Table 6. TREAT Package Measures for Building 3.

Measure	Cost ($)	Annual MMBtu Source Savings	Annual MMBtu Site Savings	Annual $ Savings	Percent Site Savings	Payback Years
Air seal and insulate roof cavity	5,642	153.12	153.12	1531	8.1%	3.7
Install five 95% AFUE furnaces	12,310	191.90	191.90	1919	10.2%	6.4
Air seal around window frames	2,000*	53.30	53.30	533	2.8%	3.8
Air seal and insulate basement ductwork	3,420	1665.96	221.21	2,212	11.7%	1.5

* Price of window frame air sealing estimated based on past Energy Savers buildings, as the cost of air sealing was not directly shown in the cost of the window replacement.

Figure 13. Left: Old furnace. Right: New high efficiency (95% AFUE) furnace with PVC venting.

Window Replacement

Window replacement is not a typical Energy Savers recommendation and was not included in the retrofit measure package for this building due to its poor cost effectiveness as an energy-saving measure in multifamily buildings. However, the owner was preparing to make a capital improvement regarding the windows, and Energy Savers helped him to choose an efficient product and ensure proper installation. In particular, the team recommended and performed proper sealing around the frame and rough opening with low-expansion foam as part of the installation of the new windows.

Figure 14. Left: Air gap between window frame and wall. Right: Newly installed windows.

2.7 Results

This project demonstrated the feasibility of designing prescriptive retrofit measure packages for common building types to achieve projected energy savings of 20%-30%. In these three buildings, highest cost-effective energy savings potential was gained by measures that addressed the thermal envelope, heating system, and distribution and electrical equipment. Air sealing was recommended for the three buildings and is an important part of reducing heating system energy usage. The Energy Savers program experience has shown that a base package of roof cavity air sealing can improve energy savings, but additional air sealing measures raise air quality concerns and are harder to measure and cost out. Blower door tests on large multifamily buildings are impractical and, therefore, air leakage is difficult to measure. Moreover, making a building envelope tighter with air sealing can have impacts on the combustion safety of naturally vented gas appliances, accumulation of radon and volatile organic compounds, make-up air for fireplaces, risk of mold in walls, and occupant ventilation.

Table 7 summarizes the retrofit measures that were recommended and implemented for the three buildings in this study, showing examples of effective and marketable prescriptive packages for typical Chicago multifamily walk-ups.

Table 7. Summary of TREAT Package Measures for All Buildings.

Pre-retrofit Condition	Retrofit	Percent Site Savings	Payback Years
Building 1			
• Steam and domestic hot water pipes are uninsulated in unconditioned space	Insulate steam and DHW pipes with fiberglass	5.5%	4.2
• There is a roof cavity, but no air sealing or insulation	Air seal roof cavity with foam and insulate to R-49 with blown-in cellulose or fiberglass	10.9%	3.7
• Bathroom and kitchen water fixtures are standard	Install low-flow showerheads (1.5 GPM) and faucet aerators (1.5 kitchen; 1.0 bathroom)	1.1%	
• Boiler operates on a timer	Install boiler controls with indoor averaging temperature sensors and outdoor reset	5.7%	5.2
• Steam risers are incorrectly sized and main line air vents have failed	Resize risers and replace main line air vents	8.6%	6.0
Building 2			
• Heating hot water pipes are uninsulated in unconditioned space	Insulate heating hot water pipes with fiberglass	11.9%	2.1
• Basement has barely covered window openings which allow significant air and thermal leakage into the basement	Foam seal window and insulate the cavities with R-19 batt insulation	5.0%	0.4
• Existing standard efficiency refrigerators are in need of replacement	Install ENERGY STAR rated refrigerators	0.8%	4.4
• Hot water boiler is operated by aquastat and outdoor reset control only	Install control system which includes eight indoor temperature averaging sensors as well as outdoor sensor and strap-on aquastat	5.2%	4.8
• Exterior doors in unit and in stairwells have missing or ineffective weatherstripping, allowing air leakage	Weatherstrip exterior doors	1.0%	7.3
Building 3			
• There is a roof cavity, but no air sealing or insulation	Air seal roof cavity with foam and insulate to R-49 with blown-in cellulose or fiberglass	8.1%	3.7
• Existing furnaces are rated for AFUE 80% and test for even lower efficiency due to age	Install new 95% AFUE furnaces	10.2%	6.4
• Existing windows have gap between frame and wall, allowing air leakage	Air seal around window frames	2.8%	3.8
• Furnace ductwork for first floor units runs through unconditioned basement space	Air seal basement ductwork with water based duct sealant and insulate with reflective duct insulation	11.7%	1.5

Prescriptive retrofit packages can be a time- and resource-efficient way to scale up building energy efficiency improvements; however, they should be informed by modeling tests on typical buildings and post-retrofit analysis in order to guarantee a reasonable degree of accuracy in future savings and payback estimates. A potential follow-up study to this project could analyze the post-retrofit energy usage in the three test buildings to see if actual savings matched the predicted amounts. To this end, the Energy Savers program regularly performs post-retrofit analyses on its buildings at one year and two years after construction. Retrofit packages also should be regularly updated to include new and emerging technologies that are cost effective and have been shown to save energy. As part of this effort, this research project investigated two emerging technologies and conducted a short potential acceptance survey of some local building owners and contractors. See Appendix A for the results of this survey.

3 Conclusion

Using three case studies, this project asked and answered the following research questions:

- **Question**: Which measure packages are appropriate for different building types and building system types that attain high levels of source energy savings?

  Answer: In order for retrofit measure packages to attain high levels of source energy savings, they should address the thermal envelope, heating system, and distribution and electrical equipment.

- **Question**: Which measures require additional research and field testing or case studies to advance in the Chicago area marketplace and be adopted by contractors and consumers?

  Answer: Air sealing, a common measure for single family homes, can be complicated to recommend in multifamily buildings because of the greater opportunities for air leakage. The Energy Savers program experience has shown that a base package of roof cavity air sealing can improve energy savings, but additional air sealing measures are harder to cost out and bring air quality concerns. Air sealing in multifamily buildings should be researched further to determine best practices and reasonable expectations for typical energy savings and payback.

- **Question**: How should building energy simulation tools be utilized for multifamily analysis?

  Answer: Prescriptive retrofit packages can be a time- and resource-efficient way to scale up building energy efficiency improvement. However, they should be designed by energy efficiency programs using modeling software and post-retrofit analysis on a meaningful sample of typical buildings to ensure that savings and payback estimates are reasonably consistent and accurately predicted.

By developing and implementing retrofit packages that were projected to achieve 20%-30% source energy savings in three typical Chicago area multifamily buildings, this research explored the feasibility of applying prescriptive packages to common building types. While the prescriptive approach should always involve some level of common-sense tailoring to specific buildings, including a walk-through and interview with the building owner, it is a time- and cost-saving approach to retrofitting buildings that could be applicable to many climates. By reducing

the time and cost required to retrofit multifamily buildings to improve energy efficiency, energy efficiency programs across the country can ramp up their efforts to lower the nation's residential energy usage.

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Appendix A: New Technology Acceptance Potential Survey

To ensure that retrofit packages cover the most cost-effective measures, energy efficiency programs should periodically consider updating prescriptive retrofit packages to include new and emerging technologies. To that end, this research project included a market scan to identify promising retrofit measures applicable to the Chicago region and a short survey to determine their current market penetration and potential.

After an initial search, effort was focused on investigating technologies that would be either suitable to our climate region or applicable to domestic hot water use. This focus led to the decision to investigate on-demand hot water circulators and electronically commutated motors.

- **On-demand water circulators** save energy in multifamily buildings with domestic hot water recirculation loops by circulating hot water only when necessary, avoiding heat loss from pipes due to radiation and reducing the operating time of the pump. As advertised by one manufacturer, on-demand circulators can lower domestic hot water energy costs by 10%-30% and have a payback of between six months to three years (Enovative Group, 2012).
- **Electronically commutated motors (ECMs)** use a built-in inverter to maintain a high level of efficiency at various speeds. In HVAC systems, they are estimated to reduce operating costs by 20%-60% as well as produce less noise, remove less indoor air moisture, and last longer than traditional constant flow volume motors (ThomasNet.com, 2012).

These two technologies were claimed to be suitable for use in the multifamily market and boast considerable energy savings. To better gauge market interest in, opinions of, and capacity for these technologies, a phone survey was developed to administer to building owners and contractors that had been involved in the Energy Savers program. The survey included questions about participants' familiarity, experience, and evaluation of the technologies. Questions included, but were not limited to:

- Are you familiar with demand-controlled domestic hot water circulators?
- What further information would you need in order to decide whether to install an ECM for an HVAC system?
- Did you encounter any barriers to installing the system, such as financing or initial cost?
- Have you seen significant cost savings since installing the technology? What has your return on investment been?
- Do you work with a supplier, and if so, do they offer this product?

Building owners and contractors who had worked with Energy Savers before and were known to be interested in energy efficiency were targeted. Seven building owners were contacted and all took the survey; six contractors were contacted and three of these took the survey.

Of building owners, only two had heard of on-demand water circulators and none were familiar with the technology. All were interested in learning more about the technology and wanted

additional information about sizing, brands, costs and payback, availability of local installers, required access, and level of disruption to tenants during installation. Five building owners thought the technology might be useful in solving a problem or saving them money in their buildings. Familiarity with ECMs was more common: four building owners had heard of the technology, three considered themselves familiar with it, and two had installed HVAC systems with ECMs in their own buildings. Two owners requested additional details regarding costs and payback, and one showed interest in the availability of parts and local installers.

Of the contractors, none were familiar with on-demand water circulators. Two contractors were familiar with and had installed ECMs in HVAC systems.

In favor of ECMs, the contractors cited:

- Lower electricity usage, especially in buildings which require a continuous fan (e.g. offices, when dealing with allergens or for smokers)
- A quieter fan
- Increased comfort and usefulness in zoned buildings
- General satisfaction among their customers thus far
- Growing competition among the manufacturers, leading to a lower cost
- A 10-year manufacturer's warranty which is becoming standard.

Against ECMs, the contractors cited:

- A high initial cost which is not offset in applications with only intermittent operation
- Misleading marketing to residential customers who do not necessarily need continuous operation and thus for whom the technology is not cost effective
- Inaccessibility of replacement parts and a design that was not meant to be serviced.

This survey suggests that ECMs present some cost savings potential but are not suitable for general inclusion in a prescriptive retrofit package for typical buildings, due to their low cost effectiveness in intermittent-use situations and difficulties with servicing. Of on-demand hot water circulators, results from the survey suggest that more objective and quantitative research is warranted in order to determine the technology's advantages and disadvantages in multifamily settings. Due to low familiarity, contractor training may also be needed.

Appendix B. Energy Savers: Strategies for Working With Owners

Although implementation of recommended retrofit packages was a requirement for participating in this research project, it is not a requirement of the Energy Savers program. Convincing owners of the wisdom and cost effectiveness of retrofitting their buildings is a task that requires strategies tailored to the type of building owner and their level of engagement. Energy Savers' strategies include:

- Understanding the building owner's level of experience with and knowledge of energy efficiency (EE) measures in order to talk on their level, not above or below it.
- Listening and responding to the building owner's needs and intentions, such as improving cash flow or addressing tenant concerns.
- Recognizing the barriers to "closing the deal." These could include the following:
    - They do not feel confident in their knowledge of EE in making such a big decision. Solution: Be very clear about the costs, steps and benefits of each recommendation.
    - They are worried about the finances. Solution: Highlight the very favorable loans from CIC (Community Investment Corporation). Emphasize how easy the process is and how attractive the loan terms are.
    - They do not have time to implement EE measures. Solution: They do not need to spend a lot of time—the program's job is to simplify and streamline the process.
- Emphasizing that the energy assessment has a $1000 value and they are getting it for free.
- Emphasizing that the program recommends the high return on investment improvements but will help the owner make their priorities happen, as well (e.g., window replacement).
- Highlighting the unpredictability of the price of gas and the possibility of reducing energy bills through EE measures.
- Showing a real-world example of a building in the program that has already been retrofitted.
- Encouraging the owner to think about what they would do with the estimated yearly savings.
- Encouraging the owner to give some indication of their level of interest and identifying a next step.
- Giving "social proof": validation from the experience of others.
- Demonstrating authority, knowledge, and experience, while being accessible, likeable and approachable.

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