Need for Systematic Retrofit Analysis in Multifamily Buildings

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ABSTRACT

Multifamily housing offers high potential for energy savings through retrofits. A comprehensive energy audit with systematic evaluation of alternative energy measures is one of the key steps to realizing the full energy savings potential. However, this potential often remains unrealized when the selection of measures is (1) based on a one-size-fits-all approach originating from accustomed practices, (2) intended merely to meet code-compliance requirements, and/or (3) influenced by owner–renter split incentive. In such cases, the benefits of comprehensive energy auditing are disregarded in view of the apparent difficulty in diagnosing multifamily buildings, evaluating alternative measures, and installing customized sets of measures.

This paper highlights some of the barriers encountered in a multifamily housing retrofit project in Georgia and demonstrates the merits of systematic retrofit analysis by identifying opportunities for higher energy savings and improved comfort and indoor air quality that were missed in this project. The study uses a whole-building energy analysis conducted for a 10-unit, low-rise, multifamily building of a 110-unit apartment complex. The analysis projected a 24% energy savings from the measures installed in the building with a payback period of 10 years. Further analysis with a systematic evaluation of alternative measures showed that without compromising on the objectives of durability, livability, and appearance of the building, energy savings of up to 34% were achievable with a payback period of 7 years. The paper concludes by outlining recommendations that may benefit future retrofit projects by improving the audit process, streamlining tasks, and achieving higher energy savings.

Introduction

According to 2009 Residential Energy Consumption (RECS) survey data (EIA 2013), among 113.6 million housing units in the United States, 28.1 million (24.7%) are in multifamily buildings. The annual income of 38% of multifamily households is less than $20,000, and 25.5% of these households have incomes below the poverty line. The annual average energy expenditure in multifamily units is $1,290/household, 41% less than the national average of $2,204/household. However, given their lower average income, the energy expenditure is a larger burden for multifamily households. The energy use intensity in multifamily units is 60 kBtu/ft^2, 32% higher than the national average of 45.5 kBtu/ft^2 in a housing unit (EIA 2013). Over 70% of existing multifamily buildings were built before the introduction of energy codes in 1978 (Benningfield Group 2009). With these facts in view, multifamily buildings present a tremendous opportunity for improving energy efficiency.

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Several studies have estimated the potential for energy savings in multifamily buildings. Current programs have shown that comprehensive retrofits can cost-effectively improve the energy efficiency of multifamily buildings by 30% for natural gas and 15% for electricity, which would translate into annual utility bill cost savings of almost $3.4 billion (ACEEE 2013). Benningfield Group (2009) estimated that energy retrofits could achieve a 30% improvement in energy efficiency by 2020. McKinsey and Company estimated potential energy cost savings of $16 billion in low-income multifamily buildings between 2009 and 2020 (Granade et al. 2009). Several case studies have reported over 40–50% measured or simulated savings for multifamily retrofit projects that used systematic selection of measures (Lyons 2013; Lyons et al. 2013; Majersik 2005; Arena and Williamson 2013).

Some studies have investigated the potential barriers to investing in multifamily housing retrofits, which is one of the first steps in realizing the projected savings. According to the 2009 RECS survey data (EIA 2013), about 85% of multifamily units are rented; and in 83% of the rental units, tenants are responsible for the energy/utility bills. Thus the owner–renter split incentive, whereby the building owners gain no apparent benefits from energy retrofits, is considered a major barrier in pursuing energy retrofits in multifamily buildings (Golove and Eto 1996; HUD 2011a). On the other hand, a survey conducted by Dyson et al. (2010) found no evidence supporting this theory. In fact, the survey identified as the key barriers a lack of awareness on the part of building owners of programs, incentives, and financing options; a lack of data on savings from energy retrofits; a lack of installation and maintenance expertise; and legal/regulatory procedures. The Energy Programs Consortium (EPC 2013) provides a comprehensive review of such barriers and of emerging practices aimed at addressing these barriers through a wide variety of initiatives, pilots and programs. These practices aim to educate, encourage, and enable building managers/owners to pursue energy retrofits (HUD 2011b; SCE 2014) and strengthen the retrofit workforce through training and technical assistance (Somers et al. 2011).

Despite these efforts, properties receiving energy retrofits often fail to realize the higher potential for energy savings for the cost incurred when the selection, installation, or maintenance of energy efficiency measures (EEMs) is not conducted properly. Several factors contribute to this effect. Many times, the retrofit program requirements are prescriptive rather than performance-based, usually generated from minimum code-compliance requirements. They offer no incentives to consider energy auditing for systematic selection of measures to achieve higher energy savings. Moreover, energy auditing and installation of a customized set of measures require more time and money and require skills beyond the customary practices. Also, the owner–renter split incentives, once again, may influence the retrofit decisions to favor the appraisal of property value versus maximizing energy efficiency. These factors often result in a "less-than-optimum" solution for the allocated cost.

This paper highlights some of the barriers encountered in a multifamily housing retrofit project in Georgia. Through a systematic analysis, this study identifies opportunities for higher energy savings and improved comfort and indoor air quality that were missed in this project. The paper concludes by outlining recommendations that may benefit future retrofit projects by improving the audit process, streamlining tasks, and achieving higher energy savings.

Recommended Energy Audit and Retrofit Analysis Approaches

Energy auditing with systematic selection of EEMs is one of the key steps in realizing potential savings from energy retrofits. Some programs are designed to mandate or encourage systematic evaluation of measures. For example, the Weatherization Assistant Program (WAP) requires that EEMs be selected systematically either using energy audits or from a priority list developed using energy audits (10 CFR §440.21 2014). The Multifamily Energy Efficiency Program (MEEP) encourages the use of energy modeling by providing incentives when energy modeling is used to investigate the economics and technical feasibility of energy-efficiency investment options (APS 2014).

A building energy audit comprises several steps. These steps are categorized differently by different entities. ASHRAE (2011) defines three levels of audits for commercial buildings (Table 1) that could be adapted to all building types. Each audit level builds on the previous level. As audit complexity increases, so do the thoroughness of the site assessment, the amount of data collected, and the detail provided in the final audit report. This effort can translate into higher energy savings (PNNL 2011).

Table 1. Audit levels for commercial building energy audit (ASHRAE 2011)

Audit level	Objectives	Activities
Preliminary Energy Use Analysis	Benchmark building energy use	Assessment of energy bills and comparison with similar buildings
Level I: Walk-through	Identify no-cost and low-cost energy saving opportunities and obtain a general view of potential capital improvements	A brief site inspection of the building, a rough cost and savings analysis for EEMs
Level II: Energy Survey and Analysis	Provide EEM recommendations in line with the financial plans and potential capital-intensive energy savings opportunities	In-depth analysis of energy costs, energy usage, and building characteristics, and a more refined survey of how energy is used in the building
Level III: Detailed Survey and Analysis	Provide refined recommendations and financial analysis for major capital investments	Monitoring, data collection, and a thorough analysis of EEMs

EPA (2013) describes two basic approaches to calculate energy savings: deemed savings and measured savings. The deemed savings approach uses energy savings estimates per EEM derived from historical evaluations and is appropriate for evaluating simpler measures with well–known and consistent performance characteristics. This approach aligns with ASHRAE audit level I. The measured savings approach is appropriate for large buildings with complex systems, for EEMs that are expected to result in significant savings or have a high degree of uncertainty, or for situations in which interactive impacts of all energy measures are accounted for. This approach seems in line with ASHRE audit levels II and III. This approach involves determining energy savings from pre- and post-retrofit energy use estimation using one or more of the following techniques:

- Engineering methods, based on standard formulas and assumptions
- Statistical analyses, while accounting for weather, occupancy, hours of operation, and other factors that affect energy use
- Computer simulations, which are typically calibrated with actual performance data
- Metering and monitoring, while accounting for the non-energy factors that affect energy use.

Depending on the available resources, one or more of these techniques can be employed to estimate energy savings with a desired level of accuracy. However, to avoid results that yield too much or too little detail, the analysis methodology should be determined from the project goals (PNNL 2011). Regardless of the approach selected, a key goal for evaluation is to minimize uncertainty while balancing evaluation costs with the value of the information received (EPA 2013).

Energy Audit Challenges in Multifamily Buildings

In multifamily buildings, energy auditing is highly challenging at each audit level. Preliminary energy use analysis requires only utility data. However, because multifamily buildings contain multiple units, auditors may need to resort to a sample of units. Sample size and sampling methods may vary by program requirements and audit protocols. Uncertainty arises because sample units may not always represent the variability among the multifamily units. A Level I audit requires site inspection and may require inspecting sample units, which is often difficult to do in occupied units. Level II and III audits require more detailed energy and cost analysis, end-use energy use determination, instrumented building diagnosis, and energy modeling. Because of the diversity of building types and metering configurations and the variability of occupancy characteristics of households in a building, end-use energy use determination is not straightforward. Diagnosis of multifamily buildings, especially multi-blower door testing is challenging, time consuming, and costly. Energy modeling of multifamily buildings consisting of multiple thermal zones and complex system configurations is another challenging task, especially because of the lack of simple and easy-to-use tools. The following case study is no exception.

Case Study of a Multifamily Housing Retrofit

Maplewood Park Apartments (Figure 1a) consists of 11 low-rise, 10-unit, garden style apartments that provide low-income rental housing to families and senior citizens. It is located in Union City, Georgia—a suburb, 18 miles southwest from Atlanta. Built in 1993, Maplewood underwent minor renovations in 2008, during which heating, ventilation, and air-conditioning (HVAC) systems, appliances, and/or domestic water heaters in some units were replaced because of specific system failures. In 2010, Maplewood received federal Low Income Housing Tax Credit (LIHTC) financing via the 2010 Georgia Qualified Allocation Plan (QAP) through a competitive process. Renovation of Maplewood started in December 2011 and was completed in October 2012.

The following sections outline the circumstances that drove the retrofit selection process in this project to deviate from the recommended approaches discussed earlier and demonstrate the application of systematic retrofit analysis in 1 of the 11 buildings of Maplewood (Figure 1b).

Figure 1. Case-study building[2] in Maplewood Park Apartments.

Motivation for Renovation and Measure Selection Criteria

According to the eligibility criteria for LIHTC financing through QAP (GDCA 2010), the building owner must commit to long-term ownership, all major renovations must incorporate EEMs, and the project must obtain a third-party green building certification. The 2010 QAP requires the project to earn a minimum of 10 out of 40 points in at least 4 out of 7 categories, which include energy-efficient building envelope, lighting, water conservation, indoor air quality, resource efficiency, education, and innovation. In addition, the project must meet or exceed compliance with the Georgia Energy Code (i.e., 2009 International Energy Conservation Code); meet or exceed minimum efficiency standards for HVAC and domestic hot water (DHW) systems; and install Energy Star® refrigerators, dishwashers, and clothes washers.

These requirements motivated the property owners to invest in upgrades for energy efficiency, durability, and appearance of the buildings. However, the selection of energy measures was made without performing an energy audit. To meet the program eligibility requirements, the selected measures included air sealing and duct sealing; installation of insulation in crawlspace and attic; and replacement of windows and doors, HVAC and DHW systems, plumbing fixtures, lighting and appliances, and roofing and wall siding. Table 2 summarizes the pre and post-retrofit building characteristics of Maplewood.

Energy Audit for HERS Rating

To obtain the third-party green building certification, energy professionals were consulted at a later stage to conduct an energy audit and generate a Home Energy Rating System (HERS) rating for the building with pre-selected measures. Energy consultants performed a detailed visual assessment and diagnostic testing of a randomly selected sample of 21 units before and after the retrofits. Pre- and post-retrofit blower door and duct blaster testing were conducted on the sample units to determine the envelope and duct leakage and the effectiveness of air sealing.[3] Using the diagnostic testing results, pre-retrofit characteristics of the units, and selected improvements, pre- and post-retrofit HERS indexes were generated using REM/Rate™. For the sample units, the estimated average pre- and post-retrofit HERS index was 107 and 87,

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[2] The case-study building consists of six two-bedroom units (Type A) and four three-bedroom units (Type B) on the three floors of the building, with two units on the first floor abutting a vented crawlspace on a sloping site.

[3] Also, guarded and unguarded blower door tests were conducted on the case study building before and after the retrofits to quantify the air leakage to the outdoors and to the adjacent units.

respectively, indicating a 20% improvement in energy efficiency; and the estimated average annual pre- and post-retrofit site energy consumption was 50 MBtu and 40 MBtu, respectively, indicating 18% energy savings.[4]

Table 2. Selected retrofit measures

Retrofit measures	Pre-retrofit characteristics	Planned improvements
Energy retrofit measures		
Crawlspace insulation	No effective insulation	R-19 fiberglass batt under crawlspace ceiling
Attic insulation	R-30 blown-in fiberglass	Additional 4 in. of blown-in fiberglass over existing insulation to achieve R-38
Window replacement	Single-pane, aluminum frame (1.31 U-value, 0.80 SHGC)	Double-pane, low-e, vinyl frame (0.35 U-value, 0.27 SHGC)
HVAC system replacement	Unit A: 18 kBtu/h, 12 SEER, 7.5 HSPF heat pump; Units B and C: 24 kBtu/h, 12 SEER, 7.5 HSPF heat pump	Unit A: 18 kBtu/h, 14.5 SEER, 8.3 HSPF heat pump; Units B and C: 24 kBtu/h, 14.5 SEER, 8.5 HSPF heat pump
DHW system replacement	Electric 40-gal, 0.90 EF	Electric 40-gal, 0.93 EF
Low-flow plumbing fixtures	2 gpm faucets, 1.6 gpf toilets, and 5.0 gpm showerheads	1.5 gpm faucets, 1.28 gpf toilets, and 1.5 gpm showerheads.
Lighting replacement	Unit A: Two T12 lamps, a 15 W pin-base tube, and 18–60 W incandescent lamps; Units B and C: Two T12 lamps, a 15 W pin-base tube , and 21–60 W incandescent lamps	Unit A: Two T12 lamps and 18–13 W CFLs; Units B and C: Two T12 lamps and 21–13 W CFLs
Appliance replacement	Standard-efficiency cooking range/oven, refrigerator, and dishwasher	Standard cooking range/oven, Energy Star qualified refrigerator and dishwasher
Air sealing	Gaps around service penetrations through walls and ceiling	Air sealing and caulking
Other retrofit measures		
Wall siding replacement	Vinyl siding	Fiber cement siding
Roofing replacement	Asphalt shingles	Asphalt shingles
Duct sealing	Seams and joints not sealed	Mastic applied to the seams and joints of ductwork in the air handler

SHGC: solar heat gain coefficient; SEER: seasonal energy efficiency ratio; HSPF: heating seasonal performance factor; CFL: compact fluorescent lamp

Proposed Systematic Retrofit Analysis

Among the 11 buildings of Maplewood, a whole-building energy analysis of the case study building was performed after the retrofit to estimate energy savings from the installed measures and determine whether higher energy savings could be achieved. The complete analysis is documented in Im et al. (2012). The energy analysis was conducted using a multi-zone, flexible, DOE-2.1e simulation model developed for the audit tool MulTEA[5] (Malhotra and

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[4] The sample included fairly equal distribution of units on different floors. The energy savings estimates ranged between 18.5% and 32% for units on the third floor, 16% and 20% on the second floor, and 12% and 24% on the first floor, which can be attributed to the sizes of the units and variations due to their locations in the buildings.

[5] MulTEA (Multifamily Tool for Energy Audit) is a DOE-sponsored energy audit tool for multifamily buildings, currently under development, to allow a comprehensive energy and cost analysis of multifamily building retrofits with simplified modeling inputs.

Im 2012). Using the observed building information and diagnostic measurements (which included blower door test results for determining the envelope leakage) combined with Building America House Simulation Protocols (Hendron and Engebrecht 2010), a baseline building energy model was established. The baseline model was calibrated using the pre-retrofit monthly utility bills and actual weather data for year 2011 (WBT 2012). The compliance requirements of ASHRAE Guideline 14 (ASHRAE 2002) were followed for model calibration. Using the calibrated model, first the implemented EEMs were analyzed (EEMs 1 through 8 in Table 3), and then, additional measures were evaluated to identify a more cost-effective set of measures (EEMs 9 through 14). These included air sealing the crawlspace and insulating crawlspace walls, installing exterior insulation on exterior walls (since the wall siding replacement was already considered for implementation for appearance and durability), storm windows, programmable thermostats, and heat pump water heaters.

Table 3 summarizes the results of the whole-building energy analysis. It shows that with a careful selection of measures, energy savings of up to 34% could be achieved with a payback period of 7 years, whereas the installed EEMs were projected to save 24% of energy use[6] with a 10-year simple payback.

Table 3. Results of energy and economic analysis of EEMs

Energy efficiency measures		Energy use (kWh)	Savings			Measure cost ($)	Payback (year)
			kWh	%	$		
	Baseline	117,201	–	–	–	–	–
Implemented measures							
1	Insulate crawlspace ceiling with R-19 batt insulation	114,494	2,707	2.31%	$393	$300	0.8
2	Increase attic insulation from R-30 to R-38	116,870	331	0.28%	$48	$1,205	25.1
3	Replace windows and doors	107,208	9,993	8.53%	$1,449	$5,850	4.0
4	Replace 12 SEER, 7.5 HSPF heat pumps with 14 SEER, 8.3/8.5 HSPF units	112,533	4,668	3.98%	$677	$5,871	8.7
5	Replace incandescent lamps and fixtures with CFLs	113,070	4,131	3.52%	$599	$7,851	13.1
6	Replace kitchen appliances	116,211	990	0.84%	$144	$10,544	73.4
7	Replace 0.9 EF electric water heaters with 0.93 EF units	114,193	3,008	2.57%	$436	$3,012	6.9
8	Air seal building to reduce air infiltration by 25%	114,339	2,862	2.44%	$415	$4,758	11.5
Additional measures							
9	Air seal crawlspace and insulate crawlspace walls with R-5 rigid insulation	113,735	3,466	2.96%	$503	$3,809	7.6
10	Air seal crawlspace and insulate crawlspace walls with R-13 batt insulation	113,411	3,790	3.23%	$550	$3,134	5.7
11	Install R-5 rigid insulation on exterior walls	113,864	3,337	2.85%	$484	$3,371	7.0
12	Install storm windows	112,294	4,907	4.19%	$712	$3,080	4.3
13	Install programmable thermostats	115,595	1,606	1.37%	$233	$1,700	7.3
14	Replace electric water heaters with heat pump water heaters	101,515	15,686	13.38%	$2,275	$16,000	7.0
Implemented EEMs package (EEM 1 through 8)		89,715	27,486	23.5%	$3,986	$39,390	9.9
Cost-optimized EEMs package (EEM 1, 3, 4, 5, 11, 13 and 14)		76,891	40,310	34.4%	$5,845	$40,943	7.0

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[6] The whole-building energy savings estimate of 25% for the case study building is higher than the energy savings estimate of 18% predicted by REM/Rate™ for the 21 sample units. However, the difference is small compared with the variation in energy savings estimates (12–32%) among the sample units (see footnote 4).

EF: energy factor

Challenges in Performing Systematic Energy Analysis

Several issues were encountered while performing the systematic energy analysis of the case study building. The analysis required comprehensive building data, utility bills for model calibration, and cost data for the retrofit measures. Obtaining these data for this project was not straightforward. In addition, making use of the available data was no less challenging.

Building data for this project were available in great detail, but occupancy characteristics could not be determined. Since the energy audit was not a program requirement, energy professionals were consulted at a late stage, after the building was vacated for renovation. Therefore, interviewing occupants and building staff to determine occupancy and operational characteristics was not possible.

Acquiring utility bills was not a program requirement. However, pre-retrofit utility data could be collected after obtaining individual tenant waivers to grant access to the utility bills. But the utility data provided did not have the billing cycle dates. This made weather normalization of the data a challenging task requiring an iterative process to deduce the billing dates.

Analysis of utility bills. The results showed (1) anomalies in billed energy use across units, suggesting a high level of irregularity in the occupancy, usage, and operational characteristics of the units; (2) anomalies in billed energy use across 12 months, as several units did not follow the typical weather-driven heating and cooling energy use profiles; and (3) inconsistent energy use profiles across units. Normalization of utility bills was extremely difficult given the unexplainable energy use profiles observed in the utility bill data.

The cost data for measures implemented in the project was available from contractor quotes, some of which included unexpected costs.[7] Costs of additional measures were determined from other databases. Cost data from these two resources were found to differ for implemented measures. Therefore, comparisons among measures analyzed using one cost data source with those using another source should be used with reservations.

ASHRAE Standard 62.2 Compliance Check

For the case study building, guarded and unguarded blower door tests were conducted before and after the retrofits to quantify the air leakage to the outdoors and to the adjacent units. The guarded blower door measurements were used to account for the infiltration credit while checking the compliance with ASHRAE Standard 62.2-2010 (ASHRAE 2010).

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[7] The project execution notes indicated that selection of retrofit materials was based on cost, disregarding the durability, effectiveness, and workability of alternative materials and options. For example, fiberglass batt insulation (which is less durable and has lower air sealing benefits, but costs only \$0.30/ft^2) was selected for insulating the above-crawlspace floor, instead of spray foam insulation (\$1.50/ ft^2). The installation incurred unexpected additional costs for repetitive efforts to fix installation shortcomings due to the open-web truss wood framing system and the plumbing lines.

The units had recirculation-type range hoods in the kitchen and small bathroom exhaust fans vented to the outside, which were replaced by new equipment of the same type/size during the retrofits. Accounting for the infiltration credit and considering the exhaust deficits in the bathrooms and kitchen, the units were found to be under-ventilated before the retrofits, requiring 41 cfm of continuous ventilation or equivalent intermittent ventilation. Air sealing of the building decreased the air infiltration rate by about 25%, which required higher (i.e., 49 cfm) continuous ventilation to comply with the standard. Installing new exhaust ducts in the kitchen and providing outdoor-vented exhaust fans of adequate size in the kitchens and bathrooms would have addressed the issue of deficient ventilation. However, because there were no ventilation conditions in the program requirements, no consideration was given to achieving compliance with ASHRAE 62.2 to maintain acceptable indoor air quality.

Missed Opportunities

In this case study, the application process for the QAP did not require the involvement of energy consultants in determining the EEMs. Most of the EEMs were pre-determined to fulfill program requirements for energy efficiency and durability. Energy professionals were consulted only after the project schedule had already been initiated. Energy analysis was conducted after construction began. All measures implemented in Maplewood greatly improved the appearance and durability of the buildings and its systems, were expected to improve thermal comfort for the occupants, and achieved a projected 24% energy savings in the case study building. However, this case study identified several missed opportunities that either were not pursued or could not be achieved. Although improvements in comfort and livability were the aim of this project, some of the following aspects were overlooked and not pursued:

- Wall siding and roofing replacements were selected for durability and enhanced appearance, not for potential energy savings. These measures, if strategically selected or combined with other measures, (i.e., wall siding replacement combined with adding exterior continuous insulation, and roofing replacement with products having improved thermal properties) could have added to the more cost-effective energy retrofit package.
- Air sealing was targeted mainly to reduce infiltration to the outdoors. Air sealing of shared surfaces was disregarded, although it would have reduced air leakage and improved the noise barrier between units.
- An ASHRAE Standard 62.2 compliance check revealed that the dwelling units were under-ventilated. Air sealing resulted in a higher mechanical ventilation requirement. However, no consideration was given to providing mechanical ventilation.
- The replacement HVAC systems were selected based on the sizes of the existing systems. Because the post-retrofit HVAC loads are lower, the systems may be oversized and cycle more frequently than necessary, decreasing their energy efficiency performance and reducing thermal comfort in the units.
- With a careful selection of measures, energy savings of up to 34% could have been achieved with a payback period of 7 years, whereas the implemented EEMs were projected to achieve a 24% energy savings and a 10-year simple payback.

Conclusions

This paper reviewed current statistics for multifamily housing characteristics, studies that projected high energy savings through multifamily building retrofits, studies that identified potential barriers in realizing those savings, and programs designed to overcome those barriers. However, because of the complexity in auditing multifamily buildings and conducting a thorough energy and cost analysis to select retrofit measures, the full energy savings potential and supplementary benefits (e.g., improved health and safety conditions) are often unrealized. Through a case study of a multifamily building retrofit and a systematic energy analysis, this paper identifies missed opportunities for higher energy savings and improved comfort and indoor air quality, and it demonstrates the merits of following a systematic approach to retrofit analysis.

In multifamily buildings, program requirements play an important part in determining the audit approach. In view of the missed opportunities, the following recommendations can be made for improving the building audit process, streamlining tasks, and achieving higher energy savings in multifamily housing retrofits that would benefit future projects:

- Revising program requirements to follow established audit protocols to encourage and enable a systematic audit and analysis.
- Access to easy-to-use energy audit tools for multifamily retrofit analysis that do not require custom modeling, a high level of skill, and a large investment of time.
- Revising program requirements to include health and safety aspects of the buildings and protocols while integrating energy retrofits with health and safety improvements. This approach has been adopted in many programs. Access to audit tools (such as checklists, surveys, and computerized audits being developed for integrating retrofits) would help other programs to easily adopt this approach.

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