MULTIFAMILY ENERGY AUDIT GUIDE

MARYLAND DEPARTMENT OF
HOUSING & COMMUNITY DEVELOPMENT

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Contents

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INTRODUCTION

Document Purpose

- The purpose of this document is to establish best practices and guidance for conducting the energy analysis required for multifamily (MF) building energy improvement projects funded by the various programs of the Maryland Department of Housing and Community Development (DHCD). The intended audience includes energy auditors, building owners and operators, contractors, designers, architects, engineers, and energy efficiency consultants and program staff. Use of the best practices in this guide will improve the accuracy and uniformity of energy audits, and increase the alignment between predicted and actual energy savings in retrofitted MF buildings.
- This document is not specifically tied to a particular DHCD program. Rather it is intended to be flexible enough to use across different MF programs administered by DHCD.
- The guidance in this document is based on DHCD's direct experience with energy upgrades in MF buildings, as well as current program models and industry standards for MF building energy audits and upgrades. Key references include standards and program references from the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), the Building Performance Institute (BPI), the New York State Energy Research and Development Authority (NYSERDA), the U.S. Department of Energy (DOE), and the U.S. Environmental Protection Agency's ENERGY STAR program.
- Keep in mind that locally applicable building codes and standards take precedence over any guidance found in this guide. Further, auditors and the construction teams must also comply with any referenced codes, standards, or green building programs which are part of the DHCD program under which their project is being funded.

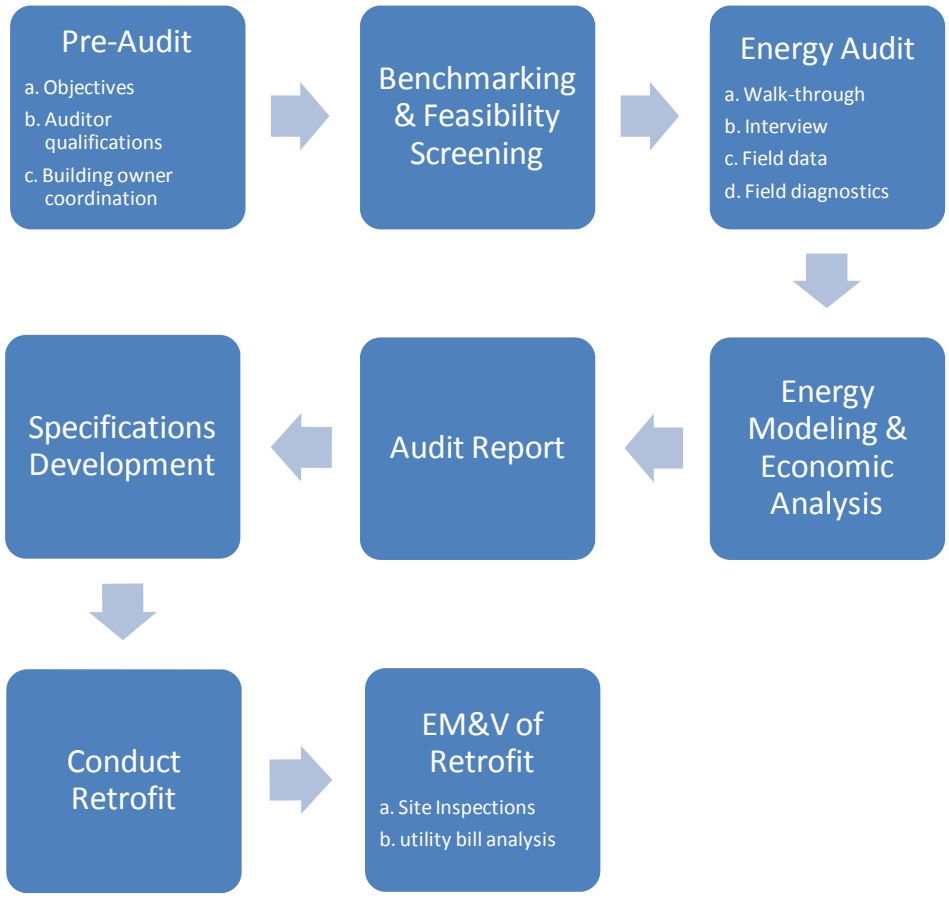
How to Use the Guide

- The information in this guide is ordered based on the typical sequence of an energy audit and retrofit project.

- The guide contains many recommended practices. These practices will improve the quality of energy audits and retrofits and their ability to deliver on predicted energy savings. In some cases a given practice may be ***required***, and will be noted accordingly.
- DHCD may elevate some recommended practices to required provisions over time, so auditors and others are expected to utilize recommended practices to the extent possible.
- "Energy improvements," "energy conservation measures," and similar terms are used in the auditing arena to represent various upgrade measures to a building. The terms energy conservation measures (ECMs) or simply "measures" are used in this document. Note that "measures" may also represent water conservation measures.

Process Overview

The flow chart below outlines the steps in the audit/retrofit/verification process. The guidance in this document will generally follow this same sequence.



PRE-AUDIT CONSIDERATIONS

Audit Objectives

The key objectives for building energy audits must include:

- Documenting existing conditions affecting the building's energy and water use.
- Identifying cost-effective energy conservation measures (ECMs) in the areas of heating, cooling, ventilation, building envelope, water heating, lighting , appliances, miscellaneous equipment and plug loads.
- Identifying cost-effective water conservation measures.
- Assessing the need for ventilation or moisture management upgrades to accompany recommended energy efficiency improvements.
- Documenting any observed safety and health concerns with the building, which are encountered in the course of conducting the energy audit.

Auditor Qualifications

The auditor on a MF project must be a building performance specialist who has demonstrated the ability to objectively examine a multifamily building and all of its various operating systems.

DHCD's minimum auditor qualifications are that the auditor must be a Building Performance Institute (BPI) certified Multifamily Building Analyst. It is important to note that BPI accreditation may be required in order to be eligible for State and Federal incentive programs.

For MF buildings with centralized heating, cooling, or hot water systems, DHCD requires that the inspection, evaluation, and upgrade analysis of these systems be conducted by 1) an auditor with ongoing experience evaluating and modeling central systems of similar type and complexity, 2) a licensed mechanical engineer, or 3) a mechanical contractor with ongoing experience evaluating and modeling central systems of similar type and complexity. In the event that the HVAC auditor of a central mechanical system is an auditor, DHCD may require that the auditor provide documentation demonstrating previous experience in evaluating such systems.

The HVAC auditor of a central system must be clearly identified in the audit report if it is someone other than the auditor for the overall energy audit.

Auditor Responsibilities

Key responsibilities for the auditor on a project include:

- Identifying space types, square footage, occupancy and usage levels

- Documenting all inspected systems and residential units within the building
- Staying involved from start to finish for consistency
- Noting observed safety concerns/issues
- Avoiding measures that worsen building operations or resident safety - do no harm.
- Adhering to BPI Technical Standards for the Multifamily Building Analyst Professional (BPI, 2008)[1].

Building Owner/Property Manager Responsibilities

The building owner/property manager also has responsibilities before, during, and after the audit is conducted. A successful audit and subsequent improvements are as dependent upon engaged and cooperative building owners/operators as they are on well-qualified auditors and contractors. Generally, the building owner/property manager will be the primary liaison with the building residents. It is imperative that this party notifies all of the residents that the audit and work will be taking place; advise them of the anticipated schedule and hours that their units must be available; and earn their overall cooperation in order that the work is completed in an efficient and timely manner. Below, the specific responsibilities of the building owner/property manager are listed.

- Providing details such as the age of building, previous rehab work, names of maintenance or service contractors that have routinely worked on systems in the building, utility company name and contact information, and utility billing history over 1-2 years;
- Providing building drawings and other key documents about the building and its systems.
- Providing a list of current issues or concerns within the building.
- Identifying the potential for hazardous existing conditions (e.g. lead, asbestos, mold).
- Providing access to the building in coordination with the auditor's inspection and testing plans.
- Communicating with residents about the purpose and logistics of the audit process.
- After retrofit, ensuring that the Operations & Maintenance Plan for the building is diligently maintained. Otherwise energy and cost savings will fall off over time.

For more information on proper O&M, see the BPI Technical Standards for the Multifamily Energy Efficient Building Operator (BPI, 2012). Topics covered include to preventative maintenance, record keeping, combustion safety, IAQ, air barriers and energy management.

[1] Available online at: http://www.bpi.org/standards_approved.aspx

Classifying Multifamily Buildings – Key Criteria

Multifamily (MF) buildings vary in key ways which can affect how an energy audit may be conducted. The following MF building characteristics are particularly important:

- **Building size**: Low-Rise (≤3 stories) or Mid/High-Rise (>3 stories) building heights may impact the mechanical systems found within a MF building, as well as applicable codes/standards for fire safety, ventilation, etc. The selection of appropriate energy modeling software may also be affected by building size.

- **Meter Configuration**:
  - In master-metered buildings, all energy use is measured with one or more central meters. This can simplify the process of obtaining a utility bill history. However, it can also create a split incentive if building owners pay for the energy consumption, yet residents have significant impact on energy use (such as their thermostat set points).
  - In direct-meter configurations, all energy use is measured with a designated meter for each individual residential unit. This generally complicates the process of collecting a utility bill history due to resident turnover and the need to obtain billing access permission.
  - In mixed-meter configurations, one energy source like natural gas is centrally metered while another energy source like electricity is directly metered at each residential unit. This situation introduces elements of both the master-metered building and the direct-metered configuration.

- **Utility Billing Structure**
  - The format of a MF building's utility bill can have implications on the audit and potential ECMs. A building's recent utility bills should be reviewed to identify if Demand Charges are applied, or if Time-of-Use Rates or Block Rates are used. These billing features can increase the cost effectiveness of peak load reduction and load shifting in MF buildings.

- **HVAC**: Two common HVAC configurations in MF buildings are central plants or individual, residential unit-level space heating and cooling units. MF buildings with central plants will require appropriate modeling software or analysis tools for evaluation, and the replacement of such systems will require careful planning to ensure adequate space conditioning during tasks which greatly increase thermal loads such as window replacement (if the building is still occupied). Central systems will also tend to have more extensive distribution systems (pipes, ducts) which may offer significant energy saving opportunities for measures such as insulating, air sealing, balancing, and

improved controls. Individual HVAC systems can offer simpler, staged replacement opportunities, and can be more readily modeled in simulation software.

- **Hot water plants**: Two common configurations are central hot water systems and individual, residential unit-level water heaters. The same "central versus individual" implications for HVAC systems will also apply to water heating. For central systems, an important ECM to consider is improving the hot water distribution system with insulation or an energy efficient recirculation system.

- **Lighting**: Lighting systems in MF buildings are found within residential units, in common or public spaces within the building, and in exterior lighting systems. Lighting component upgrades (lamps, ballasts) are often cost effective in all three categories. Advanced lighting controls (e.g. occupancy sensors, photo sensors, timers, lighting reduction controls) should be evaluated particularly for public space lighting (interior and exterior). MF buildings with more extensive indoor common space or exterior lighting will usually offer greater energy savings potential. Adherence to minimum standards for light levels must be maintained[2]. Likewise, building areas where the light levels *exceed* the lighting standards should also be noted.

- **Structural system**: Potential building structural systems include wood framing, steel framing, or concrete/masonry. The structural system of a building will be a strong determining factor in the types of envelope energy improvements that are feasible and realistic. While air sealing measures are always possible, the cost of adding insulation may not be reasonable. For instance in a wood or steel frame building, blown insulation will often be an option. However, in a concrete or masonry building, adding wall insulation may not be realistic unless other improvements are necessary to exterior or interior finishes.

Sampling

Conducting audit inspections and testing on just a sample of residential unit in a MF building is often a practical and cost-effective approach, but sampling also requires adequate planning. Prior to conducting the energy audit a determination should be made whether sampling will be used. The size of the building along with the building make-up will determine how many units and which types of units will be included in the audit process. The following guidelines should be followed when developing a sampling protocol:

[2] For guidance on lighting levels for different types of spaces, reference the Illuminating Engineering Society of North America's (IESNA) Lighting Handbook (www.ies.org) or comparable industry guidance.

- Sampling should include a cross section of units within the building.
- The audit should be completed on at least 10% of each unit type within the building or a minimum of 5 units if the building is small. (If results are inconclusive, additional units should be sampled.)
- Units which are part of the audit sample should undergo a uniform scope of inspections and diagnostic testing.
- When sampling is utilized, energy and economic analysis of ECMs must be weighted appropriately to reflect how the sample relates to the actual numbers and types of residential units in the building.

BENCHMARKING & FEASIBILITY SCREENING

DHCD strongly recommends undertaking the steps outlined below before a project proceeds to an energy audit and the economic analysis of potential ECMs. These initial steps allow an assessment of whether a particular project is likely to meet program goals such as a minimum energy savings percentage, before greater effort and resources are applied to an audit.

Based on preliminary data collection, an initial Feasibility Screening should develop the following information which is valuable in assessing if a project should move forward to a more complete audit.

- A high-level report on energy saving opportunities broken out by building system (but not necessarily including economic analyses);
- Benchmarking results for the project, including its ranking relative to similar buildings;
- Identification of related work which must occur in parallel or prior to energy upgrades (e.g., electrical upgrades, asbestos, lead, mold removal);
- Discussion of *how and when* work could feasibly be conducted, given climate considerations and occupancy levels; and
- Overall likelihood of the project achieving program goals.

<u>Preliminary Data Collection</u>

Preliminary (meaning pre-audit) data collection allows the energy auditor to collect and evaluate baseline data on a candidate building or project; use this data to screen the project's potential to meet specific program goals; and make a determination on the need to continue with an energy audit. The data collected during this step should be collected in a way such that it is usable on subsequent steps in the audit, assuming the project moves forward.

Preliminary data collection should include obtaining and reviewing:

- Building plans, current equipment schedules, current system specifications
- Identification of major space usage categories

- Plans and specifications from previous building renovations, if available;
- Previous energy audit reports, if any;
- Type and approximate age of space conditioning, water heating, other equipment in the building;
- Condition, location of visible ductwork and/or piping;
- Utility bill history for electricity, natural gas, water, heating oil, or propane (as appropriate for the building):
  - Minimum 1 year record for all applicable sources; 2 year record is preferable;
  - Type of metering for each source: master metered, direct metered, or a combination (Note: direct meter configurations often require more time to obtain utility billing historical data because resident consent must be obtained first).
  - Utility billing characteristics such as Time of Use rates or demand-based charges (if so, consider load-shifting and demand reduction measures in the audit.).
- Type and general condition of doors and windows;
- Evidence or lack of insulation where easily accessible.

Important outputs from the Preliminary Data Collection should include:

- Annual energy consumption and energy cost totals, by source
- Annual water consumption and cost totals
- Annual energy consumption normalized by square footage
- Breakdown of energy consumption and cost between residential units and common areas
- Identification of attractive ECMs based on prior project experience, such as high efficiency lighting, air sealing, attic insulation, appliance replacements, etc.
- Identification of unique conditions which may offer major opportunities for energy savings

Ideally the candidate building will show the potential to save roughly 20% of its annual energy use with a menu of ECMs that have a Savings to Investment Ratio (SIR) ≥ 1. SIR is explained below in the economic analysis section.

<u>Project Benchmarking</u>

Project benchmarking accompanies the Preliminary Data Collection as an effective screening tool for projects. DHCD strongly recommends that potential audit projects first be benchmarked against similar buildings. This is particularly important for larger buildings where an energy audit will be more costly and time-intensive to conduct.

Benchmarking a project should be conducted using EPA's Portfolio Manager[3] , the HUD Residential Energy Use Benchmarking Tool[4], the HUD Residential Water Use Benchmarking Tool, or comparable tools which can compare the MF building to similar buildings. Benchmarking will compare the building's energy and water consumption to other buildings of similar size and characteristics from data collected nationwide. If the score or rank is low, then the building will generally have greater potential for energy savings. However, average or above-average benchmarks may still not preclude a building from being a viable retrofit candidate. Benchmarking is also a valuable tool in prioritizing which buildings in a portfolio should be retrofitted first.

ENERGY AUDIT

The following sections explain the key elements of the energy audit. MF buildings are unique, and modifications and additions to this guidance will be necessary in many projects.

Site Walk-Through

- Plan access to the property in coordination with the owner/manager. Access must include public areas, residential units, mechanical rooms, and attics.
- If a Sample of residential units is being inspected, clearly communicate the type and quantity of residential units to be inspected to the owner/manager in advance.
- In addition to the Field Data Collection steps noted in the sections below, also be aware of other symptoms of building performance issues. These may include things like open windows during the heating season, large temperature variations from one area to another, noticeable drafts, condensation, the presence of auxiliary heaters in residential units, etc.

Survey/Interview

- Conduct interviews with property staff regarding operational issues with building systems, the presence of hazardous materials in the building (e.g. asbestos, mold), comfort issues (e.g. hot or cold spaces), hot water supply issues, indoor air quality (IAQ) concerns, combustion safety issues, maintenance protocols. Review record keeping for building's systems and maintenance or repair history.

[3] Available Online: http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

[4] Both HUD Benchmarking Tools are available online: http://portal.hud.gov/hudportal/HUD?src=/program_offices/public_indian_housing/programs/ph/phecc/ubenchtool

- Interview a cross-section of building tenants regarding energy use levels, comfort, and indoor air quality.

Field Data Collection and Diagnostics

The primary objective of this phase of the audit is to collect the data necessary to accurately analyze/model the building's current energy performance and evaluate the energy savings impact of potential ECMs. A second important objective is to screen for non-energy issues which are observed in the course of conducting the audit. Critical non-energy issues include existing combustion safety conditions, major moisture problems, the presence of hazardous materials, and significant IAQ problems. Water consumption is also a key area to evaluate during the data collection period for both indoor and outdoor use. The benchmarking tool discussed above can be helpful in identifying unusually high water use.

The audit itself focuses on the different systems and assemblies in the MF building. Depending upon the preference of the auditor and the layout/type of building, the audit can either be conducted on a floor-by-floor basis or focus upon each system consecutively. This guide is laid out by building systems, but either method can be used.

Heating, Ventilation and Air Conditioning (HVAC) System

- Collect nameplate information (system type, capacity, fuel type, model number, serial number, manufacture date). Also estimate the remaining service life of the equipment, based on industry sources for expected life cycles of equipment. "Appendix C - General Guidelines for Determining Energy Conservation Measure (ECM) Service Lifetimes and Maintenance Fractions" of the RESNET Mortgage Industry National HERS Standards or a similar industry reference may be used to estimate remaining equipment life.[5]
- Identify system efficiency levels. The efficiency level of existing systems can be field tested, taken from nameplate ratings, or possibly adjusted downward from nameplate ratings based on age and maintenance. The method used can have strong implications for the HVAC upgrade recommendations. The audit report must document the method used.
    - For fossil fuel-fired equipment older than 10 years, combustion efficiency testing must be performed based on the BPI Technical Standards for Multifamily Building Analysts[6]. While efficiency alone may not be a sufficient reason to replace equipment, the combustion efficiency test can signal a need for adjusting equipment controls or settings.

[5] Available online: http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf
[6] Available online: http://www.bpi.org/standards_approved.aspx

- For equipment that is not tested for efficiency, any assumptions or algorithms used for calculating efficiency reductions must be based on an industry reference and clearly stated in the audit report.

- Combustion Safety: auditors must comply with the applicable combustion safety provisions required in the BPI Technical Standards for Multifamily Building Analysts. These requirements include evaluating supply air to mechanical rooms, CO testing of combustion equipment, and recommending CO detectors in the audit report.
- Record information about HVAC controls, including features such as programmable, outdoor reset, zoning, etc.
- Record information about HVAC distribution systems (ducts, pipes), including the location, presence/level of insulation, and air sealing features.
  - If the system is ducted, duct leakage testing is recommended to determine the total amount of leakage and leakage to outdoors. High levels of leakage to outdoors yield a good energy savings opportunity.
- Conduct overall visual inspection of all system components including equipment, distribution system, and registers or radiators.
- COMMON ECMs:
  - HVAC controls upgrades (e.g., programmable thermostats, thermostatic regulators)
  - Duct air sealing; either mastic or aerosolized duct sealing
  - Duct or pipe insulation
  - System balancing
  - Replacement HVAC: ENERGY STAR rated for residential systems; fuel-switching or dual fuel systems;

Plumbing Equipment and Fixtures

- Note the location, age, type, efficiency, general condition of water heaters and auxiliary systems (pumps, pressure tanks, etc. as applicable). Also estimate the remaining service life of the water heating equipment, based on industry sources for expected life cycles of equipment.
- Record temperature settings on water heater(s), and specifically note un-safe settings which are either too high or too low.
- Note presence of hot water recirculation systems. If present, document the control of the recirculation pump (e.g. continuous, temperature sensor) via inspection or interview with site staff.
- Conduct visual inspection of visible supply and drain piping. Note evidence of leaks, corrosion, damage, or potential for freezing.
- Conduct visual inspection of plumbing fixtures, faucets, and toilets. Note any leaky components (e.g. leaky faucet).

- Document fixture, faucet, and toilet flow rates based on product age/specifications, or a field flow test.
- Document presence/number of clothes washing machines, their age, and model number and specifications.
- Document presence/number of dishwashers, their age, and model number and specifications.
- Inspect outdoor faucets to look for complete shutoff and potential for freezing. Make sure outdoor watering practices are covered in your interviews with the building owner and maintenance staff.
- COMMON ECMs:
    - replacement water heater(s): either ENERGY STAR storage tank systems; gas-fired instantaneous or tankless systems; or heat pump water heaters;
    - low flush or dual flush toilets; faucet aerators; low flow shower heads
    - high efficiency dishwashers and washing machines (for residential systems this means ENERGY STAR qualified units)

Air Infiltration

- Visually inspect the audited areas of the building inside and outside to identify evidence of air leakage. This will include but not be limited to windows, doors, common walls, exterior walls, utility penetrations, ductwork, window/wall air conditioners, ceiling/wall intersections, floor/wall intersection, basements, crawlspaces, slab edge, vents, rim joist, cantilevered floors, stairwells, elevator shafts, attic hatches, etc. Soiled insulation, carpeting, or wall finishes are also an indicator of air leakage.
- Using a hand-held smoke tool around or in front of potential leakage areas is also effective in identifying air leakage locations.
- Blower door testing: please see "Testing and Measurement" section below for a more in-depth discussion of considerations and decision-making regarding blower door testing in multi-family buildings.
- COMMON ECMs:
    - Air sealing using caulk, spray foam, gaskets, or solid blocking materials at the various air leakage sites listed above. Larger holes, and holes which appear consistently in a particular assembly throughout the building, take priority.

Insulation Levels

- Inspect and document all areas of the building that are accessible including but not limited to: basement, crawlspace, floors over unconditioned space, walls, attic/roof.
- If areas are inaccessible (such as concealed walls or inaccessible attic spaces), determine with the building owner if areas can be opened up for viewing. This may involve an

exploratory search that will require minimal damage to an existing wall, ceiling, or floor area.

- COMMON ECMs:
  - Additional attic insulation
  - Blown insulation into uninsulated walls
  - Additional foundation insulation

Windows and Doors

- Document approximate age, condition, style, and ease of use.
- Note cracked or missing glass.
- Note air gaps around exterior doors, windows.
- COMMON ECMs:
  - Replacement of inoperable or broken windows
  - Weather-stripping and door sweeps

Lighting and Electrical

- Document existing lighting fixtures, number and type of fixture and lamps, broken out into these space groups:
  - Common areas
  - Private residential units
  - Exterior
- Document lighting controls, noting timers, photo sensors, occupancy sensors, etc.
- Document switching patterns. Note inefficiencies as well as potential safety concerns.
- Document any non-working lighting or receptacles which are observed.
- COMMON ECMs:
  - Lamp and ballast replacements (moving to electronic ballasts, T8 fluorescent lamps)
  - Lighting controls for public areas and exterior spaces

Appliances & Miscellaneous Equipment

- Document nameplate information including manufacturer, model, size, approximate age, condition, any available information indicating energy consumption.
- Document type of fuel used for each appliance.
- Check for proper operation of washing machines, dryers, range burners, ovens.
- Check dryer venting and range hood operation, if applicable.
- For miscellaneous equipment such as vending machines, document when machines are typically used (via staff interview).
- COMMON ECMs:

- Refrigerator replacements to an ENERGY STAR qualified unit
- Converting public washing machines to cold water rinse only
- "Energy Miser" systems on vending machines to cycle them off during non-usage times

Elevators

- Document most recent inspection, approximate age, energy consumption, motors.
- COMMON ECM:
  - Motor and drive system overhauls

Air Leakage and Ventilation Air Testing Scope in Multi-Family Buildings

Blower Door Testing

According to HUD, air sealing can reduce energy usage by approximately 25 to 40 percent in multi-family buildings. Major and minor air leaks should be identified during the audit process so that the leaks are dealt with during the retrofit/rehab of the building.

Accurately estimating pre- and post- air leakage in multi-family buildings is complicated. Visual and tactile inspection will reveal large and obvious areas of infiltration, but blower door testing is necessary to more accurately **quantify** existing leakage rates, air leakage reductions, and consequently, energy and dollar savings.

Typically a blower door test is used to determine where infiltration is occurring in an individual unit. Two types of blower door testing are available for measuring air leakage of a single residential unit in a MF building: *guarded* and *un-guarded* blower door tests. A guarded blower door test, done properly, will indicate the residential unit's total leakage to the exterior of the building. An un-guarded blower door test will indicate the unit's leakage rate to outdoors and adjoining units and other adjacent spaces. A guarded blower door test is resource intensive and logistically complicated. The pros and cons of each type of test are shown in Table 1 below.

Table 1: Guarded and Unguarded Blower Door Tests

Type of Blower Door Test	Pros	Cons
Guarded blower door test	Good indicator of total infiltration/leakage rates for individual units.	A sufficient number of blower door units must be used in order to collect the proper infiltration rates. This can require upwards of 6 blower door units.
	Sufficient evidence can be collected for a more accurate economic assessment of air	Coordinating a date and time with building owners, staff, and residents can be

	sealing measures.	complicated logistically. If even one resident does not allow entry, testing is difficult to complete properly.
Unguarded blower door test	Quick deployment and ease of collecting infiltration/leakage rate from one unit in a MF building.	Air leakage rate is not strictly to the outdoors, so it is difficult to accurately estimate energy and dollar savings.
	Useful for identifying leakage sites when used in tandem with a smoke pencil and/or IR camera.	

When Should Testing be Conducted

If an air sealing ECM is part of a retrofit project, DHCD requires that unguarded (at a minimum) blower door testing be conducted on a sample of the residential units, to quantify the pre-retrofit leakiness (see Sampling section above). Estimates of the expected air leakage reduction from air sealing ECMs should be based on clearly stated air sealing tasks. Assumptions used in the estimate of air leakage reduction must be clearly stated.

Common Areas

Air leakage testing in the common areas must also be addressed. How this is done will depend upon the size and configuration of these areas, as well as how numerous they are. If air sealing of common areas including vestibules, corridors, laundry areas, etc. is an ECM investment, DHCD requires air leakage testing to better quantify air sealing potential.

Test-Out

Regardless of the type of testing performed or the building areas tested, post-retrofit "test-out" diagnostics should be completely consistent with the pre-retrofit testing setup and should be documented in the same manner. See the Quality Assurance & Post-Retrofit section below.

Evaluation of Ventilation Air

Ventilation air typically carries an energy penalty; however the post-retrofit building must comply with the applicable ventilation codes/standards for the program and building type (e.g. ASHRAE 62.1 or 62.2).

Options for evaluating ventilation air include:

- Direct air flow measurements,
- Acceptance of design values, or
- Acceptance of nameplate air flow values on equipment.

Direct measurement is recommended but requires more time and equipment, especially on central ventilation systems in larger MF buildings. However, larger central ventilation systems have also been shown to offer enormous energy savings in MF buildings if they are sized and balanced correctly.

At a minimum, auditors must evaluate the ventilation airflows using some appropriate method, and document this method. Auditors must also check the ventilation system(s) for operation, and any sign of obvious over- or under-ventilation in particular areas.

Duct Leakage Testing

Similar to blower door testing, duct leakage testing can offer valuable information in some scenarios but can also be complicated and time consuming to conduct. Accordingly, if duct sealing is to be a major ECM investment in a project, a sample of duct systems must be tested to quantify leakage to outdoors. This testing requirement may be waived by DHCD if the duct system cannot be tested for leakage to outdoors based on the size or layout of the duct system.

ENERGY MODELING & ECONOMIC ANALYSIS

The objective of this phase of the energy audit process is to create an energy model of the building using appropriate software or analysis methods which will accurately portray the current energy performance of the building, as well as estimate the energy consumption reduction associated with potential energy or water conservation measures. Energy/water savings are evaluated against installed costs of each measure to develop cost effectiveness metrics and ultimately select the retrofit work scope.

Energy Simulation Software

Acceptable software programs include but are not limited to eQUEST, DOE-2, Energy Plus, Energy Pro, EA-Quip, REM Rate and TREAT. At minimum, the software must be the current version and be capable of modeling the HVAC, hot water equipment, and envelope characteristics of the building. For example, software which has a limited menu of residential-scale HVAC systems should not be used to model a central hydronic system with multiple zones.

Modeling should result in an estimate of pre-retrofit, whole building energy use – or a "baseline model." This estimate may be based on a whole-building model, or it may be based on models of individual unit type totals which are then multiplied out by unit quantities to arrive at a building total. Note that DHCD may require submission of building model files, such as a report of the building characteristics.

Actual utility rates and delivery charges should be used along with annual energy totals to estimate annual energy costs.

Modeling Assumptions and Methodology

In developing the baseline model, auditors must follow these steps:

- Clearly state assumptions and how building components which cannot be physically verified were addressed.
- If individual residential units are being modeled, create a model variation for each major type of floor plan (e.g. a model for 3 bedroom units; a model for 2 bedroom units)
- Air leakage (infiltration) rates should reflect outdoor air leakage only and should attempt to exclude air leakage between adjacent units. If only unguarded testing was conducted, estimates should be made about what proportion of this leakage was from outdoors (as opposed to adjacent residential units).

Calibrating the Baseline Model

Calibrating the energy model so it accurately describes the pre-retrofit building involves adjusting the software model in reasonable ways, such that the annual energy total estimates better align with historical totals. A model calibration may also be called a "true up."

It is recommended that the utility bill calibration bring the baseline model within 10% of actual utility bill history on a monthly basis. Otherwise, artificially high baseline model estimates can result in ECMs which appear to save more energy than they realistically will be able to achieve.

General guidelines for baseline model calibration include:

- Baseline model adjustments should not contradict field observations or data. E.g., do not change envelope insulation levels in the model to better align the energy totals with actual billing data, if the model already is using field-verified R-values.
- The baseline model and the utility bill history should both be based on the same annual weather profile. This will involve normalizing either the model or the utility billing history so the comparison in their annual energy totals is "apples to apples." Many of the software modeling programs listed above have a function for conducting this analysis, using the project's location and the time window of the historical billing data.

Even a basic calibration of the baseline energy model can be very helpful in gaining confidence in the accuracy of the model.

Alternate Energy Analysis Methods

In some cases an auditor may elect to analyze energy and water conservation methods using an approach that does not involve building energy simulation software. Non-software –based analysis methods are allowable; however the analysis of particular ECMs must be based on engineering calculations and be completely transparent. The following requirements apply:

- the calculation methodology used to assess energy savings, energy cost savings, and economic variables (e.g. simple payback, SIR) must be clearly stated
- the value of input variables for calculations must be clearly stated, along with the source of the input values

This type of analytical method is typically conducted using spreadsheet-based worksheets. If auditors are using a worksheet template from another source, this source should be noted.

Economic Analysis

To calculate the estimated cost effectiveness of an ECM, energy saving estimates are combined with the estimated cost of implementing the ECM along with the value of future energy savings. This process involves calculations and assumptions within these calculations. Requirements for conducting this process are listed below.

- Implementation Costs: Implementation costs, meaning the cost of materials, equipment, and installation for a given ECM, must be based on valid sources. RS Means data, contractor bids, or estimates based on prior project experience are allowable sources. The source of the implementation cost for a given ECM must be clearly documented, and included in the audit report. For more costly ECMs, DHCD may require contractor bids as the basis for implementation costs.
- Replacement Cost: Generally the implementation cost for a replacement piece of equipment will be the full replacement cost of the new system. In limited cases where equipment (e.g. a furnace) is already being replaced as part of a renovation, an auditor may evaluate the use of a higher efficiency system than the scheduled baseline replacement system. In such cases the implementation cost of the high efficiency system can be estimated as the *marginal cost* between the baseline replacement system and the higher efficiency alternative. The auditor must clearly document if the implementation cost is assumed to be the marginal cost. Note that in such cases, the full replacement cost should also be reported to DHCD, even if marginal cost is being used as the implementation cost.

- Service Lifetime: the service life of a given ECM must be based on a clearly documented source. The RESNET Mortgage Industry National HERS Standards Appendix C[7] is one option for referencing ECM service lifetime data. Auditors may also use other third-party industry references.
- Utility Rates: the rates used in estimating energy costs must be based on the actual, current rates which apply to the MF building. Auditors may also elect to show building owners other cost scenarios (e.g. 3% escalation in energy rates) to inform their planning of maintenance and upgrades; however analyses for DHCD must use actual, current rates.
- Credits/Rebates: Available tax credits and/or rebates which would apply to an ECM may be factored into the economic analysis, if the auditor is certain that the building owner/operator would definitely qualify for the incentive.
- Metrics:
    - Savings to Investment Ratio, or "SIR". SIR represents the lifetime energy cost savings of an ECM divided by the cost of the measure. Within DHCD's programs, the collective SIR of all proposed ECMs must be ≥ 1.5 for approval. DHCD provides the following formula for calculating the SIR of an ECM:

Yearly Energy Savings ($/yr) * Useful Life (yrs) / Implementation Cost ($)

Non-Energy Upgrade Measures

There may be a number of measures to consider which will not necessarily reduce the energy use in the building, but may be advisable for the health and safety of the occupants and the durability of the building. A few examples are listed below, but there could be additional items depending upon the particular conditions of the building.

- Building Ventilation: Building ventilation in the pre-retrofit building may be inadequate and/or air sealing may create insufficient ventilation in the post-retrofit building. The post-retrofit building must comply with the applicable ventilation codes/standards for the program and building type (e.g. ASHRAE 62.1 or 62.2).
- Moisture Management: Alteration to the building exterior may present issues with how the building envelope allows water the drain away, as well as managing the potential for condensation within building assemblies. In some cases, adding insulation or air sealing to exterior walls will also necessitate steps to manage bulk water and avoid condensation potential. These two issues should be considered in any type of alteration to the building envelope.

[7] Available online: http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf

- Fire Safety: Numerous fire safety issues may arise as buildings are renovated and there is the opportunity to improve fire-rated assemblies. These issues should be anticipated as cascading requirements which follow from some ECMs.

AUDIT REPORT

The purpose of the audit report is to provide a comprehensive summary of findings during the audit so that the building owner and efficiency program managers can make informed decisions and efficiently apply energy and water conservation measures. The report should provide a pathway for rationally moving forward with well conceived upgrades. The following is a recommended outline for the Audit Report.

- Executive Summary
  - Project background and summary
  - Summarize primary recommended ECMs
  - Safety concerns/hazards identified
  - Air quality concerns/recommendations
- Background Information
  - Description of building and site
  - Major assumptions made during the audit process
  - Summary of utility bill history
  - Contact information for all parties involved
- Benchmarking Results
- Summary of Building Systems
  - Building envelope (foundation, walls, attics, roof)
  - Mechanical systems (heating, ventilation, air conditioning, water heating, distribution systems)
  - Lighting Systems (interior and exterior)
  - Appliances and Other Major Systems
- Energy and Water Conservation Measures Summary Table
  - Ordered list based on SIR (highest to lowest)
  - For each ECM also include service life, energy savings (by energy source), implementation cost, and life cycle savings
- Supporting Information
  - Descriptions and Specifications for recommended ECMs. Include energy and non-energy ECMs.
  - Heating/cooling design loads for updated residential units with ECMs applied.
  - Operations & Maintenance Recommendations
  - Building plans
  - Appendices to include, but not limited to:

- Building plans (as applicable)
- Previous additions, remodeling, and/or building improvements details (as applicable)
- References used to determine implementation costs, service life, or other inputs
- Digital images
- Various equipment schedules and analyses too lengthy to include in main body of the report
- Auditor qualifications/certifications

CONSERVATION MEASURE SPECIFICATIONS

Once the energy and water conservation measures have been determined, the contractor will need detailed guidance for implementing the measures efficiently, effectively, and with few, if any callbacks. The specifications should be clear and sufficiently detailed so that the contractor can accurately bid the work and then efficiently carry it out. Specific types, models, and sizes of equipment should be specified.

To assist auditors in developing effective ECM specifications, DHCD strongly encourages the use of DOE's "Standard Work Specifications for Multifamily Energy Upgrades." [8]

Prior to any work start-up, the contractor and the energy auditor should conduct an onsite walk-through of at least three units to discuss the ECMs and expected work products. During the walk- through, the contractor should be provided with a detailed checklist of the ECMs and all other measures that are to be implemented.

A form listing the improvements to be made should be used to track the work progress of each unit or building area. This form should be posted within each unit and have space available for notes and initialing by the contractor(s) and project supervisor after each ECM has been completed to satisfaction. The project supervisor should review these forms daily. This will help to ensure a positive outcome during the post-retrofit test-out requirements.

During the work phase, the auditor, building owner, and any other involved party should set up a schedule to meet with the contractor on-site to review the work completed and clarify any questions or issues that may arise. Depending upon the work scope, these meetings may occur on a daily, semi-weekly, or weekly basis. They are crucial to assure a quality product and to

[8] As of late 2012 this database of measures and specifications was available in a draft form via the U.S. DOE website link: http://www1.eere.energy.gov/wip/retrofit_guidelines_overview.html. This resource can also provide auditors with additional ECMs to consider as part of their audit. If auditors elect to use other language for specifications, it must be consistent with the level of detail found in the DOE standard specifications.

correct any deficiencies as early as possible before they are concealed. The success of the project is best ensured with quality controls and checks throughout the entire time that the work is carried out.

Operations & Maintenance

Proper maintenance of ECMs is essential to ensuring their performance over time. To the extent possible given the auditor's knowledge of the specific systems and ECMs to be incorporated in the project, the auditor should include "Operations & Maintenance (O&M) Recommendations" in the Audit Report as noted above. Such recommendations should include the following types of information for specific systems/ECMs:

- Common mishaps to check for and avoid during installation (e.g. HVAC controls)
- Critical maintenance tasks to ensure performance (e.g. cleaning the filter on an HRV)
- Important resident responsibilities (e.g. thermostat set points)
- Annual maintenance milestones (e.g. exterior light controls)

These recommendations should leverage the auditor's knowledge of particular ECMs and key O&M issues that can affect their performance over time. Additionally, auditors should make recommendations on maintenance policies which have proven effective in similar projects.

Quality Assurance

Inspections of Completed Work

The goal of QA verification and testing is to improve the likelihood that the selected ECMs and their predicted results will align with actual savings in the post-retrofit building. Inspections conducted during construction and in the post-retrofit time window allow for verification and testing of new systems that have been installed in the building.

The party responsible for conducting field verification of installed systems, for testing and commissioning systems, and for submitting verification documentation to DHCD will depend on the specific agreement between DHCD and a building owner/operator. In many cases, DHCD will stipulate these types of requirements within their agreement with the building owner/operator and responsibilities may fall to the building owner, contractors, the auditor, and/or an EM&V contractor.

Table 2 below describes the general tasks that DHCD requires to be undertaken during inspection, testing, and verification activities. However, the assignment of responsibility for conducting these tasks, the exact document requirements, and inspection sampling provisions will depend on the project terms.

Table 2: General Description of QA Inspection, Testing, and Verification Activities

Building System/Component	Type of Inspection, Testing, or Verification Activities	Type of Documentation Required
Appliances, including refrigerators, dishwashers, washing machines, stoves, etc.	Site inspections to confirm that installed equipment matches ECM specifications (e.g. ENERGY STAR labeled). Sampling is typically allowed [A]. Photo documentation is collected too.	Written inventories of all installed units and comparison with ECM provisions. Signed statement of Substantial Completion. [B]
Water Conservation – low-flow fixtures	Site inspections to confirm that installed low-flow aerators, low-flow showerheads, low-flow toilets, and other water conservation equipment matches ECM specifications. Sampling is typically allowed. Photo documentation is collected too. Record the fixture location, type, GPM, and quantity of all devices.	Written inventories of all installed low-flow equipment and comparison with ECM provisions. Signed statement of Substantial Completion.
Lighting, including in-residence units, common spaces, and exterior	Site inspections to confirm that installed lighting (and controls) matches ECM specifications in terms of quantity, wattage, type, controls, and ENERGY STAR labeling. Sampling is typically allowed. Photo documentation is collected too. CFL distribution to residents programs may require a resident sign-off sheet to show receipt.	Written lighting schedule per the relevant ECMs and comparison with field inspection results. Signed statement of Substantial Completion.

Building System/Component	Type of Inspection, Testing, or Verification Activities	Type of Documentation Required
Building Envelope Insulation	Site inspections to record insulation type, thickness, R-value, and quality of installation. Sampling is typically allowed for repeated assemblies. Photo documentation is required for areas which become inaccessible at project finish and depth markers in attics.	Written schedule of envelope insulation ECM requirements compared to field verified assemblies. Signed statement of Substantial Completion.
Windows and Doors, including sliding glass doors	Site inspections to record quantities and locations of all new components, and specs including window type, frame material, U-value, gas fill, SHGC, low-e type, and ENERGY STAR labeled. Sampling is typically allowed.	Written schedule of window and door ECM specifications compared to field verified fenestration. Signed statement of Substantial Completion.
Building Envelope – air sealing	Site inspections to record and document that air sealing measures established in ECMs are present and properly installed. Photo documentation is required. Sampling is typically allowed. Where pre-retrofit blower door testing was conducted, post-retrofit blower door testing should also be conducted under the same test set-up.	Written record of air sealing ECMs and comparison to the locations or areas inspected, noting the observed evidence of air sealing activities. Written comparison of estimated air leakage reduction in the energy audit to measured air leakage reduction (when blower door testing is conducted). Signed statement of Substantial Completion.

Building System/Component	Type of Inspection, Testing, or Verification Activities	Type of Documentation Required
HVAC – Heating Systems	Site inspections to confirm that installed heating equipment matches ECM specifications. Record equipment type, capacity, make, model #, and nameplate efficiency of all newly installed equipment. Confirm that manuals have been provided to building staff. Conduct (or obtain copies of) start-up reports and checklists. Condensing boilers: start-up report must contain efficiency testing in low- and high-fire modes. Hot Water Heating Systems: measure & record supply and return water temperature. Record control set point. For outdoor reset controls, record design set points and actual settings. Steam Systems: Record system pressure and control set points. Sampling is allowed for in-residential unit devices.	Written comparison of ECM specifications compared to field recorded specifications and operating parameters, noting any differences. Signed statement of Substantial Completion.

Building System/Component	Type of Inspection, Testing, or Verification Activities	Type of Documentation Required
HVAC – Cooling Systems	Site inspections to confirm that installed cooling equipment matches ECM specifications. Record equipment type, capacity, make, model #, and nameplate efficiency of all newly installed equipment. Confirm that manuals have been provided to building staff. Conduct (or obtain copies of) start-up reports and checklists. All primary equipment (chillers, air handling units, etc.) should be inspected. Sampling is allowed for in-residential unit devices (e.g. PTACs). Central A/C Systems: - Confirm that system capacity is no greater than 10% greater than the design cooling load - Confirm duct systems are sealed per IECC - Record duct R-value	Written comparison of ECM specifications compared to field recorded specifications and operating parameters, noting any differences. Signed statement of Substantial Completion.

Building System/Component	Type of Inspection, Testing, or Verification Activities	Type of Documentation Required
HVAC – Ventilation Systems	Site inspections to confirm that installed ventilation systems (including heat recovery units) matches ECM specifications. Record equipment type, make, model #, wattage, flow rate, and nameplate efficiency of newly installed ventilation equipment. Confirm that manuals have been provided to building staff. For Heat Recovery Systems: measure & record entering and leaving air temp. for intake and exhaust air flows. Measure and record exhaust and intake air flows. Calculate heat recovery efficiency and compare to manufacturer's rating at measured airflow and temperature conditions. Ensure supply air is 70˚ F ± 5 ˚ F. For Ventilation Fans: record (via nameplate or measurement) ventilation air flows. Ventilation Fan Timers: record the timer set points. Also record time of day and current on/off fan status. Sampling is allowed for in-residential unit ventilation devices.	Written comparison of ECM ventilation specifications compared to field recorded specifications and operating parameters, noting any differences. Signed statement of Substantial Completion.

Building System/Component	Type of Inspection, Testing, or Verification Activities	Type of Documentation Required
Domestic Hot Water Systems	Site inspections to confirm that installed water heating systems match ECM specifications. Record equipment type, capacity, make, model #, and efficiency (nameplate or measured) of newly installed domestic hot water heating equipment. Record water temperature at a faucet nearest and a faucet farthest from the water heater (as measured along the distribution system) and the location where the recording was made. Sampling is allowed for in-residential unit water heating devices.	Written comparison of ECM domestic water heating specifications compared to field recorded specifications and operating parameters, noting any differences. Signed statement of Substantial Completion.
Thermal Distribution Systems (pipes, ducts)	Site inspections to confirm that installed duct insulation, duct sealing, and pipe insulation components match ECM specifications. Record insulation type, thickness, and R-value. Photo documentation is required for areas which become inaccessible at project finish. For duct sealing, post-sealing duct leakage testing should be conducted to measure leakage reduction results.	Written record of duct/pipe insulation and air sealing ECMs and comparison to the ducts/pipes inspected, noting any differences. Written comparison of estimated duct leakage reduction in the energy audit to measured duct leakage reduction (when duct leakage testing is conducted). Signed statement of Substantial Completion.

Notes:

A. When Sampling is used in field inspections, if problems are identified then the sample must be expanded to better determine the scope of the problem.
B. A Statement of Substantial Completion must include the following elements at a minimum:
    - Document appears on the partner's letterhead
    - Statement contains name and address of the project
    - Statement contains the name and contact information of the individual completing the statement
    - Statement confirms that all fixtures and equipment have been installed and verified to demonstrate confirmation with all construction specifications including the ECM specifications
    - Statement contains individual's signature and date signed

    DHCD will also consider other proxy documents which have substantially the same information as the Statement of Substantial Completion (e.g. AIA Documents G702 Application and Certification for Payment; AIA G703 Application and Certification for Payment Continuation Sheet).

Post-Project Utility Bill Tracking

DHCD will require access to utility billing records for a two-year period following completion of the retrofit. For master-metered buildings, DHCD will require the building owner/operator to provide access to current utility bills for a 2-year period post-retrofit for the purpose of tracking the building's performance against predicted savings. For direct-metered buildings, DHCD will request that the building owner/operator facilitate a utility bill access authorization to allow DHCD to access utility bills for a representative set of residential units for a 2-year period post retrofit.

Additionally, building owners are strongly encouraged by DHCD to engage in the utility bill tracking which DHCD will manage after the retrofit. Reviewing actual monthly energy performance and comparisons to the pre-retrofit building energy costs is extremely valuable in understanding the project's results.

Appendix A – Additional References

ASHRAE, 2011. Procedures for Commercial Building Audit Standards. Available for purchase at www.ashrae.org.

Building Performance Institute, Inc., 2008. BPI Technical Standards for Multifamily Building Analysts. Available online: http://www.bpi.org/Web%20Download/BPI%20Standards/Multi%20Family%20Building%20Analyst%20Prof%20FD%203.0%202-20-08.pdf

Building Performance Institute, 2012. Technical Standards for the Multifamily Energy Efficient Building Operator. Available online: http://www.bpi.org/Web%20Download/BPI%20Standards/Multi%20Family%20Energy%20Efficient%20Building%20Operator%20FINAL%20DRAFT%202.1%20ma.pdf.

NYSERDA, 2010. Multifamily Performance Program, Existing Buildings Component - Program Guidelines. Available online: http://www.nyserda.ny.gov/~/media/Files/FO/Closed%20Opportunities/2012/RFP%202545/2545attf-eb-guidelines.pdf?sc_database=web

U.S. Department of Energy, 2012. Standard Work Specifications for Multifamily Energy Upgrades – Draft. Available online: http://www1.eere.energy.gov/wip/retrofit_guidelines_overview.html.