

Evaluation of CNT Energy Savers Retrofit Packages Implemented in Multifamily Buildings

Jenne Farley and Russell Ruch
Partnership for Advanced Residential Retrofit (PARR)

September 2013

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, subcontractors, or affiliated partners makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Available electronically at <http://www.osti.gov/bridge>

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728

email: <mailto:reports@adonis.osti.gov>

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900

email: orders@ntis.fedworld.gov

online ordering: <http://www.ntis.gov/ordering.htm>



Evaluation of CNT Energy Savers Retrofit Packages Implemented in Multifamily Buildings

Prepared for:

The National Renewable Energy Laboratory

On behalf of the U.S. Department of Energy's Building America Program

Office of Energy Efficiency and Renewable Energy

15013 Denver West Parkway

Golden, CO 80401

NREL Contract No. DE-AC36-08GO28308

Prepared by:

Partnership for Advanced Residential Retrofit (PARR)

CNT Energy

2125 W North Ave

Chicago, IL 60647

NREL Technical Monitor: Stacey Rothgeb

Subcontractor Number KNDJ-0-4346-03

September 2013

[This page left blank]

Contents

List of Figures	vi
List of Tables	vii
Definitions	viii
Executive Summary	ix
1 Introduction	1
1.1 Chicago Region Multifamily Housing	1
1.2 CNT Energy Savers	1
1.3 Need for Prescriptive Retrofit Packages	2
1.4 Relevance to Building America’s Goals	3
2 Research	3
2.1 Building Selection Criteria	3
2.2 Building Auditing and Analysis	5
2.3 Implementation	7
2.4 Building 1: Central Steam Boiler	7
Steam and DHW Piping	9
Boiler Controls	9
Air Sealing and Insulating the Roof Cavity	10
2.5 Building 2: Central Hot Water Boiler	11
Heating Hot Water Pipe Insulation	12
Basement Window Air Sealing and Insulation	12
Boiler Controls	12
2.6 Building 3: Individual Gas Forced Air Furnaces	13
Window Replacement	14
2.7 Results	15
3 Conclusion	17
References	19
Appendix A: New Technology Acceptance Potential Survey	20
Appendix B. Energy Savers: Strategies for Working With Owners	22

List of Figures

Figure 1. Typical multifamily walk-up buildings in Chicago. U-shaped (left) and rectangular (right).4

Figure 2. Distribution of heating system types in Energy Savers buildings. 4

Figure 3. Building 1 from the front entrance. 8

Figure 4. Left: Uninsulated steam piping. Right: Steam pipes insulated with jacketed fiberglass.... 9

Figure 5. Left: Previous timer control, which operated boiler by signaling it to fire during certain times of the day. Right: New boiler reset control with four remote indoor temperature sensors and one remote outdoor temperature sensor. 9

Figure 6. Air sealing around the perimeter of the roof cavity. 10

Figure 7. Insulating the roof cavity with loose fill fiberglass. 10

Figure 8. Building 2 from the front entrance. 11

Figure 9. Left: Bare hot water pipes. Right: Pipes insulated with 1 in. jacketed fiberglass..... 12

Figure 10. Window opening sealed and insulated with batt insulation..... 12

Figure 11. Left: Existing outdoor reset controller. Right: New room temperature averaging control.13

Figure 12. Building 3 from the front entrance. 13

Figure 13. Left: Old furnace. Right: New high efficiency (95% AFUE) furnace with PVC venting. 14

Figure 14. Left: Air gap between window frame and wall. Right: Newly installed windows. 15

Unless otherwise noted, all figures were created by the PARR team.

List of Tables

Table 1. Buildings Included in the Study.....	5
Table 2. Comparison of Natural Gas Heating and Hot Water EUI of Buildings 1 and 2 with other Energy Savers program buildings.....	6
Table 3. Summary of TREAT Package Savings.	6
Table 4. TREAT Package Measures for Building 1.	8
Table 5. TREAT Package Measures for Building 2.	11
Table 6. TREAT Package Measures for Building 3.	14

Unless otherwise noted, all tables were created by the PARR team.

Definitions

AFUE	Annualized Fuel Utilization Efficiency: A thermal efficiency measure of combustion equipment like furnaces, boilers, and water heaters.
CIC	Community Investment Corporation: A Chicago area nonprofit lender and partner to CNT Energy.
CNT	Center for Neighborhood Technology: An implementer of the proposed plan, currently running a portfolio of energy efficiency programs. CNT Energy is the energy division of Center for Neighborhood Technology.
DOE	U.S. Department of Energy, a sponsor
ECM	Electronically Commutated Motor
EE	Energy Efficiency
EUI	Energy Use Intensity: A standardized comparison for benchmarking buildings, measured in kBtu per ft ² per year
GTI	Gas Technology Institute, an implementer
NOAA	National Oceanic Atmospheric Administration
PARR	Partnership for Advanced Residential Retrofit
SIR	Savings to Investment Ratio: A calculation showing how many times an investment pays itself back in its lifetime; defined here as the retrofit cost divided by annual savings, divided by the expected length of the retrofit's lifetime

Executive Summary

Through the study of three case studies, this evaluation explored the feasibility of designing prescriptive retrofit measure packages for typical Chicago region multifamily buildings in order to achieve 25% source energy savings. There is an urgent need to scale up energy efficiency retrofitting of Chicago's multifamily buildings to address rising energy costs and a rapidly depleting rental stock. Aimed at retrofit program administrators and building science professionals, this research project investigates the possibility of using prescriptive retrofit packages as a time- and resource-effective approach to the process of retrofitting multifamily buildings.

The research was conducted by the U.S. Department of Energy Building America research team Partnership for Advanced Residential Retrofit (PARR), in conjunction with CNT Energy, a division of the Center for Neighborhood Technology. This organization provides energy efficiency services through the Energy Savers program, a one-stop shop for owners of multifamily buildings in the Chicago region.¹ Using the insights and methodology developed from the Energy Savers program, the research project:

- Identified three common multifamily building types
- Selected three buildings in the program that fit into these types
- Performed energy audits on the buildings
- Used modeling software to design retrofit packages with the highest savings measures balancing cost effectiveness
- Implemented the retrofit packages. In line with Energy Savers program recommendations, these packages included air sealing and insulation of the roof cavity, installation of boiler controls, lighting retrofits, and insulation of the heating and domestic hot water pipes.

This exercise found that the highest cost-effective energy savings potential was gained by measures that addressed the thermal envelope, heating system, and heating 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 roof cavity air sealing can improve energy savings, but more extensive air sealing measures are harder to cost out and require additional precautions. Programs should employ modeling software and post-retrofit analysis to ensure that expected savings and payback estimates for their prescriptive retrofit packages are accurate.

¹ For more information, visit the following websites:

- Center for Neighborhood Technology: <http://www.cnt.org/>
- CNT Energy: <http://www.cntenergy.org/>
- Energy Savers: <http://www.cntenergy.org/buildings/energysavers/>

1 Introduction

1.1 Chicago Region Multifamily Housing

The Chicago region is defined here as the seven counties in northern Illinois surrounding Chicago, spanning about 4,000 square miles of land and over 3.3 million housing units (U.S. Census, 2011). The multifamily housing stock in this region is older and energy intensive, and it represents over one quarter of the housing stock. The energy efficiency potential of this market is significant.

Buildings with five or more units in the Chicago region total 874,107 units, and more than two-thirds of these units were built before 1980 (U.S. Census, 2011). These buildings were not designed for energy efficiency and are becoming less energy efficient over time through deterioration. Illinois ranks second in the country in gas usage per residential gas customer, behind only Alaska, and residential buildings in the Chicago area use nearly 60% more heating energy than the Illinois state average (AGA, 2010). Ongoing analysis by Energy Savers shows that buildings in its program use twice as much energy per square foot as buildings on average nationwide.

Because 80% of buildings existing today will be in use in 2020, their level of energy efficiency will impact operating costs for owners and individual utility bills for tenants for years to come (Ludwig, 2008). By 2007, condominium conversion in Chicago had supplanted energy cost-driven abandonment as the primary means of attrition in the affordable rental housing stock. More than 50,000 Chicago area homes were in foreclosure in 2007, a 50% increase from 2006 (Yue, 2008). These trends in the instability of the housing market further underscore the important role energy efficiency can play in preserving housing affordability. By improving the physical conditions of existing housing stock through retrofits, energy efficiency programs can help to address the issue of the widening gap between supply of and demand for multifamily affordable housing across the United States.

1.2 CNT Energy Savers

CNT's program to improve energy efficiency and housing preservation was instigated by high fuel costs and concerns about rental housing stock attrition. Housing trends in Chicago indicated that from 1973 to 1989, available private market (unsubsidized) rental housing dropped by 41% due to abandonment of units, conversion to higher priced rental units and condominiums, and rising energy costs (Katrakis, 1994). In 2007, the Preservation Compact was formed in response to a combination of increasing energy costs, deteriorating rental market due to abandonment and condominium conversion, and poor quality of low-income housing buildings. The Preservation Compact is a multifaceted strategy that includes many initiatives, namely the establishment of funds to acquire, hold and maintain at-risk and existing rental units, a focus on community organizations and effective tenant organization to preserve housing, and data review and property surveys to collect new characteristic baseline property data. CNT Energy is a keystone partner and essential part of the Preservation Compact.

Since 2008, CNT Energy's Energy Savers program has audited more than 20,000 units and successfully overseen retrofits of more than 7,500 units. The program targets Chicago's older multifamily housing stock, which presents a considerable potential for energy savings. Post-

retrofit analysis has shown some buildings benefitting by as much as 30% to 40%, when comparing their usage before and after installation.

CNT Energy's Energy Savers program serves multifamily building owners through its one-stop shop approach to energy efficiency retrofitting, which includes:

- Identifying opportunities in their buildings for energy savings
- Connecting owners to financing options and rebates
- Recommending trusted contractors to do the work
- Overseeing the retrofitting process
- Reporting on the energy savings after upgrades.

The program has been very successful in its approach and cost effectiveness, focusing on measures that achieve significant savings and are tailored for each building. As the program grows, and cost effectiveness and streamlined service delivery become more crucial, Energy Savers aims to refine the recommended measure packages and create retrofit packages that are specific to building and heating type and can reach the targeted savings for typical building types in Chicago.

1.3 Need for Prescriptive Retrofit Packages

For buildings with typical layouts and heating systems, offering a prescriptive package of retrofit measures can take less time and use fewer resources than auditing, modeling, and tailoring specific packages to each building. Retrofit packages promise one approach to ramping up retrofitting and significantly decreasing the amount of energy consumed by inefficient buildings.

CNT has found that multifamily building owners tend to be uninformed about cost-effective ways to reduce their energy operating costs and that few resources for this sector of the market exist. Market incentives such as tax credits and rebates are usually targeted toward single family owners and commercial industries. The multifamily building sector is often overlooked and underserved in the utility efficiency portfolios because they are sometimes classified as residential and other times fall under commercial energy efficiency programs.

Centrally heated multifamily buildings also suffer from the split incentive problem. Building owners pay for the installation, maintenance, and upgrades to their central heating systems, as well as for the fuel that provides heat for tenants. Therefore, tenants have little incentive to modify their energy use in order to limit the building's heating fuel usage. The consequences of this incentive configuration are costly and can lead to significant energy waste. Unfortunately, it is not always practical to target these tenant behavioral issues in an attempt to reduce the overall energy consumption of the building. However, as this report will help to show, there are many cost-effective and "tenant-proof" ways to reduce overall building energy usage that can be included in a prescriptive retrofit package. Some of these measures, such as balancing the heat in a building, also help to prevent the tenant behaviors that exacerbate energy waste in the first place.

In this study, PARR modeled three types of Chicago-style multifamily buildings, compared the model outputs to the pre-retrofit actual usage, and estimated the fuel savings for the measures. This approach was intended to:

- Create the most cost-effective retrofit packages to easily market to the multifamily building owners
- Provide better detail to multifamily building owners who are interested in cost-effective measures
- Increase the visibility of the measures to energy efficiency portfolios of utility companies.

1.4 Relevance to Building America's Goals

The U.S. Department of Energy's (DOE) Building America program is designed to “reduce the home energy use by 30%-50% (compared to 2009 energy codes for new homes and pre-retrofit energy use for existing homes).” The program seeks to conduct research to “develop market-ready energy solutions that improve efficiency of new and existing homes in each U.S. climate zone, while increasing comfort, safety, and durability” (DOE, 2011).

To this end, PARR conducted this research in order to develop and evaluate prescriptive packages for affordable multifamily residential buildings in the Chicago region that would reduce energy usage with cost-effective savings measures. While the intended target of the package measures and the focus of the CNT Energy program is to reduce energy costs and improve comfort in a heating-dominated climate, many of these retrofit strategies are applicable for energy savings in all regions of the country. These strategies include air sealing and insulating the top of the thermal enclosure, reducing hot water usage, upgrading to more efficient appliances, weather-stripping, and insulating ductwork in unconditioned space.

The project served to answer the following research questions:

- Which cost-effective measure packages are appropriate for different building types and building system types that attain high levels of source energy savings?
- 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?
- How should building energy simulation tools be utilized for multifamily analysis?

2 Research

2.1 Building Selection Criteria

Common multifamily building types were determined after an analysis of the 900 buildings in the Energy Savers program, representing more than 35,000 units. Most of the buildings were three-story walk-up brick buildings constructed around 1920; consequently the three buildings chosen for this study fell within this category. Common layouts for these buildings include rectangular, L-shaped and U-shaped courtyard buildings (Ludwig, 2008). The typical Chicago three-story walk-up building has a flat roof, single pipe steam heat with cast-iron radiators and

atmospheric gas boilers that are between 15 and 20 years old. Figure 1 shows two typical multifamily walk-up buildings.



Figure 1. Typical multifamily walk-up buildings in Chicago. U-shaped (left) and rectangular (right).

Most Energy Savers buildings have between six and 30 units, so buildings with more than 30 units were excluded from consideration. Variation in the sample was introduced through the selection of heating system type. Representing the three most prevalent types of heating systems in this region, the participant buildings were heated by central steam heating boiler, central hot water boiler, and individual forced air furnaces. Figure 2 shows the incidence of different heating system types in the Energy Savers profile. A large portion of these buildings have central steam boilers, which are representative of Chicago’s older building stock. However, the trend in recent years has been to convert central heating systems to individual gas forced air heating systems.

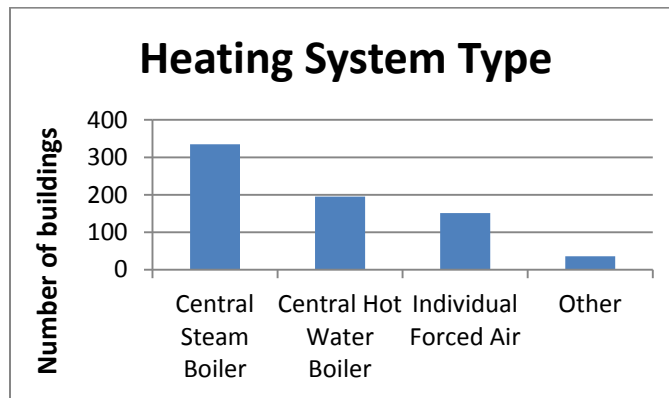


Figure 2. Distribution of heating system types in Energy Savers buildings.

As natural gas is the primary heating fuel in this region and electric heat is uncommon, all buildings selected were heated by natural gas. Only buildings that could achieve high energy savings from measures with savings to investment ratios (SIRs) greater than 1, based on Energy Savers experience, were selected. (A measure’s SIR must be at least 1 in order to be included as an Energy Savers program recommendation.)

The buildings selected were in the beginning process steps of the Energy Savers program; they had received an audit and were getting bids or were otherwise ready to proceed. In order to qualify for the study, building owners had to be willing to participate, able to complete retrofits within the study timeline, and willing to implement all of the recommended measures. It was

important for this research study that participants implement all of the recommended measures. Financing, rebates and available grant funds were leveraged to ensure that all measures were installed. (The Energy Savers program does not generally require that owners implement all of its recommended measures; owners decide which building energy investments to prioritize and implement.²) Table 1 gives an overview of the three buildings selected for inclusion in the study.

Table 1. Buildings Included in the Study.

	Heating Type	# of Units	Total Size
Building 1	Central steam boiler	6 units	7,200 ft ²
Building 2	Central hot water boiler	19 units	16,000 ft ²
Building 3	Individual gas forced air furnaces	6 units	10,600 ft ²

2.2 Building Auditing and Analysis

The three buildings had been given standard Energy Savers program audits, which include a physical and visual analysis of the building, combustion analysis of the heating system and domestic hot water system, and interviews with the building owner, building maintenance operator, and available tenants. A data collection sheet, photographic camera, and infrared camera were used to record observations.

As part of the standard Energy Savers procedure, the researchers requested and analyzed utility bill data from the utility companies. Base load was separated from heating load, usage was weather-normalized, and the energy use intensity of the building was calculated. Energy use intensity (EUI) is a measurement of annual energy use per square foot, measured in units of kBtu/ft²/year. Building natural gas usage for heating and hot water is usually reflected by the owner’s gas bill, for which data is relatively easy to request access. On the other hand, electricity usage throughout the building is typically paid for through multiple individual tenant accounts and is overly time intensive to request and analyze. Thus, Energy Savers typically focuses on calculating only the natural gas EUI of its buildings. Summary natural gas EUI results are presented for Buildings 1 and 2 in Table 2 below. EUI was not calculated for Building 3 as building natural gas usage was paid for through multiple individual accounts and this data was inaccessible to the auditor.

² An overview of strategies for working with different types of building owners follows in Appendix B.

Table 2. Comparison of Natural Gas Heating and Hot Water EUI of Buildings 1 and 2 with Other Energy Savers Program Buildings*.

	EUI of natural gas base load (kBtu/ft ² /year)	EUI of natural gas heating load (kBtu/ft ² /year)	EUI of natural gas total load (kBtu/ft ² /year)
Average Energy Savers building	24	78	102
Building 1	17	118	135
<i>Percent with lower EUI</i>	<i>22%</i>	<i>90%</i>	<i>81%</i>
Building 2	21	96	117
<i>Percent with lower EUI</i>	<i>45%</i>	<i>76%</i>	<i>67%</i>

* EUI was not calculated for Building 3.

The test buildings were then modeled using the TREAT Multifamily software. This is one of the few available software programs with the ability to model multifamily buildings; other software programs have limitations on the number of units, floors, heating system size and overall modeling capacity relevant to the Energy Savers Program’s building stock.³ The test buildings were modeled using information about size measurements, spatial characteristics, walls, doors, windows, thermostat settings, heating and hot water systems, lighting, appliances, and the estimated level of air infiltration. The models were then calibrated to historical utility data for the buildings for one to two years.

Using the building models, it was possible to estimate the impact of different retrofits on the building’s energy usage. Retrofit measures were inputted into the TREAT software and evaluated for their estimated savings potential. Measures were selected from typical Energy Savers program recommendations in order to achieve 20%-30% energy savings with a simple cost SIR of at least 1. Analysis of previous bids for prior buildings in the program determined the initial cost estimates. After proposals had been accepted, the costs were updated in the model to ensure accuracy. As a check, the software program’s savings estimates were compared to Energy Savers’ program experience. The modeled savings were generally similar to the savings Energy Savers had measured in past buildings. Table 3 below shows the savings and average SIR for installing the retrofit packages in each of the three buildings. These numbers considered interactive effects among the individual retrofit measures; more discussion of these phenomena follows in the section below.

Table 3. Summary of TREAT Package Savings.

Building	Total Cost (\$)	Annual MMBtu Savings*	Annual \$ Savings	Payback Years	Percent Site Savings
Building 1	16,797	266.67	2,667	6.30	24.0%
Building 2	19,725	596.94	7,774	2.54	24.6%
Building 3	23,373	617.90	6,179	3.78	26.4%

* MMBtu savings include savings from both natural gas and electricity usage.

³ As of the time this report was written, this assessment of other modeling packages includes BEopt.

The chosen measures addressed the building envelope and insulation, heating system and distribution effectiveness, and electrical and mechanical devices. Building envelope measures included air sealing and insulating the roof cavity, air sealing and insulating the basement windows, air sealing around windows in the units, and installing weather-stripping and door sweeps on exterior doors. Heating system and distribution effectiveness measures differed according to the heating system: boiler controls and pipe insulation were considered for the centrally heated buildings, while furnace replacements were considered for the individual gas forced air buildings. Electrical and mechanical upgrades included lighting and appliance replacements, as well as the replacement of circulators and motors. Each building had a different type of heating system and unique opportunities for savings, but in each, the building envelope, heating system and distribution, and electrical and mechanical appliances were addressed.

2.3 Implementation

The Energy Savers staff requested proposals for the measure packages through a competitive bid process from approved program contractors. The building owners selected the contractor to perform the work. As part of the typical Energy Savers program process, CNT Energy Savers construction managers provided oversight and inspected the retrofit installations once construction was complete.

The three sections below detail the specific measures that were included in the retrofit measure packages and provide photographs illustrating some of these measures. Summary tables of the TREAT modeling projections are included for each building. It is important to note that the savings estimates for the recommended measures in these tables are not interactive; they are calculated independent of one another in an “all else being equal” situation. Since reducing energy usage from one retrofit measure will reduce the amount of energy that can be saved by another retrofit measure, combining the individual savings projections on the following tables will sum to a higher percentage than what is shown in Table 3 above. Because this research project considers retrofit packages and not just individual measures, the combined savings estimates calculated from interactive retrofits shown in Table 3 are more accurate.

2.4 Building 1: Central Steam Boiler

Building 1 was a three-story, six unit central steam boiler heated building.



Figure 3. Building 1 from the front entrance.

The measures installed at this building included air sealing and insulating the roof cavity, reworking the risers and header piping on the boiler for better distribution, replacing main line vents, insulating the heating and domestic hot water (DHW) pipes in unconditioned space, installing boiler controls with indoor sensors, and installing low-flow showerheads and faucet aerators.

Table 4. TREAT Package Measures for Building 1.

Measure	Cost (\$)	Annual MMBtu Site Savings	Annual MMBtu Source Savings	Annual \$ Savings	Percent Site Savings	Payback Years
Insulate steam pipes	1,450	54.30	54.30	543	4.8%	2.7
Air seal and insulate roof cavity	4,612	124.06	124.06	1,240	10.9%	3.7
Install low-flow fixtures	0*	12.85	12.85	129	1.1%	--
Install boiler controls and indoor sensors	3,395	65.48	65.48	655	5.7%	5.2
Insulate domestic hot water pipes	1,200	8.13	8.13	81	0.7%	14.8
Resize risers and replace main line vents	5,890	97.99	97.99	980	8.6%	6.0

* Low-flow showerheads and faucet aerators were directly installed at no charge to the customer through the Small Business Energy Savings Direct Install program run by Peoples Gas and ComEd.



Figure 4. Left: Uninsulated steam piping. Right: Steam pipes insulated with jacketed fiberglass.

Steam and DHW Piping

All accessible steam and domestic hot water supply piping was insulated with all-service jacket fiberglass and fitted with PVC. Steam lines 3 in. and larger received 1½ in. thick fiberglass; smaller steam pipes and DHW supply pipes received 1 in. thick fiberglass. Often, steam pipes were stripped of their asbestos-containing insulation and substitute material was not replaced. Replacing the missing steam pipe insulation is a relatively simple and very cost-effective measure in this type of building.



Figure 5. Left: Previous timer control, which operated boiler by signaling it to fire during certain times of the day. Right: New boiler reset control with four remote indoor temperature sensors and one remote outdoor temperature sensor.

Boiler Controls

The team replaced a timer control with a new R&D Electronics 1404T main control panel. The new system takes the average temperature of multiple indoor temperature sensors and compares it to the current temperature setpoint to determine boiler action. Four new hard-wired indoor temperature sensors were installed and strategically located throughout the building to achieve a representative average building temperature. One new outdoor temperature sensor was installed

on an external building wall, high enough to prevent easy tampering. The team demonstrated the operation of the system to building personnel to ensure its correct use.



Figure 6. Air sealing around the perimeter of the roof cavity.

Air Sealing and Insulating the Roof Cavity

All accessible penetrations, open walls, and chases in the roof cavity were air sealed. Seventeen and a quarter inches of loose fill fiberglass insulation was then blown in over approximately 2,500 ft² of accessible ceiling area for a total R-value of R-49.



Figure 7. Insulating the roof cavity with loose fill fiberglass.

2.5 Building 2: Central Hot Water Boiler

Building 2 was a three-story, centrally heated hydronic building with 19 units.



Figure 8. Building 2 from the front entrance.

In this building, all of the refrigerators were replaced with ENERGY STAR[®] units, weatherstripping was installed around all exterior doors, boiler controls with averaging sensors were added, and the pipes were insulated. A survey of the roof cavity by an insulation contractor showed 12-14 in. of blown-in fiberglass insulation. Additional roof cavity insulation was not found to be economical.

Table 5. TREAT Package Measures for Building 2.

Measure	Cost (\$)	Annual MMBtu Source Savings	Annual MMBtu Site Savings	Annual \$ Savings	Percent Site Savings	Payback Years
Insulate heating hot water pipes	4,720	229.38	229.38	2,294	11.9%	2.1
Air seal and insulate basement windows	390	96.15	96.15	962	5.0%	0.4
Install Energy Star refrigerators	8,550	46.38	15.46	1,960	0.8%	4.4
Install boiler controls and indoor sensors	4,735	99.23	99.23	992	5.2%	4.8
Weather-strip exterior doors	1,330	18.10	18.10	181	1.0%	7.3

Heating Hot Water Pipe Insulation

All accessible heating hot water piping in the unconditioned basement was insulated with 1-in. all-service jacket fiberglass and fitted with PVC.



Figure 9. Left: Bare hot water pipes. Right: Pipes insulated with 1 in. jacketed fiberglass.

Basement Window Air Sealing and Insulation

A barely covered plywood window opening allowed significant air and thermal leakage into the basement. The team sealed the window with foam and insulated with R-19 batt insulation.



Figure 10. Window opening sealed and insulated with batt insulation.

Boiler Controls

The team installed an RC2100 wireless heat control system, along with eight wireless indoor wall sensors, to work in conjunction with the existing two-stage outdoor reset controller. In addition, an aquastat was included to provide minimum water temperature.



Figure 11. Left: Existing outdoor reset controller. Right: New room temperature averaging control.

2.6 Building 3: Individual Gas Forced Air Furnaces

Building 3 is a three-story building with six units, heated by individual gas forced air furnaces.



Figure 12. Building 3 from the front entrance.

Based on the audit recommendations and the projected savings from the TREAT modeling, the energy efficiency measures included replacing five of the six furnaces with 95% AFUE furnaces, replacing the windows (but more importantly, air sealing around the window frames), air sealing and insulating the roof cavity, air sealing and insulating the ductwork located in unconditioned space, and replacing all incandescent light bulbs with compact fluorescent light bulbs in the units and common area spaces.

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.

References

AGA (2010). Residential Natural Gas Market Survey, 2009 Data. Washington, D.C. American Gas Association.

CNT (2008). Chicago Greenhouse Gas Emissions: An Inventory, Forecast, and Mitigation Analysis for Chicago and Metropolitan Region. Chicago, IL. The Center for Neighborhood Technology, accessed at:
http://www.cnt.org/repository/CNT_Climate_Research_Summary_9.17.08.pdf.

Deutsche Bank (2012). The Benefits of Energy Efficiency in Multifamily Affordable Housing. Accessed at:
https://www.db.com/usa/docs/DBLC_Recognizing_the_Benefits_of_Efficiency_Part_B_1.10.pdf.

Enovative Group (2011). Frequently Asked Questions. Venice, CA. Accessed at:
<http://www.enovativegroup.com/dmand-circ/faqs/>.

Institute for Housing Studies at DePaul University (2012). The Composition of Cook County's Housing Stock. Chicago, IL. Accessed at:
http://www.housingstudies.org/media/filer_public/2012/08/29/ihs_data_brief_housing_stock.pdf.

Ludwig, P.; Evens, A.; Kotewa, L. (2008). Cook County Energy Savers: How Energy Efficiency in Chicago's Multi-Family Buildings Has Evolved to Meet New Challenges from the 1980's to the Present Day. ACEEE Summer Study on Energy Efficiency in Buildings. Accessed at:
<http://aceee.org/proceedings-paper/ss08/panel02/paper18>.

Katrakis, J.T.; Knight, P.A.; and Cavallo, J.D. (1994). Energy-Efficient Rehabilitation of Multifamily Buildings in the Midwest. Argonne, IL., Argonne National Laboratory. Accessed at:
<http://www.osti.gov/bridge/servlets/purl/10186292-Xtn9vf/webviewable/10186292.pdf>.

McKibbin, A.; Evens, A.; Nadel, S.; and Mackres, E. (2012). Engaging as Partners in Energy Efficiency: Multifamily Housing and Utilities. CNT Energy and the American Council for Energy-Efficient Economy (ACEEE). Accessed at: <http://www.cntenergy.org/media/Engaging-as-Partners-in-Energy-Efficiency-MF-Housing-and-Utilities-Final-012512.pdf>.

ThomasNet.com (2012). Using ECM Motors in HVAC Systems. Accessed at:
<http://www.thomasnet.com/articles/machinery-tools-supplies/ECM-Motors-HVAC-Systems>.

U.S. Census Bureau (2011). American Community Survey 1-Year Estimates. Accessed November 11, 2012 at <http://factfinder2.census.gov/>.

Yue, L., Chicago foreclosure rate up 50% in 2007, February 13, 2008, Crain's Chicago Business, <http://www.chicagobusiness.com/cgi-bin/news.pl?id=28177>.

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.

U.S. DEPARTMENT OF
ENERGY | Energy Efficiency &
Renewable Energy

DOE/GO-1020130-3931 • September 2013

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post-consumer waste.