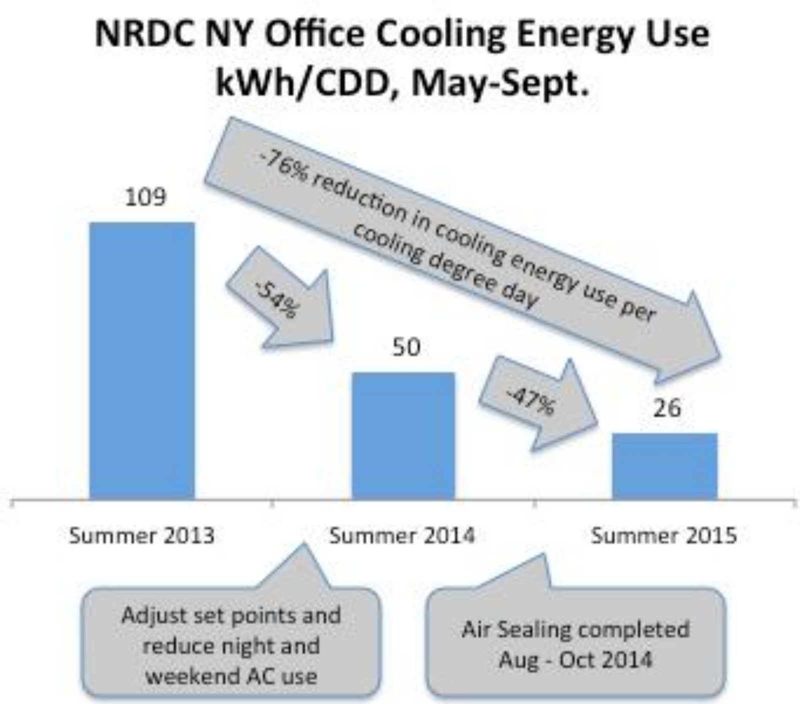
Analysis of Improvements in Cooling Efficiency

In order to isolate improvements in cooling efficiency, we used electricity meter readings on HVAC-specific meters installed on each floor (8-12) of NRDC's occupied space. Because the HVAC system is used for ventilation as well as space cooling, we assumed a base load of 18,000 kWh monthly (based on November, the lowest energy use month in 2015)[8]. We compared meter readings for Summer (May – September) 2013 with the same 5 months of 2014 and 2015, and adjusted for temperature variance between years (Summer 2014 was 10% cooler than Summer 2013, and Summer 2015 was 41% warmer than Summer 2014).

[8] The lowest usage for the HVAC system is in the shoulder months of spring and fall; in winter usage is higher. Our hypothesis is that this is due to a flaw in the AC system through which turns it on when the heat is on in the winter. This represents a significant source of inefficiency and opportunity for further improvement.

Cooling Efficiency Findings

Cooling efficiency improved by 76% over the period analyzed, from 109 kWh per cooling degree day in Summer 2013 to 26 kWh per cooling degree day in Summer 2015. Two separate improvements were noted. First, minimizing night and weekend air conditioner use reduced energy use per cooling degree day by 54%, comparing Summer 2014 to Summer 2013. Energy usage by the HVAC system totaled 223 MWh in Summer 2013, of which 90 MWh was base load ventilation, and 133 MWh was for cooling the space. Air conditioners on floors 8-12 used a total of 145 MWh in Summer 2014, of which we estimate only 55 MWh was used for space cooling (assuming the same 90 MWh base load). The second improvement, air sealing, seems to have had a significant further impact on cooling efficiency. For the same five months in 2015, after the air sealing was completed, the space cooling required only 40 MWh (130 MWh total minus 90 MWh base load). This is a 26% decrease. However, because summer 2015 was much hotter than summer 2014, the cooling electricity use per cooling degree day was 47% lower; reduced from 50 kWh/CDD down to 26 kWh/CDD.



Cost benefit analysis

Summary and Methodology

Total annual savings of all heating and cooling ECMs investigated are estimated at $34k in the first year, and $43k for subsequent years. Benefits have been calculated based on the estimated avoided costs in the heating or cooling season post-implementation, comparing the level of heating or cooling efficiency pre- and post-implementation for each energy conservation measure. The savings in the first year post-implementation of each ECM were calculated using the actual weather that year and the actual energy prices NRDC experienced. For subsequent years (in order to calculate IRR and NPV), a 10 year average was used for weather conditions, a five-year average cost for B100 biodiesel, $4.82/gallon[9], and NRDC's average summer 2016 cost for 100% New York State wind- and solar-generated electricity, 26 cents/kWh. For additional detail, see the financial analysis supplement.

Costs

Boiler Controls:	$8k
Air Sealing:	$68k
Electric Water Tank Heater:	$11k
Total:	$87k

Benefits

Heating Benefits

Adjusting set points and timing of heating improved heating efficiency by 10% in Winter 2012-2013, avoiding the combustion of 991 gallons of #2 heating oil and saving $3,974 at that winter's average price. Lower heating fuel use due to air sealing, possibly in combination with improved usage of the boiler controls, likely saved around $3,203 in Winter 2014/2015, estimating that an additional 575 gallons of biodiesel would have been used if heating efficiency had been at the prior winter's level. In Winter 2015/2016, installing the electric water heater for the sprinkler water tank saved $6,108, or 1,420 gallons of fuel. The total annual savings in winter 2015/2016 attributable to the sum of all heating ECMs over the 5 years investigated, was $15,304. This figure was obtained by comparing winter 2015/2016's heating efficiency of 73.1 kWh per heating degree day to 103.8 kWh per heating degree day (the average of the three winters prior to winter 2012/2013, when the first ECM investigated was implemented). At winter 2015-2016's relatively mild 3,248 heating degree days, an additional 100,000 kWh of heating

[9] Central Atlantic average from 2012-2016, according to the US Department of Energy's Alternative Fuels Data Center: http://www.afdc.energy.gov/fuels/prices.html

energy would have been required at pre-ECM levels of heating efficiency (337,000 vs. 237,000 kWh). This represents a 30% reduction in fuel use, or the avoided combustion of 2,748 gallons of biodiesel.

Cooling Benefits

Lower electricity use due to reduction in night and weekend air conditioner use probably saved around $13k in summer 2014. Lower electricity use due to air sealing probably saved around $7.7k in electricity costs in summer 2015. During the warm Summer 2015 (1,553 cooling degree days), had efficiency been at 2013 levels, NRDC would likely have spent an additional $27k in cooling.

Return on Investment

Overall, the combination of all the ECMs taken paid for itself in around 2 years. Some of the Energy Conservation Measures had no cost; specifically adjusting heating and cooling set points, and reducing air conditioning and heating on nights, weekends, and holidays. The electric water tank heater had a simple payback of around 1.9 years[10]. The boiler controls may have had some impact once they were used effectively (the heating season after implementation), but it's not possible to distinguish this impact on heating efficiency from that of the air sealing, which was completed at the same time. The two together had a simple payback period of 6.3 years. A ten-year net present value was calculated at a 5% discount rate based on the costs of these ECMs and the savings they generated. The NPV for all ECMs was $186,893, with an internal rate of return of 36%. The NPV for just those ECMs requiring an investment (excluding the set points and timing adjustments) was $42,615, with an internal rate of return of 7%.

[10] The electric water heater does require incremental electricity, but we don't have an accurate measurement for its consumption. We have conservatively estimated around 100 kWh a year, and the savings shown above have been reduced by $22 to account for this estimated cost. It is not primarily a fuel-switching measure, however: the electric immersion water heater heats only the water in the tank, at virtually 100% efficiency, since all heat is generated in the water. (Considering source energy used to generate the electricity, and transmission & distribution losses, efficiency would be closer to 30%.) However, in the previous situation, when the boiler was running in order to warm the water, seven floors of the building were being heated in addition to the water in the tank. This must be considered far less efficient, given that the boiler was being triggered at times due solely to low temperature of water in the exposed tank, especially on weekends when office set points were lower than on weekdays.

Financial Analysis Supplement

Simple Payback: Energy Conservation Measures	First Year Heating Savings	First Year Cooling Savings	Total First Year Savings	Total Costs	Simple Payback (years)
Set points/timing	$3,973	$13,031	$17,005	-	-
Water heater	$6,108		$6,108	$11,300	1.9
Air sealing & Boiler Controls	$3,203	$7,666	$10,869	$68,027	6.3
First Year Total	$13,284	$20,697	$33,982	$79,327	2.3

Energy Conservation Measures: Detailed Savings Calculations

ECM:		Set points/timing: heating			
Date Completed	Summer 2012		Efficiency Improvement	10%	
Cost:	$0	IRR:	N/A	10 yr NPV @5%:	N/A
Pre-ECM Efficiency	103.8	kWh per HDD	Post-ECM Efficiency	93.7	kWh per HDD
First Year Savings Estimate[11]			Ongoing Savings Estimate		
Post ECM Season	Winter 2012 - 2013		Weather Assumption	10 Year Avg	
Post ECM Weather	4,042	HDD	10 Year Avg. Winter	4,006	HDD
Actual Heating Energy Used	378,881	kWh	Heating Energy Needed Post-ECM	375,535	kWh
Heating Energy at Pre-ECM Efficiency	419,363	kWh	Heating Energy at Pre-ECM Efficiency	415,659	kWh
Energy Avoided	40,482	kWh	Energy Avoided	40,125	kWh
% Avoided	10%		% Avoided	10%	
Fuel	#2	Fuel Oil	Fuel	B100	Biodiesel
Fuel Use Avoided	991	gallons	Fuel Use Avoided	1,106	gallons
Cost, U.S. Avg. in Jan. 2013	$4.01	per gallon	Cost - 5 yr. avg., Central Atlantic	$4.82	per gallon
First Year Heating Cost Avoided	$3,974		Annual Heating Cost Avoided	$5,330	

ECM:		Set points/timing: cooling			
Date Completed	Spring 2014		Efficiency Improvement	54%	
Cost:	$0	IRR:	N/A	10 yr NPV @5%:	N/A
Pre-ECM Efficiency	108.6	kWh per CDD	Post-ECM Efficiency	49.5	kWh per CDD
First Year Savings Estimate			Ongoing Savings Estimate		
Post ECM Season	Summer 2014		Weather Assumption	10 Year Avg	
Post ECM Weather	1,103	CDD	10 Year Avg. Summer	1,247	CDD
Actual Cooling Energy Used	54,614	kWh	Cooling Energy Needed Post-ECM	61,734	kWh
Cooling Energy at Pre-ECM Efficiency	119,771	kWh	Cooling Energy at Pre-ECM Efficiency	135,386	kWh
Energy Avoided	65,157	kWh	Energy Avoided	73,652	kWh
% Avoided	54%		% Avoided	54%	
NRDC Cost, Summer 2014	$0.20	kWh	NRDC Cost, Summer 2016	$0.26	kWh
First Year Cooling Cost Avoided	$13,031		Annual Cooling Cost Avoided	$19,149	

[11] First year savings use weather and energy costs in first year post-ECM implementation.

ECM:	Air Sealing & Boiler Controls				
Date Completed	Oct. 2014		Efficiency Improvement	5%	
Cost:	$76,027	IRR:	2.2%	10 yr NPV @ 5%:	$(1,981)
Pre-ECM Efficiency	93.5	kWh per HDD	Post-ECM Efficiency	88.9	kWh per HDD
First Year Savings Estimate			Ongoing Savings Estimate		
Post ECM Season	Winter 2014 - 2015		Weather Assumption	10 Year Avg	
Post ECM Weather	4,563	HDD	10 Year Avg. Winter	4,006	HDD
Actual Heating Energy Used	405,799	kWh	Heating Energy Needed Post-ECM	356,291	kWh
Heating Energy at Pre-ECM Efficiency	426,654	kWh	Heating Energy at Pre-ECM Efficiency	374,601	kWh
Energy Avoided	20,855	kWh	Energy Avoided	18,310	kWh
% Avoided	5%		% Avoided	5%	
Fuel	B100	Biodiesel	Fuel	B100	Biodiesel
Fuel Use Avoided	575	gallons	Fuel Use Avoided	505	gallons
Avg. Cost, Central Atlantic in Jan. 2015	$5.57	per gallon	Cost - 5 yr. avg., Central Atlantic	$4.82	per gallon
First Year Heating Cost Avoided	$3,203		Annual Heating Cost Avoided	$2,432	

ECM:	Air Sealing				
Date Completed	Oct. 2014		Efficiency Improvement[12]	47%	
Cost:	$68,027	IRR:	See above	10 yr NPV @ 5%	See above
Pre-ECM Efficiency	49.5	kWh per CDD	Post-ECM Efficiency	26.0	kWh per CDD
First Year Savings Estimate			Ongoing Savings Estimate		
Post ECM Season	Summer 2015		Weather Assumption	10 Year Avg	
Post ECM Weather	1,553	CDD	10 Year Avg. Summer	1,247	CDD
Actual Cooling Energy Used	40,391	kWh	Cooling Energy Needed Post-ECM	32,427	kWh
Cooling Energy at Pre-ECM Efficiency	76,895	kWh	Cooling Energy at Pre-ECM Efficiency	61,734	kWh
Energy Avoided	36,504	kWh	Energy Avoided	29,307	kWh
% Avoided	47%		% Avoided	47%	
NRDC Cost, Summer 2015	$0.21	kWh	NRDC Cost, Summer 2016	$0.26	kWh
First Year Cooling Cost Avoided	$7,666		Annual Cooling Cost Avoided	$7,620	

[12] Our hypothesis for why the efficiency improvement was so much higher for cooling than for heating is that the boiler was being triggered to heat the exposed rooftop water tank.

ECM:		Electric Water Tank Heater			
Date Completed	Dec. 2015		Efficiency Improvement	18%	
Cost:	$11,300	IRR:	162.5%	10 yr NPV @ 5%:	$60,575
Pre-ECM Efficiency	88.9	kWh per HDD	Post-ECM Efficiency	73.1	kWh per HDD
First Year Savings Estimate			Ongoing Savings Estimate		
Post ECM Season	Winter 2015 - 2016		Weather Assumption	10 Year Avg	
Post ECM Weather	3,248	HDD	10 Year Avg. Winter	4,006	HDD
Actual Heating Energy Used	237,334	kWh	Heating Energy Needed Post-ECM	292,743	kWh
Heating Energy at Pre-ECM Efficiency	288,853	kWh	Heating Energy at Pre-ECM Efficiency	356,291	kWh
Energy Avoided	51,520	kWh	Energy Avoided	63,548	kWh
% Avoided	18%		% Avoided	18%	
Fuel	B100	Biodiesel	Fuel	B100	Biodiesel
Fuel Use Avoided	1,420	gallons	Fuel Use Avoided	1,752	gallons
Avg. Cost, Central Atlantic in Jan. 2015	$4.30	per gallon	Cost - 5 yr. avg., Central Atlantic	$4.82	per gallon
First Year Heating Cost Avoided	$6,108		Annual Heating Cost Avoided	$8,441	

Total First Year Heating Costs Avoided	$13,284
Total First Year Cooling Costs Avoided	$20,697
Total First Year Energy Costs Avoided	$33,982

Total Annual Heating Costs Avoided	$16,203
Total Annual Cooling Costs Avoided	$26,769
Total Annual Energy Costs Avoided	$42,972

Historical Weather Data – New York City

Cooling Season (May - Sept)	Cooling Degree Days
Summer 2007	1,112
Summer 2008	1,146
Summer 2009	831
Summer 2010	1,515
Summer 2011	1,301
Summer 2012	1,243
Summer 2013	1,223
Summer 2014	1,103
Summer 2015	1,553
Summer 2016	1,441
10 Year Average	1,247

Heating Season (Oct - Mar)	Heating Degree Days
Winter 2006/2007	3,884
Winter 2007/2008	3,966
Winter 2008/2009	4,312
Winter 2009/2010	4,007
Winter 2010/2011	4,299
Winter 2011/2012	3,270
Winter 2012/2013	4,042
Winter 2013/2014	4,472
Winter 2014/2015	4,563
Winter 2015/2016	3,248
10 Year Average	4,006

Source: Weather Underground, KNYC Central Park Weather Station, sum of daily average degrees over 65 Fahrenheit (cooling) and under 65 Fahrenheit (heating).