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Cost Optimization for Reducing Heating Demand in New York Residential Buildings

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by

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With Honors

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Abstract

Heating residential buildings is a major expense to homeowners in cold climates and a contributor to worldwide greenhouse gas emissions due to the high percentage of homes heated by fossil fuels. Both heating demand and cost can be minimized using energy conservation measures, but optimal levels of such measures depend on current building characteristics. Using data from the Residential Energy Consumption Survey, the average existing building characteristics of New York State single family detached residential buildings were found for houses heated by natural gas and houses heated with fuel oil. Using Building Energy Optimization software (BEopt), created by the National Renewable Energy Laboratory, the energy performance of these buildings as well as the pricing for performing several energy conservation measures were modeled. Simulation energy demand was compared with the survey values for validation analysis. Results showed that out of the energy conservation options considered, the most effective methods of decreasing energy costs in both model houses were through infiltration reduction, basement insulation, and ceiling insulation, though the ceiling option could be taken to a further level in the oil fueled house. Maximizing cost savings from energy retrofitting translated into an energy savings of around 40% for each house and a conservative thirty year net present value of $3,650 for the average natural gas fueled house and $5,030 for the average oil fueled house.

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Acknowledgements

Above all, I thank my Lord and Savior Jesus Christ for giving me the ability and strength to excel in my academic studies. He is the constant force in my life that drives me to excellence, and without Him, I would be nothing.

I have also been blessed by so many people who have helped me throughout my college undergraduate years. It is impossible to name them all so here is one collective thank you for all the assistance.

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I would like to acknowledge the faculty of the Environmental Science program, notably Mr. Knight, Dr. Briggs, and Dr. Volk, for helping push me along and force me to get going on this project before it's too late. If it wasn't for them, I do not know if I would be having a thesis.

To Mr. Knight, my second reader: I got him involved with the honors project at the last second, but he had definitely been helping me on this paper already; he just didn't know it was for honors too.

To Dr. Briggs, who has been my unofficial advisor since my second day of orientation at ESF: He has been a friendly mentor as the head of my division, and has allowed me into his office multiple times to discuss academic programs.

To Dr. Volk, who taught the renewable energy capstone planning class: He has been an amazing example of how to be a researcher, and he helped me start the process of creating this project.

I would also like to thank the honors program, and of course, Dr. Shields for accepting and keeping me in the program and allowing me to turn this thesis in at the last minute.

And of course, I have to thank my parents, family, church, and friends for helping me get through these college years.

Advice to Future Honors Students

It can be done! I am graduating a year early from ESF, and I really didn't work on my project until my last year, with the fall semester essentially just a planning stage. To make it harder on myself, my thesis project has been my own independent research as opposed to doing a spinoff of a professor's project. That has leant itself to a massive amount of work in a short time frame, so to all future honors student, please, give yourself more time for your thesis. Take special care to not underestimate the amount of planning and preparation that will go into it. There may be multiple false starts in the project and you may spend significant time on something that never actually makes it into your final report, so leave yourself with ample time to determine what it is you actually want to be doing. However, if you do get caught in a jam with little time left, know that you can still finish up. This thesis is not all I had planned it to be, but it is still a presentable document, and I am proud of it.

However, even though this project is important, try not to make it your life. There are so many more things to see and do here in this short life God has graced us with. ESF is a small close-knit school; I love the fact that I can walk into the library at almost any time and within 10 seconds find someone I know by name. So take time to enjoy it and make relationships and connections with other people.

And finally, don't be afraid to speak up for what's right. In lower division honors we held discussion sessions, and as a Christian, I often brought up topics of God and morality. As you can probably imagine, this led to some quite intense discussions. Was I right every time? – probably not. Did I always know what to say? – certainly not. But I spoke up for my faith, and to my fellow Christians, you should too. Many will disagree (as many did in my lower division honors class), but how will they or you learn more if you don't talk about it? I have not been an amazing evangelist, but I swung the bat multiple times, and I'm proud I did.

1.0 Introduction

1.1 Energy improvements in residential buildings.

In the United States, the residential sector consumes approximately 22% of the country's total energy (21.4 quads), with a majority of this energy coming from fossil fuels (EIA 2012a). If the US residential sector was its own separate country, it would be the 5th largest energy consumer in the world after China, the rest of the US, Russia, and India (EIA 2013). Combustion of fossil fuels releases carbon dioxide (CO_2) which is widely known as a contributor to global climate change (Pachauri and Reisinger 2007, Ramanathan and Feng 2009). Continuing to use fossil fuels for residential energy requirements poses negative environmental effects through pollution and CO_2 emissions, as well as significant monetary costs to homeowners purchasing the energy.

A significant portion of residential energy use goes into space heating, though the specific amount varies by region and climate zone. There is a diversity of options available to homeowners that can reduce their fossil fuel heating requirements. One of the most common is through energy conservation measures (ECMs). ECMs, such as installing insulation or air sealing the building envelope, reduce the amount of heat loss from the building thereby making the building more energy efficient by decreasing the amount of energy needed to heat the space. Installing ECMs will necessitate initial capital investment with the goal being that they will reduce utility costs over the long term. While this initial investment can be large, once it is accomplished there are no further or annual costs because ECMs do not need continual monetary inputs like a fuel system does. This has multiple advantages to the energy user including the protection from potential price escalation and variability of other fuels and/or electricity. But even if fossil fuel prices fall for the short term, ECMs will still reduce the amount of energy demanded and can still be a net positive investment over the long term.

Another factor affecting fossil fuel use in buildings is the type of technology used to provide space heating. Renewable energy technologies could replace a conventional fossil fuel-consuming system with more sustainable sources of energy. Multiple options for renewables exist, for example: solar, biomass, and wind. Of course, there are many ways to combine the two methods of fossil fuel reduction and convert the heating source to renewables while simultaneously reducing heat demand by improving energy efficiency. Optimally, we could get our buildings to become net-zero, meaning that the buildings would be so efficient that they are able to produce all the energy they need from renewables on site (Kapsalaki *et al.* 2012). This would come from a combination of ECMs and renewable energy technologies. Realistically though, some fossil fuel energy sources are too cheap for renewables to compete in such a manner as to make net-zero buildings economically attractive in the traditional timeframe required.

However, even in buildings with low cost fossil fuels, installing ECMs is often practical and will lead to a net cost savings. Modern building codes are, over time, mandating an increasing level of energy efficiency. However, building turnover is slow, so, to have a significant effect on the amount of energy demanded by the residential sector, we need to look at retrofitting existing residential buildings (Joelsson and Gustavsson 2008).

1.2 The need for financial analysis.

In order to install ECMs in the real world, the economics as well as the energy analysis must be favorable. The exact lowest cost energy retrofit is surely unique to each different building, but generalizations can be useful for an overview to understand approximately how much money must be spent and/or could be saved in an energy retrofit.

To compute the economically optimal investment, we need to analyze the life cycle cost of performing ECMs which is the sum of all costs over a given time period (Gustafsson 2000). This life cycle cost includes the upfront installation cost and the remaining energy costs after retrofit (Kaynakli 2012). To calculate the energy demands, and by extension utility bills, the energy usage in the building needs to be modeled. To make generalizations, the average building characteristics must be found and then various ECMs can be modeled to determine their effects on the energy demand and utility bills in the building. For example, the optimal level of insulation is a function of the characteristics of the building including: shape, construction materials, the current energy type, and the current cost of energy (Kaynakli 2012). Energetically, as insulation is added, the amount of energy production required to heat the building will decrease. Monetarily, more insulation requires more upfront investment. The optimal level of ECMs finds the middle ground between these two issues in order to get the best return on investment.

Building Energy Optimization software (BEopt) was created by the National Renewable Energy Laboratory (NREL), and it can be used to model a building and determine energy demand (Hendron and Engebrecht 2010). BEopt provides a user friendly interface for utilizing the energy simulation program DOE-2. The building size, characteristics, and location are inputted into BEopt which packages the information, exports it to the DOE-2 simulation, and then receives and displays the energy use results in a visual manner. Energy and material prices can also be inputted into BEopt so as to determine the costs of operating the building under the given conditions or a hypothetical set of new conditions. Under the retrofit optimization mode, the output screen displays the costs, methods, and amount of energy savings by end use, for a number of different combinations of ECMs installed.

From the costs optimized by BEopt, the payback time for installing ECMs can be found, which for realistic implementation, is also critical to the homeowner. The longer the payback time, the greater the uncertainty about the investment (and correspondingly the less chance of its implementation). Additionally, the longer the payback time the more other issues like equipment failure, replacement costs, opportunity costs, energy security, etc. come into play, and the analysis becomes more complicated.

1.3 New York State

In order to find optimal energy improvement installations, it is necessary to define where the building being optimized is geographically, as different climates will affect the amount of heat demanded. The state of New York is the 4th most populous state in the country (Census Bureau 2011) and out of the 50 states the New York residential sector consumes: the 4th most total energy, the 3rd most electricity, the 3rd most natural gas, and the most fuel oil (EIA 2012b). With a cold climate and a high population, New York is an ideal state to consider for energy retrofitting. The residential housing stock can be separated into different groups categorized by their fuel source for space heating. The most common residential heating fuels for New York are natural gas and fuel oil, which are used by over 85% of all houses in New York (EIA 2009).

Separated by heating fuel, the specifics for the average house in each category can be developed, thereby reducing the entire housing stock to a few model buildings. The specifics of these buildings can be inputted into BEopt to determine cost optimization for energy efficiency improvements. There are many policy statements that support the reduction of fossil fuel use and the improvement of energy efficiency. The Department of Energy's (DOE's) Building America program calls for a long term 50% reduction in energy use by residential buildings (Bianchi 2011). This report will look at whether that goal, or one like it, gives the most cost optimal position.

2.0 Methods

2.1 Narrowing the Scope

As alluded to previously, the scope of the analysis was narrowed down from all energy use in the residential sector to cost optimizing improving heating energy efficiency in New York State existing single family detached residential buildings that currently heat with fuel oil or natural gas. A schematic of the breakdown is given in figure 2-1 to the right.

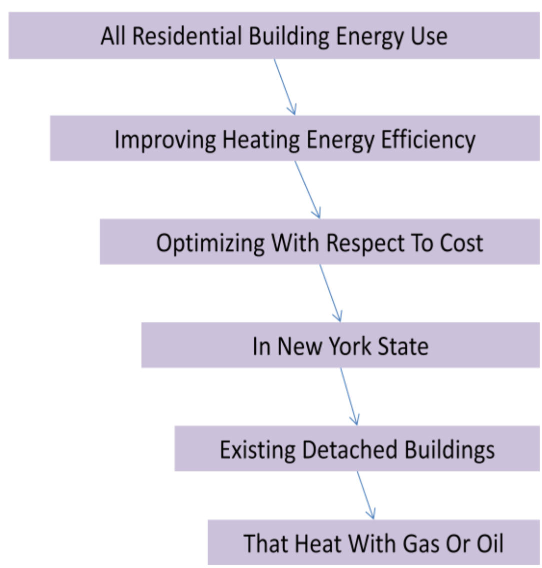

Figure 2-1: A schematic of how this report narrowed the analysis of residential buildings.

2.2 Finding Current Building Characteristics with RECS

In order to complete any feasibility analysis, the performance of existing buildings must first be known. The Residential Energy Consumption Survey (RECS), published by the EIA (2009), is a survey of a representative sample of US housing units. The survey asks residents what their energy use is and what the characteristics of their house are. For example, RECS asks the homeowners how big their houses are, how many windows they have and what type they are, how drafty their houses are, how many stoves they have, how often the clothes dryer is used, etc. A special feature of RECS is that it combines these survey questions with energy uses for these houses in order to estimate energy costs and usage for different segments of the house. In 2009, 12,083 households were surveyed across the United States.

RECS gives an national overview of energy usage, so the specific data needed for this analysis had to be narrowed down and extracted from the microdata spreadsheet. New York single family detached houses with heating systems of natural gas were tabulated separately than those with fuel oil systems. The total number of units surveyed in RECS that met these specifications were 228 for natural gas houses and 104 for oil houses. For each of the survey questions the average response was calculated. In the advent that the average had no physical meaning (e.g. what material the outside wall consisted of) often the most common answer was taken (e.g. more people had vinyl/aluminum/steel siding than brick, stucco, concrete, etc.). If RECS did not contain the building characteristic value needed, a number typical of building construction was inserted (e.g. ½ in drywall for wall interiors). As a result, through the RECS, a list of characteristics was compiled that described the average natural gas fueled and the average oil fueled houses in New York. This is with the exception the characteristics of window area and building orientation as these were considered critical enough to total building energy use so as to perform sensitivity analysis with varying designs.

2.3 BEopt Simulation

BEopt was used to simulate the energy usage of the houses. The geometry, characteristics, and site were inputted in order to construct a house inside the computer program. An example of what the simulation looks like is given in figure 2-2. For a geographic location, the site of Newburgh, New York was chosen because it had an average heating degree day (HDD) load of 5937 from 1995 to 2012 (Weather Data Depot 2013). This is close to the average load for the houses surveyed for RECS.

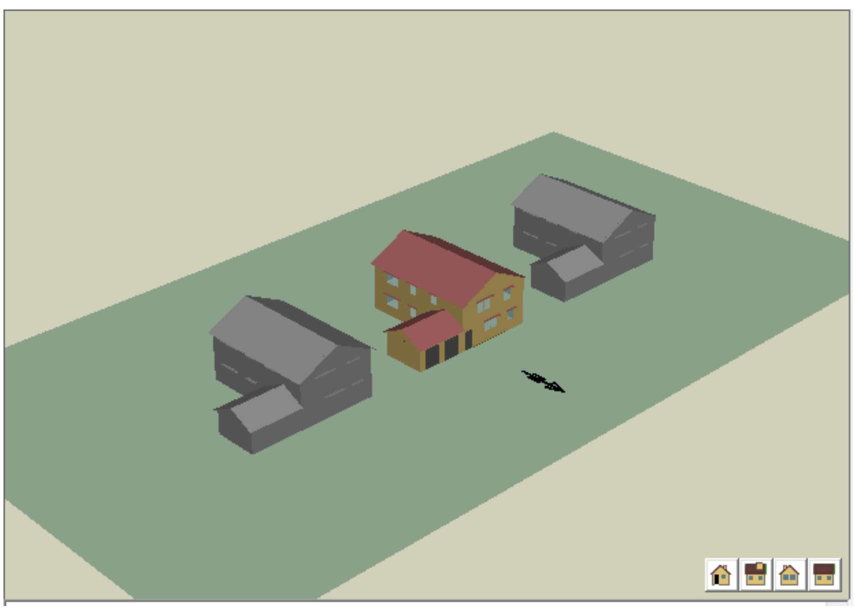

Figure 2-2: Sample geometry input screen on BEopt.

With the building geometry, characteristics, and site inputted, BEopt runs through its simulation algorithms to predict how much energy the house uses, what type of fuel is needed, what sector (e.g. heating, appliances, lighting) the energy is used for, and how much the utility bills will be. Prices inputted for simulation come from the New York State Research and Development Authority (NYSERDA 2013) and are average fuel prices for the state of New York throughout the year excluding the warm months (May through September). These prices were $1.2366/therm for natural gas and $4.07/gallon for fuel oil. The current costs of fuel determine cost optimal savings of retrofit, so if these prices change significantly, the BEopt model should be run again using updated costs.

2.4 Cost Optimization

After the initial model was run to determine current heating demand, various simulations were run looking at the results of performing the following ECMs: infiltration reduction, insulation improvements (basement, attic, and walls evaluated separately), and fenestration upgrades (window replacement). These three categories of ECMs can make major impacts on the heating demands of a house because they define the building's thermal envelope which determines how much heat can pass out of the building. Costs for implementing these measures are also readily available and were taken from the National Residential Energy Efficiency Measures Database which gives average costs across the country for ECMs (NREL 2013). BEopt was run going through multiple iterations in order to combine different combinations of ECMs with various levels of implementation to see which ones gave the maximum cost savings.

3.0 Results

3.1 Existing Building Energy Use

The current fuel energy use for the various designs of both the natural gas fueled house and the oil fueled house are given in figures 3-1 and 3-2 below. These results model the current average energy use for existing homes before energy retrofitting. To isolate the fuel used for heating, only that component of the overall energy use is shown (though BEopt can model whole house energy use not just heating).

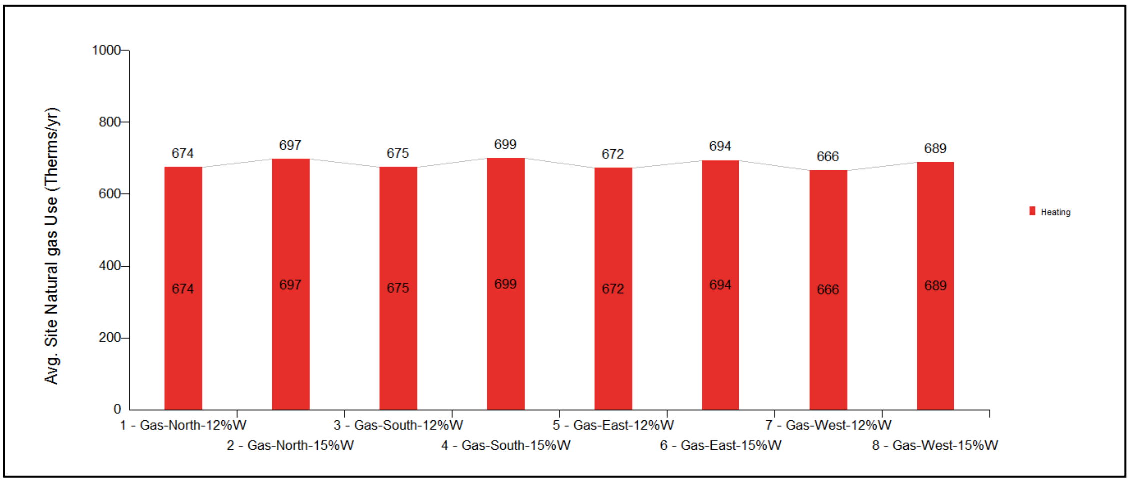

Figure 3-1: Site natural gas use for heating an average natural gas fueled New York house for different designs varying orientation and window area.

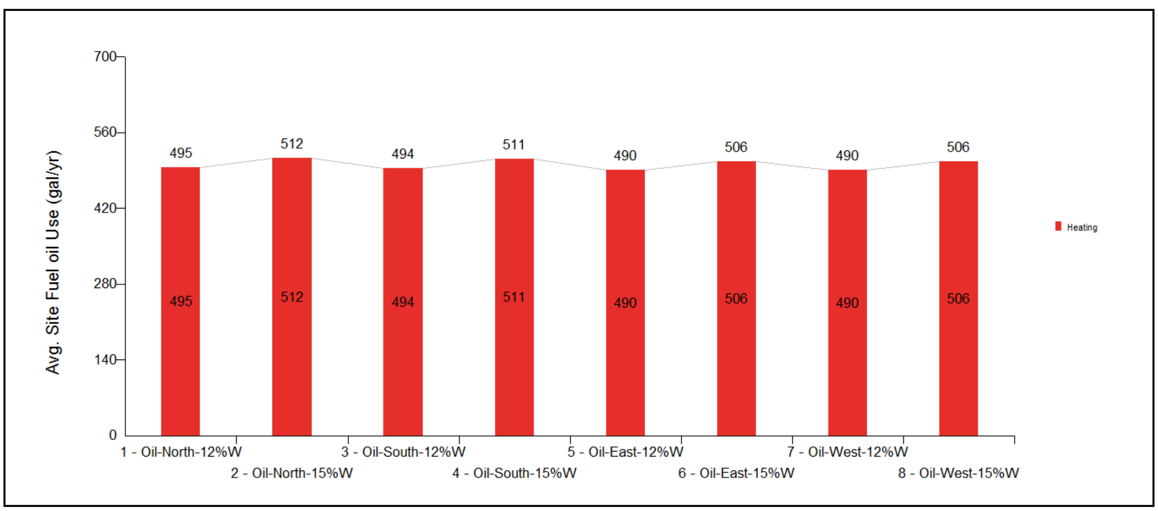

Figure 3-2: Site fuel oil use for heating an average oil fueled New York house for different designs varying orientation and window area.

As shown in the above graphs, the building orientation had almost no impact on total heating energy use. A factor contributing to this is that the houses were modeled using the same proportion of window area on each side of the building (25% of total window area on the front, 25% on the back, 25% on the left side, and 25% on the right side). The differences in orientation affected the face of the roof, as well as the location of the outside door and attached garage (for the natural gas house). There was a slight increase in the amount of energy needed for the north and south facing designs, but as seen in the graphs, this change was negligible.

Furthermore, changing the window area from 12% to 15% of total building surface area increased the heating energy use by only a small factor as well. For the natural gas house, the range of outputs for any one orientation was at most 24 therms/yr (675 to 699 for the south orientation) which gave the largest percent difference as 3.5%. For the oil house, the largest range of outputs was 17 gallons/yr (494 to 511 for the south orientation and 495 to 512 for the north orientation) which gave the largest percent difference as 3.4%. Models, by nature, are an estimation, so such small differences between the trials indicates that window area and building orientation make only modest changes to the overall heating energy use.

Because of these consistent outputs, optimization results use only one of the eight designs to simplify the amount of simulation needed. Averaging the output energies for the natural gas house gives a value of 683.25 therms/yr used making the west oriented 15% window area the average design. Averaging the output energies for the oil house gives a value of 500.5 gal/yr used making several designs equally spaced from the average, so the north oriented 12% window area design was chosen.

3.2 Comparing BEopt and RECS Energy Data

As previously mentioned, it is difficult to achieve 100% accuracy using building models, but it would be helpful to compare the aforementioned energy output results from BEopt with what the actual energy uses are in the houses it is modeling. Fortunately, RECS has calculated the energy uses in the houses it surveyed and has reported the value in energy units and in dollars spent. To validate the BEopt model, the energy used by the model average houses was compared to the RECS averages. All values were converted to the common units of mmBTU for easier comparison. For the gas house, a conversion from therms to mmBTU is straightforward as 1 therm equals 100,000 BTU. The average natural gas usage for heating across all eight designs is 68.3 mmBTU while RECS reports a value of 73.3mmBTU. That gives a percent error of -6.8%. For the oil house, the average oil use for heating across all eight designs is 500.5 gal. RECS uses the conversion factor of 1 gal equals 138,700BTU which when applied gives an average of 69.4mmBTU used. RECS gives a value of 84.2 mmBTU which has -17.6% error. The results are summarized in table 3-1.

Table 3-1: A comparison between the energy results of the BEopt simulation and RECS

Fuel Type	**Beopt Energy Use (average)**	**Beopt Energy Use (average)**	**RECS Energy Use (average)**	**% Error**
Natural Gas	683 therm	68.3 mmBTU	73.3 mmBTU	-6.8%
Oil	500.5 gal	69.4 mmBTU	84.2 mmBTU	-17.6%

The errors show that the BEopt model is underestimating the amount of energy the houses actually need. The natural gas house has a single digit percent error but the oil house shows an error greater than 10%. Fortunately, both models are under predicting the amount of energy demanded. This is believed to mean that the following optimization analysis using these models will actually under predict the amount of energy and money that can be saved. So the following optimization results can be viewed as a conservative estimate.[1]

3.3 Energy Efficiency Optimization: Cost Effective ECMs

Using the model houses, BEopt performed multiple iterations using different ECMs applied in varying degrees in order to find the cost optimal combinations. The resulting combination s are similar between the natural gas and oil house as shown in table 3-2.

Table 3-2: Energy characteristics in average New York State houses after cost optimal energy retrofitting

Energy Area	Initial Conditions	Post-retrofit Gas House	Post-retrofit Oil House
Wall Insulation	R15 batting	No change	No change
Attic Insulation	R30 insulation	R38 insulation	R60 insulation
Basement Insulation	No insulation	R18 Whole wall insulation board	R18 Whole wall insulation board
Window Type	2-pane nonmetal frame	No change	No change
Infiltration	7.4ACH50	1ACH50	1ACH50

As shown, both houses started with the same conditions, and had similar energy conservation measures taken. The only difference was that it was not as economical to

[1] Note: See further comments about error in the *Discussion* section.

insulate the attic in the natural gas house as much as in the oil house, likely because of the low cost of gas when compared to oil. Basement insulation and significant infiltration reduction both proved to be very effective, though the increased need for ventilation was not considered in the infiltration analysis. Note in both cases, upgrading wall insulation and window type are not as cost effective.

3.4 Energy Efficiency Optimization: Energy and Monetary Savings

The BEopt output graphs for annualized energy costs versus source energy savings are shown in figure 3-3 for the natural gas house and figure 3-6 for the oil house. The various points on the graph indicate the results of each different iteration the software performed. The black solid line at the base of the data points shows the path of minimal costs for the degree of energy savings implemented. The percentage of savings on the horizontal axis is calculated based on whole house energy demand, not just the heating component. Because only heating saving measures were inputted, the total energy savings did not reach close to 100%.[2]

[2] Note: BEopt calculates these graphs in terms of source energy which is the amount of energy it takes to bring 1 unit of energy delivered to the house (site energy). Because we are not optimizing electricity use, the source to site ratio is only slightly above one: 1.092 for natural gas and 1.158 for oil (BEopt defaults). Therefore, the cost optimal source energy combination should be approximately the same as the cost optimal site energy combination. The costs to the homeowner are only for the site energy, and it is that energy that the rest of the results will be given in unless noted.

3.4.1 Natural Gas Fueled House

The cost versus energy savings output graph for the natural gas house is shown in figure 3-3. Highlighted in the graph is the location of maximum cost savings (the point with the lowest y-value).

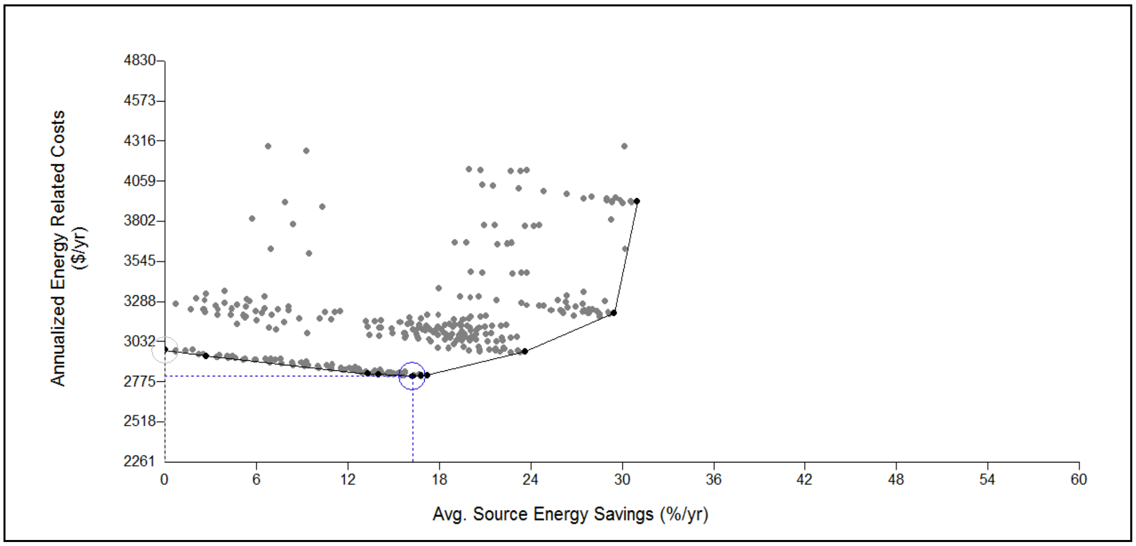

Figure 3-3: Annual energy costs versus source energy savings for implementing various energy conservation measures in an average New York natural gas fueled house

Taking a closer look at this area of maximum savings reveals a sharp decrease in the amount of heating energy needed as shown in figure 3-4.

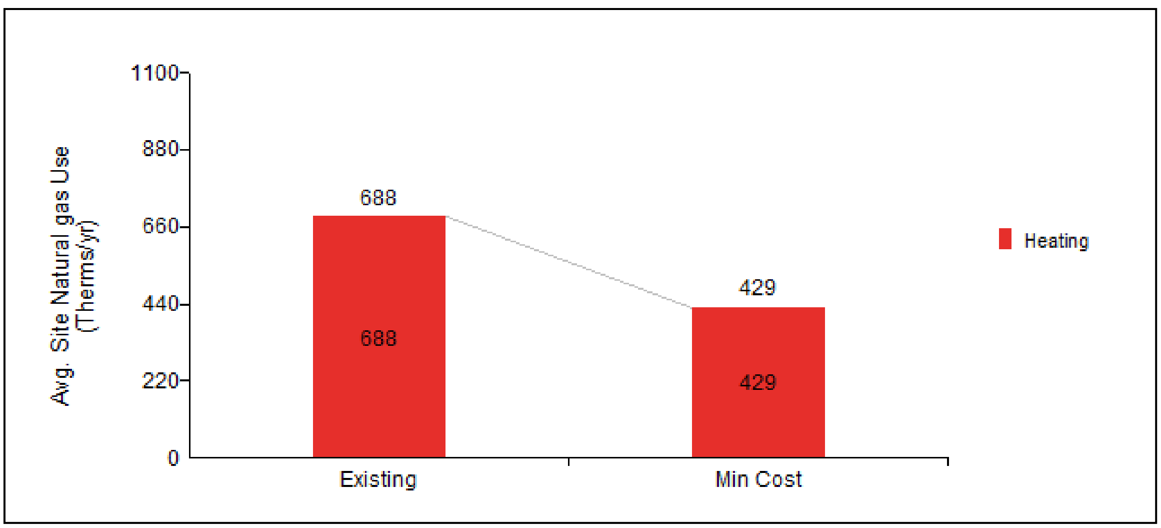

Figure 3-4: Decrease in annual natural gas demands for heating in the cost optimally retroffited average New York natural gas fueled house

As the previous figure shows, the annual amount of natural gas energy demanded for heating decreases from 688 therms to 429 therms, a decrease of 37.6% or 259 therms/yr.

This amount of energy decrease will save the maximum amount of money over the 30 year analysis period out of all the options considered. Figure 3-5 shows that decrease in utility bills.

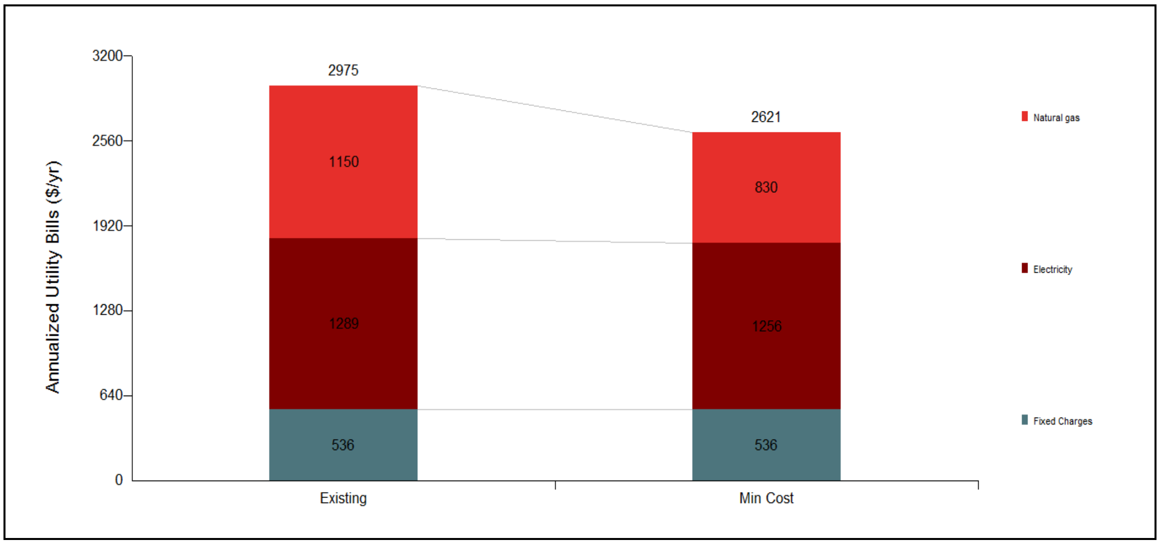

Figure 3-5: Annual utility bills for an average New York natural gas fueled house before and after optimal energy retrofit

As figure 3-5 shows, natural gas bills will decrease from $1150/yr to $830/yr; a savings of $320 annually. The decline doesn't look as dramatic in this graphic because it includes all the utility bills including electricity which was not optimized and fixed connection costs which will not change.

Over the 30 year analysis period, a $320/yr decrease will lead to a net savings of $9,600. This initial capital cost of this retrofitting project is estimated at $5,118 giving a simple payback of 16.0 years. Assuming an inflation rate of 2% (A. 2010), a real discount rate of 3.0% (BEopt default) and 0.0% real fuel escalation rate, gives a 30 year net present value of the installation as $3,648.[3] Because a 0% real fuel escalation cost is used, the savings estimate is conservative, though still quite attractive.

3.4.2 Oil Fueled House

The cost versus energy savings output graph for the oil house is shown below in figure 3-6. Highlighted in the graph is the location of maximum cost savings.

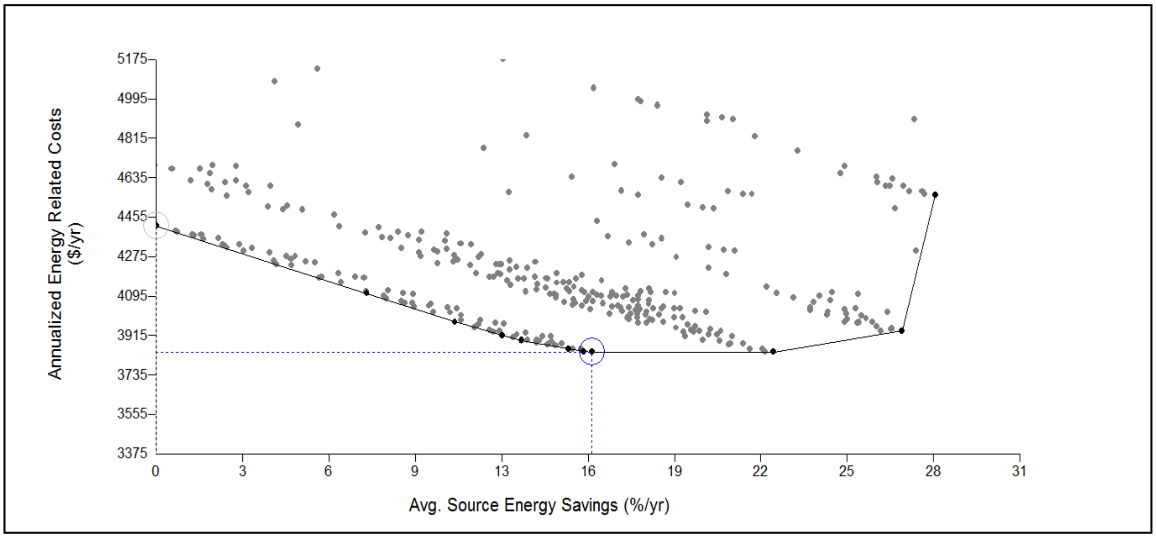

Figure 3-6: Annual energy costs versus source energy savings for implementing various energy conservation measures in an average New York oil fueled house

Like with the natural gas results, the heating fuel can be looked at specifically to see the changes made. The results are shown in figure 3-7.

[3] Note: The BEopt calculated net present value includes the small savings predicted in the electricity sector. This small savings was not included in the other parts of the financial analysis for neither the natural gas nor the oil model houses.

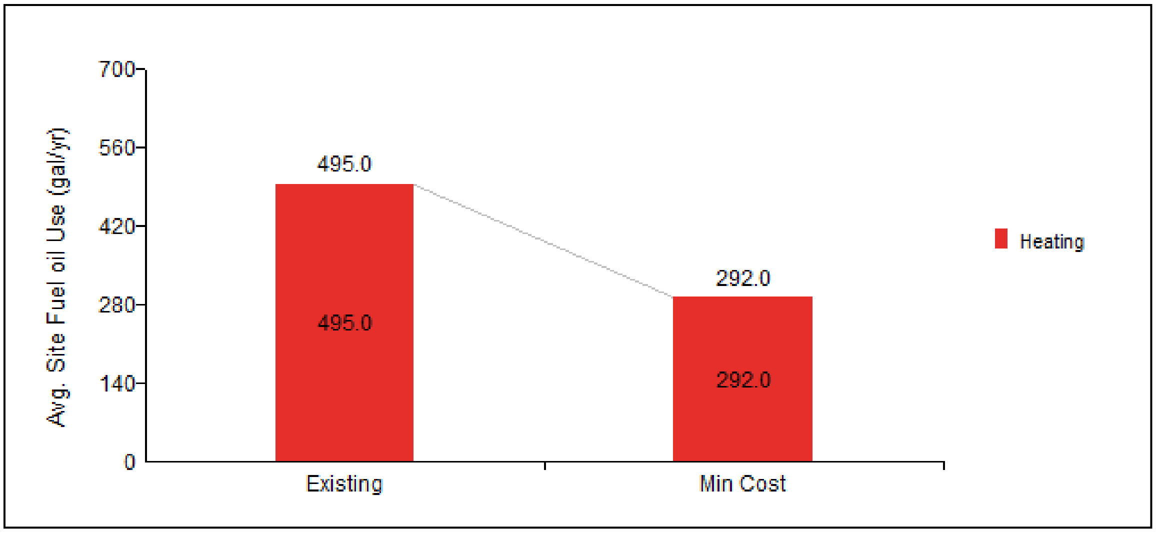

Figure 3-7: Decrease in annual oil demands for heating in the cost optimally retroffited average New York oil fueled house

From the above figure, we see that the annual amount of oil demanded for heating decreases from 495 gallons to 292 gallons, a decrease of 41.0% or 203 gallons/yr. The cost savings of performing this energy retrofit is graphed in figure 3-8 below.

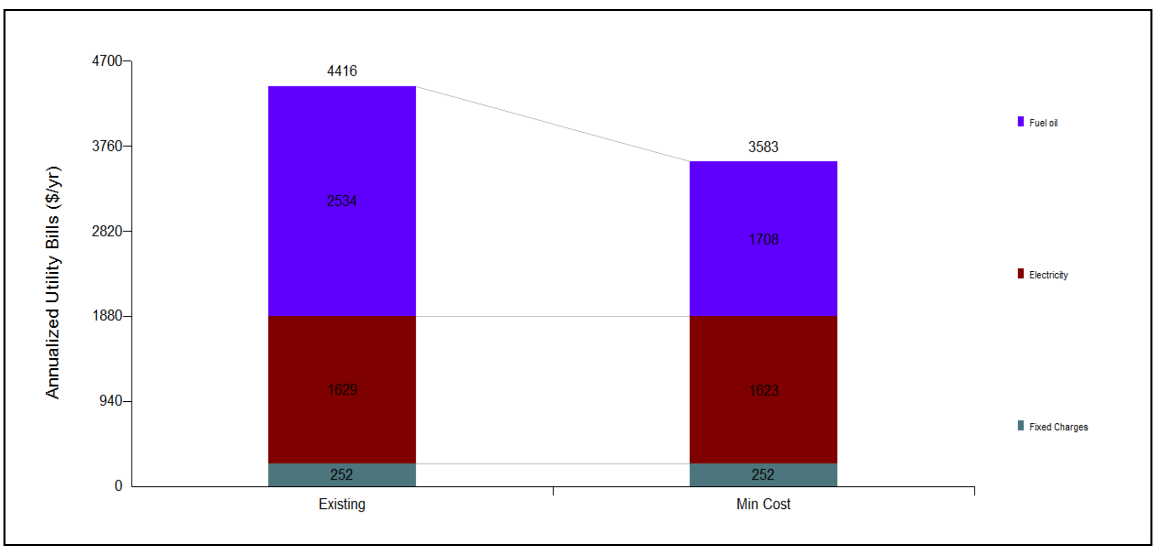

Figure 3-8: Annual utility bills for an average New York oil fueled house before and after optimal energy retrofit

As figure 3-8 shows, oil bills will decrease from $2534/yr to $1708/yr; a savings of $826 annually. Over the 30 year analysis period, an $826/yr decrease will lead to a net savings of $24,780. This initial capital cost of this retrofitting project is estimated at $7,055 giving a simple payback of 8.5 years. The 30 year net present value of the installation is $5,029 using similar financial assumptions as done with the natural gas house.

4.0 Discussion

4.1 BEopt Modeled Houses

Before retrofit, BEopt modeled both houses as having similar fuel demands: 68.3 mmBTU were needed annually for natural gas and 69.4 mmBTU were needed annually for oil. This is true even though the oil house is quite a bit larger than the gas house. This is likely in part due to the efficiencies of the boilers and the fact that the gas furnace was modeled as slightly less efficient than the oil boiler, 78% to 80% respectfully. However, the real life efficiency of the oil boiler may be less than 80% if it is old (as many are) and not properly maintained (as many likely aren't). This potential for efficiency reduction can also help explain why the BEopt model was under predicting the amount fuel oil demanded as compared to RECS.

A more important issue is that some of the data inputted into BEopt doesn't have a quantitative basis in RECS. Though RECS asked many specific questions, it did not ask for technical values such as: "What is the R value of the attic insulation?" or "How many air changes per hour does the house experience?" Rather, it asked if the house was well insulated, adequately insulated, poorly insulated, or not insulated. A similar relative scale was used for infiltration values asking how drafty the house is. People may not know how insulated their house is, or they might respond based on when the house was built (maybe it was well insulated for 1950 standards, but not now). In natural gas houses, more respondents answered that the house was adequately insulated than any other category but for modeling purposes what does "adequately insulated" mean? It could be R10, R20, or even R30, depending on the individual responding. The values that were inputted into BEopt for these highly critical yet uncertain values likely helped cause the underestimation of building energy use.

As stated before though, under predicting real life energy use is not necessarily an undesirable result because under predicting likely leads to a conservative estimate of the amount of energy and money that could be saved. Even where they stand now, both model houses show significant possibilities for cost effective energy improvement. A summary of the important monetary information is given in table 4-1 below.

Table 4-1: Summary of cost information and savings for retrofitted New York State model residential buildings

	Natural Gas House	Oil House
Percentage Heating Fuel Energy Reduction	37.5%	41.0%
Initial Capital Cost	$5,118	$7,055
Annual Savings on fuel bills	$320	$826
Gross Savings over 30 years	$9,600	$24,780
Simple Payback Time	16.0 years	8.5 years
Present Value over 30 years	$3,648	$5,029

The results clearly show that energy retrofitting is a positive monetary investment, saving homeowners thousands of dollars and presenting positive present values and reasonable payback times if the homeowner plans to keep living in the same house. These benefits are strictly monetary, but if externalities are included, such as less environmental pollution and smaller risk in energy price fluctuations, the resulting benefits are even greater. Also add in that gas and oil costs have the potential to rise over time, and the economics improve even more. This analysis is done for an average house, so some houses will not be able to benefit as much, while at the same time, there will be many older houses with poorer energy situations where the benefits will be even greater.

For comparison, the model oil house demanded a greater up front capital cost than the model natural gas house, but saved more money and had a shorter payback time. This likely comes mostly from the fact that oil is much more expensive on a mmBTU basis than natural gas. Therefore, it is more cost effective to go further with the energy conservation measures in oil houses than in natural gas houses. After energy retrofit, costs for heating fuels were still larger in the model oil house than in the model natural gas house, but closer to even. However, even houses heated by natural gas can reduce their energy demands in the most cost effective way with a percentage energy reduction similar to that of the oil houses.

4.2 Potential for Statewide Benefits

Since the preceding results looked at the average single family detached houses in New York, they can now be extrapolated to look at the effects of retrofitting all natural gas and oil fueled houses in the state. Although the true statewide benefit would need to look at houses at a much more detailed spatial level and more than just one house per fuel type, this data can give a quick estimate of the statewide energy, monetary, and environmental benefits that performing such an energy transition would create. Suppose every house in the state preformed the same series of ECMs that were found to be most cost optimal. Because the average houses were modeled, the energy and cost data for those houses can simply be multiplied by the number of houses in New York. RECS reports that there are 3.1 million single family detached houses in the state. When doing the survey, 61.6% of the respondents had natural gas as their primary fuel and 28.1% having fuel oil (with 10.3% having other). These percentages are assumed to be true for the entire state. Table 4-2 shows the state wide results.

Table 4-2: Potential statewide results for energy retrofitting all natural gas and oil fueled houses in New York for cost optimization

Utility	**Total New York Detached Houses**	**Current Costs of Fuel for Heating**	**State-wide Initial Capital Cost**	**State-wide Heating Energy Savings**	**State-wide Yearly Fuel Bill Savings**	**State-wide Gross Cost Savings (30 year)**	**State-wide Present Value (30 year)**
Gas	1,910,270	$1.63 billion	$9.78 billion	49.5 million mmBTU	$0.61 billion	$18.39 billion	$6.97 billion
Oil	871,351	$1.76 billion	$6.15 billion	24.6 million mmBTU	$0.72 billion	$21.59 billion	$4.38 billion
Total	2,781,622	$3.38 billion	$15.92 billion	74.0 million mmBTU	$1.33 billion	$39.93 billion	$11.35 billion

Note: The total may not equal the sum of the oil and gas components due to rounding.

Of course, the costs for a statewide energy retrofit are enormous, but they are not so high as to be incomprehensible. As shown, current spending on heating runs approximately $3.38 billion annually. The initial investment for retrofitting would be approximately $15.92 billion with $1.33 billion in annual savings. This would give a total payback of 12.0 years.

For a monetary comparison, the New York State budget is $141 billion for the fiscal year 2013-2014 (New York Times Editorial Board 2013) and by early 2013, British Petroleum had paid over $30 billion on cleanup costs, settlements, and fines for its 2010 Deepwater Horizon oil spill and could pay much more (Fowler 2013). Therefore, although it would take a large effort, there is potential for huge energy retrofitting measures in New York State.

5.0 Conclusion

This study shows that in average New York State single family detached residential buildings, reducing heating energy demand by around 40% results in the optimal level of cost savings. The results also show that the similar steps of basement insulation, attic insulation, and infiltration reduction can be taken regardless of whether the house is heated with natural gas or fuel oil. This general knowledge of useful energy conservation methods will be benefit homeowners who do not have the knowledge or resources to do a comprehensive analysis on their home energy use like was done in this study. Houses that currently use fuel oil have potential to save more than natural gas houses, which is likely due to the high cost of oil as opposed to natural gas; but both retrofits have positive net present values in the thousands of dollars showing potential for large energy and monetary savings. Applying these retrofitting strategies to the entire state housing stock would be a formidable task, but one that would save billions of dollars in the long run. Performing energy retrofits has multiple benefits to the state for example: by keeping more money in the local economy instead of buying fuels from other areas, by helping citizens have less burdensome utility bills, and by reducing the environmental consequences of greenhouse gas emissions.

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