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Predicted Versus Actual Savings for a Low-Rise Multifamily Retrofit in Boulder, Colorado

L. Arena and J. Williamson

Consortium for Advanced Residential Buildings

November 2013

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Predicted Versus Actual Savings for a Low-Rise, Multifamily Retrofit in Boulder, Colorado

Prepared for:

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Office of Energy Efficiency and Renewable Energy

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Definitions

ACH50	Air changes per hour at 50 Pascals
AFUE	Annual fuel utilization efficiency
BA	Building America
BEopt™	Building Energy Optimization Program
CARB	Consortium for Advanced Residential Buildings
DOE	U.S. Department of Energy
E+	EnergyPlus
FFA	Finished floor area
HDD	Heating degree day
HVAC	Heating, ventilation, and air conditioning
MEL	Miscellaneous electric load
NREL	National Renewable Energy Laboratory
OAT	Outdoor air temperature
SHGC	Solar heat gain coefficient
TMY3	Typical Meteorological Year dataset

Executive Summary

There are approximately 28 million multifamily units in the United States (RECS 2009). In addition, about 70% of the U.S. housing stock is more than 30 years old (HUD 2011). This represents an enormous opportunity to retrofit older multifamily units that are very similar to the six Boulder, Colorado units discussed in this report.

The purpose of this project was to follow up on a Building America (BA) retrofit project to determine the actual savings. In addition, this project provided a perfect opportunity to look at the use of the Building Energy Optimization Program (BEopt™) as it applies to multifamily retrofits. BEopt is a tool that is used by the BA Program to determine cost optimized packages in both new and retrofit construction. It also provides a consistent way to compare one BA project from another in various climate regions.

BEopt was not originally built for multifamily, nor for retrofit projects. However, when Vice President Biden announced Recovery through Retrofit in 2009, BA took on the challenge of existing homes. BEopt was one component of the BA Program that added retrofits into its repertoire and has been continually improved since then.

Polly et al. (2011) propose a method for improving the accuracy of residential energy analysis methods. A key step in this process involves the comparison of predicted versus metered energy use and savings. This report will challenge BEopt's relatively new capabilities and provide recommendations for how to improve it in the area of multifamily retrofit.

In support of these research needs, the Consortium for Advanced Residential Buildings (CARB) evaluated the retrofit of a multifamily building in Boulder, Colorado. The updated property is a 37-unit, two-story apartment complex built in 1950, which underwent renovations in early 2009 to bring it into compliance with Boulder, Colorado's SmartRegs ordinance (LBNL 2012). Goals of this study were to: 1) evaluate predicted versus actual savings due to the improvements, 2) identify areas where the modeling assumptions may need to be changed, and 3) determine common changes made by renters that would negatively impact energy savings. In doing so, CARB seeks to improve the accuracy of modeling software while assessing retrofit measures to specifically determine which are most effective for large multifamily complexes in the cold climate region. Other issues that were investigated include the effects of improving building efficiency on tenant comfort, the impact on tenant turnover rates, and the potential market barriers for this type of community-scale project.

Savings from the retrofit measures implemented in Boulder, Colorado were calculated on an individual apartment basis and for all six apartments together. Total savings for the six units showed excellent agreement between predicted and actual values for both gas and electricity use. Total gas and electricity savings for the six apartments were predicted to be 61% and 27%, respectively. Actual gas and electricity savings were 58% and 30%, respectively. A cost optimization using BEopt shows that, for this complex, the measures implemented were a cost-effective method of achieving the minimum efficiency levels mandated by the City of Boulder's SmartRegs ordinance.

1 Introduction and Background

Of the approximately 28 million multifamily housing units in the United States, about 30%, or 9.7 million, are located in the very cold/cold climates like Boulder's (RECS 2009). These numbers indicate the potential for significant energy savings if improvements can be implemented. Performing an in-depth energy analysis to determine the most cost-effective improvements is essential to ensure optimal return on investment for property owners. However, multiple studies confirm that analysis methods tend to overpredict energy use in poorly insulated, leaky homes and thus, the savings associated with improving those homes (Polly et al. 2011).

If actual pre-retrofit energy usage is lower than predicted, as was the case for the units initially analyzed, actual savings may also be lower than predicted. Analyzing the accuracy of modeling software for these types of buildings is essential to ensure that consultants, property owners, and efficiency program administrators are suggesting and making the most efficient and cost-effective energy improvements.

Polly et al. (2011) propose a method for improving the accuracy of residential energy analysis methods. A key step in that process involves the comparison of predicted versus metered energy use and savings. While studies on attached housing have been conducted in the last several years, few compare actual bills to predicted.

In 2011, a research study conducted in the cold climate zone evaluated the retrofit performance of a small, stacked, three-family building (Gates and Osser 2011). Findings from that study also support Polly's conclusions: modeling overpredicted the actual energy use in the pre-retrofit case more significantly than in the post-retrofit case. However, it does not fully encompass the results that are likely to occur in large-scale multifamily complexes. Another study recently conducted involved a multifamily retrofit on a medium-scale, 12-unit complex in the mixed-humid climate zone (Lyons 2013). That research provides recommendations for the most effective retrofit measures for multifamily buildings in that climate zone, but there is no comparison of utility bills to modeling predications.

In a previous research effort under the U.S. Department of Energy's (DOE) Building America (BA) Program, the Consortium for Advanced Residential Buildings (CARB) compared pre-retrofit utility bills to modeling predictions from REM/Rate for a 37-unit rental property (shown in Figure 1 and Figure 2). This property underwent renovations in 2009 to bring it into compliance with Boulder, Colorado's new efficiency requirements for rental properties. Key retrofits included insulating and tightening the building envelope, replacing inefficient lights and appliances, and replacing the windows and doors. A more detailed list of the pre- and post-retrofit building components is provided in Table 1.

Figure 1. Overhead view of building complex

Figure 2. Side view of one unit

Table 1. Building Specifications Before and After Retrofits

	Before	After
Attic	R-9 attic insulation	R-50 blown-in cellulose
Walls	No insulation	R-13 blown-in cellulose
Windows	Single-pane, metal	Double-pane, low-e, vinyl
Slab floor	No insulation	Same
Doors	Metal	Foam-filled, fiberglass
Air Leakage*	11.4 ACH50	8.7 ACH50
Appliances	850 kWh/yr	450 kWh/yr
Fluorescent Lighting	0%	100%
Domestic Hot Water	Central 0.59 energy factor	Same
Cooling	None	Same
Heating	60 annual fuel utilization efficiency (AFUE), natural gas convection, unit heaters	Same

* Unguarded blower door leakage rates listed are an average of all units monitored. "After" data is an average leakage rate from tests done in 2011 retrofit analysis.

The focus of that research project was to evaluate the effectiveness of the City of Boulder's SmartRegs program—an ordinance that requires rental property owners to bring their rentals up to an efficiency level similar to that of the 2004 International Energy Conservation Code by 2018 (or below a Home Energy Rating System score of about 120). REM/Rate was used in that analysis because it was the software that Boulder's SmartRegs program administrators had used to develop their requirements (Arena and Vijaykumar 2012; LBNL 2012). Pre-retrofit predictions from that study were found to be significantly higher than actual energy use, supporting Polly et al. (2011). The major findings from that study included.

- The models sometimes underpredicted and sometimes overpredicted electricity consumption.
- The models consistently and significantly overpredicted gas consumption.

- Spikes in actual electricity consumption indicated the possible use of supplemental space conditioning in both the summer and winter.

Because post-retrofit bills were not available at that time, a continuation of that study was proposed that would include additional spot audits on a variety of apartment types, a comparison of pre- and post-retrofit utility bills and the corresponding energy savings, and a cost analysis of the upgrades. A graphic illustrating the timeline leading up to this project is displayed in Figure 3.

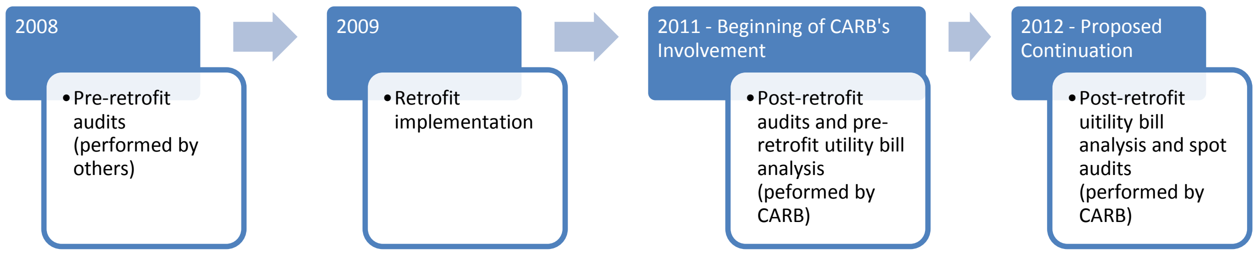

Figure 3. Timeline of project

This report provides comparisons of pre- and post-retrofit utility bills for this low-rise, multifamily building in climate zone 5B and examines the potential causes of differences between actual energy usage and modeled predictions. In doing so, it seeks to improve the accuracy of modeling software while assessing retrofit measures to specifically determine which are most effective for large multifamily complexes in the cold climate region. Other issues that were investigated include the impact of tenant modifications on post-retrofit energy savings, the effects of improving building efficiency on tenant comfort and turnover, and the potential market barriers for this type of community-scale project.

1.1 Research Questions

To help consultants, property owners, and program administrators determine the most cost-effective methods of improving these buildings, accurate analysis and prediction of the energy use of existing buildings are essential. In light of the information presented thus far, it was the intent of this research effort to answer the following questions:

- For this building complex in Boulder, Colorado, what are the actual energy savings realized from the improvements compared to the predicted savings?
- Can discrepancies between modeled bills and actual bills be explained? If so, are changes to the accepted modeling assumptions needed?
- What are the most common changes made by renters that will negatively impact post-retrofit energy savings? And what is the extent of that impact?

CARB's path to answer these research questions involved a variety of tasks, including evaluation of utility bills, energy modeling using the Building Energy Optimization Program EnergyPlus (BEopt E+) 1.4, and follow-up spot audits on several units.

2 Methodology

2.1 Evaluation of Post-Retrofit Utility Bills

Post-retrofit data were collected from the property owner and compared to pre-retrofit data to determine the energy savings from the renovations. Both gas and electricity bills were collected. With the assistance of the property management company, utility bill releases were distributed to all the tenants in the building. Six occupants signed and returned the releases. It should be noted that this complex is primarily inhabited by university students, generally resulting in annual turnover of apartments. The majority of the tenants had moved in during August 2012, and therefore, an entire year of data was not available. Even though pre-retrofit utility bills were available for the entire year, data analysis was limited to the time period of August through November. The pre- and post-retrofit utility bill data compared for this retrofit analysis are provided in Appendices A and B. It is important to note that these observations may not apply to all multifamily housing because the tenants in this study were university students with possibly uncharacteristic energy usage patterns.

The energy usage was read and reported by the utility company in one-month increments. However, full billing cycles were found to range between 29 and 33 days. Furthermore, during August, when most tenants were moving in, some billing cycles include as few as 11 nonvacant days. CARB had originally intended to perform utility bill analysis for a longer time period, but contract timeline restrictions coupled with typical tenant moving schedules limited the size of the dataset. In order to minimize differences that developed from utility metering intervals, the data were normalized per day. Electrical energy use for each month was analyzed with the metric of total kilowatt-hours used/total metered days over the four-month period. Natural gas usage was normalized to a similar effect. In order to allow for equal data comparison among unique time periods with variant weather conditions, gas usage was evaluated per heating degree day (HDD) over the four-month analysis period.

2.2 Comparison of Actual Bills to Modeling Predictions

Energy modeling was performed using BEopt E+ v1.4 to assess savings that resulted from each retrofit measure. Because BEopt cannot model a multifamily building as a single building with multiple apartments, separate models were created for each of the six units that had both pre-and post-retrofit utility bills available. CARB also investigated differences in predicted and actual energy use, and differences between actual weather data and the model weather data.

Errors in this analysis may have been introduced by the nonstandard use of BEopt as a multifamily modeling tool, the fact that this was a self-selected group of participants, and by the fact that all the apartments were occupied by different tenants in the pre- and post-retrofit periods. The influence of different tenants on energy usage behavior will have a significant impact on the actual savings. The potential impact of this difference was considered when assessing the savings; however, it was not directly accounted for in the modeling. Additionally, not all gas consumption is attributed to heating—a small portion is also used for cooking needs. This was accounted for in the energy model.

The modeling predictions were then compared to actual savings as indicated by utility bill differences between pre-and post-retrofit periods. In order to minimize the variation caused by tenant move-in dates and weather conditions, electricity usage was normalized as the average kWh/day and gas usage as therms/HDD. A summary of the complete data analysis method is provided below:

1. Normalized usage rates were determined for gas (therms/HDD) and electricity (kWh/day) for each unit in the pre- and post-retrofit case. Predicted usage rates were developed through BEopt energy simulations, while actual utility usage rates were calculated directly with tenant utility bills.

    a. Electricity usage was normalized by summing the kilowatt-hours over the active August through November usage period and dividing by the total number of days in that period (this varied depending on move-in date).

    b. Gas usage was normalized by summing the therms used over the four-month period and dividing by the total HDDs during that time. This was done to eliminate the effects of different weather conditions between the energy model and the actual period for which the bills were available.

2. The electricity and gas values obtained in step 1 above were multiplied by 121 days and 1,314 HDDs respectively (a typical August through November time period) to obtain each unit's total normalized gas and electrical energy usage.

The normalized predicted and actual energy usage was aggregated to obtain the total consumption for all six units. Total usage was determined for each of the four corresponding categories: 2008 utility bills, 2012 utility bills, BEopt results pre-retrofit, and BEopt results post-retrofit.

2.3 Cost-Benefit Analysis

The cost effectiveness of this community-scale project was determined by quantifying the costs of the renovation, the cost savings from the utility bills, and the impact of financial incentives. The cost-benefit analysis was performed to assess the economic feasibility of each retrofit measure while identifying the improvements that yielded the highest savings. A simulated cost analysis was performed over a 30-year period with BEopt to forecast the average utility bills and upgrade and maintenance payments that the building owner and tenants would incur. Additionally, BEopt was used to develop a retrofit optimization curve that provides insight into the upgrade combinations that can be implemented for the lowest cost and greatest savings. Lastly, the report discusses various federal, state, and other incentives that impact the economic feasibility of these improvements.

2.4 Research/Experimental Method

In addition to modeling and utility bill analysis, spot audits were conducted on several units to evaluate the condition of the improvements several years after completion**.** The goals of the audits were to determine the longevity of the retrofit measures, to assess if any had been changed or degraded over time, and to investigate if the occupants had made any changes that would impact the expected energy savings. The audits included:

- Envelope air leakage tests
- Showerhead and faucet water flow measurements
- Lighting and appliance surveys
- Verification of attic insulation levels
- Visual inspection of the condition of the units
- Identification of any supplemental heating or cooling equipment.

CARB had intended to supplement the audits with occupant interviews to determine comfort levels and satisfaction with the renovated property; however, after speaking to the property management company, it was decided that these would hold little value, primarily due to two factors: (1) most of the tenants whose apartments were audited had been there only a few months; and (2) most tenants stayed for only a year due to the fact that they were university students. While vacancies in Boulder are extremely low, turnover is very high in most rentals, especially near the university.

3 Results

Post-retrofit utility bills were obtained for six of the units in the apartment complex and represented a wide array of apartment styles. Table 2 provides a basic description of each of the post-retrofit units where utility bills were analyzed. A summary of post retrofit characteristics for all buildings audited is shown in Appendix C.

Table 2. Units Included in Utility Bill Analysis

Unit #	Type	Floor Area (ft^2)	# Attached Walls	# Bedrooms
106	First-floor middle unit conditioned space above	433	2	1
108	First-floor middle unit conditioned space above	573	2	2
121	First-floor end apartment no apartment above	433	1	1
208	Second-floor middle unit conditioned space below	647	2	2
211	Second-floor end unit conditioned space below	490	1	1
215	Second-floor middle unit conditioned space below	490	2	1

3.1 Spot Audit Findings

Spot audits were conducted on 9 of the 37 apartments to evaluate the condition of the improvements several years after completion. A summary of spot audit findings is shown in Appendix D. The goals of the audits were to determine the longevity of the retrofit measures, to assess if any had been changed or degraded over time, and to investigate if the occupants had made any changes that would impact the expected energy savings.

Several of the apartments had incandescent bulbs in the light fixtures, but not in every fixture. The largest percentage of incandescent to fluorescent noted was approximately 50%. Three of the nine units inspected had window air conditioners, but none had more than one. No supplemental heaters were found in any unit despite the fact that the heating systems are convection, point-source heaters located in the living room. All faucets that were inspected still tested to low flow specifications, thus none had been switched back by the tenants.

As part of a qualitative assessment, CARB suspects that there is no correlation between the few changes made and the variations in predicted versus actual energy use in the apartments. For units that had a window air conditioner installed or a large number of incandescent bulbs, there was no consistent evidence to indicate substantial energy increases. Further research and larger datasets are needed to fully confirm these findings.

3.2 Predicted Versus Actual Energy Use

Energy modeling was performed with the National Renewable Energy Laboratory's (NREL) hourly energy simulation software, BEopt E+ 1.4. This modeling was completed for each of the units that had both pre and post-retrofit utility bills available. Consequently, 12 models were created: a pre-retrofit and a post-retrofit case for each of the six apartments. All of the predicted modeling results were then compared to the actual energy usage that was obtained from the tenants' utility bills (Figure 4 and Figure 5) for both the pre- and post-retrofit cases. Again, all results are normalized, and describe site energy use from August through November only.

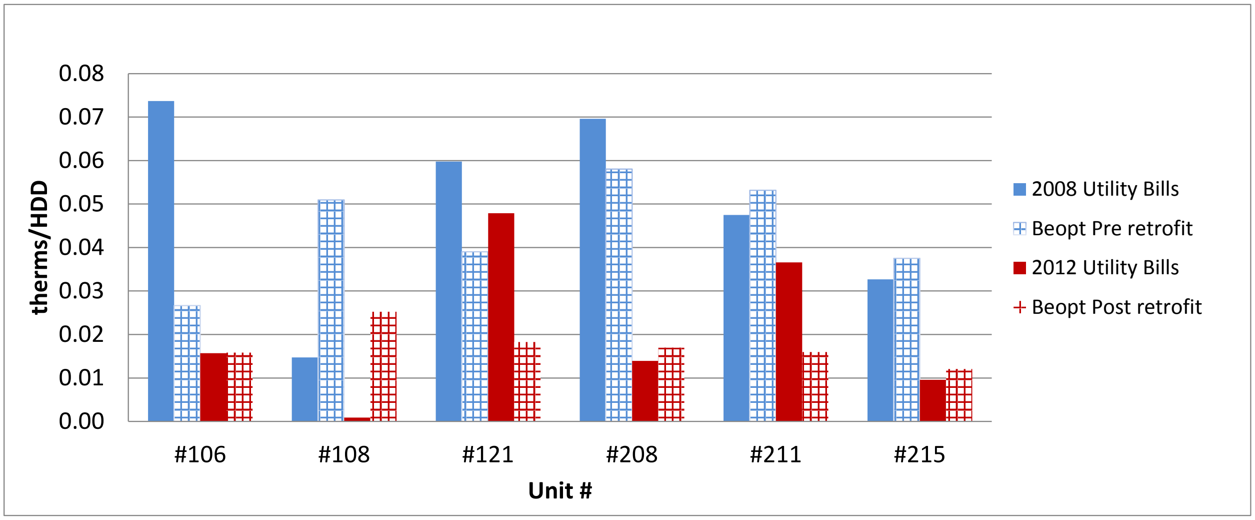

Figure 4. Gas usage rate (August through November)

As seen in Figure 4, actual natural gas savings and predicted savings vary significantly between units. The models did not consistently over- or underpredict gas use for the six units when analyzed individually. The only trend displayed is a consistent decrease in actual gas usage between pre- and post-retrofit periods for every unit, though the magnitude of that savings varies significantly.

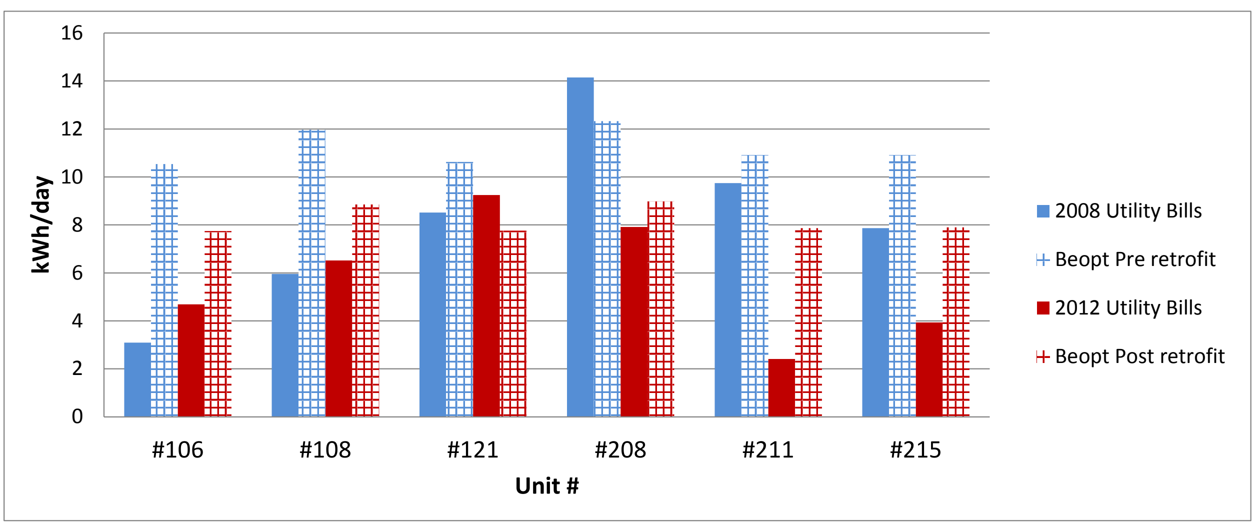

Figure 5. Electricity usage rate (August through November)

Alternatively, Figure 5 demonstrates the average rate (kWh/day) at which electricity was consumed. This comparison of actual and predicted electricity savings yielded an unexpected result. For all three first floor units, the utility bills indicated that electricity use increased slightly from the pre- to post-retrofit case, while all three second-floor units saw a significant decrease in electricity usage. The reasons for this are unclear at this time, but could be due to differences in consumption between the 2008 and 2012 occupants. Unlike gas use, the energy model consistently overpredicted electricity use in all but 2 of the 12 models.

Total gas and electricity usage values for all six apartments are shown in Figure 6 and Figure 7. Adding the values for all six apartments produces closer agreement between utility bills and modeling as compared to evaluating them individually. Overall, gas use was slightly underpredicted for the six apartments and electricity use was significantly overpredicted. However, gas and electricity savings between pre- and post-retrofit conditions show good agreement between the predicted and actual values.

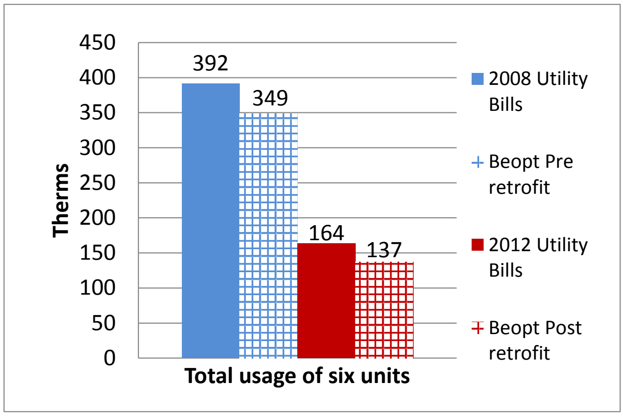

Figure 6. Total gas usage (August through November)

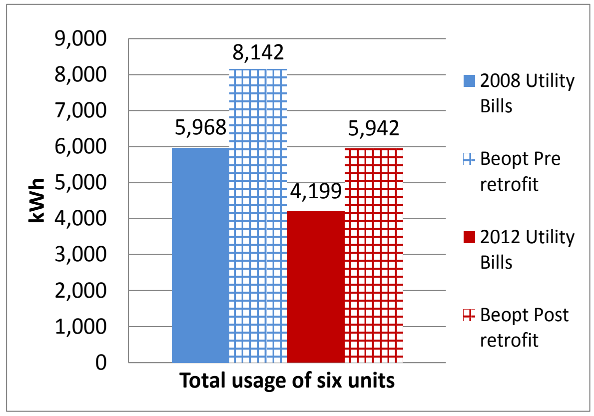

Figure 7. Total electricity usage (August through November)

Over a typical August through November period of 1,314 HDDs, gas usage rates translate to a total actual gas usage of 392 therms in the pre-retrofit case and 164 therms in the post-retrofit case. Alternatively, BEopt modeling predicted a total pre-retrofit usage of 349 therms and a post-retrofit usage of 137 therms. At an estimated $8/month gas service charge per unit and a rate of $0.7901/therm, the actual gas savings would result in a savings of $372 over the course of four months. In comparison, BEopt predicted savings of 212 therms, which would amount to a total monetary savings of $360. Total actual gas use in the retrofitted apartments was 58.2% lower than the pre-retrofit cases. In comparison, the energy model predicted total savings of 60.7% compared to the pre-retrofit case, showing very good agreement with the actual savings.

Agreement between predicted and actual total electricity savings was also good. Over a typical August through November period of 121 days, electricity usage rates translated to a total actual electricity usage of 5,968 kWh in the pre-retrofit case and 4,199 kWh in the post-retrofit case. Alternatively, BEopt modeling predicted a total pre-retrofit usage of 8,142 kWh and a total post-retrofit usage of 5,942 kWh. At an estimated $8/month electricity service charge per unit and a rate of $0.1013/kWh, the actual 1,769 kWh savings would result in a total monetary savings of

$371 over the course of four months. The total BEopt predicted electricity savings of 2,200 kWh amounts to a monetary savings of $415 over this same four-month period. Overall, the total electricity usage decreased by 29.6% for the six units. In comparison, the model predicted a total savings of 27.0%, once again, showing excellent agreement with the actual savings.

Agreement between actual and predicted savings quantifies only a portion of the energy model's accuracy. It is also important to compare the magnitude of each of the two energy usage values. The relationship between predicted and actual energy use values has been plotted in Figure 8. The line "y = x" signifies the region where modeling predictions match utility bills (line of perfect fit). Thus, the closer the ratio is to this line, the more accurate the modeling prediction.

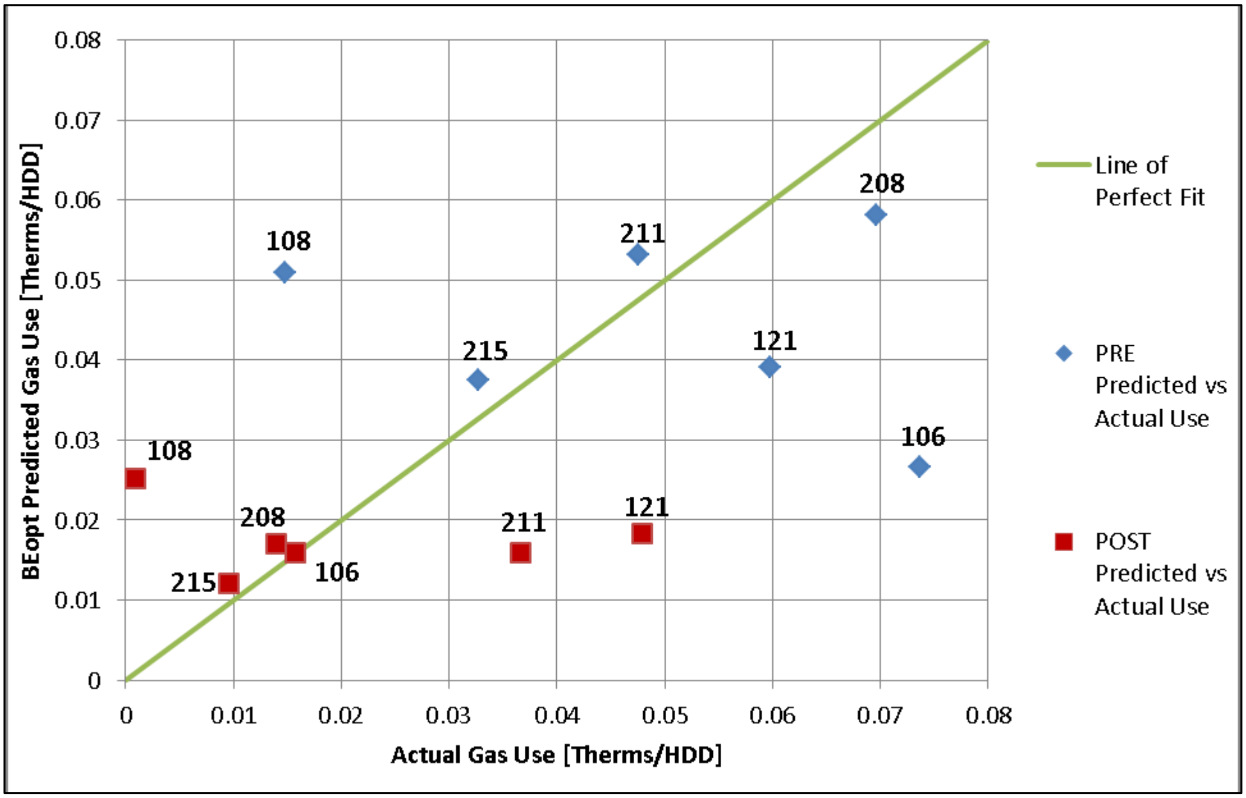

Figure 8. BEopt predicted versus actual gas use (August through November)

As seen in Figure 8, the pre-retrofit gas utility usage points appear to be equally scattered both above and below the line of perfect fit (with three overpredictions and three underpredictions). In fact, the total sum of all six pre-retrofit predictions was only 11.0% less than the total actual usage. Alternatively, the post-retrofit bills are distributed with a majority lying close to or slightly above the line of perfect fit. However, the sum of post-retrofit predictions is 16.2% less than total actual energy usage. Even though the energy use in the majority of the post-retrofit units is overpredicted, the total sum of the predictions is still less than the total actual use. This indicates that the two underpredicted values carry a greater combined error than the four overpredicted values.

A similar plot describing the relationship between the model's predicted electricity use and the actual electricity use is provided in Figure 9. As seen from the plot, both the pre- and post-retrofit cases are predominantly distributed above the line of perfect fit. Hence, the model overpredicts electricity consumption in both cases. The total sum of pre-retrofit predictions was 36.4% greater than total actual energy usage while total post-retrofit predictions were 41.5% greater.

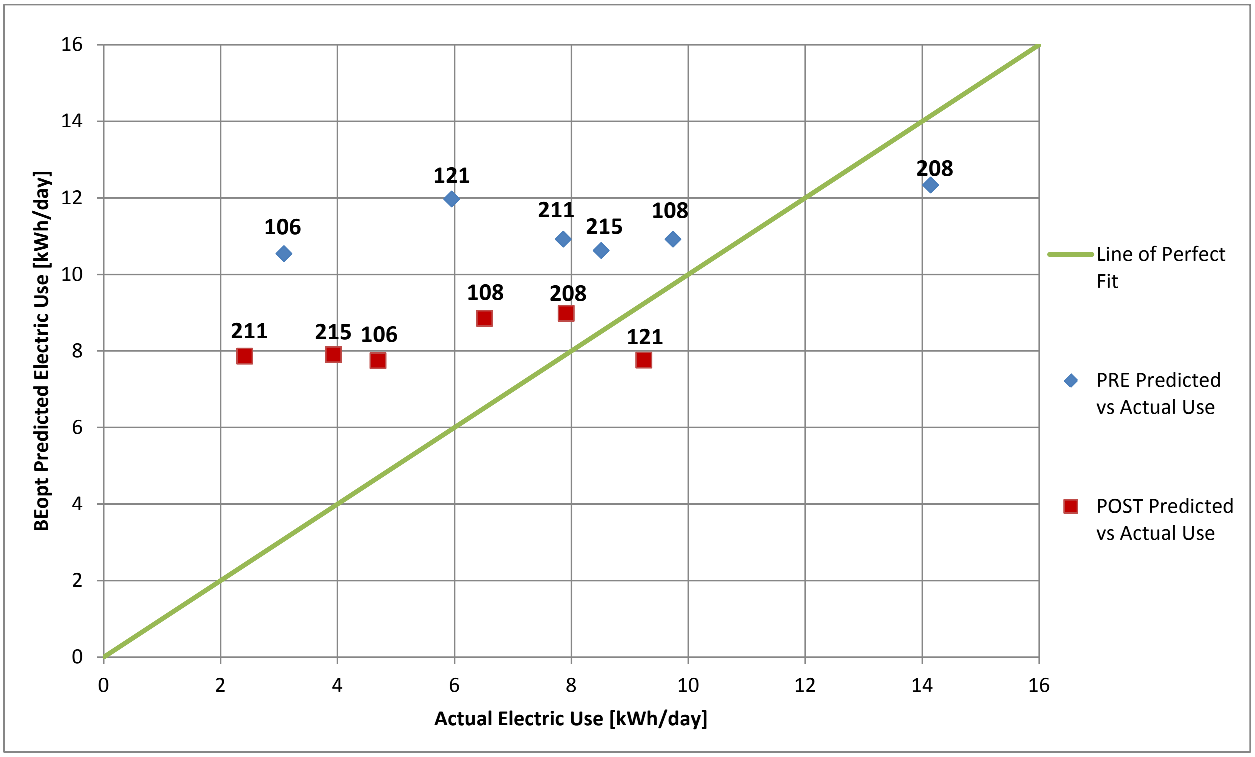

Figure 9. BEopt predicted versus actual electricity use (August through November)

4 Cost Effectiveness Analysis

The primary renovations made to this community-scale project entailed increasing the attic and wall insulation, installing high efficiency windows and doors, replacing the appliances with energy-efficient models, and installing efficient lighting. Modeling predicts that improvements will result in source energy savings of 26%–41%.

Using BEopt E+ 1.4, a cost optimization was performed on the retrofit package implemented to determine how close it came to the lowest-cost optimization curve. Ideally, the package selected would fall on the lowest-cost curve, indicating that the package was a cost-effective method of achieving the predicted energy savings. Table 3 lists the pre- and post-retrofit building specifications (first and last items listed for each component) along with any other efficiency levels analyzed in the optimization. Combinations of the options shown were run for a second-floor middle unit (#211).

Table 3. Options Evaluated in Optimization

Component	Option
Attic Insulation	Ceiling, R-9, cellulose, blown-in, vented Ceiling, R-38, cellulose, blown-in, vented Ceiling, R-50, cellulose, blown-in, vented
Wall Insulation	Uninsulated, 2 × 4, 16 in. o.c. R-13, loose-fill, cellulose, no void 2 × 4 16 in. o.c.
Windows	Single-pane, clear, metal Double-pane, low-e, nonmetal, air, low solar heat gain coefficient (SHGC)
Lighting	0% fluorescent hardwired and plugin 100% fluorescent hardwired and plugin
Infiltration	13.5 ACH50 10.1 ACH50
Furnace	Unit heater (AFUE = 60%) Unit heater (AFUE = 80%)

HVAC retrofits were not implemented for several reasons. The units were heated with individual unit gas heaters without blowers. To retrofit each of the 37 apartments with new heaters would require costly electrical and venting upgrades as well as substantial cosmetic repairs, all of which made this improvement cost prohibitive. Domestic hot water was left as is because the water heaters were not considered to be at the end of their useful lives, and the improvement over the existing efficiency levels would also have been cost prohibitive. Apartments were not previously equipped with window air conditioners by the property management company. No changes to this condition were made during the renovation.

For a majority of the retrofit measures, costs were referenced from NREL's material cost database (BEopt default costs). However, for some improvements, costs were estimated based on prior experience with specific retrofit measures. For instance, infiltration improvements were given no additional cost because no "air sealing task" was physically performed for these apartments. Air sealing benefits are a byproduct of attic insulation, wall insulation, and properly installed windows. Additionally, an upgrade of the furnaces to AFUE 80% unit heaters was valued at $2,500. This increased cost includes additional installation costs for wiring and venting that would be required to comply with the current building code and interior cosmetic work that would be required after the replacement.

For the financial analysis, the economic values listed in Table 4 were used as modeling inputs. The BEopt default loan rate of 7.0% was used for this analysis, as it was close to true rates being offered at the time the improvements were made (2008–2009). BEopt's Colorado state utility rate average was used for both pre- and post-retrofit cases. These rates were found to be within an acceptable range of what was actually charged by the local utility company.

Table 4. Modeling Inputs for Economic Analysis

Economic Variables	Modeling Inputs
Project Analysis Period	30 years
Inflation Rate	1.6%
Discount Rate (Real)	3.0%
Loan Period	30 years
Loan Interest Rate	7.0%
Electricity Rate	$0.1013/kWh + $8.00 monthly charge
Natural Gas Rate	$0.7901/therm + $8.00 monthly charge
Fuel Escalation Rate	0.0%

The optimization curve that resulted from this analysis is provided in Figure 10. Each point on this graph represents the annualized energy-related costs and source energy savings associated with the selected material options. The lowest cost option at various savings is connected to form the minimum cost optimization line.

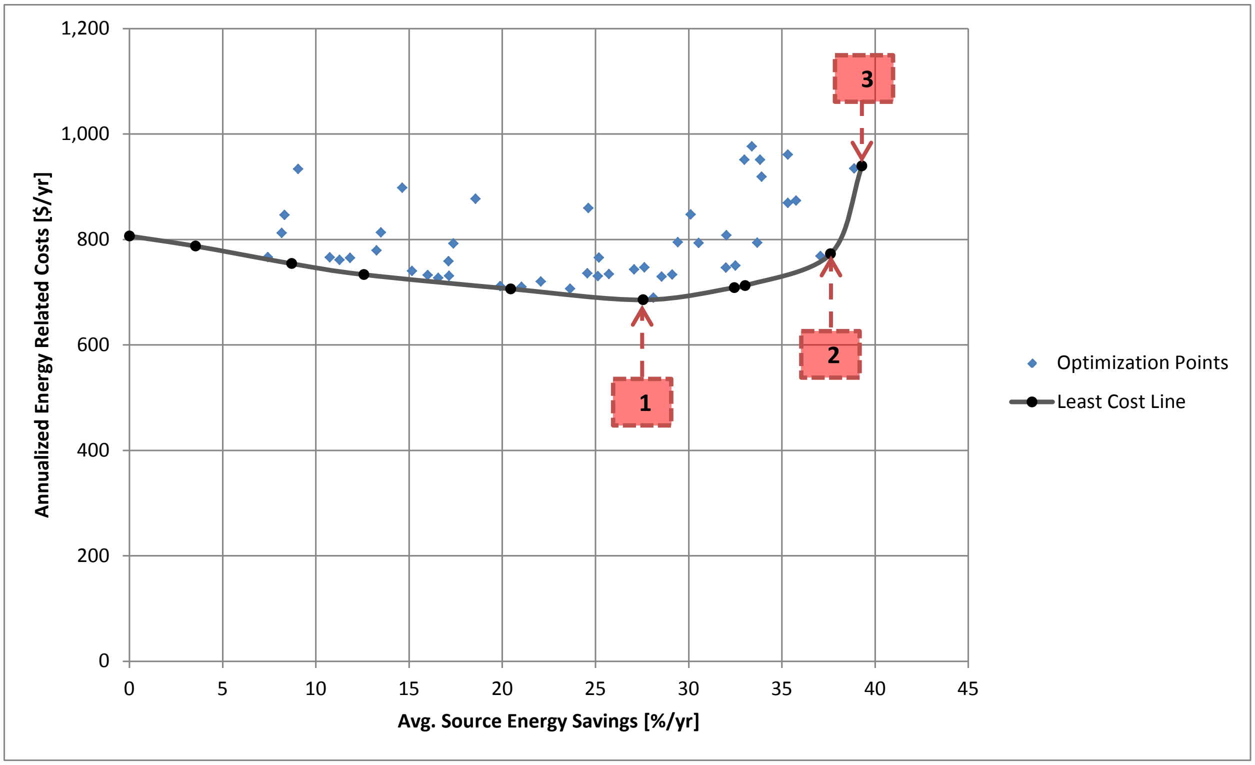

Figure 10. BEopt optimization curve

Along the lowest cost optimization curve, there are three points of significance: (1) the lowest cost case; (2) the selected post-retrofit design case; and (3) the highest savings option. Table 5 displays a summary of the building components associated with each case. Case #2 was chosen as the retrofit package for this complex because it was the most cost-effective combination of improvements that would result in compliance with the SmartRegs ordinance. Additionally, this design case lies at the point which provides the greatest savings that can be achieved from the selected construction options without increasing annualized energy related costs above the pre-retrofit costs.

Table 5. Significant Points On Optimization Curve

Point	1	2	3
Classification	Minimum cost	Selected design case for second-floor unit	Maximum % savings
Water Loads	Low-flow showers and sinks	Low-flow showers and sinks	Low-flow showers and sinks
Wood Stud	R-13 loose-fill cellulose no void 2 × 4 16 in. o.c.	R-13 loose-fill cellulose no void 2 × 4 16 in. o.c.	R-13 loose-fill cellulose no void 2 × 4 16 in. o.c.
Unfinished Attic	Ceiling R-38 cellulose blown-in vented	Ceiling R-50 cellulose blown-in vented	Ceiling R-50 cellulose blown-in vented
Window Type	Single-pane clear metal	Double-pane low-e nonmetal air low SHGC	Double-pane low-e nonmetal air low SHGC
Infiltration	Reduced by 25% (from 13.5 ACH50 to 10.1 ACH50)	Reduced by 25% (from 13.5 ACH50 to 10.1 ACH50)	Reduced by 25% (from 13.5 ACH50 to 10.1 ACH50)
Refrigerator	Inefficient old refrigerator	Electrolux ENERGY STAR® efficient refrigerator	Electrolux ENERGY STAR efficient refrigerator
Lighting	100% fluorescent hardwired and plugin	100% fluorescent hardwired and plugin	100% fluorescent hardwired and plugin
Furnace	Unit heater (AFUE = 60%)	Unit heater (AFUE = 60%)	Unit heater (AFUE = 80%)
Energy Savings	27.6%	37.6%	39.3%
Annualized Energy-Related Costs ($/yr)	$685	$773	$939

It is important to note that the cost analysis performed in this section does not account for the federal, state, and local funding that has been put in place to help finance the cost of the retrofit improvements. Rental property owners have access to retrofit incentives that involve insulation, appliance, lighting, water conservation, energy auditing, financing options, and more. As a result, these financial incentives may also have a significant impact on a rental property's decision on which retrofit measures are economically desirable.

Each individual upgrade was evaluated to determine the corresponding energy savings. Figure 11 is a modified version of a Pareto diagram, which describes how each of the building improvements influenced the overall predicted source energy savings of 37.6% (analysis performed on unit #215). The plot provides an end-use breakdown of each cumulative measure. Upgrades are ordered from left to right in decreasing order of savings.

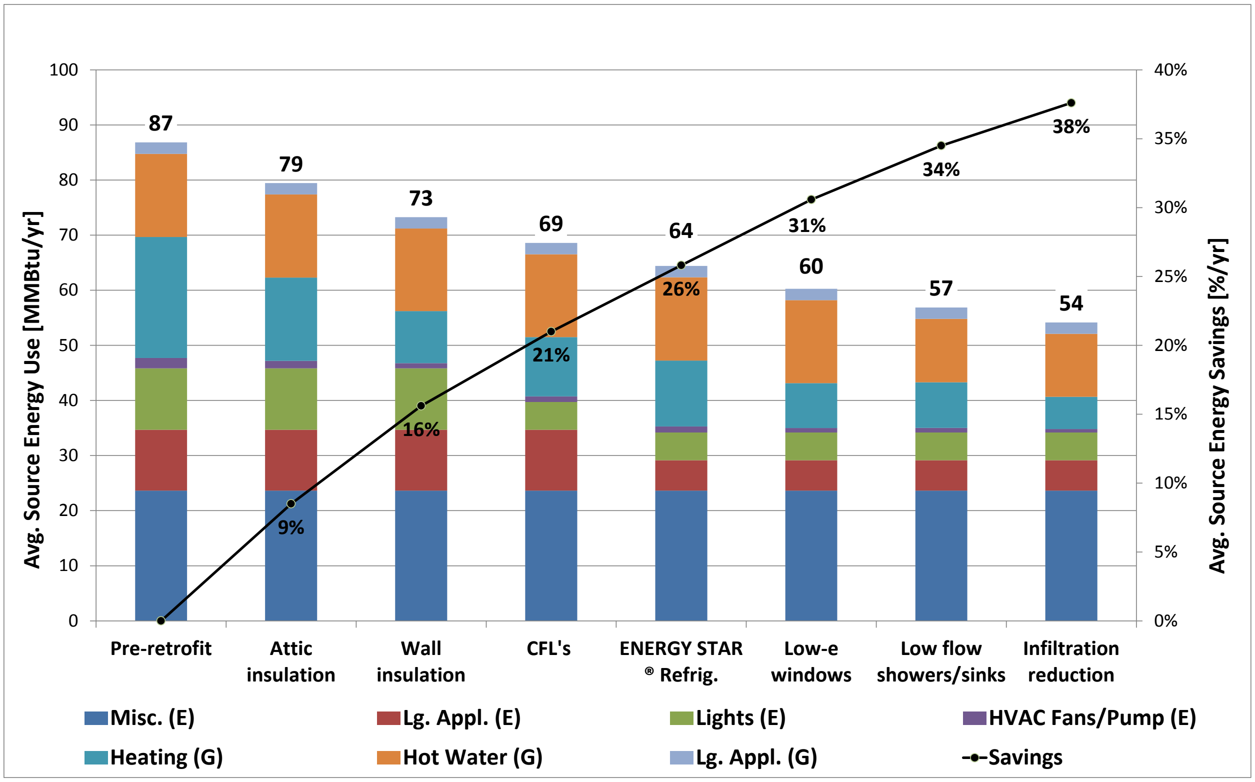

Figure 11. Cumulative energy savings

As seen in Figure 11, adding attic floor insulation results in the greatest savings for these units. This diagram also reveals that improvements to the building envelope (added insulation, window upgrades, and the infiltration reductions that result) account for ~60% of the total savings. As expected, these building envelope improvement measures are most effective in reducing gas usage. Lighting and refrigerator placements also provide significant contributions to the total savings. These two electricity-based measures are responsible for ~30% of the total savings. The last portion of the savings, ~10% of the total, comes from benefits of low-flow sinks and showerheads. This improvement saves both gas needed to provide domestic hot water while also preserving water itself. (Note: recent versions of BEopt software no longer have inputs for modeling savings from low-flow fixtures.)

5 Discussion

Since post-retrofit bills were available for only four months, the building improvements were compared for the four-month period of August through November only. Fortunately, this time period encompasses both heating and cooling conditions for the region. However, extrapolating the four-month, post-retrofit utility usage out to an entire year would have stretched the limits of its accuracy. Year-long extrapolation, on a per-day or HDD basis, would involve making several assumptions that would have significantly skewed the accuracy of the analysis.

There are a variety of elements that influence the model's projected savings and energy use of each unit. Primary factors include number of exposed walls, number of shared walls, finished floor area (FFA), number of bedrooms, and presence of vented attic space. A categorized breakdown of each unit's pre- and post-retrofit energy uses, as well as the projected savings, based on simulation, has been provided in Figure 12. Total source energy savings between pre- and post-retrofit cases (show at the top of the chart) ranged from 27% to 41%.

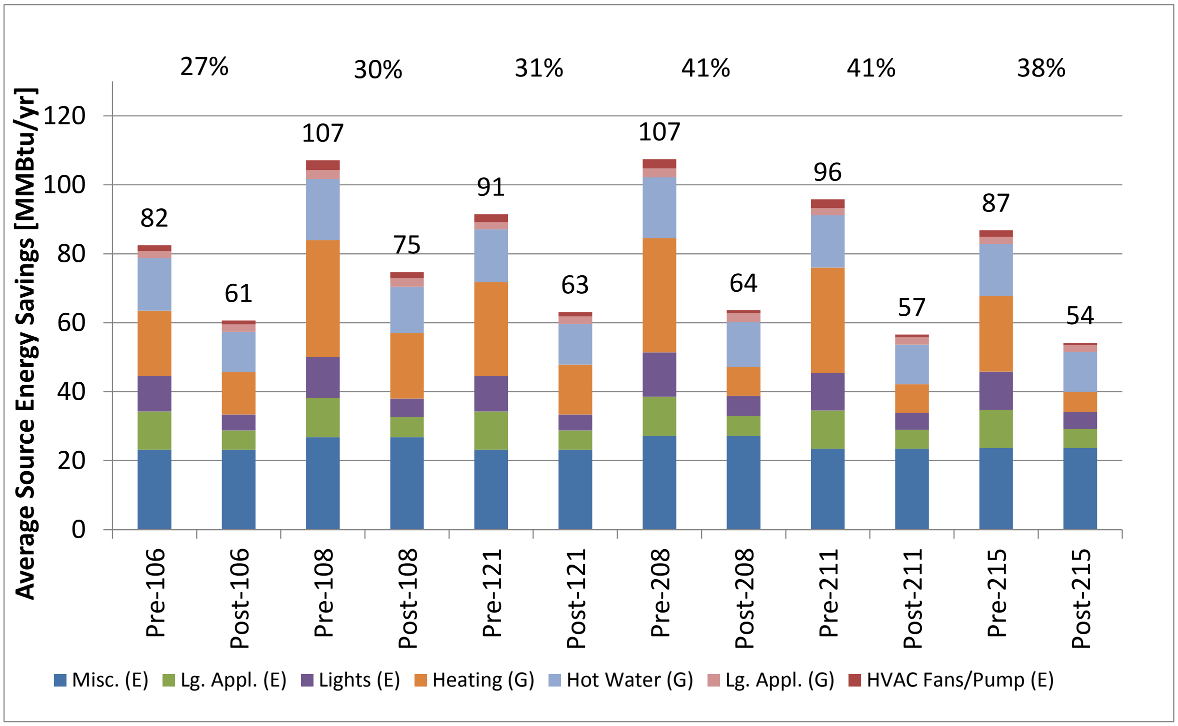

Figure 12. Individual unit predicted savings

Units that are located on the second floor were projected to experience significantly higher savings than first-floor units. This difference in savings is primarily due to the R-50 cellulose insulation upgrade performed in all second-floor units. On average, second-floor units saw projected savings 10.5 percentage points higher than first-floor units.

Another important difference between the first- and second-floor units stems from the impact that an uninsulated slab-on-grade foundation has on overall heating use. As seen in Figure 12, the energy usage predictions of pre-retrofit units #108 and #208 are very similar. However, it would intuitively seem that the second floor units should use significantly more heating energy during the pre-retrofit case because of their poorly insulated attics. (Note: the pre-retrofit first-floor ceilings are modeled as adiabatic surfaces while second-floor ceilings are modeled with R-9 ceiling insulation). This indicates that the model predicts that a poorly insulated foundation slab in cold-climate regions can have a comparably negative impact to a poorly insulated roof.

The effect of insulating the slab to theoretical adiabatic conditions was examined in BEopt. The results indicate that unit #108, with an adiabatic slab, would use ~38% less space heating energy than with its current uninsulated case. The prediction for such a large reduction in energy use is partly due to the fact that the slab perimeter is a large percentage of the total exposed surface area in the model even though the area itself is not very large. Even so, in reality it seems highly unlikely that insulating the slab would have a similar effect to that of insulating an R-9 vented attic to R-50.

Unit location (interior versus exterior) also had a significant influence on savings levels. An aerial view of the complex with each unit's approximate location is provided in Figure 13. Units located on the end of the complex, as opposed to those located between two others, often saw higher savings due to the greater percentage of exposed wall area.

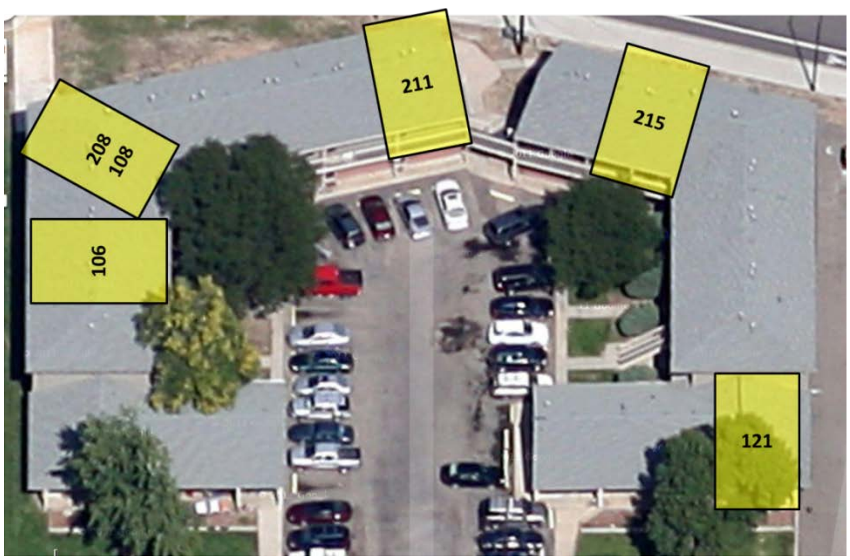

Figure 13. Building location of analyzed units

5.1 Assessing Modeling Assumptions

Energy modeling can be a useful tool for forecasting savings that accompany a building retrofit. However, the accuracy of modeling is directly contingent upon user input and software capabilities. There are limitations to all energy modeling software that can influence the accuracy of their predictions. The following sections discuss modeling assumptions and limitations of the results generated with BEopt E+ 1.4.

5.1.1 Weather Files

It is important to consider the differences that exist between the input weather data used by modeling software and the actual weather conditions experienced during the time of utility bill collection. The modeling software used in this analysis utilizes weather characteristics from the TMY3 database. This database includes weather files for Boulder, Colorado based on typical conditions between 1976 and 2005. Consequently, this database represents the weather values for a typical year only and will not be fully applicable to the analysis of a year when extreme weather patterns existed. In order to minimize this effect, gas use data were normalized per HDD.

The differences between the TMY3 weather data used in modeling and the actual conditions are summarized in Table 6. Compared to the typical year, the heating seasons for both 2008 and 2012 were milder than the TMY3 data indicate.

Table 6. HDD Data

Weather Conditions (August Through November)	HDD_{65} (°F-day)	Percent Difference From Typical (%)
TMY3 (30-Year Typical)	1,314	–
Pre-Retrofit Bills (2008)	1,221	–7.1%
Post-Retrofit Bills (2012)	1,148	–12.6%

5.1.2 Shared Surfaces

Some of the discrepancies between actual energy use and modeled results may be explained by the limitations of the software and assumptions that were made when modeling the building geometry of each unit. For instance, modeling only one floor of a multiple-story building (when units are located on either the first floor or second floor) presented a unique challenge that stretched the capabilities of BEopt. Since the software does not directly have an option to model this feature, shared floors and ceilings were modeled as near-adiabatic surfaces by increasing the R-values to extremely high levels and reducing the framing factors drastically. The ceiling of a first-floor unit (with another unit above) was modeled as a high resistance, near-adiabatic surface. Alternatively, the floor of a second-story unit was modeled as a crawlspace with near-adiabatic qualities. Figure 14 and Figure 15 show examples of these occurrences in units #108 and #208. Even though these units were attached, with #208 being the second floor over #108, they needed to be modeled as two separate buildings in order to run a BEopt energy simulation.

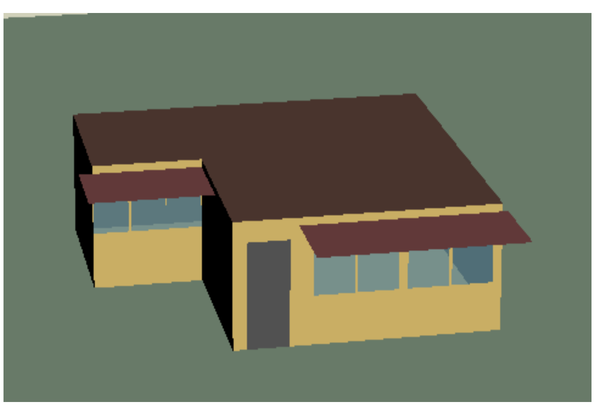

Figure 14. Geometry of unit #108

Figure 15. Geometry of unit #208

Since the temperature difference between the two floors was not exactly zero, the intermediate surface between them was not truly adiabatic. It is likely that a significant amount of heat from the first-floor units was transferred to the second-floor units. This provides a probable explanation as to why the model overpredicted energy use on all three second-floor apartments.

5.1.3 Predicted Electric Loads

Besides making predictions for major appliances, lighting, and heating, ventilation, and air conditioning, energy modeling software estimates miscellaneous electric loads (MELs). These electric loads include plug-in electronics such as televisions, computers, and microwaves. There are various methods for estimating this electricity use, however, energy modeling typically makes predictions that are heavily influenced by FFA and number of bedrooms (#BR) in the home. For instance, the MEL estimate for a gas/electric household in BEopt is based on the BA House Simulation Protocol developed by NREL and is calculated with the linear equation form that is indicated in Equation 1 (Hendron and Engebrecht 2010).

$$\mathrm{MEL}_{\mathrm{Total}} = \mathrm{MEL}_{\mathrm{Baseline}} + C_1(\#\,\mathrm{BR}) + C_2(\mathrm{FFA.}). \qquad (1)$$

C_1 is a coefficient in the units of MEL kWh/#BR, and C_2 is a coefficient in the units of MEL kWh/FFA. This equation assumes that all units use at least a baseline MEL of 1,595 kWh/yr (barring unit size or occupancy levels and based on 100% of benchmark use).[1] To put this into perspective, the actual 2008 total annual pre-retrofit electricity use of the one-bedroom units in this study averaged only 2,462 kWh, while the BEopt model predicted an average MEL of 2,038 kWh. Hence, even before major appliances and lights have been factored into the modeling estimates, the model already accounted for 83% of the actual pre-retrofit energy usage. It is important to note that this equation was developed to model single-family homes. As a result, using it to estimate electricity usage in smaller multifamily apartments may be inappropriate. Further research needs to be carried out in order to develop an appropriate MEL equation that can be used to accurately describe energy usage in small multifamily units.

In order to quantify the baseline electrical energy use, actual and predicted pre-retrofit electricity usage for two units was plotted against outdoor air temperature (OAT). Total baseline electricity use is referred to as the building's electricity use that is independent of heating or cooling consumption. Figure 16 demonstrates this relationship for unit #106. As seen from modeling predictions, baseline energy appears to decrease as OAT increases. This trend is a factor of increased lighting needed during winter months rather than electrical energy needed for supplemental heat. From actual use, it appears that this tenant used a supplemental electric resistance heater during cold OATs. As a result, these occurrences were excluded from the baseline calculation.

[1] Energy usage of a benchmark home is structured after a typical 2009 International Energy Conservation Code-built home

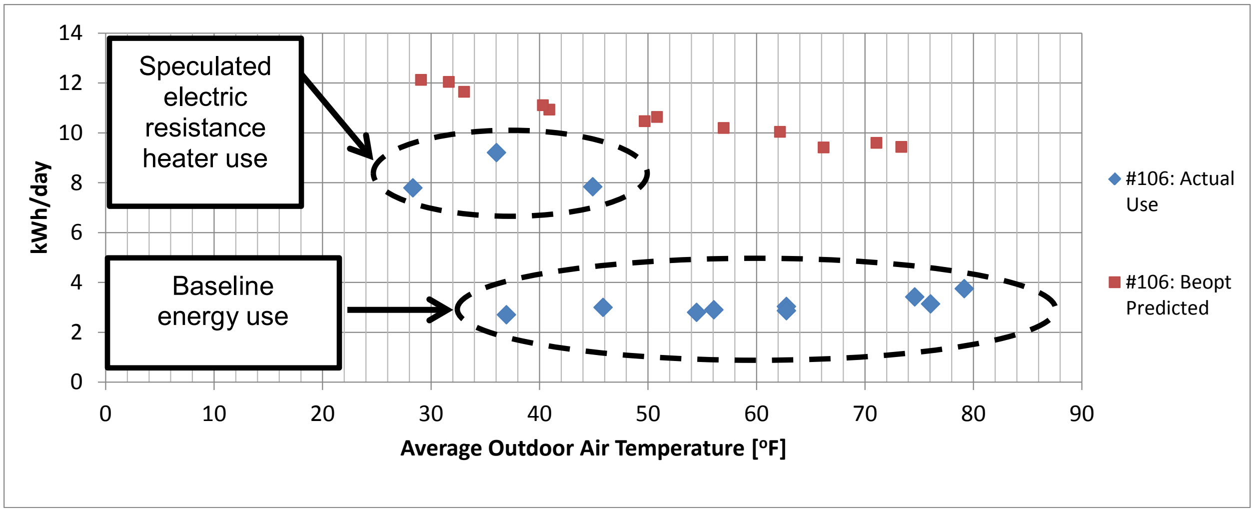

Figure 16. Electricity usage rate versus OAT for #106

Alternatively, Figure 17 shows electricity usage rates for unit #208. The large electricity usage spike that occurs during hot temperatures (> 75°F) is likely a result of the tenant using a window air conditioning unit. These occurrences were also excluded from the baseline energy estimates. As opposed to unit #106, the model was able to accurately predict baseline energy use for this unit. The increased accuracy may be dependent on the fact that this is one of the larger units in the study (~650 ft^2 and 2); therefore more directly correlating with the electrical usage trends of the benchmark home.

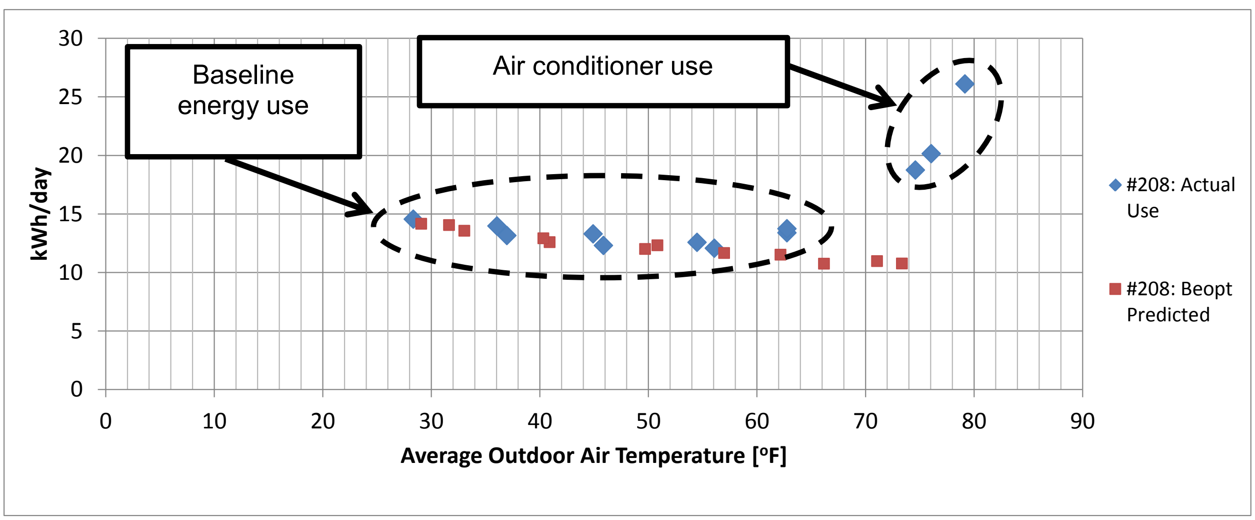

Figure 17. Electric usage rate versus outdoor air temperature for #208

After removing supplemental electric heating and cooling use with the filtering method shown above, the average kWh/day baseline electrical use was determined for each unit. These rates ranged from 2.9 to 13.2 kWh/day. There is a large variation between the units, indicating the significant impact that tenant behavior has on energy usage. This rate was then used to estimate annual baseline usage and was compared to BEopt's predictions. The agreement between actual and predicted baseline use is shown in Figure 18. As seen from this graph, a majority of the baseline use is overpredicted. On average, BEopt total baseline energy use overpredicted electricity usage by 49% for these small attached units. Further disaggregation of the baseline energy use was not possible with just utility bill data.

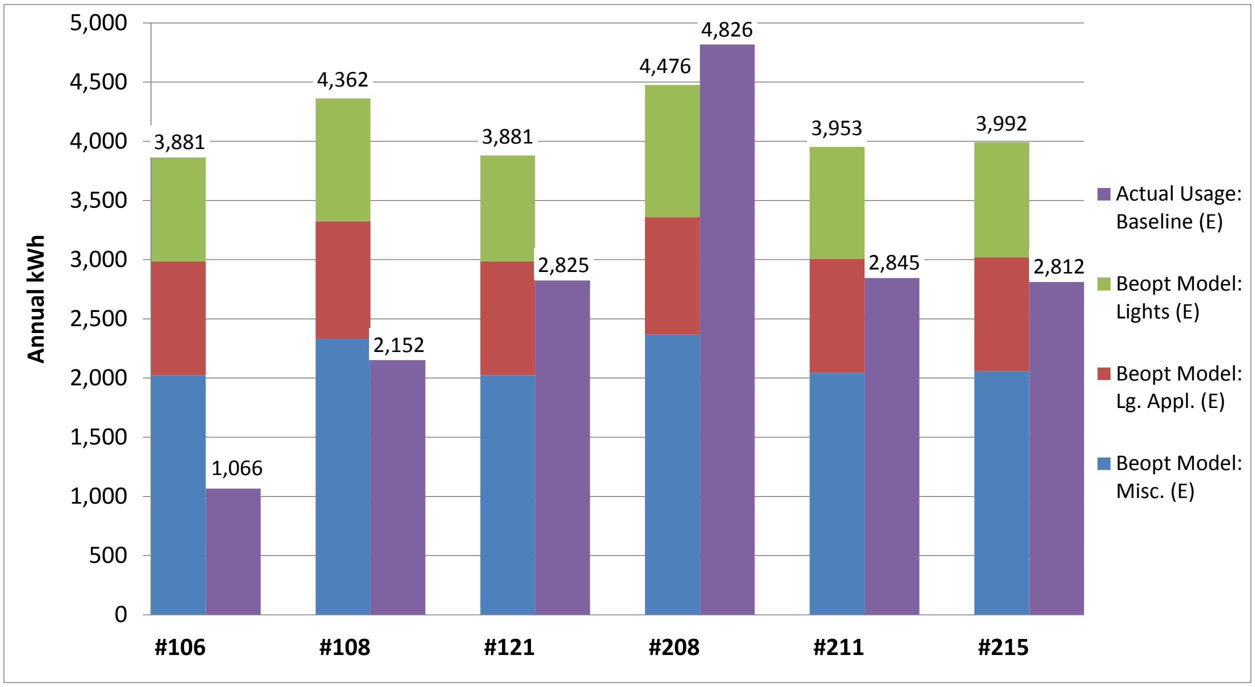

Figure 18. Comparison of predicted and actual baseline electrical energy use

While MEL energy use is often hard to predict, because it is highly dependent on the individual homeowner, past research has shown that MELs are expected to consume 29% of total electric load and the percentage is expected to grow to 36% by 2020 (Roth et al. 2008). However, predicted MELs for these units account for more than 50% of the predicted total baseline electricity consumption. Based on this fact and the results of this study, further analysis into the appropriateness of the BA house simulation protocol assumptions for MELs for multifamily apartments seems warranted.

5.1.4 Occupant Behavior

One of the most important influences on a building's energy use is the tenant's behavior. Unfortunately, this is often one of the most difficult factors to predict. Energy simulation software makes assumptions on tenant-influenced factors such as indoor temperature set points and occupancy schedules. Any changes to these assumptions by the occupants will significantly skew the results. For instance, indoor set point was assumed to be 71°F for all units in this analysis. If some units were kept at a lower set point (which is likely), the model would have overpredicted natural gas usage. During the spot audits, it was noted that several thermostats were set lower than 71°F. They were not programmable thermostats though, and therefore, it could not be determined what their normal settings were. Only one occupant was available the day of the audit to answer these types of questions, and indicated that the thermostat was kept at 68°F most of the time. This tenant also indicated that, even while his heat wasn't working at the time of the audit, the apartment never really got very cold in the winter. He did have a room air conditioner in his apartment, but indicated that he rarely used it. As a matter of record, several of the students had their thermostats completely turned off the day of the audits despite the OAT being only 30°F.

Overall, because this housing complex is primarily inhabited by students who are extremely transient, the energy improvements have not resulted in reduced occupancy turnover. The management company indicated that, while it has no problem renting the units, the ultimate goal of many of the students is to eventually find housing in a more desirable location in one of Boulder's more popular areas. Evaluating the effects of energy improvements on occupant turnover would be better answered in a multifamily building where turnover is more typical. The fact that there were different tenants during the pre- and post-retrofit case introduces an additional source of error to the study's results.

5.1.5 Measuring Infiltration in Attached Dwellings

Some of the differences between the energy model and actual energy usage may have evolved from the way that infiltration was measured and modeled. For this analysis, unguarded blower door tests were performed during the pre- and post-retrofit cases. As a result, air leakage values were collected and modeled under the assumption that all measured air leakage was through surfaces exposed to the outdoors. However, for units with shared walls, some of the leakage was most likely between the conditioned spaces and would not directly attribute to heating energy use.

In a previous study, CARB analyzed the relationship between guarded and solo blower door testing. The intent of this study was to investigate an approach for developing an algorithm that helped indicate the corresponding guarded blower door leakage based on a solo leakage value and a collection of variables (unit location, exposed wall area, common wall area, etc.). This study suggested that for retrofit work, if total leakage is assumed to be all to the outside, the energy benefits of air sealing can be significantly over-predicted. (Faakye et al. 2013).

In this study, the total gas savings were overpredicted by 2.5 percentage points. This overprediction may have stemmed from an overprediction in infiltration due to the testing method chosen. For instance, results from the unguarded blower door measurements show that infiltration was reduced from 17.1 ACH50 to 12.8 ACH50 (a net reduction of 4.3 ACH50). The algorithm developed by CARB (still a work in progress) suggests that the actual leakage to the exterior may have only been 70% of the leakage measured during the unguarded test. This would mean that the true reduction in air leakage due to the retrofits may have been closer to a reduction from 11.97 ACH50 to 8.96 ACH50 resulting in a net reduction of only 3 ACH50.

6 Conclusions

Given the age and number of existing multifamily housing units in the United States, there is the potential for substantial reductions in building energy use if improvements are made. The first step to achieving this reduction is the accurate modeling and prediction of the buildings' existing consumption. If accurate models are not available, designers, property owners, and administrators of efficiency programs will not have the ability to make the most cost-effective, impactful recommendations and decisions. This project attempted to provide insight into the predicted versus actual energy use of a 37-unit, multifamily apartment complex in climate zone 5B. Utility bill analysis, spot audits, and modeling have led to the following conclusions.

Q. For this building complex in Boulder, Colorado, what are the actual energy savings realized from the improvements compared to the predicted savings?

A. Savings from the retrofit measures were calculated on an individual apartment basis and for all six apartments together. Total savings for the six units showed excellent agreement between predicted and actual values for both gas and electricity use. Total gas and electricity savings for the six apartments were predicted to be 61% and 27%, respectively. Actual gas and electricity savings were 58% and 30%, respectively.

Q. Can discrepancies between modeled bills and actual bills be explained? If so, are changes to the accepted modeling assumptions needed?

A. Differences between predicted and actual savings for the individual apartments varied more widely than differences between the totals of all six apartments. Actual natural gas savings and predicted savings vary significantly between units. The model did not consistently over- or underpredict gas use for the six units when analyzed individually. The only consistent trend displayed is a consistent decrease in actual gas usage between pre-and post-retrofit periods for every unit, though the magnitude of that savings varies significantly.

No discernible patterns in the predictions for gas use were found. There were both under- and overpredictions for the apartments and the magnitude of those predictions varied widely as well. Discrepancies between predicted and actual bills may have arisen through a variety of sources and were discussed in detail in the previous section. The most significant factor may be that all of these units were occupied by two different tenants during the two periods analyzed—2008 and 2012. Considering that not one thermostat was set to 71°F during the spot audits, this room temperature assumption may need to be reevaluated. This activity is currently underway by NREL.

Unlike gas use, the energy model consistently overpredicted electricity use in all but one of the 12 models. Researchers anticipate that the BA house simulation protocol assumptions for baseline electricity usage (lighting, appliances, and MELs) may be too high for small apartments. The appropriateness of these BA assumptions should be examined for multifamily housing units.

Q. What are the most common changes made by renters that will negatively impact post-retrofit energy savings; e.g., replacing compact fluorescent lamps with incandescent light, installing window air conditioners? And what is the extent of that impact?

Several of the apartments had incandescent bulbs in the light fixtures, but not in every fixture. The largest percentage of incandescent to fluorescent noted was approximately 50%. Three of the nine units inspected had window air conditioners in the apartments, but none had more than one. No supplemental heaters were found in any unit despite the fact that the heating systems are convection, point-source heaters located in the living room. Very few post-retrofit changes were discovered.

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Appendix A. Pre-Retrofit Utility Data

Unit	Usage month	Read date	Days	Therms	HDD	Gas bill	Read date	Days	KWh	KWh bill	Therm/HDD	KWh/day
#106	Nov	12/4/2008	31	32	713	$ 35.71	12/3/2008	30	90	$ 16.05	0.07	3.09
	Oct	11/3/2008	31	31	363	$ 34.22	11/3/2008	31	90	$ 16.09		
	Sep	10/3/2008	29	17	102	$ 22.61	10/3/2008	29	88	$ 17.58		
	Aug	9/4/2008	31	10	43	$ 22.62	9/4/2008	31	106	$ 19.87		
#108	Nov	12/4/2008	31	4	713	$ 14.86	12/3/2008	30	196	$ 26.06	0.01	5.96
	Oct	11/3/2008	31	5	363	$ 15.49	11/3/2008	31	166	$ 23.24		
	Sep	10/3/2008	29	4	102	$ 14.41	10/3/2008	29	142	$ 23.71		
	Aug	9/4/2008	31	5	43	$ 17.40	9/4/2008	31	217	$ 32.69		
#121	Nov	12/4/2008	31	37	713	$ 39.46	12/3/2008	30	300	$ 35.91	0.06	8.51
	Oct	11/3/2008	31	24	363	$ 29.17	11/3/2008	31	255	$ 31.61		
	Sep	10/3/2008	29	10	102	$ 18.16	10/3/2008	29	230	$ 33.68		
	Aug	9/4/2008	31	2	43	$ 13.94	9/4/2008	31	245	$ 35.93		
#208	Nov	12/4/2008	31	42	713	$ 43.16	12/3/2008	30	369	$ 42.40	0.07	14.15
	Oct	11/3/2008	31	31	363	$ 34.21	11/3/2008	31	374	$ 42.85		
	Sep	10/3/2008	29	7	102	$ 16.26	10/3/2008	29	388	$ 51.59		
	Aug	9/4/2008	31	5	43	$ 16.98	9/4/2008	31	581	$ 74.78		
#211	Nov	12/4/2008	31	36	713	$ 38.71	12/3/2008	30	178	$ 24.39	0.05	9.74
	Oct	11/3/2008	31	18	363	$ 24.85	11/3/2008	31	224	$ 28.70		
	Sep	10/3/2008	29	4	102	$ 14.37	10/3/2008	29	260	$ 37.08		
	Aug	9/4/2008	31	0	43	$ 11.88	9/4/2008	31	517	$ 67.36		
#215	Nov	12/4/2008	31	18	713	$ 25.29	12/3/2008	30	264	$ 32.46	0.03	7.87
	Oct	11/3/2008	31	14	363	$ 21.95	11/3/2008	31	218	$ 28.15		
	Sep	10/3/2008	29	7	102	$ 19.86	10/3/2008	29	257	$ 51.67		
	Aug	9/4/2008	9	0	15	*	9/4/2008	9	40	$0		

* Bill was added to following month

Appendix B. Post-Retrofit Utility Data

Unit	Usage month	Read date	Days	Therms	HDD	Gas bill	Read date	Days	KWh	KWh bill	Therm/HDD	KWh/day
#106	Nov	12/4/2012	33	4	614	$ 15.15	12/3/2012	33	138	$ 23.13	0.016	4.69
	Oct	11/1/2012	29	3	455	$ 14.57	10/31/2012	29	136	$ 22.93		
	Sep	10/3/2012	29	3	79	$ 30.96	10/2/2012	29	137	$ 59.58		
	Aug	9/4/2012	32	8	0	*	9/3/2012	29	152	*		
#108	Nov	12/4/2012	33	0	614	$ 12.81	12/3/2012	33	137	$ 23.03	0.001	6.52
	Oct	11/1/2012	29	0	455	$ 12.80	10/31/2012	29	138	$ (8.03)		
	Sep	10/3/2012	29	1	79	$ 13.08	10/2/2012	29	250	$ 48.66		
	Aug	9/4/2012	32	0	0	$ 12.63	9/3/2012	29	257	$ 49.27		
#121	Nov	12/4/2012	33	16	614	$ 20.73	12/3/2012	33	253	$ 35.38	0.05	9.24
	Oct	11/1/2012	29	14	455	$ 19.61	10/31/2012	29	242	$ 34.21		
	Sep	10/3/2012	29	12	79	$ 16.78	10/2/2012	29	286	$ 37.29		
	Aug	9/4/2012	32	13	0	$ 17.06	9/3/2012	29	328	$ 41.40		
#208	Nov	12/4/2012	33	4	614	$ 15.15	12/3/2012	33	213	$ 31.14	0.01	7.91
	Oct	11/1/2012	29	5	455	$ 15.74	10/31/2012	29	179	$ 27.48		
	Sep	10/3/2012	29	3	79	$ 13.97	10/2/2012	29	285	$ 37.20		
	Aug	9/4/2012	22	4	0	$ 11.01	9/3/2012	21	209	$ 35.21		
#211	Nov	12/4/2012	33	18	614	$ 23.42	12/3/2012	33	60	$ 14.82	0.04	2.41
	Oct	11/1/2012	29	10	455	$ 18.69	10/31/2012	29	64	$ 15.23		
	Sep	10/3/2012	29	8	79	$ 16.23	10/2/2012	29	77	$ 16.18		
	Aug	9/4/2012	24	6	0	$ 12.71	9/3/2012	23	74	$ 22.18		
#215	Nov	12/4/2012	33	4	614	$ 15.15	12/3/2012	33	103	$ 19.36	0.01	3.93
	Oct	11/1/2012	29	3	455	$ 14.57	10/31/2012	29	111	$ 20.25		
	Sep	10/3/2012	29	3	79	$ 13.97	10/2/2012	29	133	$ 21.84		
	Aug	9/4/2012	12	1	0	$ 5.49	9/3/2012	11	54	$ 16.83		

* Bill was added to following month

Appendix C. Post-Retrofit Audit Summary

Unit #	Type	Utility Bill Data?	Floor Area (ft^2)	# Attached Walls	# Bedrooms
103	First-floor end apartment – no apartment above	No	433.3	1	1
106	First-floor middle unit – conditioned space above	Yes	433.3	2	1
108	First-floor middle unit – conditioned space above	Yes	573.0	2	2
117	First-floor middle unit – conditioned space above	No	433.3	2	1
119	First-floor end unit – no apartment above	No	729.5	1	3
121	First-floor end apartment – no apartment above	Yes	433.3	1	1
208	Second-floor middle unit – conditioned space below	Yes	647.3	2	2
211	Second-floor end unit	Yes	490.4	1	1
215	Second-floor middle unit	Yes	490.4	2	1

Appendix D. Spot Audits: Tenant Modification Assessment

Unit #	Lighting		Space Conditioning Modifications	Faucet Flow Rate (GPM)	ACH 50
	Compact Fluorescent Lamps	Incandescent			
103	8	0	N/A	N/A	10.6
106	N/A	N/A	N/A	-	12.8
108	13	4	N/A	<1.5	10.3
117	5	0	A/C in living room	<1.5	N/A
119	9	8	A/C in bedroom	<1.5	8.4
121	5	1	A/C in bedroom	N/A	15.8
208	5	3	Fans in rooms	<1.5	8.8
211	11	0	none	<1.5	10.1
215	5	2	none	<1.2	12.8

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