New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Multifamily Programs

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Prepared for

New York Department of Public Service
3 Empire State Plaza, 8th Floor
Albany, New York 12223

Prepared by:
New York Evaluation Advisory Contractor Team
Nick Hall, Pete Jacobs, Paul Horowitz,
Rick Ridge, Gil Peach, Ralph Prahl

TecMarket Works
165 West Netherwood Road, Suite A
Oregon, WI 53575
Voice: (608) 835-8855
Fax: (608) 835-9490

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INTRODUCTION

This document presents the measure-specific energy and demand savings estimation approach to be used by organizations delivering energy efficiency programs to the citizens of New York that are funded via the Systems Benefits Charge. As evaluations are conducted the approaches will be revised and up-dated so that they move toward high levels of estimation accuracy.

LIFE-CYCLE SAVINGS

The energy savings methodologies presented in this manual are designed to provide first year annual gross energy savings. To calculate life-cycle savings, the annual first year energy savings must be multiplied by the measure life. For program savings purposes, we believe that measure life should represent not only the engineering/rated life of the product but also the degree to which the product might be removed before its rated life. We thus propose that the term "measure life" be consistent with that used in the *Measure Life Report* prepared by GDS Associates for the New England State Program Working Group (SPWG):[1]

"For programs delivered by program administrators in New England, Measure Life includes equipment life and measure persistence (not savings persistence).

- Equipment Life means the [mean] number of years that a measure is installed and will operate until failure, and
- Measure Persistence takes into account business turnover, early retirement of installed equipment, and other reasons measures might be removed or discontinued."

This approach is consistent with the approach taken by the California Database for Energy Efficiency Resources (DEER). The DEER study includes recommendations on effective useful life (EUL). The EUL is an estimate of the point in time when 50% of the measures are expected to be removed or no longer functional, which includes the effects of measure persistence and technical degradation. The measure life assumptions to be used in this manual are shown in the Table below.

[1] GDS Associates, Inc. (2007) *Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures*. Prepared for The New England State Program Working Group for use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM).

Table 1. Measure Life Estimates

Measure	Sector	Effective Useful Life	Source
CFL	Residential	Coupon - 5 Direct Install - 7 Markdown - 7	New England SPWG[1]
CFL LIGHT FIXTURE	Residential	7	Residential Lighting Measure Life Study[2]
ELECTRIC HEAT PUMP WATER HEATER	Residential	10	DEER[3]
CENTRAL AIR CONDITIONING	Residential	15	DEER
CENTRAL HEAT PUMPS	Residential	15	DEER
REFRIGERANT CHARGE CORRECTION	Residential	10	DEER
Refrigerator	Residential	12	DEER
Room air conditioners	Residential	10	DPS
Geothermal Heat Pump	Residential	20	DPS
Master metering	Residential	14	DPS
Clothes washers	Residential	14	NWPPC
Showerheads	Residential	10	CA 2001 LIEEP evaluation and others
Aerators	Residential	10	CA 2001 LIEEP evaluation

EARLY REPLACEMENT

For early replacement of operating but older measures, the remaining useful life (RUL) of the existing equipment must be considered. The measure savings are calculated in a two step process as follows:

1. Calculate savings using the existing equipment efficiency as the baseline over the remaining life of the existing equipment.
2. After the existing equipment has reached the end of its remaining useful life, calculate savings using normal replacement efficiency as the baseline over the remaining effective useful life of the new equipment.

For example, savings calculations for early replacement of an air conditioner with 5 years of remaining useful life with a SEER 15 new air conditioner are as follows:

[2] Residential Lighting Measure Life Study, prepared for the New England Residential Lighting Program Sponsors by Nexus Market Research Inc. and RLW Analytics Inc., June 4, 2008.
[3] Effective Useful Life tables to be used by California IOUs for 2009-2011 program cycle planning. From the California DEER website: www.deeresources.com

- The SEER of the existing air conditioner is estimated to be 10 SEER. The savings for the first five years would be evaluated using the efficiency of the new air conditioner (15 SEER) against a baseline 10 SEER air conditioner.
- After the original air conditioner reached the end of its remaining life, the savings would be evaluated for the remaining 10 years of the life of the new air conditioner (15yr EUL minus 5 yr RUL), evaluated using the efficiency of the new air conditioner (15 SEER) against a normal replacement baseline of 13 SEER.

NET TO GROSS ADJUSTMENTS

The savings approaches presented in this manual provide gross energy saving estimates and specify the approaches for obtaining those estimates. The New York Department of Public Service policy specifies that savings projections used for predicting energy savings will be net savings. To arrive at net savings the gross estimates presented in this manual must be adjusted to account for free riders and spillover.

Free rider adjustments act to erode the gross savings estimate by subtracting the savings that would have occurred without the program's incentive or influence. Spillover adjustments act to increase savings by counting the additional savings that occur as a result of two possible conditions. First, participants can replicate that same action (participant spillover) outside of the program participation process, providing additional savings. Second, the program can influence the way non-participants make energy saving decisions that result in additional savings not associated with a specific participation event. Together, the subtraction of savings for free riders, plus the addition of savings for spillover tend to offset each other to a significant degree. As a result, for the purposes of estimating program impacts, the savings estimates presented in this manual, or the savings produced using the calculation approaches described in this manual, must be multiplied by 0.90 to arrive at an estimated net energy savings for each measure.

As program evaluations are completed this factor will be adjusted up or down, as appropriate by program, for each measure included in this manual. Over time, the adjustment factor will evolve to be more accurate and will be focused on specific types of programs and delivery approaches. At the current time, to standardize the net impact estimation approach, a net to gross conversion factor of 0.90 will be applied to the gross saving estimates.

CFL

Measure Description

An Energy Star compliant screw-based CFL whose wattage is known. Programs with this characteristic include direct install, catalog, instant and mail-in coupon, and programs such as negotiated cooperative promotions in which product sales at the retail level are reported. The approach below excludes outdoor and common area applications, which tend to have longer run times.

Savings Estimation Approach

Annual Energy Savings = Δ Watts x Hours x Days-per-Year/1000

Variables and Assumptions
1) Δ Watts (delta watts) – the difference between the lamp that is installed (replacement bulb) or would have been installed (new bulb) and the higher efficiency CFL.

Because the purchase of light bulbs is diffuse, through many product sources (drug stores, supermarkets, hardware stores, discount stores, etc.), and because light bulbs are purchased by large numbers of people, it is not practical to obtain information directly from consumers about the wattage of the baseline bulb (what is being replaced or what would have been used instead of the CFL). The alternative approach is to use a method that avoids the determination of the baseline for each recorded CFL by assuming that the CFL purchased is one of the standard replacement products for the incandescent, in terms of light output equivalency (see http://www.energystar.gov/index.cfm?c=cfls.pr_cfls). The method is to assume that the baseline is an incandescent light source with a wattage which is 3.4 times higher than the wattage of the CFL - the general relationship between the equivalency values of incandescents and CFLs. For dimmable or three-way CFLs, assume the highest wattage/setting when calculating the baseline equivalent.

Δ Watts = 2.4 x CFL wattage. This is based on an "incandescent to CFL" wattage ratio of 3.4 to 1.

2) Hours of lamp use per day

Hours = 3.2 Hours per day

The 3.2 hours of use per day is a value derived from an extended (nine month – May through February) logger study conducted during 2003 in Massachusetts, Rhode Island, and Vermont.[4] The Connecticut 2008 Program Savings Documentation uses 2.6 hours per day, based on a 2003 Connecticut-based study. A study of the 2005-2006 residential

[4] "Extended residential logging results" by Tom Ledyard, RLW Analytics Inc. and Lynn Heofgen, Nexus Market Research Inc., May 2, 2005, p.1.

lighting program for Efficiency Maine reports daily hours of use at 4.8 hours from the markdown program component and 3.2 from the coupon program component.[5] This value represents a trade-off among factors which may affect the extent to which any out-of New York State value is applicable to NY. These include such factors as differences among the study area and NYS related to maturity of the CFL markets, program comparability, consumer knowledge of CFLs, and mix of locations within the house (which affects average hours of use). On balance, in considering the data and reports reviewed to date, 3.2 appears to be the most reasonable value until New York specific data are available. .

3) Days per year during which the CFL is on.
Without any indication to the contrary it is assumed that the CFL is used 365 days per year.

The following chart can be used to derive annual savings for various size CFLs. This uses the assumed values above to provide the annual kWh savings. Note that actual CFL wattage should be used to calculate energy savings; using a default average could lead to a large margin of error.

CFL Wattage	Annual kWh Savings	**CFL Wattage**	Annual kWh Savings
7	19.6	**19**	53.3
8	22.4	**20**	56.1
9	25.2	**21**	58.9
10	28.0	**22**	61.7
11	30.8	**23**	64.5
12	33.6	**24**	67.3
13	36.4	**25**	70.1
14	39.2	**26**	72.9
15	42.0	**27**	75.7
16	44.9	**28**	78.5
17	47.7	**29**	81.3
18	50.5	**30**	84.1

Demand Savings
The demand savings here represent the level of reduction in demand at the time of system peak. They are typically calculated for a portfolio of installed or planned installations of lighting products rather than a single lamp. The calculation, however, is the same. Demand savings are calculated by multiplying the kW difference between the wattage or total load of the energy efficient product(s) and that of the baseline product(s), or delta

[5] Process and Impact Evaluation of the Efficiency Maine Lighting Program, RLW Analytics, Inc, and Nexus Market Research Inc., April 10, 2007, Table 1-2, p. 12.

watts, by the coincidence factor that reflects the amount of that demand which is in use at the time of system peak. The coincidence factors presented below are used to adjust the maximum delta watts into a demand value that is coincident to the specified peak summer and winter periods.[6]

Demand savings = delta watts x coincidence factor

The coincidence factors presented were derived from an examination of studies throughout New England that calculated coincident factors based on the definition of system peak period at the time, as specified by the New England Power Pool and later, ISO-New England.

Lighting Summer On-Peak Hours (1PM-5PM)	Coincidence Factor
June	0.07
July	0.09
August	0.09
Average Summer	0.08

Lighting Winter On-Peak Hours (5pm – 7pm)	Coincidence Factor
December	0.28
January	0.32
Average Winter	0.30

References/Sources Reviewed

1. This method is based on the documentation provided in the CL&P and UI Program Savings Documentation for 2008 Program Year. Other similar reports under review include the Efficiency Vermont and Efficiency Maine Technical Reference User Manuals.
2. Impact evaluations of residential lighting programs in several New England states reviewed in preparing the proposed hours-of-use values and coincidence factors include:

   Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs, prepared for Cape Light Compact, Vermont Public Service Department, National Grid Massachusetts and Rhode Island, Western Massachusetts Electric Company, NSTAR Electric, Fitchburg G&E by Nexus Market Research Inc., and RLW Analytics Inc., Oct 1, 2004

[6] Coincidence Factor Study Residential and Commercial & Industrial Lighting Measures - For use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM), prepared for the New England State Program Working Group by RLW Analytics Inc., Spring 2007, p. III.

"Extended residential logging results" memo to Angela Li, National Grid, by Tom Ledyard, RLW Analytics Inc., and Lynn Hoefgen, Nexus Market Research Inc., May 2, 2005

Market Progress and Evaluation Report for the 2005 Massachusetts ENERGY STAR Lighting Program, prepared for Cape Light Compact, National Grid – Massachusetts, NSTAR, Western Massachusetts Electric Company by Nexus Market Research Inc, RLW Analytics, Inc., Shel Feldman Management Company, Dorothy Conant. September 29, 2006

Process and Impact Evaluation of the Efficiency Maine Lighting Program, prepared for Efficiency Maine by Nexus Market Research Inc. and RLW Analytics Inc., April 10, 2007

Coincidence Factor Study Residential and Commercial & Industrial Lighting Measures - For use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM), prepared for the New England State Program Working Group by RLW Analytics Inc., Spring 2007

CFL LIGHT FIXTURE

Measure Description

An Energy Star hardwired interior fluorescent fixture with a pin based CFL whose wattage is known. Programs focusing on installation of fixtures include new construction and major renovation programs. Fixtures with screw-based CFLs are treated as CFLs for savings calculations. The approach below excludes outdoor and common area applications, which tend to have longer run times.

Savings Estimation Approach

Annual Energy Savings = Δ Watts x Hours x Days-per-Year/1000

Variables and Assumptions
1) Δ Watts (delta watts) – the difference between the bulb that is installed (replacement bulb) or would have been installed (new lamp) and the higher efficiency CFL.

Because light bulb purchases are diffuse, made from many sources (drug stores, supermarkets, hardware stores, discount stores, etc.), and by large numbers of people, it is not practical to obtain information directly from consumers about the wattage of the baseline bulb (what is being replaced or what would have been used instead of the CFL). The alternative approach is to use a method that avoids the determination of the baseline for each recorded CFL by assuming that that the CFL purchased is one of the standard replacement products for the incandescent, in terms of light output equivalency (see http://www.energystar.gov/index.cfm?c=cfls.pr_cfls). The method is to assume that the baseline is an incandescent light source with a wattage that is 3.4 times higher than the wattage of the CFL - the general relationship between the equivalency values between incandescents and CFLs. For dimmable or three-way CFLs, assume the highest wattage/setting when calculating the baseline equivalent.

Δ Watts = 2.4 x CFL wattage. This is based on an "incandescent to CFL" wattage ratio of 3.4 to 1.

2) Hours of fixture use per day

Hours = 2.5 Hours per day

The 2.5 hours of use per day is a value derived from an extended (nine month – May through February) logger study conducted during 2003 in Massachusetts, Rhode Island, and Vermont.[7] The Connecticut 2008 Program Savings Documentation uses 2.6 hours per day, based on a 2003 Connecticut-based study. A study of the 2005-2006 residential

[7] "Extended residential logging results" by Tom Ledyard, RLW Analytics Inc. and Lynn Heofgen, Nexus Market Research Inc., May 2, 2005, p.1.

lighting program for Efficiency Maine reports daily hours of use at 2.4 for interior fixtures.[8] The proposed value represents a trade-off among factors which may affect the extent to which any out-of New York State value is applicable to NY. These include such factors as differences among the study area and NYS related to maturity of the CFL markets; program comparability; consumer knowledge of CFLs; and mix of locations within the house (which affects average hours of use). On balance, in considering the data and reports reviewed to date, 2.5 appears to be the most reasonable value until New York-specific data are available.

3) Days per year during which the fixture is on.

Without any indication to the contrary it is assumed that the fixture is used 365 days per year.

The following chart can be used to derive annual savings for various size CFL fixtures. This uses the assumed values above to provide the annual kWh savings. Note that actual lamp wattage should be used to calculate energy savings; using a default average could lead to a large margin of error.

CFL Wattage	Annual kWh Savings	**CFL Wattage**	Annual kWh Savings
7	15.3	**19**	41.6
8	17.5	**20**	43.8
9	19.7	**21**	46.0
10	21.9	**22**	48.2
11	24.1	**23**	50.4
12	26.3	**24**	52.6
13	28.5	**25**	54.8
14	30.7	**26**	56.9
15	32.9	**27**	59.1
16	35.0	**28**	61.3
17	37.2	**29**	63.5
18	39.4	**30**	65.7

Demand Savings

The demand savings here represent the level of reduction in demand at the time of system peak. They are typically calculated for a portfolio of installed or planned installations of lighting products rather than a single lamp. The calculation, however, is the same. Demand savings are calculated by multiplying the kW difference between the wattage or total load of the energy efficient product(s) and that of the baseline product(s), or delta

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watts, by the coincidence factor that reflects the amount of that demand which is in use at the time of system peak. The coincidence factors presented below are used to adjust the maximum delta watts into a demand value that is coincident to the specified peak summer and winter periods.[9]

Demand savings = delta watts x coincidence factor

The coincidence factors presented were derived from an examination of studies throughout New England that calculated coincident factors based on the definition of system peak period at the time, as specified by the New England Power Pool and later, ISO-New England.

Lighting Summer On-Peak Hours (1PM-5PM)	Coincidence Factor
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Lighting Winter On-Peak Hours (5pm – 7pm)	Coincidence Factor
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Average Winter	0.30

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Coincidence Factor Study Residential and Commercial & Industrial Lighting Measures - For use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM), prepared for the New England State Program Working Group by RLW Analytics Inc., Spring 2007

ACES: Default Deemed Savings Review Final Report for State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation, prepared by Ron Swager and Chris Burger, Patrick Engineering for PA Government Services Inc., June 24, 2008

REFRIGERATORS

Description of Measure

This section covers energy-efficient multi-family residential refrigerators and freezers. High-efficiency refrigerators and freezers save energy and demand through improved compressor design, better case wall insulation, improved door seals, and improvements to defrost and anti-sweat heater controls.

The approach for estimating the savings from multi-family refrigerators replaced by an energy efficiency program are based on early short-term in situ participant field metering. This approach is established because of the wide variance in potential savings from refrigerator/freezer replacement programs that are significantly influenced by the conditions associated with the typical participating facility as well as the program implementation approach. As a result, the application of the short-term metering approach is expected to produce savings ranging from a low of 300 kWh per unit, to a high of 2,000 kWh per unit. Programs that focus their operations on replacing only the most energy inefficient units will achieve savings near the upper end of this estimated savings range. Programs that do not distinguish the replacement need for each individual unit are expected to have savings near the lower end of this range.

Annual Energy and Demand Savings

To estimate annual savings, the program administrators will select a representative sample of refrigerator/freezer units to be replaced from each participating multi-family facility. The sample should represent the typical type, size, and age of the units to be replaced within each facility. The program administrators will then conduct short term metering on a small sample within each participating facility to establish the projected energy savings from that facility. This effort will be completed early in the program participation process prior to replacements being made at each facility. It is up to the program administrators to identify a sample of refrigerators and freezers within each facility and to select the sample size for the estimation process so that the resulting estimated savings can be expected to be representative of each participating facility. The program administrators are free to set the sample size as long as that sample is no less than the size specified in the following table.

Table 2 Multi-family refrigerator-freezer short term metering minimum sample size

Number of units expected to be replaced per facility	Minimum short term metering sample (refrigerators and freezers sampled separately using same sampling approach)
10 or less	3*
11 to 20	4
21-50	6
51- 100	8
100-150	10
150-200	12
200-300	17
300 or more	20

*If less than 3 units are projected to be replaced in a facility, sample all units projected to be replaced

For facilities that have identical refrigerators or freezers (same make, model, year, size) within each facility, the sample can be small. For facilities that have a wide mix of brands, models, sizes, and ages, the sample should be selected to represent that diversity. In these cases the sample size may need to be larger. However, in no case does the sample *need* to be above 20 units for a participating facility. The evaluation efforts will more accurately estimate ex-post savings as the studies are designed, approved by DPS, and implemented.

Program administrators are free to increase the sample size if they elect to have a more rigorous sampling and estimation process. However, care should be exercised to so that the sampled units can be expected to be representative of the typical unit replaced by the program in terms of unit size, age, and design.

Once the sample size and representative units are identified, program administrators will then install short term metering on that sample to obtain a baseline from which savings can be estimated. The metering approach will be conducted in accordance with the following approach:

The units are to be tested as functioning within the multi-family unit (in situ). The program will arrange for a skilled metering professional to conduct the metering test. The metering professional will install a digital power meter directly into the refrigerator's/freezer's power cord. The metering equipment can be selected by the program administrator; however, it should be able to record both kW (instantaneous demand) and kWh (energy consumption) and record the number of minutes the unit is being metered. The professional should confirm that the meter has been calibrated according to the manufacturer's recommendations. The meter should be set to zero at the beginning of each test. The test shall be conducted for a period of time of no less than 2 hours. At least 2 hours is required to allow the units to stabilize and cycle. While more time would allow increased accuracy, 2 hours is enough time to estimate the amount of energy typically consumed by the unit over a year or 8,760 hours. The resulting total kWh consumed over the metering period will be divided by the number of metering hours

and then multiplied by 8760 (hours per year). The resulting energy use calculation will be set for the baseline energy consumption for that metered unit.

Similarly, the unit's average operating baseline demand (kW) will be estimated by dividing the accumulated kWh during the test by the duration of the test (in hours).

The following steps will be used in the metering approach.

Metering Steps

1. *Open door and record the following data:*

   Brand _____

   Model Number _____ *Size* _____*cu ft*

   *Serial Number*_____
2. *Close Door after compressor comes on and note wattage. (Remember to zero the watt meter before starting.) Record running compression wattage:*

   _____ *watts*
3. *Let operate normally for two hours or more with door closed and record the total metering minutes and the kWh reading.*

   *Total Minutes:*_____ *Total kWh Reading:* _____
4. *Calculate and record Annual Estimated Energy Consumption* ____ *kWh and Average Demand s* _____ *kW*

The tests of the new program installed units can be conducted by an independent metering professional acquired to conduct the tests, by a testing laboratory hired to conduct the tests, or by applying test results conducted by independent organizations that have no conflicting relationship with the program administrator or with refrigerator/freezer manufactures, distributors, dealers, retailers or associated trade organizations. (For example, this data can be acquired from USDOE Energy Star test results, from Consumers Union, or from other independent testing organizations.)

If independent testing is selected, short term metering on no less than three new units for each size and type of units to be installed by the program shall be conducted. Should the results of these tests show a greater than 12% difference in the energy consumption levels across the three units, the test will be repeated with three different units and the six test results will be averaged. If the test results are within a 12% spread across the three units, the average of the test results will be used for the energy consumption of the new units.

In conducting the energy and demand savings estimation efforts using the above described approach the program administrators should make every reasonable effort to

have the units tested (old and new) in a way that the results are representative of the size, age, and type of units being removed and replaced.

Summer Peak Demand and Energy Savings

$$\Delta kW_s = units \times \left[\overline{kW}_{base} - \overline{kW}_{ee}\right] \times CF_s \times (1 + HVAC_{d,\,s})$$

$$\Delta kWh = units \times \left[\overline{kW}_{base} - \overline{kW}_{ee}\right] \times 8760 \times (1 + HVAC_c)$$

$$\Delta therm = units \times \left[\overline{kW}_{base} - \overline{kW}_{ee}\right] \times 8760 \times HVAC_g$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
$\Delta therm$	= gross annual gas impacts from heating system interactions
units	= number of refrigerators or freezers installed under the program
$\overline{kW}_{base}$	= average kW of existing refrigerator during monitoring period
$\overline{kW}_{ee}$	= average kW of replacement refrigerator during monitoring period
CF	= coincidence factor
$HVAC_c$	= HVAC system interaction factor for annual energy consumption
$HVAC_d$	= HVAC system interaction factor at utility peak hour
$HVAC_g$	= HVAC system interaction factor for annual gas consumption
8760	= conversion factor (hr/yr)

Operating Hours

The equations above assume the refrigerator/freezer is operating year round. The cycling of the compressor is considered in the annual energy consumption and compressor duty cycle run time.

Incremental Cost

The incremental cost of a program installed refrigerator is considered to be one that meets Energy Star standards and is estimated to be $75.

HVAC Interactions

Efficient refrigerators reject less heat into the conditioned space, which must be made up by the space heating system, but can also provide savings on cooling loads. Calculations must include space heating interactions with efficient refrigerators. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in the Tables below:

Multifamily Low-rise Building

HVAC Type: Split AC/gas furnace

City	Vintage	$HVAC_c$	$HVAC_d$	$HVAC_g$
Albany	Average	0.020	0.128	-0.017
Albany	Old	0.015	0.141	-0.015
Binghamton	Average	0.003	0.137	-0.018
Binghamton	Old	0.000	0.140	-0.016
Buffalo	Average	0.014	0.142	-0.017
Buffalo	Old	0.008	0.145	-0.015
Massena	Average	0.015	0.158	-0.018
Massena	Old	0.011	0.162	-0.016
NYC	Average	0.055	0.136	-0.016
NYC	Old	0.052	0.138	-0.014
Syracuse	Average	0.017	0.140	-0.018
Syracuse	Old	0.016	0.142	-0.014

HVAC Type: Split heat pump

City	Vintage	$HVAC_c$	$HVAC_d$	$HVAC_g$
Albany	Average	-0.140	0.150	0.000
Albany	Old	-0.134	0.156	0.000
Binghamton	Average	-0.178	0.151	0.000
Binghamton	Old	-0.155	0.144	0.000
Buffalo	Average	-0.143	0.157	0.000
Buffalo	Old	-0.139	0.150	0.000
Massena	Average	-0.161	0.181	0.000
Massena	Old	-0.157	0.170	0.000
NYC	Average	-0.064	0.163	0.000
NYC	Old	-0.054	0.177	0.000
Syracuse	Average	-0.160	0.150	0.000
Syracuse	Old	-0.108	0.185	0.000

HVAC Type: Split AC / electric furnace

City	Vintage	$HVAC_c$	$HVAC_d$	$HVAC_g$
Albany	Average	-0.329	0.128	0.000
Albany	Old	-0.307	0.141	0.000
Binghamton	Average	-0.384	0.137	0.000
Binghamton	Old	-0.338	0.140	0.000
Buffalo	Average	-0.332	0.142	0.000
Buffalo	Old	-0.313	0.145	0.000
Massena	Average	-0.349	0.158	0.000
Massena	Old	-0.321	0.162	0.000
NYC	Average	-0.260	0.136	0.000
NYC	Old	-0.232	0.138	0.000
Syracuse	Average	-0.361	0.140	0.000
Syracuse	Old	-0.272	0.142	0.000

HVAC Type: Electric heat no AC

City	Vintage	$HVAC_c$	$HVAC_d$	$HVAC_g$
Albany	Average	-0.363	0.000	0.000
Albany	Old	-0.341	0.000	0.000
Binghamton	Average	-0.407	0.000	0.000
Binghamton	Old	-0.361	0.000	0.000
Buffalo	Average	-0.359	0.000	0.000
Buffalo	Old	-0.341	0.000	0.000
Massena	Average	-0.377	0.000	0.000
Massena	Old	-0.348	0.000	0.000
NYC	Average	-0.320	0.000	0.000
NYC	Old	-0.291	0.000	0.000
Syracuse	Average	-0.391	0.000	0.000
Syracuse	Old	-0.307	0.000	0.000

HVAC Type: Gas Heat, no AC

City	Vintage	$HVAC_c$	$HVAC_d$	$HVAC_g$
Albany	Average	-0.014	0.000	-0.017
Albany	Old	-0.019	0.000	-0.015
Binghamton	Average	-0.020	0.000	-0.018
Binghamton	Old	-0.024	0.000	-0.016
Buffalo	Average	-0.014	0.000	-0.017
Buffalo	Old	-0.019	0.000	-0.015
Massena	Average	-0.013	0.000	-0.018
Massena	Old	-0.017	0.000	-0.016
NYC	Average	-0.005	0.000	-0.016
NYC	Old	-0.007	0.000	-0.014
Syracuse	Average	-0.013	0.000	-0.018
Syracuse	Old	-0.020	0.000	-0.014

HVAC Type: PTAC

City	Vintage	$HVAC_c$	$HVAC_d$	$HVAC_g$
Albany	Average	-0.299	0.198	0.000
Albany	Old	-0.313	0.172	0.000
Binghamton	Average	-0.348	0.182	0.000
Binghamton	Old	-0.361	0.198	0.000
Buffalo	Average	-0.333	0.211	0.000
Buffalo	Old	-0.352	0.240	0.000
Massena	Average	-0.348	0.184	0.000
Massena	Old	-0.365	0.201	0.000
NYC	Average	-0.226	0.220	0.000
NYC	Old	-0.247	0.173	0.000
Syracuse	Average	-0.294	0.224	0.000
Syracuse	Old	-0.308	0.218	0.000

HVAC Type: PTHP

City	Vintage	$HVAC_c$	$HVAC_d$	$HVAC_g$
Albany	Average	-0.228	0.198	0.000
Albany	Old	-0.227	0.172	0.000
Binghamton	Average	-0.264	0.182	0.000
Binghamton	Old	-0.261	0.198	0.000
Buffalo	Average	-0.237	0.211	0.000
Buffalo	Old	-0.246	0.240	0.000
Massena	Average	-0.279	0.184	0.000
Massena	Old	-0.282	0.201	0.000
NYC	Average	-0.128	0.220	0.000
NYC	Old	-0.125	0.173	0.000
Syracuse	Average	-0.223	0.224	0.000
Syracuse	Old	-0.227	0.218	0.000

Multifamily High-rise Building

HVAC Type: Fan coil system with central electric chiller and gas hot water boiler

City	Vintage	$HVAC_c$	$HVAC_d$	$HVAC_g$
Albany	Average	0.086	0.121	-0.114
Albany	Old	0.076	0.112	-0.118
Binghamton	Average	0.073	0.121	-0.137
Binghamton	Old	0.062	0.112	-0.112
Buffalo	Average	0.078	0.121	-0.091
Buffalo	Old	0.062	0.112	-0.127
Massena	Average	0.079	0.121	-0.176
Massena	Old	0.071	0.112	-0.106
NYC	Average	0.102	0.121	-0.143
NYC	Old	0.090	0.112	-0.139
Syracuse	Average	0.013	0.121	-0.153
Syracuse	Old	0.078	0.112	-0.105

Lifetime Energy Savings

The lifetime energy savings is the total savings that is expected to be achieved by the program over the effective remaining life of the replaced units. This estimate is projected by multiplying the annual energy savings from the replaced unit by the number of years the old unit is expected to remain in service in that multi-family unit. In order to simplify this calculation the remaining useful life of the replaced units is set at 10 years.

Revision Number

0

CLOTHES WASHERS

Measure Description

Residential clothes washers meeting the minimum qualifying efficiency standards established under the Energy Star Program. The washers are assumed to be located within the residential unit, not commercial washer in a common area laundry room.

Savings Estimation Approach[10]

A description of how to calculate lifetime savings using these data is presented in the lifetime savings section below.

Annual Energy Savings

For new clothes washer units and for early retirement units the table below shows , the savings in electricity resulting from the installation of energy efficient clothes washers that meet Energy Star and CEE Tier 3 standards, in comparison to a minimum federal standard clothes washer. The electric savings are those associated with the electric water heater that is needed less to heat the efficient clothes washer than the standard unit. The gas savings are those associated with the gas-fired hot water heater that is needed less to heat the efficient clothes washer than the standard unit. The more efficient clothes washer also yields reduced use of electricity and water in the clothes washer itself, and these too are in the table below. The savings presented are taken directly from the CL&P and UI document noted above, some of which are derived directly from the EPA savings calculator[11]. The number of wash cycles per year is 392, and is used to interpolate the results from the EPA savings calculator to derive the Energy Star unit savings.

Table 1 - Annual Energy and Resource Savings

Clothes Washer Specifications[12]		Savings from Hot Water Heater		Savings from Clothes Washer	
	MEF	Natural Gas (Ccf)	Electric (kWh)	Electric (kWh)	Water (Gallons)
Savings - New Units					
Base Line	1.26	-	-	-	-
Energy Star	1.72	2.16	38	15	6,993
CEE Tier 3	2.2	4.03	71	22.4	7,397
Savings - Early Retirement					
Typical washer	-	-	-	-	-
Energy Star	1.72	9.36	165	50	9,932
CEE Tier 3	2.2	11.23	197	57.4	10,336

[10] This methodology is derived from CL&P and UI Program Savings Documentation for 2008 Program Year, pp. 155-156.
[11] See http://www.energystar.gov/ia/partners/manuf_res/downloads/2007CW_SavingsCalculator.pdf
[12] See http://www.cee1.org/resid/seha/rwsh/reswash_specs.pdf

Lifetime Energy Savings

Lifetime savings are shown in Table 2. For a new clothes washer (not replacing an existing operating unit), the measure life is 14 years, reported in the CL&P and UI document and in other sources.[13] Lifetime natural gas, electricity, and water savings are the product of the savings shown in the upper portion of Table 1 and the measure life, 14 years.

For early retirement of operating but older units, the measure life of the new clothes washer remains 14 years. However, the savings for the first four years are calculated based against the resource use of the old, replaced washer (under the assumption that the old washer would have been used another 4 years) and for the remaining 10 years the savings are calculated against the resource use of the federal standard clothes washer.

Table 2 - Lifetime Energy and Resource Savings

Clothes Washers Specifications		Savings from Hot Water Heater		Savings from Clothes Washer	
	MEF	Natural Gas (Ccf)	Electric (kWh)	Electric (kWh)	Water (Gallons)
Savings - New Units					
Base Line	1.26			0	0
Energy Star	1.72	30.2	531	210	97,902
CEE Tier 3	2.2	56.4	992	314	103,558
Savings - Early Retirement					
Typical washer	-			0	0
Energy Star	1.72	59.0	1037	350	109,658
CEE Tier 3	2.2	85.2	1498	454	115,314

Demand Savings

Apply coincidence factors to the energy savings:
Coincidence factors for electric use:
kW = CF * kWh savings

Based on data from the Efficiency Vermont TRM[14], CF = .06

[13] See, for example, the Northwest Power & Conservation Council, www.nwcouncil.org/energy/rtf/supportingdata/CRDiscountCalc.xls
[14] Technical Reference User Manual (TRM) No. 4-19, Efficiency Vermont, 9/5/2003

OPAQUE SHELL INSULATION

Description of Measure

This section covers improvements to the thermal conductance of the opaque building shell, which includes upgrading insulation in walls, roofs, and so on. Energy and demand saving are realized through reductions in the building heating and cooling loads.

Method for Calculating Summer Peak Demand and Energy Savings

Gross Summer Coincident Demand Savings

$\Delta kW_S = SF \times (\Delta kW/SF) \times DF_S \times CF_S$

Gross Annual Energy Savings

$\Delta kWh = SF \times (\Delta kWh/SF)$

$\Delta therm = SF \times (\Delta therm/SF)$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
SF	= insulation square feet installed
DF	= demand diversity factor
CF	= coincidence factor
ΔkW/SF	= electricity demand savings per square foot of insulation installed
ΔkWh/SF	= electricity consumption savings per square foot of insulation installed
Δtherm/SF	= gas consumption savings per square foot of insulation installed

Unit energy and demand savings calculated from the building prototype simulation models are shown below. The savings are tabulated by building type, vintage, and HVAC system type.

Multifamily Low-rise

HVAC System: Split AC/gas furnace

City	Vintage	Wall Insulation		Roof Insulation	
		ΔkWh/ 1000SF	ΔkW/ 1000SF	ΔkWh/ 1000SF	ΔkW/ 1000SF
Albany	Old	71	0.057	77	0.053
Albany	Average	47	0.023	34	0.026
Binghamton	Old	64	0.034	65	0.061
Binghamton	Average	43	0.011	28	0.009
Buffalo	Old	57	0.023	60	0.053
Buffalo	Average	39	0.011	24	0.018
Massena	Old	69	0.034	80	0.070
Massena	Average	43	0.011	33	0.018
NYC	Old	64	0.046	75	0.061
NYC	Average	43	0.023	29	0.018
Syracuse	Old	73	0.057	77	0.044
Syracuse	Average	45	0.023	32	0.009

HVAC System: Split heat pump

City	Vintage	Wall Insulation		Roof Insulation	
		kWh/ 1000SF	kW/ 1000SF	kWh/ 1000SF	kW/ 1000SF
Albany	Old	925	0.057	613	0.061
Albany	Average	640	0.011	274	0.018
Binghamton	Old	999	0.034	635	0.053
Binghamton	Average	686	0.011	279	0.009
Buffalo	Old	957	0.023	625	0.053
Buffalo	Average	652	0.011	261	0.018
Massena	Old	1,076	0.046	643	0.079
Massena	Average	739	0.011	284	0.018
NYC	Old	566	0.057	413	0.079
NYC	Average	387	0.023	177	0.018
Syracuse	Old	967	0.057	632	0.044
Syracuse	Average	654	0.034	283	0.018

HVAC System: Split AC / electric furnace

City	Vintage	Wall Insulation		Roof Insulation	
		kWh/ 1000SF	kW/ 1000SF	kWh/ 1000SF	kW/ 1000SF
Albany	Old	1,649	0.057	1,303	0.053
Albany	Average	1,140	0.023	573	0.026
Binghamton	Old	1,719	0.034	1,310	0.061
Binghamton	Average	1,196	0.011	583	0.009
Buffalo	Old	1,627	0.023	1,241	0.053
Buffalo	Average	1,129	0.011	535	0.018
Massena	Old	1,902	0.034	1,537	0.070
Massena	Average	1,297	0.011	661	0.018
NYC	Old	1,182	0.046	921	0.061
NYC	Average	827	0.023	405	0.018
Syracuse	Old	1,690	0.057	1,283	0.044
Syracuse	Average	1,153	0.023	572	0.009

HVAC System: Electric heat no AC

City	Vintage	Wall Insulation		Roof Insulation	
		kWh/ 1000SF	kW/ 1000SF	kWh/ 1000SF	kW/ 1000SF
Albany	Old	1,617	0.000	1,233	0.000
Albany	Average	1,115	0.000	546	0.000
Binghamton	Old	1,701	0.000	1,260	0.000
Binghamton	Average	1,181	0.000	564	0.000
Buffalo	Old	1,612	0.000	1,192	0.000
Buffalo	Average	1,111	0.000	516	0.000
Massena	Old	1,880	0.000	1,474	0.000
Massena	Average	1,280	0.000	637	0.000
NYC	Old	1,129	0.000	825	0.000
NYC	Average	786	0.000	371	0.000
Syracuse	Old	1,658	0.000	1,213	0.000
Syracuse	Average	1,132	0.000	545	0.000

HVAC System: PTAC

City	Vintage	Wall Insulation		Roof Insulation	
		kWh/ 1000SF	kW/ 1000SF	kWh/ 1000SF	kW/ 1000SF
Albany	Old	1,288	0.046	1,659	0.167
Albany	Average	305	0.011	624	0.061
Binghamton	Old	1,371	0.034	1,698	0.105
Binghamton	Average	327	0.011	638	0.035
Buffalo	Old	1,328	0.034	1,651	0.114
Buffalo	Average	316	0.000	620	0.035
Massena	Old	1,541	0.046	1,963	0.158
Massena	Average	367	0.000	738	0.044
NYC	Old	929	0.069	1,193	0.176
NYC	Average	218	0.011	442	0.044
Syracuse	Old	1,265	0.069	1,609	0.167
Syracuse	Average	301	0.011	606	0.061

HVAC System: PTHP

City	Vintage	Wall Insulation		Roof Insulation	
		kWh/ 1000SF	kW/ 1000SF	kWh/ 1000SF	kW/ 1000SF
Albany	Old	1,074	0.046	1,413	0.167
Albany	Average	260	0.011	544	0.061
Binghamton	Old	1,117	0.034	1,411	0.105
Binghamton	Average	271	0.011	542	0.035
Buffalo	Old	1,045	0.034	1,330	0.114
Buffalo	Average	255	0.000	512	0.035
Massena	Old	1,324	0.046	1,717	0.158
Massena	Average	319	0.000	657	0.044
NYC	Old	647	0.069	860	0.176
NYC	Average	158	0.011	334	0.044
Syracuse	Old	1,050	0.069	1,361	0.167
Syracuse	Average	254	0.011	521	0.061

All Gas heating systems:

City	Vintage	Wall	Roof
		Δtherm/ 1000SF	Δtherm/ 1000SF
Albany	Old	72	56
Albany	Average	50	25
Binghamton	Old	75	56
Binghamton	Average	53	25
Buffalo	Old	71	53
Buffalo	Average	50	23
Massena	Old	84	66
Massena	Average	58	29
NYC	Old	52	39
NYC	Average	37	18
Syracuse	Old	74	55
Syracuse	Average	51	25

Multifamily High-rise

HVAC System: Fan coils with air cooled electric chiller and gas hot water boiler

City	Vintage	Wall Insulation			Roof Insulation		
		kWh/ 1000SF	kW/ 1000SF	Δtherm/ 1000SF	kWh/ 1000SF	kW/ 1000SF	Δtherm/ 1000SF
Albany	Old	21	0.027	340	10	0.088	447
Albany	Average	3	0.008	90	0	0.035	174
Binghamton	Old	13	0.016	260	12	0.070	327
Binghamton	Average	0	0.005	83	0	0.026	184
Buffalo	Old	16	0.016	262	5	0.070	355
Buffalo	Average	1	0.005	82	0	0.035	171
Massena	Old	25	0.038	330	5	0.105	366
Massena	Average	4	0.008	106	0	0.044	228
NYC	Old	49	0.033	237	44	0.061	259
NYC	Average	9	0.005	68	6	0.026	112
Syracuse	Old	23	0.024	303	10	0.114	371
Syracuse	Average	3	0.005	103	0	0.035	213

The ***demand diversity factor*** is used to account for the fact that not all HVAC systems in all buildings in the population are operating at the same time. The demand diversity factor is defined as the average fraction of installed capacity of a population of HVAC systems that are operating at the time of the end-use peak.

The ***coincidence factor*** is used to account for the fact that peak measure savings may not be coincident with utility peak demands. The coincidence factor is defined as the portion of the end-use demand reduction that is coincident with the system peak.

Recommended values for the demand diversity factor and coincidence factors are shown below:

Parameter	Recommended Values
Demand diversity factor	0.8
Coincidence factor	1.0

Baseline Efficiencies from which savings are calculated

Baseline wall and roof insulation levels by vintage are as follows:

Vintage	Assumed R-value of insulated wall	Notes
Older, poorly insulated	7	No insulation; air gap resistance only
Existing, average insulation	11	

Vintage	Assumed R-value of insulated roof	Notes
Older, poorly insulated	11	Minimal ceiling insulation
Existing, average insulation	19	Insulation per MEC 1980

Compliance Efficiency from which incentives are calculated

Measure wall and ceiling insulation levels by vintage are as follows:

Vintage	Assumed R-value of insulated wall	Notes
Older, poorly insulated	13	
Existing, average insulation	18	

Vintage	Assumed R-value of insulated ceiling	Notes
Older, poorly insulated	30	Additional blown-in insulation
Existing, average insulation	30	Additional blown-in insulation

Operating Hours

The energy savings for insulation are dependent on the HVAC system operating hours and thermostat setpoints. See Appendix A for the modeling assumptions for each building prototype

Incremental Cost

TBD

Non-Electric Benefits - Annual Fossil Fuel Savings

N/A

Notes & References

1. Typical values for demand diversity factor (DF) and coincidence factor (CF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA. August, 1993.

Revision Number
0

HIGH PERFORMANCE WINDOWS

Description of Measure

Energy Star windows with reduced thermal conductance solar heat gain coefficient

Method for Calculating Summer Peak Demand and Energy Savings

Gross Summer Coincident Demand Savings
ΔkW_S = Glazing area (100 SF) $\times$ (ΔkW/100 SF) $\times$ $DF_S \times CF_S$

Gross Annual Energy Savings
ΔkWh = Glazing area (100 SF) $\times$ (ΔkWh/ 100 SF)

Δtherm = Glazing area (100 SF) $\times$ (Δtherm/ 100 SF)

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
Glazing area	= Area of windows replaced in 100 SF
DF	= demand diversity factor
CF	= coincidence factor
ΔkW/100 SF	= electricity demand savings per 100 SF of window area
ΔkWh/100 SF	= electricity consumption savings per 100 SF of window area
Δtherm/100 SF	= gas consumption impact per 100 square foot of glazing.

Unit energy and demand savings calculated from the building prototype simulation models are shown below. The savings are tabulated by building type, vintage, and HVAC system type.

Multifamily low-rise

City	Vintage	AC with gas furnace		Heat pump		AC with electric heat	
		kWh/ 100 SF	kW/ 100SF	kWh/ 100 SF	kW/ 100SF	kWh/ 100 SF	kW/ 100SF
Albany	Old	135	0.178	1,283	0.171	2,272	0.178
Albany	Average	128	0.111	904	0.114	1,535	0.111
Binghamton	Old	119	0.111	1,404	0.111	2,454	0.111
Binghamton	Average	108	0.124	1,010	0.121	1,721	0.124
Buffalo	Old	118	0.091	1,372	0.094	2,355	0.091
Buffalo	Average	115	0.121	1,074	0.114	1,805	0.121
Massena	Old	126	0.127	1,474	0.137	2,641	0.127
Massena	Average	115	0.124	1,075	0.124	1,859	0.124
NYC	Old	149	0.158	847	0.134	1,677	0.158
NYC	Average	166	0.137	641	0.134	1,194	0.137
Syracuse	Old	135	0.141	1,315	0.151	2,307	0.141
Syracuse	Average	122	0.134	874	0.158	1,469	0.134

City	Vintage	Gas heat no AC		Elec heat no AC	
		kWh/ 100 SF	kW/ 100SF	kWh/ 100 SF	kW/ 100SF
Albany	Old	53	0.000	2,190	0.000
Albany	Average	39	0.000	1,446	0.000
Binghamton	Old	61	0.000	2,396	0.000
Binghamton	Average	43	0.000	1,656	0.000
Buffalo	Old	57	0.000	2,294	0.000
Buffalo	Average	42	0.000	1,732	0.000
Massena	Old	58	0.000	2,572	0.000
Massena	Average	42	0.000	1,786	0.000
NYC	Old	23	0.000	1,551	0.000
NYC	Average	26	0.000	1,054	0.000
Syracuse	Old	55	0.000	2,227	0.000
Syracuse	Average	39	0.000	1,387	0.000

Multifamily high-rise

City	Vintage	kWh/ 100 SF	kW/ 100SF
Albany	Old	73	0.128
Albany	Average	22	0.099
Binghamton	Old	64	0.116
Binghamton	Average	11	0.085
Buffalo	Old	68	0.101
Buffalo	Average	20	0.079
Massena	Old	66	0.127
Massena	Average	20	0.098
NYC	Old	118	0.119
NYC	Average	56	0.098
Syracuse	Old	73	0.195
Syracuse	Average	23	0.092

The therm impacts per unit for buildings with gas heat are shown below:

City	Vintage	MF low-rise	MF high-rise
Albany	Old	98	364
Albany	Average	64	516
Binghamton	Old	106	392
Binghamton	Average	73	502
Buffalo	Old	101	348
Buffalo	Average	76	524
Massena	Old	115	427
Massena	Average	79	554
NYC	Old	70	330
NYC	Average	47	365
Syracuse	Old	99	396
Syracuse	Average	61	536

The ***demand diversity factor*** is used to account for the fact that not all HVAC systems in all buildings treated by window films were installed or are operating at the same time. The demand diversity factor is defined as the average fraction of installed capacity of the HVAC systems that are operating at the time of the end-use peak.

The ***coincidence factor*** is used to account for the fact that peak measure savings may not be coincident with utility peak demands. The coincidence factor is defined as the portion of the end-use demand reduction that is coincident with the system peak.

Recommended values for the demand diversity factor and coincidence factors are shown below:

Parameter	**Recommended Values**
Demand diversity factor	0.8
Coincidence factor	1.0

Baseline Efficiencies from which savings are calculated

The baseline condition for the old vintage building is assumed to be single pane clear glass with a solar heat gain coefficient of 0.87 and U-value of 1.2 Btu/hr-SF-deg F. The baseline condition for the average vintage building is assumed to be double pane clear glass with a solar heat gain coefficient of 0.77 and U-value of 0.87 Btu/hr-SF-deg F.

Compliance Efficiency from which incentives are calculated

The Energy Star window is assumed to provide a solar heat gain coefficient of 0.35 and a glass conductance of 0.41 Btu/hr-SF-deg F.

Operating Hours

The energy savings for insulation are dependent on the HVAC system operating hours and thermostat setpoints. See Appendix A for the modeling assumptions for each building prototype

Incremental Cost

TBD

Non-Electric Benefits - Annual Fossil Fuel Savings

N/A

Notes & References

1. Window properties taken from ASHRAE Handbook of Fundamentals
2. Typical values for demand diversity factor (DF) and coincidence factor (CF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.

Revision Number
0

AIR LEAKAGE SEALING

Description of Measure

Reduction in the natural infiltration rate of the home through sealing air leaks in the building envelope.

Method for Calculating Summer Peak Demand and Energy Savings

Gross Summer Coincident Demand Savings
ΔkW_S = Floor area (1000 SF) $\times$ (ΔkW/1000 SF) $\times$ DF_S $\times$ CF_S

Gross Annual Energy Savings
ΔkWh = Floor area (1000 SF) $\times$ (ΔkWh/ 1000 SF)

Δtherm = Floor area (1000 SF) $\times$ (Δtherm/ 1000 SF)

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
Floor area	= Conditioned floor area
DF	= demand diversity factor
CF	= coincidence factor
ΔkW/1000 SF	= electricity demand savings per 1000 SF of conditioned floor area
ΔkWh/1000 SF	= electricity consumption savings per 1000 SF of conditioned floor area
Δtherm/ 1000 SF	= gas consumption impact per 1000 square foot of conditioned floor area.

Unit energy and demand savings calculated from the building prototype simulation models are shown below. The savings are tabulated by building type, vintage, and HVAC system type.

Multifamily low-rise

City	Vintage	AC with gas furnace		Heat pump		AC with electric heat	
		kWh/ 1000 SF	kW/ 1000 SF	kWh/ 1000 SF	kW/ 1000 SF	kWh/ 1000 SF	kW/ 1000 SF
Albany	Old	25	0.061	386	0.061	676	0.061
Albany	Average	15	0.013	203	0.009	367	0.013
Binghamton	Old	27	0.022	431	0.022	738	0.022
Binghamton	Average	13	0.009	218	0.009	387	0.009
Buffalo	Old	23	0.018	464	0.022	770	0.018
Buffalo	Average	12	0.004	246	0.009	429	0.004
Massena	Old	19	0.004	388	0.000	672	0.004
Massena	Average	10	0.000	210	0.000	372	0.000
NYC	Old	32	0.061	324	0.040	648	0.061
NYC	Average	21	0.018	180	0.035	374	0.018
Syracuse	Old	24	0.053	395	0.053	660	0.053
Syracuse	Average	14	0.031	210	0.018	364	0.031

City	Vintage	Elec heat no AC		Gas heat no AC	
		kWh/ 1000 SF	kW/ 1000SF	kWh/ 1000 SF	kW/ 1000SF
Albany	Old	670	0.000	19	0.000
Albany	Average	360	0.000	8	0.000
Binghamton	Old	734	0.000	23	0.000
Binghamton	Average	386	0.000	12	0.000
Buffalo	Old	771	0.000	23	0.000
Buffalo	Average	427	0.000	11	0.000
Massena	Old	671	0.000	18	0.000
Massena	Average	371	0.000	9	0.000
NYC	Old	631	0.000	15	0.000
NYC	Average	360	0.000	7	0.000
Syracuse	Old	655	0.000	19	0.000
Syracuse	Average	359	0.000	9	0.000

Multifamily high-rise

City	Vintage	kWh/ 1000 SF	kW/ 1000SF
Albany	Old	73	0.128
Albany	Average	22	0.099
Binghamton	Old	64	0.116
Binghamton	Average	11	0.085
Buffalo	Old	68	0.101
Buffalo	Average	20	0.079
Massena	Old	66	0.127
Massena	Average	20	0.098
NYC	Old	118	0.119
NYC	Average	56	0.098
Syracuse	Old	73	0.195
Syracuse	Average	23	0.092

The therm impacts per unit are shown below:

City	Vintage	MF low-rise Therm/ 1000SF	MF high-rise Therm/ 1000SF
Albany	Old	30	87
Albany	Average	16	52
Binghamton	Old	33	75
Binghamton	Average	17	49
Buffalo	Old	34	81
Buffalo	Average	19	59
Massena	Old	30	79
Massena	Average	17	50
NYC	Old	29	94
NYC	Average	17	59
Syracuse	Old	29	71
Syracuse	Average	16	50

Baseline Efficiencies from which savings are calculated

Baseline infiltration rate is assumed be as follows:

Vintage	Infiltration rate (natural ACH)
Old	1.0
Average	0.5

Compliance Efficiency from which incentives are calculated

Savings are based on an infiltration rate reduction of 15%

Operating Hours

The energy savings for insulation are dependent on the HVAC system operating hours and thermostat setpoints. See Appendix A for the modeling assumptions for each building prototype

Incremental Cost

TBD

Non-Electric Benefits - Annual Fossil Fuel Savings

N/A

Notes & References

1. Typical values for demand diversity factor (DF) and coincidence factor (CF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.

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CENTRAL AIR CONDITIONING

Description of Measure

Central air conditioning systems with rated efficiency of 14 SEER or higher in Multifamily Residential applications.

Method for Calculating Summer Peak Demand and Energy Savings

$$\Delta kW_S = units \times \frac{tons}{unit} \times RLF \times \left(\frac{12}{EER_{base,\,pk} \times \eta_{duct}} - \frac{12}{EER_{ee,\,pk} \times \eta_{duct}} \right) \times DF_S \times CF_S$$

$$\Delta kWh = units \times \frac{tons}{unit} \times RLF \times \left(\frac{12}{\overline{EER}_{base} \times \eta_{duct}} - \frac{12}{\overline{EER}_{ee} \times \eta_{duct}} \right) \times CLH$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
units	= the number of air conditioning units installed under the program
tons/unit	= tons of air conditioning per unit, based on nameplate data
$\overline{EER}$	= average energy efficiency ratio over the cooling season. (Btu/watt-hour)
EER_{pk}	= energy efficiency ratio under peak conditions (Btu/watt-hour)
CLH	= cooling load hours
RLF	= rated load factor
DF	= demand diversity factor
CF	= coincidence factor
12	= conversion factor (kBtuh/ton)

The ***rated load factor*** is the ratio of the peak cooling load imposed on the cooling equipment to the total rated cooling capacity. This factor compensates for oversizing of the air conditioning unit.

$$RLF = \frac{peak\ \ cooling\ \ load}{nameplate\ \ capacity}$$

The ***average seasonal cooling efficiency*** ($\overline{EER}$) is an estimate of the average efficiency of the air conditioner over the cooling season at the location of the measure. Most air conditioning equipment installed in residences has a SEER efficiency rating, which is an estimate of the seasonal energy efficiency for an average US city. Programs should use

the manufacturers' rated SEER until data can be developed that is more appropriate for NY climates.

Cooling load hours are defined as the ratio of the building annual cooling load to the building peak cooling load:

$$\text{CLH} = \frac{\text{Annual Cooling Load (Btu)}}{\text{Peak Cooling Load (Btu / hr)}}$$

Cooling **equivalent full-load hours** (EFLH) are sometimes used to estimate total energy savings. EFLH are defined as follows:

$$\text{EFLH} = \frac{\text{Annual kWh}_{\text{cooling}}}{\text{kW}_{\text{peak, cooling}}}$$

Since EFLH are calculated from the total kWh and peak kW of the air conditioner, the efficiency characteristics of the air conditioner affect the EFLH. To eliminate the dependence on HVAC system performance characteristics, the EFLH can be converted to CLH using the following equation:

$$\text{CLH} = \text{EFLH} \times \frac{\overline{\text{EER}}}{\text{EER}_{\text{pk}}}$$

where:

EFLH = equivalent full-load hours
$\overline{\text{EER}}$ = average air conditioning equipment energy efficiency ratio
EER_{pk} = air conditioning equipment energy efficiency ratio under peak conditions

The ***demand diversity factor*** is used to account for the fact that not all HVAC systems in all buildings in the population are operating at the same time. The demand diversity factor is defined as the average fraction of installed capacity of a population of HVAC systems that are operating at the time of the end-use peak.

The ***coincidence factor*** is used to account for the fact that peak measure savings may not be coincident with utility peak demands. The coincidence factor is defined as the portion of the end-use demand reduction that is coincident with the system peak.

Recommended values for the rated load factor, demand diversity factor, and coincidence factors are shown below:

Parameter	Recommended Values
Rated Load Factor	0.8
Demand diversity factor	0.8
Coincidence factor	1.0

Baseline and measure efficiency assumptions for air conditioners and heat pumps in several SEER classes are shown below:

Baseline and Measure Efficiency Assumptions

System Type	Baseline or Measure Assumption	Seasonal Efficiency (SEER)	Peak Efficiency (EER)
Central Air conditioner	Early replacement baseline	SEER 10	9.2
	Replace on failure baseline	SEER 13	11.09
	Measure	SEER 14	11.99
		SEER 15	12.72
		SEER 16	11.61
		SEER 17	12.28
Central Heat Pump	Early replacement baseline	SEER 10	9.0
	Replace on failure baseline	SEER 13	11.07
	Measure	SEER 14	11.72
		SEER 15	12.32
		SEER 16	12.06
		SEER 17	12.52
		SEER 18	12.80

Early replacement units are assumed to be no more than 15 years old, with no less than 5 years remaining life. According to the 2004-5 DEER update study, equipment of this vintage is generally SEER 10.

Cooling load hours for residential buildings were calculated from a DOE-2.2 simulation of prototypical multifamily residential buildings. The prototype building characteristics are described in Appendix A. Residential prototypes for three different classes of building vintage were developed:

1. Old: Poorly insulated building constructed in the 1950s or earlier. This vintage is referred to as the “old” vintage
2. Existing: Average insulated building conforming to 1980s era building codes. This vintage is referred to as the “average” vintage.
3. New: Construction conforming to current NY state standards for residential new construction. This vintage is referred to as the “new” vintage.

The CLH for three building vintages and six different cities in NY are shown below:

Multifamily Low-Rise Cooling Load Hours by Vintage and City

City	Old	Average	New
Albany	358	369	349
Binghamton	271	274	262
Buffalo	337	342	320
Massena	287	285	272
NYC	634	688	702
Syracuse	331	355	371

Baseline Efficiencies from which savings are calculated

The baseline efficiency for new construction and replace on failure is SEER 13. Baseline for early replacement is SEER 10.

Compliance Efficiency from which incentives are calculated

TBD

Operating Hours

The operating hours by climate zone and building vintage are shown above.

Incremental Cost

TBD

Non-Electric Benefits - Annual Fossil Fuel Savings

Minor heating interactions are expected with efficient furnace fans used in most high efficiency air conditioners. These have not been quantified at this time.

Notes & References

1. Unit seasonal and peak efficiency data taken from the California DEER update study: 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December, 2005. Available at http://www.calmac.org/publications/2004-05_DEER_Update_Final_Report-Wo.pdf

2. Typical values for demand diversity factor (DF), coincidence factor (CF) and rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.

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CENTRAL AIR SOURCE HEAT PUMPS

Description of Measure

A heat pump with improved heating efficiency. Note only the heating savings is presented here; cooling savings from an efficient heat pump is the same as the cooling savings for an efficient air conditioner.

Method for Calculating Annual Energy Savings

$$\Delta kWh = units \times \frac{kBtuh}{unit} \times RLF_{heat} \times \left(\frac{1}{\overline{COP}_{base}} - \frac{1}{\overline{COP}_{ee}} \right) \times \frac{HLH}{3.413}$$

where:

ΔkWh	= gross annual energy savings
units	= number of heat pumps installed
kBtuh/unit	= the nominal rating of the heating capacity of the heat pumps in kBtu/hr
$\overline{COP}$	= average heating season coefficient of performance of heat pump
HLH	= heating load hours
RLF_{heat}	= heating mode rated load factor
3.413	= conversion factor (Btu/Wh)

The ***rated load factor*** is the ratio of the peak heating load imposed on the heating equipment to the total rated heating capacity, including the supplemental heating (strip heat). This factor compensates for oversizing of the heat pump.

$$RLF = \frac{peak\ heating\ load}{nameplate\ \text{heating}\ capacity}$$

Recommended value for the rated load factor is 0.8.

The ***HSPF*** is an estimate of the seasonal heating energy efficiency for an average US city. The average COP in the equation above is equal to the HSPF/3.413. Programs should use the manufacturers' rated HSPF until data can be developed that are more appropriate for NY climates. Efficiency assumptions for heat pumps of different SEER classes are shown below:

	Cooling Seasonal Efficiency (SEER)	Heating Seasonal Efficiency (HSPF)
Early replacement baseline	SEER 10	6.8
Replace on failure baseline	SEER 13	8.1
Measure	SEER 14	8.6
	SEER 15	8.8
	SEER 16	8.4
	SEER 17	8.6
	SEER 18	9.2

Early replacement units are assumed to be no more than 15 years old, with no fewer than 5 years remaining life. According to the 2004-5 DEER update study, equipment of this vintage is generally SEER 10.

Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

$$\text{HLH} = \frac{\textit{A}\text{nnual Heating Load (Btu)}}{\textit{Peak}\text{ Heating Load (Btu/hr)}}$$

Heating load hours for residential buildings were calculated from a DOE-2.2 simulation of prototypical multifamily residential buildings. The prototype building characteristics are described in Appendix A. The HLH for three building vintages and six different cities in NY are shown below:

Multifamily Low-Rise Heating Load Hours by Vintage and City

City	Old	Average	New
Albany	1,287	1,265	911
Binghamton	1,650	1,556	1,124
Buffalo	1,524	1,519	1,104
Massena	1,632	1,658	1,205
NYC	946	904	629
Syracuse	1,469	1,507	1,056

Baseline Efficiencies from which savings are calculated

New construction and replace on failure baseline efficiency should be consistent with a SEER 13 heat pump (HSPF = 8.1). Early replacement efficiency is assumed to be consistent with a SEER 10 heat pump (HSPF -=6.8).

Compliance Efficiency from which incentives are calculated

Heat pump efficiency must be greater than or equal to SEER 14.

Operating Hours

Heating load hours vary by climate and building vintage. See table above.

Incremental Cost

TBD

Non-Electric Benefits - Annual Fossil Fuel Savings

None anticipated – electric heating system

Notes & References

1. Unit seasonal and peak efficiency data taken from the California DEER update study: 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December, 2005. Available at http://www.calmac.org/publications/2004-05_DEER_Update_Final_Report-Wo.pdf

2. Typical values for rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.

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GROUND SOURCE HEAT PUMPS

Description of Measure

A high-efficiency ground source heat pump with a closed loop vertical heat exchanger field is evaluated for multi-family applications. The system is compared to a standard efficiency air conditioner with electric resistance heat or an air-source heat pump. The heat pump system uses a water to water heat pump, two pipe distribution system, fan coils located in each zone of the apartment, and circulation pumps between the heat pump and the fan coils and between the heat pump and the ground loop. The baseline system is either a packaged terminal air conditioner (PTAC) with electric resistance heat or a packaged terminal heat pump (PTHP) with an electric resistance supplemental heating system.

Method for Calculating Annual Energy Savings

$$\Delta kWh = units \times [\frac{tons}{unit} \times RLF_{cool} \times \left(\frac{12}{\overline{EER}_{base}} - \frac{12}{\overline{EER}_{ee}} \right) \times CLH + \frac{kBtuh}{unit} \times RLF_{heat} \times \left(\frac{1}{\overline{COP}_{base}} - \frac{1}{\overline{COP}_{ee}} \right) \times \frac{HLH}{3.413}]$$

$$\Delta kW_S = units \times \frac{tons}{unit} \times RLF_{cool} \times \left(\frac{12}{EER_{base,\,pk}} - \frac{12}{EER_{ee,\,pk}} \right) \times DF_S \times CF_S$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
units	= number of heat pumps installed
tons/unit	= tons of cooling per unit, based on nameplate data
$\overline{EER}$	= average energy efficiency ratio over the cooling season. (Btu/watt-hour)
EER_{pk}	= energy efficiency ratio under peak conditions (Btu/watt-hour)
CLH	= cooling load hours
RLF	= rated load factor
DF	= demand diversity factor
CF	= coincidence factor
12	= conversion factor (kBtuh/ton)
kBtuh/unit	= the nominal rating of the heating capacity of the heat pumps in kBtu/hr
$\overline{COP}$	= average heating season coefficient of performance of heat pump
HLH	= heating load hours
RLF_{heat}	= heating mode rated load factor
3.413	= conversion factor (Btu/Wh)

The ***rated load factor*** for cooling is the ratio of the peak cooling load imposed on the cooling equipment to the total rated cooling capacity. This factor compensates for oversizing of the air conditioning unit.

$$RLF = \frac{\text{peak cooling load}}{\text{nameplate capacity}}$$

Recommended value for the rated load factor is 0.8.

Baseline Efficiencies from which savings are calculated

New construction and replace on failure baseline efficiency should be consistent with a SEER 13 heat pump (HSPF = 8.1). Early replacement efficiency is assumed to be consistent with a SEER 10 heat pump (HSPF -=6.8). Note: The seasonal baseline systems with electric resistance heat should use a COP of 1.0. average COP = HSPF/3.413

Compliance Efficiency from which incentives are calculated

Ground source heat pumps are rating at full-load and standard operating conditions.

Equipment type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency	Test Procedure
Water-Source (Cooling Mode)	<17,000 Btu/hr	All	86°F EWT	11.2 EER	ISO-13256-1
	≥17,000 Btu/hr and <65,0000	All	86°F EWT	12.0 EER	ISO-13256-1
	≥65,000 Btu/hr and <135,0000	All	86°F EWT	12.0 EER	ISO-13256-1
Groundwater-Source (Cooling Mode)	<135,000 Btu/hr	All	59°F EWT	16.2 EER	ISO-13256-1
Ground Source (Cooling Mode)	<135,000 Btu/hr	All	77°F EWT	13.4 EER	ISO-13256-1
Water-Source (Heating Mode)	<135,000 Btu/hr (Cooling Capacity)	-	68°F EWT	4.2 COP	ISO-13256-1
Groundwater-Source (Heating Mode)	<135,000 Btu/hr (Cooling Capacity)	-	50°F EWT	3.6 COP	ISO-13256-1
Ground Source (Heating Mode)	<135,000 Btu/hr (Cooling Capacity)	-	32°F EWT	3.1 COP	ISO-13256-1

The efficiency specifications account for the compressor only (water to water heat pump) or the compressor and supply fans (water to air heat pump). In order to present a valid comparison to a standard HVAC system, the energy required to run all system auxiliaries

(fans, building circulating pumps, and ground loop pumps) must also be included in the full load and seasonal average efficiencies. Suggested values for a water to water system are shown below:

City	Vintage	Cool avg EER	Cook pk EER	Heat avg COP	Heat pk COP
Albany	Old	4.8	13.4	2.8	3.2
Binghamton	Old	4.2	13.0	2.9	3.2
Buffalo	Old	4.4	13.5	2.8	3.1
Massena	Old	6.9	13.3	2.8	3.5
NYC	Old	4.8	13.2	2.8	3.2
Syracuse	Old	3.7	13.5	2.8	3.0
Albany	Existing	5.8	13.8	2.7	3.2
Binghamton	Existing	5.3	13.6	2.8	3.2
Buffalo	Existing	5.3	13.9	2.8	3.0
Massena	Existing	8.0	13.6	2.6	3.5
NYC	Existing	5.9	13.7	2.7	3.1
Syracuse	Existing	4.8	13.9	2.8	3.1
Albany	New	6.8	14.1	2.8	3.2
Binghamton	New	6.1	13.9	2.9	3.2
Buffalo	New	6.2	14.1	2.8	3.1
Massena	New	9.1	14.1	2.7	3.5
NYC	New	6.8	14.0	2.8	3.2
Syracuse	New	5.6	14.1	2.8	3.1

These full load and average efficiencies were developed from a simulation of a low-rise apartment retrofit to a water-to-water system with zone level fan coils, seasonal changeover from heating to cooling mode, and closed-loop vertical ground loop system. System design assumptions are as follows:

Equipment	Efficiency	Notes
Heat pump (cooling mode)	17 EER	44°F chilled water, 85°F ground loop temp
Heat pump (heating mode)	4.1 COP	95°F hot water, 32°F ground loop temp
Fan coil	0.067 kW/ton	0.178 W/cfm and 375 cfm/ton
Building pump	0.041 kW/ton	10°F loop design delta T
Ground loop pump	0.11 kW/ton	10°F loop design delta T; ground loop sized at 300 LF per ton

Operating Hours

Cooling load hours are defined as the ratio of the building annual cooling load to the building peak cooling load:

$$\text{CLH} = \frac{\textit{A}\text{nnual Cooling Load (Btu)}}{\textit{Peak}\text{ Cooling Load (Btu/hr)}}$$

Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

$$\text{HLH} = \frac{\textit{A}\text{nnual Heating Load (Btu)}}{\textit{Peak}\text{ Heating Load (Btu/hr)}}$$

See sections on air conditioners and air-source heat pumps above for more information

Incremental Cost

TBD

Non-Electric Benefits - Annual Fossil Fuel Savings

None anticipated – electric heating system

Notes & References

1. Typical values for rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.

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BOILERS

Description of Measure

High efficiency condensing and non-condensing hot water and steam boilers

Method for Calculating Energy Savings

$$\Delta\text{therms} = \text{units} \times \frac{\text{kBtuh}}{\text{unit}} \times \text{RLF}_{\text{heat}} \times \left(\frac{1}{\bar{\eta}_{base} \times \bar{\eta}_{dist,base}} - \frac{1}{\bar{\eta}_{ee} \times \bar{\eta}_{dist,ee}} \right) \times \frac{\text{HLH}}{100}$$

where:

Δtherms	= gross annual gas savings
units	= number of furnaces installed
kBtuh/unit	= the nominal rating of the heating capacity of the boiler in kBtu/hr
$\bar{\eta}$	= average heating season efficiency of boiler
$\bar{\eta}_{\text{dist}}$	= average heating season distribution system efficiency
HLH	= heating load hours
RLF_{heat}	= heating mode rated load factor
100	= conversion factor (kBtuh/therm)

The ***rated load factor*** is the ratio of the peak heating load imposed on the heating equipment to the total rated heating capacity. This factor compensates for oversizing of the boiler.

$$\text{RLF}_{\text{heat}} = \frac{peak\ \ heating\ \ load}{nameplate\ \ \text{heating}\ \ capacity}$$

Recommended value for the rated load factor is 0.8.

The ***average seasonal efficiency*** of the boiler is the ratio of the heating output to the fuel input (in consistent units) over a heating season. This factor accounts for combustion efficiency, standby losses, cycling losses, and other sources of inefficiency within the boiler itself. The ***AFUE*** is an estimate of the seasonal heating energy efficiency for an average US city calculated according to a standard US DOE method and reported by the boiler manufacturer. Programs should use the manufacturers' rated AFUE until data can be developed that are more appropriate for NY climates.

Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

$$\text{HLH} = \frac{\textit{A}\text{nnual Heating Load (Btu)}}{\textit{Peak}\text{ Heating Load (Btu/hr)}}$$

Heating load hours for multifamily residential buildings were calculated from DOE-2.2 simulations of prototypical multifamily residential buildings. See section on furnaces above for the HLH values.

Distribution efficiencies for hydronic heating systems are generally higher than ducted systems because leakage is not an issue and the surface area for heat losses is much lower. A value of 1.0 is recommended.

Baseline Efficiencies from which savings are calculated

The baseline efficiency ($\bar{\eta}_{base}$) is as follows:

New construction and replace on failure: minimum AFUE for new boilers per NAECA is 80% for hot water boilers and 75% for steam boilers < 300,000 Btu/hr output.

Compliance Efficiency from which incentives are calculated

The measure efficiency ($\bar{\eta}_{ee}$) is as follows:

ACEEE recommends two tiers for hot water boilers: ≥85% for non-condensing applications and ≥ 90% for condensing applications. Steam boiler efficiency recommendations are: ≥ 82% AFUE with electronic ignition.

Operating Hours

Heating load hours calculated from building energy simulation models described in Appendix A and summarized in previous section.

Notes & References

1. Typical value for rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.
2. A distribution system efficiency calculation method for hydronic systems is included in ANSI/ASHRAE Standard 152 – 2004. Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems, American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta, GA. www.ashrae.org.
3. The HLH values assumed in this section include a 3°F night time setback of the room temperature setpoint. See the section on programmable setback thermostats and Appendix A for more information.

BOILER RESET CONTROLS

Description of Measure

Reset of hot water setpoint in multifamily residential buildings with zone thermostat control. The measure is assumed to be applied to existing non-condensing boiler systems.

Method for Calculating Energy Savings

$$\Delta\text{therm} = \text{units} \times \text{kBtuh/unit} \times \text{RLF} \times (1 / \bar{\eta}) \times \text{HLH}/100 \times \text{ESF}$$

where:

Δtherm	= gross annual gas savings
units	= number of boiler reset controls installed
kBtuh/unit	= size of boiler served by each reset controller
100	= conversion factor (therm/kBtuh)
$\bar{\eta}$	= average seasonal efficiency of the boiler system without reset controls
RLF	= rated load factor
HLH	= Heating load hours
ESF	= energy savings factor computed with a building energy simulation model

The ***rated load factor*** is the ratio of the peak heating load imposed on the heating equipment to the total rated heating capacity. This factor compensates for oversizing of the boiler.

$$\text{RLF}_{\text{heat}} = \frac{peak\ \ heating\ \ load}{nameplate\ \ \text{heating}\ \ capacity}$$

Recommended value for the rated load factor is 0.8.

The ***average seasonal efficiency*** of the boiler is the ratio of the heating output to the fuel input (in consistent units) over a heating season. This factor accounts for combustion efficiency, standby losses, cycling losses, and other sources of inefficiency within the boiler itself. The ***AFUE*** is an estimate of the seasonal heating energy efficiency for an average US city calculated according to a standard US DOE method and reported by the boiler manufacturer. Programs should use the manufacturers' rated AFUE until data can be developed that are more appropriate for NY climates.

Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

$$\text{HLH} = \frac{\textit{A}\text{nnual Heating Load (Btu)}}{\textit{Peak}\text{ Heating Load (Btu/hr)}}$$

Heating load hours for residential buildings were calculated from DOE-2.2 simulations of prototypical multifamily. See section on furnaces above for the appropriate HLH values.

The recommended **Energy Savings Factor (ESF)** for boiler reset controllers in residential applications is 0.05.

Baseline Efficiencies from which savings are calculated

Constant hot water setpoint temperature of 180F

Compliance Efficiency from which incentives are calculated

Reset hot water temperature to 160F. Energy Savings Factor (ESF) of 0.05 recommended.

Operating Hours

Heating load hours calculated from building energy simulation models described in Appendix A and summarized in previous section.

Non-Gas Benefits - Annual Electric Savings

Lower setpoint temperature may cause hot water circulator to run longer cycles. Minor impact not accounted for in this procedure.

Notes & References

1. Energy savings factor for residential applications taken from an article published by the Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. See: http://www.energysolutionscenter.org/BoilerBurner/Eff_Improve/Efficiency/Boiler_Reset_Control.asp
2. The HLH values assumed in this section include a 3°F night time setback of the room temperature setpoint. See the section on programmable setback thermostats and Appendix A for more information.

SETBACK THERMOSTAT

Description of Measure

Programmable setback thermostats applied to multifamily residential air conditioners heat pumps, furnaces and boilers.

Method for Calculating Energy Savings

$$\Delta kWh = units \times \left[\frac{ton}{unit} \times RLF_{cool} \times \frac{12}{\overline{EER}_{base} \times \overline{\eta}_{dist,base}} \times CLH \times ESF_{cool} + \frac{kBtuh}{unit} \times RLF_{heat} \times \frac{1}{\overline{\eta}_{base} \times \overline{\eta}_{dist,base}} \times \frac{HLH}{3413} \times ESF_{heat} \right]$$

$$\Delta therms = units \times \frac{kBtuh}{unit} \times RLF_{heat} \times \frac{1}{\overline{\eta}_{base} \times \overline{\eta}_{dist,base}} \times \frac{HLH}{100} \times ESF_{heat}$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
$\Delta therms$	= gross annual gas savings
units	= the number of air conditioning units installed under the program
tons/unit	= tons of air conditioning per unit, based on nameplate data
$\overline{EER}$	= average energy efficiency ratio over the cooling season. (Btu/watt-hour)
EER_{pk}	= energy efficiency ratio under peak conditions (Btu/watt-hour)
CLH	= cooling load hours
RLF	= rated load factor
DF	= demand diversity factor
CF	= coincidence factor
12	= conversion factor (kBtuh/ton)
ESF	= energy savings factor
kBtuh/unit	= the nominal rating of the heating capacity of the heat pumps in kBtu/hr
$\overline{COP}$	= average heating season coefficient of performance of heat pump
$\overline{\eta}$	= average seasonal efficiency of furnace or boiler
$\overline{\eta}_{dist}$	= average seasonal distribution system efficiency
HLH	= heating load hours
RLF_{heat}	= heating mode rated load factor
3.413	= conversion factor (Btu/Wh)

The ***nominal rating of the cooling capacity of the air conditioner or heat pump*** should be equal to the rated capacity of all cooling equipment controlled by a setback thermostat in the home. The energy savings should be calculated per residence rather than per thermostat.

The ***nominal rating of the heating capacity of the furnace, heat pump or boiler*** should be equal to the rated capacity of all heating equipment controlled by a setback thermostat in the home. The energy savings should be calculated per residence rather than per thermostat.

The ***distribution system efficiency*** accounts for losses from the distribution system due to leakage and/or inadequate insulation. See section on duct leakage sealing and insulation for more information.

Baseline Efficiencies from which savings are calculated

The baseline efficiency for air conditioners and heat pumps should be set according to the sections on air conditioner and heat pump efficiency above. Distribution system efficiency ($\bar{\eta}_{dist,base}$) should be set to the unsealed and uninsulated values from the duct leakage sealing section for the appropriate building type. Distribution efficiencies for hydronic heating systems should be set to 1.0.

Studies of residential heating thermostat setpoint behavior indicate some amount of manual setback adjustment in homes without programmable thermostats. This behavior is accounted for in the prototypical building simulation model used to calculate heating load hours, as described in Appendix A. An assumption of 3°F of night time setback behavior is embedded in the models.

Efficiency from which incentives are calculated

The ***Energy Savings Factor*** (ESF) is the ratio of the energy savings resulting from installation of a programmable setback thermostat to the annual heating energy.
The energy savings factor (ESF) assumption is taken from a study of programmable thermostat savings in Massachusetts conducted by GDS Associates for KeySpan Energy Delivery. The study estimated an energy savings of 3.6% of the annual heating energy consumption for programmable setback thermostats in residential applications.

Operating Hours

Heating load hours calculated from building energy simulation models described in Appendix A and summarized above.

Non-Electric Benefits - Annual Fossil Fuel Savings

N/A

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Notes & References

1. Typical value for rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.
2. For examples of studies on residential thermostat setpoint behavior, see the literature review conducted for the California Energy Commission project Residential Thermostats: Comfort Controls in California Homes, CEC-500-03-026, available at http://comfortcontrols.lbl.gov/pdf/tstats-lit-review.pdf.
3. Baseline thermostat setback assumptions taken from: Conner, C.C. and Lucas, R.L. 1990. Thermostat Related Behavior and Internal Temperatures Based on Measured Data in Residences. PNL-7465, Pacific Northwest Laboratory. Richland, WA.
4. Energy Saving Factor for setback thermostats taken from Programmable Thermostats. Report to KeySpan Energy Delivery on Energy Savings and Cost Effectiveness, GDS Associates, Marietta, GA. 2002.

REFRIGERANT CHARGE CORRECTION

Description of Measure

Correcting refrigerant charge on air conditioners and heat pumps in multifamily residential applications

Method for Calculating Summer Peak Demand and Energy Savings

$$\Delta kW_S = \text{units} \times \frac{\text{tons}}{\text{unit}} \times \text{RLF} \times \left(\frac{12}{\text{EER}_{\text{uncorr, pk}}} - \frac{12}{\text{EER}_{\text{corr, pk}}} \right) \times \text{DF}_S \times \text{CF}_S$$

$$\Delta kWh = \text{units} \times \frac{\text{tons}}{\text{unit}} \times \text{RLF} \times \left(\frac{12}{\overline{\text{EER}}_{uncorr}} - \frac{12}{\overline{EER}_{corr}} \right) \times \text{CLH}$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
units	= the number of air conditioning units installed under the program
tons/unit	= tons of air conditioning per unit, based on nameplate data
$\overline{\text{EER}}$	= average energy efficiency ratio over the cooling season. (Btu/watt-hour)
EER_{pk}	= energy efficiency ratio under peak conditions (Btu/watt-hour)
CLH	= cooling load hours
RLF	= rated load factor
DF	= demand diversity factor
CF	= coincidence factor
12	= conversion factor (kBtuh/ton)

The **rated load factor** (RLF) is the ratio of the peak cooling load imposed on the cooling equipment to the total rated cooling capacity. This factor compensates for oversizing of the air conditioning unit.

$$\text{RLF} = \frac{\text{peak cooling load}}{\text{nameplate capacity}}$$

Cooling load hours are defined as the ratio of the annual building cooling load to the peak building cooling load:

$$\text{CLH} = \frac{\text{Annual Cooling Load (Btu)}}{\text{Peak Cooling Load (Btu / hr)}}$$

The ***demand diversity factor*** is used to account for the fact that not all HVAC systems in all buildings in the population are operating at the same time. The demand diversity factor is defined as the average fraction of installed capacity of a population of HVAC systems that are operating at the time of the end-use peak.

The ***coincidence factor*** is used to account for the fact that peak measure savings may not be coincident with utility peak demands. The coincidence factor is defined as the portion of the end-use demand reduction that is coincident with the system peak.

Recommended values for the rated load factor, demand diversity factor, and coincidence factors are shown below:

Parameter	Recommended Values
Rated Load Factor	0.8
Demand diversity factor	0.8
Coincidence factor	1.0

The ***average seasonal cooling efficiency*** ($\overline{\text{EER}}$) is an estimate of the average efficiency of the air conditioner over the cooling season at the location of the measure. The ***SEER*** is an estimate of the seasonal energy efficiency for an average US city. Programs should use the manufacturers' rated SEER until data can be developed that is more appropriate for NY climates.

Efficiency assumptions for properly charged air conditioners and heat pumps in several SEER classes are covered in the air conditioner sections above. Refrigerant charge adjustments applied to existing units should use the SEER 10 data. Adjustments to new units should use the SEER of the unit treated.

The efficiency improvement resulting from refrigerant charge adjustment depends on how far off the unit was before the adjustment was done, and whether the adjustment was done correctly. The DEER study lists two levels of charge adjustment, with a corresponding efficiency improvement:

• Efficiency gains of 7% for refrigerant charge adjustments less than 20%
• Efficiency gains of 16% for refrigerant charge adjustments greater than 20%

The magnitude of the charge adjustments expected are not known at this time, so a default value of 10% improvement in unit efficiency is recommended. That is, the efficiency of an uncorrected unit is 10% below that of a corrected unit.

Parameter	Recommended Values
$\text{EER}_{\text{pk, uncorr}}$	0.9 x $\text{EER}_{\text{pk, corr}}$
$\overline{\text{EER}}_{\text{uncorr}}$	0.9 x $\overline{\text{EER}}_{\text{corr}}$

Cooling load hours for residential buildings were calculated from a DOE-2.2 simulation of prototypical residential buildings. See the section on air conditioning above.

Baseline Efficiencies from which savings are calculated
See table above.

Compliance Efficiency from which incentives are calculated
TBD

Operating Hours

Cooling load hours vary by city and building vintage. See table above.

Incremental Cost

TBD

Non-Electric Benefits - Annual Fossil Fuel Savings

None anticipated

Notes & References

1. Unit seasonal and peak efficiency data taken from the California DEER update study: 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December, 2005. Available at http://www.calmac.org/publications/2004-05_DEER_Update_Final_Report-Wo.pdf

2. Typical values for demand diversity factor (DF), coincidence factor (CF) and rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.

Revision Number
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HIGH EFFICIENCY GAS FURNACES

Description of Measure

High efficiency condensing gas furnaces with AFUE > 90%.

Method for Calculating Energy Savings

$$\Delta\text{therms} = \text{units} \times \frac{\text{kBtuh}}{\text{unit}} \times \text{RLF}_{\text{heat}} \times \left(\frac{1}{\bar{\eta}_{base} \times \bar{\eta}_{duct,base}} - \frac{1}{\bar{\eta}_{ee} \times \bar{\eta}_{duct,ee}} \right) \times \frac{\text{HLH}}{100}$$

where:

Δtherms	= gross annual gas savings
units	= number of furnaces installed
kBtuh/unit	= the nominal rating of the heating capacity of the furnace in kBtu/hr
$\bar{\eta}$	= average seasonal efficiency of furnace
$\bar{\eta}_{\text{duct}}$	= average seasonal duct system efficiency
HLH	= heating load hours
RLF_{heat}	= heating mode rated load factor
100	= conversion factor (kBtuh/therm)

The ***rated load factor*** is the ratio of the peak heating load imposed on the heating equipment to the total rated heating capacity. This factor compensates for oversizing of the furnace.

$$\text{RLF}_{\text{heat}} = \frac{peak\ \ heating\ \ load}{nameplate\ \ \text{heating}\ \ capacity}$$

Recommended value for the rated load factor is 0.8.

The ***average seasonal efficiency*** of the furnace is the ratio of the heating output to the fuel input (in consistent units) over a heating season. This factor accounts for combustion efficiency, standby losses, cycling losses, and other sources of inefficiency within the furnace itself. The ***AFUE*** is an estimate of the seasonal heating energy efficiency for an average US city calculated according to a standard US DOE method and reported by the furnace manufacturer. Programs should use the manufacturers' rated AFUE until data can be developed that are more appropriate for NY climates.

The ***duct system efficiency*** accounts for losses from duct systems due to leakage and inadequate insulation. See section on duct leakage sealing and insulation for more

information. When calculating the impacts of gas furnaces only, use the same duct efficiency in the pre and post case.

Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

$$\text{HLH} = \frac{\textit{A}\text{nnual Heating Load (Btu)}}{\textit{Peak}\text{ Heating Load (Btu/hr)}}$$

Heating load hours for multifamily residential buildings were calculated from a DOE-2.2 simulation of prototypical buildings. The prototype building characteristics are described in Appendix A[15]. The HLH for three building vintages and six cities in NY are shown below:

Multifamily Low-Rise Heating Load Hours by Vintage and City

City	Old	Average	New
Albany	1,287	1,265	911
Binghamton	1,650	1,556	1,124
Buffalo	1,524	1,519	1,104
Massena	1,632	1,658	1,205
NYC	946	904	629
Syracuse	1,469	1,507	1,056

<u>Baseline Efficiencies from which savings are calculated</u>

The baseline efficiency ($\bar{\eta}_{base}$) is as follows:

For new construction and replace on failure: minimum AFUE for new gas furnaces per NAECA is 78%. Common practice generally leads code, but there are no New York specific baseline data on furnace efficiency available at this time.

Distribution system efficiency ($\bar{\eta}_{\text{dist,base}}$) should be set to the unsealed and uninsulated values from the duct leakage sealing section for the appropriate building type. See duct leakage sealing and insulation section in this manual for more information.

<u>Compliance Efficiency from which incentives are calculated</u>

The measure efficiency ($\bar{\eta}_{ee}$) is as follows:

ACEEE recommends two tiers: > 92% and > 95% AFUE

[15] HLH values used for gas furnace calculations use a 3 degree temperature setback assumption, consistent with the NY DPS Gas Manual published in March, 2009. See Appendix A for more information.

Operating Hours

Heating load hours calculated from building energy simulation models described in Appendix A and summarized above.

Non-Gas Benefits - Annual Electric Savings

EC motors included with high efficiency gas furnaces may provide electricity savings benefits. However, studies in Wisconsin indicate that homeowners are more likely to operate their furnace fans continuously after installing a furnace with an EC motor, potentially reducing or eliminating these savings.

Notes & References

1. Typical value for rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.
2. For more information on EC motor savings and occupant behavior see: Pigg, Scot. "Variable Speed Furnaces Come of Age," Wisconsin Perspective, November/December 2004. Energy Center of Wisconsin, Madison, WI. www.ecw.org/download.php?producturl=/prod/articles/art1_furn.pdf
3. The HLH values assumed in this section include a 3°F night time setback of the room temperature setpoint. See the section on programmable setback thermostats and Appendix A for more information.

DUCT INSULATION AND LEAKAGE SEALING

Description of Measure

Improvements to duct systems made separately or in conjunction with high efficiency furnace, air conditioner, and heat pump installations.

Method for Calculating Energy Savings

$$\Delta kWh = units \times \left[\frac{ton}{unit} \times RLF_{cool} \times \left[\frac{12}{\overline{EER}_{base} \times \overline{\eta}_{dist,base}} - \frac{12}{\overline{EER}_{ee} \times \overline{\eta}_{dist,ee}} \right] \times CLH + \frac{kBtuh}{unit} \times RLF_{heat} \times \left[\frac{1}{\overline{COP}_{base} \times \overline{\eta}_{dist,base}} - \frac{1}{\overline{COP}_{ee} \times \overline{\eta}_{dist,ee}} \right] \times \frac{HLH}{3413} \right]$$

$$\Delta therms = units \times \frac{kBtuh}{unit} \times RLF_{heat} \times \left(\frac{1}{\overline{\eta}_{base} \times \overline{\eta}_{duct,base}} - \frac{1}{\overline{\eta}_{ee} \times \overline{\eta}_{duct,ee}} \right) \times \frac{HLH}{100}$$

where:

Δ kWh	= gross annual electricity (kWh) savings
Δtherms	= gross annual gas savings
units	= number of furnaces installed
kBtuh/unit	= the nominal rating of the heating capacity of the furnace in kBtu/hr
$\overline{EER}$	= average energy efficiency ratio over the cooling season. (Btu/watt-hour)
$\overline{COP}$	= average heating season coefficient of performance of heat pump
$\overline{\eta}$	= average heating season efficiency of furnace
$\overline{\eta}_{duct}$	= duct system average seasonal efficiency
CLH	= cooling load hours
HLH	= heating load hours
RLF_{cool}	= cooling mode rated load factor
RLF_{heat}	= heating mode rated load factor
100	= conversion factor (kBtuh/therm)
3413	= conversion factor (Btu/kwh)

The ***rated load factor*** for cooling is the ratio of the peak cooling load imposed on the cooling equipment to the total rated cooling capacity. This factor compensates for oversizing of the air conditioning unit.

$$RLF_{cool} = \frac{\text{peak cooling load}}{\text{nameplate capacity}}$$

The ***rated load factor*** for heating is the ratio of the peak heating load imposed on the heating equipment to the total rated heating capacity. This factor compensates for oversizing of the furnace.

$$RLF_{heat} = \frac{\textit{peak heating load}}{\textit{nameplate} \text{ heating } \textit{capacity}}$$

Recommended value for the rated load factor is 0.8.

The $\overline{EER}$ is an estimate of the average efficiency of the air conditioner over the cooling season. Most air conditioning equipment installed in residences has a SEER efficiency rating, which is an estimate of the seasonal energy efficiency for an average US city. Programs should use the manufacturers' rated SEER until data can be developed that is more appropriate for NY climates.

Cooling load hours are defined as the ratio of the building annual cooling load to the building peak cooling load:

$$CLH = \frac{\text{Annual Cooling Load (Btu)}}{\text{Peak Cooling Load (Btu / hr)}}$$

See section on high efficiency air conditioners for more information

Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

$$HLH = \frac{\textit{A}\text{nnual Heating Load (Btu)}}{\textit{Peak} \text{ Heating Load (Btu/hr)}}$$

See section on high efficiency heat pumps and furnaces for more information

The ***average seasonal cooling efficiency*** ($\overline{EER}$) is an estimate of the average efficiency of the air conditioner over the cooling season. Most air conditioning equipment installed in residences has a SEER efficiency rating,, which is an estimate of the seasonal energy efficiency for an average US city. Programs should use the manufacturers' rated SEER until data can be developed that is more appropriate for NY climates.

The ***average seasonal efficiency*** of the heat pump ($\overline{COP}$) is the ratio of the heating output to the electricity input (in consistent units) over a heating season. The ***HSPF*** is an estimate of the seasonal heating energy efficiency for an average US city. The average COP in the equation above is equal to the HSPF/3.413. Programs should use the

manufacturers' rated HSPF until data can be developed that are more appropriate for NY climates. See heat pump section for more information.

The ***average seasonal efficiency*** of the furnace ($\bar{\eta}$) is the ratio of the heating output to the fuel input (in consistent units) over a heating season. This factor accounts for combustion efficiency, standby losses, cycling losses, and other sources of inefficiency within the furnace itself. The ***AFUE*** is an estimate of the seasonal heating energy efficiency for an average US city calculated according to a standard US DOE method and reported by the furnace manufacturer. Programs should use the manufacturers' rated AFUE until data can be developed that are more appropriate for NY climates.

Duct system efficiencies were calculated utilizing the building energy simulation model described in Appendix A. The cooling and heating season average distribution efficiencies for duct systems in multi-family buildings across six New York cities are summarized below. Note: duct systems in lowrise multifamily buildings are assumed to run in an unconditioned space above an insulated ceiling in the top floor units, and through an unconditioned plenum space in the bottom floor units.

Distribution System Efficiency in Heating Mode

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.821	0.817	0.819	0.813	0.843	0.822
15%	Uninsulated	0.794	0.791	0.793	0.785	0.816	0.795
20%	Uninsulated	0.774	0.773	0.774	0.765	0.797	0.775
25%	Uninsulated	0.754	0.754	0.755	0.744	0.778	0.756
30%	Uninsulated	0.735	0.736	0.735	0.724	0.758	0.736
8%	R-6	0.943	0.944	0.944	0.941	0.949	0.944
15%	R-6	0.913	0.915	0.915	0.909	0.920	0.914
20%	R-6	0.892	0.895	0.894	0.887	0.900	0.893
25%	R-6	0.870	0.874	0.873	0.864	0.879	0.871
30%	R-6	0.848	0.853	0.852	0.841	0.858	0.849

Distribution System Efficiency in Cooling Mode

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.814	0.797	0.821	0.805	0.859	0.808
15%	Uninsulated	0.792	0.774	0.799	0.776	0.838	0.782
20%	Uninsulated	0.770	0.750	0.781	0.759	0.824	0.767
25%	Uninsulated	0.757	0.739	0.762	0.744	0.810	0.752
30%	Uninsulated	0.738	0.720	0.748	0.726	0.795	0.734
8%	R-6	0.941	0.936	0.945	0.938	0.951	0.939
15%	R-6	0.912	0.909	0.916	0.913	0.929	0.910
20%	R-6	0.893	0.890	0.899	0.889	0.911	0.888
25%	R-6	0.871	0.870	0.879	0.870	0.894	0.870
30%	R-6	0.852	0.851	0.863	0.849	0.876	0.851

The ***demand diversity factor*** is used to account for the fact that not all HVAC systems in all buildings in the population are operating at the same time. The demand diversity factor is defined as the average fraction of installed capacity of a population of HVAC systems that are operating at the time of the end-use peak.

The ***coincidence factor*** is used to account for the fact that peak measure savings may not be coincident with utility peak demands. The coincidence factor is defined as the portion of the end-use demand reduction that is coincident with the system peak.

Recommended values for the rated load factor, demand diversity factor, and coincidence factors are shown below:

Parameter	Recommended Values
Rated Load Factor	0.8
Demand diversity factor	0.8
Coincidence factor	1.0

<u>Baseline Efficiencies from which savings are calculated</u>

The baseline efficiency ($\overline{COP}_{base}$) for heat pumps should be set according to the method described in the sections on heat pump efficiency. The baseline efficiency ($\overline{\eta}_{base}$) for furnaces should be set according to the method described in the sections on furnace efficiency. Distribution system efficiency ($\overline{\eta}_{\text{dist,base}}$) should be set to the unsealed and uninsulated values from the duct leakage sealing section for the appropriate building type. The US EPA estimates total duct leakage for typical residential construction at 20% of system air flow. Uninsulated ducts are considered to be the baseline condition.

Compliance Efficiency from which incentives are calculated

The measure efficiency ($\overline{COP}_{ee}$) for heat pumps should be set according to the section on efficient heat pumps. The measure efficiency ($\overline{\eta}_{ee}$) for furnaces should be set according to the section on efficient furnaces. Distribution system efficiency ($\overline{\eta}_{dist,ee}$) should be set to the Air Conditioning Contractors of America (ACCA) Quality Installation (QI) Standard specifications:

Construction type	Duct location	Total Leakage (%)
New	Inside thermal envelope	10%
New	Outside thermal envelope	6%
Existing	All	20% or 50% reduction (which ever is greater)

Operating Hours

Heating load hours calculated from building energy simulation models described in Appendix A and summarized in previous section.

Non-Electric Benefits - Annual Fossil Fuel Savings

N/A

Notes & References

1. Typical value for rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.
2. ACCA QI specs can be found in: ANSI/ACCA Standard 5 QI-2007. HVAC Quality Installation Specification. Air Conditioning Contractors of America, Arlington, VA. www.acca.org
3. An alternative source of distribution system efficiency calculation methods is included in ANSI/ASHRAE Standard 152 – 2004 Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems, American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta, GA. www.ashrae.org
4. The HLH values assumed in this section include a 3°F night time setback of the room temperature setpoint. See the section on programmable setback thermostats and Appendix A for more information.

WATER HEATING

Description of Measure

Efficient instantaneous and storage type water heaters installed in multifamily applications. Electric demand savings occur due to reduced standby losses.

Method for Calculating Energy Savings

$$\Delta kW_S = \text{units} \times \frac{(UA_{base} - UA_{ee}) \times \Delta T_s}{3413} \times DF_s \times CF_s$$

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \overline{\Delta T_w}}{3413} \times \left[\frac{1}{EF_{base}} - \frac{1}{EF_{ee}} \right]$$

$$\Delta therm = units \times \frac{GPD \times 365 \times 8.3 \times \overline{\Delta T_w}}{100{,}000} \times \left[\frac{1}{EF_{base}} - \frac{1}{EF_{ee}} \right]$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
$\Delta therm$	= gross annual gas savings
units	= number of high efficiency water heaters installed under the program
UA_{base}	= overall heat loss coefficient of base water heater (Btu/hr-°F)
UA_{ee}	= overall heat loss coefficient of efficient water heater (Btu/hr-°F)
ΔT_s	= temperature difference between the stored hot water and the surrounding air (°F)
GPD	= average daily water consumption (gallons/day)
$\overline{\Delta T}_w$	= average difference between the cold inlet temperature and the hot water delivery temperature (°F)
EF_{base}	= baseline water heater energy factor
EF_{ee}	= efficient water heater energy factor
DF	= demand diversity factor
CF	= coincidence factor
3413	= conversion factor (Btu/kWh)
8.3	= conversion factor (Btu/gallon-°F)
100,000	= conversion factor (Btu/therm)
365	= conversion factor (days/yr)

The ***ambient temperature difference*** between the water heat setpoint and the ambient room temperature is used to calculate the standby losses. Water heaters are generally located in conditioned or partially conditioned spaces to avoid freezing. A room temperature of 70°F is the default value.

The ***water temperature difference*** between the water heat setpoint and cold water mains temperature is used to calculate the hot water load. If the water heater has sufficient capacity to meet the load, hot water will be delivered at the water heater setpoint temperature. Water heater setpoint for residential buildings is usually in the range of 120 °F to 140°F. The water heater setpoint should be consistent with temperature assumed in the water use data.

Cold water entering temperatures vary according to water source and climate. Ground water temperatures from wells tend to be fairly stable year-round, and are approximately equal to the annual average outdoor temperature. Ground and surface water temperatures from water utilities fluctuate seasonally due to the influence of climate on reservoir or storage tank water temperature. Water temperature is usually monitored by the water utility, and is available on request. Cold water entering temperatures based on the annual outdoor temperature are shown below:

City	Annual average outdoor temperature (°F)
Albany	48.2
Binghamton	46.9
Buffalo	48.3
Massena	44.7
NYC	49.4
Syracuse	48.6

Hot water use varies by family size. Estimates of hot water use per person as a function of number of people in the home is shown below:

Number of people	Gal/person-day
2	18
3	22
4	16
5 or more	12

The ***energy factor*** is used to calculate seasonal water heater efficiency. The energy factor is reported by manufacturers according to a standard test procedure. The energy factor takes into account the efficiency of the heat source (electricity or gas) and the effectiveness of the tank insulation in reducing standby losses.

Tank overall heat loss coefficient is calculated from the energy factor, recovery efficiency, and heater electric element or gas burner output capacity:

$$UA = \frac{\frac{1}{EF} - \frac{1}{RE}}{67.5 \times \left(0.000584 - \frac{1}{RE \times Cap}\right)}$$

RE_{base} = recovery efficiency
Cap_{base} = water heater capacity (Btu/hr)

Standard assumptions for recovery efficiency are shown below:

Water Heater Type	Recovery efficiency
Electric	0.97
Gas	0.75

The ***demand diversity factor*** is used to account for the fact that not all water heating systems in all buildings in the population are operating at the same time. The demand diversity factor is defined as the average fraction of installed capacity of a population of water heating systems that are operating at the time of the end-use peak.

The ***coincidence factor*** is used to account for the fact that peak measure savings may not be coincident with utility peak demands. The coincidence factor is defined as the portion of the end-use demand reduction that is coincident with the system peak.

Recommended values for the demand diversity factor and coincidence factors are shown below:

Parameter	**Recommended Values**
Demand diversity factor	1.0
Coincidence factor	1.0

<u>Baseline Efficiencies from which savings are calculated</u>

The baseline energy factor (EF_{base}) is as follows:

New construction and replace on failure: efficient water heater is assumed to replace a standard efficiency tank-type water heater. Energy Factors (EF) according to NAECA for storage water heaters are calculated as a function of storage volume:

Electric water heaters: EF = 0.93-0.00132V
Gas water heaters: EF = 0.62-0.0019V

where V is tank volume in gallons.

Compliance Efficiency from which incentives are calculated

ACEEE recommendations for the measure energy factor (EF_{ee}) are as follows:

Electric: EF $\geq$ .93

Gas: EF $\geq$ .82 plus electronic ignition

Operating Hours

Water heater assumed to be available at all hours

Non-Electric Benefits - Annual Fossil Fuel Savings

Reduction in standby heat losses will have some impact on space heating and cooling when water heater located in conditioned space. These are considered small and not included in these calculations.

Notes & References

1. Average hot water use per person taken from: Perlman, M., B.E. Mills, and B.T. Barber; Development of Residential Hot Water Use Patterns; Ontario Hydro Research Division, RP-430, 1984.
2. Average annual outdoor temperature taken from the National Renewable Energy Laboratory TMY 3 long-term average weather data sets, processed with the DOE-2.2 weather data statistics package. www.nrel.gov

ROOM AIR CONDITIONER

Description of Measure

Room air conditioners installed in multifamily residential buildings.

Method for Calculating Summer Peak Demand and Energy Savings

$$\Delta kW_S = \text{units} \times \frac{\text{tons}}{\text{unit}} \times RLF \times \left(\frac{12}{EER_{base,\,pk}} - \frac{12}{EER_{ee,\,pk}} \right) \times DF_S \times CF_S$$

$$\Delta kWh = \text{units} \times \frac{\text{tons}}{\text{unit}} \times RLF \times \left(\frac{12}{\overline{EER}_{base}} - \frac{12}{\overline{EER}_{ee}} \right) \times CLH$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
units	= the number of air conditioning units installed under the program
tons/unit	= tons of air conditioning per unit, based on nameplate data
$\overline{EER}$	= average energy efficiency ratio over the cooling season. (Btu/watt-hour)
EER_{pk}	= energy efficiency ratio under peak conditions (Btu/watt-hour)
CLH	= cooling load hours
RLF	= rated load factor
DF	= demand diversity factor
CF	= coincidence factor
12	= conversion factor (kBtuh/ton)

The ***rated load factor*** is the ratio of the peak cooling load imposed on the cooling equipment to the total rated cooling capacity. This factor compensates for oversizing of the air conditioning unit.

$$RLF = \frac{\text{peak cooling load}}{\text{nameplate capacity}}$$

Cooling load hours are defined as the ratio of the building annual cooling load to the building peak cooling load:

$$CLH = \frac{\text{Annual Cooling Load (Btu)}}{\text{Peak Cooling Load (Btu / hr)}}$$

The ***demand diversity factor*** is used to account for the fact that not all HVAC systems in all buildings in the population are operating at the same time. The demand diversity factor is defined as the average fraction of installed capacity of a population of HVAC systems that are operating at the time of the end-use peak.

The ***coincidence factor*** is used to account for the fact that peak measure savings may not be coincident with utility peak demands. The coincidence factor is defined as the portion of the end-use demand reduction that is coincident with the system peak.

Recommended values for the rated load factor, demand diversity factor, and coincidence factors are shown below:

Parameter	**Recommended Values**
Rated Load Factor	0.8
Demand diversity factor	0.8
Coincidence factor	1.0

<u>Baseline Efficiencies from which savings are calculated</u>

Baseline efficiency assumptions for normal replacement are shown below:

Product Class (Btu/hr)	Seasonal average efficiency ($\overline{EER}$)	Efficiency under Peak Conditions (EER_{pk})
< 8,000	9.7	9.7
8,000 – 13,999	9.8	9.8
14,000 – 19,999	9.7	9.7
≥ 20,000	8.5	8.5

Note: seasonal and peak efficiencies are set to the same value until additional information on the seasonal efficiency of room air conditioners can be developed.

<u>Compliance Efficiency from which incentives are calculated</u>

Product Class (Btu/hr)	Energy Star		CEE Tier 1		CEE Tier 2	
	$\overline{EER}$	EER_{pk}	$\overline{EER}$	EER_{pk}	$\overline{EER}$	EER_{pk}
< 8,000	10.7	10.7	11.2	11.2	11.6	11.6
8,000 – 13,999	10.8	10.8	11.3	11.3	11.8	11.8
14,000 – 19,999	10.7	10.7	11.2	11.2	11.6	11.6
≥ 20,000	9.4	9.4	9.8	9.8	10.2	10.2

Note: seasonal and peak efficiencies are set to the same value until additional information on the seasonal efficiency of room air conditioners can be developed.

Operating Hours

See central air conditioner section for operating hours by climate zone and building vintage.

Incremental Cost

TBD

Non-Electric Benefits - Annual Fossil Fuel Savings

None anticipated

Notes & References

1. Typical values for demand diversity factor (DF), coincidence factor (CF) and rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol 2. Electric Power Research Institute, Palo Alto, CA August, 1993.

Revision Number
0

HEAT PUMP WATER HEATER

Measure Description
An electric heat pump water heater is a domestic water heater that uses a heat pump technology for moving heat from the air (inside or outside the home) to the water storage tank. The heat pump is essentially similar to a standard air conditioner, but instead of exhausting the heat to the outside of the home and putting the cooled air into the home, the heat pump water heater places the heat from the air into the water that is then stored in the hot water tank. The cooled air is exhausted into the home (for interior installed units) or can be vented outside of the home. If the cooled air is exhausted into the home it can affect the energy consumption of the home's heating and cooling system. When air conditioning is required, the water heat pump can lower the amount of air conditioning required. During cooler months, additional heating is required for the home to off-set the cold air from the water heater unless the chilled air is vented to the outside of the home. Savings calculation approaches need to consider the energy impacts to both the domestic water heating system and to the home in which the units are installed to estimate the energy impacts on the home (rather than just the hot water supply). Impacts for both electric and non-electric energy consumption need to be reported for programs that include systems that vent cooled air into the home.

Savings Estimation Approach

1. New Construction, Replace on Failure and Early Replacement
This savings will be estimated as follows:

<u>Annual kWh Savings</u>
Annual Energy Savings = (estimated baseline electric hot water energy consumption) - (estimated heat pump energy consumption for same water volumes and temperature conditions) = (estimated electric savings) + (positive or negative impacts on the home's heating and cooling system under average participant household conditions).

Total Energy Impacts[16] = (BE – HPWH) + HCI

Where: BE = baseline electric energy consumption. If new construction, the baseline is the typical system that would have been installed without the program. If a replace on failure system, the baseline is the typical system that would have been installed without the program. If it is an early replacement, the baseline is the typical system that was removed for the remaining useful life of the system plus the savings associated with the system that would have been installed without the program based on market averages.
HPWH = Heat pump electric water heating consumption

[16] See FEMP Federal Technology Alert for Residential Water Heat Pump Water Heaters for detailed calculation approach. All temperature and environmental conditions will use New York specific temperature data. See page 32 of the FEMP publication for water input temperatures for New York. Typical historic temperatures should be used for heating and cooling degree days.

HCI = Heating and cooling impact. The negative or positive impacts on the home's heating and cooling systems. If electric, the impacts are embedded in the calculation. If other than electric impacts, the impacts are reported separately (see below).

If participants' homes are heated or cooled with electricity, the impacts on the water heating estimate are adjusted to account for increases or decreases on the homes' heating and cooling systems. If the participants' homes are heated by non-electric fuels, the impacts of the water heating system on the homes' heating and cooling energy use are also reported. This will require multi-fuel impact reporting when non-electric heated homes are allowed to be participants.

Energy savings calculations will be estimated following FEMP's [17] Federal Technology Alert
http://www1.eere.energy.gov/femp/pdfs/FTA_res_heat_pump.pdf Appendix C, Calculations (page 31) for the typical program installation condition. Heating and cooling degree days will be the typical condition for the typical installation for the program participants.

Peak Savings

Peak savings calculation will follow FEMP's Technical Alert Appendix C approach for summer afternoon peak conditions for New York reflective of the typical conditions that apply to the program service area as a whole, weighted to the participant distribution across the state.

Sample Calculation

Inserted below is the sample calculation presented in FEMP's Technical Alert. However, this calculation is for a warmer climate than what New York experiences. The inputs for water temperature and climate will be based on typical program conditions for the typical installation (See following page).

[17] FEMP = Federal Energy Management Program

Sample Calculation Approach (from Appendix C of FEMP's Technical Alert.

Calculations
("eq" followed by individual numbers in brackets refer to results of the equation identified by the number)

(1) Hot-water Usage Estimate (Number of Occupants -1) x 10.7 gal/day/occupant + 32.2 gal/day) _____ gal/day
(2) Daily Hot-water Energy Load = 8.28 Btu/gal x _____ gal/day x (135-CW supply temperature) _____ Btu/day

HPWH EF
If supplemental electric resistance heat not anticipated
(3a) $EF_{hpwh} = EF_{tank}$

If supplemental electric resistance heat anticipated
(3b) $EF_{hpwh} = EF_{tank} \times (1 - FLR) + FLR$

Where FLR = Tank Size (gal) x 0.25 x 8.28 Btu/gal-°F x (135°F - CW supply temperature) x 25%/(eq2)

Annual Hot-water Energy Requirements

$$\textit{Annual Electric Energy} = \frac{\textit{Hot Water Energy Load (Btu/day)}}{\textit{Water Heater EF}} \times \frac{\textit{365 days/yr}}{\textit{3413 Btu/kWh}}$$

(4) Electric Resistance Water Heater _____ kWh/yr
(5) Heat Pump Water Heater _____ kWh/yr

Annual Space conditioning effect of ambient-air HPWHs

(6) DF = [A x HR65 + (1-A) x HR80)] / (HR65)

where A = 2 x (Design 2.5% T_{wb} °F/ Design 2.5% T_{db} °F) - 0.9
HR65 = number of hours per year with outdoor temperature > 65°F = _____ hr/yr
HR80 = number of hours per year with outdoor temperature > 80°F = _____ hr/yr

(7) Beneficial Space Cooling = DF x HR65 x (eq2) / 24 hr/day x ($1/EF_{ac}$ -$1/EF_{hpwh}$) / 1000 = _____ kBtu/yr
(8) Detrimental Space Cooling = (8760-HR65) x (eq2) / 24 hr/day x ($1/EF_{ac}$-$1/EF_{hpwh}$) /1000 = _____ kBtu/yr

(9) Annual Space Cooling Energy Savings= (eq7)/(SEER) = _____ kWh/yr
(10) Annual Additional Space Heating Energy
(10a) Electric Resistance Heat= (eq8)/(3.413 kBtu/kWh) = _____ kWh/yr
(10b) Electric Heat Pump= (eq8)/HSPF kBtu/kWh) = _____ kWh/yr
(10c) Gas Heat= (eq8)/(EFF * 10) = _____ therms/yr

Annual Energy Requirements:
Electric Resistance Water Heater
(11) Electric Energy = (eq4) = _____ (kWh/yr

Heat Pump Water Heater
(12a)Electric Energy = (eq5) - (eq9) + (eq10a) + (eq10b) = _____ kWh/yr
(12b)Gas Energy = (eq10c) _____ therms/yr

Contribution to Demand (non-morning demand peak)
(13) Electric Resistance Water Heater Demand (kW) = (eq4) / 8760 hr/yr x 12 mo/yr = _____ kW-mo/yr
(14) HPWH Demand = (eq5) / 8760 hr/yr x 12 mo/yr = _____ kW-mo/yr

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Calculations
("eq" followed by individual numbers in brackets refer to results of the equation identified by the number)

(1) Hot-water Usage Estimate (Number of Occupants -1) x 10.7 gal/day/occupant + 32.2 gal/day) _____ gal/day
(2) Daily Hot-water Energy Load = 8.28 Btu/gal x _____ gal/day x (135-CW supply temperature) _____ Btu/day

HPWH EF
If supplemental electric resistance heat not anticipated
(3a) $EF_{hpwh} = EF_{rated}$

If supplemental electric resistance heat anticipated
(3b) $EF_{hpwh} = EF_{rated} \times (1 - FLR) + FLR$

Where FLR = Tank Size (gal) x 0.25 x 8.28 Btu/gal-°F x (135°F - CW supply temperature) x 25%/(eq2)

Annual Hot-water Energy Requirements

$$\textit{Annual Electric Energy} = \frac{\textit{Hot Water Energy Load (Btu/day)}}{\textit{Water Heater EF}} \times \frac{\textit{365 days/yr}}{\textit{3413 Btu/kWh}}$$

(4) Electric Resistance Water Heater _____ kWh/yr
(5) Heat Pump Water Heater _____ kWh/yr

Annual Space conditioning effect of ambient-air HPWHs

(6) DF = [A x HR65 + (1-A) x HR80)] / (HR65)

where A = 2 x (Design 2.5% T_{wb} °F/ Design 2.5% T_{db} °F) - 0.9
HR65 = number of hours per year with outdoor temperature > 65°F = _____ hr/yr
HR80 = number of hours per year with outdoor temperature > 80°F = _____ hr/yr

(7) Beneficial Space Cooling = DF x HR65 x (eq2) / 24 hr/day x ($1/EF_{std}$ - $1/EF_{hpwh}$) / 1000 = _____ kBtu/yr
(8) Detrimental Space Cooling = (8760-HR65) x (eq2) / 24 hr/day x ($1/EF_{std}$ - $1/EF_{hpwh}$) /1000 = _____ kBtu/yr

(9) Annual Space Cooling Energy Savings= (eq7)/(SEER) = _____ kWh/yr
(10) Annual Additional Space Heating Energy
(10a) Electric Resistance Heat= (eq8)/(3.413 kBtu/kWh) = _____ kWh/yr
(10b) Electric Heat Pump= (eq8)/HSPF kBtu/kWh) = _____ kWh/yr
(10c) Gas Heat= (eq8)/(EFF * 10) = _____ therms/yr

Annual Energy Requirements:
Electric Resistance Water Heater
(11) Electric Energy = (eq4) = _____ (kWh/yr

Heat Pump Water Heater
(12a)Electric Energy = (eq5) - (eq9) + (eq10a) + (eq10b) = _____ kWh/yr
(12b)Gas Energy = (eq10c) _____ therms/yr

Contribution to Demand (non-morning demand peak)
(13) Electric Resistance Water Heater Demand (kW) = (eq4) / 8760 hr/yr x 12 mo/yr = _____ kW-mo/yr
(14) HPWH Demand = (eq5) / 8760 hr/yr x 12 mo/yr = _____ kW-mo/yr

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LOW FLOW SHOWERHEADS

Measure Description

A low flow showerhead is a water saving showerhead rated at 2.5 gallons per minute (gpm) - the federal statutory standard for showerheads – or fewer. It reduces the amount of water flowing through the showerhead, compared with a standard showerhead, while maintaining similar shower pressure.

Savings Estimation Approach – Method and Results[18]

Annual Energy Savings

Method

The savings estimations were derived through the following steps:

1. Develop estimate of annual gallons of water saved from the measure (Table 1)
2. Calculate the amount of heat required to heat that much water (Table 2)
3. Develop an estimate of the total energy saved based on the efficiency of the hot water heater. (Table 3)

Savings

Table 1 below provides a range of baseline shower flows (the columns), related input assumptions, and the resulting water savings. Two different flows for the new showerhead are included below: 2.5 gallons per minute (gpm) and 1.5 gpm, at the lower end of available products. The duration of the shower used in the calculations is 8 minutes. This is based on reported savings in research conducted in the development of deemed savings in Wisconsin and an LBNL examination of potential savings from showerheads.[19]

Table 1. Water Savings (Gallons/year)

Water Savings = ((Actual GPM - 2.2 GPM) X (minutes/shower) X (#showers/day) X (days/year))

Actual shower flow in GPM as found	3	4	5	2.5	5
Replacement showerhead (GPM)	2.5	2.5	2.5	1.5	1.5
Savings in GPM	0.5	1.5	2.5	1	3.5
Duration of use (minutes)	8	8	8	8	8
No. of showers/day	2	2	2	2	2
Days/year	365	365	365	365	365
Gallons of water saved/year	2,920	8,760	14,600	5,840	20,440

[18] This methodology is derived from CL&P and UI Program Savings Documentation for 2008 Program Year, pp. 155-156.

[19] State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation ACES: Default Deemed Savings Review Final Report June 24, 2008 and Potential Water and Energy Savings from Showerheads, by Peter J. Biermayer, LBNL 58601-Revised, March 17, 2006

Table 2. Energy Savings (MMbtu/year)

Energy Savings =((water savings x (temp to shower-temp to heater) x (8.3BTU per gallon) / (1,000,000))

Gallons of water saved/year	2,920	8,760	14,600	5,840	20,440
Temperature of water to the house (degrees F)	55	55	55	55	55
Temperature of water to the shower (degrees F)	105	105	105	105	105
Change in temperature	50	50	50	50	50
Weight of water (lbs/gallon)	8.3	8.3	8.3	8.3	8.3
BTUs to heat 1 lb of water one degree F	1	1	1	1	1
Energy saved at showerhead (MMBTu/year)	1.212	3.635	6.059	2.424	8.483

Table 3. Natural Gas Savings (Mbtu/year and Therms/year)

Natural Gas Savings = = ((Savings at shower in MMbtu/y) /(0. 6)))

Energy saved at showerhead (MMBTU/year)	1.212	3.635	6.059	2.424	8.483
Estimated efficiency of gas water heater	0.6	0.6	0.6	0.6	0.6
Natural gas saved at water heater in MMBTU/yr	2.020	6.059	10.098	4.039	14.138
Natural gas saved at water heater in Therms/yr	20.20	60.59	100.98	40.39	141.38

Table 4. Electricity Savings (Mbtu/year and kWh/year)

Electricity Savings = = ((Savings at shower in MMbtu/y) /(1.0)))

Energy saved at showerhead (MMBTU/year)	1.212	3.635	6.059	2.424	8.483
Estimated efficiency of electric water heater	1.0	1.0	1.0	1.0	1.0
Electricity saved at water heater in MMBTU/yr	1.212	3.635	6.059	2.424	8.483
Electricity saved at water heater in kWh/yr	355	1,065	1,775	710	2,485

Lifetime Energy Savings = Annual savings x measure life

The measure life of showerheads is assumed to be 10 years[20].

Table 5 – Lifetime Natural Gas Savings (Therms)

Natural gas saved at water heater in Therms/yr	20.20	60.59	100.98	40.39	141.38
Measure life	10	10	10	10	10
Lifetime natural gas savings (therms)	202	606	1,010	404	1,414

[20] Based on the effective useful life of 10 years, in California Joint Utility Low Income Energy Efficiency Program Costs and Bill Savings Standardization Report Final Report February 1, 2001 (Revised as of March 5, 2001). The effective useful life (EUL) is defined as the median number of years that a measure is in place and operable. See also Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures, prepared for The New England State Program Working Group (SPWG) for use as an Energy Efficiency Measures/Programs
Reference Document for the ISO Forward Capacity Market (FCM) by GDS Associates, Inc., June 2007

Table 6 – Lifetime Electricity Savings (kWh)

Electricity saved at water heater in kWh/yr	355	1,065	1,775	710	2,485
Measure life	10	10	10	10	10
Lifetime natural gas savings (therms)	3550	10650	17750	7100	24850

FAUCET AERATORS

Measure Description

A faucet aerator is a water saving device that, by federal guidelines that took effect in 1994, enables no more than 2.2 gallons per minute (gpm) to pass through the faucet. Low flow faucet aerators can reduce water flow to 1.5 gpm while maintaining appropriate water pressure and flow.

Savings Estimation Approach – Method and Results[21]

Annual Energy Savings

Method

The savings estimations were derived through the following steps:
1. Develop estimate of annual gallons of water saved from the measure (Table 1)
2. Calculate the amount of heat required to heat that much water (Table 2)
3. Develop an estimate of the total energy saved based on the efficiency of the hot water heater. (Table 3)

Savings

Table 1 below provides the baseline (standard) and low flow aerator water flows, related input assumptions, and the resulting water savings. Assumptions regarding average duration of use and number of uses per day are also presented. This is based on the CL&P and UI savings document, which itself relied on FEMP assumptions.[22]

Table 1. Water Savings (Gallons/year)

Water Savings = ((Standard – low flow aerator GPM) X (duration/use) X (#uses/day) X (days/year))

Standard aerator (GPM)	2.2
Replacement low flow aerator (GPM)	1.5
Savings in GPM	0.7
Duration of use (minutes)	0.5
No. of uses/day	30
Days/year	260
Gallons of water saved/year	2,730

[21]This methodology is derived from CL&P and UI Program Savings Documentation for 2008 Program Year, pp. 157-158.

[22] Federal Energy Management Program "Domestic Water Conservation Technologies" at http://www1.eere.energy.gov/femp/pdfs/22799.pdf and other sources.

Table 2. Energy Savings (MMbtu/year)

Energy Savings =((water savings x (temp faucet-temp to heater) x (8.3BTU per gallon) / (1,000,000))

Gallons of water saved/year	2,730
Temperature of water to the house (degrees F)	55
Temperature of water at faucet (degrees F)	80
Change in temperature (degrees F)	25
Weight of water (lbs/gallon)	8.3
BTUs to heat 1 lb of water one degree F	1
Energy saved at faucet (MMBTU/year)	0.566

Table 3. Natural Gas Savings (Mbtu/year and Therms/year)

Natural Gas Savings = = ((Savings at faucet in MMbtu/y) /(0. 6)))

Gas saved at faucet (MMBTU/year)	0.566
Estimated efficiency of gas water heater	0.6
Natural gas saved at water heater in MMBTU/yr	0.944
Natural gas saved at water heater in Therms/yr	9.44

Table 4. Electricity Savings (Mbtu/year and kWh/year)

Electricity Savings = = ((Savings at faucet in MMbtu/y) /(1.0)))

Electricity saved at faucet (MMBTU/year)	0.566
Estimated efficiency of electric water heater	1.0
Electricity saved at water heater in MMBTU/yr	0.566
Electricity saved at water heater in kWh/yr	166

Lifetime Energy Savings = Annual savings x measure life

The measure life of faucet aerators is assumed to be 10 years[23].

Table 5 – Lifetime Natural Gas Savings (Therms)

Natural gas saved at water heater in Therms/yr	9.44
Measure life	10
Lifetime natural gas savings (therms)	94

[23] Based on the effective useful life of 10 years, in California Joint Utility Low Income Energy Efficiency Program Costs and Bill Savings Standardization Report Final Report February 1, 2001 (Revised as of March 5, 2001). The effective useful life (EUL) is defined as the median number of years that a measure is in place and operable.

Table 6 – Lifetime Electricity Savings (kWh)

Electricity saved at water heater in kWh/yr	166
Measure life	10
Lifetime electricity savings (kWh)	1660

HOT WATER TANK WRAPS

Description of Measure

This section covers additional thermal insulation blankets for storage-type gas water heaters. These blankets are intended to reduce standby heat losses through the side of the water heater.

Method for Calculating Energy Savings

$$\Delta kW_S = units \times \frac{(UA_{base} - UA_{ee}) \times \Delta T_s}{3413} \times DF_s \times CF_s$$

$$\Delta kWh = units \times \frac{(UA_{base} - UA_{ee}) \times \overline{\Delta T}}{3413} \times 8760$$

$$\Delta therm = units \times \frac{(UA_{base} - UA_{ee}) \times \overline{\Delta T}}{\eta_{waterheater}} \times \frac{8760}{100000}$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
units	= number of water heaters installed under the program
UA_{base}	= overall heat transfer coefficient of base water heater (Btu/hr-°F)
UA_{ee}	= overall heat transfer coefficient of improved water heater (Btu/hr-°F)
ΔT	= temperature difference between the water inside the tank and the ambient air (°F)
DF	= demand diversity factor
CF	= coincidence factor
3413	= conversion factor (Btu/kWh)
8760	= conversion factor (hr/yr)
100000	= conversion factor (Btu/therm)
$\eta_{waterheater}$	= water heater electric resistance element or burner efficiency

The ***overall heat transfer coefficient*** for the base and improved (insulated) water heater can be estimated from the following equations:

$$UA_{base} = \frac{2\pi k_{side} H}{\ln(\frac{r_2}{r_1})} + \frac{\pi r_1^2 k_{bot}}{th_{bot}} + \frac{\pi r_1^2 k_{top}}{th_{top}}$$

$$UA_{ee} = \frac{2\pi H}{\ln(\frac{r_2}{r_1}) / k_{side} + \ln(\frac{r_3}{r_2}) / k_{wrap}} + \frac{\pi r_1^2 k_{bot}}{th_{bot}} + \frac{\pi r_1^2}{(th_{top} / k_{top} + th_{wrap} / k_{wrap})}$$

where:

k_{side} = thermal conductivity of tank sidewall insulation (Btu/hr-ft-°F)
k_{bot} = thermal conductivity of tank bottom insulation (Btu/hr-ft-°F)
k_{top} = thermal conductivity of tank top insulation (Btu/hr-ft-°F)
k_{wrap} = thermal conductivity of tank wrap (Btu/hr-ft-°F)
r_1 = radius of bare tank (ft)
r_2 = radius of tank plus existing insulation (ft)
r_3 = radius of tank plus existing insulation plus additional insulation (ft)
H = height of tank (ft)
th_{bot} = thickness of insulation on tank bottom (ft)
th_{top} = thickness of insulation on tank top (ft)
th_{wrap} = thickness of tank wrap (ft)

Using the equations for tank heat loss coefficient above, water heater tank UA values are estimated for standard residential water heater sizes, assuming 1 inch of fiberglass insulation in the existing water heater and an additional 2 inches of fiberglass insulation for the tank wrap. The tank wrap is assumed to cover the tank sides only. Water heater tank height and diameter in the table below were taken from a survey of manufacturers' literature for typical water heaters. Note: The radius of the bare tank is calculated from the radius of the finished tank (which is one-half of the diameter shown in the table below) less the insulation thickness.

Water heater size (gal)	Height	Diameter	UAbase	UAee
30	60	16	5.48	2.13
40	61	16.5	5.77	2.23
50	53	18	5.65	2.19
66	58	20	6.94	2.67
80	58	22	7.79	3.00

The ***efficiency*** of an electric storage type water heater is assumed to be 1.0. The ***combustion efficiency*** of a non-condensing storage type water heater is assumed to be 0.78.

The ***ambient temperature difference*** between the water heat setpoint and the ambient room temperature is used to calculate the standby losses. Water heaters are generally located in conditioned or partially conditioned spaces to avoid freezing. A room temperature of 70°F is the default value.

The ***demand diversity factor*** is used to account for the fact that not all water heating systems in all buildings in the population are operating at the same time. The demand diversity factor is defined as the average fraction of installed capacity of a population of water heating systems that are operating at the time of the end-use peak.

The ***coincidence factor*** is used to account for the fact that peak measure savings may not be coincident with utility peak demands. The coincidence factor is defined as the portion of the end-use demand reduction that is coincident with the system peak.

Recommended values for the demand diversity factor and coincidence factors are shown below:

Parameter	Recommended Values
Demand diversity factor	1.0
Coincidence factor	1.0

Baseline Efficiencies from which savings are calculated

The UA_{base} for existing water heaters should be calculated assuming 1 inch of fiberglass insulation as the factory standard insulation level.

Compliance Efficiency from which incentives are calculated

The UA_{ee} for wrapped water heaters should assume the tank wrap adds 2 inches of fiberglass insulation to the existing tank.

Operating Hours

The water heater is assumed to be available during all hours.

Non-Gas Benefits - Annual Electric Savings

None anticipated

Notes & References

1. The thermal conductivity of various tank insulation materials is available in the ASHRAE Handbook of Fundamentals (ASHRAE, 1989). The thermal conductivity of fiberglass insulation is assumed to be 0.021 Btu/hr-ft-°F.

PHOTOVOLTAICS

Description of Measure

Grid tied photovoltaic systems applied to multifamily residential buildings

Method for Calculating Summer Peak Demand and Energy Savings

kWh = kW_{rated} x annual full sun hours

kW = kW_{rated} x Peak output factor x CF

The annual sun hours and peak output factors are shown below:

City	kWh/kW rated DC output (annual sun hours)	July pk kW/kW rated DC output (peak output factor)
Albany	1159	.710
Binghamton	1109	.712
Buffalo	1075	.735
Massena	1163	.721
NYC	1218	.677
Syracuse	1123	.688

The ***coincidence factor*** for PV systems is assumed to be 1.0

Baseline Efficiencies from which savings are calculated

NA

Compliance Efficiency from which incentives are calculated

Grid tied fixed tilt PV system with tilt = site latitude. DC to AC Derate Factor = 0.77

Operating Hours

Grid tied system is assumed to be operating whenever solar energy resource is available, regardless of home occupancy. Excess energy production is added to the grid.

Incremental Cost

TBD

Non-Electric Benefits - Annual Fossil Fuel Savings

None anticipated

Notes & References

1. System output calculated from NREL PVWatts performance calculator for grid-connected PV systems (ver 1.0) See http://www.nrel.gov/rredc/pvwatts/

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SUBMETERING

Description of Measure

Submetering of apartments in multi-family buildings, where tenants pay for their own electricity consumption according to their metered usage.

Method for Calculating Summer Peak Demand and Energy Savings

kWh = kWh/SF x SF x ESF

where:

kWh/SF	= annual electricity consumption per SF of conditioned floor area
SF	= conditioned floor area per apartment subject to submetering
ESF	= energy savings factor from submetering

Annual energy consumption per square foot of conditioned floor area should come from utility data specific to the multifamily housing stock in their service territory. The default value of ESF is set at 0.08.

There is a significant research literature substantiating the belief that submetering of master-metered multifamily buildings can result in significant energy savings (see Munley et al, 1990 and Hackett & Lutzenheiser, 1991). However, rigorous estimates of the percentage of savings to be expected are scarce. A rigorous study of water submetering commissioned by the EPA (Aquacraft 2004) found savings of approximately 15%. While water is not electricity, arguably the same behavioral impulses can be expected to be at work. Recent NYSERDA program submittals suggested an 8% savings in total energy consumption. 8% seems to be a reasonable, albeit relatively conservative, default assumption. However, given the scarcity of recent, reliable studies, it is particularly important that savings claims from submetering be rigorously evaluated through ex-post studies.

Baseline Efficiencies from which savings are calculated
NA

Compliance Efficiency from which incentives are calculated
NA

Operating Hours

NA

Incremental Cost
NA

Notes & References

"Electricity Demand in Multi-Family, Renter-Occupied Residences." Munley, Vincent G.; Taylor, Larry W; Formby, John P. *Southern Economic Journal.* July 1990, pp. 178-194.

"Social Structures and Economic Conduct: Interpreting Variations in Household Energy Consumption." Hackett, Bruce, and Loren Lutzenheiser. *Sociological Forum*, Vol 6, No.3 (September 1991) pp. 449-470.

National Multiple Family Submetering and Allocation Billing Program Study. Prepared by Aquacraft for the UP EPA. August 2004.

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APPENDIX A PROTOTYPICAL BUILDING DESCRIPTIONS

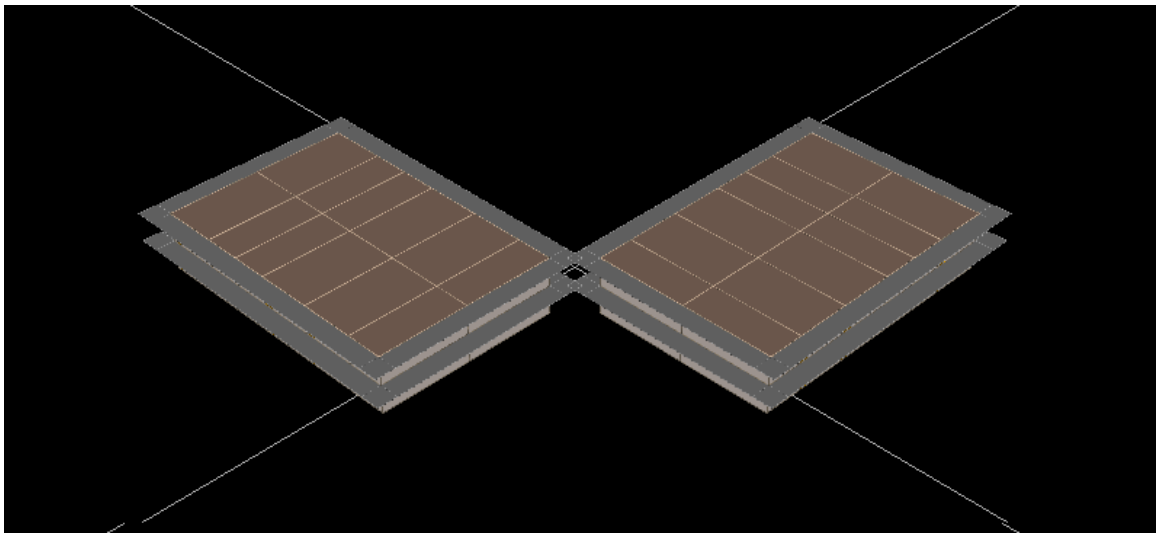
MULTIFAMILY LOW-RISE

Analysis used to develop parameters for the energy and demand savings calculations are based on DOE-2.2 simulations of a set of prototypical multifamily buildings. The prototypical simulation models were derived from the multifamily residential building prototypes used in the California Database for Energy Efficiency Resources (DEER)[24] study, with adjustments made for local building practices and climate. The low-rise prototype "model" in fact contains 2 separate buildings. Each version of the buildings is identical except for the orientation, which is shifted by 90 degrees. The selection of these 2 buildings is designed to give a reasonable average response of buildings of different design and orientation to the impact of energy efficiency measures.

Three separate models were created to represent general vintages of buildings:

1. Old: Poorly insulated building constructed in the 1950s or earlier. This vintage is referred to as the "old" vintage
2. Existing: Average insulated building conforming to 1980s era building codes. This vintage is referred to as the "average" vintage.
3. New: Construction conforming to the NY State energy standards for residential buildings. This vintage is referred to as the "new" vintage.

Each building vintage was run with 7 different HVAC system types to capture the range of HVAC systems common in low-rise multifamily buildings. A sketch of the low-rise prototype buildings is shown below.



[24] 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December, 2005. Available at http://www.calmac.org/publications/2004-05_DEER_Update_Final_Report-Wo.pdf

The general characteristics of the residential building prototype model are summarized below:

Multifamily Low-Rise Residential Building Prototype Description

Characteristic	Value
Vintage	Three vintages simulated – old poorly insulated buildings, existing average insulated buildings and new buildings
Conditioned floor area	949 SF per unit; 6 units per floor, 2 floors per building, 11,388 SF total.
Wall construction and R-value	Wood frame with siding, R-value varies by vintage
Roof construction and R-value	Wood frame with asphalt shingles, R-value varies by vintage
Glazing type	Single or double pane; properties vary by vintage
Lighting and appliance power density	0.87 W/SF average in bedrooms, 0.58 W/SF in living space
HVAC system types	1. Split system AC with gas heat 2. Split system AC with electric heat 3. Split system heat pump 4. PTAC with electric heat 5. PTHP 6. Electric heat only (no AC) 7. Gas heat only (no AC)
HVAC system size	Based on peak load with 20% oversizing.
HVAC system efficiency	AC and heat pump: SEER = 13 PTAC and PTHP: EER = 7.7 Furnace AFUE = 78
Thermostat setpoints	Heating: 70°F with setback to 67°F Cooling: 75°F with setup to 78°F
Duct location	In attic and plenum space between first and second floors. PTACs and PTHPs have no duct work.
Duct surface area	256 SF supply, 47 SF return per system
Duct insulation	Uninsulated
Duct leakage	20% of fan flow total leakage, evenly split between supply and return.
Natural ventilation	Allowed during cooling season when cooling setpoint exceeded and outdoor temperature < 65°F. 3 air changes per hour

Wall and Ceiling Insulation Levels

The assumed values for wall and ceiling by vintage are below:

Wall Insulation R-Value Assumptions by Vintage

Vintage	Assumed R-value of insulated wall	Notes
Older, poorly insulated	7	No insulation in 2 by 4 wall; 3.5 in. air gap resistance only
Existing, average insulation	11	Fiberglass insulation in 2 by 4 wall per MEC 1980
New construction	19	Code

Ceiling Insulation R-Value Assumptions by Vintage

Vintage	Assumed R-value of insulated ceiling	Notes
Older, poorly insulated	11	Minimal ceiling insulation
Existing, average insulation	19	Fiberglass insulation per MEC 1980
New construction	30 (NYC), 38 (all others)	Code

Windows

The glazing U-value and solar heat gain coefficient (SHGC) assumptions for the three vintages are shown below.

Window Property Assumptions by Vintage

Vintage	U-value (Btu/hr-F-SF)	SHGC	Notes
Older, poorly insulated	0.93	0.87	Single pane clear
Existing, average insulation	0.68	0.77	Double pane clear
New construction	0.28	.49	Double low e per code

Infiltration

Infiltration rate assumptions were set by vintage as shown below.

Infiltration Rate Assumptions by Vintage

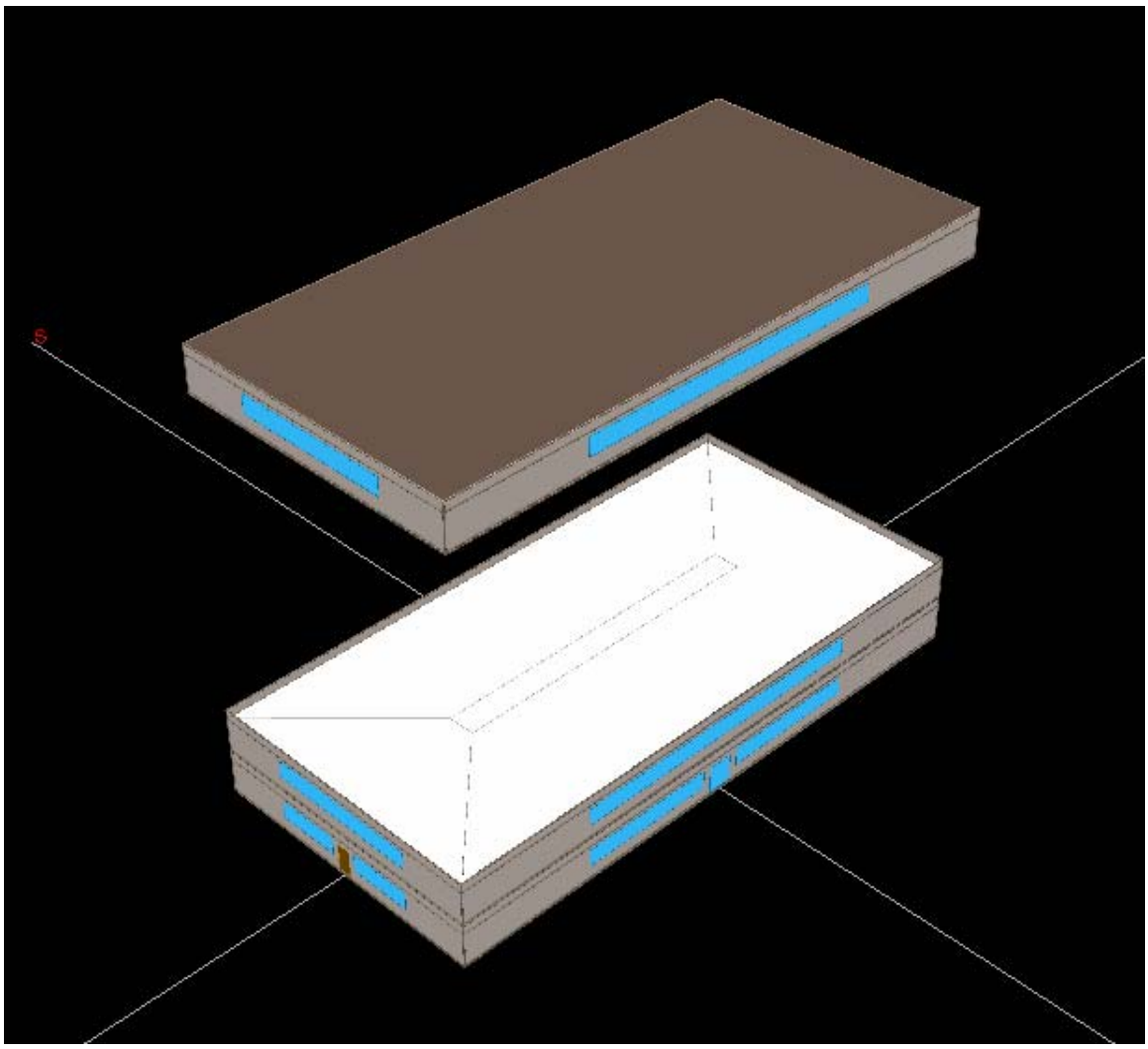
Vintage	Assumed infiltration rate	Notes
Older, poorly insulated	1 ACH	
Existing, average insulation	0.5 ACH	
New construction	0.35 ACH	Minimum without forced ventilation per ASHRAE Standard 66.

MULTIFAMILY HIGH-RISE

Analysis used to develop parameters for the energy and demand savings calculations are based on DOE-2.2 simulations of a set of prototypical multifamily buildings. The multifamily high-rise model was developed using the conceptual design "wizard" in eQUEST program. Three separate models were created to represent general vintages of buildings:

1. Old: Poorly insulated building constructed in the 1950s or earlier. This vintage is referred to as the "old" vintage
2. Existing: Average insulated building conforming to 1980s era building codes. This vintage is referred to as the "average" vintage.
3. New: Construction conforming to the NY State energy standards for residential buildings. This vintage is referred to as the "new" vintage.

A computer-generated sketch of the multi-family high rise prototype is shown in the figure below.



Note, the middle floors, since they are thermally equivalent, are simulated as a single floor, and the results are multiplied by 8 to represent the energy consumption of the 8 middle floors. The general characteristics of the multifamily high rise building prototype model are summarized below:

Multifamily High-Rise Residential Building Prototype Description

Characteristic	Value
Vintage	Three vintages simulated – old poorly insulated buildings, existing average insulated buildings and new buildings
Conditioned floor area	810 SF per unit; 10 units per floor, 10 floors per building; 81,000 SF total living space. Corridors and common space: 18,255 SF; Laundry rooms: 6,845 SF Storage: 7,985 SF Total: 114,085 SF
Wall construction and R-value	Masonry wall with brick exterior, R-value varies by vintage
Roof construction and R-value	Wood frame with built-up roofing, R-value varies by vintage
Glazing type	Single or double pane; properties vary by vintage
Lighting and appliance power density	0.7 W/SF average
HVAC system type	Four pipe fan coil with air cooled electric chiller and gas hot water boiler
HVAC system size	Based on peak load with 20% oversizing.
HVAC system efficiency	Chiller: COP = 3.9 Boiler: Thermal efficiency = 78%
Thermostat setpoints	Heating: 70°F with setback to 67°F Cooling: 75°F with setup to 78°F

Wall, Floor Insulation Levels

The assumed values for wall and ceiling by vintage are shown below:

Wall Insulation R-Value Assumptions by Vintage

Vintage	Assumed R-value of insulated wall	Notes
Older, poorly insulated	7	No insulation; air gap resistance only
Existing, average insulation	11	Same as low rise
New construction	19	Code

Roof Insulation R-Value Assumptions by Vintage

Vintage	Assumed R-value of insulated ceiling	Notes
Older, poorly insulated	11	Same as low rise
Existing, average insulation	19	Same as low rise
New construction	30 (NYC), 38 (all others)	Code

Windows

The glazing U-value and solar heat gain coefficient (SHGC) assumptions for the three vintages are shown below.

Window Property Assumptions by Vintage

Vintage	U-value (Btu/hr-F-SF)	SHGC	Notes
Older, poorly insulated	0.93	0.87	Single pane clear
Existing, average insulation	0.68	0.77	Double pane clear
New construction	0.28	.49	Double low e per code

Infiltration

Infiltration rate assumptions were set by vintage as shown below.

Infiltration Rate Assumptions by Vintage

Vintage	Assumed infiltration rate	Notes
Older, poorly insulated	1 ACH	Same as low rise
Existing, average insulation	0.5 ACH	Same as low rise
New construction	0.35 ACH	Minimum without forced ventilation per ASHRAE Standard 66.