

Final Version 1.0

New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs

Selected Residential & Small Commercial Gas Measures

March 25, 2009

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 Prah

TecMarket Works

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



Table of Contents

INTRODUCTION.....	3
LIFE-CYCLE SAVINGS	3
NET TO GROSS ADJUSTMENTS	4
SINGLE FAMILY RESIDENTIAL MEASURES	5
CLOTHES WASHERS	5
HIGH EFFICIENCY GAS FURNACES	7
SETBACK THERMOSTAT	10
DUCT INSULATION AND LEAKAGE SEALING.....	14
BOILERS.....	17
BOILER RESET CONTROLS	20
INSTANTANEOUS WATER HEATERS.....	23
SOLAR HOT WATER	25
LOW FLOW SHOWERHEADS	29
FAUCET AERATORS	31
HOT WATER TANK WRAPS	33
SMALL COMMERCIAL MEASURES	36
HIGH EFFICIENCY FURNACES.....	36
SETBACK THERMOSTAT	39
DUCT INSULATION AND LEAKAGE SEALING.....	42
BOILERS.....	46
BOILER RESET CONTROLS	49
INSTANTANEOUS WATER HEATERS.....	52
SOLAR HOT WATER	55
APPENDIX A PROTOTYPICAL BUILDING DESCRIPTIONS.....	57
SINGLE FAMILY RESIDENTIAL	57
SMALL RETAIL	60
FULL-SERVICE RESTAURANT	62
FAST FOOD RESTAURANT	63
ASSEMBLY	65

Introduction

This document presents the measure-specific energy savings estimation approaches to be used by organizations delivering natural gas energy efficiency programs to the citizens of New York that are funded via the Systems Benefits Charge.

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 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 include the effects of measure persistence and technical degradation. The measure life assumptions to be used in this manual are shown in the Table below.

Table 1. Measure Life Estimates

Measure	Sector	Effective Useful Life	Source
Clothes washers	Residential	11	DEER ²
Furnaces	Residential and Commercial	20	DEER
Programmable thermostats	Residential and Commercial	11	DEER
Boilers	Residential and Commercial	20	DEER

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).

² DEER effective useful life data from 2008 study used. See: www.deeresources.com

Measure	Sector	Effective Useful Life	Source
Boiler reset controls ³	Residential and Commercial	20	DEER
Duct insulation and leakage sealing	Residential and Commercial	10	DEER
Instantaneous water heaters	Residential and Commercial	20	DEER
Solar water heaters	Residential and Commercial	15	DEER
Low flow showerheads	Residential	10	DEER
Faucet aerators	Residential	10	DEER
Water heater tank wrap ⁴	Residential	11	DEER

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 definition 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 freeriders and spillover. Freerider adjustments act to erode the gross savings estimate by subtracting out 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 freeriders, 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. However, at the current time, to standardize the net impact estimation approach a net to gross conversion factor of 0.90 will be applied.

³ Measure life set to DEER estimate for energy management system (EMS) controls

⁴ Measure life set to DEER estimate for water heater pipe insulation

Single Family Residential Measures

CLOTHES WASHERS

Measure Description

Residential clothes washers whose water is heated by natural gas, meeting the minimum qualifying efficiency standards established under the Energy Star Program.

Savings Estimation Approach⁵

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

Annual Energy Savings

The table below shows, for new clothes washer units and for early retirement units, the savings in natural gas 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 gas savings are the associated with the gas-fired hot water heater which is needed less to heat the efficiency 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 calculator⁶. 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 ⁷	MEF	Savings from Hot Water Heater	Savings from Clothes Washer	
		Natural Gas (Ccf)	Electric (kWh)	Water (Gallons)
Savings - New Units				
Base Line	1.26	-	-	-
Energy Star	1.72	2.16	15	6,993
CEE Tier 3	2.2	4.03	22.4	7,397
Savings - Early Retirement				
Typical washer	-	-	-	-
Energy Star	1.72	9.36	50	9,932
CEE Tier 3	2.2	11.23	57.4	10,336

Lifetime Energy Savings

⁵ This methodology is derived from CL&P and UI Program Savings Documentation for 2008 Program Year, pp. 155-156.

⁶ See http://www.energystar.gov/ia/partners/manuf_res/downloads/2007CW_SavingsCalculator.pdf

⁷ See http://www.cee1.org/resid/seha/rwsh/reswash_specs.pdf

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.⁸ 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)	Water (Gallons)
Savings - New Units				
Base Line	1.26	0	0	0
Energy Star	1.72	30.2	210	97,902
CEE Tier 3	2.2	56.4	314	103,558
Savings - Early Retirement				
Typical washer	-	0	0	0
Energy Star	1.72	59.0	350	109,658
CEE Tier 3	2.2	85.2	454	115,314

Demand Savings

Gas – none

Electric:

Apply coincidence factors to the energy savings:

Coincidence factors for electric use:

$kW = CF * kWh \text{ savings}$

Based on data from the Efficiency Vermont TRM⁹, $CF = .06$

⁸ See, for example, the Northwest Power & Conservation Council, www.nwcouncil.org/energy/rtf/supportingdata/CRDiscountCalc.xls

⁹ Technical Reference User Manual (TRM) No. 4-19, Efficiency Vermont, 9/5/2003

HIGH EFFICIENCY GAS FURNACES

Description of Measure

High efficiency condensing gas furnaces with AFUE > 90%.

Method for Calculating Energy Savings

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

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.

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

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.

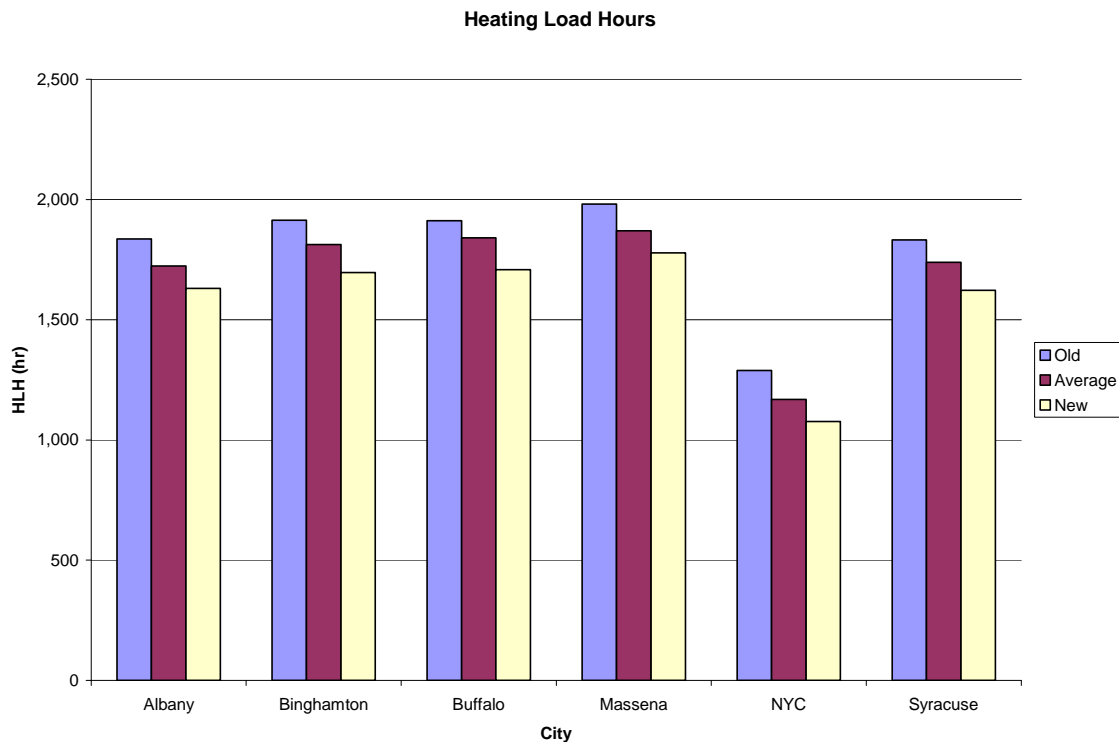
Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

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

Heating load hours for residential buildings were calculated from a DOE-2.2 simulation of prototypical 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:

City	Old	Average	New
Albany	1,836	1,724	1,630
Binghamton	1,618	1,410	1,261
Buffalo	1,912	1,841	1,708
Massena	1,982	1,870	1,778
NYC	1,288	1,168	1,076
Syracuse	1,832	1,739	1,622

These data are also shown in the following Figure:



Baseline Efficiencies from which savings are calculated

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 baseline furnace efficiency available at this time.

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.

Compliance Efficiency from which incentives are calculated

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

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

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.

SETBACK THERMOSTAT

Description of Measure

Programmable setback thermostats applied to residential furnaces and boilers

Method for Calculating Energy Savings

$$\Delta \text{therms} = \text{units} \times \frac{\text{kBtuh}}{\text{unit}} \times \text{RLF}_{\text{heat}} \times \frac{1}{\eta_{\text{base}} \times \eta_{\text{dist,base}}} \times \frac{\text{HLH}}{100} \times \text{ESF}$$

where:

Δtherms	= gross annual gas savings
units	= number of homes with setback thermostats
kBtuh/unit	= the nominal rating of the heating capacity of the furnace in kBtu/hr
$\bar{\eta}$	= average seasonal efficiency of furnace or boiler
$\bar{\eta}_{\text{dist}}$	= average seasonal distribution system efficiency
HLH	= heating load hours
RLF_{heat}	= heating mode rated load factor
100	= conversion factor (kBtuh/therm)
ESF	= energy savings factor

The **nominal rating of the heating capacity of the furnace** should set 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 **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.

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

Recommended value for the rated load factor is 0.8.

The **average seasonal efficiency** of the furnace or 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 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 *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.

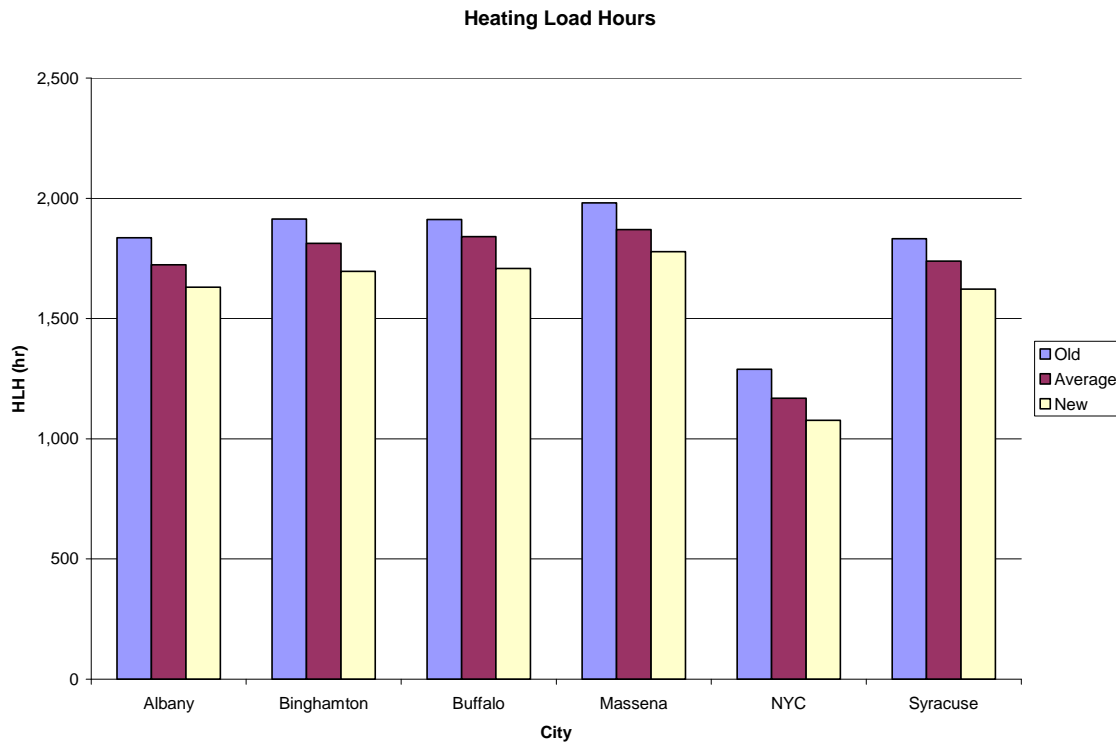
Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

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

Heating load hours for residential buildings were calculated from a DOE-2.2 simulation of prototypical 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:

City	Old	Average	New
Albany	1,836	1,724	1,630
Binghamton	1,618	1,410	1,261
Buffalo	1,912	1,841	1,708
Massena	1,982	1,870	1,778
NYC	1,288	1,168	1,076
Syracuse	1,832	1,739	1,622

These data are also shown in the following Figure:



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.

Baseline Efficiencies from which savings are calculated

The baseline efficiency ($\bar{\eta}_{base}$) for furnaces and boilers should be set according to the sections on furnace and boiler efficiency. 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.

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) 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-Gas Benefits - Annual Electric Savings

Installation of a programmable setback thermostat is expected to save electricity in homes with central air conditioning. Electricity savings will be addressed in a future version of the electric manual.

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.

DUCT INSULATION AND LEAKAGE SEALING

Description of Measure

Improvements to duct systems made in conjunction with high efficiency furnace installation.

Method for Calculating Energy Savings

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

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 heating season efficiency of furnace
$\bar{\eta}_{\text{duct}}$	= duct system average seasonal efficiency
HLH	= heating load hours
RLF_{heat}	= heating mode rated load factor
100	= conversion factor (kBtuh/therm)

Duct system efficiencies were calculated utilizing the building energy simulation model described in Appendix A. The heating season average distribution efficiencies for duct systems located in unconditioned basements in across the six New York cities are summarized below:

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.951	0.946	0.947	0.949	0.957	0.949
15%	Uninsulated	0.941	0.936	0.939	0.940	0.946	0.941
20%	Uninsulated	0.936	0.931	0.932	0.933	0.939	0.934
25%	Uninsulated	0.929	0.924	0.925	0.928	0.934	0.929
30%	Uninsulated	0.924	0.919	0.920	0.922	0.926	0.922
8%	R-6	0.980	0.979	0.978	0.978	0.980	0.979
15%	R-6	0.968	0.967	0.967	0.967	0.969	0.967
20%	R-6	0.959	0.959	0.959	0.960	0.962	0.960
25%	R-6	0.953	0.952	0.952	0.951	0.954	0.951
30%	R-6	0.946	0.944	0.944	0.944	0.946	0.944

Baseline Efficiencies from which savings are calculated

The baseline efficiency ($\bar{\eta}_{base}$) for furnaces should be set according to the sections on furnace efficiency. 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. The US EPA estimates total duct leakage for typical residential construction at 20% of system air flow.

Compliance Efficiency from which incentives are calculated

The measure efficiency ($\bar{\eta}_{ee}$) for furnaces should be set according to the section on efficient furnaces. Distribution system efficiency ($\bar{\eta}_{dist,ee}$) 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-Gas Benefits - Annual Electric Savings

Duct leakage sealing will improve efficiency of air conditioning systems in homes with central AC utilizing the same duct system.

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.

BOILERS

Description of Measure

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

Method for Calculating Energy Savings

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

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.

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

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.

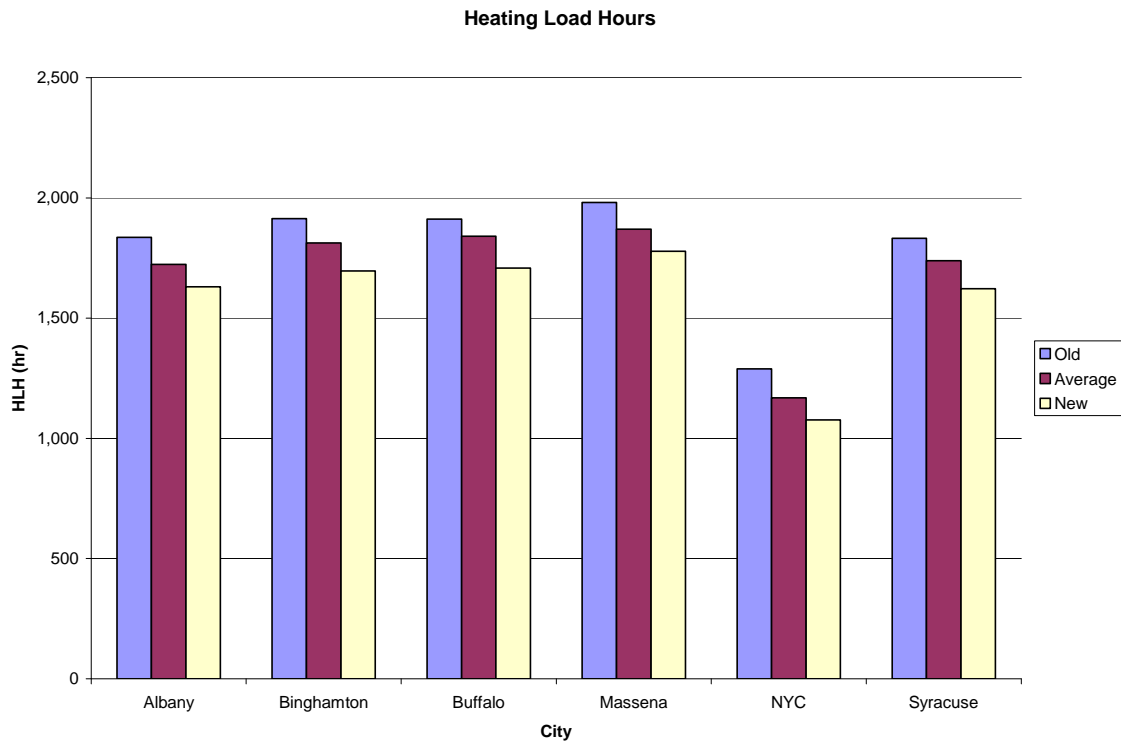
Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

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

Heating load hours for residential buildings were calculated from a DOE-2.2 simulation of prototypical 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:

City	Old	Average	New
Albany	1,836	1,724	1,630
Binghamton	1,618	1,410	1,261
Buffalo	1,912	1,841	1,708
Massena	1,982	1,870	1,778
NYC	1,288	1,168	1,076
Syracuse	1,832	1,739	1,622

These data are also shown in the following Figure:



Distribution efficiencies for hydronic heating systems generally higher than ducted systems, since leakage is not an issue and the surface area for heat losses to unconditioned spaces 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: $\geq 85\%$ for non-condensing applications and $\geq 90\%$ for condensing applications. Steam boiler efficiency recommendations are: $\geq 82\%$ AFUE with electronic ignition.

Operating Hours

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

Non-Gas Benefits - Annual Electric Savings

None addressed in this procedure.

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 single family 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:

Δ_{therm}	= 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.

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

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.

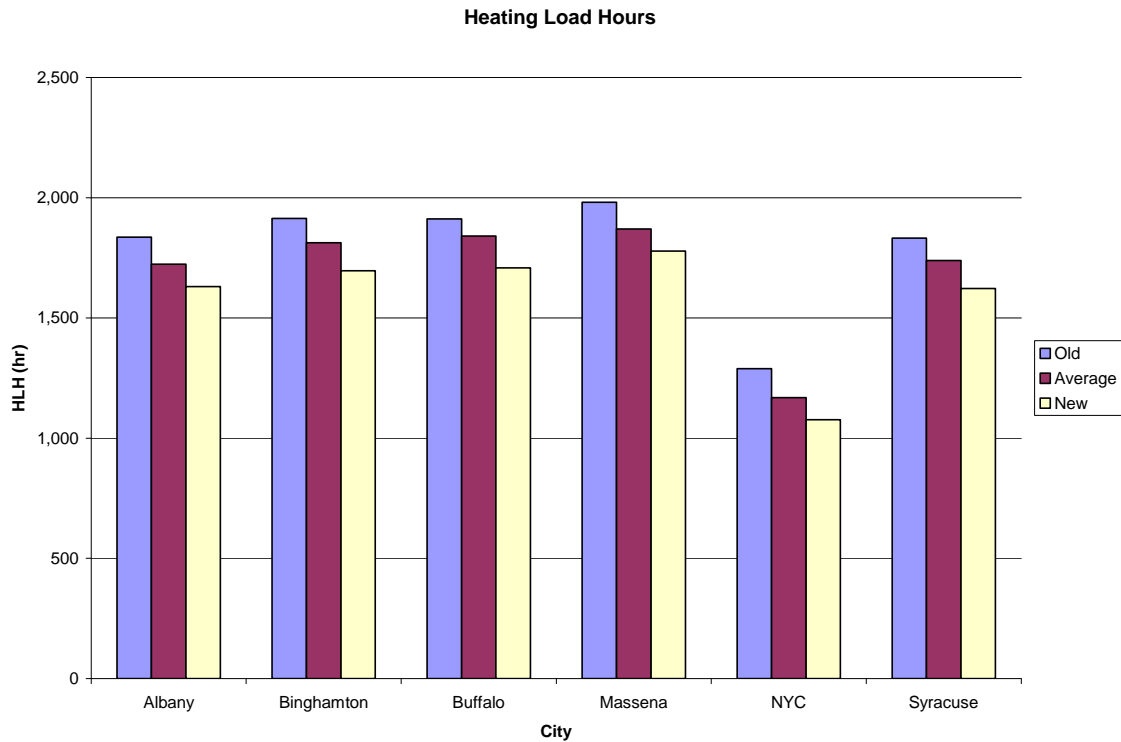
Heating load hours are defined as the ratio of the annual building heating load to the peak building heating load:

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

Heating load hours for residential buildings were calculated from a DOE-2.2 simulation of prototypical 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:

City	Old	Average	New
Albany	1,836	1,724	1,630
Binghamton	1,618	1,410	1,261
Buffalo	1,912	1,841	1,708
Massena	1,982	1,870	1,778
NYC	1,288	1,168	1,076
Syracuse	1,832	1,739	1,622

These data are also shown in the following Figure:



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.

INSTANTANEOUS WATER HEATERS

Description of Measure

Tankless gas water heaters installed in whole-house applications.

Method for Calculating Energy Savings

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

where:

Δ_{therm}	= gross annual gas savings
units	= number of high efficiency water heaters installed under the program
GPD	= average daily water consumption (gallons/day)
$\overline{\Delta T}$	= average difference between the cold inlet temperature and the hot water delivery temperature (°F)
EF_{base}	= baseline water heater energy factor
EF_{ee}	= baseline water heater energy factor
8.3	= conversion factor (Btu/gallon-°F)
100,000	= conversion factor (Btu/therm)
365	= conversion factor (days/yr)

Water heating energy consumption is calculated from the hot water use and difference in the water heater delivery temperature and entering cold water temperature. If the supplemental 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

City	Annual average outdoor temperature (°F)
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

Baseline Efficiencies from which savings are calculated

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

New construction and replace on failure: Instantaneous 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: $0.62 - 0.0019V$ EF, where V is tank volume in gallons.

Compliance Efficiency from which incentives are calculated

The measure energy factor (EF_{ec}) is as follows:

ACEEE recommends $EF \geq .82$ plus electronic ignition

Operating Hours

Water heater assumed to be available at all hours

Non-Gas Benefits - Annual Electric Savings

None

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

SOLAR HOT WATER

Description of Measure

Solar water heaters convert radiant energy from the sun to thermal energy, which is used to meet a portion of the hot water load. Active systems generally use roof mounted flat plate collectors, with water or an antifreeze solution as the collector fluid, and a pump to circulate the collector fluid through a tank-mounted heat exchanger. Water is sometimes run directly through the collector in non-freezing climates, eliminating the need for a heat exchanger. A separate water heater is generally used as a supplemental heat source for all systems.

Method for Calculating Energy Savings

$$\Delta_{\text{therm}} = \text{units} \times \frac{\text{GPD} \times 365 \times 8.3 \times \overline{\Delta T}}{\text{EF}_{\text{base}} \times 100,000} \times \text{ESF}$$

where:

Δ_{therm}	= gross annual gas savings
units	= number of solar water heaters installed under the program
EF_{base}	= energy factor of supplemental electric water heater
GPD	= average daily water consumption (gallons/day)
$\overline{\Delta T}$	= average difference between the cold inlet temperature and the hot water delivery temperature (°F)
ESF	= energy savings factor
100,000	= conversion factor (therm/Btu)
365	= conversion factor (days/yr)
8.3	= conversion factor (Btu/gallon-°F)

The **energy factor** is a measure of the overall efficiency of the supplemental water heater. The energy factor applies to storage-type water heaters up to 120 gallons, and is determined according to the US DOE standard test procedure.

The **average daily hot water usage**, expressed in gallons per day 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 savings factor** (ESF) is the fraction of the annual water heating load which is met by solar energy. This factor is also called the **solar savings fraction**. Residential active solar DHW systems are typically analyzed by a solar water heater sizing program such as the FCHART program.

The ESF for a residential solar DHW system is influenced by climate, collector area, water heating load, collector efficiency, heat exchanger performance, pipe heat losses, storage tank heat losses, and storage tank size. The method used to calculate ESF should account for these parameters. Values for typical solar hot water systems for a family of 4 derived from the FCHART¹⁰ program are shown below:

City	2 collector	3 collector
Albany	0.296	0.396
Binghamton	0.281	0.379
Buffalo	0.275	0.370
Massena	0.294	0.394
NYC	0.320	0.421
Syracuse	0.290	0.388

These calculations are based on a 32 SF gross surface area per collector, an 80 gallon storage tank for the 2 collector system and a 120 gallon storage tank for the 3 collector system. The family of 4 is assumed to use 64 gallons of hot water per day at a hot water setpoint temperature of 135°F. The calculations assume a good quality flat plate collector with a heat exchanger separating the collector fluid and the solar storage tank¹¹. The energy factor (EF) of the backup tank is assumed to be 0.6.

The Solar Rating and Certification Corporation (SRCC) publishes solar water heating system performance ratings under the SRCC OG-300 protocol. The SRCC uses a Solar Energy Factor (SEF) to rate the performance of solar water heating systems, which is roughly equivalent to the Energy Factor (EF) used to rate the performance of conventional water heaters. The SEF and the ESF are related as follows:

$$ESF = 1 - EF/SEF$$

¹⁰ Standard FCHART outputs show ESF as a fraction of hot water load not including backup tank efficiency. These data were modified to account for backup water heater efficiency consistent with the equation above.

¹¹ Collector performance specs: $F_R \tau \alpha = 0.75$, $F_R U_L = 0.74$. Incident angle modifier constant = -0.28. Heat exchanger modifier (F_R' / F_R) = 0.9.

where:

SEF = solar energy factor from SRCC OG-300

EF = energy factor of the backup water heater, which is assumed to be 0.6 for gas water heaters.

The SRCC rating is based on a set of standard rating conditions, including a 64.3 gallon per day hot water usage, cold water mains temperature of 58°F and hot water setpoint temperature of 135°F.

Baseline Efficiencies from which savings are calculated

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

New construction and replace on failure: Solar water heater is assumed to supplement 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: $0.62 - 0.0019V$ EF, where V is tank volume in gallons.

Compliance Efficiency from which incentives are calculated

The Energy Savings Factor specifications can be taken from the ESF table above. Alternatively, minimum specifications for SEF from the SRCC systems rating can be used to define solar water heater performance. These values should be converted to ESF using the above equations.

Operating Hours

The backup water heater is assumed to be available during all hours. The solar water heater operates only when useful solar energy can be collected.

Non-Gas Benefits - Annual Electric Savings

Active solar water heaters require electricity to operate circulating pumps and controls. These impacts are not accounted for in this procedure.

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

3. Solar water heater performance can be estimated using the FCHART method: Beckman, W.A., S.A. Klein, and J.A. Duffie; Solar Heating Design by the FCHART Method; Wiley and Sons, New York, 1977.
4. More information on the SRCC Solar Collector and Solar Hot Water System certification programs can be obtained from: <http://www.solar-rating.org/>

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 less. 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 Results¹²

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: 2.2 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.¹³

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

¹²This methodology is derived from CL&P and UI Program Savings Documentation for 2008 Program Year, pp. 155-156.

¹³ 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
Gas 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))

Gas 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

Lifetime Energy Savings = Annual savings x measure life

The measure life of showerheads is assumed to be 10 years¹⁴.

Table 4 – 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

Demand Savings

There are no demand savings associated with this measure.

¹⁴ 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

FAUCET AERATORS

Measure Description

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

Savings Estimation Approach – Method and Results¹⁵

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.¹⁶

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

¹⁵This methodology is derived from CL&P and UI Program Savings Documentation for 2008 Program Year, pp. 157-158.

¹⁶Federal 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
Gas 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

Lifetime Energy Savings = Annual savings x measure life

The measure life of faucet aerators is assumed to be 10 years¹⁷.

Table 4 – 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

Demand Savings

There are no demand savings associated with this measure.

¹⁷ 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.

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

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

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)
$\eta_{\text{waterheater}}$	= water heater combustion efficiency

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

$$UA_{\text{base}} = \frac{2\pi k_{\text{side}} H}{\ln\left(\frac{r_2}{r_1}\right)} + \frac{\pi r_1^2 k_{\text{bot}}}{\text{th}_{\text{bot}}} + \frac{\pi r_1^2 k_{\text{top}}}{\text{th}_{\text{top}}}$$

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

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	Gas	
			UAbase	UAee
30	60	16	5.2	2.9
40	61	18.5	6.2	3.5
50	53	18	5.2	2.8
66	58	20	6.4	3.5
80	58	22	7.1	3.9

The *combustion efficiency* of a non-condensing storage type water heater is assumed to be 78%

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.

Small Commercial Measures

HIGH EFFICIENCY FURNACES

Description of Measure

High efficiency furnace sections included in rooftop AC systems and furnaces included in split AC systems. Applications in small commercial buildings utilizing residential gas service.

Method for Calculating Energy Savings

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

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 heating season efficiency of furnace
η_{duct}	= 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.

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

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.

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

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

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

Building	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
Assembly	1191	1155	1179	1567	707	1142
Fast Food Restaurant	1725	1840	1799	2045	979	1631
Full Service Restaurant	1872	2013	1958	2200	1018	1767
Small Retail	1322	1333	1366	1417	757	1287

Baseline Efficiencies from which savings are calculated

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 baseline furnace efficiency available at this time.

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.

Compliance Efficiency from which incentives are calculated

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

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

Operating Hours

Operating hour assumptions for the prototypical building models are described in Appendix A.

Non-Gas Benefits - Annual Electric Savings

High efficiency furnaces may be packaged with high efficiency cooling equipment and/or electronically commutated (EC) motors, which may provide electricity 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. The HLH values assumed in this section include a 3°F setback of the room temperature setpoint during unoccupied hours. See the section on programmable setback thermostats and Appendix A for more information.

SETBACK THERMOSTAT

Description of Measure

Programmable setback thermostats applied to furnaces and boilers in small commercial buildings.

Method for Calculating Energy Savings

$$\Delta \text{therms} = \text{units} \times \frac{\text{kBtuh}}{\text{unit}} \times \text{RLF}_{\text{heat}} \times \frac{1}{\eta_{\text{base}} \times \eta_{\text{dist,base}}} \times \frac{\text{HLH}}{100} \times \text{ESF}$$

where:

Δtherms	= gross annual gas savings
units	= number of buildings with programmable thermostats
kBtuh/unit	= the nominal rating of the heating capacity of the furnace in kBtu/hr
$\bar{\eta}$	= average seasonal efficiency of furnace or boiler
$\bar{\eta}_{\text{dist}}$	= average seasonal distribution system efficiency
HLH	= heating load hours
RLF_{heat}	= heating mode rated load factor
100	= conversion factor (kBtuh/therm)
ESF	= energy savings factor

The **nominal rating of the heating capacity of the furnace** should set equal to the rated capacity of all heating equipment controlled by a setback thermostat in the commercial facility. The energy savings should be calculated per commercial facility rather than per thermostat.

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.

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

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 *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.

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

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

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

Building	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
Assembly	1191	1155	1179	1567	707	1142
Fast Food Restaurant	1725	1840	1799	2045	979	1631
Full Service Restaurant	1872	2013	1958	2200	1018	1767
Small Retail	1322	1333	1366	1417	757	1287

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.

Baseline Efficiencies from which savings are calculated

The baseline efficiency ($\bar{\eta}_{base}$) for furnaces and boilers should be set to according to the sections on furnace and boiler efficiency. 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.

Studies of residential heating thermostat setpoint behavior indicate some amount of manual setback adjustment in homes without programmable thermostats. This behavior is assumed to be present in the small commercial buildings addressed in this manual. An assumption of 3°F of night time setback behavior is embedded in the prototypical simulation models.

Efficiency from which incentives are calculated

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. This assumption is also applied to the small commercial buildings addressed in this manual

Operating Hours

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

Non-Gas Benefits - Annual Electric Savings

Installation of a programmable setback thermostat is expected to save electricity in homes with central air conditioning. Electricity savings will be addressed in a future version of the electric manual.

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. 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.

DUCT INSULATION AND LEAKAGE SEALING

Description of Measure

Improvements to duct systems made in conjunction with high efficiency furnace or rooftop system installation. Duct systems are assumed to be located in an unconditioned plenum space between insulated finished ceiling and roof surface.

Method for Calculating Energy Savings

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

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 heating season efficiency of furnace
η_{duct}	= 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.

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

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. Duct system efficiencies were calculated for duct systems located in unconditioned plenum space between an insulated finished ceiling and roof surface in four small commercial building types and six New York cities.

Assembly Building

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.909	0.923	0.918	0.925	0.857	0.881
15%	Uninsulated	0.879	0.890	0.889	0.890	0.829	0.851
20%	Uninsulated	0.858	0.868	0.867	0.869	0.810	0.831
25%	Uninsulated	0.835	0.848	0.846	0.849	0.793	0.812
30%	Uninsulated	0.816	0.829	0.828	0.829	0.776	0.795
8%	R-6	0.951	0.961	0.959	0.956	0.896	0.915
15%	R-6	0.917	0.930	0.926	0.923	0.863	0.883
20%	R-6	0.895	0.906	0.902	0.901	0.841	0.861
25%	R-6	0.871	0.884	0.879	0.881	0.821	0.840
30%	R-6	0.849	0.862	0.860	0.862	0.801	0.819

Fast Food Restaurant

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.809	0.807	0.804	0.820	0.766	0.805
15%	Uninsulated	0.784	0.784	0.781	0.797	0.734	0.778
20%	Uninsulated	0.766	0.768	0.765	0.780	0.714	0.759
25%	Uninsulated	0.750	0.753	0.749	0.765	0.693	0.742
30%	Uninsulated	0.734	0.739	0.734	0.750	0.675	0.725
8%	R-6	0.901	0.904	0.901	0.905	0.875	0.898
15%	R-6	0.862	0.867	0.864	0.867	0.825	0.858
20%	R-6	0.836	0.844	0.840	0.844	0.794	0.831
25%	R-6	0.813	0.822	0.817	0.822	0.765	0.806
30%	R-6	0.791	0.801	0.796	0.801	0.739	0.783

Full Service Restaurant

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.816	0.821	0.816	0.819	0.797	0.810
15%	Uninsulated	0.789	0.797	0.791	0.794	0.765	0.782
20%	Uninsulated	0.770	0.781	0.775	0.776	0.743	0.763
25%	Uninsulated	0.753	0.765	0.760	0.759	0.721	0.745
30%	Uninsulated	0.736	0.750	0.745	0.744	0.701	0.728
8%	R-6	0.904	0.910	0.905	0.902	0.893	0.901
15%	R-6	0.866	0.876	0.869	0.866	0.848	0.861
20%	R-6	0.840	0.853	0.847	0.841	0.818	0.834
25%	R-6	0.816	0.832	0.825	0.818	0.789	0.809
30%	R-6	0.794	0.812	0.805	0.797	0.763	0.786

Small Retail

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.657	0.646	0.648	0.670	0.614	0.656
15%	Uninsulated	0.624	0.614	0.617	0.637	0.581	0.623
20%	Uninsulated	0.602	0.594	0.596	0.615	0.559	0.601
25%	Uninsulated	0.582	0.574	0.577	0.594	0.538	0.581
30%	Uninsulated	0.563	0.556	0.559	0.575	0.520	0.562
8%	R-6	0.792	0.787	0.788	0.798	0.767	0.789
15%	R-6	0.742	0.736	0.739	0.748	0.714	0.738
20%	R-6	0.710	0.704	0.707	0.716	0.679	0.705
25%	R-6	0.680	0.674	0.678	0.686	0.648	0.676
30%	R-6	0.652	0.646	0.652	0.659	0.619	0.648

Baseline Efficiencies from which savings are calculated

The baseline efficiency ($\bar{\eta}_{base}$) for furnaces should be set according to the sections on furnace efficiency. Distribution system efficiency ($\bar{\eta}_{dist,base}$) should be set as follows:

Overall baseline duct leakage is assumed to be 30%, based on work done by Modera and Proctor on small commercial buildings in California. The baseline duct system is assumed to be uninsulated.

Compliance Efficiency from which incentives are calculated

The measure efficiency ($\bar{\eta}_{ee}$) for furnaces should be set according to the section on efficient furnaces. The improved duct system efficiency ($\bar{\eta}_{dist,ee}$) should be set assuming 15% total leakage in existing construction and 8% total leakage in new construction, with R-6 duct insulation.

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

Duct leakage sealing will improve efficiency of air conditioning systems in homes with central AC utilizing the same duct system.

Notes & References

:

1. For the purposes of this manual, duct efficiency calculations should only be done on buildings with duct systems located in unconditioned plenum spaces. For all other buildings, a duct efficiency value of 1.0 should be used.
2. Typical duct leakage values in small commercial buildings can be found in Modera, M. and J. Proctor, 2002. *Combining Duct Sealing and Refrigerant Charge Testing to Reduce Peak Electricity Demand in Southern California*, Final Project Report for Southern California Edison.
3. The fraction of the duct leakage assumed to be made up with outside air is 0.50. See: Cummings, J.B., C.R. Withers, N. Moyer, P. Fairey, and B. McKendry. 1996. "Uncontrolled Air Flow in Non-Residential Buildings; Final Report" FSEC-CR-878-96 Florida Solar Energy Center, Cocoa, FL, April, 1996.
4. The HLH values assumed in this section include a 3°F setback of the room temperature setpoint during unoccupied hours. See the section on programmable setback thermostats and Appendix A for more information.

BOILERS

Description of Measure

High efficiency condensing and non-condensing hot water and steam boilers in small commercial buildings utilizing residential gas service.

Method for Calculating Energy Savings

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

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
$\overline{\eta}$	= average heating season efficiency of boiler
$\overline{\eta}_{\text{dist}}$	= 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.

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

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:

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

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

Building	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
Assembly	1191	1155	1179	1567	707	1142
Fast Food Restaurant	1725	1840	1799	2045	979	1631
Full Service Restaurant	1872	2013	1958	2200	1018	1767
Small Retail	1322	1333	1366	1417	757	1287

Distribution efficiencies for hydronic heating systems generally higher than ducted systems, since leakage is not an issue and the surface area for heat losses to unconditioned spaces 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 ($\bar{\eta}_{e}$) is as follows:

ACEEE recommends two tiers for hot water boilers: $\geq 85\%$ for non-condensing applications and $\geq 90\%$ for condensing applications. Steam boilers $\geq 82\%$ AFUE with electronic ignition.

Operating Hours

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

Non-Gas Benefits - Annual Electric Savings

None anticipated

Notes & References

1. The HLH values assumed in this section include a 3°F setback of the room temperature setpoint during unoccupied hours. 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 small commercial buildings with zone thermostat control. 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:

Δ_{therm}	= 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.

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

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:

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

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

Building	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
Assembly	1191	1155	1179	1567	707	1142
Fast Food Restaurant	1725	1840	1799	2045	979	1631
Full Service Restaurant	1872	2013	1958	2200	1018	1767
Small Retail	1322	1333	1366	1417	757	1287

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

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

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 setback of the room temperature setpoint during unoccupied hours. See the section on programmable setback thermostats and Appendix A for more information.

INSTANTANEOUS WATER HEATERS

Description of Measure

Tankless gas water heaters installed in whole-building applications.

Method for Calculating Energy Savings

$$\Delta_{\text{therm}} = \text{units} \times \frac{\text{GPD} \times 365 \times 8.33 \times \overline{\Delta T}}{100,000} \times \left[\frac{1}{EF_{\text{base}}} - \frac{1}{EF_{\text{ee}}} \right]$$

where:

Δ_{therm}	= gross annual gas savings
units	= number of high efficiency water heaters installed under the program
GPD	= average daily water consumption (gallons/day)
$\overline{\Delta T}$	= average difference between the cold inlet temperature and the hot water delivery temperature (°F)
EF_{base}	= baseline water heater energy factor
EF_{ee}	= baseline water heater energy factor
8.33	= conversion factor (Btu/gallon-°F)
100,000	= conversion factor (Btu/therm)
365	= conversion factor (days/yr)

Water heating energy consumption is calculated from the daily hot water use and the difference in the water heater delivery temperature and entering cold water temperature. If the supplemental 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. If the water heater does not have sufficient capacity to meet the load, the hot water delivery temperature may need to be reduced from the setpoint temperature.

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. Cold water entering temperatures estimated for this manual are shown below:

City	Annual average outdoor temperature (°F)
Albany	48.2
Binghamton	46.9

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

The **energy factor** is a measure of the overall efficiency of the instantaneous and storage water heaters. This factor is based on a standard US Department of Energy test procedure, and is applicable to residential water heater load profiles. The energy factor should be used until better data on average water heater efficiency for commercial applications are developed.

The **average daily hot water usage**, expressed in gallons per day, normalized for occupancy or restaurant meal volume is shown below:

Building Type	Average gallons per day (ASHRAE)
Office Building	1.0 gal/day per person
Full service restaurant	2.4 gal / day per meal
Fast food restaurant	0.7 gal /day per meal

Baseline Efficiencies from which savings are calculated

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

New construction and replace on failure: Instantaneous 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: $0.62 - 0.0019V$ EF, where V is tank volume in gallons.

Compliance Efficiency from which incentives are calculated

The measure energy factor (EF_{ec}) is as follows:

ACEEE recommends $EF \geq .82$ plus electronic ignition

Operating Hours

Water heater assumed to be available at all hours

Non-Gas Benefits - Annual Electric Savings

None

Notes & References

1. 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
2. Average hot water use data taken from the 2007 ASHRAE HVAC Applications Handbook, Chapter 49 – Service Water Heating. American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta GA.

SOLAR HOT WATER

Description of Measure

Solar water heaters convert radiant energy from the sun to thermal energy, which is used to meet a portion of the hot water load. Active systems generally use roof mounted flat plate collectors, with water or an antifreeze solution as the collector fluid, and a pump to circulate the collector fluid through a tank-mounted heat exchanger. Water is sometimes run directly through the collector in non-freezing climates, eliminating the need for a heat exchanger. A separate water heater is generally used as a supplemental heat source for all systems.

Method for Calculating Energy Savings

$$\Delta_{\text{therm}} = \text{units} \times \frac{\text{GPD} \times 365 \times 8.33 \times \overline{\Delta T}}{EF_{\text{base}} \times 100,000} \times \text{ESF}$$

where:

Δ_{therm}	= gross annual gas savings
units	= number of solar water heaters installed under the program
EF_{base}	= energy factor of supplemental electric water heater
GPD	= average daily water consumption (gallons/day)
$\overline{\Delta T}$	= average difference between the cold inlet temperature and the hot water delivery temperature (°F)
ESF	= energy savings factor
100,000	= conversion factor (therm/Btu)
365	= conversion factor (days/yr)
8.33	= conversion factor (Btu/gallon-°F)

The **energy factor** is a measure of the overall efficiency of the supplemental water heater. The energy factor applies to storage-type water heaters up to 120 gallons, and is determined according to the US DOE standard test procedure.

The **average daily hot water usage**, expressed in gallons per day, normalized for occupancy or restaurant meal volume is shown below:

Building Type	Average gallons per day (ASHRAE)
Office Building	1.0 gal/day per person
Full service restaurant	2.4 gal / day per meal
Fast food restaurant	0.7 gal /day per meal

The *energy savings factor* (ESF) is the fraction of the annual water heating load which is met by solar energy. This factor is also called the *solar savings fraction*. Small commercial active solar DHW systems are typically analyzed by a solar water heater sizing program such as the FCHART program.

The ESF for a commercial solar DHW system varies widely based on the magnitude of the hot water load and available roof area for solar collectors. Solar water heater performance is influenced by climate, collector area, water heating load, collector efficiency, heat exchanger performance, pipe heat losses, storage tank heat losses, and storage tank size. The method used to calculate ESF should account for these parameters.

Baseline Efficiencies from which savings are calculated

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

New construction and replace on failure: Solar water heater is assumed to supplement 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: $0.62 - 0.0019V$ EF, where V is tank volume in gallons.

Compliance Efficiency from which incentives are calculated

ESF for solar water heaters in commercial applications vary widely. Calculations showing the expected ESF for solar water heaters in commercial applications should be submitted.

Operating Hours

The backup water heater is assumed to be available during all hours. The solar water heater operates only when useful solar energy can be collected.

Non-Gas Benefits - Annual Electric Savings

Active solar water heaters require electricity to operate circulating pumps and controls. These impacts are not accounted for in this procedure.

Notes & References

1. Solar water heater performance can be estimated using the FCHART method: Beckman, W.A., S.A. Klein, and J.A. Duffie; Solar Heating Design by the FCHART Method; Wiley and Sons, New York, 1977.

Appendix A Prototypical Building Descriptions

SINGLE FAMILY RESIDENTIAL

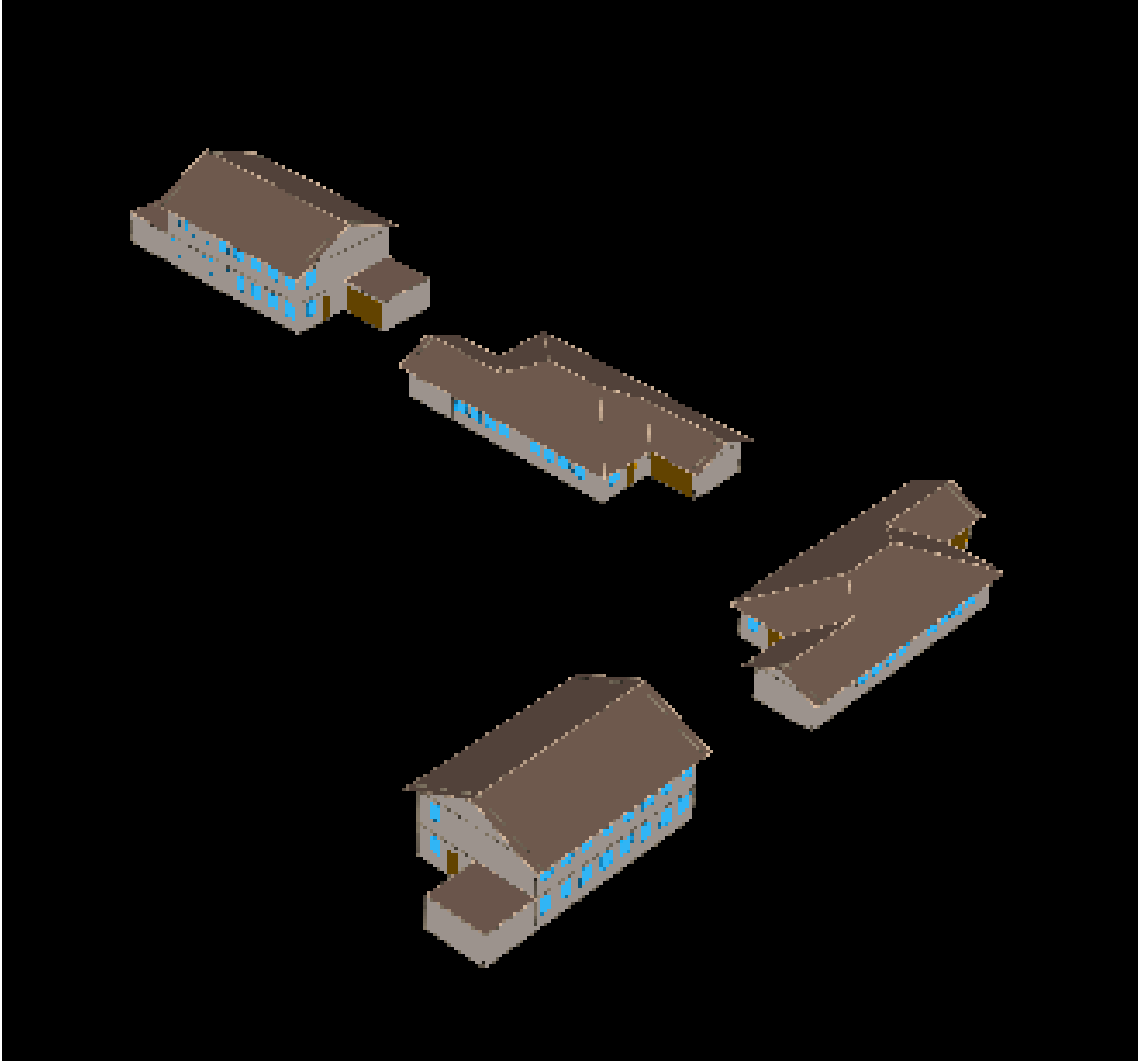
Analysis used to develop parameters for the energy and demand savings calculations are based on DOE-2.2 simulations of a set of prototypical residential buildings. The prototypical simulation models were derived from the residential building prototypes used in the California Database for Energy Efficiency Resources (DEER)¹⁸ study, with adjustments made for local building practices and climate. The prototype “model” in fact contains 4 separate residential buildings; 2 one-story and 2 two-story buildings. Each version of the 1 story and 2 story buildings are identical except for the orientation, which is shifted by 90 degrees. The selection of these 4 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.

A sketch of the residential prototype buildings is shown below.

¹⁸ 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



Computer rendering of residential building prototypical DOE-2 model.

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

Residential Building Prototype Description

Characteristic	Value
Vintage	Three vintages simulated – old poorly insulated buildings, existing average insulated buildings and new buildings
Conditioned floor area	1 story house: 1465 SF (not including basement) 2 story house: 2930 SF (not including basement)
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	Average of single and double pane; properties vary by vintage

Characteristic	Value
Lighting and appliance power density	0.51 W/SF average
HVAC system type	Packaged single zone AC or heat pump
HVAC system size	Based on peak load with 20% oversizing.
HVAC system efficiency	Baseline SEER = 13
Thermostat setpoints	Heating: 70°F with setback to 67°F Cooling: 75°F with setup to 78°F
Duct location	Buildings without basement: attic Buildings with basement: basement
Duct surface area	Single story house: 390 SF supply, 72 SF return Two story house: 505 SF supply, 290 SF return
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, Floor and Ceiling Insulation Levels

The assumed values for wall and ceiling by vintage are shown in Table 2 through Table 3

Table 2. 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

Table 3. 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 in Table 4.

Table 4. 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 in Table 5.

Table 5. 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.

SMALL RETAIL

A prototypical building energy simulation model for a small retail building was developed using the DOE-2.2 building energy simulation program. The characteristics of the small retail building prototype are summarized in Table 6.

Table 6. Small Retail Prototype Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	6400 square foot sales area 1600 square foot storage area 8000 square feet total
Number of floors	1
Wall construction and R-value	Concrete block with brick veneer, R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Sales area: 3.4 W/SF Storage area: 0.9 W/SF
Plug load density	Sales area: 1.2 W/SF Storage area: 0.2 W/SF
Operating hours	10 – 10 Monday-Saturday 10 – 8 Sunday
HVAC system type	Packaged single zone, no economizer
HVAC system size	230 – 250 SF/ton depending on climate
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 78 cooling, 67 heating

A computer-generated sketch of the small retail building prototype is shown in Figure 1.

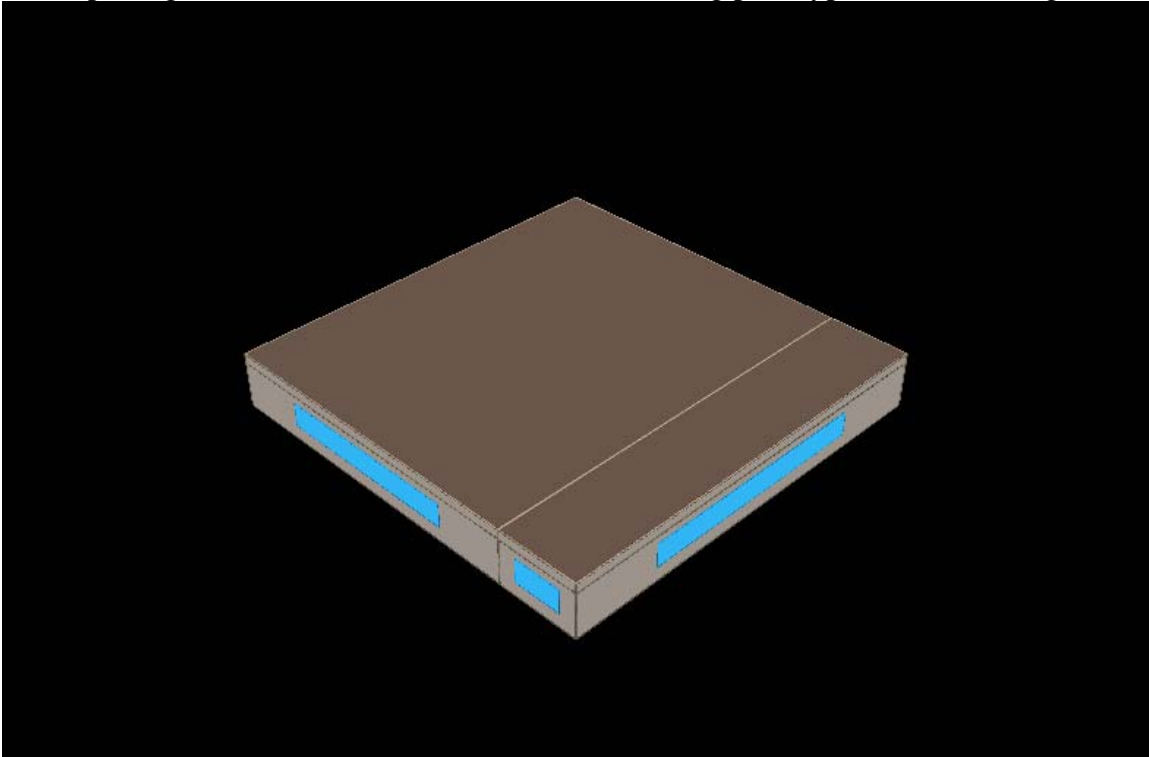


Figure 1. Small Retail Prototype Building Rendering

FULL-SERVICE RESTAURANT

A prototypical building energy simulation model for a full-service restaurant was developed using the DOE-2.2 building energy simulation program. The characteristics of the full service restaurant prototype are summarized in Table 7.

Table 7. Full Service Restaurant Prototype Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	2000 square foot dining area 600 square foot entry/reception area 1200 square foot kitchen 200 square foot restrooms
Number of floors	1
Wall construction and R-value	Concrete block with brick veneer, R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Dining area: 1.7 W/SF Entry area: 2.5 W/SF Kitchen: 4.3 W/SF Restrooms: 1.0 W/SF
Plug load density	Dining area: 0.6 W/SF Entry area: 0.6 W/SF Kitchen: 3.1 W/SF Restrooms: 0.2 W/SF
Operating hours	9am – 12am
HVAC system type	Packaged single zone, no economizer
HVAC system size	140 – 160 SF/ton depending on climate
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 78 cooling, 67 heating

A computer-generated sketch of the full-service restaurant prototype is shown in Figure 2.

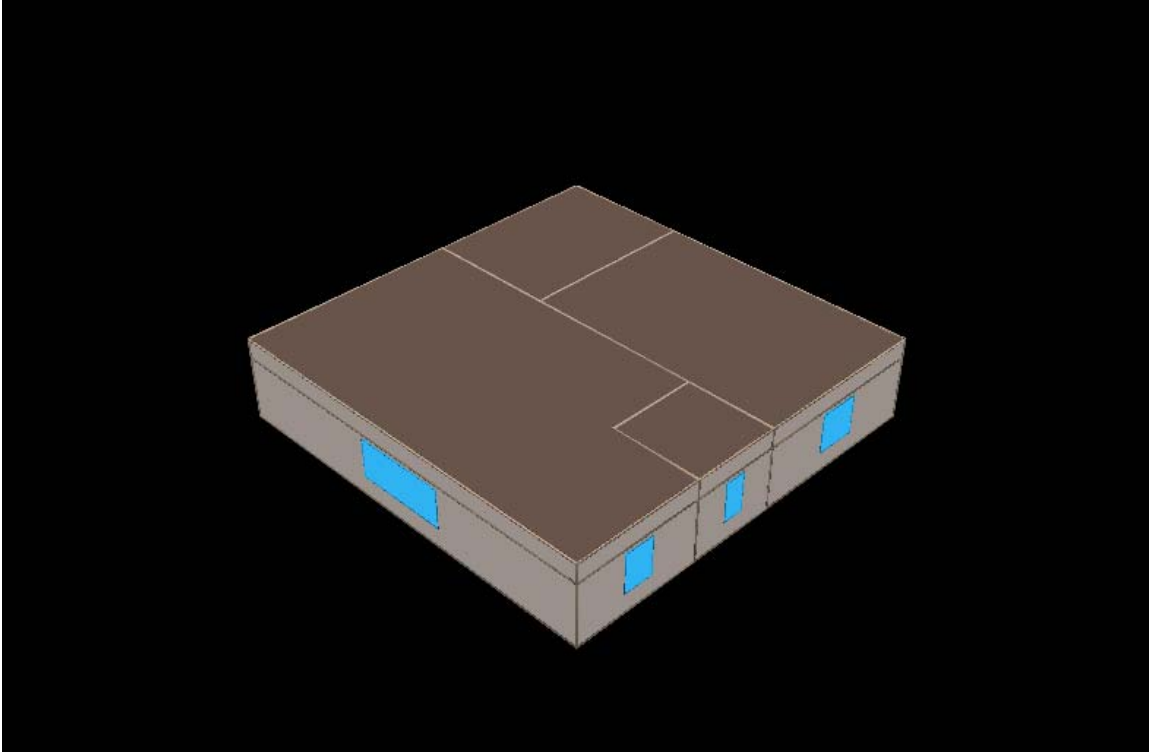


Figure 2. Full Service Restaurant Prototype Rendering

FAST FOOD RESTAURANT

A prototypical building energy simulation model for a fast food restaurant was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized in Table 8.

Table 8. Fast Food Restaurant Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	2000 square feet 1000 SF dining 600 SF entry/lobby 300 SF kitchen 100 SF restroom
Number of floors	1
Wall construction and R-value	Concrete block with brick veneer, R-5
Roof construction and R-value	Concrete deck with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	1.7 W/SF dining 2.5 W/SF entry/lobby 4.3 W/SF kitchen 1.0 W/SF restroom
Plug load density	0.6 W/SF dining 0.6 W/SF entry/lobby 4.3 W/SF kitchen 0.2 W/SF restroom
Operating hours	Mon-Sun: 6am – 11pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	100 – 120 SF/ton depending on climate
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 78 cooling, 67 heating

A computer-generated sketch of the prototype is shown in Figure 3.

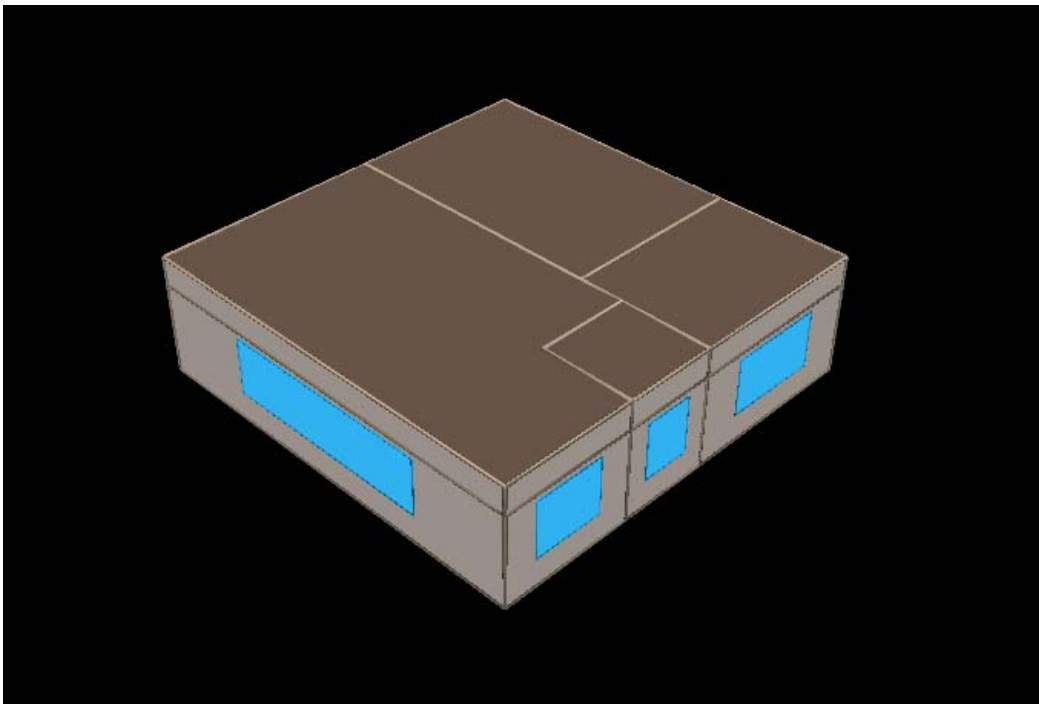


Figure 3. Fast Food Restaurant Building Rendering

ASSEMBLY

A prototypical building energy simulation model for an assembly building was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized in Table 9.

Table 9. Assembly Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	34,000 square feet Auditorium: 33,240 SF Office: 760 SF
Number of floors	1
Wall construction and R-value	Concrete block, R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Auditorium: 3.4 W/SF Office: 2.2 W/SF
Plug load density	Auditorium: 1.2 W/SF Office: 1.7 W/SF
Operating hours	Mon-Sun: 8am – 9pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	100 - 110 SF/ton depending on climate
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 78 cooling, 67 heating

A computer-generated sketch of the prototype is shown in Figure 4.

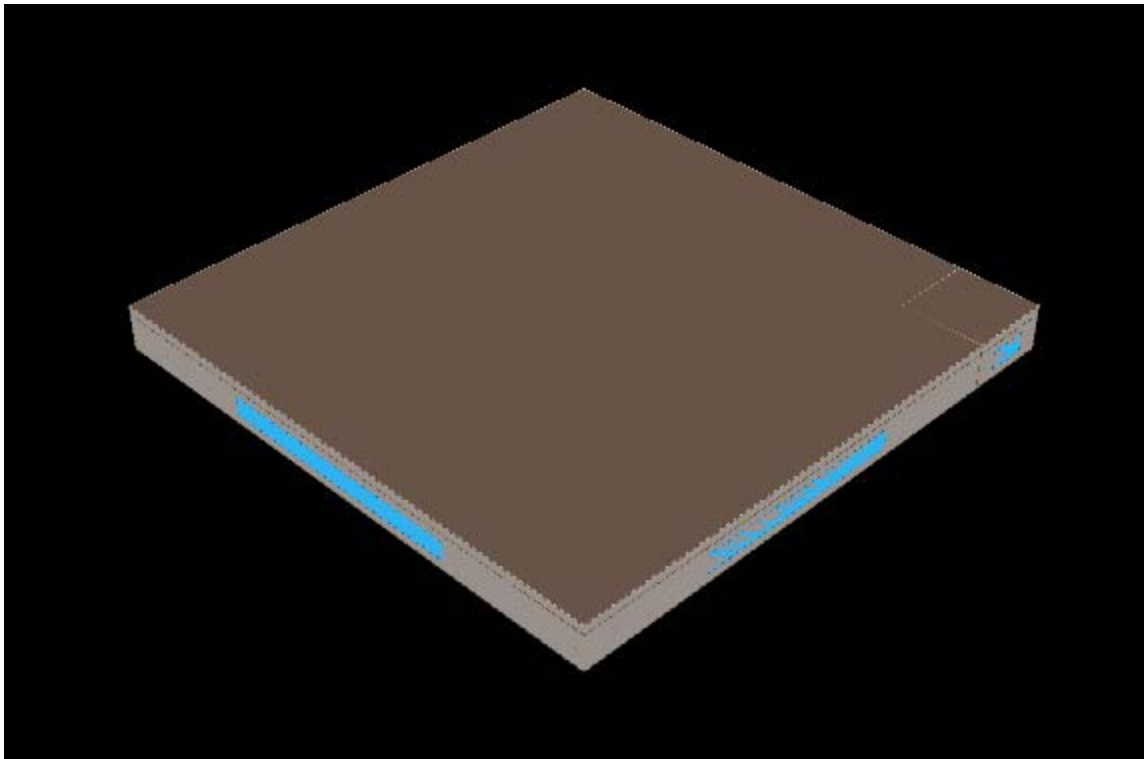


Figure 4. Assembly Building Rendering