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Public Housing: A Tailored Approach to Energy Retrofits

Jordan Dentz, Francis Conlin, David Podorson, and Kunal Alaigh
Advanced Residential Integrated Energy Solutions (ARIES) Collaborative

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Definitions

AC	Air conditioner
ACH50	Air Changes per Hour at 50 Pascal pressure differential
ARIES	Advanced Residential Integrated Energy Solutions Collaborative Building America team
BEopt™	Building Energy Optimization™ software
CFL	Compact Fluorescent Lamp
CFM	Cubic Feet per Minute
CFM25	Cubic Feet per Minute at 25 pascal pressure differential
EPC	Energy Performance Contractor
HUD	U.S. Department of Housing and Urban Development
IHA	Islip Housing Authority
LED	Light-Emitting Diode
PHA	Public Housing Authority
RHA	Raleigh Housing Authority

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Executive Summary

More than 1 million U.S. Department of Housing and Urban Development-supported public housing units provide rental housing for eligible low-income families across the country. These units range from scattered single-family houses to high-rise apartments. In this project, the Advanced Residential Integrated Energy Solutions Collaborative (ARIES) worked with two public housing authorities (PHAs) to develop packages of energy efficiency retrofit measures the PHAs can cost-effectively implement with their own staffs in the normal course of housing operations at the time when units are refurbished between occupancies.

ARIES conducted a survey of PHAs to assess their receptiveness to this concept and the applicability of the concept to PHA units. The results of the survey, to which more than 100 PHAs responded, support the proposed approach.

The project consisted of a field evaluation in which energy audits were performed on a sample of PHA units at two housing authorities. Energy efficiency turnover protocols were developed for typical units, the protocol was implemented by PHA staff, and the effectiveness of the protocol was quantified through field testing and modeling.

The energy efficiency turnover protocols emphasized air infiltration reduction, duct sealing, and measures that improve equipment efficiency. In the 10 housing units in which ARIES documented implementation, reductions in average air leakage of 16%–20% and duct leakage of 38% were obtained. Total source energy consumption savings was estimated at 6%–10% based on Building Energy Optimization™ modeling with a simple payback of 1.7–2.2 years.

Implementation challenges were encountered, mainly related to required operational changes and budgetary constraints. Lack of complete training and inadequate quality control can prevent PHAs from effectively retrofitting units to their full potential. Nevertheless, despite these hurdles, simple improvements, such as caulking and sealing penetrations, windows, and doors; sealing duct boots; and adding pipe insulation into a standardized turnover protocol can feasibly be accomplished by PHA staff at low or no cost. At typical housing unit turnover rates, these measures could impact hundreds of thousands of units per year nationally.

1 Introduction and Background

1.1 Introduction

Public housing was established to provide decent and safe rental housing for eligible low-income families, the elderly, and persons with disabilities. Public housing comes in all sizes and types, from scattered single-family houses to high-rise apartments. There are approximately 1.2 million households living in public housing units, managed by some 3,300 public housing authorities (PHAs). The U.S. Department of Housing and Urban Development (HUD) administers federal aid to local PHAs that own and manage the housing for low-income residents. HUD furnishes technical and professional assistance in planning, developing, and managing these developments (U.S. Department of Housing and Urban Development, 2012).

In this project, the Advanced Residential Integrated Energy Solutions Collaborative (ARIES) worked with two PHAs to develop packages of energy efficiency retrofit measures the PHAs can cost-effectively implement with their own staffs in the normal course of housing operations, specifically when units are refurbished between occupancies. These packages are termed the Energy Efficiency Turnover Protocols.

1.2 Background

PHAs across the nation endeavor to provide good-quality housing for a poor population while working under a number of financial and legal constraints. Living units are small, densely occupied, and primarily attached or in low-rise multifamily buildings.

Challenges to reducing energy use in public housing include the following factors:

- Because of federal rules, residents are generally not responsible for the bulk of their energy costs, which are paid by the agency through a voucher system. Therefore, residents have a reduced financial incentive to conserve energy.
- PHAs in turn have their energy costs reimbursed by HUD based on the previous 3-year average of energy costs; therefore PHAs have a limited ability to recoup money spent on energy efficiency and little incentive to spend their own money on such measures.
- While new PHA construction is often built to be energy efficient, many PHA buildings were built before modern energy standards were in place and so are highly inefficient.
- While PHA management may place a high value on improving energy efficiency, the knowledge, skills, time, and resources to implement cost-effective improvements are often lacking at the operational level.
- PHAs have a strong incentive to minimize downtime between occupancies because of lost rental income. Their desire to avoid disrupting or temporarily displacing occupants inhibits making energy upgrades.

Despite these challenges, there are a number of opportunities for PHAs to make energy efficiency improvements:

- HUD requires PHAs to perform energy audits on their properties every 5 years and offers capital grants that can be used for major energy efficiency upgrades recommended as a result of these audits. In recent years HUD has begun to require PHAs to act on audit findings.

- HUD permits PHAs to contract with energy performance contractors (EPCs) and to share the resulting savings with those contractors. EPCs are a significant source of project funding, particularly for larger PHAs. However EPCs have minimum project size requirements and typically focus on major replacements and improvements rather than smaller scale upgrades and maintenance improvements that can still have a significant impact on energy use.
- State and utility energy efficiency programs often offer increased incentives for affordable housing.
- Public housing is eligible for the U.S. Department of Energy Weatherization Program.

Even with these programs and funding sources, many units remain inefficient. Capital grants and energy performance contracting are suitable for large one-time projects that affect a limited number of units. Weatherization and utility program funding cannot reach all units. However, PHAs typically have a professional staff that performs work on units each time occupancy changes (on average every 6–7 years according to a survey of PHAs conducted by ARIES as noted below).

The vacant period between occupancies presents a brief window of opportunity to work on the units. PHAs typically paint and make necessary repairs during this period, but additional energy efficiency work could also be done. Taking the low end of the range of turnover rates yields an opportunity of refurbishing nearly 250,000 units each year across the nation. This opportunity has been noted by others. For example, general recommendations for "green" measures at "unit turnaround" are incorporated into the Green Building Operations and Maintenance Manual (Green Seal, Inc. and Siemens Industry, Inc., 2011). However, quantifying the energy savings and costs and generalizing that information for typical PHA unit types so PHAs can act on it with confidence has not been done.

This report describes the development, implementation, and evaluation of Energy Efficient Turnover protocols at two PHAs.

1.3 Public Housing Authority Survey

In 2012 preparatory work on this effort included preliminary research on PHAs to assess and quantify the potential opportunity for this approach. An online survey was developed to help determine how broadly applicable a limited set of standard protocols can be and the degree to which PHAs would be interested. It was vetted by PHA industry members and distributed via industry publications and direct emails to PHA contacts across the country. Information collected included the following:

1. The characteristics (type, quantity, etc.) of housing owned by PHAs
2. The typical turnover rates at PHAs
3. The typical turnover process with respect to time and tasks completed
4. Methods for paying utility costs

5. The willingness of PHAs to implement energy efficiency measures during turnover
6. The cost-effectiveness criteria used by PHAs in deciding on energy efficiency investments and related funding sources
7. The general skill levels of PHA maintenance staff (i.e., ability to implement energy measures).

The survey was completed by 109 PHAs, representing 3% of PHAs nationally. The results of the survey support the overall hypothesis of this effort: that a prescriptive set of cost-effective energy measures implemented by PHA staff during turnover is feasible and sensible for some PHAs. Key findings supporting this hypothesis are listed below:

- A large share of PHA units are low-rise, wood frame attached or multifamily units owned by small to midsize PHAs.
- Many PHAs have substantial resident turnover and turnover times are sufficient in most cases to implement limited energy measures.
- No evidence of this approach being used today was discovered, yet almost all responding PHAs expressed an interest in the concept.
- Many PHAs have some limited funds to spend on energy measures, as long as they are cost effective; and most PHAs are interested in efficiency.
- Almost all responding PHAs have staff with moderate to high skill levels who could presumably be trained to implement simple energy efficiency measures.
- Most PHA units are more than 30 years old and many have not been weatherized.

It is recognized that the respondents may be self-selected for their interest in energy efficiency; however, the housing characteristics are presumed to be approximately representative of PHAs nationally. Appendix A summarizes the survey results; Appendix B contains the survey instrument.

1.4 Relevance to Building America's Goals

The Building America Standing Technical Committee on Implementation identified the following critical path milestones at the April 2012 Denver meeting (Gestwick, 2012):

- **2012:** Identify key stakeholders and associated channels that can have the most impact (change) with the least amount of effort. Identify documentation/communication needs of key stakeholders and associated channels. Change key Building America deliverables to cater to the documentation needs of key stakeholders and associated channels.
- **2013:** Develop audience-specific communications and outreach strategies with a core focus on measuring results to show change in practice (define key performance indicators to measure adoption).

PHAs are key stakeholders in that they own and operate 1.2 million housing units nationwide, many of which are in older buildings. PHAs are a distinct group with established communication and outreach channels. This project developed and tested technical outreach materials (the energy efficiency turnover protocol guidelines) suitable for many PHAs. In a parallel effort, the Building America Research Alliance team is developing outreach strategies for this approach.

1.5 Research Questions

This research addressed the following questions:

1. Is it feasible to implement a prescriptive set of cost-effective energy measures in public housing units during the short turnover periods when the units are vacant?
2. Using partner PHAs as case studies, what specific package(s) of energy measures can routinely be installed during these periods that would be cost effective?
3. What are the estimated costs and energy savings of such a protocol in typical PHA units?

2 Research Methods

The approach to developing the Energy Efficiency Turnover protocols included the following tasks:

1. **Select partners.** From among survey participants, two PHAs were selected to serve as research partners with whom to develop and pilot the protocols. Both PHAs are located in the mixed-humid climate zone and primarily own attached low-rise housing stock. The two PHAs are:

    a. **Raleigh Housing Authority (RHA).** RHA is one of approximately 130 PHAs in North Carolina (U.S. Department of Housing and Urban Development, 2012). RHA owns 1,723 public housing units, mostly in developments ranging from a few dozen to a few hundred units each (Raleigh Housing Authority, 2012). Of RHA's units, 1,109 are one- and two-story, wood-framed attached units in 14 developments; 388 are in two multifamily high rises; and 226 are scattered single-family detached homes. Raleigh, North Carolina is located in climate zone 4.

    b. **Town of Islip Housing Authority (IHA).** The Town of Islip is located on the South Shore of Long Island in Suffolk County, New York (also in climate zone 4). IHA owns and operates four developments with 360 units. All units are in low-rise attached or multifamily buildings; are wood-framed construction, and most have electric resistance heat.

2. **Conduct audits.** ARIES conducted detailed energy audits in eight units at each PHA representing a cross-section of properties. The purpose of the audits was to identify opportunities for low-cost measures and assess the consistency of the features and conditions of the units across the PHA portfolios. The audits gathered information required for Building Energy Optimization™ (BEopt™) modeling, including duct and envelope leakage testing, ventilation airflow measurements, and inspection of insulation and equipment.

3. **Perform modeling.** Typical units at each PHA were modeled using BEopt software version 2.1.0.2 (National Renewable Energy Laboratory, 2014).

4. **Develop protocols.** Based on the audit and modeling results and discussions with PHA management, protocols were developed. The packages were low cost, feasible to install during turnover time constraints, and achievable with staff skills.

5. **Implement and evaluate protocols.** PHA staffs were trained in the protocols. The protocols were then implemented in each unit that was being prepared for new a tenant. In a sample of units (five per PHA), ARIES conducted before and after inspections and tests to measure implementation effectiveness and cost. The protocols were refined based on implementation feedback and post-retrofit testing.

3 Islip Housing Authority

3.1 Energy Audits

Energy audits were conducted in eight vacant and occupied units in IHA's Oakdale, Mill Pond, Southwind, and Alyn Lane, representing a cross-section of IHA's properties (Figure 1).

Figure 1. Typical IHA housing unit

IHA's apartments are predominantly single-floor studios and one-bedroom units in two-story framed buildings that contain about eight units each. Three hundred thirty of the 360 units have electric resistance heat, electric storage water heaters, and through-the-wall sleeves for resident-owned air conditioners (ACs). Tenants pay their own utility bills and are provided an allowance by IHA based on historical energy use for each unit size. Cooling energy is not reimbursed and room ACs (for the 330 electric units) are owned by the tenants (about half of these residents own ACs). A summary of audit findings and recommendations is provided in Table 1. In general, the units were leaky, with second-floor units being substantially worse than ground-floor units. Some apartments showed signs of earlier attempts at air sealing.

Table 1. IHA Audit Findings

Inspection Item	Findings
Envelope Leakage	Blower door test results (unguarded, ACH50): 6.8, 8.9, 9.7, 11.1, 16.2, 16.5, 20.2, 22.3 – average 13.9 ACH50
Windows	Single and double glazed with metal frame
Heating	Electric resistance baseboard (except for gas-fired forced air at one 30-unit site)
Cooling	Sleeves for through-wall ACs except for central forced air at one 30-unit site
Lighting	Mostly CFLs, pin fluorescent in kitchen, some incandescent in bathrooms
Bath Exhaust Ventilation	Ranged from 0–60 CFM (only two of eight above 20 CFM)
Hot Water	Storage tank (electric resistance, except gas at one 30-unit site) Some tanks had insulation jackets; pipe insulation inconsistent; some tank thermostats set overly high (160°F)
Ducts	One unit tested at the 30-unit site with ducts: total leakage 350 CFM25, leakage to outside 290 CFM25
Attic	Fiberglass batt, mostly evenly dispersed, grade II and III; ¼-in. thick uninsulated plywood attic hatch

3.2 Protocol Development

A typical second-floor IHA unit was modeled using BEopt version 2.0.0.6 in order to predict energy savings of potential measures. The pre-retrofit model was adjusted to match average utility bills obtained for IHA units of the same type. Table 2 summarizes the measures modeled. The BEopt results are provided in Figure 2 for a unit with existing double-glazed windows (majority of units are double glazed). The model predicts a potential source energy and site electricity savings of 26%.

Table 2. Measures Modeled

Area	Measure
Attic	Insulate the attic hatch with 2-in., R-10 XPS insulation and gasket
Air Sealing	Air sealing: 32% reduction in leakage from 11.8 ACH50 to outside to 9.5 ACH50 to outside[1]
Water Heating	Install insulated water heater jacket; pipe insulation
Windows	Install storm windows in units with single-glazed windows
Heating	Replace room (through-wall) AC with room (through-wall) heat pump
Lighting	Convert to 100% fluorescent lighting

[1] A 15% reduction factor was used to convert from unguarded envelope leakage test results to envelope leakage used for energy modeling (ARIES Collaborative, 2012).

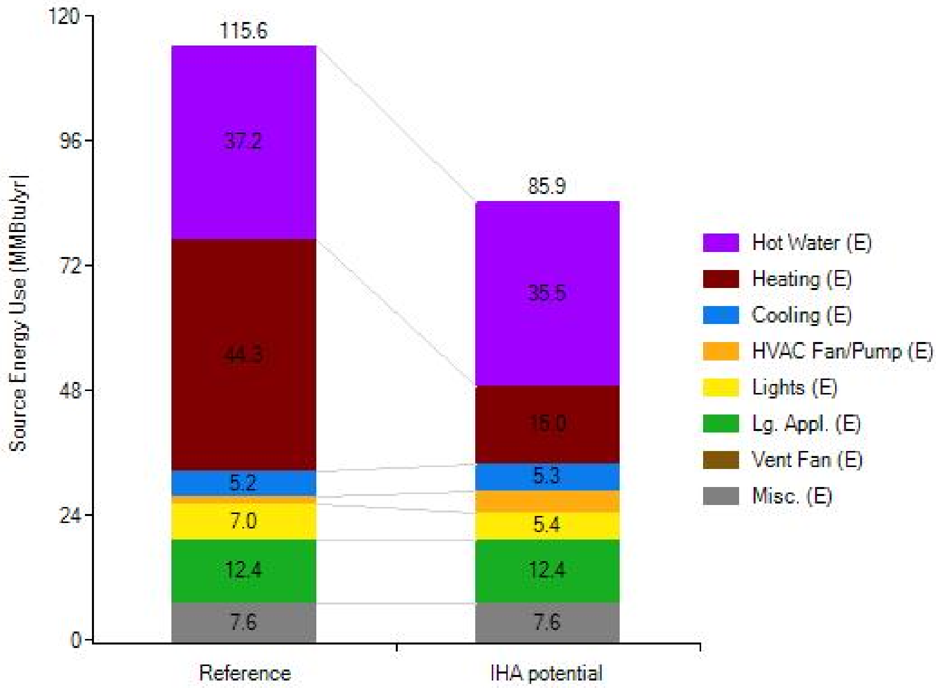

Figure 2. Source energy for typical IHA second floor end unit (double glazing)

Table 3 and Table 4 list the costs for each measure, total costs, projected annual utility bill savings, and annualized energy-related costs[2] for this typical unit.

IHA elected to include in its turnover protocols most recommendations with the exception of the programmable thermostat, heat pumps, and storm windows, because of their higher initial cost. A detailed summary of recommendations adopted by IHA is provided in Table 5. The implementation cost for the selected measures was $235. The complete IHA Energy Efficiency Turnover guidelines are provided in Appendix C.

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[2] BEopt calculates the *annualized energy related costs* by annualizing the energy-related cash flows over the analysis period. Cash flows consist of mortgage/loan payments, replacement costs, utility bill payments, mortgage tax deductions (for new construction), and residual values. Costs, excluding mortgage/loan payments, are inflated based on the time they occur in the analysis period. The cash flows are annualized by determining the present worth of the cash flow by converting the total cost for each year to the value at the beginning of the analysis period (National Renewable Energy Laboratory, 2012).

Table 3. Recommended Measures—Estimated Costs

Measure	Estimated Costs Using IHA Staff
Attic Hatch	$5 for a ¼ sheet of insulation $5 for a ¼ roll of rubber gasket $2 for caulk to fasten insulation to attic hatch
Air Sealing	$30 for caulk and foam
Programmable Thermostat	$85 for thermostat
Water Heater Jacket	$25 for materials
Storm Windows	$650 installed estimate (homewyse, 2014)
Heat Pump	$800 equipment cost estimate
Lighting	$48 fixture cost
Labor	$120 for 6 labor-hours

Table 4. Recommended Measures—
Estimated Costs and Savings Not Including Storm Windows

Total Capital Costs (Not Including Storm Windows)	$1,120
Projected Annual Utility Bill Savings	$442
Annualized Energy-Related Costs	Reduced by $434 from $1,805 to $1,371.

Table 5. IHA Adopted Measures

Item	Adopted Measure
Envelope Leakage	• Caulk bottom plates in rooms without carpet or if replacing carpet • Foam plumbing penetrations • Seal electrical penetrations including boxes to wallboard, openings in data boxes, and lighting penetrations • Foam or tape (with metal foil tape) gaps around exhaust fan and duct boots to wall/ceiling • Caulk gaps in door frame and/or molding around frame and replace weather-stripping if worn • Tape/gasket all seams between AC and sleeve and inside sleeve if no AC unit exists
Lighting	• Replace incandescent bulbs with standard or warm tone compact fluorescent lamps (CFLs) • Replace pin fluorescent lamps with light-emitting diode (LED) lamps when replacing fixtures
Bath Exhaust Ventilation	• Check fan flow 3 • Vacuum fan blades, motor, and housing (wipe with rag before air sealing)

[3] The credit card method was suggested for checking exhaust fan flow; see NYSERDA's "Homeowner's Guide to Ventilation" (New York State Energy Research and Development Authority, 2013).

Item	Adopted Measure
	• If flow still insufficient, check duct connection and consider fan replacement
Hot Water	• Install insulation jacket or re-install properly if poorly installed (electric tanks) • Add pipe insulation to un-insulated pipes in domestic hot water tank closet • Set domestic hot water temperature (measured at faucets) to 120°F max
Ducts	• Seal gaps between duct boots and ceiling/floor/wall
Attic	• Check that ceiling insulation is evenly dispersed without gaps, water damage, and covering rafters and other framing members to the exterior walls. • When/if replacing attic insulation over framed walls, foam penetrations where accessible • Glue 2-in. rigid foam to back of hatch • Add gasket/weather stripping to attic hatch

3.3 Implementation

IHA staff was trained in the protocols in a 3-hour on-site training session. Following the training, they implemented the protocols in each unit that was prepared for new a tenant (Figure 3 and Figure 4). ARIES conducted before and after inspections and tests of five units, including the training unit, to measure implementation effectiveness and estimate costs.

Figure 3. Electric storage water tank with insulation wrap (left) and foamed plumbing penetrations (right) at IHA

Figure 4. Installing gasket on attic hatch (left) and caulking gap around window (right) at IHA

One of the major focuses of the turnover protocols is air sealing. During the training session a 32% reduction in tested envelope air leakage was achieved. During subsequent implementations the average air leakage reduction was lower by 14%–19% reduction (average of 16%). This fall-off in performance is likely due to less on-site focus and supervision by IHA management and ARIES researchers, and likely represents an achievable level going forward by IHA staff in these units. Results of all five units tested at IHA are in Table 6.

Table 6. IHA Air Sealing Results

Site	Address	Pre-Date	Post-Date	Pre-CFM50	Post-CFM50	Post-ACH50	% Change
Oakdale	308 Ockers (training unit)	6/12/2013	6/12/2013	1,325	900	8	–32%
Central Islip	600 Allyn 212	6/12/2013	6/21/2013	1,285	1,110	13.2	–14%
Bayshore	20 Millpond	7/1/2013	7/10/2013	1,624	1,309	13.5	–19%
Oakdale	112 Ockers	8/1/2013	8/16/2013	1,219	1,001	14	–18%
Oakdale	607 Ockers	8/1/2013	8/16/2013	726	621	8.9	–14%

Updating the IHA BEopt models with the measures implemented (and with the average measured infiltration reduction of 16%) yields a predicted whole-house annual energy savings of the IHA units of 6.2% (7.2 MBtu; $107 utility costs). BEopt plots comparing potential savings to predicted savings as implemented are shown in Figure 5 and Figure 6. The annualized energy-related costs are based on actual costs incurred by IHA. Substantially more savings and lower annualized energy costs are possible with the full set of recommended measures; the additional air sealing and heat pumps being most important.

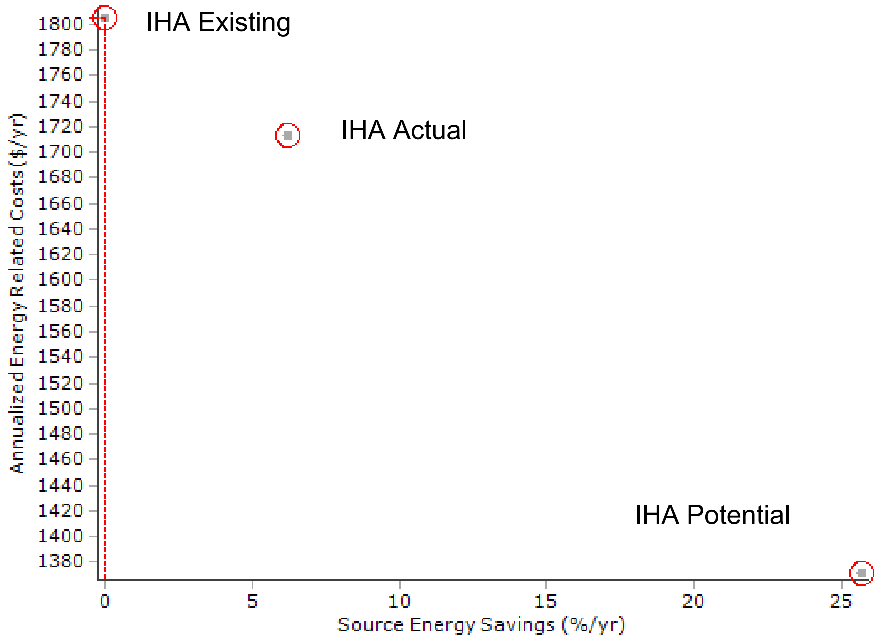

Figure 5. Annualized energy-related costs and source energy savings for IHA units

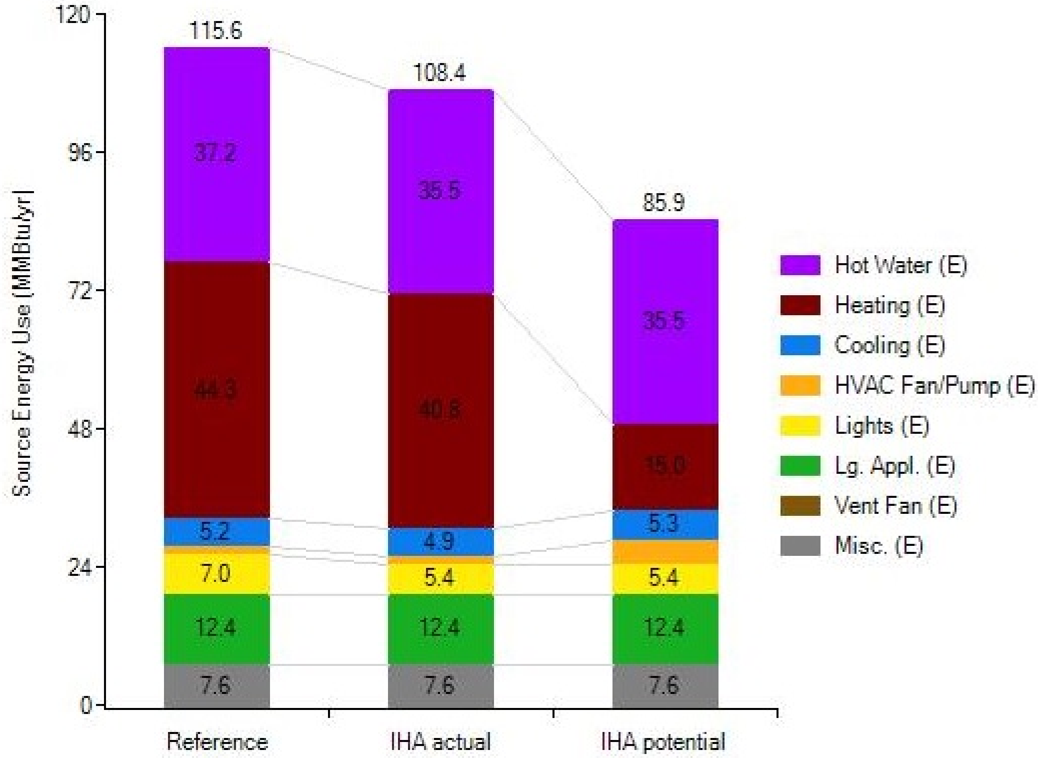

Figure 6. Source energy use for IHA units

4 Raleigh Housing Authority

4.1 Energy Audits

Energy audits were conducted in nine vacant and occupied units in the Kentwood, Heritage Park, Mayview, Birchwood, Berkshire Village, Oaks, Stonecrest, Valleybrook, and Terrace Park developments representing a cross-section of RHA's properties. The apartments are predominantly one- and two-story, one- and two-bedroom units in one- and two-story framed buildings some with brick cladding. All buildings have natural gas-fired forced-air heating and central forced-air cooling. Water heating is by natural gas-fired storage tank. Tenants pay their own utility bills and are given an allowance by RHA. Typical units are shown in Figure 7. A summary of audit findings and recommendations is provided in Table 7.

Figure 7. Typical RHA housing units

Table 7. RHA Audit Findings

Inspection Item	Findings
Envelope Leakage	Blower door test results (unguarded, ACH50): ranged from 17 to 25 with an average of 20.2
Windows	Single and double glazed with metal frame, one vinyl; no storm windows
Heating	Forced hot-air, natural draft furnace located within conditioned space
Cooling	Forced air, traditional coil system; filters dirty
Lighting	Mostly incandescent lighting
Bath Exhaust Ventilation	Low ventilation in bathrooms (0–48 CFM) and kitchens (14–102 CFM), fan covers very dirty
Hot Water	Storage tank, natural gas fuel; none had insulation jackets; thermostats set about 120°–129°F
Ducts	Average duct leakage to outside tested 29 CFM25/100 ft^2; average total duct leakage 31 CFM25/100 ft^2; ducts very dirty
Attic	Combination fiberglass batts, blown cellulose, and blown fiberglass; inconsistent coverage, grade II to III, ranging from 6 in. to 14 in. in depth.

4.2 Protocol Development

A typical two-story RHA unit was modeled using BEopt version 2.1.0.2 in order to predict energy savings of potential measures. Table 8 summarizes the measures modeled. The BEopt results are provided in Figure 8 for a unit with existing double-glazed windows (most units had double-pane windows). The model predicts a potential energy savings of 12%.

Table 8. Measures Modeled for Potential Savings

Area	Measure
Attic	Insulate the attic hatch with 2-in., R-10 extruded polystyrene insulation and gasket, improve insulation
Air sealing	Air leakage reduction from 17.2 ACH50 to outside to 13.1 ACH50 to outside (24% decrease) (using the 15% reduction factor applied to the unguarded test result)
Water heating	Install insulated water heater jacket; pipe insulation
Heating	Replace louvered door with solid door and gasket to prevent back-drafting into living space and to reduce infiltration
Cooling	Replace air filters, seal air handler to stop leaks, clean supply and return grilles, seal duct boot to ceiling/floor/wall
Lighting	Convert to 100% fluorescent lighting

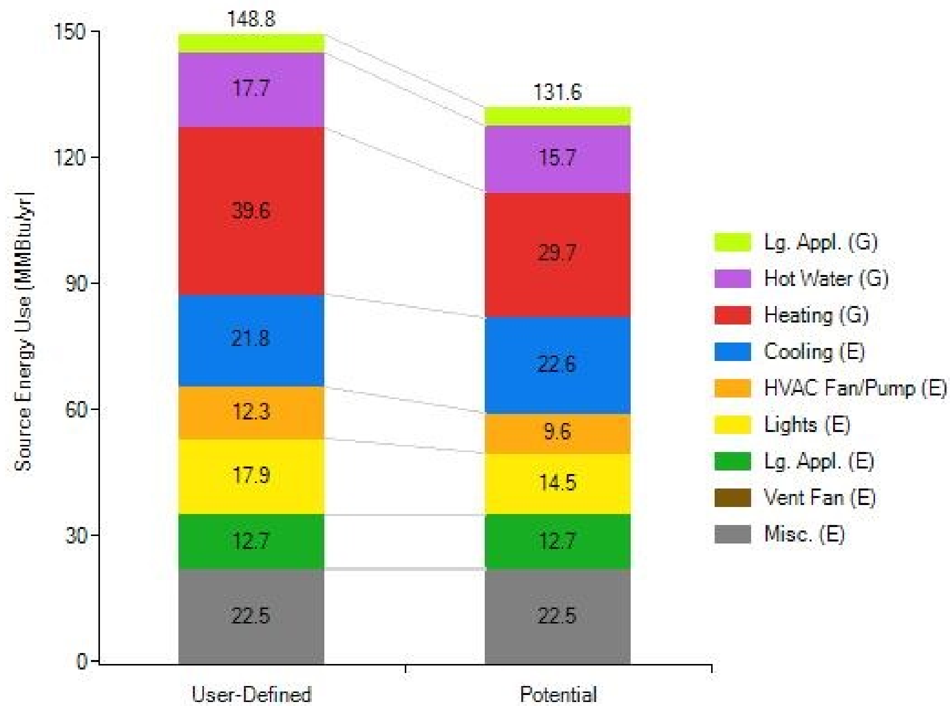

Figure 8. BEopt results for typical RHA two-story unit (terrace park two--story end unit) (G = gas, E = electricity)

Table 9 lists the costs for each measure, total costs, projected annual utility bill savings, and annualized energy-related costs for this typical unit.

Table 9. Estimated Costs for Recommended Measures (Not Including Mechanical Room Door)

Measure	Estimated Costs Using RHA Staff
Insulate Water Heater	$25 for insulating jacket
Insulate the Attic Hatch With 2-in., R-10 XPS Insulation and Gasket	$5 for a ¼ sheet of insulation $5 for a ¼ roll of rubber gasket $2 for adhesive to fasten insulation to attic hatch
Air Sealing	$30 for caulk and foam $1 for acetone for cleaning
Install Fluorescent/LED Lighting	$45 for kitchen fixture; $15 for CFLs
Seal the Air Handler and Duct Returns With Mastic, and Seal the Register Boots to the Wall/Ceiling With Foil Tape	$12 for duct mastic (small tub) $4 for foil tape $2 for flashing and screws
Improve Ceiling Insulation	$10 for bag of cellulose insulation – hand distributed
Staff Labor	$116 for 8.5 hours of labor

Table 10. Estimated Costs for the Recommended Measures and Projected Savings

Total Capital Costs	$272
Projected Annual Utility Bill Savings	$173
Annualized Energy-Related Costs	Reduced by $723

RHA elected to include in its turnover protocols most recommendations with the exceptions of insulating the water heater and replacing the mechanical room louvered door, with a solid one. A detailed summary of recommendations adopted by RHA is provided in Table 11. The estimated cost for the adopted measures was $247. The complete RHA Energy Efficiency Turnover guidelines are provided in Appendix D

Table 11. RHA Adopted Measures

Item	Adopted Measure
Envelope Leakage	• Caulk bottom plates in rooms without carpet or if replacing carpet • Foam plumbing penetrations, including bases of toilets • Seal electrical penetrations including boxes to wallboard, openings in data boxes and lighting penetrations • Foam or tape (with metal foil tape) gaps around exhaust fan and duct boots to wall/ceiling • Caulk gaps in door frame and/or molding around frame and replace weather-stripping if worn • Foam door latches
Lighting	• Inspect lighting and replace with high efficiency (CFL or LED) if necessary
Bath Exhaust Ventilation	• Check fan flow • Vacuum fan blades, motor, and housing (wipe with rag before air sealing) • If flow still insufficient, check duct connection and consider fan replacement
Domestic Hot Water	• Adjust hot water temperature if necessary • Insulate hot water pipes
Ducts	• Seal gaps between duct boots and ceiling/floor/wall • Seal around air handler/return ducts • Clean/replace filter
Attic	• Check that ceiling insulation is evenly dispersed without gaps, water damage, and covering rafters and other framing members to the exterior walls. • When/if replacing attic insulation over framed walls, foam penetrations where accessible • Glue 2-in. rigid foam to back of hatch • Add gasket/weather stripping to attic hatch

4.3 Implementation

RHA staff was trained in the protocols and then implemented the protocols in units being prepared for new tenants. ARIES conducted before and after inspections and tests of five units to measure implementation effectiveness and estimate costs. Table 12 summarizes the before and after envelope and duct leakage test results in chronological order.

Table 12. RHA Envelope and Duct Test Results

Address	Envelope Leakage (CFM50)			Duct Leakage to Outside (CFM25)		
	Before	After	Change	Before	After	Change
460 Dorothea Dr.	2,820	2,648	–6%	170	154	–9%
4711 Leafcrest Ct.	2,112	1,808	–14%	Unreliable results		
404 Swain St.	1,662	1,447	–13%	280	240	–14%
1150 Clanton St.	2,048	1,607	–22%	850	437	–49%
3960 Haresnipe Ct.	2,015	1,531	–24%	717	454	–37%

By sealing penetrations, windows and doors, and the overall building envelope, RHA staff was able to lower the infiltration rate by an average of 20% after the initial learning curve was surmounted. By sealing duct boots the walls and floors, RHA was also able to lower the duct leakage to the outside. In some units, such as 3960 Haresnipe Court, RHA was able to reduce leakage rates significantly, although compared to new construction standards envelope and duct leakage is still high. Note that RHA staff did not try to seal ducts, only the visible connections between the boots and the ceiling.

Bathroom ventilation fan flow was measured in two units with initial flow measurements found to be low. After RHA staff cleaned the fans and grilles, the flow increased (Table 13). Final flow rates are still well below the 50 CFM target rate.

Table 13. RHA Exhaust Fan Test Results

Address	Pre-Test Result (CFM)	Post-Test Result (CFM)	Percent Increase (%)
3960 Haresnipe Ct.	0	16	N/A
1150 Clanton St.	Upstairs 19 Downstairs 24	Upstairs 32 Downstairs 31	68 29

Updating the RHA BEopt models with the measures implemented and average leakage reduction values (20% for envelope[4] and 38% for ducts) yields a predicted whole-house annual source energy savings of approximately 10% (14.7 MBTU; $149 annual utility costs). BEopt plots comparing potential and predicted savings as implemented are shown in Figure 9 and Figure 10.

[4] Only the last three units were used to derive the average achievable envelope leakage reduction because during the first two the learning curve was not yet overcome.

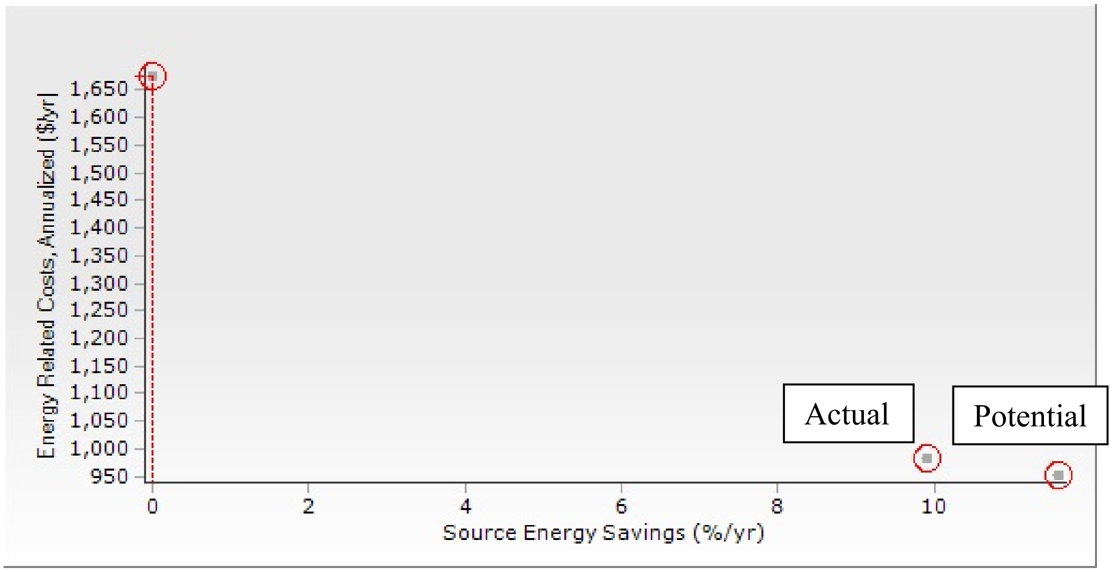

Figure 9. Annualized energy-related costs and source energy savings for RHA unit

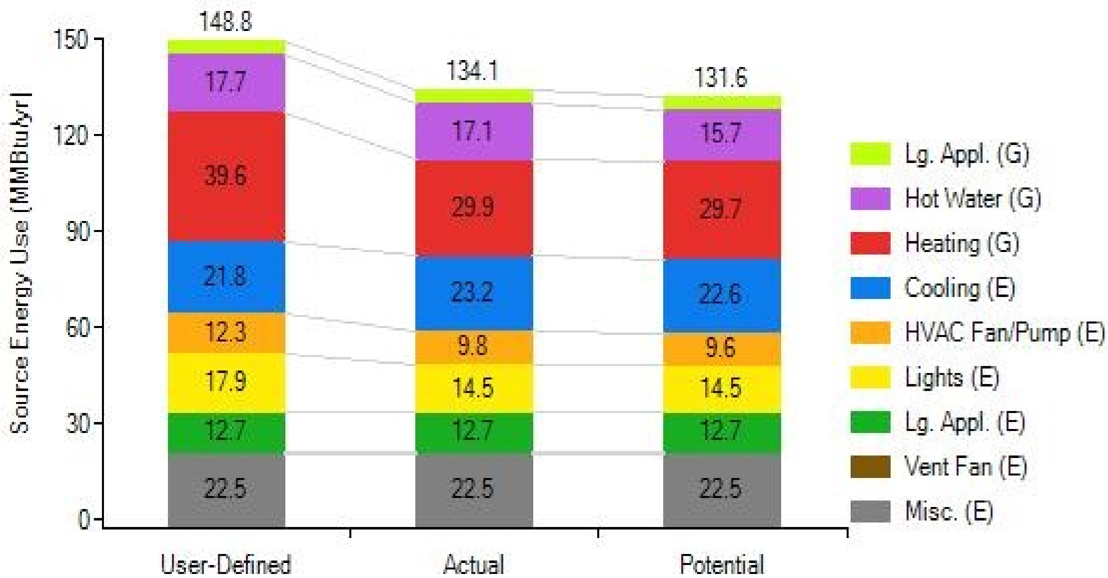

Figure 10. Source energy use reduction for RHA unit

5 Uncertainties

For envelope leakage measurements, the Energy Conservatory Blower Door with DG-3 or DG-700 manometer was used with a standard accuracy test (one-point test with baseline range < 5 Pa. This test yields an uncertainty of ± 10% (Nelson, 2013). For duct leakage measurements, the Energy Conservatory Duct Blaster with DG-700 manometer was used. This equipment has a flow accuracy of +/- 3% (The Energy Conservatory, 2014). Combined with the blower door to measure duct leakage to outside, the total error in the measurements (duct blaster plus blower door) is < ± 10.5%.

6 Cost Effectiveness

PHAs have a limited ability to fund energy efficiency improvement out of operating budgets. Most major improvements are made through one of the programs or funding sources described in Section 1.2, each of which has its own cost-effectiveness criteria. The measures included in the turnover protocols are very low cost because of limited operating budgets and because PHAs do not recoup most of the energy savings from reductions in apartment energy use.

7 Risks and Barriers

The approach of using PHA staff to implement a standard set of energy efficiency measures at unit turnover has some potential risks, some of which were encountered during this project. Risks include:

- PHA staff, due to staff changeover or inadequate training, may be underqualified to install the measures, or neglect to do so. This could result in missed savings opportunities, or the creation of new problems if measures are improperly installed. Attention to proper training along with supervision and a quality control procedures can help mitigate this risk. The National Renewable Energy Laboratory has developed the Standard Work Specifications for Home Energy Professionals (National Renewable Energy Laboratory, 2013). These "Guidelines for Home Energy Professionals," available for single-family homes, manufactured homes, and multifamily buildings, can help PHAs establish quality standards, worker certifications, and standard work specifications.
- A PHA may come to rely solely on the standard protocol for energy efficiency improvements, ignoring other potentially important measures appropriate for individual dwellings, or measures such as equipment replacement that require greater funding or special expertise. The periodic HUD-required audits should mitigate this risk.
- Certain housing units may not fit the standard protocol if they are atypical. Again, the HUD-required periodic audits should catch these instances, allowing customized measures to be specified for those units.

Air sealing units that do not have active whole-house fresh air ventilation systems are potential concerns if infiltration is reduced significantly. ASHRAE 62-89, utilized by the Building Performance Institute Building Analyst Technical Standards (Building Performance Institute, 2012), provides guidance on when infiltration reductions trigger the need to add fresh air ventilation systems. All of the units involved in this study had at least 20% higher tested infiltration levels than would lead to recommendations for mechanical ventilation according to this standard.

7.1 Barriers

Introduction of the new energy efficiency turnover process was not without complications as certain barriers arose when attempting to implement the process. These barriers can be categorized as operational, field, and budgetary issues.

7.1.1 Operational

- Some PHA staff members had little to no background knowledge to help them understand the basics of energy efficiency or building science. Developing relationships with local weatherization assistance agencies to train PHA staff could potentially improve skills and provide a local resource, but funding may prove challenging.
- Training sessions were not fully attended because of scheduling conflicts or emergencies.
- Trained staff did not adequately pass the knowledge on to new staff members or those who missed training sessions. High staff turnover made it difficult to institutionalize the knowledge and skills needed to properly implement the protocol.

- Quality control was difficult to enforce due to a lack of supervisors and/or inconsistent use of protocol checklists and punch-lists that staff should have completed for each unit.
- Use of subcontractors to perform certain work made it difficult to implement some measures (such as air sealing behind switch and wall receptacle cover plates that were removed and replaced by painting subcontractors) as efficiently as possible. Integration into the subcontractors' scope is the ultimate goal, but may increase costs.

7.1.2 Field

- Due to age of the units, some components such as duct boots were hard to access because register covers were sealed to the ceiling with multiple layers of paint.
- Despite undergoing training, misunderstandings and misconceptions by PHA staff sometimes led them to spend inordinate amounts of time on unimportant items.
- PHA managers sometimes emphasized aesthetics at the expense of energy savings; for example, prohibiting caulk where it may be visible.
- In a few cases, a PHA made incorrect assumptions regarding building code requirements that they said would prevent them from implementing recommended measures (e.g., sealing the louvered mechanical room doors or air sealing at electrical receptacles or switches).

7.1.3 Budgetary

PHA budgetary policies can sometimes prevent even small purchases of inexpensive items such as caulk, weather-stripping and insulation, even when the funds are available.

8 Conclusions

A survey of more than 100 PHAs across the country indicated that there is a high level of interest in developing low-cost solutions that improve energy efficiency and can be seamlessly included in the refurbishment process. Further, PHAs have incentives (both internal and external) to reduce utility bills.

Partnering with two PHAs, ARIES tested the energy savings potential of a standard set of efficiency measures that could be implemented by PHA staff during unit turnover. The measures reduced air infiltration, resulted in tighter ducts, and improved equipment efficiency. ARIES documented the implementation of these measures in ten housing units. These resulted in average air leakage reductions of 16%–20% and duct leakage to outside reductions of 38%. Total source energy reduction based on BEopt modeling was 6%–10%. A simple payback of 1.7–2.2 years was estimated based on modeling of typical units at IHA and RHA.

Difficulties exist in the form of operational and budgetary issues. Lack of complete training and inadequate quality control can prevent PHAs from effectively retrofitting all units to their full potential. Nevertheless, while implementation challenges exist, it was demonstrated that combining simple improvements like sealing and caulking penetrations, windows and doors, sealing duct boots, and adding pipe insulation can create a turnover package that is feasible for PHA staff to accomplish with little budgetary impact. At average housing unit turnover rates, these measures could impact hundreds of thousands of unit per year nationally.

The initial research questions, and the answers provided by this work are provided below:

1. Is it feasible to implement a prescriptive set of cost-effective energy measures in public housing units during the short turnover periods when the units are vacant?

It is feasible to implement a prescriptive set of cost-effective energy measures in public housing units during unit turnover periods. Most of the required work can be completed within a short period of time, the work has a significant impact on pressurization test results, and it does have an effect upon the energy efficiency of the unit as estimated via modeling.

2. Based on partner PHAs as case studies, what specific package(s) of energy measures can routinely be installed during turnovers that would be cost effective?

Some energy measures that can be routinely and easily installed are air sealing, duct boot sealing, cleaning bath fans, installing energy-efficient lighting, and insulating attics where needed. Detailed protocols were developed describing the measures and are included in the appendices.

3. What are the estimated costs and energy savings of such a protocol in typical PHA units?

Complete labor and material costs were about $250 per unit and annual utility bill savings ranged from about $100–$150 per unit, or 6%–10% of the total utility bill.

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Appendix A: Survey Results Report

ARIES conducted a survey of PHAs to better understand their housing stock, experience with and interest in energy efficiency improvements, and to gauge interest in participating in Building America research. The survey was conducted online (see Appendix B for a copy of the survey instrument). Notice of the survey was sent out to PHA contact emails obtained from HUD, published in industry newsletters and in some states re-distributed by local contacts. Responses were received from 109 PHAs, representing 3% of the 3300 PHAs in the country. The major findings of the survey are presented below.

Characteristics of Respondents

Responses were received from PHAs in 33 states. While PHAs ranged in size from single development PHAs with fewer than 20 units owned by PHAs with thousands of units in scores of developments, most PHAs are small (Figure 12). Of all respondents, 72% of the PHAs own fewer than 300 units (Figure 11), and 61% own fewer than three developments (sites).

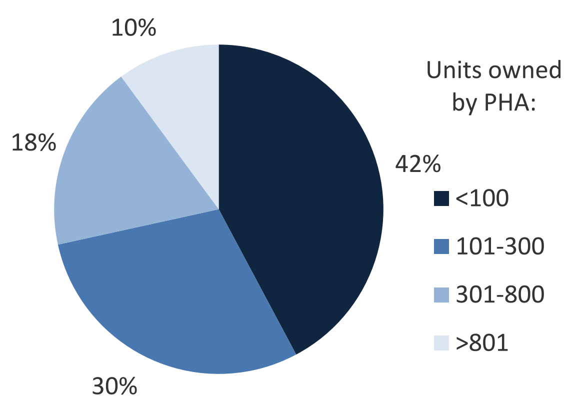


Figure 11. Percentage of PHAs responding by size (as measured by number of units owned)

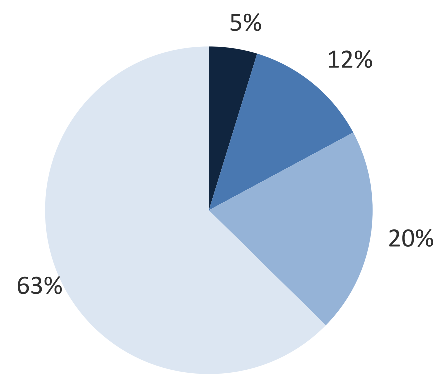


Figure 12. Percent of all units by PHA size

Turnover

Because the research hypothesis is that an opportunity exists to implement energy efficiency measures during unit turnover, five questions were asked relating to this subject. Of respondents, the average annual unit turnover rate is 16%, but it can be much higher: up to 45% (Figure 13). The average turnover time is 21 days, but it can be as short as 3–4 days in high demand areas, or much longer in lower demand areas (Figure 14).

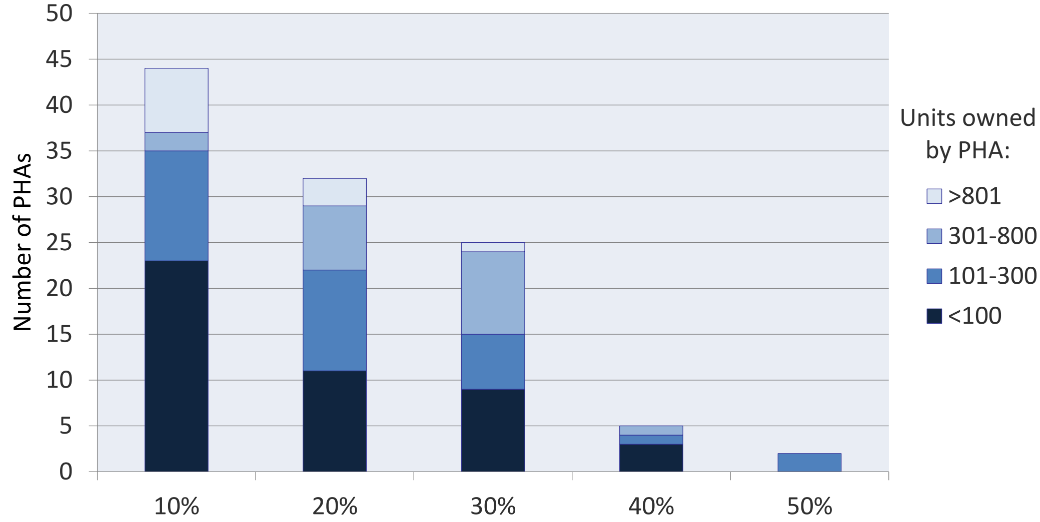


Figure 13. Annual turnover rate

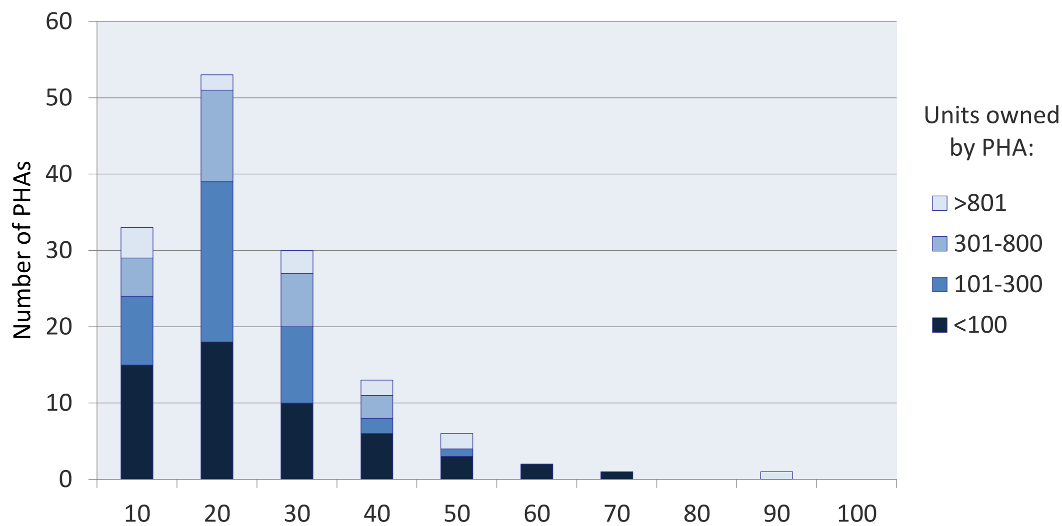


Figure 14. Turnover time (in days)

Almost all PHAs paint, clean, and make minor repairs during turnover, but very few do major work at this time (Figure 15). The vast majority of PHAs have in-house staff who perform this work (Figure 16).

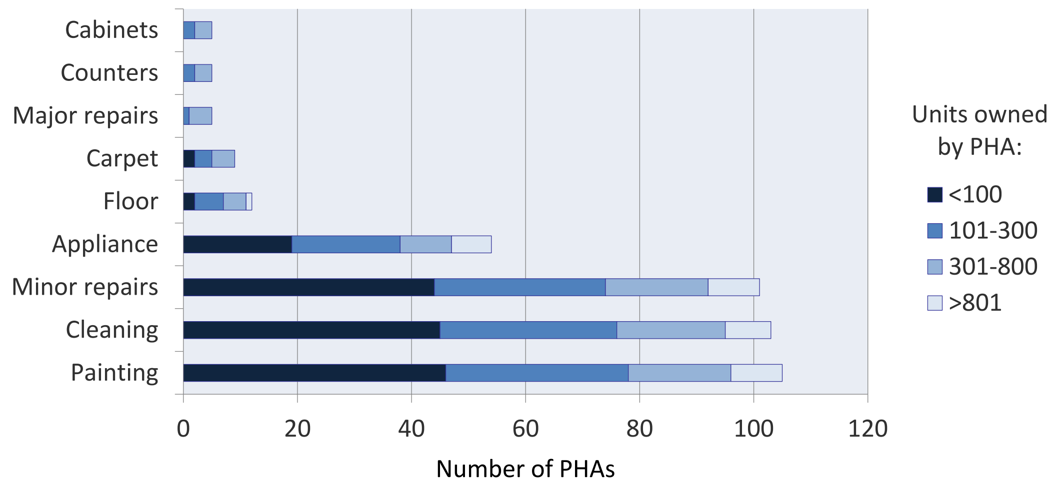


Figure 15. Activities conducted at unit turnover

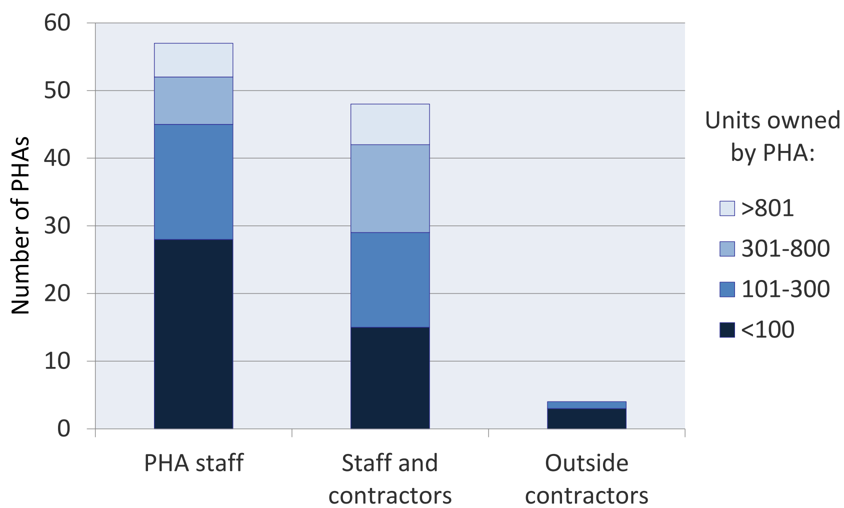


Figure 16. Repairs conducted by staff or contractors

Unit Characteristics

PHAs were asked to estimate the percentage of their units by building type (single-family detached or attached, multifamily low or high rise), material (wood frame or masonry), and age. The single most common unit type is single-family attached (40%), although multifamily units outnumber single-family overall (23% low-rise and 34% high-rise). Single-family detached homes are relatively rare (3%). Figure 17 shows the breakdown of unit type by PHA size.

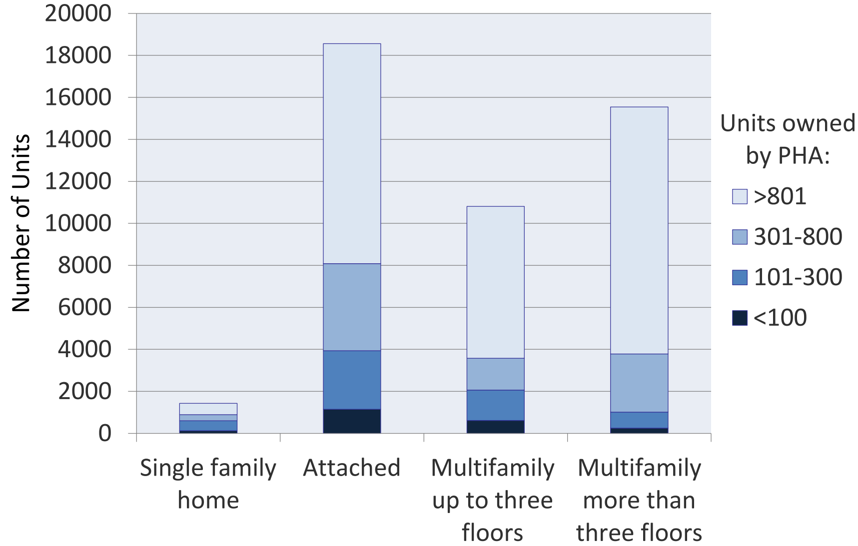


Figure 17. Unit type

Except for the larger PHAs (mostly in major cities), the vast majority of public housing represented by respondents is wood frame (Figure 18). Roof type tracks this distribution, with a similar percentage having pitched roofs.

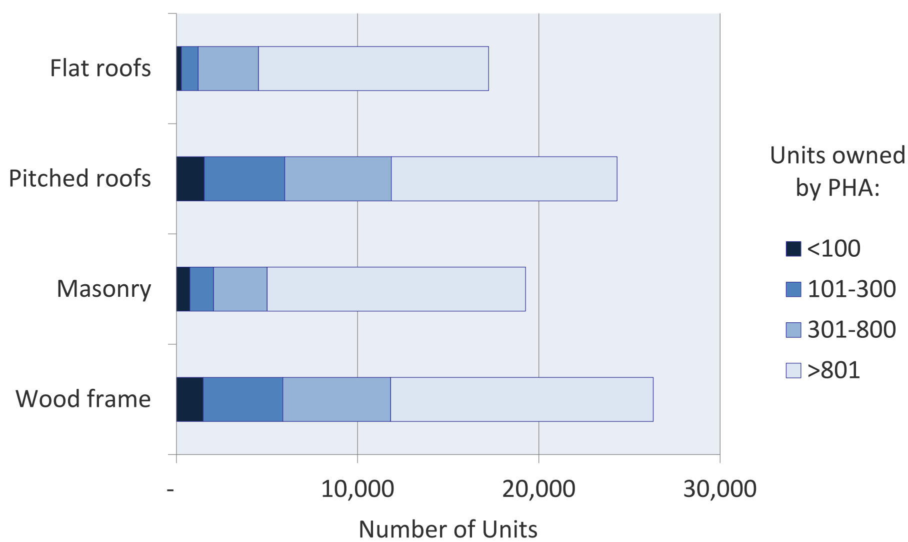


Figure 18. Building construction

Approximately 60% of the units are more than 30 years old, meaning they were built well before the stricter energy codes of recent years. As can be seen from Figure 19, smaller PHAs are less likely to have constructed units within the past 30 years. 84% of units less than 30 years old are owned by PHAs with more than 800 units in the portfolio.

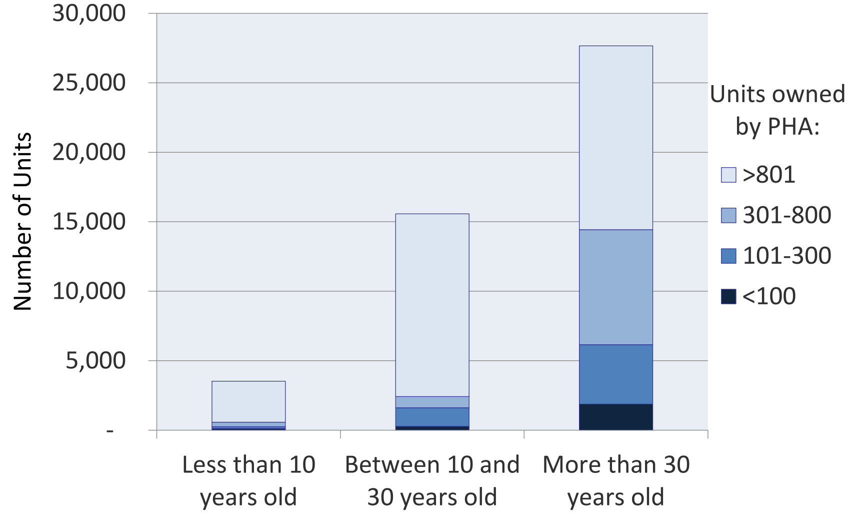


Figure 19. Building Age

And about half of the PHA units surveyed have utilities submetered, sometimes just for electricity (Figure 20). In those units not submetered (often multifamily high-rises), the PHA pays the utility bills.

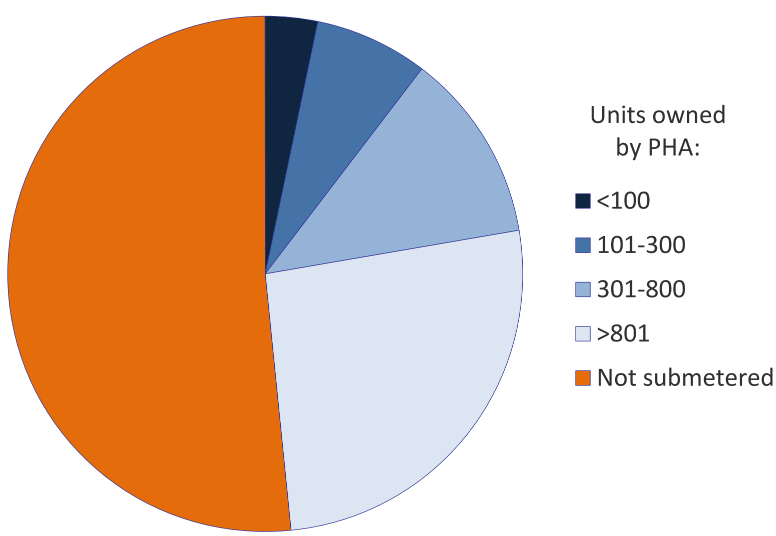


Figure 20. Buildings submetered

Gas furnaces are the dominant appliance providing space heating among respondents, except for the larger PHAs, where boilers predominate in large multifamily buildings (Figure 21). Electric heating is fairly common overall (nearly 13% of units), and even more common in mixed or cold climate areas (20% of units). For cooling, room ACs are common in multifamily buildings (Figure 22). Of the units represented by the respondent PHAs, about 4% had renewables installed, which were mainly in the larger PHAs (Figure 23).

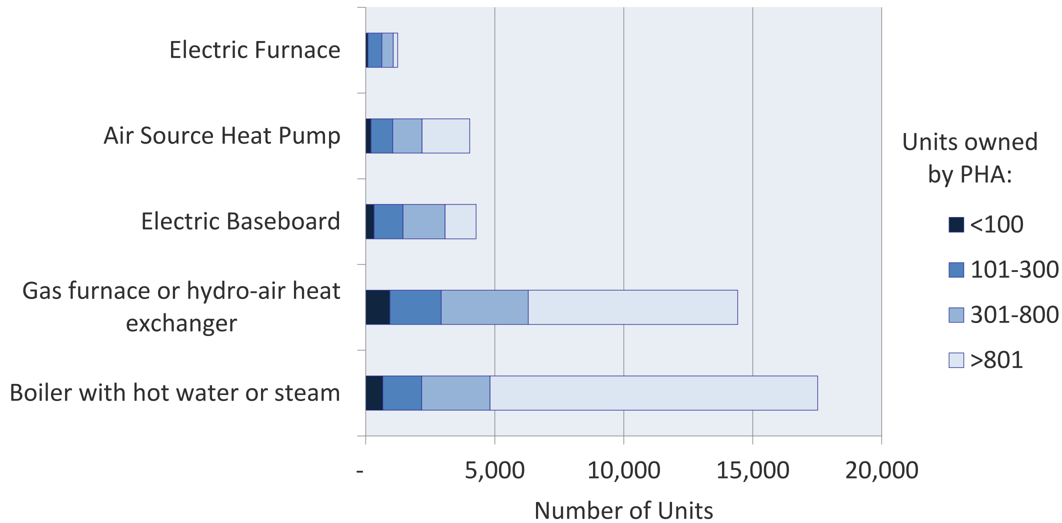


Figure 21. Heating system type

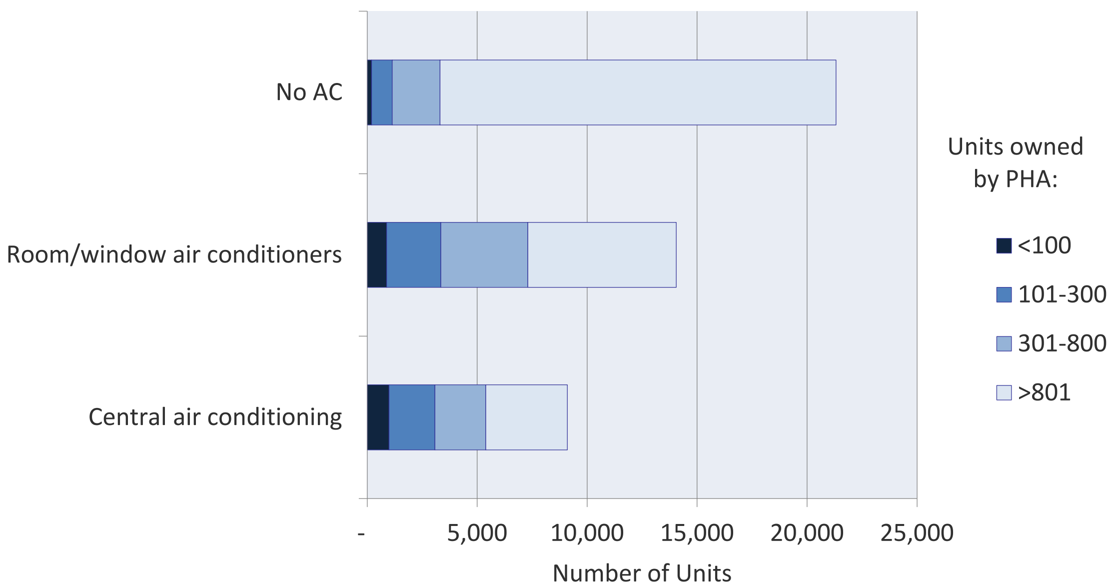


Figure 22. Cooling system

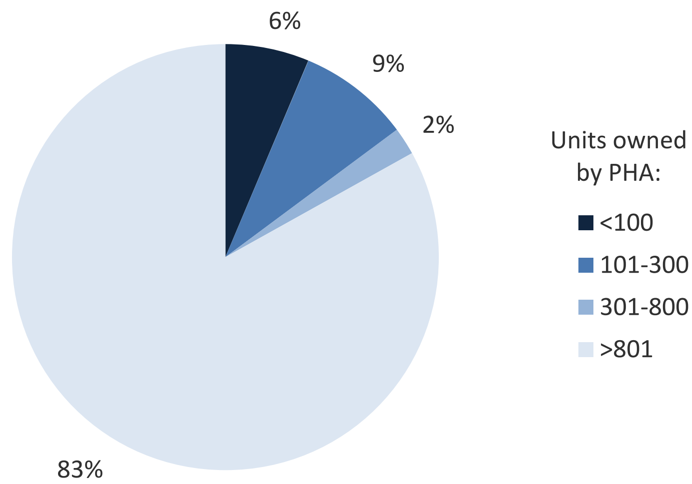


Figure 23. Use of renewables by PHA size

Interest in Efficiency Measures

Of the respondents, similar numbers of PHAs have weatherized all their units as have weatherized very limited numbers of units, with few PHAs in between (Figure 24). In addition, water efficiency is very important to many PHAs (Figure 25).

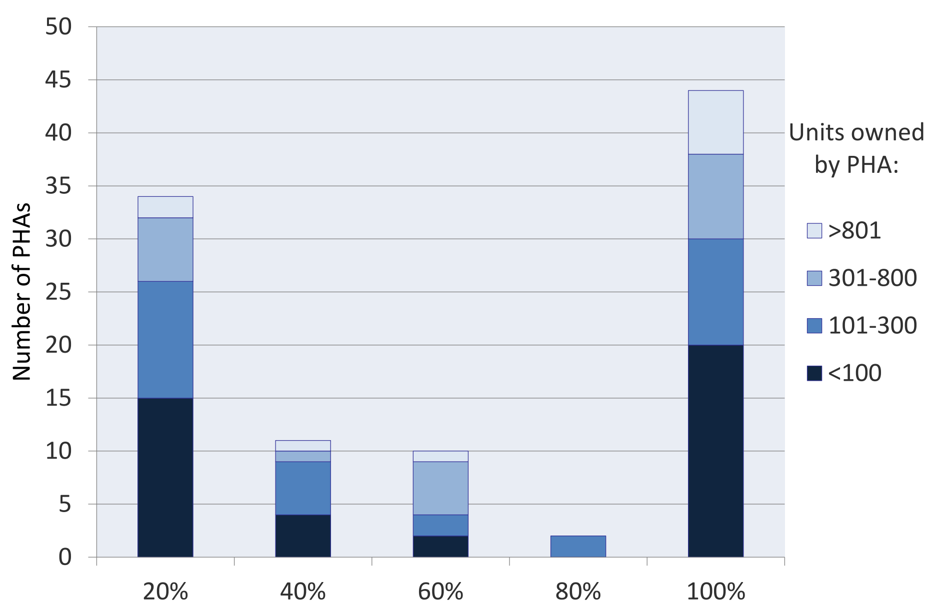


Figure 24. Weatherization

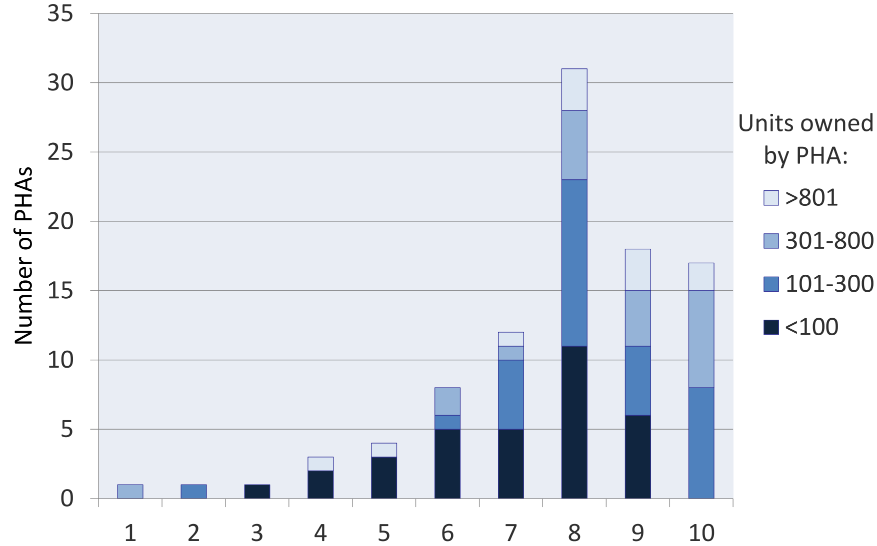


Figure 25. Interest in water conservation (1 = not important; 10 = very important)

Most PHAs are willing to invest to some degree on energy efficiency measures, with about a third of respondents replying that they invest significant sums (Figure 26). Most have no payback criteria for energy efficiency measures, although very small PHAs are less tolerant of long paybacks (Figure 27). HUD is the main source of energy efficiency funding, but a large number of respondents indicate they also self-fund improvements (Figure 28). EPCs are better suited to the larger PHAs that can meet their minimum savings targets.

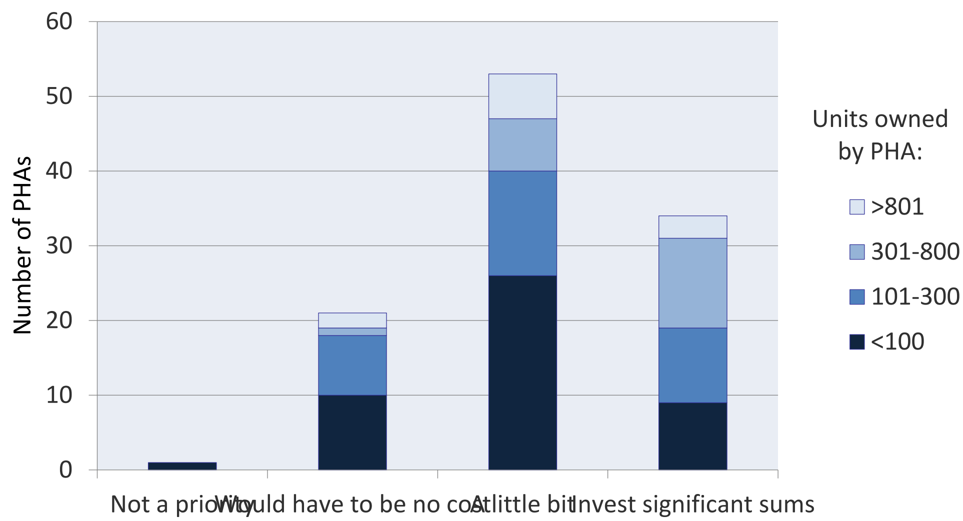


Figure 26. Spending on energy efficiency

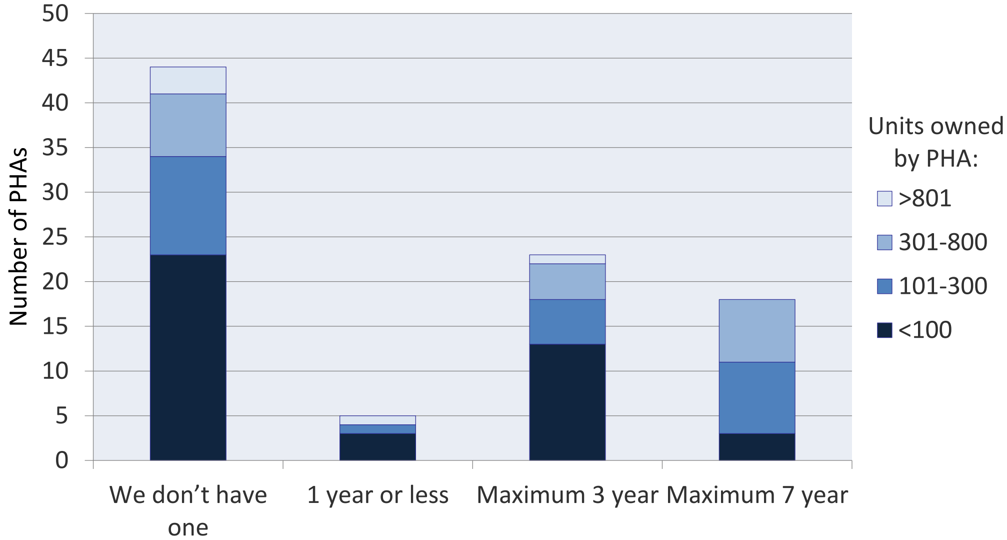


Figure 27. Payback requirements

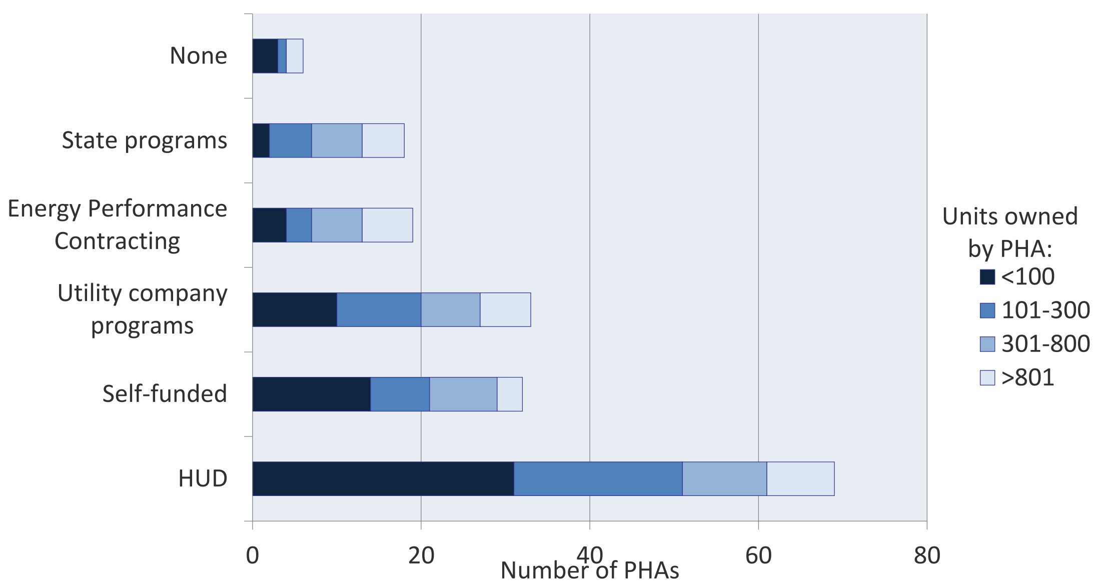


Figure 28. Funding sources

Ninety-five percent of respondents said that having PHA staff implement energy efficiency measures during turnover was of interest (Figure 29), although none of the PHA administrators spoken to during this process indicated that this was part of their standard operating procedures (this latter question was not specifically asked on the survey). More than 75% of responding PHAs, representing all size categories, indicated an interest in working with Building America to develop energy efficiency protocols for staff to implement at unit turnover (Figure 30).

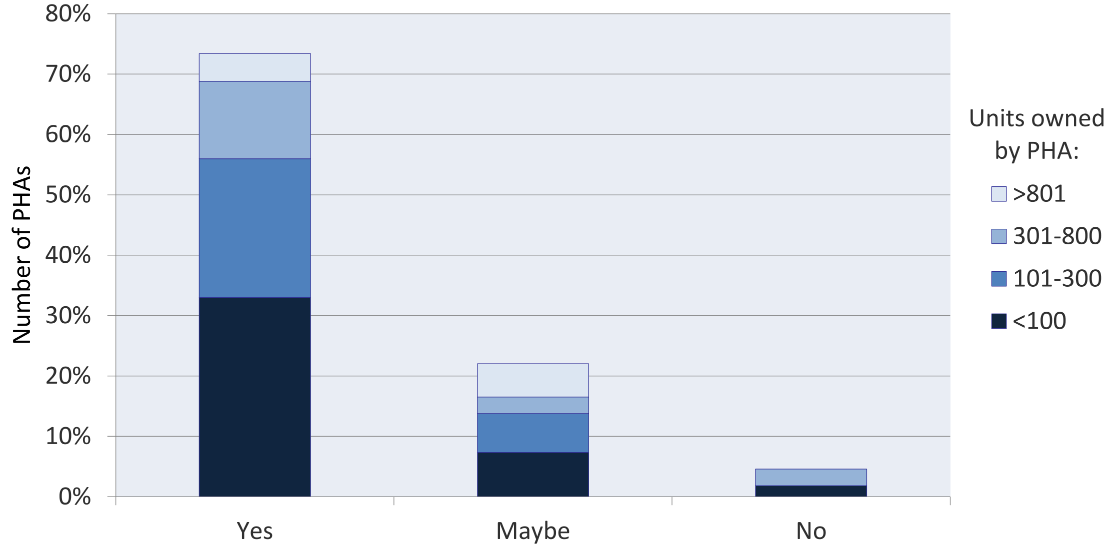


Figure 29. Interest in concept

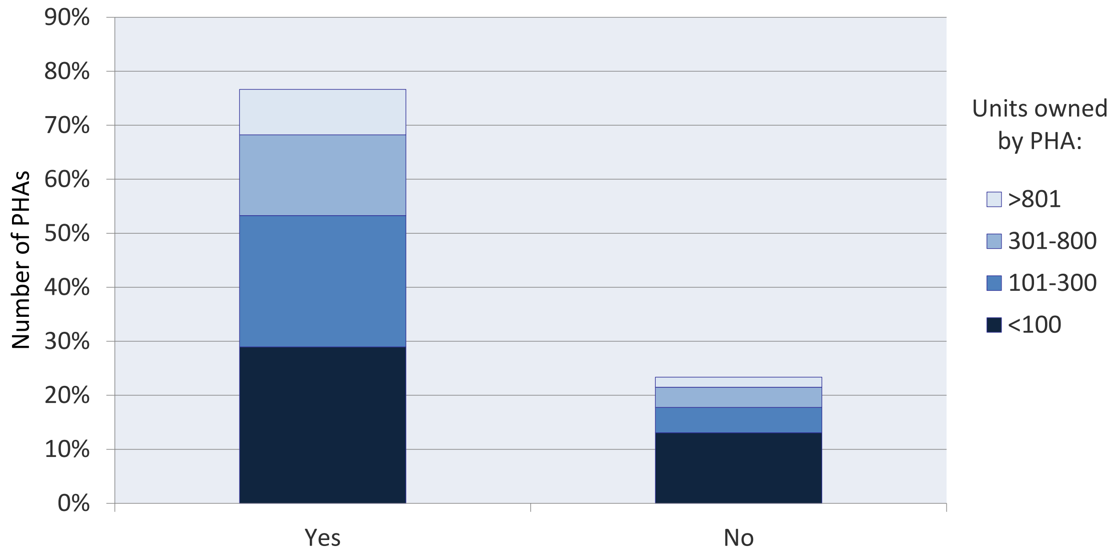


Figure 30. Interest in working with Building America

Appendix B: Survey Instrument

PHA Survey Email Introduction

Building America is a U.S. Department of Energy program that develops and evaluates technologies that improve the comfort, safety, durability and energy efficiency of the nation's housing. The program is implemented by several multidisciplinary teams. The ARIES Collaborative is one of these teams. ARIES's unique focus is on reducing energy use in affordable housing, including public housing.

As part of our current work, ARIES is developing a set of cost-effective energy efficiency measures designed specifically for use by PHAs. The measures will be low- or no-cost items and consider the financial and operational impact on PHAs. They will result in safer, healthier, more durable, and comfortable homes and will provide a positive return on investment.

This project is starting with a survey of selected PHAs. The survey will help us assess the potential opportunity associated with implementing a set of energy improvements in the short period (several days) between occupancies. Selected PHAs will be invited to participate in field evaluations of the improvements planned for the latter phases of the program.

Please follow this link to access the survey.

Thank you.
Jordan Dentz
ARIES Collaborative

Public Housing Agency On-Line Survey

Please answer as many of the following questions as possible, providing your best estimates. This survey should take approximately 15 minutes to complete. Exact numbers are not necessary.

1. Contact information
    a. PHA name
    b. Contact name
    c. Contact job function/position at PHA (this survey is intended for personnel involved in facilities management or capital improvement)
    d. Contact phone
    e. Contact email
2. General information about your PHA
    a. Number of developments owned/managed
    b. Number of living units owned/managed
3. Operating issues
    a. What is the typical annual resident turnover rates overall at your PHA?
    b. How many days do units typically remain vacant between occupancies?

c. At unit turnover what are the typical activities performed by your PHA (select one or more)?

    i. Painting

    ii. Cleaning

    iii. Minor repairs

    iv. Appliance replacement (if old)

    v. Other – please list:

d. Who performs these activities between occupancies (select one or more)?

    i. PHA staff

    ii. Outside contractors

    iii. Staff and contractors

e. How would you describe the overall skill level of your staff?

    i. Modestly skilled: Able to perform simple maintenance tasks such as painting, filter changes, faucet drips, etc.

    ii. Moderately skilled: Able to handle small improvement projects such as weather-stripping, appliance replacement, wall repairs

    iii. Highly skilled: Able to complete moderate to major renovations such as window replacement, plumbing repairs, electrical work.

f. Approximately what percentage of your living units have been weatherized in the past 10 years?

g. How much does your PHA pay annually for living unit utility costs (recognizing that these costs are reimbursed)?

h. How much does this represent as a percentage of your PHA operating budget?

4. Interest in energy efficiency

    a. Recognizing that PHAs are reimbursed by HUD for most energy expenses, how interested is your PHA in reducing energy use at your sites?

        i. Not a priority for us

        ii. We would do it, but there would have to be no cost to us

        iii. We spend a little bit on energy efficiency

        iv. We invest significant sums in energy efficiency

b. What is your PHA's cost-effectiveness or payback criterion for deciding on energy efficiency investments?
    i. We don't have one
    ii. 1 year or less payback
    iii. Maximum 3 year payback
    iv. Maximum 7 year payback
    v. Other criteria:__________

c. What sources of funding does/has your PHA used for energy efficiency measures (select one or more)?
    i. None (we have not done any)
    ii. Self-funded
    iii. HUD
    iv. Energy Performance Contracting
    v. Utility Company programs
    vi. State programs
    vii. Other ____________

d. Is the idea of implementing during unit turnover low-cost energy efficiency measures that have proven and quantified effectiveness appealing to your PHA?
    i. Yes. Please explain:__________________________
    ii. Maybe. Please explain:__________________________
    iii. No. Please explain:__________________________

e. How important is water conservation to your PHA?
    i. Not on our radar (1) ….. A top priority for us (10)

5. Characteristics of the housing operated by your PHA
    a. Approximate number of **sites (not buildings)** that have:
        i. 1 living unit (i.e. a stand-alone single-family home)
        ii. 2-4 living units
        iii. 5-50 living units
        iv. More than 50 living units (i.e. could be one large building or 50 single-family homes at one site)
    b. Approximate percentage of living units that are in:
        i. Single-family homes
        ii. Attached (townhome/duplex type) buildings

      iii. Multifamily buildings up to three floors (multifamily buildings generally have common areas and/or living units stacked vertically)
      iv. Multifamily buildings more than three floors
   c. Approximate percentage of living units that are built with:
      i. Wood frame construction (may have brick cladding)
      ii. Masonry construction
      iii. Pitched roofs (with attics)
      iv. Flat roofs
   d. Approximate percentage of living units that have:
      i. Electric baseboard heat
      ii. Electric furnace (forced air) heat
      iii. Air source heat pumps
      iv. Gas furnace or hydro-to-air exchanger (with forced air distribution)
      v. Boiler with hot water or steam distribution
      vi. Central air conditioning
      vii. Room/window air conditioners
      viii. Renewables (PV, solar thermal or ground source heat pumps)
   e. Approximate percentage of living units that are:
      i. Less than 10 years old
      ii. Between 10 and 30 years old
      iii. More than 30 years old
   f. Approximate percentage of living units that are individually (sub)metered for utilities (whether or not paid for by the resident).
6. Building America
   a. Thank you for participating in this survey. Would you be interested in discussing Building America research opportunities such as field evaluations of the energy efficiency protocols at your PHA?

Appendix C: IHA Implementation Guidelines

Islip Housing Authority: Unit Turnover Protocol Checklist

Address and apartment number: ______________________________

	ITEM	COMPLETE	N/A
AIR SEALING	Seal bottom of walls to floor if carpet removed and/or where accessible		
	Seal plumbing penetrations (all walls): shower heads, under sinks, water heater		
	Seal electrical penetrations (all walls, ceilings): outlets, switches, behind oven/fridge, telephone box, intercom, in closet ceilings/floors		
	Re-grout tile floors and walls		
	Seal at base of bathtubs, toilets		
	Seal ceiling penetrations at lighting fixtures		
	Seal exhaust fan housing and ducts boots to ceiling		
	Replace entry door weather stripping if necessary		
	Caulk around entry door frame and windows		
	Foam inside door latches (all doors)		
	Seal at stair treads and risers		
AC	Clean AC filter if necessary		
	Seal around AC unit		
	Clean/replace air handler filter if present		
WATER	Check and adjust hot water temperature		
	Insulate hot water tank		
	Insulate exposed DHW pipes		
	Correct faucet/shower drips		
	Check shower flow and install low-flow showerhead if necessary		
ATTIC	Check and fix attic insulation		
	Seal wall top plates in attic if accessible		
	Add attic hatch insulation		
	Add attic hatch gasket		
LIGHTS	Check and replace light bulbs		
	Install LED surface mount light fixtures		
VENTILA-TION	Check bath and kitchen exhaust fan flow		
	Clean bath and kitchen exhaust fans		
	Check bath and kitchen exhaust fan condition		

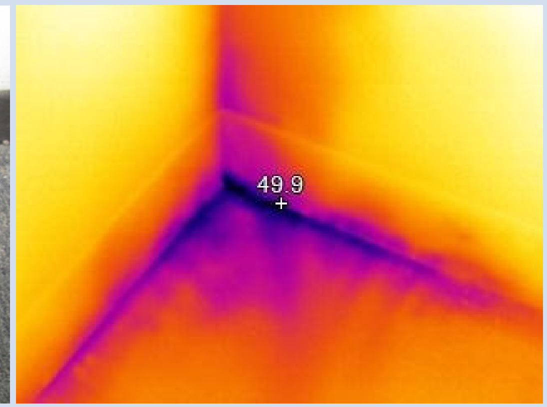
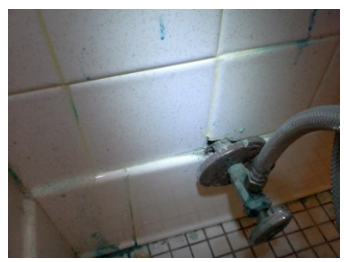
Date completed: ______________________________

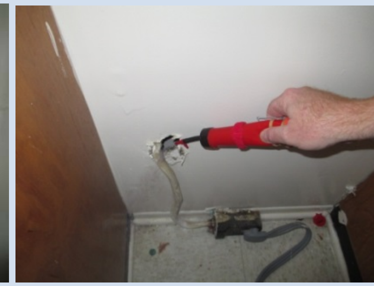
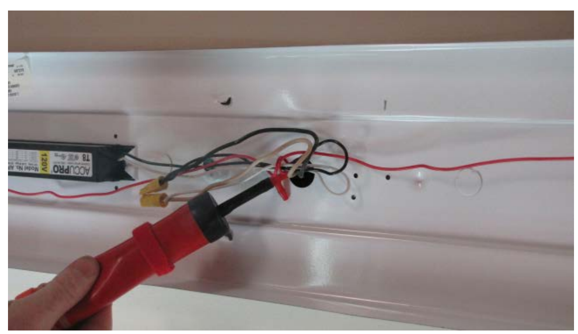
Signature of responsible staff: ______________________________

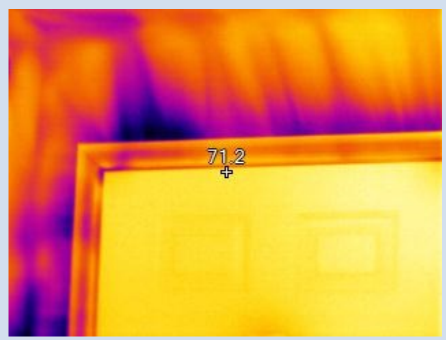
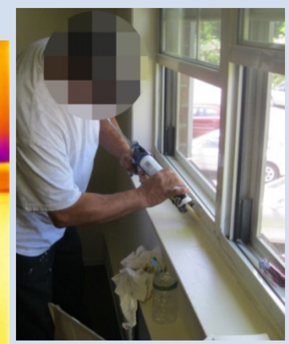
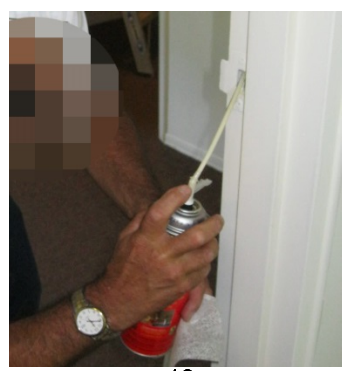
Name: ______________________________

Islip Housing Authority: Unit Turnover Protocol and Guidelines

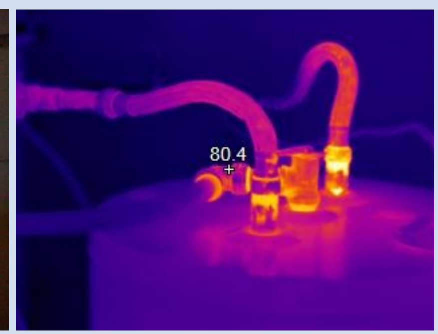
The following guidelines are intended for use when apartments are prepared for new residents. All activities are intended to be low-cost, achievable by IHA staff with readily available tools and materials, and fit within the time available during unit turnover. The guidelines are organized by topic and include information on location, how to accomplish the task, materials required and photos illustrating typical conditions

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
INTERIOR AIR SEALING	1. Bottom of walls	In rooms without carpet, caulk bottom of wall to floor and/or base molding (may require removal and replacement of vinyl cove). If replacing carpet, caulk between bottom of wall and floor before new carpet is installed. Seal around baseboard heaters with caulk suitable for high temperatures.	Caulk, cove molding and adhesive	 
	2. Plumbing penetrations (all walls)	Foam-seal plumbing penetrations	Foam	  

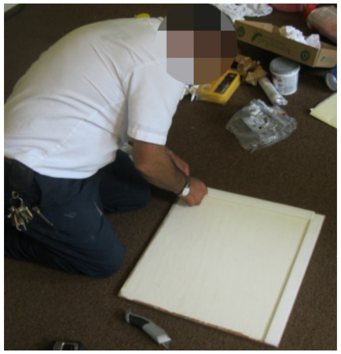
	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
INTERIOR AIR SEALING	3. Electrical penetrations (all walls)	Caulk or foam around electrical panel box and data boxes (i.e. Verizon); or install gasketed outlet box covers	Caulk, foam, or gasketed outlet covers	  
	4. Tile floors and walls	If grout is not intact, re-grout	Grout	
	5. Base of bathtubs, toilets, shower heads	Foam gap around shower heads and caulk gaps in top of shower tile and around base of toilet if missing.	Foam, caulk	  
	6. Lighting fixtures	Caulk or foam ceiling lighting penetrations (convert to surface mount LED fixtures when changing fixtures)	Foam	 

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
INTERIOR AIR SEALING	7. Exhaust fan and ducts registers	Foam or tape (with metal foil tape) gaps between exhaust fan housing or duct boots and wall/ceiling, completely sealing the perimeter of the fan/boot from the ceiling/wall cavity.	Metal tape (UL 181) and/or foam	  
	8. Door weather striping	If not intact and in good working order, replace	Replacement weather stripping	
	9. Entry door and window frames	Caulk gaps between entry door molding and wall; caulk gaps around window frames	Caulk	  
	10. Latches on all doors	Foam inside open door latches; ensure foam fills frame cavity above, below and to sides of latch opening. After foam hardens, cut away any foam that interferes with latch operation.	Foam	

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
AIR SEALING	11. Stair treads and risers	Caulk gaps around risers, treads and stringers and between stringers and wall.	Caulk	
AC	12. AC filter	Check and clean if necessary	N/A	
	13. AC unit	Tape/gasket gaps between AC and sleeve if AC present	Tape or gasket	
	14. Air handler filter	Clean or replace filter if dirty	Vacuum or compressed air; replacement filter	

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
WATER	15. Hot water temperature	If over 120°F at taps, reduce water tank temperature	Thermometer, screwdriver to adjust tank temperature	
	16. Hot water tank	If hot water heater does not have an insulation jacket installed, install one (with opening for heating element). If it does have a jacket installed, remove air gaps for a snug fit and fasten with tape. Insulation should be free of air gaps but not compressed. Attempt to completely surround the tank.	Water tank insulation jacket and compatible fastening tape	 
	17. Exposed DHW pipes	Add pipe insulation to un-insulated pipes in DHW tank closet	Pipe insulation and compatible tape	 
	18. Faucets or shower heads	If drips exist replace O-rings or washers	Replacement O rings / rubber washers	

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
WATER	19. Shower head	Ensure low-flow showerhead installed - if it takes less than 20 seconds to fill a one gallon container, replace with low-flow showerhead	Low-flow shower head, thread sealant / compound	
ATTIC	20. Attic insulation depth and distribution	Check that ceiling insulation is dispersed evenly without gaps, is free of water damage, and covers rafters and other framing members fully to the exterior walls. Re-arrange insulation or supplement if necessary.	Flashlight, attic insulation	  
	21. Wall top plates intersection with attic	When/if replacing attic insulation over framed walls, foam penetrations where accessible	Foam, flashlight	

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
ATTIC	22. Attic hatch insulation	Glue 2" rigid foam to back of hatch	Rigid foam board and construction adhesive	
	23. Attic hatch air leakage	Add gasket/weather stripping to seal hatch to opening	Gasket or weather stripping	 
LIGHTS	24. Light bulbs	Replace incandescent bulbs with standard or warm tone CFLs	CFLs	
	25. Pin-based fluorescent lamps	Consider replacing with LED when replacing fixtures	LED fixtures	

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
VENTILATION	26. Bath and kitchen exhaust fans (check flow)	Check fan flow. See NYSERDA's "Homeowner's Guide to Ventilation" (http://www.nyserda.ny.gov/~/media/Files/EERP/Residential/home_vent_guide.pdf?sc_database=web)	See NYSERDA guide (attached)	
	27. Bath and kitchen exhaust fans (check grime build-up)	If excessively dirty, vacuum fan blades, motor, and housing (wipe with rag before air sealing)	Vacuum, rags	
	28. Bath and kitchen exhaust fans (check condition)	If fan makes irregular mechanical noises, then replace	Replacement exhaust fan	

Appendix D: RHA Implementation Guidelines

Raleigh Housing Authority: Unit Turnover Protocol Checklist

Address and apartment number: ____

	ITEM	COMPLETE	N/A
AIR SEALING	Seal bottom of walls to floor if carpet removed and/or where accessible		
	Seal plumbing penetrations (all walls): shower heads, under sinks, water heater; inspect and seal plumbing access as necessary.		
	Seal electrical penetrations (all walls, ceilings): outlets, switches, behind oven/fridge, telephone box, intercom, in closet ceilings/floors		
	Re-caulk tile floors and walls using bath and tile caulk.		
	Seal at base of bathtubs, toilets		
	Seal ceiling penetrations at lighting fixtures		
	Seal exhaust fan housing and ducts boots to ceiling		
	Replace entry door weather stripping if necessary		
	Caulk around entry door frame and windows; be sure to get the tops.		
	Foam inside door latches (all doors)		
	Seal at stair treads and risers		
AC	Replace louvered mechanical room door with solid, weather-stripped door		
	Seal air handler cabinet and return ductwork and filter slot.		
	Clean/replace air handler filter; clean return air grille		
WATER	Check and adjust hot water temperature		
	Insulate hot water tank		
	Insulate exposed DHW pipes		
	Correct faucet/shower drips		
	Check shower flow and install low-flow showerhead if necessary		
ATTIC	Check and fix attic insulation		
	Seal wall top plates and wire penetrations within reach in attic if accessible		
	Add attic hatch insulation		
	Add attic hatch gasket		
LIGHTS	Check and replace light bulbs		
	Install LED surface mount light fixtures		
VENTILA-TION	Check bath and kitchen exhaust fan flow		
	Clean bath and kitchen exhaust fans		
	Check bath and kitchen exhaust fan condition		

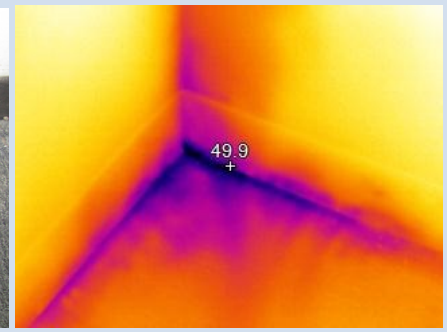
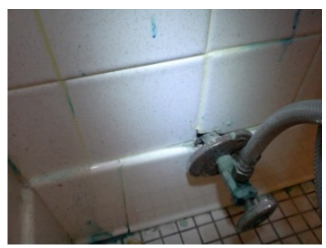
Date completed: ____

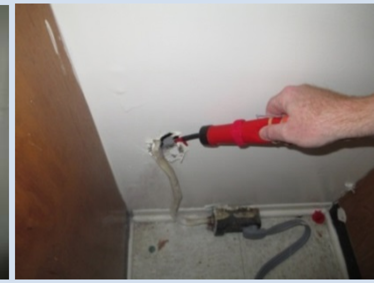
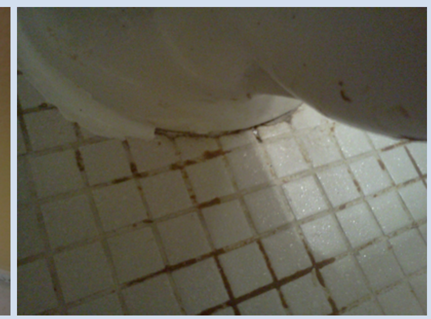
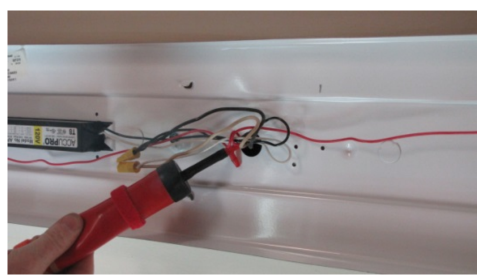
Signature of responsible staff: ____

Name: ____

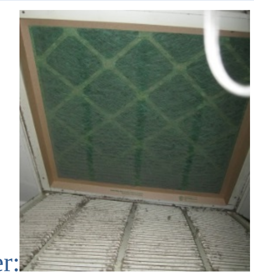
Raleigh Housing Authority: Unit Turnover Protocol and Guidelines

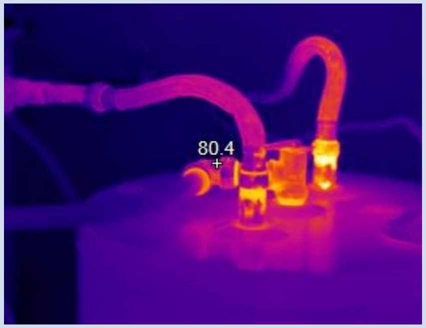
The following guidelines are intended for use when apartments are prepared for new residents. All activities are intended to be low-cost, achievable by RHA staff with readily available tools and materials, and fit within the time available during unit turnover. The guidelines are organized by topic and include information on location, how to accomplish the task, materials required and photos illustrating typical conditions.

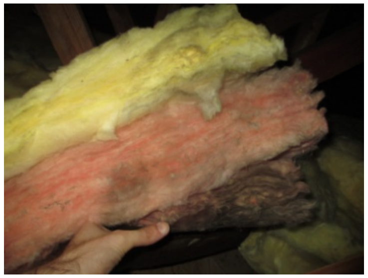
	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
INTERIOR AIR SEALING	1. Bottom of walls	In rooms without carpet, caulk bottom of wall to floor and/or base molding (may require removal and replacement of vinyl cove). If replacing carpet, caulk between bottom of wall and floor before new carpet is installed. Seal around baseboard heaters with caulk suitable for high temperatures.	Caulk, cove molding and adhesive.	 
	2. Plumbing penetrations (all walls)	Foam-seal plumbing penetrations. Look for all plumbing accesses, inspect and seal as needed.	Foam	  

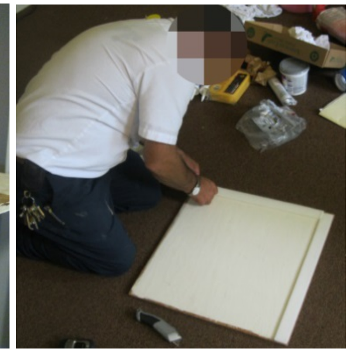
	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
INTERIOR AIR SEALING	3. Electrical penetrations (all walls)	Caulk or foam around electrical panel box and data boxes (i.e. Verizon); or install gasketed outlet box covers	Caulk, foam, or gasketed outlet covers	  
	4. Tile floors and walls	If caulk is not intact, re-caulk.	Bath and Tile Caulk	
	5. Base of bathtubs, toilets, shower heads	Foam gap around shower heads and caulk gaps in top of shower tile and around base of toilet if missing.	Foam, caulk	  
	6. Lighting fixtures	Caulk or foam ceiling lighting penetrations (convert to surface mount LED fixtures when changing fixtures)	Foam	 

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
INTERIOR AIR SEALING	7. Exhaust fan and ducts registers	Foam or tape (with metal foil tape) gaps between exhaust fan housing or duct boots and wall/ceiling, completely sealing the perimeter of the fan/boot from the ceiling/wall cavity.	Metal tape (UL 181) and/or foam	  
	8. Door weather striping	If not intact and in good working order, replace	Replacement weather stripping	
	9. Entry door and window frames	Caulk gaps between entry door molding and wall; caulk gaps around window frames. Be sure to seal the tops. Caulk underneath the sill if a crack is visible.	Caulk	  
	10. Latches on all doors	Foam inside open door latches; ensure foam fills frame cavity above, below and to sides of latch opening. After foam hardens, cut away any foam that interferes with latch operation.	Foam	

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
AIR SEALING	11. Stair treads and risers	Caulk gaps around risers, treads and stringers and between stringers and wall when wall is connected to outside or crawlspace.	Caulk	
AC	12. Mechanical room door	Replace louvered door with solid door with weather stripping to seal mechanical equipment room from conditioned space.	Solid door, weather stripping	Before: 
	13. Air handler	Ensure that leaks in air handler and return ductwork inside mechanical room are well sealed (including around filter slot).	Mastic and/or foil tape	Well sealed:  
	14. Air handler filter and grille	Clean or replace filter if dirty; clean return air grille	Vacuum or compressed air; replacement filter; rags	Clean filter:  Dirty grille: 

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
WATER	15. Hot water temperature	If over 120°F at taps, reduce water tank temperature	Thermometer, screwdriver to adjust tank temperature	
	16. Hot water tank	If water heater has no insulation jacket, install one (with opening for heating element). If it has a jacket, remove gaps for a snug fit and fasten with tape. Insulation should not be compressed. Completely surround the tank.	Water tank insulation jacket and compatible fastening tape	Before:  After: 
	17. Exposed DHW pipes	Add pipe insulation to un-insulated pipes in DHW tank closet	Pipe insulation and compatible tape	 
	18. Faucets or shower heads	If drips exist replace O-rings or washers	Replacement O rings / rubber washers	

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
WATER	19. Shower head	Ensure low-flow showerhead installed - if it takes less than 20 seconds to fill a one gallon container, replace with low-flow showerhead.	Low-flow shower head, thread sealant / compound	
ATTIC	20. Attic insulation depth and distribution	Check that ceiling insulation is dispersed evenly without gaps, is free of water damage, and covers rafters and other framing members fully to the exterior walls. Re-arrange insulation or supplement if necessary.	Flashlight, attic insulation	Poor insulation condition:   
	21. Wall top plates intersection with attic	When/if replacing attic insulation over framed walls, foam penetrations where accessible. Also foam wire penetrations in top plates that are within reach.	Foam, flashlight	Electrical penetration at top plate: 

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
ATTIC	22. Attic hatch insulation	Glue 2" rigid foam to back of hatch	Rigid foam board and construction adhesive	
	23. Attic hatch air leakage	Add gasket/weather stripping to seal hatch to opening	Gasket or weather stripping	 
LIGHTS	24. Light bulbs	Replace incandescent bulbs with standard or warm tone CFLs.	CFLs	
	25. Pin-based fluorescent lamps	Consider replacing with LED when replacing fixtures.	LED fixtures	

	LOCATION	INSTRUCTIONS	MATERIALS	PHOTOS
VENTILATION	26. Bath and kitchen exhaust fans (check flow)	Check fan flow. See NYSERDA's "Homeowner's Guide to Ventilation" (http://www.nyserda.ny.gov/~/media/Files/EERP/Residential/home_vent_guide.pdf?sc_database=web)	See NYSERDA guide (attached)	
	27. Bath and kitchen exhaust fans (check grime build-up)	If excessively dirty, vacuum fan blades, motor, and housing (wipe with rag before air sealing)	Vacuum, rags	
	28. Bath and kitchen exhaust fans (check condition)	If fan makes irregular mechanical noises, then replace	Replacement exhaust fan	

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