



MULTIFAMILY UPGRADE RATER AND CONTRACTOR HANDBOOK

This Handbook was developed on behalf of
Pacific Gas and Electric Company

By

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What's new in Version 6

This document was last updated January 31, 2017.

Changes made between versions include the following:

Version 6:

Section 2: Program deadlines updated for the 2017 program year. Projects must complete all enrollment procedures, including the submittal of a complete application package, and successfully pass the assessment review process by September 29, 2017. Projects must complete construction and submit all completion documentation to MUP Staff by within 30 days of the completion date milestone identified in incentive reservation letter, or by November 13, 2017, whichever comes first.

Section 4: Updates to fuel switching guidelines. Provided clarification on claiming savings for low-flow water fixture measures.

Section 4: Updated eligibility requirements to include minimum program specifications for appliances and fixtures: All upgrades must comply with current California codes, meet or exceed minimum program specifications for appliances and fixtures, and be installed to manufacturer specifications.

Section 5: Updated combustion appliance safety testing protocols to reference *ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings*, rather than the BPI Building Analyst Professional guidelines.

Section 9: Program milestone updates for the 2017 program year. Three project team check-in meetings with MUP Staff.

Appendix: California Multifamily Retrofit Energy Modeling Guidelines, Version 2.

1. Introduction

The Multifamily Upgrade Program (MUP) Rater and Contractor Handbook is intended for raters and contractors serving projects in PG&E's Multifamily Upgrade Program and is designed as supplemental material to the Multifamily Upgrade Program Customer Handbook.

Multifamily Upgrade Program participants must work with a participating rater and a participating contractor, as described herein, to conduct assessments and upgrade installations on their project (the "project team").

PG&E and MUP staff, at their discretion, may make policy and procedure changes at any time. The policies and procedures in place at the time of incentive reservation for a given project shall stand true through the completion of that project. Multifamily Upgrade raters and contractors will be informed via email two weeks in advance of all program policy changes.

2. Program Summary

The Pacific Gas and Electric Company (PG&E) Multifamily Upgrade Program (MUP) promotes and facilitates energy-efficient retrofits of multifamily housing through design assistance, cash incentives, and program coordination. TRC Energy Services (TRC) implements, oversees and coordinates this program on behalf of PG&E. To promote a comprehensive, whole-building upgrade strategy, projects must adhere to the following minimum criteria to qualify for the program:

- Improve building energy efficiency by ten percent as compared to existing conditions
- Install a minimum of two upgrade measures, in two of the four unique measure categories (envelope, heating/cooling, water heating, and appliances/lighting)
- Engage the services of a Multifamily Upgrade Program approved rater and contractor (project team) to conduct building audit, analysis, and verification

Projects must complete all enrollment procedures, including the submittal of a complete application package, and successfully pass the assessment review process by September 29, 2017. Projects must complete construction and submit all completion documentation to MUP Staff within 30 days of the completion date milestone identified in the program incentive reservation letter, or by November 13, 2017, whichever comes first. Projects not able to meet the completion deadline due to unforeseen circumstances may apply for a one-time extension by contacting MUP staff at least four weeks prior to the project completion deadline. **If projects fail to meet the completion deadline identified in the incentive reservation letter, or approved extension deadline, this failure may result in significant changes to the final incentive amount (including loss of incentive reservation).**

3. Rater and Contractor Qualification

All raters and contractors must be qualified and accepted by the program prior to commencing work on any project. Follow these steps to become a participating program rater or contractor.

1. Attend a Multifamily Upgrade Program rater or contractor orientation (live or on demand).
2. Review, sign, and abide by the PG&E Multifamily Upgrade Program *Contractor Participation Agreement* or *Rater Participation Agreement*.
3. Satisfy and provide supporting documentation for all license, certification, and insurance requirements.

Note: A single company may serve as both the rater and the contractor on a project as long as the company meets program-specified certification, insurance, and licensing requirements for both roles. All code-triggered HERS testing is required to be performed by a qualified HERS rater. Partners and project teams must adhere to all applicable laws, ordinances, and rules, applicable to the project. All companies that perform dual roles on a single project may be subject to a higher level of program quality control.

Insurance Requirements

Insurance Provision	Raters and Contractors
Commercial General Liability – for bodily injury, property damage, and personal injury.	\$1,000,000 – each occurrence \$2,000,000 – in aggregate
Business Automobile Liability – “any auto” (<i>Company Vehicles</i>) or “scheduled auto” (<i>with vehicle listed</i>) or Personal Automobile Liability – “any auto” (<i>Personal Vehicles</i>)	At least \$1,000,000 At least \$500,000
Worker’s Compensation and Employers’ Liability* – injury or death, each accident	At least \$1,000,000 *Not required for Sole Proprietor
Professional Liability/Errors and Omissions	Not required

Figure 1. Approved Rater and Contractor Insurance Requirements

Description of operations, locations, and vehicles should state:

The additional insured requirement requires the rater/contractor to add the following insureds to their policy: PG&E, TRC, and their respective affiliates, subsidiaries, parent companies, directors, officers, agents and employees with respect to liability arising out of or connected with the work performed by or for the Rater/Contractor are additional insured under a blanket endorsement.

Certificate Holder should be:

TRC Energy Services
11211 Gold Country Blvd. Suite 103
Gold River, CA 95670

Participating Raters

Figure 2 lists the minimum certification requirements for participating raters. Requirements in the low-rise column must be met on all projects. In addition to meeting the requirements of low-rise projects, high-rise project raters must have previous multifamily whole building utility program experience and BPI Multifamily Analyst certification.

To maintain participating rater status in the program, a rater must perform a minimum of one assessment in the first eight months of the program. If a rater is inactive for eight months, the rater’s participation in the program may undergo internal review to determine whether the partner will be removed from the participating rater list. During the internal review process, the rater may not submit new projects to the program and may appeal to PG&E to continue participation in the program.

License Requirements

Scope of Work	Low-Rise (All projects)		Additional High-Rise Requirements
Energy Modeling and Utility Data Analysis	CA HERS Whole House Rater RESNET Rater Certified Energy Analyst (CEA)	<i>or</i> <i>or</i>	Previous multifamily whole building utility program participation
Whole Building Energy Assessment, Recommendations, and 3rd Party Verification	CA HERS Whole House Rater RESNET Rater BPI Multifamily Building Analyst GreenPoint Rater Existing Home Multifamily	<i>or</i> <i>or</i> <i>or</i>	BPI Multifamily Building Analyst
Combustion Appliance Safety (CAS)	BPI Building Analyst or Envelope Professional		BPI Multifamily Building Analyst

Figure 2. Approved Rater Qualifications

Continuing Education

Participating raters are expected to complete four hours of continuing education training per program year and attend the quarterly program update meetings. At least three of the continuing education hours must come from Multifamily Upgrade Program trainings. For the additional hour of required training, participating raters must submit documentation certifying completion of industry-related training from one of the organizations listed below. TRC will approve training courses from other sources on a case-by-case basis.

- Building Performance Institute (BPI)
- PG&E Energy Training Center
- Residential Energy Services Network (RESNET)
- CalCERTS
- CHEERS
- Community Colleges
- Efficiency First CA
- Build It Green
- Affordable Comfort Institute (ACI)

Participating raters that do not meet the required education threshold in any given program year will not be able to submit new projects to the Multifamily Upgrade Program until the required training hours are completed and documented.

Participating Contractors

Multifamily property owners may work with any contractor(s) they choose if the contractor(s) maintain appropriate licenses for work conducted, abide by California laws, and follow the three steps above to become a program contractor.

License Requirements

Scope of Work	Required	Recommended
Structural Evaluation	CSLB 'A' General Engineering License	Licensed engineer
General Contracting	CSLB 'B' General Building Contractor	BPI Multifamily Building Analyst
Specialty Trade	CSLB 'C' Specialty Contractor	BPI Multifamily Building Analyst

Figure 3. Approved Contractor Qualifications

Note: An A or B-General Building Contractor License may be supplied by the partner contractor to cover all scopes, but it is the responsibility of that partner contractor to ensure any subcontractors hired are licensed and certified for the project's scope of work. Contractors must demonstrate proof of insurance (due within 30 days of signing the contractor agreement).

4. Assessment

There are two primary objectives of the property assessment:

- Conduct a comprehensive analysis to identify and quantify specific opportunities to achieve a minimum 10% reduction in whole building energy use.
- Evaluate the buildings' integrity to identify any deficiencies that could result in health and safety hazards to residents.

This section of the handbook includes guidance for approved raters when conducting property assessments.

Site Visits

Preparation, Scheduling, and Tenant Notification

- Rater should, but is not required to, review 12 months of prior utility bills if possible (including gas, electric, and water), to identify annual utility cost by fuel type and seasonal variations.
- Rater shall review as-built drawings (if available) and any other pertinent information about the site, the building, and its systems, provided by the property owner or owner's representative.
- Rater shall schedule the site visits with the owner's representative at a time convenient for the representative. The site visit shall seek to cause minimal disruption to the project's residents and neighbors.
- Property owner shall notify all residents in advance of the site visit, whether or not their unit is included in the planned sampling. This will allow for increased sampling in the event that the approved rater finds inconsistency (see below). This notification shall be the sole responsibility of property owner or their representative.
- Rater shall notify TRC of anticipated site assessment dates **five business days in advance**. TRC will notify PG&E to have a gas service representative (GSR) on-site or on-call for any gas safety issues uncovered during the assessment.

Project Interviews

The rater shall interview at least one of the following persons prior to or at the time of the site visit:

- Property manager
- Maintenance director or maintenance staff
- Owner or owner's representative

The purpose of the interviews is to discuss:

- Assessment's objectives and the client's goals for the scope of retrofit
- Building characteristics, existing documentation, and project energy and water use
- An approach to interviewing residents and access dwelling units for the site visit in order to assess residents' perception of comfort, health, and safety at the site. If any interviewee wishes their responses to remain confidential, the rater shall respect those requests.
- Operations and maintenance procedures
- Stakeholder questions or concerns

Visual Inspection and Data Collection

The site visit shall involve visual inspections of the building envelope (including roof, floor, overhangs, walls, and windows), mechanical systems, lighting, and appliances. The approved rater shall identify and record all building assembly and equipment specifications (nameplate data) necessary for building energy simulation.

Data Collection Form Preapproval

Approved raters and contractors may use data collection sheets of their own design to collect information on-site. Multifamily Upgrade Program staff at TRC will review all data collection submittals for clarity and organization. The program may request revisions or re-organization of the content. MUP staff will review and provide feedback about data collection forms and procedures if requested by approved raters.

Safety and Code Observations

If during the course of the site visit the rater observes a condition that, in his or her judgment, may be a building code violation or a potential threat to health or safety, the rater shall notify the designated person(s) in the project application and/or any individuals that are present and representing the owner.

Sampling Protocol

Unit Sampling

- High-Rise Buildings:** For buildings over four habitable stories in size, the sample shall include units in the top floor, bottom floor, and middle floors of the building.
- Multiple Building Sampling:** For sites with multiple buildings, an on-site evaluation shall be completed, at a minimum, for at least one unit in each unique building type.
- Unique Building Type:** Variations in building volume, square footage, geometry, occupant type, or the number of HVAC units located in each building shall cause the building to be considered a unique type.

The approved rater should increase the sampling rate if they discover inconclusive and/or inconsistent findings.

Project Size (total number of units)	Number of Units to Sample	
	Minimum	Recommended
5 - 9	2	3
10 - 19	3	5
20 - 29	4	7
30 - 49	5	9
50 - 74	6	11
75 - 99	7	13
100 - 149	8	16
150 - 200	9	20
>200	10	25

Figure 4. Table of Units Sampled by Project Size

Common Area Sampling

The approved rater shall meet the following requirements for sampling of common area spaces:

- Unique Area Sample Size:** The approved rater shall inspect 100 percent of unique common area spaces such as basements, lobbies, etc.
- Repetitive Area Sample Size:** The approved rater shall inspect a representative a 20 percent sample (with a minimum of five areas) of similar or repetitive areas such as stairwells and stairwell landings, corridors, trash chute rooms, etc.

Upgrade Recommendations

The approved rater's assessment shall include observations and recommendations for implementation of the building retrofit measures listed here and described in more detail below.

Weatherization Measures

During the site visit the rater shall document opportunities to improve the building envelope by:

- Installing weather stripping on all doors or hatches that lead from conditioned to unconditioned space.
- Sealing accessible duct joints with approved mastic or foil tape and insulating to at least R-4.2.
- Installing or repairing dampers, doors, or other devices to reduce unintended airflow.
- Repairing or replacing visible envelope leaks including pipe and conduit cuts, window sashes and glass, caulking around frames, sills, and other linear joints.
- Blower door envelope leakage tests are not required because of their cost, technical complexity, and limited data available to provide substantive results. Accordingly, performance envelope measures (e.g. air sealing) cannot be claimed for credit in the energy performance model.

Upgrades for Minimum 10% Improvement

To qualify for the program, the property must achieve a minimum 10% reduction in whole-building energy use as demonstrated by the Residential Performance or Non Residential Performance modules in EnergyPro version 5. To achieve the minimum reduction, raters should consider all potential energy efficiency measures and identify opportunities to reduce energy used for space heating, space cooling, HVAC systems, domestic hot water systems, pumps, fans, appliances, and lighting. All measures that cannot be modeled in EnergyPro version 5's alteration tab will be considered on a case-by-case basis; email the MUP team at multifamilyupgrade@trcsolutions.com with any questions. While additional savings are available for solar thermal measures (funded by the California Solar Initiative Solar Thermal program), the energy savings cannot be considered part of the 10% scope of work for MUP.

All upgrades must comply with current California codes, meet or exceed minimum program specifications for appliances and fixtures, and be installed to manufacturer specifications.

Any project that is considered new construction by code is not eligible to participate in the Multifamily Upgrade Program. New construction projects may be eligible to participate in PG&E's California Multi-Family New Homes program. For more information, visit www.cmfnh.com.

Duct Leakage

Raters shall conduct duct leakage tests, following the same sampling protocol for both test-in and test-out established Figure 4, for all systems that have more than 12 feet of supply or return air ducts in unconditioned space. For purposes of the duct test requirements, the program considers ducts located in the space between two conditioned floors to be within conditioned space. Ducted system leakage

must be corrected per the Title 24 protocols and leakage targets for existing buildings, additions, and alterations.

Fuel Switching

Fuel switching upgrades are reviewed on a case-by-case basis for program eligibility. If there is a plan to change the fuel source of an upgrade in the program, the rater shall contact MUP Staff to determine whether the proposed measure qualifies.

Analysis

Energy Modeling

Raters shall complete an energy simulation using Residential Performance or Non Residential Performance modules in EnergyPro version 5, for each building to document the building's existing conditions and expected post-retrofit conditions. The rater shall base the simulation on building plans, initial inspection data, and diagnostic data collected during the on-site visits. MUP Staff will use the energy model results to estimate annual energy consumption and energy cost savings of potential energy conservation measures. The following EnergyPro version 5 module will be used in accordance with building type:

- **Low-rise residential buildings:** Residential Performance Module
- **High-rise residential buildings:** Non-Residential Module

Methods and Assumptions

All major assumptions used to develop the energy model and analysis must be clearly stated in the assessment report. Raters should place reporting emphasis on the assumptions that have the most impact on estimated energy savings: DHW, HVAC, lighting, duct leakage, and insulation.

Occasionally, some building features may be difficult to verify in the field, such as the insulation in crawl spaces. When certain building features cannot be verified, the values from Table R3-50, Default Assumptions for Existing Buildings, in Appendix B of the 2013 Building Energy Efficiency Standards shall be used as the default conditions in the energy model and analysis.

Utility Rates

The project shall be modeled using the current local utility rate schedules as verified during the review of the utility bills. The local utility rate may have to be created in the energy modeling software. Energy cost savings calculated outside of the modeling software shall be based on actual energy bills or average utility rates.

Model Calibration

The energy model for buildings that are master-metered should be calibrated, if possible, to actual utility billing data. Modeled baseline energy consumption shall be calibrated to monthly utility bills for a

minimum of 12 months. The intent is to establish the modeling results verified for consistency and accuracy.

The energy model estimates of electricity and natural gas should calibrate to actual monthly consumption, to within ten percent annually and 25 percent monthly. Raters may use typical meteorological year 30-year average weather data in lieu of actual weather data.

Any adjustments made to the building description inputs used to calibrate the simulated building to actual energy usage shall be justified with explicit, transparent information and documented in the assessment report.

Exceptional Calculations

Energy conservation measures not directly modeled with the energy modeling software may be calculated outside of the software, provided that raters use generally accepted engineering calculations and methodologies. A rater may submit a request for credit for exceptional calculations. In order to calculate the rebate incentive, MUP staff and PG&E must approve exceptional calculations. Raters must account for interactive effects in exceptional calculations. Raters must document the methodologies, assumptions, and constants used in the exceptional calculations in the assessment report. Sources of deemed savings must be referenced.

Low-flow Fixtures

Low-flow fixtures are an eligible measure in the Multifamily Upgrade Program. Raters must document existing flow rates using the nameplate on the fixture or by measuring flow using a flow bag. The rater must ensure the appropriate number of units are sampled to determine existing fixture flow rate. Raters should calculate savings from low-flow fixtures using the program approved work paper. Note: According to the program approved work paper, the baseline condition of fixtures must be ≥ 2.5 gallons per minute for faucet aerators and ≥ 2.5 gallons per minute for showerheads. Based on the sampling results, if the average flow rate of existing fixtures is greater than or equal to the minimum baseline specified, savings can be claimed on 100% replacement. If the average of sampled fixtures is less than the minimum baseline, savings can be claimed for the proportion of fixtures that exceed baseline flow rates. Savings cannot be scaled to allow replacement of lower-than-baseline fixtures.

Utility Bill Analysis

If possible, the assessment should include a utility bill analysis. Analysis must include base load evaluation, seasonal evaluation, and recommendations for energy usage reduction.

The rater should acquire one or two years of utility bills and analyze use patterns. Rater shall provide a summary report or assessment to the property owner that discusses baseline loads and recommendations for the reduction of utility bills and improvement of tenant comfort.

Optional Measures and Analysis

In addition to energy efficiency, raters should consider a comprehensive building upgrade project that incorporates other *green* measures including on-site generation, operations and maintenance enhancements, water efficiency, resource conservation, and indoor air quality measures. These measures improve tenant comfort, create a safer and quieter living environment for tenants and property staff, reduce the property's negative impact on the environment, and, if undertaken at the time of other upgrade work, lowers the incremental cost of implementation.

Below is a description of optional components and evaluations that raters may include in the assessment. Raters may include the information in the report to educate customers on additional best practices. The program does not require this additional evaluation and information for program participation.

- **On-Site Energy Generation:** Identify opportunities for onsite energy generation including photovoltaic arrays, solar thermal collectors, small wind turbines, and heat recovery and cogeneration systems.
- **Operations & Maintenance:** Identify operations and maintenance opportunities with demonstrated potential to achieve quantifiable electricity or gas (kWh, kW or therm) savings. This includes activities such as building commissioning, retrocommissioning, building automation systems, central water heating tune-ups and controls, operations and maintenance procedural changes, producing an operations and maintenance manual, and related management training.¹
- **Water Efficiency, Resource Conservation, and Indoor Air Quality:** Identify opportunities for non-energy utility cost savings including permanently installed water efficiency measures such as high-efficiency toilets, landscaping and irrigation improvements, and recycling facility upgrades.

Identify opportunities for non-permanent resident upgrades such as low-flow showerheads and faucet aerators.

Identify additional resource conservation and indoor air quality opportunities that might not have a financial payback, but that will have a lower incremental cost if undertaken at the time of retrofit will provide comfort and environmental benefits to tenants.

- **Financial/Payback Analysis:** Provide financial analyses for a portfolio of measures that yields a positive net present value (NPV) in the format of the financial analysis table. The program recommends that raters prepare cash flow analyses that provide a calculated NPV and internal rate of return using the following default assumptions: 5% discount rate, 4% electricity rate escalator, and 3% natural gas cost escalator. Clearly state all assumptions including water rates, life of the measure, incremental costs, interactive effects, etc. Include as credits any applicable rebates, tax credits, grants, and loans.

¹ See BPI Building Operator Certification & NAHMA Green Building Operator Certification.

Assessment Report

For each facility, the rater must submit an assessment report that addresses the scope of the assessment. The assessment report shall include all the data collected, the evaluation of the building, and diagnostic testing reports including the Multifamily CAS Compliance Workbook. The rater shall present the assessment report to the client in a face-to-face meeting. The assessment report shall include the following sections and content:

Executive Summary

Summarize the major findings of the assessment, at minimum include:

- Number of units, building construction type, number of stories, year built, total building area identified by use (residential, community/common, commercial), history of previous retrofits or rehabs, and other significant building features.
- Date of site visit.
- Names of individuals interviewed.
- Overall physical condition of the building (good, fair, or poor with respect to structural integrity, maintenance, and repair).
- Recommended energy efficiency conservation measures and projected savings

Narrative

Include a written narrative that describes existing property conditions in the following categories:

- Site description including landscaping, walkways, entryways, signage, parking areas, etc.
- Building envelope including roof and windows, air flow, insulation, and ducts
- Building mechanical and electrical systems including (when applicable) heating, ventilation, cooling and electrical systems, and elevators
- Mechanical room, including (when applicable) boilers, domestic hot water, and plumbing systems
- Common areas including community rooms, kitchens, lobbies, corridors, and commercial spaces
- Dwelling units, as relates to: health and safety, energy efficiency conservation

Include information from the site visit to verify that any available building drawings are accurate. If the site conditions do not match design conditions, use the site conditions for analysis and reporting.

Include information on equipment specifications. Also, include photo documentation of the property, specifically targeting the relevant physical conditions and potential energy efficiency and water conservation measures.

Combustion Safety Testing

Include a summary of the combustion analysis testing completed during the energy assessment. For all assessed dwelling units, include the results of combustion safety testing and identify if action is required. The report shall indicate whether carbon monoxide detectors are installed and state the requirement that carbon monoxide detectors need to be installed, if they are not already installed in each dwelling unit. Identify issues that the owner must address prior to construction and issues that the owner must address within the scope of the retrofit. If applicable, state that the owner must fix all

combustion safety failures prior to submission of rebate incentive. The report shall include results and copies of the Multifamily CAS Compliance Workbook.

Energy Assessment

Energy Analysis Methodology

Summarize the modeling approach and other calculation methods used in the energy and water analysis. Include the name and version of the energy modeling software used and indicate if the project is using exceptional calculations to estimate energy and energy cost savings outside of the parameters of the model. Provide a summary of the approach and detailed calculations used in any exceptional calculations. Energy efficiency analysis is required to be included in the assessment; Water analysis is optional.

Utility Analysis and End Use Breakdown

Describe the applicable end uses for each type of fuel used at the project site and show a breakdown of the annual energy usage and cost by fuel type. If possible, the rater should:

- Graph energy usage for each fuel type for a minimum of 12 months.
- Review the utility rate structure to determine if it seems appropriate for the project.
- If the rate structure does not match the utility data, make a recommendation for further investigation

Source of Information

Briefly describe all sources of information used to inform the analysis including:

- Source and scope of utility billing data supplied to the rater including the data source, the duration in months that the data covers, and whether the rater received copies of the actual utility bills or electronic interval data.
- Construction cost information used in economic analysis.
- Whether building plans or site verified data were used in the analysis.
- Any discrepancies between plans and verified conditions.
- Utility rate and schedules.
- Source of deemed energy savings.

Energy Model Inputs and Assumptions

State any assumptions used when analyzing energy and water utility data. Reference the data collected through assessment as well as the building simulation program input file.

Energy Model Documentation

Provide final energy model input and output files used to report energy and energy cost. The rater shall submit a log of all justified adjustments made to the energy model during the calibration process in the assessment report.

Qualifications and Certifications

Include a description of the qualifications and professional certification of any person who worked on the assessment.

Representation

Include a statement from an officer or owner of the firm conducting the assessment that states that the assessment meets the assessment specifications without exception. For quality assurance purposes, the rater shall review and certify that the principal or representative of the assessment firm reviewed the final assessment report.

Description of Energy Efficiency Recommendations

Provide information on each recommended measure and improvement, including but not limited to:

- Description of measures and recommended loading order
- Rationale for recommendation
- Estimated useful life of existing component
- Recommendation for timing to implement the measure/replacement/improvement

5. Combustion Safety

Include the results of the diagnostic testing conducted on-site and describe how the test results informed the rationale for the above recommendations. Based on diagnostic test results, raters may also offer recommendations for the retrocommissioning of certain existing equipment.

This section proposes baseline multifamily combustion safety testing protocols that are consistent with the current combustion safety testing protocols found in the standard *ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings*, with amendments made when PG&E standards are more stringent.

Testing Parameter

The rater shall test the following in multifamily existing buildings:

- Central mechanical equipment in accordance with sampling requirements shown in Figure 4.
- All units undergoing work either on combustion appliances or on other aspects of the unit that may affect the unit's pressure dynamics. Pressure dynamics can be defined as changes to air pressure that could have any impact on combustion safety or air leakage through the shell.
- All units whose pressure dynamics may be affected by work in other parts of the building.
- Gas line testing within the combustion zone in the unit, the mechanical room, and at the central appliance. Gas line testing is not required at the meter or meter to unit.

According to the BPI Technical Standards, the rater must complete a preliminary and post-installation safety inspection of all combustion appliances whenever changes to the building envelope and/or heating system are part of the work scope. This inspection includes visual inspection and all tests for vented appliances identified in *ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings*. Please refer to the BPI reference sheet *Combustion Appliance Safety Inspection for Vented Appliances* at www.bpi.org for more details. An overview of the process follows:

1. **Measure the Base Pressure:** Start with all exterior doors, windows, and the fireplace damper closed. Set all combustion appliances to the pilot setting or turn off the service disconnect. Combustion appliances include: boilers, furnaces, space heaters, and water heaters. With the home in this configuration, measure and record the baseline pressure of the mechanical room with reference to (WRT) outside.
2. **Establish the Worst Case:** Turn on the dryer and all exhaust fans. Close all interior doors that make the CAZ pressure more negative. Turn on the air handler, if present, and leave on if the pressure in the CAZ becomes more negative, then re-check the door positions. Measure the net change in pressure from the CAZ to outside, correcting for the base pressure. Record the *worst case depressurization*.
3. **Measure Worst Case Spillage, CO:**

Fire the appliance with the smallest Btu capacity first. For space heating equipment with a cold vent, test for spillage at the draft diverter with a mirror or smoke test at the two-minute mark, and test for CO in the flue at five minutes. For domestic hot water heaters or space heating equipment with a warm vent, test for spillage at the draft diverter at five minutes, and test for CO in the flue at five minutes. Fire all other connected appliances in order of increasing Btu capacity

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and test the draft diverter of each appliance for spillage. Test for CO in all appliances before the draft diverter.

4. **Compare Results to Action Levels:** Take steps according to the action levels in Figure 5 to determine the cause, and make recommendations for repair as needed.

CO Thresholds for Fossil-Fuel Fired Combustion Appliances	
Appliance	Threshold Limit
Central Furnace (all categories)	400 ppm air free
Boiler	400 ppm air free
Floor Furnace	400 ppm air free
Gravity Furnace	400 ppm air free
Wall Furnace (BIV)	200 ppm air free
Wall Furnace (Direct Vent)	400 ppm air free
Vented Room Heater	200 ppm air free
Unvented Room Heater	200 ppm air free
Water Heater	200 ppm air free
Oven/Broiler	225 ppm as measured
Clothes Dryer	400 ppm air free
Refrigerator	25 ppm as measured
Gas Log (gas fireplace)	25 ppm as measured in vent
Gas Log (installed in wood burning fireplace)	400 ppm air free in firebox

Figure 5. CO Thresholds

- In addition to the CO thresholds identified in Figure 5, the GSR should be notified if any of the conditions noted in Figure 6 and Figure 7 are met.

CO Thresholds that Require GSR Notification		
Appliance	Spillage Test Result	CO Threshold
All Vented Appliances	Fails	26 ppm air free
All vented appliances	Passes	100 ppm air free
All unvented appliances	NA	26 ppm as measured

Figure 6. Flue Gas CO Results that Require GSR Notification

Inspection Findings that Require GSR Notification	
Defective heat exchanger	Charring of combustibles
Delayed ignition	Flame roll out
Flame interference caused by fan	Draft diverter spillage, missing, or misaligned
Evidence of incomplete combustion (50% yellow)	Short cycling

Figure 7. Conditions for GSR Notification

Ambient CO: Monitor the ambient CO in the breathing zone during the test procedure and abort the test if ambient CO goes over 35 ppm. Turn off the appliance, ventilate the space, and recommend repairs by a professional. The appliance must be repaired and the problem corrected prior to completing the combustion safety diagnostics. If the ambient levels exceed 70 ppm during testing, disable the appliance, evacuate the building, notify emergency personnel, and instruct the homeowner to have the appliance repaired prior to operating it again. The building may be re-entered once ambient CO levels have gone below 35 ppm.

- Additionally, PG&E requires notification (call to the GSR) if ambient CO exceeds thresholds included in Figure 8 below

Appliance	Ambient CO at which GSR must be contacted
Furnace	2 ppm
Oven, Range Top, or Broiler	10 ppm
Water Heater	10 ppm
Central Boiler	10 ppm
Gas Dryer	10 ppm
Room	10 ppm

Figure 8. PG&E Required Ambient CO Thresholds by Appliance

- **Action Levels:** Make recommendations or complete work order for repairs based on test results and combustion safety test action level tables.

Combustion Ventilation Air (CVA)

CVA requirements only apply to open-draft combustion furnaces and water heaters.

Confined space is an area designed for the operation of combustion appliances that has a total volume less than 50 cubic ft. per 1000 BTUs input of all open combustion furnaces/heaters and water heaters within the space.

The procedure for determining if an open combustion appliance is located in a confined space

1. Measure enclosure or room: L (length) X W (width) X H (height) = Existing Area in Cubic Feet.
2. Divide the total BTU of all open draft appliances in the space by 20.
 - If the result of 1 is less than 2, CVA calculation is required.
 - If the result of 1 is equal to or greater than 2, CVA calculation is not required.

CVA Calculation Rules

Determine the required net free vent (NFV) area, per opening(s) for the confined space.

Example: The total BTU input is 80,000 BTUs. You have chosen rule 4 (below).

80,000 divided by 4000 = 20. sq. in. in required NFV area.

- **Rule 1:** Requires two openings. CVA from conditioned space requires that each opening shall have a NFV area of at least 1 sq. in. for every 1000 BTUs input. 1 upper vent within 12" of ceiling and 1 lower vent within 12" of floor venting to unconfined space. Each opening, minimum 100 sq. in.

- **Rule 2:** Requires two openings. CVA supplied by horizontal ducts to the outside (unconditioned space). 1 upper duct and 1 lower duct. Each opening requires a NFV area of at least 1 sq. in. for every 2000 BTUs input.
- **Rule 3:** Requires one opening. CVA to outside (unconditioned space). 1 upper opening (or vertical or horizontal duct) may be used to provide the combustion air. The vent/duct must provide 1 sq. in. NFV area per 3,000 BTUs input. Appliance must have clearances of 1 inch on sides and back and 6 inches in front from appliance to wall/door.
- **Rule 4:** Requires two openings. CVA to the outside (unconditioned space). 1 upper and 1 lower vent or vertical duct opening is required. Each opening shall have a NFV area of a least 1 sq. in. for every 4000 BTUs input. This rule applies to unconditioned garages that are considered confined spaces.

Calculations

Area of a Circle (sq. in.)

- Area of a Circle = Radius X Radius X 3.14 where Radius = Half the diameter
- 3" diameter circle = 7.1 sq. in.
 4" = 12.6
 5" = 19.6
 6" = 28.3
 7"=38.5
 8" = 50.3
 9"=63.6
 10" = 78.5
 12" = 113

Vent Opening Multipliers

Note: Use only one of the following multipliers to calculate NFV area. Use the multiplier that will reduce the overall NFV area to the lowest term.

- MESH, ¼ in. or Larger = 90% of the actual vent opening.
- METAL LOUVERS = 75% of the actual vent opening.
- MESH, LESS THAN ¼ in. = 50% of the actual vent opening.
- WOODEN LOUVERS = 25% of the actual vent opening.

Estimated BTUh Input Ratings of Unmarked Open Combustion Furnaces/Heaters and Water Heaters

- Wall Furnaces and Free-Standing Heaters:
 - Single-sided: 25,000 BTUh
 - Small: 25,000 BTUh
 - Double-sided: 50,000 BTUh
 - Standard (24" + 12" deep): 50,000 BTUh

- Floor Furnaces:
 - Standard (usually 22" wide): 30,000 BTU/h
 - Large (usually larger than 1 floor-joist bay): 60,000 BTU/h
- Water Heaters:
 - Standard: 1000 BTU/h per gallon
 - Tankless / Instantaneous: 200,000 BTU/h
- Forced Air Furnace:
 - 25,000 BTU/h per burner

Test-In and Test-Out Protocols

Test-In

A test-in at the audit stage helps identify issues that the owner needs to address as part of the project. This test-in will use the sampling protocol identified in section 3.1.

The owner must address, or must contract a specialist to address, all issues that require correction based on the action levels table (as defined by BPI BA Technical Standards), as well as all in-unit gas leaks prior to commencement of work. Corrections may be completed by contractor and documentation of correction submitted to the BPI building professional. The owner must address, and the program will verify, any non-critical issues identified at completion of work in accordance with the BPI building analyst professional requirements.

Prior to commencement of work, the owner shall install a CO alarm in every unit that is affected by the scope of work. The CO alarm and installation shall be compliant with California law. If in-unit CO alarms are present and working during test-in and the scope of work includes upgrading the combustion appliance, then test-in of that appliance does not need to be conducted. If the appliance upgrade is canceled then test-in will be required for that appliance. This applies to all open-combustion appliances that are located in an indoor environment connected to living spaces.

The BPI professional shall review the scope of work, identify and document whether pressure dynamics within the building will be affected, and determine whether combustion safety testing shall be required at the completion of work. If the BPI professional determines that CAS testing is not required, they BPI professional shall indicate in their report why the testing is not required.

Dwelling Units

Identify all sources of combustion in, or connected to, the building.

For units with open combustion appliances that are affected by the scope of work, the testing shall include the following:

- Follow BPI Technical Standard *ANSI/BPI-1200-S-2015*.
- Additional protocols may be required beyond BPI Technical Standards, as specified by the utility.

If a gas stove is the only combustion appliance in the dwelling unit, the testing shall include CO testing for sampled units according to protocols in *ANSI/BPI-1200-S-2015*.

Gas stove action levels:

- 100 ppm to 225 ppm as measured the rater must recommend service of the equipment.

Systemic Failures

If during the initial CAS test-in, failures occur in 50% or more of the sample set (as defined in Figure 4) the rater shall double sample size. If failures occur in 50% or more of the larger sample size, the rater shall deem the project a *systemic failure*. The BPI professional may choose to make the systemic failure determination after the initial sample group if the BPI professional has reason to believe that the failure conditions identified are likely to occur throughout the property.

When systemic failures are identified, the BPI professional shall:

- Notify the property owner, manager, or their authorized agent.
 - It is advisable for the BPI professional to obtain signed documentation from the authorized agent acknowledging the combustion safety issues while on site.
- Provide recommendations in the scope of work that the owner have all remaining units tested and repaired prior to project completion.
 - Include specific recommendations for how to address each issue.
- Perform 100% CAS test-out upon project completion, regardless of upgrade scope of work.

<u>SYSTEMIC FAILURE EXAMPLE:</u>	<u>ACTIONS: BPI professional shall:</u>
<ul style="list-style-type: none"> • 55 unit multifamily building • As per Figure 4, sample size = min of 6 units • 1 unit has a gas leak • 1 unit fails spillage under natural conditions • 1 unit fails oven CO test at 226 ppm <p>50% of the sampled units failed CAS testing; therefore, the sample size is doubled from 6 units (minimum) to 12 units (minimum).</p> <ul style="list-style-type: none"> • The professional identifies gas leaks in two more of the units, and high CO (226 ppm) is found in the oven of the third unit. <p>3 or more <u>additional</u> units fail CAS tests (6 out of the 12 units failed); therefore, a Systemic Failure has been identified.</p>	<ol style="list-style-type: none"> 1. Communicate the spillage test and gas leak failures to the property owner, manager, or their authorized agent. 2. Request that the owner or authorized agent sign an acknowledgment form that indicates that they have been informed of the gas leaks and spillage failures and of their exact locations. 3. Include recommendations in the scope of work that the owner have all remaining units tested and repaired prior to project completion. 4. Include specific recommendation in the scope of work for how to address the spillage issue and the oven CO issues in the affected units. 5. Perform 100% CAS test-out at project completion.

Regardless of the results, the BPI professional will include a recommendation to the building owner to have stoves and ovens cleaned and maintained annually. If there are no combustion appliances in the dwelling units and it is determined that the testing is unnecessary, the BPI professional will provide a written statement confirming this fact and provide it to the building owner and MUP Staff.

Central Equipment

The BPI professional shall perform CAS testing on central mechanical equipment in accordance with sampling requirements in Table 4. If the number of central mechanical equipment is below five, then the rater will perform CAS testing on at least three.

Additionally, the BPI professional shall perform a visual inspection of at least 50% of all central equipment. This should include visual inspections for:

- Flue/chimney conditions
- Signs of spillage
- Appropriate CVA (see [Combustion Ventilation Air](#))
- Non-compliant gas lines
- Presence of CO detectors
- Other issues that can be determined visually
- Information required for energy audit/modeling

The BPI professional shall report deficiencies to the owner or owner's representative in the case where any system fails any of the testing. The BPI professional shall correct deficiencies according to BPI Technical Standard *ANSI/BPI-1200-S-2015*.

Test-Out

All units or spaces undergoing work on combustion appliances shall undergo CAS test-out.

All units or spaces where the pressure dynamics may be affected by work in the unit or in other parts of the building shall undergo CAS test-out. For the purposes of this protocol, pressure dynamics are only relevant when dealing with drafting equipment. Ovens are not drafting equipment.

The BPI professional must re-test *all* combustion appliance units that failed during test-in, regardless of the upgrade scope of work at test-out. Systemic failures identified at test-in require 100% testing at test-out.

The BPI professional shall document test-out results for all units and submit to the building owner and program administrators.

The BPI professional shall work with the owner to make all necessary corrections according to BPI Technical Standard *ANSI/BPI-1200-S-2015*, and PG&E EUC Action Levels.

Limitations and Exclusions

- **Accessible Areas:** Accessible areas are defined as areas that are accessible via permanent access systems such as roof hatches with permanent ladders or stairways, or via a standard A-frame 6' step ladder (such as most attics).
- **Inaccessible Areas:** Inaccessible areas are defined as those areas which require the use of a portable ladder greater than 6' in height, or are located on pitched roofs.
- **Inaccessible Terminations:** CO testing of appliances which can only be tested at flues that terminate on or through a roof, or are not accessible without a 6' step ladder, is not required.
- **Access to Dwelling Units:** The BPI professional must make every reasonable effort to have the building owner, manager, or their authorized agent provide access to 100% of the dwelling units and mechanical rooms that require testing.
- **The BPI professional must access and test at least 90% of all dwelling units and repetitious mechanical rooms that require testing in order for the test-out to be deemed complete.**
- **Access to Equipment:** The BPI professional must make every reasonable effort to have the building owner, manager, or their authorized agent provide access to all appliances requiring testing. However, the BPI professional is not responsible for moving heavy furniture or other impediments to access appliances.
- **Outdoor Equipment:** Combustion equipment located completely outside (not directly connected to a living space or space otherwise utilized by tenants and/or building management) of the building enclosure and are not affected by pressure dynamics within the building shall undergo gas line testing and meet CVA requirements.
- **New Ranges & Ovens:** Ranges and ovens that have been newly installed as part of the scope of work do not need to be tested.
- **Drilling of B-Vent:** Vent CO measurements of appliances with B-Vent type venting material shall be conducted to the best of the professional's ability without drilling a new hole into the B-vent. If the appliance does not have a draft hood or barometric draft regulator that would allow for the insertion of a probe, a vent CO measurement is not required.
- **Category III and Category IV Vented Appliances:** Vent CO measurements and spillage testing of Category III and Category IV appliances (those that have positively pressurized vent systems), and any direct vent sealed combustion appliances are not required.

6. Project Submission

Prior to incentive reservation and construction commencement, the participating rater shall submit a test-in submittal package on behalf of the project owner. The test-in package will include:

- EnergyPro model (.bld file) for each building
- ECON2 for each building
- Data collection forms, take-offs, and photos of existing building conditions
- Assessment report
- Multifamily CAS compliance results (workbook or report)
- Construction schedule

The test-in submittal package will undergo a robust desktop review by the program's quality assurance staff at TRC to ensure completeness, accuracy, and compliance with program requirements. See section 8 for more detail about program quality assurance.

First Project Submission

Raters submitting their first project to the program are required to participate in a multi-step review process of the test-in submission. The first step includes review of the data collection forms and EnergyPro model of existing conditions only. Once approved, the rater may complete analysis and reports, including adding upgrade measures to the model, and submit the complete test-in package, as described above.

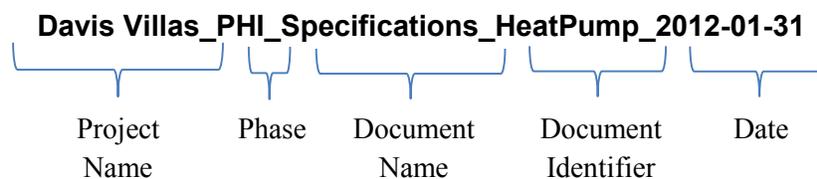
File Upload

Upon approval as an approved rater, MUP Staff will set up a SharePoint folder for the rater to share project files with program staff. When a complete submission package (test-in or test-out) is uploaded, the approved rater shall send an email to multifamilyupgrade@trcsolutions.com to inform MUP staff that the project is ready for quality assurance review.

Naming Convention Guidelines

Six strings of identification are required in the naming process for all documents and files associated with a project. The rater and MUP Staff use the naming convention when sharing and storing files.

Below is an example of a complete file name:



Project Name

The project name is the same name stated on the project interest form.

Example: San Diego Villas

Phase

The phase indicates whether the file contains test-in or test-out documentation by the following strings:

- PHI – through reservation letter (test-in)
- PHII – post reservation through completion (test-out)

Document Name

The document name will be one of the following:

- | | |
|--------------------------|-----------------------------|
| ▪ Application | ▪ Invoice |
| ▪ Architectural Drawings | ▪ Permit |
| ▪ Assessment Report | ▪ Project Interest Form |
| ▪ Assessment Review Form | ▪ Reservation Letter |
| ▪ Building Simulation | ▪ Site Plan |
| ▪ Building Sketch | ▪ Specifications |
| ▪ Completion Letter | ▪ Survey |
| ▪ Construction Schedule | ▪ Unit Plan |
| ▪ Data Collection Form | ▪ Project Verification Form |
| ▪ ECON2 | ▪ W-9 |
| ▪ Floor Plan | |

Document Identifier (optional)

The document identifier adds detail to the document name. Examples include:

- Building or unit number
- Specific equipment type

Date

The date is formatted as a 4-digit year followed by a 2-digit month and ends with a 2-digit day.

Example: 2012-01-31

7. Post-Retrofit Verification and Documentation

Site Verification

Approved raters, as the first level of program quality assurance, are responsible for verifying energy measure installation. This includes the following:

- **Are the measures installed to meet the efficiency specifications listed in the program reservation letter?** If the efficiency specifications of the installed measures, or the upgrade scope of work do not match the reservation letter, the approved rater must revise simulation files to match post-retrofit conditions. This may result in a change to the incentive amount for the project. PG&E can only guarantee incentives up to the amount on the reservation letter. The program administration may increase project incentives due to adjustments in project scope of work as funding allows.
- **Are the measures installed to manufacturers' specifications?** The project team must correct for the inadequate installation of a measure. The rater must verify the correction in order to qualify for program incentives.
- **Are measures installed according to the by Multifamily Upgrade Program Quick Reference Checklists?** The project team must verify all measures are installed according to the quick reference guides found on: www.multifamilyupgrade.com. Quick reference guides may be signed off by the program approved rater or contractor.
- **Do the upgrades pass program-required combustion safety testing** (see Section 5)? The project team must address all combustion safety issues, as defined by BPI prior to test-out project submission.

Approved raters and contractors are required to report scheduled test-out inspection dates to MUP Staff with a minimum one-week notice.

Project Submission

Following construction completion and verification, the approved rater shall submit a test-out submittal package on behalf of the project applicant to the project's SharePoint folder. The test-out package will include:

- Project verification form
- Photo documentation of upgrades based on sampling protocols
- Multifamily CAS compliance results (workbook or report)
- Cut sheets for installed upgrade measures
- Copies of permits for upgrades (as applicable)
- Copies of invoices for upgrade measures
- W-9 form for each incentive payee (owner, approved rater, or approved contractor)
- Energy model files and ECON2s, if there have been any specification changes to the scope of work
- Lighting Schedule (according to Figure 9)
- Quick Reference Checklists

Description	Lighting Category	Lamps (Qty/Fixture)	Lamps (Watt/Lamp)	Qty of Fixtures in Project	Location of Fixtures
Hallway Wall Sconces	High-Efficacy	2	17	45	Hallways, Entryway
Ceiling lights	High-Efficacy	2	11	60	Kitchens (in unit)
Bath vanity	High-Efficacy	4	16	60	Living room spotlight
Recessed Can	CFL	1	40	60	Living room spot light
Wall Sconces	Incandescent	1	60	60	Exterior Light

Figure 9. Example Lighting Schedule

The test-out submittal package will undergo a robust desktop review by program quality assurance staff to ensure completeness, accuracy, and compliance with program requirements. See section 8 for more detail about program quality assurance.

8. Quality Assurance

Request for reservation and request for incentive each trigger participation in the Multifamily Upgrade Program quality assurance process. This process has two components:

- **Field Quality Assurance:** Site visit by MUP staff to verify pre- or post-retrofit conditions
- **Desktop Review:** Review project submission package for completion and review of data collection forms and building simulation files for accuracy of reported energy savings.

Field Quality Assurance

At least ten percent of projects will undergo field inspection by MUP Staff at assessment and completion.

Assessment Field QA

MUP staff will notify the applicant and approved rater within three business days of application submission as to whether MUP staff has selected the project for field quality assurance. When possible, MUP staff expect the approved rater to coordinate their assessment site visit with the MUP staff site visit in order to limit resident disturbance and minimize burden on property management staff.

Program site inspection will include verification of existing conditions, aligned with the program's assessment protocols, and program-required CAS testing on a sample of units. The units sampled may or may not be identical to those sampled by the approved rater. MUP staff will compare data collected to data submitted by the approved rater to confirm accuracy.

Completion Field QA

Within three business days of receiving test-out inspection dates from the approved rater, MUP staff will select a project and notify the applicant and approved rater about required completion field QA. Completion QA by MUP staff will occur during the partner inspection times when possible to minimize disruption to residents and property managers. When circumstances warrant, MUP staff reserves the right to schedule test-out inspections after receipt of test-out documents from the partner.

Site inspection at completion will include verification of installed upgrades and compliance with combustion safety policies on a sample of units that may or may not be the same sample selected by the approved rater. The project team must correct any failures identified by MUP staff. MUP staff will inspect all corrections made by the project team prior to release of project incentives.

Desktop Review

Assessment Review (Test-In)

When MUP staff receives complete energy assessment documentation from the rater, MUP Staff will complete a review to document the upgrades using TRC's assessment review procedures. **The Multifamily Upgrade Program cannot reserve incentives until the project completes assessment review and submits an application with a project team consisting of an approved rater and approved contractor.**

The assessment review process is as follows:

1. The approved rater uploads assessment documentation to the partner portal and then emails multifamilyupgrade@trcsolutions.com to inform MUP staff that project is ready for review.
2. MUP staff reviews data collection forms and building simulation files to verify that the rater modeled existing conditions correctly. MUP staff makes comparisons against data collected during field QA (if applicable).
3. MUP staff verifies that the proposed energy measure upgrades have been modeled correctly, meet minimum efficiency requirements and that the energy savings are at least 10% above existing conditions for each participating building.
4. MUP staff verifies that combustion safety testing has been completed per program protocols and action items communicated to the applicant.
5. MUP staff schedules a live assessment review (via phone and computer screen share) to discuss and assist the approved rater with required modeling and documentation revisions. Live assessment reviews are required and are at the discretion of the MUP staff member conducting the assessment review.
6. Letter of reservation issued to the applicant and project team.

Design Assistance & Energy Savings Estimates

An integral part of the assessment review process is providing design assistance to improve the energy performance of a property in the event it does not qualify or where additional savings are available.

When a property does not qualify, TRC will discuss the issues with the project team and work to find a solution. The extent of design assistance will vary by property, based on the needs of the project team and the willingness and ability of the approved rater to perform this role. MUP staff can meet with the property owner in person or by conference call to discuss energy efficiency upgrade options and help the owner select the measures that will meet energy efficiency and program goals. The meeting should include the approved rater and other project team members. Additional research may be required to answer the owner or staff's questions or address concerns with new technologies or solutions.

TRC will evaluate the baseline and energy savings (TDV, kW, kWh, and Therms) calculations as part of the assessment review procedures. The program will track information on total square footage of each building, climate zone, energy savings/year for heating, cooling and water heating. MUP Staff will translate total kBtu savings/year into total kWh, kW, and therm savings per building.

Incentive Reservation

Once the assessment review is completed, MUP staff will confirm the upgrade work scope with the property owner by sending a *letter of reservation* to the project team. The letter contains a list of the energy upgrade and combustion safety measures that the owner agrees to implement, details the incentives reserved, and serves as an approval to start construction and implementation of the energy upgrade measures. At this time, TRC will submit assessment review and application documentation to PG&E for incentive reservation.

Completion Review (Test-Out)

Upon submission of test-out documentation by the approved rater, MUP staff will review documentation to verify that:

- Permits were pulled and signed by the local building inspector for all applicable upgrades.
- Cut sheets, post-retrofit photos, and modeled conditions are in agreement and in compliance with applicable minimum efficiency requirements.
- Combustion safety testing results and remediation comply with program policies and have been communicated to the applicant.
- Cost information for *each* energy upgrade measure in the project scope of work. The cost shall include all labor and materials *required* to complete the upgrade. This may include equipment and appliance costs, electrical and plumbing improvements, structural changes to support the upgrade measure, and cosmetic improvements to cover evidence of construction. The measure cost shall not include upgrades or improvements unrelated to the energy efficiency measure itself. If the energy efficiency measure can be installed safely, in compliance with building codes, and to manufacturer's specifications without an upgrade or improvement, the cost of that upgrade or improvement shall not be included in the cost of the energy efficiency measure. For example:
 - The total cost of a domestic hot water heater may include plumbing costs associated with relocating the water heater for appropriate draft clearance, but should not include the cost of painting the door on the water heater closet.
 - The cost of window replacement may include patching the stucco around the window, but should not include new siding for the entire building.
 - The cost of refrigerator replacement may include removal and replacement of doorframes too small to accommodate the width of the refrigerator, but should not include aesthetic or spatial improvements made in the kitchen (e.g. counters, cabinets, flooring, etc.).
- If total project cost (sum of costs from each measure) is less than total project incentive, the project will receive an incentive equal to, but not more than the total project cost.

If the scope of work installed varies materially from the scope of work for which incentives were reserved, MUP staff will review that the post-retrofit conditions reported match those included in the revised EnergyPro model(s), and that the project achieves at least ten percent savings for each participating building. Project incentives will be recalculated based on the revised scope of work and may be reduced. Project incentives may only be increased from the reservation amount if program funding is available.

Completion Letter

Once a project has passed test-out desktop review, MUP staff will confirm project eligibility and incentive amounts with a completion letter to the project team. The letter contains a list of upgrades performed at the project. TRC will submit all project documentation to PG&E for incentive processing.

Non-Compliance Corrective Action

All participating raters and participating contractors shall submit accurate, complete, and quality work to MUP Staff for review. If program submittals and fieldwork do not meet program standards, the following corrective actions are enacted to ensure project energy savings are accurately represented through work conducted and submitted by participating raters and participating contractors.

Participating Rater and Participating Contractor Corrective Action Matrix			
Level	Issue	Recommended Action	Follow-up
1	General quality of work not up to program standards: <ul style="list-style-type: none"> ◆ Bad customer data routinely provided ◆ Miscounts ◆ Incorrect/Incomplete data 	Verbal guidance and e-mail correspondence documenting the remedial actions to bring the Partner up to expected program standards.	<ul style="list-style-type: none"> ◆ Provide more guidance on pending processes upfront ◆ Monitor their applications for improvement ◆ Re-train as needed
2	Continued subpar performance on process/field work issues	<ul style="list-style-type: none"> ◆ Probation letter is sent ◆ 30 days to correct ◆ No new project submittals until quality is marked as improved by MUP Staff. ◆ Customers will be notified if their Partner is placed on probation 	<ul style="list-style-type: none"> ◆ Remove from public listing. ◆ When work is improved, and reinstate on public list.
3	No improvement in performance during probation period <ul style="list-style-type: none"> ◆ Continuation of above 	<ul style="list-style-type: none"> ◆ Written notice of suspension. ◆ No new projects accepted. ◆ Notify customers. 	<ul style="list-style-type: none"> ◆ 60-day suspension to submit new projects pending further investigation. ◆ Enhanced supervision. ◆ Reinstatement only upon appeal and review (to 30-day probation level).

Figure 10. Participating Rater and Participating Contractor Corrective Action Matrix

9. Project Timelines

In order to best manage program volume and serve the multifamily market equitably, Multifamily Upgrade Program staff expects continual progress of each project in the program. As such, staff will monitor the following project milestones and timelines for each project. If a project does not meet a project milestone within the expected timeline, it will lose its place in the incentive queue and may rejoin the queue at the bottom of the project list. If the program is fully subscribed, this may result in the loss of assessment and upgrade incentives for the project. The table below summarizes timeline expectations for participating projects.

Project Milestone	Timeline
Assessment site visit	Within two months of application submission date
Project team check-in with MUP Staff #1	After assessment site visit and before construction commencement
Test-in submittal	Within one month of assessment date
Test-in submittal revisions	Within 7 business days once comments are issued by Multifamily Upgrade Program staff
Construction commencement	Within two months once letter of reservation is issued
Project team check-in with MUP Staff #2	Upon construction kick-off
Project team check-in with MUP Staff #3	At 50% construction completion listed on letter of reservation
Approved rater or contractor verification of installed measures	Within two weeks of construction completion
Test-out submittal	Within two weeks of approved rater verification
Test-out submittal revisions	Within 7 business days once comments are issued by MUP Staff

Figure 11. MUP Project Milestones and Timelines

MUP staff will also adhere to timelines for responding to project submittals. Staff will review and issue comments to the approved rater on all project submittals and resubmittals, both test-in and test-out, within ten business days of receipt.

Key Program Deadlines

All projects enrolling in the PG&E Multifamily Upgrade Program for the 2017 program year shall meet the below program deadlines to be eligible for incentives:

Application and test-in submittal – September 29, 2017

Test-out submittal – within 30 days of completion date milestone identified in Incentive Reservation Letter, or by November 13, 2017, whichever comes first

Projects not able to meet the completion deadline due to unforeseen circumstances may apply for a one-time extension by contacting MUP staff at least four weeks prior to the completion deadline. **If projects fail to meet the completion deadline identified in the incentive reservation letter, or a one-time approved extension deadline, this failure may result in significant changes to the final incentive amount (including void of incentive reservation).**

10. Appendix A: California Multifamily Retrofit Energy Modeling Guidelines



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California Multifamily Retrofit Energy Modeling Guidelines

Version 2.0

January 26, 2017



I. INTRODUCTION

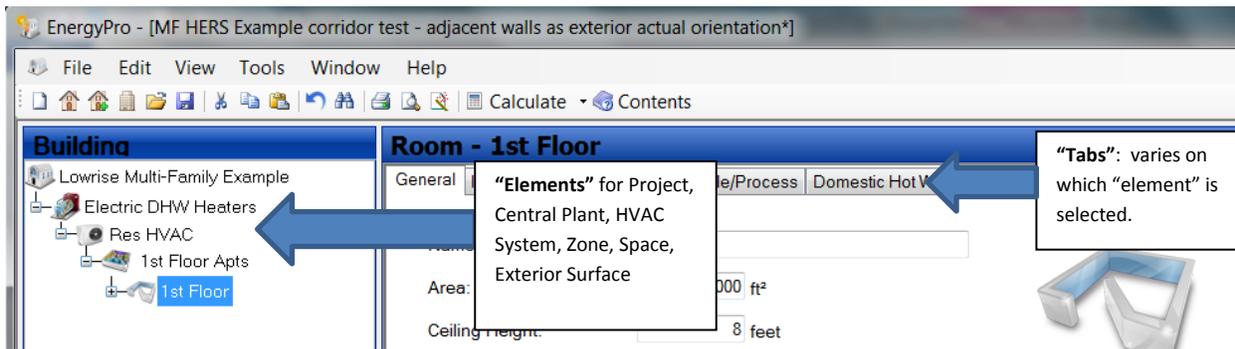
This document provides energy modeling guidance to qualified Raters/Partners serving San Diego Gas and Electric’s *Energy Upgrade California*™ Multifamily (SDG&E EUC-MF) and Pacific Gas and Electric’s Multifamily Upgrade Programs (PG&E MUP). Because both programs share the same modeling requirements, this document collectively refers to both of these programs as “the program.”

This document provides guidance and best practices for modeling existing multifamily buildings and their systems in EnergyPro 5. These guidelines intend to inform project submittals, and do not intend to be a step-by-step protocol for modeling multifamily buildings. The reader should have a basic understanding of EnergyPro, and how to navigate the software, use the libraries, and understand the different calculation modules available.

TRC Energy Services prepared this document. No other multifamily retrofit program may use or distribute this document without TRC’s written consent.

Terminology

This document refers to several EnergyPro modeling components. These include EnergyPro building *elements*, EnergyPro *tabs*, and EnergyPro *fields*. Building elements are on the left side of the EnergyPro building tree and include the *Project*, *Central Plant*, *HVAC System*, *Zone*, *Space*, and various *Exterior Surface* elements. After selecting one of these building elements, the right side of the EnergyPro screen will show *tabs* for components specific to the selected building element. Under each of the *fields*, select inputs from a drop-down list or manually input numerical values.



2. PROGRAM REQUIREMENTS

Participation in the Energy Upgrade California - Multifamily or Multifamily Upgrade Program requires the use of energy analysis software, inputs of actual and sometimes default conditions, and calculation of energy savings/improvements.

Energy Analysis Software

Program Raters must model all buildings using EnergyPro version 5. Use the Res Performance module for low-rise multifamily buildings and the Non-Residential Performance module for high-rise buildings. Title 24 Part 6 and the program consider any multifamily building with four or more habitable floors as *high-rise residential*. The programs consider a four-story building with retail on the ground level and three levels of multifamily a high-rise multifamily building.

This document uses the term *EnergyPro* whenever information applies across all modules of EnergyPro. *Res Performance* and *Non-Res Performance* will indicate when the guidelines apply specifically to those modules.

Both modules allow for parametric alternatives in analysis of energy efficiency measures using a single bld file. If the *Alternatives* tab does not allow accurate modeling of energy efficiency measures, such as a change in window or floor area, the modeler can compare building performance across two separate models to calculate project energy savings. Section 10 provides examples on modeling alternatives using one file and multiple files.

Energy Savings Improvement Calculations

Each building must meet the improvement threshold of ten percent site energy savings. The program requires project teams to report site savings from the ECON-2 report, which is generated using Res Performance or Non-Res Performance modules of EnergyPro. The program uses the site energy improvements on the ECON-2 report to qualify projects for program participation and to determine the savings and project incentive tier.

Projects may claim energy savings for upgrades to common areas that serve residents. If a property has multiple residential buildings and is conducting eligible upgrades in detached common areas, the modeler should add these (detached) common areas to the residential building with the largest number of dwelling units. This approach applies to such measures as: pools, common laundry (machines and domestic hot water) systems, and site lighting.

Multiple Buildings on One Property

Projects must submit an energy model for each eligible building located on a single property. The program will not accept files that include multiple buildings in one energy model.

For the purposes of the program, a multifamily building is:

1. Any building with five or more attached dwelling units
2. Any building with two, three, or four units in which there are any shared spaces, such as attics, hallways or other shared space
3. Any building with two, three, or four units that have at least one shared wall between any two units

It is common for multiple buildings on a single property to share central heating and domestic hot water (DHW) systems. Section 0 of this document provides guidance for modeling these types of projects.

Existing Conditions and Default Values

The modeler should use actual existing conditions whenever possible. Use default values for construction assemblies and mechanical equipment when actual values **are not** available.

When available, the modeler should include actual nameplate data for mechanical systems, assemblies, and appliances in energy simulations. If this information is not available, use efficiency values from the following directories (listed in order of preference):

1. CEC Appliance Directory, or AHRI Primenet on-line directory (<https://www.ahridirectory.org/ahridirectory/pages/home.aspx>)
2. Kouba-Cavallo Associates – refrigerator kWh database (<https://www.couba-cavallo.com/refmods.htm>)
3. Table R3-50 of the 2016 Residential Compliance Manual—use for default values for DHW and heating ventilation and air conditioning (HVAC) equipment if the above directories do not list the efficiency

When inaccessibility prohibits verification of existing conditions, the modeler shall use default construction assembly u-values, based on building vintage, from *Table R3-50 – Default Assumptions for Existing Buildings of the 2016 Residential Compliance*. Whenever National Fenestration Rating Council (NFRC) ratings are not available for windows, energy assessments shall use U-factors and solar heat gain coefficients from *Standards Tables 110.6-A and 110.6-B*, and determine values based on glazing and framing types.

Appendix C: Non-Vintage Based Default Values

summarizes all default sources and additional default values discussed throughout these guidelines. These are not vintage-based efficiency values. Examples include default total cooling capacity, estimated sensible cooling capacity from total cooling capacity, and default supply fan flow rates.

Model Calibration

The program does not require calibrating the models to utility usage data; however, it is best practice to collect and input utility bills into EnergyPro to compare against the modeled energy use for accuracy. If a modeler chooses to calibrate energy models, each energy simulation should be within ten percent of actual annual utility use and twenty percent of monthly utility use.

3. BUILDING INFORMATION

This section provides guidance on the *Building* element of EnergyPro and suggestions for organizing building data for input into the model. The *Building* element includes basic project design data. Inputs on the *Designer*, *Lighting Designer*, *Mechanical Designer*, and *Outdoor* tabs are not necessary for project submittals.

For low-rise multifamily projects using the Res Performance module, the *Building* element also includes lighting and appliances input on the HERS tab. High-rise projects using the Non-Res Performance module do not use the HERS tab for modeling lighting and appliances. The next section addresses lighting and appliance inputs for low-rise and high-rise multifamily.

Data for the *Building* element inputs comes from data collection forms. [Appendix E: Multifamily Data Collection Forms](#) includes example forms that participating program raters or modelers can use. If raters or modelers prefer to use their own data collection forms, the form must capture the same information as the program (data collection) forms.

Project Design Data

Input the following project design data.

Front Orientation

Front orientation refers to the direction of the building's front door. Some multifamily buildings may contain doors with orientations of different directions. In all cases, it is essential that the building sketches clearly illustrate the north arrow.

Rotation

The purpose of rotation is to rotate the entire building from the front orientation. It rotates the building and exterior surface orientations to the selected front orientation. For example, inputting front as west (270°) and rotating 10° would result in front orientation of 280°. To work properly, the modeler must conduct this rotation **after** completing the building model. This is useful when a property has identical buildings with different orientations; it allows the modeler to create one model, then duplicate and rotate subsequent models as necessary.

Number of Dwelling Units

Domestic hot water and appliance calculations rely on the total number of dwelling units, so it is essential that the building model include the accurate number of dwelling units.

Location: Climate Zones

Accurate analysis requires selection of the correct climate zone. Do not edit the climate zone from the default value found for the building location (city). The modeler should **not** select the *User Defined* box.

Project Title

Input the building number, or other designation (distinct from other building models for that property), in the name field. The ECON-2 report uses the project name from this field.

Utility Rates

Select the project electricity and natural gas rates. When choosing a utility rate, click on the import icon and select a rate from the software. The software frequently updates the rates; therefore, rates should not require modification after initial selection.

Organizing Building Zone Data for Input

Before creating an energy model, the first step is to understand the building zones. This is especially important for high-rise buildings and larger low-rise buildings with different dwelling unit types or large common areas. The primary zoning factors are space type (conditioned or unconditioned), and the type of HVAC system serving the dwelling units. For example, the model should contain dwelling units with electric resistance heating in zones separate from dwelling units with heat pumps because these are different HVAC system types. The modeler should also consider occupancy type, common area building operating schedules, and any unique internal gains when zoning the building for data entry.

A *thermal zone* refers to the physical space of the building and includes the exterior surfaces of the building envelope (walls, roof, floor, and windows), the assembly areas, and the internal load and occupancy assumptions for the space.

Low-Rise Dwelling Units

Identify at least one thermal zone per floor for all low-rise multifamily projects. It is possible to identify zones by floor or by dwelling unit; each approach is acceptable and has its advantages, such as ease of quality control in the dwelling unit approach. The results will be the same with either zoning approach. Low-rise multifamily buildings must have at least one zone per floor. One zone cannot include or combine multiple floors.

Low-rise multifamily buildings that receive service from hydronic heat pump systems require additional zoning detail because system operation is sensitive to individual zone temperatures and equipment performance. The best practice is to model each dwelling unit as a separate zone and room.

High-Rise Dwelling Units

High-rise models are more sensitive to thermal zoning because the Non-Res Performance module simulation engine and calculations differ from those in the Res Performance module. The high-rise multifamily modeler can define thermal zones at his or her discretion. Options include a thermal zone per floor, by exposure/orientation, or by dwelling unit; selection should depend on building layout and system types.

High-rise multifamily buildings with large amounts of glass in opposing orientations may have zones that require heating and cooling at the same time during colder months. In these situations, the modeler should create zones by exposure/orientation by combining west-facing dwelling units into one zone per floor, east-facing units into one zone per floor, south-facing units into one zone per floor, and north-facing units into one zone per floor.

High-rise multifamily buildings with hydronic heat pump systems require detailed zoning because system operation is sensitive to individual zone temperatures and equipment performance. Best practice is to model each dwelling unit as a separate zone and room.

Common Spaces

Common space refers to areas of the building that are available for all tenant use. This may include spaces such as laundry rooms, game rooms, dining rooms, computer rooms, hallways, and manager offices. Projects must model common spaces within the building with different occupancies as separate zones. This is more applicable for high-rise projects where significant amounts of support spaces such as hallways and community areas have different occupancy and load characteristics (e.g., ventilation rates and occupant density assumptions), which impact building energy usage.

Conditioned and unconditioned common spaces require different modeling approaches. Title 24 Standards identify the following types of conditioned spaces (zones):

1. **Conditioned space** is space in a building that is either directly conditioned or indirectly conditioned.
2. **Directly conditioned space** is an enclosed space that is provided with wood heating, is provided with mechanical heating that has a capacity exceeding 10 Btu/hr-ft², or is provided with mechanical cooling that has a capacity exceeding 5 Btu/hr-ft², unless the space-conditioning system is designed for a process space (typically commercial or industrial uses).
3. **Indirectly conditioned space** is enclosed space, including, but not limited to, unconditioned volume in atria, that (1) is not directly conditioned space; and (2) either (a) has a thermal transmittance area product (UA) to directly conditioned space exceeding that to the outdoors or to unconditioned space and does not have fixed vents or openings to the outdoors or to unconditioned space, or (b) is a space through which air from directly conditioned spaces is transferred at a rate exceeding three air changes per hour.
4. **Unconditioned space** is enclosed space within a building that is not directly conditioned, or indirectly conditioned.

Conditioned Common Spaces

If the conditioned common area of each building constitutes twenty percent or less of total building area, and the area will include eligible upgrade installation, the modeler can include the conditioned common area in the same model as the residential space. These (common) spaces **cannot** be part of the model if they consist of more than twenty percent. This applies to both low-rise and high-rise buildings. Detached common spaces cannot be part of the model if their total area exceeds twenty percent of total floor area for all buildings at the property.

Create at least one zone per floor for the conditioned common areas and input the envelope, domestic hot water, and HVAC system characteristics in accordance with the energy assessment findings. The modeling approach for common area lighting and appliances differs between low-rise and high-rise; the lighting and appliances section outlines these approaches.

Indirectly Conditioned Common Spaces

The model must include indirectly conditioned space as a separate conditioned space. Multifamily buildings may contain unconditioned hallways without a dedicated HVAC system. A space is indirectly conditioned if the space wall area adjacent to the conditioned zone is greater than the wall area adjacent to the unconditioned zone (or exterior) and there are no fixed openings in the zone.

An indirectly conditioned space cannot be the first zone in EnergyPro or the program will not run. The modeling approach for common area lighting and appliances differs between low-rise and high-rise; the lighting and appliances section outlines these approaches.

Unconditioned Common Spaces

If the common space does not share walls with a conditioned zone, there will be no cooling or heating energy impacts to conditioned spaces. In these cases, model the lighting and miscellaneous equipment of the common space on the Exterior uses tab.

For low-rise multifamily projects, the exterior uses tab approach is the only way to model unconditioned common spaces. EnergyPro will remove unconditioned spaces from analysis in any model running the Res Performance module.

Building Operating Schedules

Building operating schedules specify the following:

1. Percentage of full load for internal loads from lighting or miscellaneous equipment and their heat gains into the space
2. Hours of operation for heating, cooling, and ventilation systems
3. Thermostat set points for heating and cooling systems

The Non-Res Performance module uses default building operating schedules based on occupancy type provided in [Appendix D: Default Schedules for High-Rise](#).

In the Non-Res Performance module, modelers can change building operating schedules from the default schedules when they input custom schedules into the Schedules tab on the zone level. Low-rise projects can only create custom schedules for the end-uses which are modeled on the Exterior uses tab.

If an area operating schedules differ significantly from defaults (i.e., varies by two or more hours or degrees) or other areas in the building, the modeler can create a schedule representative of actual operating conditions and assign it at the Zone level for the unique zone. If the modeler creates a custom operation schedule, the modeler must document and submit assumptions to the program for review.

Example

A high-rise project has hallways with lights on 24/7 and common areas with lights on twelve hours per day. Create separate zones for the hallways and common areas and create different lighting schedules for each zone.

Example

An energy assessment determined outdoor lighting has two control zones: one zone operates 10 hours per day and the second zone operates 11 hours per day. Lighting wattage in each zone is the same. The modeler can average both schedules to a 10.5-hour schedule, or use either the 10 or 11-hour schedule for both applications. Each approach is acceptable since one hour per day is relatively insignificant.

If zone one has 1000 Watts of lighting, and zone two has 20,000 Watts of lighting, the modeler can use the zone two lighting schedule for zone one.

Example

Thermostat settings in the hallways are 78°F for cooling and 68°F for heating. The other common areas have a cooling set point of 74°F. The modeler should define and assign separate cooling schedules for both common area zones in the model.

Use of Multipliers for Zones

Low-rise modeling prohibits use of vertical and horizontal multipliers because the ground and top floors are unique (ground has a floor assembly, top has roof assembly). Therefore, use of a vertical multiplier in low-rise models is unnecessary. High-rise multifamily models often have multiple identical floors between the ground and top floors. If the floors between the ground and top floors are identical, it is appropriate to use vertical multipliers.

There is less use for horizontal multipliers in multifamily building models. It is best practice to model an entire floor as one thermal zone. Use of horizontal multipliers occurs when modeling a row of identical units. These multipliers only work for middle units that have identical external surfaces.

Combining Exterior Surface Area

Rather than building exterior surfaces separately for each dwelling unit, modelers can combine exterior surfaces (i.e., windows and walls) for each floor within a single zone.

Example

Model eight identical dwelling units as one zone. Each unit has (2) 3'0" x 4'0" windows and (2) 6'0" x 6'8" slider doors on a 25' wall facing west. The wall height is 8'. There is a 2' overhang with .1' offset on all of these windows.

- ◆ **Wall area** - Combine the wall area of the eight units: 1,600 square feet = (8) dwelling units x 25' per dwelling unit x 8' high. Set the wall orientation to West. Repeat for other exterior surface areas facing other orientations.

- ◆ **Windows** - Combine windows of the same dimensions per dwelling unit into two separate inputs:

- ◆ Combine the window area of the two 3'0" x 4'0" windows for the eight units: 192 square feet = (2) x 3'0" x 4'0" x (8) dwelling units. Model the overhang as a 2' overhang with 0.1' offset and combine the two windows per dwelling unit into one window with a width of 48'0" (3' x 2 windows x 8 dwelling units) and height modeled as 4'0".

- ◆ Combine the window area of the two 6'0" x 6'8" patio sliders for all eight units: 640 square feet = (2) x 6'0" x 6'8" x (8) dwelling units. Model the overhang as a 2' overhang with 0.1' offset and the combine the two patio sliders per dwelling unit into with a width of 96'0" (6' x 2 patio sliders x 8 dwelling units) and modeled height as 6'8".

This approach produces the same results as modeling all windows separately. Windows with different assemblies or overhang characteristics require separate (not combined) modeling.

Creating a Mirror Image of a Building

A mirror image describes when a building is flipped 180°, resulting in a mirror image of the building's floor plan. To do this in EnergyPro, create a building and input all data, then *save as* another file to create a duplicate for the mirror-building model. Proceed down into the building tree to the exterior surfaces in the *room* level to adjust the two walls that are 180° from the original building.

Example

Original front wall is set at 30°. Change the mirror image wall to 210°. The original back wall is set to 210°. Change the mirror image wall to 30° degrees. Complete these steps on each floor or zone of the building.

Multipliers and Combining Like HVAC Systems

When multifamily buildings all have the same type of HVAC equipment, use the multiplier to model more than one of the same type of HVAC equipment. To do so, create and define the HVAC system type in EnergyPro, assign a multiplier of the number of units using this system type, then create and assign the dwelling unit zones to this system.

If there are multiple system types serving the building, create a system in EnergyPro for each unique HVAC system and assign the zones that each unique HVAC system serves.

Example

A multifamily building consists of two levels with eight dwelling units on each floor. The first floor has wall furnaces; the second floor has a forced air furnace with ducted distribution. These two system types require separate modeling. Create a system for furnaces and assign the dwelling units that receive service from these furnaces. Do the same for the wall furnaces and dwelling units that receive service from wall furnaces.

4. LIGHTING AND APPLIANCE INPUTS

This section provides guidance on different best practices for modeling major appliances and interior lighting for low-rise and high-rise multifamily projects. Low-rise projects using the Res Performance module will input lighting and appliances characteristics on the HERS tab. High-rise projects using the Non-Res Performance module will input lighting and appliances as Watts/square feet and assign an annual operating schedule at the zone level.

Enter exterior site lighting on the Exterior tab for unconditioned common areas in both building types. The software will report results as an exterior end-use.

Lighting and appliance input data comes from the data collection forms found in [Appendix E: Multifamily Data Collection Forms](#).

Low-Rise Multifamily Lighting

Dwelling Unit Lighting

The lamp type, quantity, control, and location of the lighting fixture in the dwelling units are required inputs on the HERS tab. It is not necessary to input the lighting wattage for the dwelling unit lighting in the Res Performance module. The software currently accepts whole numbers only for the HERS tab lighting fixture quantity input. EnergyPro assumes default values; do not use these defaults for the program. The modeler inputs the lighting type average based on the quantity of each lamp type, location and control input.

Averaging Lighting Audit Data

Input lighting as an average based on the onsite assessment sampling. If there are multiple dwelling unit types in the building, such as a mix of 1-bedroom and 2-bedroom dwelling units, take the average lighting for the sampled dwelling by type, location and control per dwelling unit and input it into EnergyPro. A fixture with multiple lamps should count every two lamps as one fixture.

Example

Figure 12 shows lighting for three types of dwelling units. Calculate the average number of fixtures for input into the HERS tab. The software does not accept fractions; round inputs up or down. For example, model bath lighting should be modeled as two fixtures (rounded up from 1.67). It is important to document lighting calculations on each project for any reference that may be necessary for quality assurance and quality control efforts.

Room	Unit A (1-bed) CFL	Unit B (2-bed) CFL	Unit C (2-bed) CFL	Average per dwelling Unit	EnergyPro Input Number of CFLs
Bath	1	2	2	1.67	2
Kitchen	2	2	2	2.00	2
Hallway	2	4	4	3.33	3
Bedroom	1	2	2	1.67	2
Dining	1	1	1	1.00	1

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Living	2	2	2	2.00	2
Outdoor	1	1	1	1.00	1

Figure 12: Example Average Dwelling Unit Lighting

Exterior Building Lighting

Outdoor area lighting on the HERS tab pertains to any lighting attached to the exterior of the residential building, such as patio and porch lights. Input the average number of exterior lights per dwelling unit, by lamp type and control.

Conditioned Common Area Lighting

Include interior lighting for conditioned common area in low-rise projects as an average per dwelling unit, and input on the HERS tab. Add up the lighting fixtures in the common area and divide by the total number of dwelling units. Add this fixture count to the dwelling unit lighting on the HERS tab.

Unconditioned Common Area Lighting

Calculate the total lighting Watts in the unconditioned common area and input the total Watts on the Exterior Uses tab. Create and assign the lighting schedule as verified on site. A two-model approach is necessary for modeling lighting improvements; the lighting schedules must be identical in the existing and proposed energy models.

To accurately determine fixture wattage, the modeler or rater must collect the lamp type, lamp wattage, and ballast type during the energy assessment. The ballast type is necessary because the ballast impacts the total fixture wattage; the fixture wattage for ballasted lighting fixtures is not the sum of the lamp wattages. The Title 24 2016 Joint Appendices Appendix NA8 Illuminance Categories and Luminaire Power lists default wattages for typical lamp/ballast combinations.

The process is summarized below:

1. Build hourly lighting schedules for areas operating on similar schedules.
2. Calculate the total wattage of lighting fixtures as grouped with hourly schedules using equation in Figure 13. Use cut sheets (if available) or default values located in Appendix NA8 to determine fixture wattage.

$$Total W_{Fixture A} = Qty_{Fixture A} \times W_{Fixture A}$$

Figure 13: Lighting Fixture Wattage Calculation (SC-1)

3. Input the wattage and a description of the load, such as “unconditioned hallway lighting,” in the exterior use tab, and assign the hourly schedule from step one above.

Example

In unconditioned hallways, there are twenty fixtures with two T12 lamps and standard magnetic ballasts. The total fixture wattage is 72W per fixture x twenty fixtures for a total of 1,440 Watts. Enter this wattage and a schedule of operation in the exterior uses tab.

The proposed energy efficiency measure is to replace the lamps and ballasts with T8 lamps and electronic ballasts. The total proposed fixture wattage is 60W per fixture x twenty fixtures for a total of 1,200 Watts. Input the total annual kWh savings in as a Custom measure on the *Alternatives* tab.

Exterior Site Lighting

To input detached lighting, such as parking lot and other site lighting, use the same process for unconditioned common areas, and input values into the Exterior use tab.

Whether the model shall include exterior site lighting depends on which Multifamily Whole Building program the project is participating in. Refer to the program specific policies and procedures for guidance.

High-rise Multifamily Lighting

The modeling approach for lighting in high-rise multifamily buildings will depend on the location of the lighting. Model lighting using either lighting power density (LPD) or total lighting wattage. The LPD is defined as total wattage of lighting fixtures located in a space, divided by the square feet of space (Watts/sf). Side calculations are necessary to show the pre and post LPD or total lighting wattage. To accurately capture a multifamily daily lighting schedule, the program has provided the table below to be used when modeling dwelling unit lighting.

Dwelling Unit Lighting

Calculate the LPD for the dwelling units based on site assessment data. Input the LPD (W/sf) in the *Zone level* element, under the *Lighting* tab, as the *User Input LPD* under Proposed Lighting. Using the schedule in Figure 4, create and assign the dwelling unit lighting schedule with 3.5 effective full load hours per day.

Hour	Value	Hour	Value
1	0.19	14	0.00
2	0.00	14	0.00
3	0.00	15	0.00
4	0.00	16	0.00
5	0.00	17	0.00
6	0.00	18	0.00
7	0.13	19	0.00
8	0.31	20	0.56
9	0.00	21	0.56
10	0.00	22	0.56
11	0.00	23	0.50

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12	0.00	24	0.38
Hours Per Day		3.50	
Hours Per Year		1,278	

Figure 14: Hourly Values for Daily Schedule Equivalent

Conditioned Common Area Lighting

Use assessment data to calculate the LPD for the common areas. Input the LPD (W/sf) in the *Zone level* element, under the *Lighting* tab, as the *User Input LPD* under Proposed Lighting. Create and assign the lighting schedule as verified on site.

Unconditioned Common Area Lighting

Calculate the total lighting wattage in the unconditioned common area and input lighting wattage on the *Exterior Uses* tab. Create and assign the lighting schedule as verified on site.

Exterior Building and Site Lighting

Exterior and site lighting consist of lighting fixtures both mounted on the building and unattached to the residential building. Calculate the total lighting wattage and input totals into the *Exterior Uses* tab. Create and assign the lighting schedules as verified on site.

Low-rise Multifamily Appliances

For low-rise multifamily buildings, input the appliance information on the *HERS* tab based on the onsite sampling plan. To calculate and enter these values at a building level, average sampling results and use these inputs for all residential buildings on the property. Sampling should provide a good representation of existing equipment on a property level. When using the *HERS* tab, it is not necessary to calculate or report dishwasher and clothes washer hot water usage in the end uses.

Refrigerators

It is likely that projects will contain multiple refrigerator types with different average annual unit energy consumption (UEC) values (kWh/yr). The refrigerator value input in the *HERS* tab requires calculation of the average UEC.

Figure 15 presents an example method to track and calculate the average UEC for the surveyed refrigerators. The average UEC for the refrigerators in this example is 458 kWh per year; this is the input value for the *HERS* tab. HVAC, domestic hot water, and other efficiencies may also require this type of average UEC calculation. If the UEC values are not available from the nameplate, manufacturer's website, or approved industry website (see section 0 [Existing Conditions and Default Values](#)), modelers may use the programs multifamily default value of 465 kWh/yr for refrigerators.

Sampled Unit	Manufacturer	Model #	UEC
Bldg. 1, unit A	GE	GTS18CBSARWW	480
Bldg. 2, unit D	Whirlpool	ET8WTEXVQ01	388
Bldg. 3, unit B	GE	GTS18CBSARWW	482

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Bldg. 4, unit C	Magic Chef	CTB1821ARW	480
Average			458

Figure 15: Example Average Refrigerator Calculation

Dishwashers

Model all low-rise residential projects with a dishwasher using the average of all dishwashers assessed in the sampling plan. If dishwashers do not exist in the building, use the default dishwasher energy factor of 0.46. Post-retrofit models must account for any dishwasher additions.

Clothes Washer and Dryer

There are different modeling approaches for washers and dryers:

1. No washer and dryer: input *none* on *HERS* tab
2. **No** replacement of washer and dryer in dwelling units: input location on *HERS* tab
3. Washer and dryer replacement in dwelling units: model according to section 0
4. Washer and dryer in common areas: model according to section 0

The HERS Technical Reference Manual calculates clothes washer and dryer energy use based on dwelling unit square footage and does not account for equipment efficiency or clothes washer hot water consumption. To claim energy savings for efficient clothes washers located in dwelling units or common areas, follow the approach in section 0.

Pools and Spas: Low-rise

Model pools and spas according to these best practices:

1. If a property with multiple buildings has a pool, model the pool in the largest building.
2. Always select the *solar or not heated* pool type to isolate pool pumping energy from pool heating loads (even if the pool has gas heating). The model requires input of actual pool volume. A tool for calculating pool volume is available at www.pentairpool.com/pool-pro/dealer-resources/calculators/pool-volume-calc/poolcalc.htm.
3. Filter upgrades are not currently an eligible upgrade in the program. To avoid crediting or penalizing projects for filter changes, set the filter type to the proposed filter type. Input actual suction and return pipe diameters in accordance with measurements from the site assessment.
4. Set the pump type at *single speed* or *two speed*, depending on site conditions. The rated power input should match the rated horsepower, not the horsepower with service factor. The number of pumps should be the same between the base case and proposed case. Set values so that the turns per day are equal in existing and proposed conditions, and comply with applicable local health department requirements.

High-rise Multifamily Appliances

To model annual appliance energy use in high-rise projects, convert appliance energy use to watts per square foot (W/sf) value and input under the Receptacle/Process tab as a Sensible Heat value under Process Equipment. *Figure 16* provides the W/sq ft. sums for the appliances. Model major appliances located in unconditioned spaces in the *Exterior Uses* tab.

This approach is partially based on the appliance calculations implemented for HERS Whole House analysis using the HERS Technical Manual for assumptions and default values. The HERS Technical Manual calculates annual energy use for major appliances without applying an hourly schedule. When using the Non-Res Performance module, this workaround requires an hourly schedule.

Appliance	W/SF
Refrigerator	0.572
Dishwasher	0.016
Total	0.588

Figure 16: Appliance EPD Summary

Next, assign a schedule created for 2,000 annual effective load hours (EFLH) that mimics a residential appliance load profile to convert the W/sf to annual energy use (kWh). A schedule with 2,000 EFLHs lends simplicity and because actual operating patterns are difficult to verify without monitoring, accurate hourly profiles of usage are not needed. Figure 17 shows the hourly values for the daily schedule equivalent to 2,000 annual hours. The ASHRAE 90.1 Multifamily Receptacle schedule is the basis for the input into EnergyPro.

Hour	Value	Hour	Value
1	0.16	14	0.21
2	0.11	14	0.21
3	0.11	15	0.21
4	0.11	16	0.21
5	0.11	17	0.26
6	0.11	18	0.11
7	0.11	19	0.47
8	0.42	20	0.47
9	0.42	21	0.37
10	0.21	22	0.26
11	0.21	23	0.25
12	0.21	24	0.16
Hours Per Day		5.48	
Hours Per Year		2,000	

Figure 17: Hourly Values for Daily Schedule Equivalent

Refrigerators

The first step to calculate the Watt/sf input for high-rise refrigerators is to determine the total annual refrigerator energy use as verified through one of the program-approved appliance databases or through watt meter measurements of sampled units. The second step is to convert the total annual

energy use (kWh) to demand (kW) by dividing the total kWh by assumed hours of operation of 2,000 hours. Next, convert kW to Watts by multiplying the kW by 1,000. Then, divide total wattage for the refrigerators by the total square footage of all the dwelling units.

Example

A multifamily building has 198 dwelling units, each with a refrigerator rated at 550 kWh/yr. The total square footage of the dwelling units is 95,190. Calculate the W/sf as a process load in the dwelling unit spaces:

1. Calculate the total refrigerator kWh/yr for sampled refrigerators
 - a. $198 \text{ refrigerators} \times 550 \text{ kWh/yr} = 108,900 \text{ kWh/yr}$
2. Convert to kilowatts by dividing by assumed 2,000 hours per year
 - a. $108,900 \text{ kWh-yr} / 2,000 \text{ hours} = 54.450 \text{ kW}$
3. Convert to Watts
 - a. $54.450 \text{ kW} \times 1,000 \text{ W/kW} = 54,450 \text{ Watts}$
4. Calculate W/sf
 - a. $54,450 \text{ Watts} / 95,190 \text{ sf} = 0.572 \text{ W/sf}$

Figure 18 is a screenshot of a spreadsheet tool that automates the calculations based on sampled refrigerator UECs. Please request this from the program manager if you wish to use this on your projects.

Project Name	Sample		Existing			Proposed		
# Dwelling Units	198		Average kWh/unit-yr	550		Average kWh/unit-yr	312	
Total Dwelling Unit Area	95190		Total kwh/yr	108900		Total kwh/yr	61776	
Annual Hours	2000		Watts	54450		Watts	30888	
			W/SF	0.572		W/SF	0.324	
Floor	Dwelling Unit	Unit Type	Existing Refrig Type	Refrig m/n	kWh/unit	Refrig Type	Refrig m/n	kWh/unit
14th	1415	C	Sanyo		550	Sanyo		312
	1408	A	Frostman		550	Frostman		312
	1407	A	Frostman		550	Frostman		312
	1403	A	Sanyo		550	Sanyo		312
	1402	B	Sanyo		550	Sanyo		312
12th	1206	A	Kenmore		550	Kenmore		312
	1205	A	Kenmore		550	Kenmore		312
	1202	B	Sanyo		550	Sanyo		312
10th	1015	C	Sanyo		550	Sanyo		312
	1001	B	Sanyo		550	Sanyo		312
8th	812	A	Sanyo		550	Sanyo		312
	811	A	Frostman		550	Frostman		312
	810	A	Absocold		550	Absocold		312
	809	A	Absocold		550	Absocold		312
	806	A	Sanyo		550	Sanyo		312
	805	A	Absocold		550	Absocold		312
	803	A	Sanyo		550	Sanyo		312
	801	B	Sanyo		550	Sanyo		312
4th	411	A	Sanyo		550	Sanyo		312
	407	A	Sanyo		550	Sanyo		312
	405	A	Sanyo		550	Sanyo		312
	402	B	Sanyo		550	Sanyo		312
	401	B	Frostman		550	Frostman		312
3rd	309	A	Kenmore		550	Kenmore		312
	306	A	Frostman		550	Frostman		312
	304	A	Sanyo		550	Sanyo		312
	303	A	Sanyo		550	Sanyo		312
	302	B	Sanyo		550	Sanyo		312
1st	103	D	Sanyo		550	Sanyo		312

Figure 18: Sample Refrigerator Calculation Spreadsheet

Dishwashers

The equation² in Figure 19 calculates the annual dishwasher electricity use for each dwelling unit.

$$\text{Annual Electricity} = 0.27 \times \frac{\text{Cycles/year}}{\text{EnergyFactor}}$$

Figure 19: Annual Energy Use of Dishwashers

Where:

1. Energy Factor = verified energy factor of dishwasher obtained from the nameplate data, EnergyGuide label, CEC appliance database, or EPA ENERGYSTAR database

² CEC-400-2008-012-CMF HERS Technical Manual

2. Cycles/year = number of cycles per year for the dishwasher is based on HERS Technical Manual default values. The cycles per year corresponds with the number of occupants per dwelling unit, as shown in *Figure 20*.

Dwelling Unit Type	Occupants	Number of cycles
studio and 1-bedroom units	2	154
2-bedroom and 3-bedroom units	3	214

Figure 20: Table of Dishwasher Cycle Assumptions

After the modeler has calculated the annual energy use for dishwashers for all dwelling units, the modeler converts the kWh to kW, and then to W/sf using the same process as refrigerators.

Example

An apartment building has 20 1-bedroom units and 10 2-bedroom units. Each dwelling unit has a dishwasher with verified 0.46 energy factor. Calculate the annual energy use.

1. Calculate total number of cycles
 - a. $(20 \text{ one-bed units} \times 154 \text{ cycles}) + (10 \text{ two-bed units} \times 214 \text{ cycles}) = 5,220 \text{ cycles}$
2. Calculate total dishwasher annual energy use

$$\text{Annual Electricity} = 0.27 \times \frac{5,220}{0.46} = 3,063 \text{ kWh}$$

3. Convert to kilowatts by dividing kWh by assumed 2,000 hours per year
 - a. $3,063 \text{ kWh-yr.} / 2,000 \text{ hours per year} = 1.532 \text{ kW}$
4. Convert to Watts
 - a. $1.532 \text{ kW} \times 1,000 \text{ W/kW} = 1,532 \text{ Watts}$
5. Calculate W/sf
 - a. $1,532 \text{ Watts} / 95,190 \text{ sf} = 0.0161 \text{ W/sf}$

Clothes Washers and Dryers: High-rise and Common Areas

The HERS Technical Reference Manual bases clothes washer and dryer energy use calculations on dwelling unit square footage and does not account for equipment efficiency. To claim savings for efficient clothes washers located in dwelling units or common areas, use side calculations and existing data sources (primarily utility Work Papers) to estimate the energy and hot water use for the existing and proposed clothes washers and dryers. The utility EnergyStar Clothes Washers work papers include sources from the Department of Energy (DOE) division of Energy Efficiency and Renewable Energy (EERE)³.

The tables below are from the utility Work Papers and show the energy use per cycle for top loading and front loading clothes washers; efficiencies range from meeting 2007 federal minimum modified energy

³ EnergyStar Clothes Washers Work Paper SCE13AP003, PGECOAPP120

factor (MEF) requirements to high-efficiency EnergyStar certified machines. The MEF rating communicates overall efficiency; higher MEF equipment is more efficient. The MEF accounts for the energy use of the clothes washing machine motor, water heating for hot cycles, and dryer energy. These approaches assume that the machines use electric dryers and water heaters.

Top Loading Standard Capacity Clothes Washers				
MEF	Volume (ft ³)	Energy Use (kWh/cycle)		
		<i>Clothes Washer</i>	<i>Dryer</i>	<i>Water Heating</i>
1.26	3.09	0.279	2.16	1.24
1.40	3.38	0.281	2.43	0.74
1.72	3.38	0.228	1.69	0.69
1.80	3.76	0.082	1.41	1.26
2.00	3.86	0.082	1.38	0.99
2.26	3.96	0.077	1.41	0.67
2.47	4.34	0.082	1.39	0.66

Figure 21: Energy Use per Cycle by MEF - Top Loading clothes Washers

Front Loading Standard Capacity Clothes Washers				
MEF	Volume (ft ³)	Energy Use (kWh/cycle)		
		<i>Clothes Washer</i>	<i>Dryer</i>	<i>Water Heating</i>
1.72	3.00	0.113	1.31	0.70
1.80	3.00	0.113	1.31	0.60
2.00	3.30	0.163	1.42	0.40
2.20	3.41	0.154	1.34	0.36
2.40	3.60	0.164	1.41	0.20
2.60	3.83	0.167	1.37	0.21
2.89	3.90	0.155	1.38	0.04

Figure 22: Energy Use per Cycle by MEF – Front Loading clothes Washers

Use Figure 22 to correlate the equipment’s rated MEF with energy use per cycle for the existing and proposed equipment. If no source for existing equipment MEF is available, the default MEF value is 1.26, which is the 2007 federal minimum requirement. If the DHW and dryers use natural gas, the modeler shall convert the usage to therms.

To calculate annual energy use, multiply the energy use per cycle by the number of cycles per year. Use 295 cycles per year for clothes washers located in the dwelling unit and 1,241 cycles per year for clothes

washer located in common areas⁴. The number of cycles per year must be identical in the existing and proposed calculations.

Next, convert the annual energy use to demand. Input the natural gas demand on the *Exterior Use* tab. Input electric demand on the *Room* tab if located in conditioned space, or on the *Exterior Uses* tab if washers are in an unconditioned space. Assign the 2,000 EFLH annual operating schedule to these loads.

Example

An apartment building has four top-loading clothes washers and four dryers located in an unconditioned common area. The EnergyGuide label indicates the MEF is 1.40. The dryer is electric and the DHW is a natural gas system. Calculate the energy use for input into EnergyPro.

1. Determine the energy use per cycle from applicable look-up table.
 - a. Clothes washer $1.40 = 0.281$ kWh/ cycle
 - b. Dryer = 2.43 kWh/cycle
 - c. DHW = 0.74 kWh/cycle X 0.03412 therms/kWh = 0.0252 therms per cycle
2. Calculate total energy use for each fuel type based on quantity of machines and cycles per year.
 - a. Electricity: $[(4 \text{ clothes washers} \times 0.281 \text{ kWh per cycle}) + (4 \text{ dryers} \times 2.43 \text{ kWh per cycle})] \times 1,241 \text{ cycles per year} = 13,457 \text{ kWh}$
 - b. Natural gas: $(4 \text{ Clothes washers} \times 0.0252 \text{ therms cycle}) \times 1,241 \text{ cycles per year} = 125 \text{ therms}$
3. Convert kWh to Watts and therms to Btu/hour for input into EnergyPro *Exterior Use* since these are located in unconditioned common areas (if they were in each dwelling unit in a high-rise building, the electric demand values below would be converted to a W/sf and added to the total appliance load along with refrigerators and dishwashers)
 - a. $13,457 \text{ kWh per year} \times 1,000 \text{ W per kWh} / 2,000 \text{ hours per year} = 6,728 \text{ Watts}$
 - b. $125 \text{ therms} \times 100,000 \text{ Btu per therm} / 2,000 \text{ hours per year} = 6,250 \text{ Btu/hr.}$

⁴ Southern California Edison Work Paper SCE13AP003, which references DOE TSD 2012, Ch 7 page 7-6

5. BUILDING ENVELOPE AND ZONE CHARACTERISTICS

This chapter covers inputs for the building envelope, zone, and room at the zone level. Differences between low-rise and high-rise are outlined below.

Energy Pro Zone and Room Inputs

Inputs covered in this section include the thermal zone, room occupancy, and load assumptions. Additional inputs for high-rise residential include interior lighting and exhaust fans.

Zone Element Details

Based on zoning configuration identified during the energy assessment and post-processing of the data, create a *zone* in EnergyPro for each thermal zone. Input basic information about the zone and the *room* that the user will add after describing the zone details.

General Tab

Input zone type and occupancy on the *General* tab of the *Zone* element in EnergyPro according to the following:

1. Low-rise: the zone type is *conditioned* and occupancy is *multifamily*. Model conditioned common areas as *multifamily occupancy*, as opposed to *corridor* or *office*.
2. High-rise: the occupancy type of the dwelling units is *high-rise residential*. Model common areas according to the actual occupancy type (e.g. hallway, office, community room laundry).

It is important to note that models including *multifamily residential* occupancies **cannot** include *non-residential* occupancies, and vice versa. Because the Res Performance and Non-Res Performance modules of EnergyPro use different simulation engines, EnergyPro will crash if a .bld file includes both *residential* and *non-residential* occupancies.

Lighting Tab

1. Low-rise: Do not use the lighting tab for low-rise buildings unless using the Non-Res module per program requirements. Calculations for low-rise buildings reference the HERS tab.
2. High-rise: Input the LPD (W/sf) in the *Zone level* element, under the Lighting tab, as the *User Input LPD* for Proposed Lighting.

Mechanical Tab

Most multifamily buildings do not make use of the *Mechanical* tab. HVAC systems serving large common areas in high-rise multifamily buildings may need to use this tab.

Schedules Tab

1. Low-rise: Low-rise multifamily projects never use the *Schedules* tab since all residential modules use the Title 24 default schedules for low-rise multifamily, which cannot be adjusted.
2. High-rise: For areas of high use, such as hallway lighting that is always on, use the Schedules tab to select operating schedules from Title 24 defaults. Modified operating schedules require justification through utility bill analysis or field data monitoring.

Room Element Details

After inputting the zone, proceed to create a room and input the room characteristics as determined during the energy assessment and post-processing of data.

General Tab

Input the square feet, ceiling height, year built, and whether the room is existing or new.

Occupant Tab

Define the internal occupant load assumptions and ventilation rates on the *Occupant* tab.

1. Low-rise: Input the number of bedrooms and kitchens. This affects ventilation energy calculations.
2. High-rise: Confirm occupancy density, occupancy sensible and latent heat gain, and ventilation rates in the non-residential occupancy inputs. Use global replacement (Ctrl-H) for load assumptions as an easy shortcut. This will ensure correct non-residential occupancy inputs for the selected occupancy.

Receptacle/Process Tab

1. Low-rise: Do not make changes to this tab. The Res module assumes a fixed amount of miscellaneous loads for computers and other plug loads.
2. High-rise: The *Receptacle/Process* tab is used to model high-rise residential equipment described previously in the [High-rise Multifamily Appliances](#) section.

Domestic Hot Water Tab

Existing low-rise and high-rise multifamily building models do not use the *Domestic Hot Water* tab.

Exhaust Fan Tab

Only use the *Exhaust Fan* tab to input continuously operating exhaust fans in high-rise residential buildings. Do not model exhaust fans with switch controls because the program assumes 24/7 operation.

Lighting Tab

Do not use the Lighting tab for program project submittals.

Exterior Surface Inputs

Add exterior surfaces to each defined *Room* element, and include any raised floors, slab on grade floors, walls, roofs, and windows. Input gross areas for all exterior surfaces.

When labeling exterior walls it is helpful to label by *Front*, *Back*, *Right*, and *Left* instead of orientation. This is useful if you are creating a mirror image or applying rotation to models using the same base model.

A number of construction assemblies have minor distinctions that may not be easy to identify. This section covers some of the nuances of various construction assemblies that you will encounter in EnergyPro.

Default Values

Verification of construction assemblies in an unobtrusive manner may be difficult in existing buildings, and the building owner may not readily allow verification activities on-site. In these cases, use default construction assembly u-values from Table R3-50 of the 2016 Residential Compliance Manual.

Attic and Cathedral Roofs

To identify attic or cathedral ceilings, use the following criteria:

1. **Attic:** an attic roof includes a ventilated space that is greater than six inches above the insulation and below the roof.
2. **Cathedral:** a cathedral roof is any roof that has less than six inches of air space between the insulation and the roof deck.

Raised Floors

Raised floors include floors with a vented crawlspace or without a crawlspace. CEC ruling is that if the crawlspace is ventilated, the construction is considered *raised floor with crawlspace*. Anything else is considered *floor—no crawl space*.

If a raised floor is over a garage or unconditioned basement, model it as a *floor—no crawlspace* because the temperature in the space is at an intermediate condition.

Document your floor selection for ease of assessment review/quality assurance check.

Slab on Grade Floors

Slab on grade floors require inputs for floor area, perimeter length, construction assembly, and whether the slab is new or existing. Always model the slab on grade perimeter. Exterior perimeter of the slab is any slab edge that is along the outside of the slab. Select the *unheated slab construction assembly* for slabs, except those with radiant heating elements in the slab. In that case, select the heated slab on grade assembly.

Underground floor is the slab floor of a basement that is below grade. *Underground wall* is a basement wall or other wall in contact with the soil.

Exterior Walls

Exterior wall inputs require the wall area, surface type, construction assembly, orientation, and tilt. It is acceptable to group wall areas with the same orientation as described in Section 0. Wall construction assemblies found in existing multifamily buildings are typically available in the EnergyPro assembly library.

Shaded Walls

Some walls are completely shaded, yet exposed to ambient conditions. An example is an exterior wall of a dwelling unit adjacent to an unconditioned corridor. The corridor has openings that result in a corridor temperature similar to the outdoors, but with a roof that eliminates any solar heat gains.

To model this scenario, create a new wall assembly and change the aged solar reflectance to 1.0. This will simulate a wall that reflects 100 percent of solar gains. Aged solar reflectance is a dimensionless quantity ranging from 0.0 (absorbs all solar radiation) to 1.0 (absorbs no solar radiation). An assembly set to 1.0 results in its surface having no solar gain.

Windows and Overhangs

Window inputs require the area, surface type, and construction assembly. For the majority of projects, it is preferable to aggregate window area on a wall in the same zone when all windows have the same u-value, SHGC, and shading characteristics. Separate windows to account for shading, such as overhangs or side fins, or to account for different types of windows (U-values and SHGC).

Window Assemblies

The U-value and SHGC are the most important aspects to consider when selecting a window construction assembly. There are three choices to select from: Default, Center of Glass, and NFRC Rating.

1. When selecting default values, the modeler must also select the appropriate fenestration properties as these affect the default U-value and SHGC values. It is necessary to create a different window assembly for fixed and operable windows when using the default values.
2. Use center of glass values for site built windows used in high-rise buildings. These values exclude the properties of the window frame.
3. When available, use NFRC labels to describe the windows. The fenestration properties do not need adjustment when selecting NFRC labeled windows. If the modeler chooses NFRC labeled, the NFRC label must be part of the project submittal.

Overhangs, Side-fins, and Other Exterior Shading

Model **only** the shading that is permanently attached to the building. Do not use a tree or a neighboring building in the model as shading. The program requires users to model overhangs that extend at least one foot out over the window.

6. DOMESTIC HOT WATER (DHW)

All multifamily buildings will have a domestic hot water (DHW) system to model. The DHW equipment can be individual DHW units per dwelling unit, central DHW systems serving all dwelling units, or a combination of both. The modeler will input the DHW system characteristics into EnergyPro on the *Domestic Hot Water* tab of the *Plant* element.

Equipment Efficiency Determination

Raters or modelers can use the following directories to obtain efficiency values: manufacturer specifications, EnergyPro library, Energy Commission Appliance Directory, AHRI online Directory of Certified Product Performance, or Title 24 default vintage tables. If a rater cannot verify DHW equipment efficiency, use table R3-50 of the 2016 Residential Compliance Manual for default values.

The program does not generally permit de-rating of equipment nameplate or default. The program may only consider de-rating if the equipment has been field tested and the actual operating efficiency has been verified, or actual utility billing data suggests lower operating efficiency.

Domestic Hot Water Inputs

The DHW boiler equipment, circulation pump, and hydronic piping are inputs on the *Domestic Hot Water* tab.

DHW Boiler

Small storage water heaters and large storage water heaters are typically not considered boilers, but in this section and in EnergyPro, the term boiler is interchangeable with the term water heater.

The input rating of a gas-fired boiler defines whether it is a small or large boiler. Gas-fired boilers with an input rating of 75,001 Btu/hr. and greater are large capacity boilers. Gas-fired boilers with an input rating of 75,000 Btu/hr. and less are small capacity water heaters.

Required EnergyPro inputs for small storage gas-fired DHW boilers include:

1. Storage tank volume
2. Fuel input rating
3. Energy factor
4. Recovery efficiency

The energy factor rating accounts for combustion efficiency and standby loss. There is currently no method to model additional external tank insulation for small capacity boilers.

Required EnergyPro inputs for large storage gas-fired DHW boilers include:

1. Storage tank volume
2. Fuel input rating
3. Recovery efficiency
4. Standby loss

Standby loss is the percentage of heat (energy) lost per hour of operation due to radiation from the storage tank. Standby loss is a measure of equipment efficiency that applies only to the larger capacity boilers. Additional tank insulation or an increase in combustion efficiency, which lowers the waste heat leaving the flue vent, can reduce the standby loss effect. To calculate the standby loss, consult the AHRI Directory for your water heater or boiler:

- ◆ Retrieve model number, manufacturer name for all DHW equipment in your project
- ◆ Go online to ahridirectory.org
- ◆ Find the AHRI certificate of your model. The AHRI certificate will list the input (BTU/hr.) and the standby loss (BTU/hr.)
- ◆ To convert this to a number that Energy Pro can use, divide the standby loss by the Input rating.

Example

- ◆ Input 90,000 BTU/hr., Standby Loss 1530 BTU/hr. Energy Pro input = 0.017 (1.7 percent = 1530 / 90,000).

New AHRI rated large storage water heaters may also list the standby loss as a percentage in addition to the hourly loss in Btu/hr. Calculations for this percentage metric differ from the standby loss listed as Btu/hr., and should not be used as an EnergyPro input. The standby loss for the existing and proposed equipment must be the calculated value described in the above example. Large capacity boilers without a verifiable recovery efficiency or standby loss should use 0.76 recovery efficiency and a standby loss of 2.0 percent. Input the standby loss in decimal format (e.g. 0.025).

Required EnergyPro inputs for electric resistance includes:

1. Storage tank volume
2. Input rating
3. Energy factor
4. Recovery efficiency

The modeler will need to convert the input wattage to Btu/hr.

Example

4,500 Watts = 15,359 Btu/hr. (4,500 Watts x 3.413 Btu/hr.)

All indirect gas-fired boilers with separate storage tanks are considered large capacity boilers. Steam boilers are considered indirect gas-fired boilers. Required EnergyPro inputs for all indirect gas-fired boilers include:

1. Storage tank volume
2. Input rating
3. Recovery efficiency
4. Pilot loss
5. Storage tank external insulation

The Energy Commission appliance database or manufacturer specifications should include pilot loss values. If pilot loss is not available from either data source use 750 Btu/hr. as the pilot loss input for indirect fired boilers.

The storage tank external insulation input in EnergyPro assumes a minimum of R-12 external insulation on indirect fired boiler tanks based on Title 24 Part 6 ACM. If there is more insulation, input the higher figure.

MF Individual System per Unit

If each unit has its own DHW system, indicate the number of systems in that building in the *Multiplier* input. The modeler use the average values of units sampled as inputs in the energy model.

MF Central DHW Pump and Piping

If the DHW system serves more than six dwelling units, check the *multifamily central systems* box if the system is central. Input the recirculation pump and piping characteristics for multifamily central DHW systems.

Recirculation pumps: Input the recirculation pump motor horsepower and quantity of pumps. The nameplate provides the horsepower. Typically these are small pumps rated in Watts and will require conversion to horsepower using the following calculation.

$$\text{HP}_{\text{pump}} = \text{Watts}_{\text{pump}} / 746 \text{ Watts per HP}$$

Example $\text{HP}_{\text{pump}} = 50\text{W}_{\text{pump}} / 746 \text{ Watts per HP} = 0.067 \text{ HP}$

Recirculation pump controls: The energy modeler should choose the recirculation pump control for the central multifamily DHW system. Existing systems commonly run continuously or use a timer. The control options for multifamily central DHW recirculation pump include:

1. **None**: runs continuously (24/7)
2. **Timer**: time clock that turns on/off during normal use times
3. **Demand**: water heating turns on based on hot water demand
4. **Temperature**: uses a temperature sensor in the loop—when the temperature drops below a certain temperature the pump will turn on to recirculate the water
5. **Timer-temperature**: combination of a timer and temperature system

Distribution piping: The energy modeler will input the linear feet of DHW distribution piping located outside, underground, and in plenums. A DHW system serving multiple buildings on the property will likely have underground piping. Measure this length using site plans or estimate the length during the site assessment. If there is an existing recirculation pump on the central system, count only the supply length of the pipe.

Residential Distribution

Residential distribution refers to in-unit piping for individual DHW systems and systems serving fewer than seven dwelling units. The default in EnergyPro is *Kitchen Pipe Insulation*, defined as a distribution system without any pumps for distributing hot water and in which the first five feet of both hot and cold water piping from the storage tank has insulation and piping from the water heater to the kitchen has insulation. Table 5-1 of the 2008 Residential Compliance Manual, below, outlines other distribution system descriptor options the modeler can use.

Distribution Systems	Description
Standard (STD)	Standard system without any pumps for distributing hot water. The first 5 ft of pipes from the storage tank is insulated for both hot and cold water pipes. Pipes from the water heater to the kitchen must be insulated per §150(j).
Pipe Insulation (PIA)	All hot water pipes are insulated per the requirements of §150(j).
Standard Pipes with no Insulation (SNI)	Standard distribution system (STD) with no pipe insulation on lines to the kitchen.
Point of Use (POU)	System with no more than 8 ft horizontal distance between the water heater and hot water fixtures, except laundry.
Parallel Piping (PP)	Individual pipes radiate from a manifold near the water heater to each of the fixtures.
Uninsulated Pipe Below Grade (UPBG)	Piping installed below grade (outside of conditioned space) with no insulation.
Insulated and Protected Pipe Below Grade (IPBG)	Piping installed below grade (outside of conditioned space) with insulation and a protective covering.
Recirculation No Control (RNC)	Distribution system using a pump to recirculate hot water through a hot water loop that serves the individual use points. Pump operation and water flow are continuous. Pipe insulation is required per §150(j).
Recirculation with Timer Control (RTm)	Recirculation system that uses a timer control to control pump operation based on time of day. Pipe insulation is required per §150(j).
Recirculation with Temperature Control (RTmp)	Recirculation system that uses a remote temperature sensor attached to the hot water return line to cycle pump operation to maintain water temperatures within certain limits. Pipe insulation is required per §150(j).
Recirculation with Timer and Temperature Control (RTmTmp)	Recirculation system that uses both temperature and timer controls to regulate pump operation. Pipe insulation is required per §150(j).
Recirculation with Manual Demand Control (RDmc)	Recirculation system that uses brief pump operation to recirculate hot water to fixtures when a demand for hot water is initiated with push button control activation. Pipe insulation is required per §150(j).
Recirculation with Motion Sensor Demand Control (RDmc)	Recirculation system that uses brief pump operation to recirculate hot water to fixtures when a demand for hot water is initiated with motion sensor control activation. Pipe insulation is required per §150(j).
Temperature Buffering Tank (TBT)	A distribution system with a small storage electric water heater installed in the distribution system.

Figure 23: 2008 Residential Compliance Manual Table 5-1

Combined Hydronic Piping

The *Combined Hydronic Piping* section of the *Domestic Hot Water* tab details space heating distribution characteristics. This section only applies to boilers that provide both domestic hot water and space heating. Input characteristics include:

1. Length
2. Diameter
3. Insulation thickness of space heating piping in unconditioned space. This input applies to piping serving less than seven dwelling units.

MF Central DHW Serving Multiple Buildings

Many multifamily properties have one or more boilers that provide hot water for space heating or domestic hot water to multiple buildings. Programs that require a separate energy model for each building should model the DHW equipment proportionate to each building based on the number of dwelling units.

To model a central DHW that serves multiple buildings, create an adjusted DHW system for each building. System inputs should reflect the DHW being directed to each particular building based on the number of dwelling units. Consider the following aspects when performing these calculations.

1. Only use the input rating for setting the efficiency rating metric of the boiler or DHW unit. If the boiler is a large capacity boiler, e.g., greater than 75,000 Btu/hr., the input rating on the adjusted Btu/hr. must stay above 75,000. Otherwise the unit of measure will be incorrect since the input requires thermal efficiency for large capacity storage water heaters, not energy factor.
2. The hourly tank jacket heat loss calculation depends on tank size; input the storage capacity needs based on the number of dwelling units. The summation of the adjusted tanks size must equal the total tank size.
3. Input the pumps based on the number of dwelling units.
4. Input underground piping as actual; some buildings may have longer lengths of piping than others, but the modeler may input an average value.

Example

One large capacity DHW unit provides domestic hot water to 4 buildings that have a combined 24 dwelling units. *Figure 24* below provides the specifications. Buildings 1, 7, and 13 each have 4 dwelling units, or 17 percent of the total. Building 6 has 50 percent of the dwelling units. Apply these percentages to the actual DHW system to calculate the adjusted storage capacity and adjusted pump horsepower. Input the values into EnergyPro.

Note that the input rating for the 4-unit buildings would drop below 75,000 Btu/hour if the modeler adjusted the input rating based on dwelling units. Since the actual equipment is a large capacity water heater, the input capacity on the modeled water heater needs to be at least 75,001 Btu/hr. Even though the calculated inputs would be 45,833, input the adjusted DHW unit for each building in this example as 75,001 Btu/hr., except for building 6.

MF Central DHW

Input Capacity (Btu/hr)	275,000
Storage Capacity (gallons)	100
Pump HP	0.13
Thermal Efficiency	80%

Building	No. of Dwelling Units	% of Total	Adjusted Gallons	Adjusted HP	Calculated Adjusted Input (btu/hr)	EnergyPro Input (btw/hr)
1	4	17%	17	0.02	45,833	75,001
6	12	50%	50	0.07	137,500	137,500
7	4	17%	17	0.02	45,833	75,001
13	4	17%	17	0.02	45,833	75,001

Figure 24: Example Proration of MF Central DHW Systems Serving Multiple Buildings

Renewable Energy Inputs

Use this tab only if there is working existing equipment on the building.

7. CENTRAL PLANT

A central plant system refers to an HVAC system that comprises multiple pieces of equipment: heating boilers, cooling equipment (chillers), heat rejection equipment (cooling towers), indoor terminal units for the dwelling units (fan coil systems), and the pumping and distribution systems. In comparison, a typical distributed HVAC system for multifamily buildings uses individual HVAC systems such as forced air or wall furnaces for heating and packaged terminal air conditioners for cooling in each dwelling unit.

Some multifamily buildings also use components of a central plant for heating and cooling. Central hydronic space heating systems are common in low-rise and high-rise multifamily buildings. Many multifamily buildings in California use water loop heat pumps; models for these projects will require cooling tower, boiler, pumps, and system control inputs. Occasionally, high-rise multifamily buildings use fan coil units with central hot water and chilled water.

The following graphic shows some typical central system components.

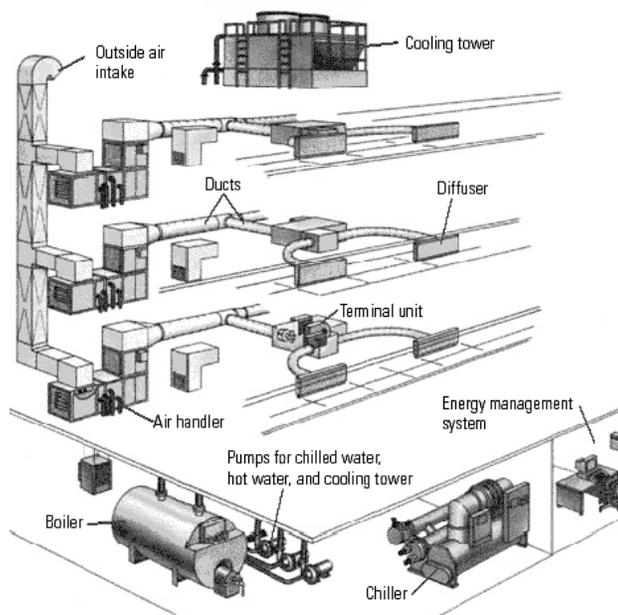


Figure 25: Central DHW System Components

There are input tabs on the EnergyPro *Plant* element for hot water, chilled water, hydronic components, domestic hot water system, combined hydronic/DHW systems, and one for renewable energy and exceptional measures.

Equipment Efficiency Determination

The input rating of a gas-fired boiler determines whether it is a small or large boiler. Classify gas-fired boilers with an input rating of 75,001 Btu/hr. and greater as large capacity and those with an input rating of 75,000 Btu/hr. and less as small capacity. Both small capacity and large capacity boilers require the storage tank volume and input rating.

Large capacity boilers also require recovery efficiency and standby loss inputs. Large capacity boilers without a verifiable recovery efficiency or standby loss should use 0.76 recovery efficiency and a standby loss of 2.0 percent. Input standby loss in decimal format (e.g., 0.025).

Small capacity boilers require the energy factor input.

Heating Hot Water Inputs

To input the boiler and distribution characteristics of central space heating systems on the *Heating Hot Water* tab, use a central hot water boiler that circulates hot water to terminal units located in the dwelling units. Examples of multifamily building central hot water heating system types include radiant baseboards and fan coil units. Inputs for the *Heating Hot Water* tab are:

1. Primary boiler equipment
2. Hot water pump
3. Hydronic piping

Hot Water Boiler

Boilers for hot water space heating systems are either gas-fired or indirect-fired boilers. Gas-fired boilers do not have a storage tank. They provide hot water instantaneously upon demand and are more commonly used as space heating boilers. The image below shows an indirect fired boiler system.

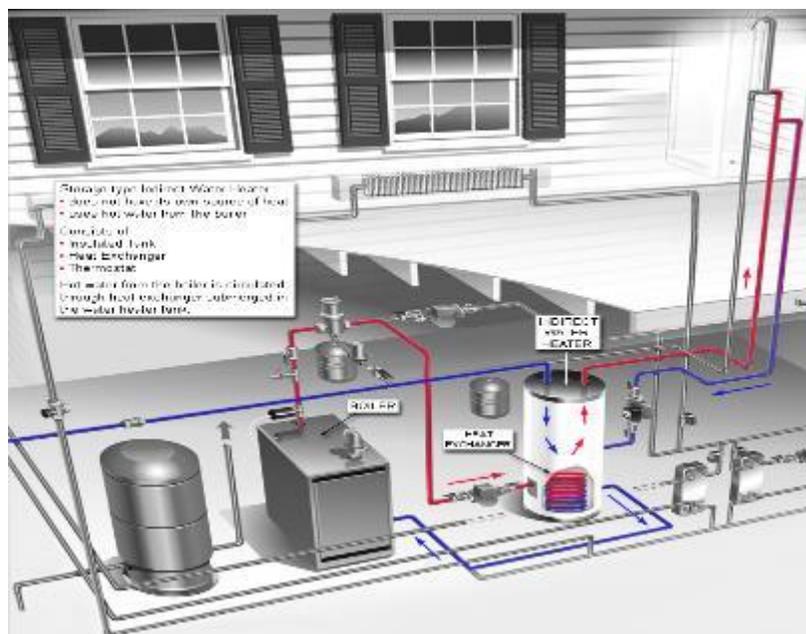


Figure 26: Diagram of Indirect Fired Boiler System

Classify all indirect gas-fired boilers as large capacity boilers. Model steam boilers as indirect gas-fired boilers.

Inputs for all indirect gas-fired boilers include:

1. Storage tank volume
2. Input rating
3. Recovery efficiency
4. Pilot loss
5. Storage tank external insulation

One can obtain boiler pilot loss from the Energy Commission appliance database or manufacturer specifications. If boiler pilot loss is not available from either data source, use 750 Btu/hr. as the pilot loss input for indirect fired boilers.

Boiler Tank Insulation: EnergyPro assumes a minimum of R-12 external insulation on indirect fired boiler tanks. If the boiler has more than R-12, input that R-value.

Water loops: Only water loop heat pump systems require input in the loop set point temperature.

Hot Water Pump

There are no vintage defaults for hot water pumping systems.

Flow Rate per Pump: This value is usually available in plans or is part of the pump nameplate information. Flow rate is not a critical input.

Design Horsepower: This value is usually found on the pump in the form of Watts. Convert Watts to hp:

$$HP_{\text{pump}} = \text{Watts}_{\text{pump}} / 746 \text{ Watts per HP}$$

Example $HP_{\text{pump}} = 50W_{\text{pump}} / 746 \text{ Watts per HP} = 0.067 \text{ HP}$

Flow Control: It is common for existing multifamily buildings to have hot water pumps with one-speed pumps with three-way valves.

Hydronic Piping

The hydronic piping section applies to any piping located in unconditioned space. EnergyPro assumes ten feet of piping is in unconditioned space, and only requires inputs if more than ten feet of the space heating hot water piping is located in unconditioned spaces.

Chilled Water Tab

- ◆ It is best practice to consider the following when using the *Chilled Water* tab.
 1. Use when the building has one or more chillers used for air conditioning. The chiller can be air-cooled or water-cooled, in which case there will also be a cooling tower. Air-cooled chillers have on-piece equipment that includes the compressors and condenser fans. Obtain equipment details from component nameplates or from the mechanical schedule on the building plans.
 2. Verify operating conditions to avoid excessive use of default values.
 3. Verify chilled water flow rates, control, and leaving temperature, or obtain them from the mechanical schedules.
 4. Verify condenser water flow rates, control, and entering water temperature, or obtain them from the mechanical schedules.

Hydronic Tab

Use the *Hydronic Tab* to define the cooling tower and condenser water pumps for any system served by a water-cooled chiller or for a water loop heat pump system. Use the site assessment (or plans) to obtain specifications and operating conditions of the cooling tower. Obtain the flow rate from pump nameplate or from the mechanical schedule on building plans if available.

8. HVAC SYSTEMS

Equipment Efficiency Determination

Use the following directories to obtain efficiency values: manufacturer specifications, Energy Commission Appliance Directory, AHRI online Directory of Certified Product Performance, or RESNET default vintage tables. If the modeler is unable to verify the efficiency with these directories, use table R3-50 of the 2016 Residential Compliance Manual to obtain default values for HVAC equipment.

The program does not permit de-rating of equipment nameplate or default ratings for project submittals, unless the project team has field-tested the equipment and verified the actual operating efficiency.

EnergyPro HVAC System Inputs

The *General*, *Distribution*, and *Residential* tabs on the *HVAC System* element are the primary fields for HVAC system data input.

General Tab and HVAC System Definition

Use the *General* tab to define the HVAC system and assign a multiplier to the system specified. Multifamily buildings typically do not use the other inputs on the *General* tab.

Existing systems found in multifamily buildings are not likely part of the default EnergyPro library. Therefore, the modeler will need to create a new HVAC system in the EnergyPro library. The creation or modification of an existing library item requires defining the following sections according to system characteristics.

There is no need for the modeler to modify any EnergyPro data pertaining to the HVAC system besides that on the *Heating*, *Cooling*, and *Fans* tabs of the actual piece of equipment. Inputs on the *Controls*, *Outdoor Air*, and *Curves* tabs do not change the energy results in a low-rise project; EnergyPro does not evaluate any modifications to these fields.

Non-Residential Defaults

The heating capacity, cooling capacity, supply fan cubic feet per minute (cfm), and supply fan horsepower all affect the estimated cooling, heating, and fan energy use when using the Non-Res Performance module. It is best practice to ensure these data are as accurate as possible to produce reliable results. If nameplate data is not available, use the following defaults:

1. Heating capacity: 21.7 Btuh/square feet
2. Cooling capacity: 1 ton (12,000 Btu/h) / 350 square feet
3. Supply fan flow rate: 400 cfm/ton of cooling
4. Split DX supply fan power: 0.8 Watts/cooling cfm
5. PTAC Supply fan power: 0.3 Watts/cooling cfm

System Heating

To define the HVAC system type, follow the process below

Use the drop-down library to select a system type. The system type selection identifies the type of installed cooling system; EnergyPro automatically populates applicable inputs for cooling and heating depending on the selected system type. The most common modeling configurations for HVAC systems in existing multifamily buildings are:

CA Multifamily Retrofit Energy Modeling Guidelines

- **Split DX:** split air conditioners (compressors are outside or on the roof), split heat pumps, and for all furnaces including forced air furnaces and wall furnaces
- **Room PTAC:** all through-the-wall and window-type air conditioners and all through-the-wall and window-type heat pumps
- **Hydronic heat pump:** central heat pumps that use a cooling tower for heat rejection and a boiler for supplemental heating
- **Four-pipe fan coil:** fan coil units served by central boilers and chillers
- **Evaporative cooler:** evaporative cooling systems

After selecting the system type, define the heating type as one of the following:

- **Gas furnace:** all furnace types
- **Electric resistance:** electric wall panels, ceiling panels, baseboards, and electric furnaces
- **Heat pump:** PTHP, split heat pump, and packaged heat pumps
- **Hot Water:** all hydronic space heating systems
- **Gas heat pump:** unlikely system for multifamily buildings

When a modeler has selected *gas furnace* as the heating type, EnergyPro will require the modeler to also select the furnace type. Furnace options include:

- Central
- Fan wall
- Gravity wall
- Floor
- Room

Definition of distribution characteristics will depend on furnace type selection.

The modeler will input the heating output and efficiency data; these inputs use data from the energy audit and are based on equipment nameplate data. While a required input, the heating capacity total output does not affect the energy modeling results for low-rise multifamily projects. The program assumes the heating capacity meets the heating loads and does not penalize for an over-sized or under-sized system. However, the heating capacity does affect the results of high-rise residential multifamily buildings.

System efficiency is based on system type and data found on the equipment nameplate. You will find the following types of system efficiencies in EnergyPro:

- **Annual Fuel Use Efficiency (AFUE):** use for all gas furnaces
- **Heating Seasonal Performance Factor (HSPF):** use for electric resistance heating and split heat pumps. Model electric resistance heating efficiency as 3.413 HSPF. The heat pump efficiency rating may need to be converted from COP to HSPF by multiplying by COP by 3.413.
- **Coefficient of Performance (COP):** use for packaged terminal heat pump heating efficiency

EnergyPro does not require the pre-heat coils, re-heat coils, and baseboard heat inputs for the heating system types described above.

System Cooling

The modeler will determine the total cooling and sensible cooling outputs from cooling equipment nameplate data, and will input these data on the *Cooling* tab of the HVAC system library component. If the modeler cannot confirm the sensible cooling output through manufacturer specifications, it is acceptable to multiply the total cooling output by 0.70 to obtain the sensible cooling output.

To model a heating-only system with no cooling present, input the total and sensible cooling output as zero. EnergyPro requires this approach to indicate when there is no installed cooling.

The cooling efficiency metric depends on the type and total capacity of the cooling equipment. For example:

- Packaged and split air conditioners and heat pumps with a cooling capacity less than 65,000 Btu/hr. (5.42 tons) use the SEER efficiency rating.
- Packaged and split air conditioners and heat pump with cooling capacity 65,000 Btu/hr. and greater use the EER rating for the cooling efficiency rating.
- Water loop heat pumps use the EER rating for cooling efficiency.
- All PTAC and PTHP systems use the EER rating for cooling efficiency.

The program does not require cooling supply air temperature input for distributed cooling HVAC equipment (packaged and split systems).

System Controls

The *Controls* tab of the HVAC System library component describes the HVAC system fan operation as continuous or intermittent. Rather than running continuously with no regard for heating or cooling demand, system fans typically cycle on and off with a call for heating or cooling. EnergyPro assumes different controls for low- and high-rise multifamily projects:

Low-rise: The HERS Technical Manual specifies how to model ventilation in low-rise multifamily buildings. Models for all low-rise multifamily buildings use continuous exhaust ventilation, regardless of whether or not there are exhaust fans in the dwelling units. The assumed energy usage of these exhaust fans is 0.25 W/cfm of ventilation. The ventilation rate is based on equation 4-1 from the 2016 Residential Alternative Calculation Method (ACM):

$$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1)$$

Where:

Q_{fan} = fan flow rate in cubic feet per minute (cfm)

A_{floor} = floor area in square feet (ft²)

N_{br} = number of bedrooms, not to be less than one

The EnergyPro results always include fan energy in low-rise residential buildings, regardless of whether or not the building has installed exhaust fans. The model for a building with radiant heating (no supply fans), no cooling, and no exhaust fans will follow exhaust fan modeling protocol and report fan energy.

High-rise: To prevent inaccurate results from a bug in the simulation engine, model fans in high-rise residential buildings as continuous. To model reasonable heating cooling and fan energy in high-rise buildings with intermittent fans (modeled as continuous) the modeler should:

- Reduce HVAC system fan power
- Reduce ventilation rates (in the occupant tab) from 30 cfm per occupant to 15 cfm per occupant

Other inputs on the controls tab are not required, and do not affect the simulation results for multifamily HVAC system types.

Setting ventilation rates in high-rise projects is important for performance runs; failure to set these rates may produce inaccurate heating and cooling energy consumption estimates. Input the loads assumptions, including the ventilation rate, on the *Nonresidential* section on the *Occupant* tab of the *Room* element. Load assumptions are based on the occupancy type selected at the Zone level.

The quickest way to set the loads assumptions is to input all the zones and select the appropriate occupancies, e.g., high-rise residential, corridors, office. After the modeler has entered all zones and assigned occupancy, enter CTRL-H on the keyboard to bring up the EnergyPro Replace Wizard dialogue. Select *Loads Assumptions*, then *Next*, then *Global*, and *Finish*; this action replaces all of the loads assumptions, including ventilation rate, in accordance with the occupancy type selected at the *Zone* element.

Input the exhaust flow and motor horsepower on the *Exhaust Fan* tab of the *Room* element. If there are individual exhaust fans for each dwelling unit, and those dwelling units make up one zone, the modeler must sum the flow rates and horsepower according to the zoning. Likewise, if a central exhaust fan serves all dwelling units, the modeler must divide the central exhaust flow rate and motor horsepower into the appropriate building zoning.

System Outdoor Air

The *Outdoor Air* tab defines economizer types for packaged HVAC equipment serving nonresidential and high-rise multifamily buildings. High-rise residential projects may require exhaust air heat recovery inputs if there is a heat recovery system installed on the exhaust air streams.

System Fans

Use the *Fans* tab to define the supply and return fans in all HVAC systems serving high-rise multifamily buildings. The program requires the modeler to input fan power (hp) and fan flow (cfm) based on nameplate data or manufacturer specifications.

The modeler can calculate default airflow as 400 cfm per ton of cooling, or 21.7 cfm per thousand Btu/hr. of heating capacity. Calculate default supply fan power for split DX and central furnaces as 0.8 W/cfm, and 0.3 W/cfm supply flow for PTAC systems.

Hot water and electric radiant systems and gravity wall furnaces will not have fan inputs.

System Evaporative Cooling

It is unlikely that multifamily buildings will have installed evaporative cooling systems; these guidelines do not cover such systems.

Distribution Tab

Select the *Distribution* tab under the system element to input the heating and cooling distribution characteristics of the HVAC system defined previously on the *General* tab.

Heating Distribution

The following heating distribution types are available: ducted, ductless with fan, ductless without fan, radiant floor, or baseboard.

Cooling Distribution

The modeler may choose a ducted or ductless cooling distribution system. Use *ducted* for a typical forced-air furnace with air-conditioning. Use *ductless* for a PTAC, PTHP, water source heat pumps, or fan coil unit.

Duct Location and Insulation

Choose the appropriate *Duct Location* from the drop down menu. Ducts in conditioned space refer to ducts that are (1) within the thermal barrier, **and** (2) in a space that is heated or cooled. Ducts located in an attic that is insulated, but not conditioned, are not in conditioned space.

Input the verified duct insulation R-value.

Duct Leakage HERS Credits

Projects in this program cannot claim credit for duct distribution HERS measures that are required due to equipment change-out. These include:

- Sealed ducts with leakage verified: EnergyPro assumes 15 percent leakage
- Low Leakage AHU or Leakage Verified: This entry is for a measurement of duct leakage to the outside. If performing a standard duct leakage test at test-in (duct blaster only, without blower door), put half the measured value into the model. This assumes half of the duct leakage is to outside. If the duct leakage to outside is measured (with a duct blaster and blower door), put the full measured value here. At test-out put the full measured value in the *Alternatives* tab. This approach allows for a conservative estimate of energy savings in the instance that you cannot measure actual leakage to outside with a blower door and duct blaster.

Residential Tab

Indicate the thermostat type in the dwelling unit on the *Residential* tab. There is no method for averaging systems that have a mix of setback and non-setback thermostats; rather, the program requires the modeler to define the predominant thermostat type. The program does not allow credit for replacing a thermostat as an eligible measure.

When a boiler or hot water heater supply hot water to the HVAC system, the modeler will use the *Hydronic Space Heating* drop down menu to select a dedicated space heating boiler or domestic hot water as the source of hot water.

HERS Credits and Mech-2 Tab

Do not check the measures on the *HERS Credits* tab for existing multifamily buildings as these apply to new construction. The program does not permit projects to claim credit for HERS measures that are required due to equipment change-out.

It is not necessary to complete inputs on the *MECH-2* tab; these apply only for Title 24 compliance documentation of nonresidential new construction projects.

Examples of Modeling Multifamily HVAC Systems

This section describes the systems most commonly found in multifamily buildings.

Forced Air Furnace with Split DX Air Conditioner

System Description: The existing system in a small townhouse style multifamily property uses a 60,000 Btu/hr. forced natural gas furnace and 3-ton split DX air conditioner. Heating efficiency is 78 percent and

cooling efficiency is 10 SEER. A ¼ hp supply fan provides airflow of 1,000 cfm. Heating and cooling ducts have R-2 insulation and are located in the unvented attic space. A setback thermostat controls the system. There are eight identical systems, each serving one of eight dwelling units.

Modeling Process:

1. On the *General* tab of the *HVAC System* element, input a system multiplier of eight. Create a new HVAC System library component and define the heating, cooling, and fan characteristics of the proposed system:
 - a. Select the *Split DX system* type
 - b. Select *Gas Furnace* as the heating type
 - c. Select *Central* as the furnace type
 - d. Input 60,000 Btu/hr. total heating output and efficiency of 0.78 AFUE
 - e. Input 36,000 Btu/hr. total cooling output (12,000 Btu per ton x 3 tons), 30,600 sensible cooling output (0.85 x 36,000), and efficiency of 10 SEER
 - f. Input the supply fan power of 0.25 hp and airflow of 1,000 cfm
2. Characterize the existing duct system on the *Distribution* tab of the *HVAC System* element:
 - a. Select *Ducted* for cooling and heating distribution
 - b. Select duct location as *Attic, ceiling insulated, unvented*
 - c. Input R-2 duct insulation
3. Select *Setback Thermostat* on the *Residential* tab of the HVAC system.

Forced Air Furnace with No Cooling

System Description: This existing system is the same as the above Forced Air Furnace with Split DX Air Conditioner system except it has no installed cooling system.

Modeling Process:

1. On the *General* tab of the *HVAC System* element input a multiplier of eight. Create a new HVAC System library component and define the heating, cooling, and fan characteristics of the proposed system:
 - a. Select the *Split DX system* type
 - b. Select *Gas Furnace* as the heating type
 - c. Select *Central* as the furnace type
 - d. Input 60,000 Btu/hr. total heating output and efficiency of 0.78 AFUE
 - e. Input 0 Btu/hr. total cooling output and 0 Btu/hr. sensible cooling output
 - f. Input the supply fan power of 0.25 hp and airflow of 1,000 cfm
2. Characterize the existing duct system on the *Distribution* tab of the *HVAC System* element:
 - a. Select *Ducted* for heating distribution
 - b. Select duct location as *Attic, ceiling insulated, unvented*
 - c. Input R-2 duct insulation
3. Select *Setback Thermostat* on the *Residential* tab of the *HVAC System* element.

Split Heat Pump with Ducts in Two Locations

System Description: The property is an eight-unit, two-story townhouse style multifamily building. The existing system is a split system heat pump used for heating and cooling. Heating capacity is 72,000

Btu/hr. Total cooling capacity is 3-tons and the sensible cooling capacity was not available from manufacturer specifications. Heating efficiency is 8.0 HSPF and cooling efficiency is 9.0 SEER.

Heating and cooling ducts are located in mechanical chases within the conditioned space for the first-floor dwelling units. Ducts serving the second-floor dwelling units are located in an unvented attic space. The ducts have R-4 insulation. A setback thermostat controls the system.

Modeling Process:

The modeler will create two HVAC Systems—an upper system and a lower system. The only difference between the two systems will be the location of the heating and cooling distribution ducts serving the upper and lower level dwelling units.

1. On the *General* tab of the *HVAC System* element create a new HVAC System library component and define the heating, cooling, and fan characteristics of the proposed system. The modeler can use this library component for both the lower and upper HVAC System:
 - a. Select the *Split DX System* type
 - b. Select *Heat Pump* as the heating type
 - c. Input total heating output of 72,000 Btu/hr. and efficiency of 8.0 HSPF
 - d. Input total cooling output of 36,000 Btu/hr. (12,000 Btu per ton x 3 tons), 30,600 sensible cooling output (0.85 x 36,000) and efficiency of 9.0 SEER
2. Using the system created in step one, assign appropriate thermal zones to the HVAC systems and input multiplier of four for each system type.

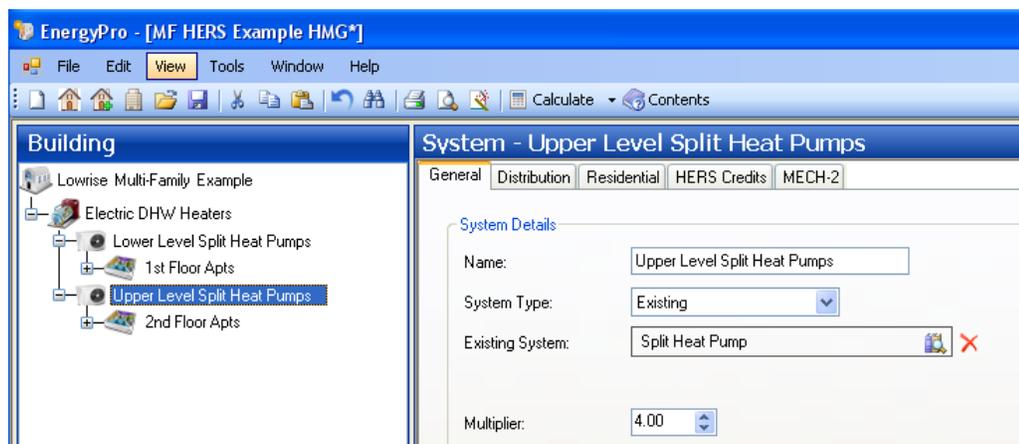


Figure 27: Screenshot of General Tab of the System Element

3. Characterize the existing duct system for the HVAC System serving the upper-level dwelling units on the *Distribution* tab of the *HVAC System* element:
 - a. Select *Ducted* for cooling and heating distribution
 - b. Select duct location as *Attic, insulated, unvented*
 - c. Input R-4 duct insulation
4. Characterize the existing duct system for the HVAC System serving the lower level dwelling units on the *Distribution* tab of the *HVAC System* element:
 - a. Select *Ducted* for cooling and heating distribution
 - b. Select *Conditioned* as the duct location

- c. Input R-4 duct insulation
5. Select *Setback thermostat* on the *Residential* tab of the *HVAC System* element. Follow this step for the upper and lower level HVAC systems.

Package Terminal Heat Pumps (PTHP)

System Description: The existing building has 50 identical studio apartments. The HVAC System consists of one package terminal heat pump per dwelling unit. The heating capacity is 24,000 Btu/hr. and the heating efficiency is 4.1 COP. There is also a 1.5 kW supplemental electric resistance heating element in the heat pump system. Total cooling capacity is 21,000 Btu/hr., sensible cooling capacity is 14,700 Btu/hr., and the cooling efficiency is 9.0 EER. The 1/8 horsepower supply fan provides airflow of 600 cfm. The modeler verified all values through nameplate data and AHRI Certified Product Performance directory.

Modeling Process:

1. On the *General* tab of the *HVAC System* element input a system multiplier of 50. Edit or create a new HVAC System library component and define the heating, cooling, and fan characteristics of the existing PTHP system:
 - a. Select the *Room PTAC system* type
 - b. Select *Heat Pump* as the heating type
 - c. Input total heating output of 24,000 Btu/hr. and efficiency of 4.1 COP. Input 1.5 kW into the Electrical field to account for the supplemental electric resistance heat strip.
 - d. Input total cooling output of 21,000 Btu/hr., sensible cooling capacity of 14,700 Btu/hr., and efficiency of 9.0 EER
 - e. On the *Fans* tab input the 600 cfm and 0.125 (1/8) horsepower supply fan
2. Characterize the existing duct system on the *Distribution* tab of the *HVAC System* element:
 - a. Select *Ductless w/fan for heating distribution* and *Ductless for cooling distribution*
3. Select thermostat type as *No setback* on the *Residential* tab of the *HVAC System* element.

Natural Gas Wall Furnace w/Package Terminal Air Conditioner

System Description: A garden style apartment building utilizes gravity wall furnaces for space heating and packaged terminal air conditioners (PTAC) for space cooling. The 30,000 kBtu/hr. wall furnaces have a heating efficiency of 65 percent AFUE. The 1-ton PTAC system has an efficiency of 7.5 EER and 1/8 hp supply fan with 400 cfm of airflow. The thermostats are non-programmable.

Modeling Process:

1. On the *General* tab of the *HVAC System* element, create a new HVAC system library component and define the heating, cooling, and fan characteristics of the proposed system:
 - a. Select the *Room PTAC system* type
 - b. Select *Heat Pump* as the heating type
 - c. Input total heating output of 24,000 Btu/hr. and efficiency of 4.1 COP. Input 1.5 kW electric resistance heat strip into the electrical power field.
 - d. Input total cooling output of 12,000 Btu/hr., sensible cooling capacity of 10,200 Btu/hr., and efficiency of 9.0 EER
 - e. On the *Fans* tab, input the 400 cfm and 0.125 horsepower supply fan

2. Characterize the existing duct system on the *Distribution* tab of the *HVAC System* element:
 - a. Select *Ductless w/out fan* for heating distribution, and *Ductless* for cooling distribution
3. Select *No setback* as the thermostat type on the *Residential* tab of the *HVAC System* element.

Natural Gas Wall Furnace with Split DX Cooling

System Description: The existing heating system in a small, townhouse-style multifamily property uses fan powered wall furnaces for heating. There are 2 furnaces in each dwelling unit and a total of 15 dwelling units. The heating capacity is 55,000 Btu/hr. per system and the heating AFUE is 60 percent.

Several years after construction, due to overheating complaints, the owner installed a ducted central-split air conditioner in each unit. The 3-ton split DX air conditioner has an efficiency of 10.8 SEER, a 0.17 hp supply fan with airflow capacity of 1,000 cfm. Cooling ducts have R-4 insulation and are located in mechanical chases in the conditioned space. A setback thermostat controls the cooling system.

Modeling Process:

1. On the *General* tab of the *HVAC System* element, input a multiplier of 15 (because there are 15 dwelling units and 15 air conditioners). Double the heating capacities of the two wall furnaces. Create a new HVAC System library component and define the heating, cooling, and fan characteristics of the proposed system:
 - a. Select the *Split DX system* type
 - b. Select *Gas Furnace* as the heating type
 - c. Select *Fan Wall* as the furnace type
 - d. Input total heating output of 110,000 Btu/hr. and 0.60 AFUE as the efficiency
 - e. Input total cooling output of 36,000 Btu/hr. (12,000 Btu per ton x 3 tons), 30,600 sensible cooling output (0.85 x 36,000), and 10.8 SEER as the efficiency
 - f. Input the fan power as 0.17 hp and flow rate as 1,000 cfm
2. Characterize the existing duct system on the *Distribution* tab of the *HVAC System element*:
 - a. Select *Ducted* for cooling distribution and *Ductless w/fan* for heating distribution
 - b. Select *Conditioned* as the duct location
 - c. Input R-4 duct insulation
3. Select *Setback thermostat* on the *Residential* tab of the *HVAC System* element.

Natural Gas Wall Furnace with No Cooling

System Description: The existing heating system in a small, townhouse-style multifamily property is a gravity wall furnace. There are two furnaces in each dwelling unit and there are a total of 15 dwelling units. The heating capacity is 55,000 Btu/hr. per system and the heating AFUE is 60 percent.

Modeling Process:

1. On the *General* tab of the *HVAC System* element, input a multiplier of 30 to account for the 15 dwelling units with two heaters per unit. Create a new HVAC System library component and define the heating, cooling, and fan characteristics of the proposed system:
 - a. Select the *Split DX system* type
 - b. Select *Gas Furnace* as the heating type
 - c. Select *Fan Wall* as the furnace type
 - d. Input 55,000 Btu/hr. total heating output and as the efficiency

- e. Input \dot{Q} total cooling and \dot{Q} sensible cooling output
 - f. Input \dot{Q} for fan power and fan flow rate
2. *Characterize* the existing duct system on the Distribution tab of the *HVAC System* element:
 - a. Select *Ductless* for heating distribution
 3. *Select Setback thermostat* on the *Residential* tab of the *HVAC System* element.

Electric Resistance Radiant Systems

System Description: The existing heating system in a high-rise residential building is an 8' electric resistance radiant baseboard per dwelling unit. Electric radiant baseboards typically consume 250 Watts per linear foot. The conversion from Watts to Btu is 3.413 Btu per Watt; 8 linear feet x 250 W/linear foot x 3.413 Btu/W = 6,826 Btu of heating capacity. 100 percent of electrical energy input into electric resistance is converted to heat; therefore, the efficiency is 3.413 HSPF.

There is also one PTAC unit for cooling in each dwelling unit. The PTAC has a cooling capacity of 1-ton, an efficiency of 8.0 EER, and a 1/8 hp supply fan with airflow of 350 cfm. There is no setback thermostat and the PTAC fans only run when there is a call for cooling.

Modeling Process:

1. Create a new *HVAC System* library component and define the heating, cooling, and fan characteristics of the proposed system:
 - a. Select the *Room PTAC* system type
 - b. Select *Electric Resistance* as the heating type
 - c. Input 6,826 Btu/hr. total heating output and 3.413 HSPF as the efficiency
 - d. Input 12,000 Btu/hr. total cooling output, 10,200 Btu/hr. (0.85 x 12,000) sensible cooling output, and 8.0 EER cooling efficiency
 - e. Since this is a high-rise project, set the fan controls to *continuous and decrease the rated fan power by 50%*
 - f. Input 0.063 hp for fan power and fan flow rate of 350 cfm
 - g. In the Occupant tab, adjust ventilation rates to 15 cfm per occupant
2. *Characterize* the existing duct system on the Distribution tab of the *HVAC System* element:
 - a. Select *Baseboard* for heating distribution and *Ductless* for cooling distribution
3. Select no *Setback thermostat* on the *Residential* tab of the *HVAC System* element.

Low-Rise MF Hot Water Heating Systems: Dedicated Hydronic Boiler

System Description: The existing heating system is a hydronic heating system. There is a dedicated central boiler providing hot water to radiant baseboards.

The mechanical plans indicated a heating capacity of 18,000 Btu/hr. per baseboard.

The gas-fired boiler has a total capacity of 800,000 Btu/hr. and a thermal efficiency of 78 percent. The modeler could not verify standby loss from certified equipment directories and will use the default of 2.0 percent. There is no storage tank but the boiler vessel has a capacity of 50 gallons. The modeler verified a 0.5 horsepower pump with 200 gpm flow rate on site. The pump is one speed. There are approximately 200 linear feet of measured hydronic piping located in the unconditioned parking garage on the first level.

Modeling Process:

1. Define the hot water heating boiler, hot water pump, and hydronic piping on the *Heating Hot Water* tab of the *Plant* element:
 - a. Create a boiler, or edit an existing one, in the EnergyPro library. Input 50 gallons for storage capacity, 800,000 Btu/hr. input, 0.78 recovery efficiency, and .025 standby loss.
 - b. Input the hot water pump flow rate of 200 gpm, power input of 0.5 horsepower, and select the control as *one speed/three way valves*.
 - c. Input 200 feet for the hydronic pipe length
2. Create a new HVAC System library component and define the heating, cooling, and fan characteristics of the proposed system:
 - a. Select the *Split DX* system type
 - b. Select *Hot Water* as the heating type
 - c. Input 18,000 Btu/hr. total heating output. The prior definition of the heating hot water boiler efficiency eliminates the need for an efficiency definition here.
 - d. Input 0 Btu/hr. total cooling output, 0 Btu/hr. sensible cooling output to model this system without cooling
3. Characterize the existing duct system on the Distribution tab of the *HVAC System* element:
 - a. Select *baseboard* for heating distribution
4. On the *Residential* tab of the *HVAC System* element, connect the space heating boiler defined in step one to the radiant baseboards created in step two by selecting *Heating Boiler Provides Heat* for the hydronic space heating.

Low-rise MF Hot Water Heating Systems: Combined Hydronic

System Description: The existing heating system is identical to the system in section 0 example except this system also provides the domestic hot water to all 40 dwelling units in the building. This system is considered a combined hydronic system and also a MF Central DHW system since it provides DHW to more than six dwelling units.

Modeling Process:

1. Define the hot water boiler, MF Central DHW characteristics, and combined hydronic piping on the *Domestic Hot Water* tab of the *Plant* element:
 - a. Create a boiler, or edit an existing one, in the EnergyPro library. Input 50 gallons for storage capacity, 800,000 Btu/hr. input, 0.78 recovery efficiency, and .025 standby loss.
 - b. Input the pump power of 0.5 horsepower, and select the control as *one speed/three way valves*.
 - c. Input 200' for the hydronic pipe length
2. Create a new HVAC System library component and define the heating, cooling, and fan characteristics of the proposed system:
 - a. Select the *Split DX system* type
 - b. Select *Hot Water* as the heating type
 - c. Input 18,000 Btu/hr. total heating output. This step does not require efficiency since the heating hot water boiler efficiency has been defined.

- d. Input 0 Btu/hr. total cooling output, 0 Btu/hr. sensible cooling output to model this system with no cooling
3. Characterize the existing duct system on the *Distribution* tab of the *HVAC System* element:
 - a. Select *Baseboard* for heating distribution
4. On the *Residential* tab of the *HVAC System* element, connect the boiler defined in step one to the radiant baseboards created in step two by selecting *DHW Boiler Provides Heat* for the hydronic space heating.

Hydronic (Water-loop) Heat Pumps

Hydronic heat pumps, also known as water loop heat pumps, provide heating and cooling for a number of individually controlled zones (dwelling units). There are two heat exchangers in the hydronic heat pump: an air-to-refrigerant heat exchanger, and a working fluid-to-refrigerant heat exchanger, which is connected to a pipe loop with circulating hydronic fluid. The circulating hydronic fluid absorbs heat from units operating in cooling mode and provides heat to those units in heating mode. When cooling demand exceeds heating demand, the pump rejects heat through an evaporative cooler or cooling tower. When heating demand exceeds cooling demand, a boiler adds heat. Common hydronic heat pump systems maintain the fluid loop temperature between 65°F and 85°F. Accurate details of the on-site control of the system are critical to ensure accurate modeling results. The modeling process for hydronic heat pumps is as follows:

- ◆ Boiler inputs:
 - Input the information for the boiler, hot water pump, and hydronic piping as previously described except for the loop set point temperature.
 - The loop set point temperature refers to the temperature of the fluid loop when the boiler provides hot water to the loop. A loop set point temperature of 70°F is common and this means that the boiler will add hot water to the loop when loop temperature falls below 70°F; this ensures the boiler can meet demand. This control point typically is set between 65°F and 85°F and requires verification during the site assessment.
- ◆ Hydronic inputs:
 - Input the condenser water pump, cooling tower, and cooling tower pump into the *Hydronic* tab of the *Plant* element.
 - The condenser water pump circulates fluid from the cooling tower to the hydronic heat pumps located in the dwelling units. The input fields for this pump are located in *Economizer/Condenser (Water)* section of the *Hydronic* tab on the *Plant* element and include flow rate (gpm), quantity of pumps, design horsepower, and flow control. You can use the pump and motor nameplates to verify these in the field. Unless there is a variable frequency drive controlling pump operation, and valves at the heat pump are not visible or plans are not available to confirm otherwise, one can presume the flow control is a one-speed/three-way valve for existing systems.
 - It is likely that the modeler will need to obtain cooling tower inputs from the mechanical plan schedules or the building operator. It will be necessary to create a new cooling tower assembly in EnergyPro based on actual conditions. On the *General* tab of the *Cooling Tower* section, select the appropriate type of tower, capacity control, and output. The set point temperature input is the temperature of the fluid leaving the cooling tower and is often referred to on mechanical plan schedules as the leaving water temperature (LWT). The

approach temperature is the difference between the LWT and the ambient wet bulb temperature for which the system operating conditions were designed. Take the ambient wet bulb from the mechanical plans schedule. For example, the LWT set point is 74°F and the mechanical schedule indicates a design wet bulb temperature of 64°F. This is an approach temperature of 10°F. If the LWT can be adjusted as the actual ambient wet bulb temperature decreases, this is considered condenser water reset control strategy and may result in improved overall system efficiency. If the modeler can verify the condenser water reset control strategy on site, the modeler must input the minimum water temperature. This is the lowest leaving water temperature the cooling tower will provide.

- ◆ HVAC system inputs
 - Input the hydronic heat pumps serving the dwelling units under the *HVAC System* element, similar to other heat pumps previously described. The system type is *hydronic heat pump*. The program automatically assigns the central boiler, cooling tower, and pumps defined on the *Hydronic* tab.
- ◆ Thermal zoning
 - Zoning is an important aspect of projects that use hydronic heat pumps for heating and cooling since all zones add or remove heat from the water loop depending on the zone loads. Some zones are likely to be cooling and others heating at different times of the year and, if combining dwelling units, it is important to model the zones according to similar thermal characteristics. At a minimum, model the thermal zoning of dwelling units by unit orientation. For example:
 - Combine west facing dwelling units into one zone
 - Combine east facing units into another zone

For improved accuracy, you can model each dwelling as a separate zone.

9. MISCELLANEOUS EQUIPMENT CALCULATIONS

The program may permit the use of approved work papers to capture existing systems' power usage and upgrades associated with those systems. All side calculations need to follow the work paper and calculation methodology must be transparent.

Exterior Uses Tab: Place equipment usage and savings located for all spaces here. These inputs do not impact heating and cooling loads. The modeler must input calculated load in either Watts or Btu/hr. and choose an hourly schedule. The hourly schedule converts the load inputs into annual energy use.

Pools: High Rise

Non-Res Performance module of EnergyPro does not recognize the *Pools* tab, instead the modeler must use the exterior uses tab for power usage.

Pool Heater Fuel Consumption

Calculate the fuel consumption to heat the pools by dividing the estimated pool heating load by the efficiency of the pool heater as verified during the audit. Use the table below to estimate the pool heating load⁵. The default assumptions and starting point for the analysis is 15 mph wind speed, 30 percent shading, 80°F water temperature, and a “high” activity level.

The heating loads reported in the table below are per 1,000 square feet of pool surface area. Loads must be proportioned based on actual pool surface area at the site.

Wind Speed (mph)	Shading	Water Temp, °F	Activity Level	Annual Pool Heating Load / 1,000 sq. ft. surface area (Therms)
15	30%	80	High	9,817
15	50%	80	High	10,642
30	30%	80	High	13,108
15	30%	80	Low	8,628
15	30%	82	High	11,050
15	30%	78	High	8,631

Figure 28: Pool Default Heating Loads

Example

Calculate the estimated annual energy consumption for a 25' x 25' pool under default conditions. The pool heater is 78% efficient.

Look up annual pool heating load from the table for the default conditions, and proportion based on actual pool size:

⁵ Obtained from PG&E Commercial Pool Workpaper PGECOPRO105. The workpaper utilized the DOE's Energy Smart Pools Software to calculate heating loads for the options presented in the table.

- a. Annual load = 9,817 therms per 1000 sq. ft..
- b. $(625 \text{ sq. ft.} / 1,000 \text{ sq. ft.}) * 9,817 = 6,135 \text{ therms per year}$
2. Calculate annual heating energy consumption based on actual heater efficiency:
 - a. $6,135 \text{ therms} / 0.78 = 7,866 \text{ therms}$
3. Process for input into EnergyPro exterior use tab:
 - a. Convert therms to Btu for input into EnergyPro exterior uses: $100,000 \text{ Btus per therm} \times 7,866 \text{ therms} = 786,600,000 \text{ Btus}$
 - b. Create an annual operating schedule with one hour of operation for the entire year. The gas utility rate is not time of use-dependent, and we do not need hourly TDV calculations for program participation.

VFD Controls for Parking Garage Fans

Title 24, Part 4, 2016 California Mechanical Code (CMC), Section 403.7.1-2, requires exhaust of air flow for enclosed parking facilities at a rate of 0.75 cubic feet/minute per square foot (CFM/ft²), and accompanying makeup air from outside or from transfer. Exhaust is not required for open parking structures, as defined by the Section 407.2, or for parking structures smaller than 1000 square feet in area or storing 5 or fewer motor vehicles.

Section 403.7.2 of the 2016 CMC allows for an intermittently-operated exhaust system that operates automatically upon detection of vehicle operation. Section 403.7.2.2 allows the use of automatic carbon monoxide sensing devices to modulate the ventilation system to maintain a maximum average concentration of carbon monoxide of 50 parts per million during any eight-hour period, with a maximum concentration not greater than 200 parts per million for a period not exceeding one hour.⁶

Use the following equation to calculate the baseline fan power of the uncontrolled garage exhaust fan:

$$\text{Exhaust Fan kW (FankW)} = \frac{0.9 * \text{Motor HP}_{\text{nominal}} * 0.746}{\text{Motor Eff}}$$

Figure 29: Fan Kw Calculation

Where:

0.90 = fan load factor

0.746 = horsepower to kW conversion

Motor HP_{nominal} = motor nameplate horsepower

Motor Eff = motor nameplate efficiency

To calculate annual energy consumption of the uncontrolled garage exhaust fan, multiply the exhaust fan kW by the annual operating hours, assumed to be 8,760 hours/year for an uncontrolled system (24 hours/day, 7 days/week, 52 weeks/year).

$$\text{Annual Energy Consumption}_{\text{uncontrolled system}} = \text{FankW} * \text{Annual Hours}$$

⁶ SCE13HC038.0 VFD Demand Control System Retrofit to Parking Structure Exhaust Fan

Figure 30: Fan kWh Calculation

To calculate the annual energy consumption for the proposed variable speed controlled exhaust fan, assume the fan will run full speed for eight hours per day and at 25 percent of full speed for sixteen hours per day. The fan energy required to operate the reduced speed fan is proportional to the cube root of the fan speed. For example, the power required to operate a fan at 25 percent of full speed is 0.25^3 , or 0.016 of the power to operate that fan at full speed. Assuming the motor is not replaced, use the following equation to calculate the exhaust fan kW operating at reduced speed. Fan motor replacement (either due to size or efficiency) will require the calculation of a revised FankW.

$$FankW_{reduced\ speed} = [FankW]_{full\ speed} * (\% \text{ of full speed})^3$$

Figure 31: VFD Controlled Fan Kw Calculation

$$\text{Annual Energy Consumption}_{VFD\ controlled\ system} = \frac{(FankW_{full\ speed} * Annual\ Hours_{full\ speed} + FankW_{reduced\ speed} * Annual\ Hours_{reduced\ speed})}{Eff_{VFD}}$$

Figure 32: Energy Savings for Garage Exhaust Fans with VFD Control

Where:

Eff_{VFD} = efficiency of the variable frequency drive motor based on manufacturer’s data or the following defaults: 95.2 percent for 10 hp motor, 95.7 percent for 15 hp motor, and 96.2 percent for larger motors⁷.

⁷ Work Paper SCE13HC038

10. ENERGY ANALYSIS AND ENERGY EFFICIENCY MEASURE ELIGIBILITY

Rather than using separate models for the existing and proposed conditions, the program prefers that projects use one energy model file for each existing building and energy efficiency measure analysis. This one-model approach has several benefits, including fewer quality control efforts and less potential for input errors. The *Alternatives* tab of EnergyPro provides the easiest way to model energy efficiency measures. However, the EnergyPro *Alternatives* tab has limitations on some energy efficiency measures; therefore, the modeler may build a separate model to claim energy savings for measures that cannot be modeled using the *Alternatives* tab.

Energy Analysis Using One EnergyPro File

The *Alternatives* tab allows for modeling of the following program incentive-eligible measures:

- ◆
 - Roof type and insulation
 - Cool roof and radiant barrier
 - Wall type and insulation
 - Floor type and insulation
 - Window performance values
 - HVAC system type and performance values
 - HVAC duct distribution type
 - HVAC duct leakage
 - HVAC duct insulation
 - Appliances
 - Indoor dwelling unit and common area lighting type and control, if hard-wired high-efficacy (low-rise)
 - Outdoor dwelling unit and common area lighting type and control, if hard-wired high-efficacy and attached to the building (low-rise)
 - DHW type and performance values
 - DHW distribution insulation and pumping controls
 - Heating boiler type and performance values
 - Pool pump efficiency
- ◆ Despite modeling functionality of the *Alternatives* tab, the following measures are not eligible program upgrades:
 - Solar savings fraction for DHW
 - Renewable energy production
 - Refrigerant charge verification
 - System airflow verification
 - System fan wattage verification
 - Programmable set-back thermostats
 - CFL bulb installation
 - Building infiltration rate

- ◆ The *Alternatives* tab does not permit modeling of the following measures. However, these are eligible program measures that can use side calculations to determine savings. These measures include:
 - Low-flow hot water fixtures
 - Others as approved on a case-by-case basis by program (EUC-MF or MUP) staff
- ◆ Ineligible program measures that cannot be modeled in the Alternatives Tab, include, but are not limited to:
 - Heat lamp removal
 - Hard-wired fixture removal (resulting in fewer hard-wired fixtures in a space)
 - Lighting not attached to building, e.g., parking lot lighting and landscape lighting (MUP permits some lighting of this type; see section 0 for modeling instructions)
 - HVAC and DHW equipment tune-ups
 - Removal (without replacement) of systems required by law in residential units (e.g., space heating)

Using Multiple Energy Models

In scenarios that require two models to complete analysis, the following steps apply:

- Correctly model all existing (pre-upgrade) conditions
- Perform quality control on the existing building inputs and results to ensure accurate models.
- Make a copy of the pre-retrofit model, save as a new file name, and adjust the post-retrofit energy model to capture the suggested energy efficiency measures

When using the two-model approach, the program recommends using an iterative process to analyze each measure by itself to ascertain individual measure savings and whether to recommend such measures to the building owner. This process also facilitates quality control.

Submit the existing pre-retrofit and proposed post-retrofit EnergyPro files to the program for assessment review.

The following measures require a two-model approach:

Envelope

- Change in window area
- Change in wall, roof, or floor area
- Change in overhang characteristics

Lighting and appliances

- Dwelling unit lighting and controls in high-rise multifamily
- Common area lighting and controls in high-rise multifamily
- Detached site lighting (MUP only)
- Appliances in high-rise multifamily

HVAC

- Some system type changes involving hydronic heating that require choosing the heating source
- Any type of central cooling systems using chillers, cooling towers, or ground source heat sinks

Domestic Hot Water

- Central system pump controls

ENERGY MODEL QUALITY CONTROL

The EnergyPro software uses many algorithms to calculate predicted energy use. As is the case with all energy modeling software, the accuracy of such calculations relies on accurate inputs. It is crucial to review inputs and results prior to presenting results to the client and submitting energy models and data collection forms for program assessment review.

Several EnergyPro reports can facilitate this quality control process. Review of these reports can also give potential insight into building energy use to suggest appropriate energy efficiency alternatives.

The EnergyPro Res Performance module can assist in review of project and energy savings estimates. These reports include:

- **Project summary:** reports the conditioned floor area, number of bedrooms, floor type, and climate zone, and brief summary of end use energy cost breakdown
- **Energy end-use summary:** provides end-use energy breakdown by fuel and allows the energy alternatives to focus on the end-use consuming the most energy according to the models
- **Recommendations:** provide a summary of the energy cost, site energy, and TDV energy saving estimates for each measure modeled on the *Alternatives* tab. This is useful in identifying which measures have the biggest impact and in suggesting recommended measures for implementation.
- **Utility bill summary:** provides the energy cost based on selected utility rates, and is useful for comparing to energy model results for quality assurance of results
- **HVAC system heating and cooling loads summary:** provides the calculated building HVAC loads, which can be useful in recommending HVAC equipment sizes if the existing system is over-sized
- **Room load summary:** provides the peak heating and cooling load components by exterior surface and internal loads for each zone. This is useful for understanding heating and cooling load dynamics. This report can provide insight on what exterior surfaces are contributing most to building heat loss and can guide energy efficiency measure selection.

Energy Model Inputs

Energy savings are dependent on the existing conditions input into the software. Use the guidelines below to check data and verify correct inputs:

- Verify that the energy model reflects the data from site collection forms
- Verify that there are roughly equal wall surface areas by opposing orientation. The area for the front and back wall should be roughly the same, as should the area for the left and right walls.
- Confirm construction assembly u-value, and window SHGC and u-value
- Confirm HVAC system types and performance characteristics
- Confirm DHW system types and performance characteristics
- Confirm high-rise occupancy assumptions, especially the ventilation rate

Reasonableness of Results

It is best practice to include the following checks when reviewing results:

- For the existing pre-retrofit model, do the energy use estimates appear reasonable by end-use and for the selected climate zone? Using the building climate zone, compare the heating and cooling energy estimates to the heating and cooling degree-day numbers.
- For each of the energy efficiency measures, can the savings be justified based on rules-of-thumb, the number of operating hours, and the indoor and outdoor temperature conditions for the building?
- Does the package of energy efficiency measures have energy efficiency savings equal to, worse than, or better than the sum of the savings for the energy efficiency measures? (Generally, the interaction between savings will result in a cumulative savings that is less than the sum of the savings.) Can the cumulative impact of the energy efficiency measures be justified?

II. REFERENCES

The following California Energy Commission documents will assist energy assessment teams in understanding the energy modeling software and requirements as they pertain to the HERS Whole-House and EnergyPro software capabilities. Several are accessible from the EnergyPro help menu.

- **HERS Technical Manual** explains the requirements for the California Home Energy Rating System (HERS) Program, including requirements for HERS providers, modeling procedures and assumptions, analysis procedures, reporting, and other requirements of the California HERS program. The document is available for download on the following website:
www.energy.ca.gov/2008publications/CEC-400-2008-012/CEC-400-2008-012-CMF.PDF
- **Residential and Nonresidential Alternative Calculation Manuals (ACM)** include approved calculation methods for Title 24 Part 6 compliance, and offer insight into the calculation methodology within the EnergyPro software. The documents are available for download on the following websites: <http://www.energy.ca.gov/2015publications/CEC-400-2015-024/CEC-400-2015-024-CMF-REV2.pdf> and <http://www.energy.ca.gov/2015publications/CEC-400-2015-025/CEC-400-2015-025-CMF.pdf>
- **2016 ACM Supporting Content** provide references for weather data, construction assembly descriptions, and residential and non-residential HERS verification procedures. The documents are available for download the following website:
http://energy.ca.gov/title24/2016standards/ACM_Supporting_Content//
- **2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings** is the current version of the state building energy code. The document is available for download on the following website: <http://www.energy.ca.gov/2015publications/CEC-400-2015-037/CEC-400-2015-037-CMF.pdf>
- **2016 Residential and Nonresidential Compliance Manuals** intend to help energy consultants comply with and enforce the California Title 24 Part 6 standards, and are useful for understanding requirements for alterations and additions. The documents are available for download from the following websites:
http://energy.ca.gov/title24/2016standards/residential_manual.html and
http://energy.ca.gov/title24/2016standards/nonresidential_manual.html

12. Appendix B: Default Vintage Table

TABLE R3-50 – DEFAULT ASSUMPTIONS FOR EXISTING BUILDINGS – VINTAGE TABLE VALUES
 Default Assumptions for Year Built (Vintage)

Conservation Measure	Before 1978	1978 to 1983	1984 to 1991	1992 to 1998	1999 - 2000	2001- 2003	2004- 2005	2006 and 2012	2013 and Later
INSULATION U-FACTOR									
Roof/Ceiling	0.079	0.049	0.049	0.049	0.049	0.049	0.049	0.049	
Wall	0.356	0.110	0.110	0.102	0.102	0.102	0.102	0.102	
Raised Floor –Crawl Space	0.099	0.099	0.099	0.046	0.046	0.046	0.046	0.046	
Cool Roof	0.10	0.10	0.10	0.10	0.10	0.10	0.10	Pres Pkg.	
Radiant Barrier	None	None	None	None	None	None	Pres Pkg.	Pres Pkg.	
Raised Floor-No Crawl Space	0.238	0.238	0.238	0.064	0.064	0.064	0.064	0.064	
Slab Edge F-factor	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	
Ducts	R-2.1	R-2.1	R-2.1	R-4.2	R-4.2	R-4.2	R-4.2	Pres Pkg.	
LEAKAGE									
Building (SLA)	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	
Duct Leakage Factor (See Table 4-13)	0.86	0.86	0.86	0.86	0.86	0.89	0.89	0.89	
FENESTRATION									
U-factor	Use Standards Table 110.6-A , §110.6 for all Vintages								
SHGC	Use Standards Table 110.6-B , §110.6 for all Vintages								
Shading Dev.	Use Table R3-27 and R3-28 for all Vintages in the Residential ACM Manual – Performance Approach								
SPACE HEATING EFFICIENCY									
Gas Furnace (Central) AFUE	0.75	0.78	0.78	0.78	0.78	0.78	0.78	0.78	
Gas Heater (Room) AFUE	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	
Hydronic/Comb Hydronic	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	
Heat Pump HSPF	5.6	5.6	6.6	6.6	6.8	6.8	6.8	7.4	
Electric Resistance HSPF	3.413	3.413	3.413	3.413	3.413	3.413	3.413	3.413	
Electric Resistance Radiant HSPF	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	
SPACE COOLING EFFICIENCY									
All Types, SEER	8.0	8.0	8.9	9.7	9.7	9.7	9.7	13.0	
WATER HEATING									
Energy Factor	0.525	0.525	0.525	0.525	0.575	0.575	0.575	0.575	

13. Appendix C: Non-Vintage Based Default Values

Input	Default Value	When to Use
Clothes Washer MEF	1.26	If Energy Guide label is not available or not found in CEC appliance database
Clothes Washer Cycles per year	295 dwelling unit 1,241 common area	Always when calculating clothes washer energy outside of HERS tab
Ballasted Lighting Fixture Wattage	See Appendix NA8 from Title 24 2008 Joint Appendices	Calculating lighting power density (LPD)
Air Conditioner Total Capacity	400 sf/ton	When nameplate total capacity is not known
Air Conditioner Sensible Capacity	0.85 * total capacity	When nameplate sensible capacity is not known
Air Conditioner Supply Fan CFM	400 cfm/ton	When nameplate cfm is not known
Supply Fan Power – Split DX/Central Furnace	0.8 W/cfm	When nameplate hp is not known
Supply Fan Power – PTAC	0.8 W/cfm	When nameplate hp is not known
Large Storage DHW Recovery Efficiency	76.0%	When not verified through approved sources
Large Storage DHW Stand-by Loss	2.0%	When not verified through approved sources
Indirect Gas-fired Boiler Pilot Loss	750 Btu/hour	Not found Energy Commission appliance database or manufacturer specifications.

14. Appendix D: Default Schedules for High-Rise

Table N2-11 – Residential Occupancy Schedules (Including Hotel/Motel Guest Rooms) Without Setback Thermostat

	Hour																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Heating (°F)	WD	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	
	SAT	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	
	Sun	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	
Cooling (°F)	WD	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	
	SAT	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	
	Sun	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	
Lights (%)	WD	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	60	80	90	80	60	30	
	SAT	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	60	80	90	80	60	30	
	Sun	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	60	80	90	80	60	30	
Equipment (%)	WD	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	60	80	90	80	60	30	
	SAT	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	60	80	90	80	60	30	
	Sun	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	60	80	90	80	60	30	
Fans (%)	WD	on																							
	SAT	on																							
	Sun	on																							
Infiltration (%)	WD	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
	SAT	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
	Sun	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
People (%)	WD	90	90	90	90	90	90	70	40	40	20	20	20	20	20	30	50	50	50	70	70	80	90	90	
	SAT	90	90	90	90	90	90	70	40	40	20	20	20	20	20	30	50	50	50	70	70	80	90	90	
	Sun	90	90	90	90	90	90	70	40	40	20	20	20	20	20	30	50	50	50	70	70	80	90	90	
Hot Water (%)	WD	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
	SAT	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
	Sun	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5

Table N2-10 – Residential Occupancy Schedules (Including Hotel/Motel Guest Rooms) with Setback Thermostat for Heating

		Hour																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating (°F)	WD	60	60	60	60	60	60	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	60	60
	SAT	60	60	60	60	60	60	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	60	60
	Sun	60	60	60	60	60	60	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	60	60
Cooling (°F)	WD	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
	SAT	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
	Sun	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
Lights (%)	WD	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	SAT	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	Sun	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Equipment (%)	WD	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	SAT	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	Sun	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Fans (%)	WD	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	SAT	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Sun	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
Infiltration (%)	WD	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	SAT	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Sun	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
People (%)	WD	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
	SAT	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
	Sun	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
Hot Water (%)	WD	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
	SAT	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
	Sun	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5

15. Appendix E: Multifamily Data Collection Forms



Multi-Family Data Collection Forms *Instructions*

Please fill out these forms as completely as possible. The information provided on this form is used to document existing conditions of a multi-family property participating in [Energy Upgrade California - Multi-Family](#) programs. This document will be used for quality assurance purposes. If you cannot fill in a field, indicate 'do not know.' If you have questions about this form, call 1-866-352-7457.

The following forms are included in this package:

1. **Project Information** - complete for each project submittal
2. **Building Information** - complete for each building on the project site
3. **Dwelling Unit** - complete for each sampled unit and each unit as entered in EnergyPro (if averaged)

- a. **Equipment**
- b. **Lighting**

Multiple sheets may be necessary if there is more than one average dwelling (e.g. one for average studios, one for average 1-bed, one for average 2-bed, etc. or just one form for all averaged dwelling units. Either is acceptable)

The following documents must be attached to this package when submitted for review to HMG:

- **Common Area documentation** - if 20% or more of the total building sf is non-residential space
- **Photos** - exterior, dwelling unit or central heating, cooling, domestic hot water
- **Sketches w/north arrow** - floor plan and dimensions; window dimensions, types, and location, overhangs, and construction assemblies (if multiple types)
- **Combustion Safety Plan**
- **Sampling Plan**



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1) MULTIFAMILY PROJECT INFORMATION FORM - 1/1

Date:	Analyst/Rater:	Cert #:			
Project Information					
Project Name:					
Project Address:					
City:	State:	Zip:			
Owner Information					
Owner/Customer Name:					
Company Address:					
Mailing Address:					
City:	State:	Zip:			
Contact:					
Work Phone:	Cell Phone:				
Email:					
Site Contact Information					
Property Manager:					
Phone:	E-mail:				
Maintenance Mngr:					
Phone:	E-mail:				
Superintendent:					
Phone:	E-mail:				
Project Characteristics					
Year Built:	Climate Zone:	# Floors:	# Occupants		
Project Area (square footage)					
Total building	Total site area	Landscaping			
Residential units	Common area	Retail/Commercial			
Building Type					
	Total # of Buildings	Total # Rental Units	Total # Ownership Units	Total # of Units	
Low-rise (<= 3 stories):					
High-rise (>=4 stories):					
Non-Residential					
Affordability (income level)					
	Low	Moderate	Market Rate		
Number of units:					
	(up to 200%)	(up to 400%)			
Dwelling Unit Meters					
	Electricity Service	Gas Service	Water	Space Heat	DHW
Individual or central:					
The following characteristics apply to the project (Check all that apply):					
<input type="checkbox"/> Live/work	<input type="checkbox"/> Historic preservation	<input type="checkbox"/> Tenant relocation required during construction			
<input type="checkbox"/> Assisted living	<input type="checkbox"/> Community facilities	<input type="checkbox"/> Building is occupied			
<input type="checkbox"/> Senior living	<input type="checkbox"/> Whole building rehab	<input type="checkbox"/> Rehab units at tenant turnover			
<input type="checkbox"/> Homeless	<input type="checkbox"/> Partial Building rehab	<input type="checkbox"/> Acquisition rehab			
<input type="checkbox"/> Other (describe)					
Utility Rate Information					
Gas Utility Provider:					Rate Schedule:
Account Number:					
Electrical Utility Provider:					Rate Schedule:
Account Number:					
Notes:					



2) MULTI-FAMILY BUILDING INFORMATION DATA COLLECTION FORM - 1/3

Date: _____

Project Name: _____

Building # _____

If any, describe which buildings are identical to the building described in this building info data collection forms:

of Floors: _____

Describe dwelling unit configuration

Unit Type and Qty: _____

Total # of Units _____

Building Plans/Sketch

a. confirm foot print dimensions close _____

b. indicate "front" of building _____

c. show north arrow _____

d. Indicate water heater locations _____

e. Indicate HVAC equipment location _____

f. indicate wall / ceiling height & specs _____

*****Attach dwelling unit data collection forms for every dwelling unit audited**

MULTI-FAMILY CENTRAL WATER HEATING

complete this only for units serving (6) or more dwelling units

	MF DWH-1	MF DWH-2	MF DWH-3
Manufacturer	_____	_____	_____
Model #	_____	_____	_____
Serial #	_____	_____	_____
Type	_____	_____	_____
Age	_____	_____	_____
Location	_____	_____	_____
Serves Bldgs	_____	_____	_____
Storage Cap (gal.)	_____	_____	_____
Input (Btu/hr)	_____	_____	_____
Recirc Control Type	<input type="checkbox"/> None <input type="checkbox"/> Timer <input type="checkbox"/> Temp <input type="checkbox"/> Demand	<input type="checkbox"/> None <input type="checkbox"/> Timer <input type="checkbox"/> Temp <input type="checkbox"/> Demand	<input type="checkbox"/> None <input type="checkbox"/> Timer <input type="checkbox"/> Temp <input type="checkbox"/> Demand
Pipe length outside	_____	_____	_____
Pipe length underground	_____	_____	_____
Pipe length in plenum	_____	_____	_____
System Description	_____	_____	_____



2) MULTI-FAMILY BUILDING INFORMATION DATA COLLECTION FORM - 2/3

Project Name: _____
 Building # _____

MULTI-FAMILY CENTRAL SPACE HEATING BOILERS

	B-1	B-2	B-3
Manufacturer	_____	_____	_____
Model #	_____	_____	_____
Serial #	_____	_____	_____
Type	_____	_____	_____
Age	_____	_____	_____
Location	_____	_____	_____
Serves Bldgs	_____	_____	_____
Storage Cap (gal.)	_____	_____	_____
Input Btu/hr	_____	_____	_____
Hot water pump HP	_____	_____	_____
Hot water pump gpm	_____	_____	_____
Piping Length (feet)	_____	_____	_____
Piping Diameter (inch)	_____	_____	_____
Piping Insulation	_____	_____	_____
System Description	_____	_____	_____

CONSTRUCTION AND WINDOWS

Reference on plan sketch and describe here

	Wall-1	Wall-2	Wall-3
Construction Type	_____	_____	_____
Cavity insulation r-value	_____	_____	_____
External insulation r-value	_____	_____	_____
Spacing if framed wall	_____	_____	_____
Description:	_____	_____	_____
	Total Wall Area by Orientation		
North	_____	_____	_____
West	_____	_____	_____
East	_____	_____	_____
South	_____	_____	_____



2) MULTI-FAMILY BUILDING INFORMATION DATA COLLECTION FORM - 3/3

CONSTRUCTION AND WINDOWS <i>cont.</i>			
Project Name:			
Building #			
	<i>Describe windows and overhangs with reference on plan sketch</i>		
	WINDOW-1	WINDOW-2	WINDOW-3
# panes			
Frame Type	<input type="checkbox"/> Metal <input type="checkbox"/> Non-Metal	<input type="checkbox"/> Metal <input type="checkbox"/> Non-Metal	<input type="checkbox"/> Metal <input type="checkbox"/> Non-Metal
U-value			
SHGC			
Rating Method	<input type="checkbox"/> NFRC <input type="checkbox"/> Default	<input type="checkbox"/> NFRC <input type="checkbox"/> Default	<input type="checkbox"/> NFRC <input type="checkbox"/> Default
	Total Window Area by Orientation and Type		
North			
West			
East			
South			
	Overhangs		
	Distance abv top of wndw	Horizontal Projection	LFT/RT exten past window
OH-1			
OH-2			
OH-3			
OH-4			
OH-5			
	Floor-1	Floor-2	Floor-3
Type	<input type="checkbox"/> Over crawl space <input type="checkbox"/> Over unconditioned <input type="checkbox"/> Slab on grade	<input type="checkbox"/> Over crawl space <input type="checkbox"/> Over unconditioned <input type="checkbox"/> Slab on grade	<input type="checkbox"/> Over crawl space <input type="checkbox"/> Over unconditioned <input type="checkbox"/> Slab on grade
Square Feet			
Slab exterior perimeter			
Framed floor joist size			
	Roof-1	Roof-2	Roof-3
Type	<input type="checkbox"/> Wood framed attic <input type="checkbox"/> Wood framed rafter <input type="checkbox"/> Concrete	<input type="checkbox"/> Wood framed attic <input type="checkbox"/> Wood framed rafter <input type="checkbox"/> Concrete	<input type="checkbox"/> Wood framed attic <input type="checkbox"/> Wood framed rafter <input type="checkbox"/> Concrete
If vaulted rafter, roof pitch			
Roofing Material	<input type="checkbox"/> Lightweight <input type="checkbox"/> Gravel <input type="checkbox"/> Concrete tile <input type="checkbox"/> Heavy <input type="checkbox"/> Very heavy	<input type="checkbox"/> Lightweight <input type="checkbox"/> Medium weight <input type="checkbox"/> Heavy weight	<input type="checkbox"/> Lightweight <input type="checkbox"/> Medium weight <input type="checkbox"/> Heavy weight
Insulation Type			
Insulation R-value			
Insulation location	<input type="checkbox"/> Ceiling <input type="checkbox"/> Roof <input type="checkbox"/> Both	<input type="checkbox"/> Ceiling <input type="checkbox"/> Roof <input type="checkbox"/> Both	<input type="checkbox"/> Ceiling <input type="checkbox"/> Roof <input type="checkbox"/> Both
Notes			



3A) MULTI-FAMILY DWELLING UNIT - EQUIPMENT FORM - 1/2

Date	
Project Name	
Building #/Address	Unit Type
Unit #	Unit Square Feet
Domestic Hot Water System	
<i>FILL OUT THIS DHW SECTION ONLY IF SERVES LESS THAN SIX (6) DWELLING UNITS</i>	
Type:	<input type="checkbox"/> Gas-fired <input type="checkbox"/> Indirect Gas <input type="checkbox"/> Electric Resistance <input type="checkbox"/> Heat Pump
Manufacturer	
Model #	
Serial #	
Input Btu/hr	
Efficiency	<input type="checkbox"/> Thermal <input type="checkbox"/> Recovery <input type="checkbox"/> Energy Factor
Storage Cap (gal.)	
Standby Loss	
External Insulation R-value	
Location	
Age	
Notes	
Air-side HVAC Systems	
Heating System Type	<input type="checkbox"/> Furnace <input type="checkbox"/> Heat Pump <input type="checkbox"/> Radiant <input type="checkbox"/> PTHP <input type="checkbox"/> PTHP <input type="checkbox"/> Fan Coil
Fuel	<input type="checkbox"/> Natural Gas <input type="checkbox"/> Electric <input type="checkbox"/> Hot Water
If furnace, type	<input type="checkbox"/> Central <input type="checkbox"/> Gravity with fan <input type="checkbox"/> Gravity no fan <input type="checkbox"/> Floor <input type="checkbox"/> Room
Manufacturer	
Model #	
Input and Output Btu/hr	
Efficiency	
Efficiency source	<input type="checkbox"/> Nameplate <input type="checkbox"/> T24 Default
Heating Distribution	<input type="checkbox"/> Dcted <input type="checkbox"/> Dctless with fan <input type="checkbox"/> Dctless no fan <input type="checkbox"/> Rad. Baseboard <input type="checkbox"/> Rad Floor <input type="checkbox"/> Conditioned <input type="checkbox"/> Outdoors <input type="checkbox"/> Crawlspace <input type="checkbox"/> Garage
Location, if ducted	<input type="checkbox"/> Basement <input type="checkbox"/> Attic Ceiling Insulated vented <input type="checkbox"/> Attic Ceiling Insulated un-vented <input type="checkbox"/> Attic Ceiling + roof Insulated
R-value	Insulation Condition
Duct Leakage @ 25CFM:	
Cooling Type	<input type="checkbox"/> None <input type="checkbox"/> Split AC <input type="checkbox"/> Split HP <input type="checkbox"/> PTAC <input type="checkbox"/> PTHP <input type="checkbox"/> Packaged AC <input type="checkbox"/> Packaged HP
Manufacturer	
Model #	
Cooling Capacity	
Efficiency and Source	<input type="checkbox"/> Nameplate <input type="checkbox"/> T24 Default
Cooling Distribution	<input type="checkbox"/> Ducted <input type="checkbox"/> Ductless <input type="checkbox"/> Conditioned <input type="checkbox"/> Outdoors <input type="checkbox"/> Crawlspace <input type="checkbox"/> Garage <input type="checkbox"/> Basement
Location, if ducted	<input type="checkbox"/> Attic Ceiling Insulated vented <input type="checkbox"/> Attic Ceiling Insulated un-vented <input type="checkbox"/> Attic Ceiling + roof
R-value	Insulation Condition
Duct Leakage @ 25CFM:	
Notes	



3A) MULTI-FAMILY DWELLING - EQUIPMENT FORM - 2/2

Date			
Project Name			
Building #/Address	Unit Type		
Unit #	Unit Square Feet		
Appliances			
Refrigerator			
Manufacturer			
Model #			
kWh/yr			
Age			
Source of efficiency	<input type="checkbox"/> Nameplate <input type="checkbox"/> Default		
Stove			
Fuel Type	<input type="checkbox"/> Gas <input type="checkbox"/> Electric		
Pilot Light	<input type="checkbox"/> Yes <input type="checkbox"/> No		
Dishwasher			
Manufacturer			
Model #			
Age:			
Energy Factor			
Source of efficiency	<input type="checkbox"/> Nameplate <input type="checkbox"/> Default		
Clothes Washer			
Fuel Type	<input type="checkbox"/> Gas <input type="checkbox"/> Electric <input type="checkbox"/> None		
Clothes Dryer			
	<input type="checkbox"/> None <input type="checkbox"/> Conditioned <input type="checkbox"/> Unconditioned		



3B) MULTI-FAMILY DWELLING UNIT - LIGHTING FORM 1/1

DWELLING UNIT DATA COLLECTION FORM				
Date				
Project Name				
Building #/Address		Unit Type		
Unit #		Unit Square Feet		
Interior Lighting				
Quantity	Type	Location		Control
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Closet <input type="checkbox"/> Bed <input type="checkbox"/> Hall/entry	<input type="checkbox"/> Living <input type="checkbox"/> Lau <input type="checkbox"/> Kit/din	<input type="checkbox"/> Switch <input type="checkbox"/> Dimmer <input type="checkbox"/> Occ Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Closet <input type="checkbox"/> Bed <input type="checkbox"/> Hall/entry	<input type="checkbox"/> Living <input type="checkbox"/> Lau <input type="checkbox"/> Kit/din	<input type="checkbox"/> Switch <input type="checkbox"/> Dimmer <input type="checkbox"/> Occ Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Closet <input type="checkbox"/> Bed <input type="checkbox"/> Hall/entry	<input type="checkbox"/> Living <input type="checkbox"/> Lau <input type="checkbox"/> Kit/din	<input type="checkbox"/> Switch <input type="checkbox"/> Dimmer <input type="checkbox"/> Occ Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Closet <input type="checkbox"/> Bed <input type="checkbox"/> Hall/entry	<input type="checkbox"/> Living <input type="checkbox"/> Lau <input type="checkbox"/> Kit/din	<input type="checkbox"/> Switch <input type="checkbox"/> Dimmer <input type="checkbox"/> Occ Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Closet <input type="checkbox"/> Bed <input type="checkbox"/> Hall/entry	<input type="checkbox"/> Living <input type="checkbox"/> Lau <input type="checkbox"/> Kit/din	<input type="checkbox"/> Switch <input type="checkbox"/> Dimmer <input type="checkbox"/> Occ Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Closet <input type="checkbox"/> Bed <input type="checkbox"/> Hall/entry	<input type="checkbox"/> Living <input type="checkbox"/> Lau <input type="checkbox"/> Kit/din	<input type="checkbox"/> Switch <input type="checkbox"/> Dimmer <input type="checkbox"/> Occ Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Closet <input type="checkbox"/> Bed <input type="checkbox"/> Hall/entry	<input type="checkbox"/> Living <input type="checkbox"/> Lau <input type="checkbox"/> Kit/din	<input type="checkbox"/> Switch <input type="checkbox"/> Dimmer <input type="checkbox"/> Occ Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Closet <input type="checkbox"/> Bed <input type="checkbox"/> Hall/entry	<input type="checkbox"/> Living <input type="checkbox"/> Lau <input type="checkbox"/> Kit/din	<input type="checkbox"/> Switch <input type="checkbox"/> Dimmer <input type="checkbox"/> Occ Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Closet <input type="checkbox"/> Bed <input type="checkbox"/> Hall/entry	<input type="checkbox"/> Living <input type="checkbox"/> Lau <input type="checkbox"/> Kit/din	<input type="checkbox"/> Switch <input type="checkbox"/> Dimmer <input type="checkbox"/> Occ Sensor
Notes				
Exterior Lighting				
Quantity	Type	Location		Control
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Garage <input type="checkbox"/> Front Entry <input type="checkbox"/> Outdoor		<input type="checkbox"/> Switch <input type="checkbox"/> Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Garage <input type="checkbox"/> Front Entry <input type="checkbox"/> Outdoor		<input type="checkbox"/> Switch <input type="checkbox"/> Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Garage <input type="checkbox"/> Front Entry <input type="checkbox"/> Outdoor		<input type="checkbox"/> Switch <input type="checkbox"/> Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Garage <input type="checkbox"/> Front Entry <input type="checkbox"/> Outdoor		<input type="checkbox"/> Switch <input type="checkbox"/> Sensor
	<input type="checkbox"/> Incand <input type="checkbox"/> CFL <input type="checkbox"/> HI Effic	<input type="checkbox"/> Garage <input type="checkbox"/> Front Entry <input type="checkbox"/> Outdoor		<input type="checkbox"/> Switch <input type="checkbox"/> Sensor
Notes				

Appendix: Version Log

Version 5:

Section 2: Program deadlines updated for 2016. All projects must complete all enrollment procedures, including the submittal of a complete application package, and successfully pass the assessment review process by **October 1, 2016**. Projects must complete construction and submit all completion documentation to MUP Staff by **November 15, 2016**.

Section 3: Approved Rater continuing education requirements updated.

Section 3: Contractor licensing requirements updated to include all 'C' Specialty licenses.

Section 4: Weatherization Measures. Clarified all performance envelope weatherization (i.e. air sealing) measures cannot be claimed for credit in the energy performance model.

Section 5: Combustion Safety. Added that if in-unit CO alarms are present and working during test-in and the scope of work includes upgrading the combustion appliance then test-in of that appliance does not need to be conducted.

Section 8: Quality Assurance. Added live assessment review requirement with Approved Rater as part of desktop review process.

Section 8: Quality Assurance. Added non-compliance corrective action matrix.

Section 9: Project Timelines: Projects must complete all enrollment procedures, including the submittal of a complete application package, and successfully pass the assessment review process by **October 1, 2016**. Projects must complete construction and submit all completion documentation to MUP Staff by **November 15, 2016**

Version 4:

Section 2: Added Program Summary from Customer Handbook.

Section 3: Upgrade Recommendation: Low-flow fixtures are an eligible measure and the rater must calculate savings using the program approved work paper. The existing condition baseline may be established using nameplate or flow bag measurement.

Section 4: Combustion Safety: Changed testing of central mechanical equipment to allow for sampling for consistency with Figure 4.

Section 4: Combustion Safety: Clarified definition of outdoor equipment.

Version 3:

Section 3: Upgrade Recommendations: Fuel switching upgrades are not eligible in the Multifamily Upgrade Program. If there is a plan to change the fuel source of an upgrade in the Multifamily Upgrade Program, the rater shall exclude the measure from the energy model.

Section 4: Combustion Safety: Changed language regarding combustion safety testing of central equipment to include test-in sampling protocol to align with HERCC protocol.

Appendices: Changed Duct Leakage HERS credits table to explicitly allow Sealed Ducts and Low Leakage AHU HERS measures. Removed requirement to use input values de-rated to 50% of tested numbers. Added clarification that HVAC systems with ducts in unconditioned space shall be modeled separately from HVAC systems with ducts in conditioned space. Added clarification that duct leakage values can be sampled at test-in and averaged for modeling purposes.

Version 2:

All Sections: All references to “Partner Rater” or “Partner Contractor” are replaced with “Approved Rater” or “Approved Contractor” respectively.

All Sections: All references to “Program Staff” and “TRC Program Staff” are replaced with “MUP Staff”.

Section 1: All references to a participant’s “project team” are defined as a team consisting of an Approved Rater and an Approved Contractor.

Section 2: Partner qualification: added policy for rater and contractor serving as a single company.

Section 2: Approved Contractors: An A or B-General Building Contractor License may be supplied by the Partner Contractor to cover all scopes.

Section 2: Approved Contractors: Proof of insurance requirements added.

Section 3: All references to Multifamily Upgrade Program Staff are defined as staff at TRC Energy Services and replaced with “MUP Staff”.

Section 3: Upgrade Recommendations: Any project that is considered new construction by code are not eligible to participate in the Multifamily Upgrade Program.

Section 3: Assessments: Removed Table 4, replaced with “All upgrades must be in compliance with current California building codes and installed to manufacturer specifications.”

Section 3: Assessments: Added language to Upgrades for Minimum 10% Improvements subsection stating that solar thermal is not an eligible measure in MUP.

Section 4: Combustion Safety: Added last two bullet points to Limitation and Exclusions subsection to reflect revised HERCC protocols. Language focuses on clarification of exiting protocols.

Section 4: Combustion Safety: Changed Testing Protocols to Testing Parameters to better capture section contents.

Section 7: Desktop Review: Added required cost information for each energy upgrade measure in the Multifamily Upgrade Program project scope of work needed for completion review (test-out).

Section 8: Added Project Milestones and Timelines section

Appendices: Added California Multifamily Retrofit Energy Modeling Guidelines