Heat Pump Water Heaters (Time of Sale)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure relates to the installation of a Heat Pump domestic hot water heater in place of a standard electric hot water heater in conditioned space. This is a time of sale measure. Savings are presented dependent on the heating system installed in the home.

Definition of Efficient Equipment
To qualify for this measure the installed equipment must be a Heat Pump domestic hot water heater.

Definition of Baseline Equipment
The baseline condition is assumed to be a standard electric hot water heater.

Deemed Savings for this Measure

Heating System:	Average Annual KWH Savings per unit	Average Summer Coincident Peak kW Savings per unit	Average Annual Fossil Fuel heating fuel savings (MMBTU) per unit	Average Annual Water savings per unit
Electric Resistance Heat	499	0.068	n/a	n/a
Heat Pump	1297	0.18	n/a	n/a
Fossil Fuel	2076	0.28	-7.38	n/a

Deemed Lifetime of Efficient Equipment
The measure life is assumed to be 10 years[212].

Deemed Measure Cost
The incremental cost for this measure is assumed to be $925 [213].

Deemed O&M Cost Adjustments
n/a

Coincidence Factor
The summer coincidence factor is assumed to be 0.346 [214].

REFERENCE SECTION

Calculation of Savings

Energy Savings

$$\Delta kWH = KWHbase * ((COPnew - COPbase)/COPnew) + KWHcooling - KWHheating$$

[212] Based on ENERGY STAR Residential Water Heaters, Final Criteria Analysis: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterDraftCriteriaAnalysis.pdf

[213] Vermont Energy Investment Corporation "Residential Heat Pump Water Heaters: Energy Efficiency Potential and Industry Status" November 2005

[214] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York, adjusted for OH peak definitions. Resultant coincident peak kW is consistent with result shown in FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf

Where:

KWHbase	= Average electric DHW consumption = 3460 [215]
COPnew	= Coefficient of Performance (efficiency) of Heat Pump water heater = 2.0 [216]
COPbase	= Coefficient of Performance (efficiency) of standard electric water heater = 0.904 [217]
KWHcooling	= Cooling savings from conversion of heat in home to water heat = 180 [218]
KWHheating	= Heating cost from conversion of heat in home to water heat.

Dependent on heating fuel as follows[219]:

KWHheating (electric resistance)	= 1,577
KWHheating (heat pump COP 2.0)	= 779
KWHheating (fossil fuel)	= 0

ΔkWH electric resistance heat = 3460 * ((2.0 – 0.904) / 2.0) + 180 - 1577
= 499 kWh

ΔkWH heat pump heat = 3460 * ((2.0 – 0.904) / 2.0) + 180 - 779
= 1,297 kWh

ΔkWH fossil fuel heat = 3460 * ((2.0 – 0.904) / 2.0) + 180 - 0
= 2,076 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh / Hours * CF$$

Where:

Hours	= Full load hours of hot water heater = 2533 [220]
CF	= Summer Peak Coincidence Factor for measure = 0.346 [221]

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[215] Assumption taken from; Residential Water Heaters Technical Support Document for the January 17, 2001, Final Rule Table 9.3.9, p9-34, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/09.pdf
Consistent with FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf

[216] Efficiency based on ENERGY STAR Residential Water Heaters, Final Criteria Analysis: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterDraftCriteriaAnalysis.pdf

[217] As above

[218] Determined by calculating the MMBtu removed from the air, applying the REMRate determined percentage (35%) of lighting savings that result in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar), assuming a SEER 11 central AC unit, multiplying by 64% to adjust for the percentage of OH homes having cooling (East North Central census division from Energy Information Administration, 2005 Residential Energy Consumption Survey; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc6airconditioningchar/pdf/tablehc12.6.pdf), and applying the Discretionary Usage Adjustment of 0.75% (Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31)

[219] Determined by calculating the MMBtu removed from the air, as above, applying the REMRate determined percentage (45%) of lighting savings that result in increased heating loads, converting to kWh and dividing by efficiency of heating system (1.0 for electric resistance, 2.0 for heat pump).

[220] Full load hours assumption based on Efficiency Vermont loadshape, calculated from Itron eShapes.

[221] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York, adjusted for OH peak definitions. Resultant coincident peak kW is consistent with result shown in FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters
http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf

ΔkW electric resistance heat	= 499 / 2533 * 0.346 = 0.068 kW
ΔkW heat pump heat	= 1297 / 2533 * 0.346 = 0.18 kW
ΔkW fossil fuel heat	= 2076 / 2533 * 0.346 = 0.28 kW

Fossil Fuel Impact Descriptions and Calculation
(For homes with fossil fuel heating system)

ΔMMBtu = -7.38 MMBtu[222]

Water Impact Descriptions and Calculation
n/a

Deemed O&M Cost Adjustment Calculation
n/a

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[222] This is the additional energy consumption (therefore a negative value) required to replace the heat removed from the home during the heating season by the heat pump water heater. Determined by calculating the MMBtu removed from the air, applying the REMRate determined percentage (45%) of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar), dividing by the efficiency of the heating system (estimated assuming that natural gas central furnace heating is typical for Ohio residences (65% of East North Central census division has a Natural Gas Furnace (based on Energy Information Administration, 2005 Residential Energy Consumption Survey: http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc4spaceheating/pdf/tablehc12.4.pdf))
In 2000, 40% of furnaces purchased in Ohio were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process). Assuming typical efficiencies for condensing and non condensing furnace and duct losses, the average heating system efficiency is estimated as follows:
(0.4*0.92) + (0.6*0.8) * (1-0.15) = 0.72.

Low Flow Faucet Aerator (Time of Sale or Early Replacement)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure relates to the installation of a low flow (1.5 GPM) faucet aerator in a home. This could be a retrofit direct install measure or a new installation. Both electric and fossil fuel savings are provided, although only savings corresponding to the hot water heating fuel should be claimed.

Definition of Efficient Equipment
The efficient equipment is a low flow aerator.

Definition of Baseline Equipment
The baseline equipment is a standard faucet aerator using 2.2 GPM.

Deemed Calculation for this Measure

Annual kWh savings = ISR * ((2.2 – GPMlow) / 2.2) * 77

Summer Coincident Peak savings = ΔkWH * 0.000125

Annual MMBTU savings = ISR * ((2.2 – GPMlow) / 2.2) * 0.3435

Annual Water savings (gallons) = ISR * ((2.2 – GPMlow) / 2.2) * 1398

Deemed Lifetime of Efficient Equipment
The measure life is assumed to be 5 years[223].

Deemed Measure Cost
As a retrofit measure, the cost will be the actual cost of the aerator and its installation.
As a measure distributed to, but installed by, participants, the cost will be the cost of the aerator and the distribution costs.
As a time of sale measure, the cost is assumed to be $2[224].

Deemed O&M Cost Adjustments
When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

Coincidence Factor
The coincidence factor for this measure is calculated at 0.0026[225].

REFERENCE SECTION

Calculation of Savings

Energy Savings
If electric domestic hot water heater:

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[223] Conservative estimate based on review of TRM assumptions from other States.
[224] Navigant Consulting, Ontario Energy Board; "Measures and Assumptions for Demand Side Management (DSM) Planning", April 2009.
[225] Calculated as follows: Assume 13% faucet use takes place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
13% * 3.6 minutes per day (10.9 * 2.56 / 3.5 / 2.2 = 3.6) = 0.47 minutes
= 0.47 / 180 (minutes in peak period) = 0.00262

ΔkWH = ISR * ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / F/home) * 8.3 * (Tft - Tmains) / 1,000,000) / DHW Recovery Efficiency / 0.003412

Where:

ISR = In Service Rate or fraction of units that get installed
Retrofit/Direct Install = 1.0
Customer self install = 0.48[226]

GPMbase = Gallons Per Minute of baseline faucet
= 2.2 [227]

GPMlow = Gallons Per Minute of low flow faucet
= Actual

people = Average number of people per household
= 2.46 [228]

gals/day = Average gallons per day used by all faucets in home
= 10.9 [229]

days/y = Days faucet used per year
= 365

DR = Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)
= 50% [230]

F/home = Average number of faucets in the home
= 3.5 [231]

8.3 = Constant to convert gallons to lbs

Tft = Assumed temperature of water used by faucet
= 80 [232]

Tmains = Assumed temperature of water entering house
= 57.8 [233]

DHW Recovery Efficiency = Recovery efficiency of electric hot water heater
= 0.98 [234]

0.003412 = Constant to converts MMBtu to kWh

For example, a 1.5GPM direct installation:

ΔkWH = 1.0 * ((((2.2 – 1.5) / 2.2) * 2.46 * 10.9 * 365 * 0.5)) / 3.5 * 8.3 * (80-57.8) / 1,000,000) / 0.98 / 0.003412

= 24.5 kWh

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226 EGD_2009_DSM_Annual Report from table 27 survey of Install rates: Overall averages of 62% and 34% for kitchen and bath aerators respectively are averaged to get 48%. There is significant variation in rates by building type, aerator type, and distribution so surveying participants is encouraged

227 In 1998, the Department of Energy adopted a maximum flow rate standard of 2.2 gpm at 60 psi for all faucets: 63 Federal Register 13307; March 18, 1998.

228 US Energy Information Administration, Residential Energy Consumption Survey, East North Central Census Division; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc12.3.pdf

229 Most commonly quoted value of gallons of water used per person per day (including in U.S. Environmental Protection Agency's "water sense" documents; http://www.epa.gov/watersense/docs/home_suppstat508.pdf)

230 Estimate consistent with Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning"

231 Estimate based on East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

232 Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year

233 Annual average of all cities obtained from OH Joint Utility TRM; Table 39: Monthly Mains Water Temperature for Selected Cities (°F).

234 Electric water heater have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/hours * CF

Where:

Hours = Average number of hours per year spent using faucet
= (Gal/person * # people * 365) / F/home / GPM / 60
= (10.9 * 2.46 * 365) / 3.5 / 2.2 / 60
= 21 hours

CF = Summer Peak Coincidence Factor for measure
= 0.00262

For example, a 1.5GPM direct installation:

ΔkW = 24.5 / 21 * 0.00262

= 0.0031 kW

Fossil Fuel Impact Descriptions and Calculation

If fossil fuel domestic hot water heater, MMBtu savings provided below:

ΔMMBtu = ISR * ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / F/home) * 8.3 * (Tft - Tmains) / 1,000,000) / Gas DHW Recovery Efficiency

Where:

Gas DHW Recovery Efficiency = Recovery efficiency of electric hot water heater
= 0.75 [235]

For example, a 1.5GPM direct installation:

ΔMMBtu = 1.0 * ((((2.2 – 1.5) / 2.2) * 2.46 * 10.9 * 365 * 0.5)) / 3.5 * 8.3 * (80-57.8) / 1,000,000) / 0.75

= 0.109 MMBtu

Water Impact Descriptions and Calculation

Water Savings = ISR * (((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / F/home

For example, a 1.5GPM direct installation:

Water Savings = 1.0 * ((((2.2 – 1.5) / 2.2) * 2.46 * 10.9 * 365 * 0.5)) / 3.5

= 445 gallons

Deemed O&M Cost Adjustment Calculation

When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

[235] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%

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Low Flow Showerhead (Time of Sale or Early Replacement)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure relates to the installation of a low flow showerhead in a home. This is a retrofit direct install measure or a new installation. Both electric and fossil fuel savings are provided, although only savings corresponding to the hot water heating fuel should be claimed.

Definition of Efficient Equipment
The efficient condition is a low flow showerhead.

Definition of Baseline Equipment
The baseline is a standard showerhead using 2.87 GPM[236].

Deemed Calculation for this Measure

Annual kWh savings	= ISR * (2.87 – GPMlow) * 179
Summer Coincident Peak savings	= ΔkWH * 0.000112
Annual MMBTU savings	= ISR * (2.87 – GPMlow) * 0.8
Annual Water savings (gal)	= ISR * ((2.87 – GPMlow) / 2.87) * 4960

Deemed Lifetime of Efficient Equipment
The measure life is assumed to be 5 years [237].

Deemed Measure Cost
As a retrofit measure, the incremental cost will be the cost of the showerhead including its installation.
As a measure distributed to, but installed by, participants, the cost will be the cost of the showerhead and the distribution costs.
As a time of sale measure, the incremental cost is assumed to be $6[238].

Deemed O&M Cost Adjustments
When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

Coincidence Factor
The coincidence factor for this measure is calculated at 0.00371 [239].

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[236] Average flow rate of replaced showerhead from Enbridge Gas Distribution Inc., April 2010; "Demand Side Management 2009 DSM Draft Annual Report", p77-78. Calculated with the average flow rate of units between 2 and 2.5GPM of 2.45GPM, average flow rate of units greater than 2.5GPM of 3.07, and 33% of all units between 2 and 2.5%, 67% of units over 2.5GPM; (2.45*0.33)+(3.07*0.67) = 2.87GPM
[237] Conservative estimate based on review of TRM assumptions from other States.
[238] Navigant Consulting, Ontario Energy Board, "Measures and Assumptions for Demand Side Management (DSM) Planning", April 2009.
[239] Calculated as follows: Assume 9% showers take place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
9% * 7.42 minutes per day (11.6 * 2.56 / 1.6 / 2.5 = 7.42) = 0.668 minutes
= 0.668 / 180 (minutes in peak period) = 0.00371

REFERENCE SECTION

Calculation of Savings

Energy Savings
If electric domestic hot water heater:

$$\Delta kWH = ISR * (GPMbase - GPMlow) * kWh/GPMreduced$$

Where:

ISR = In Service Rate or fraction of units that get installed
- Retrofit/Direct Install = 1.0
- Customer self install = 0.81[240]

GPMbase = Gallons Per Minute of baseline showerhead
= 2.87 [241]

GPMlow = Gallons Per Minute of low flow showerhead
= Actual

kWh/GPMreduced = Assumed kWh savings per GPM reduction
= 149kWh per gallon reduced[242]

For example, a 2.0 GPM direct installation:

$$\Delta kWH = 1.0 * (2.87 - 2.0) * 149$$

$$= 130 \text{ kWh}$$

Summer Coincident Peak Demand Savings
If electric domestic hot water heater:

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

Hours = Average number of hours per year spent using shower head
= (Gal/person * # people * days/y) / SH/home / GPM / 60

- gals/day = Average gallons per day used for showering
= 11.6 [243]
- # people = Average number of people per household
= 2.46 [244]
- days/y = Days shower used per year
= 365

[240] EGD_2009_DSM_Annual Report from table 27 survey of Install rates: Overall averages 81%. There may be significant variations due to specifics of the program distribution, so surveying participants is encouraged.

[241] The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

[242] This is based on an Enbridge metering study (Enbridge Gas Distribution Inc., April 2010; "Demand Side Management 2009 DSM Draft Annual Report", p75) that found 46m^3 of natural gas savings when replacing all existing showerheads (with average flow rate of 2.45 GPM) with 1.25GPM showerheads (the replacement GPM and the number of showers per home (2.1) were determined during personal conversations with study authors). This equates to 0.66MMBtu of savings per showerhead per 1GPM reduction. This is converted to kWh by multiplying by the recovery efficiency of a gas heater (0.75 based on review of AHRI Directory) over the recovery efficiency of an electric heater (0.98 from: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576) and multiplying by 293 (kWh/MMBtu).

[243] Most commonly quoted value of gallons of water used per person per day (including in U.S. Environmental Protection Agency's "water sense" documents; http://www.epa.gov/watersense/docs/home_suppstat508.pdf)

[244] US Energy Information Administration, Residential Energy Consumption Survey, East North Central Census Division; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc12.3.pdf

Showers/home = Average number of showers in the home
= 2.1 [245]

= (11.6 * 2.46 * 365) / 2.1 / 2.87 / 60
= 29 hours

CF = Summer Peak Coincidence Factor for measure
= 0.00371 [246]

For example, a 2.0 GPM direct installation:

ΔkW = 130 / 29 * 0.00371

= 0.017 kW

Fossil Fuel Impact Descriptions and Calculation
If fossil fuel domestic hot water heater:

ΔMMBtu = ISR * (GPMbase – GPMlow) * MMBtu/GPMreduced

Where:

MMBtu/GPMreduced = Assumed MMBtu savings per GPM reduction
= 0.66 MMBtu per gallon reduced [247]

For example, a 2.0 GPM direct installation:

ΔMMBtu = 1.0 * (2.87 – 2.0) * 0.66

= 0.6 MMBtu

Water Impact Descriptions and Calculation

Water Savings = ISR * (((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year)) / SH/home

For example, a 2.0 GPM direct installation:

Water Savings = 1.0* ((((2.87 – 2.0) / 2.87) * 2.46 * 11.6 * 365)) / 2.1

= 1,504 gallons

Deemed O&M Cost Adjustment Calculation
When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

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[245] Personal communication with authors of Enbridge Gas Distribution Inc., April 2010; "Demand Side Management 2009 DSM Draft Annual Report"
[246] Calculated as follows: Assume 9% showers take place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
9% * 7.42 minutes per day (11.6 * 2.56 / 1.6 / 2.5 = 7.42) = 0.668 minutes
= 0.668 / 180 (minutes in peak period) = 0.00371
[247] This is based on an Enbridge metering study (Enbridge Gas Distribution Inc., April 2010; "Demand Side Management 2009 DSM Draft Annual Report", p75) that found 46m^3 of natural gas savings when replacing all existing showerheads (with average flow rate of 2.45 GPM) with 1.25GPM showerheads (the replacement GPM and the number of showers per home (2.1) were determined during personal conversations with study authors). This equates to 0.66MMBtu of savings per showerhead per 1GPM reduction.

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Domestic Hot Water Pipe Insulation (Retrofit)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure describes adding insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed to the first length of both the hot and cold pipe up to the first elbow.

Definition of Efficient Equipment
To efficiency case is installing pipe wrap insulation to a length of hot water carrying copper pipe.

Definition of Baseline Equipment
The baseline is an un-insulated hot water carrying copper pipe.

Deemed Calculation for this Measure

Annual kWh savings (electric DHW systems) $= ((1 - 1/Rnew) * (L * C) * 170.2$

Summer Coincident Peak Savings (electric DHW systems) $= \Delta kWh/8760$

Annual MMBtu savings (fossil fuel DHW systems) $= ((1 - 1/Rnew) * (L * C) * 0.569$

Deemed Lifetime of Efficient Equipment
The measure life is assumed to be 15 years [248].

Deemed Measure Cost
The measure cost including material and installation is assumed to be $3 per linear foot[249].

Deemed O&M Cost Adjustments
n/a

Coincidence Factor
This measure assumes a flat loadshape and as such the coincidence factor is 1.

REFERENCE SECTION

Calculation of Savings

Energy Savings
For electric DHW systems:

$$\Delta kWh = ((1/Rexist - 1/Rnew) * (L * C) * \Delta T * 8{,}760) / \eta DHW / 3413$$

Where:

Rexist = Pipe heat loss coefficient of uninsulated pipe (existing) (Btu/hr-°F-ft)
= 1.0[250]

Rnew = Pipe heat loss coefficient of insulated pipe (new) (Btu/hr-°F-ft)

[248] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf
[249] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
[250] Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77.

	= Actual
L	= Length of pipe from water heating source covered by pipe wrap (ft)
	= actual
C	= Circumference of pipe (ft) (Diameter (in) * π * 0.083)
	= actual (0.5" pipe = 0.13ft, 0.75" pipe = 0.196ft)
ΔT	= Average temperature difference between supplied water and outside air temperature (°F)
	= 65°F [251]
8,760	= Hours per year
ηDHW	= Recovery efficiency of electric hot water heater
	= 0.98 [252]
3413	= Conversion from Btu to kWh

For example, insulating 5 feet of 0.75" pipe with R-4 wrap:

$$\Delta kWh = ((1/Rexist - 1/Rnew) * (L * C) * \Delta T * 8{,}760) / \eta DHW / 3413$$

$$= ((1/1 - 1/5) * (5 * 0.196) * 65 * 8760) / 0.98 / 3413$$

$$= 133 \text{ kWh}$$

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh / 8760$$

Where:

ΔkWh	= kWh savings from pipe wrap installation
8760	= Number of hours in a year (since savings are assumed to be constant over year).

For example, insulating 5 feet of 0.75" pipe with R-4 wrap:

$$\Delta kW = 133/8760$$

$$= 0.015 kW$$

Fossil Fuel Impact Descriptions and Calculation

For fossil fuel DHW systems:

$$\Delta MMBtu = ((1/Rexist - 1/Rnew) * (L * C) * \Delta T * 8{,}760) / \eta DHW / 1{,}000{,}000$$

Where:

ηDHW	= Recovery efficiency of gas hot water heater
	= 0.75 [253]

For example, insulating 5 feet of 0.75" pipe with R-4 wrap:

$$\Delta MMBtu = ((1/1 - 1/5) * (5 * 0.196) * 65 * 8760) / 0.75 / 1{,}000{,}000$$

$$= 0.60 \text{ MMBtu}$$

[251] Assumes 130°F water leaving the hot water tank and average temperature of basement of 65°F.
[252] Electric water heater have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576
[253] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%

Water Impact Descriptions and Calculation
n/a

Deemed O&M Cost Adjustment Calculation
n/a

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Wall Insulation (Retrofit)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure characterization is for the installation of new additional insulation in the walls of a residential building. The measure assumes that an auditor, contractor or utility staff member is on location, and will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and the efficiency of the heating system used in the home.

Definition of Efficient Equipment
The new insulation should meet any qualification criteria required for participation in the program. The new insulation R-value should include the total wall assembly and include any existing insulation that is left in situ.

Definition of Baseline Equipment
The existing insulation R-value should include the total wall assembly. An R-value of 5 should be assumed for the wall assembly plus the R-value of any existing insulation[254].

Deemed Calculation for this Measure

Air conditioning Savings
Annual kWh Savings = ((1/Rexist – 1/Rnew) * CDH * 0.75 * Area) / 1000 / ηCool

Summer Coincident Peak kW Savings = ΔkWh / FLHcool * 0.5

Space Heating Savings:
Annual MMBTU Savings (fossil fuel heating)
= ((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1,000,000 / ηHeat

Annual kWh Savings (electric heating)
= (((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1,000,000 / ηHeat) * 293.1

Deemed Lifetime of Efficient Equipment
The measure life is assumed to be 25 years [255].

Deemed Measure Cost
The actual insulation installation measure cost should be used.

Deemed O&M Cost Adjustments
n/a

Coincidence Factor
The summer peak coincidence factor for this measure is assumed to be 0.5[256].

[254] The R-5 assumption for wall assembly is based on J.Neymark & Associates and National Renewable Energy Laboratory, June 2009; "BESTEST-EX Interim Test Procedure" p25.
[255] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf
[256] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

REFERENCE SECTION

Calculation of Savings

Energy Savings

ΔkWh = ((1/Rexist – 1/Rnew) * CDH * DUA * Area) / 1000 / ηCool

Where:

Rexist = existing effective whole-assembly thermal resistance value or R-value[257]
= actual recorded

Rnew = new total effective whole-assembly thermal resistance value or R-value[258]
= actual recorded

CDH = Cooling Degree Hours[259].
Dependent on location:

Location	Cooling Degree Hours (75°F set point)
Akron	3,986
Cincinnati	7,711
Cleveland	5,817
Columbus	4,367
Dayton	5,934
Toledo	4,401
Youngtown	3,689

DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F
= 0.75 [260]

Area = Square footage of insulated area
= actual recorded

ηCool = Efficiency of Air Conditioning equipment
= actual recorded

For example, insulating 300 square feet of wall area from R-5 to R-20, in a Cincinnati home with AC SEER 10:

ΔkWh = ((1/Rexist – 1/Rnew) * CDH * DUA * Area) / 1000 / ηCool

= ((1/5 – 1/20) * 7711 * 0.75 * 300) / 1000 / 10

= 26 kWh

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh / FLHcool *CF

Where:

FLHcool = Full load cooling hours

Dependent on location as below:

[257] If uninsulated assembly assume R-5.
[258] Include the R-value for any existing insulation remaining.
[259] Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used) each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/)
[260] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31

Location	Run Hours[261]
Akron	476
Cincinnati	664
Cleveland	426
Columbus	552
Dayton	631
Mansfield	474
Toledo	433
Youngstown	369

CF = Summer Peak Coincidence Factor for measure
= 0.5[262]

For example, insulating 300 square feet of an attic floor from R-5 to R-20, in a Cincinnati home with AC SEER 10:

ΔkW = ΔkWh / FLHcool *CF

= 26 / 747 * 0.5

= 0.017 kW

Space Heating Savings Calculation

ΔMMBTU = ((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1,000,000 / ηHeat

Where:

HDD = Heating Degree Days (60° base temperature) for location[263]

Location	Heating Degree Days (60°F base temperature)
Akron	4,848
Cincinnati	3,853
Cleveland	4,626
Columbus	4,100
Dayton	4,430
Toledo	4,482
Youngtown	4,887

ηHeat = Average Net Heating System Efficiency (Equipment Efficiency * Distribution Efficiency) [264]

[261] Based on Full Load Hour assumptions taken from the ENERGY STAR calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 33% due to assumption that the average air conditioning is oversized by 50% (Neme, Proctor, Nadal, 1999; "National Energy Savings Potential From Addressing Residential HVAC Installation Problems"). Note this approach results in full load hour estimates within 10% of measured estimates from the Energy Center of Wisconsin, May 2008 study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

[262] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

[263] The 10 year average annual heating degree day value, using a balance point for heating equipment use of 60 degrees was calculated for each location based on data obtained from http://www.engr.udayton.edu/weather/. The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers.

[264] The System Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.
If there are more than one heating systems, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.

= actual recorded

Note for homes with electric heat (resistance or heat pump), follow the MMBTU formula above and convert to kWh by multiplying by 293.1. For heat pumps the equipment efficiency used in the above algorithm should be the Coefficient Of Performance or COP (i.e., divide HSPF by 3.412; e.g., HSPF 7.7 is COP of 2.26).

For example, insulating 300 square feet of an attic floor from R-5 to R-20, in a Cincinnati home with heating system efficiency of 70%:

$$\Delta MMBTU = ((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat$$

$$= ((1/5 - 1/20) * 3{,}992 * 24 * 300) / 1{,}000{,}000 / 0.7$$

$$= 6.2 \text{ MMBtu}$$

Water Impact Descriptions and Calculation
n/a

Deemed O&M Cost Adjustment Calculation
n/a

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Air Sealing - Reduce Infiltration (Retrofit)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure characterization is for the improvement of a building's air-barrier, which together with its insulation defines the thermal boundary of the conditioned space. Air-leakage in buildings represents from 5% to 40% of the space conditioning costs[265] but is also very difficult to control. The measure assumes that a trained auditor, contractor or utility staff member is on location, and will measure and record the existing air-leakage rate[266] and post air-sealing leakage using a blower door, and the efficiency of the heating and cooling system used in the home.

Definition of Efficient Equipment
Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be performed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

Definition of Baseline Equipment
The existing air leakage should be determined through approved and appropriate test methods. The baseline condition of a building upon first inspection significantly impacts the opportunity for cost-effective energy savings through air-sealing.

Deemed Calculation for this Measure

Annual Cooling kWh Savings = (((CFM50Exist – CFM50New) / 29.4) *60 * CDH * 0.0135) / 1000 / ηCool

Summer Coincident Peak kW Savings = ΔkWh / FLHcool * 0.5

Space Heating Savings:

MMBTU Savings (fossil fuel heating)
= (((CFM50Exist – CFM50New) / N-factor) *60 * 24 * HDD * 0.018) / 1,000,000 / ηHeat

kWh Savings (electric heating) = ((((CFM50Exist – CFM50New) / N-factor) *60 * 24 * HDD * 0.018) / 1,000,000 / ηHeat) * 293.1

Deemed Lifetime of Efficient Equipment
The measure life is assumed to be 15 years[267].

Deemed Measure Cost
The actual air sealing measure cost should be used.

Deemed O&M Cost Adjustments
n/a

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[265] Krigger, J. Dorsi, C. "Residential Energy" 2004, p.73
[266] In accordance with industry best practices see: BPI Building Analyst and Envelope Professional standards, http://www.bpi.org/standards_approved.aspx
[267] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 0.5[268].

REFERENCE SECTION

Calculation of Savings

Energy Savings (Space Cooling – if home has Central AC)

ΔkWh = (((CFM50Exist – CFM50New) / N-factor) *60 * CDH * DUA * 0.018) / 1000 / ηCool

Where:

CFM50Exist = Existing Cubic Feet per Minute at 50 Pascal pressure differential as measured by the blower door before airsealing.
= actual recorded

CFM50New = New Cubic Feet per Minute at 50 Pascal pressure differential as measured by the blower door after airsealing.
= actual recorded

N-Factor = Conversion factor to convert 50-pascal air flows to natural airflow.
= 29.4[269]

60 = Constant to convert cubic feet per minute to cubic feet per hour

CDH = Cooling Degree Hours[270].

Dependent on location:

Location	Cooling Degree Hours (75°F set point)
Akron	3,986
Cincinnati	7,711
Cleveland	5,817
Columbus	4,367
Dayton	5,934
Toledo	4,401
Youngtown	3,689

DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F
= 0.75 [271]

0.018 = The volumetric heat capacity of air (Btu/ft3°F)

ηCool = Efficiency of Air Conditioning equipment
= actual recorded

For example, reducing air leakage in a Toledo home from 5000CFM50 to 3500CFM50, with SEER 10 AC:

ΔkWh = (((5000 – 3500) / 29.4) * 60 * 4401 * 0.75 * 0.018) / 1,000 / 10

268 Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

269 Maximum n-factor from methodology developed by the Lawrence Berkeley Laboratory (LBL), since minimal stack effect for cooling savings.

270 Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used) each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/)

271 Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31

= 18 kWh

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh / FLHcool * CF

Where:

FLHcool = Full load cooling hours
Dependent on location as below:

Location	Run Hours[272]
Akron	476
Cincinnati	664
Cleveland	426
Columbus	552
Dayton	631
Mansfield	474
Toledo	433
Youngstown	369

CF = Summer Peak Coincidence Factor for measure
= 0.5[273]

For example, reducing air leakage in a Toledo home from 5000CFM50 to 3500CFM50, with SEER 10 AC:

ΔkW = 18 / 428 * 0.5

= 0.021 kW

Space Heating Savings Calculation

ΔMMBTU = (((CFM50Exist – CFM50New) / N-factor) *60 * 24 * HDD * 0.018) / 1,000,000 / ηHeat

Where:

HDD = Heating Degree Days (60° base temperature) for location[274]

Location	Heating Degree Days (60°F base temperature)
Akron	4,848
Cincinnati	3,853
Cleveland	4,626
Columbus	4,100
Dayton	4,430
Toledo	4,482
Youngstown	4,887

[272] Based on Full Load Hour assumptions taken from the ENERGY STAR calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 33% due to assumption that the average air conditioning is oversized by 50% (Neme, Proctor, Nadal, 1999; "National Energy Savings Potential From Addressing Residential HVAC Installation Problems"). Note this approach results in full load hour estimates within 10% of measured estimates from the Energy Center of Wisconsin, May 2008 study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

[273] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

[274] The 10 year average annual heating degree day value, using a balance point for heating equipment use of 60 degrees was calculated for each location based on data obtained from http://www.engr.udayton.edu/weather/. The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers.

ηHeat = Average Net Heating System Efficiency (Equipment Efficiency * Distribution Efficiency) [275]
= actual recorded

For example, reducing air leakage in a 2 story, well-shielded Toledo home from 5000CFM50 to 3500CFM50, with a gas heating system with efficiency of 70%:

ΔMMBTU = (((5000 – 3500) / 17.8) * 60 * 24 * 4569 * 0.018) / 1,000,000 / 0.7

= 14.3 MMBtu

Note for homes with electric heat (resistance or heat pump), follow the MMBTU formula above and convert to kWh by multiplying by 293.1. For heat pumps the equipment efficiency used in the above algorithm should be the Coefficient Of Performance or COP (i.e., divide HSPF by 3.412; e.g., HSPF 7.7 is COP of 2.26).

For example, reducing air leakage in a 2-story, well-shielded Toledo home from 5000CFM50 to 3500CFM50, with electric resistance heating:

ΔMMBTU = ((((5000 – 3500) / 17.8) * 60 * 24 * 4569 * 0.018) / 1,000,000 / 1.0) * 293.1

= 2925kWh

Water Impact Descriptions and Calculation
n/a

Deemed O&M Cost Adjustment Calculation
n/a

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[275] The System Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.
If there is more than one heating system, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.
In the case of electric heat use 1.0 as the heating system efficiency, and for heat pumps use COP (HSPF/3.412).

Duct Sealing (Retrofit)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure describes evaluating the savings associated with performing duct sealing using mastic sealant or metal tape to the distribution system of homes with either central air conditioning or a ducted heating system.

Two methodologies for estimating the savings associate from sealing the ducts are provided. The first preferred method requires the use of a blower door and the second requires careful inspection of the duct work.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p44 of the Energy Conservatory Blower Door Manual; http://www.energyconservatory.com/download/bdmanual.pdf

2. **Evaluation of Distribution Efficiency** – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table';
http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf

   a. Percentage of duct work found within the conditioned space
   b. Duct leakage evaluation
   c. Duct insulation evaluation

Definition of Efficient Equipment
The efficient condition is sealed duct work throughout the unconditioned space in the home.

Definition of Baseline Equipment
The existing baseline condition is leaky duct work within the unconditioned space in the home.

Deemed Calculation for this Measure

Annual kWh savings $= (((CFM50_{Whole\ House} - CFM50_{Envelope\ Only}) * SCF)_{before} - (CFM50_{Whole\ House} - CFM50_{Envelope\ Only}) * SCF)_{after}) * 60 * CDH * 0.0135) / 1000 / \eta Cool$

Or $= ((DE_{after} - DE_{before}) / DE_{after})) * FLHcool * BtuH * (1/SEER)/1000$

Summer Coincident Peak kW savings $= \Delta kWh / FLHcool * 0.5$

Annual MMBtu savings (fossil fuel) $= (((CFM50_{Whole\ House} - CFM50_{Envelope\ Only}) * SCF)_{before} - (CFM50_{Whole\ House} - CFM50_{Envelope\ Only}) * SCF)_{after}) * 60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat$

Annual MMBtu savings (electric) $= ((((CFM50_{Whole\ House} - CFM50_{Envelope\ Only}) * SCF)_{before} -$

$(CFM50_{Whole\ House} - CFM50_{Envelope\ Only}) * SCF)_{after}) * 60 * 24 * HDD * 0.018) / 1,000,000 / \eta Heat) * 293.1$

Or

Annual MMBtu savings (fossil fuel) $= ((DE_{after} - DE_{before}) / DE_{after})) * 71.2$

Annual MMBtu savings (electric) $= ((DE_{after} - DE_{before}) / DE_{after})) * FLHheat * BtuH * (1/COP * 3.413)/1000$

Deemed Lifetime of Efficient Equipment
The assumed lifetime of this measure is 20 years[276].

Deemed Measure Cost
The actual duct sealing measure cost should be used.

Deemed O&M Cost Adjustments
n/a

Coincidence Factor
The summer peak coincidence factor for this measure is assumed to be 0.5[277].

REFERENCE SECTION

Calculation of Savings

Energy Savings

Methodology 1: Modified Blower Door Subtraction

Determine Duct Leakage rate before and after performing duct sealing:

$$\text{Duct Leakage } (CFM50_{DL}) = (CFM50_{Whole\ House} - CFM50_{Envelope\ Only}) * SCF$$

Where:

$CFM50_{Whole\ House}$ = Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential

$CFM50_{Envelope\ Only}$ = Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.

SCF = Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.

Calculate Energy Savings:

$$\Delta kWh_{cooling} = ((CFM50_{DL\ before} - CFM50_{DL\ after}) * 60 * CDH * DUA * 0.018) / 1000 / \eta Cool$$

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[276] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

[277] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

Where:

$CFM50_{DL\ before}$ = Duct Leakage rate before duct sealing
= calculated as above

$CFM50_{DL\ after}$ = Duct Leakage rate after duct sealing
= calculated as above

60 = Constant to convert cubic feet per minute to cubic feet per hour

CDH = Cooling Degree Hours[278].
Dependent on location:

Location	Cooling Degree Hours (75°F set point)
Akron	3,986
Cincinnati	7,711
Cleveland	5,817
Columbus	4,367
Dayton	5,934
Toledo	4,401
Youngtown	3,689

DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F
= 0.75 [279]

0.018 = The volumetric heat capacity of air (Btu/ft3°F)

ηCool = Efficiency of Air Conditioning equipment
= Actual

For example, duct sealing in a house in Akron with SEER 11 central air conditioning and the following blower door test results:

Before: $CFM50_{Whole\ House}$ = 4800 CFM50
$CFM50_{Envelope\ Only}$ = 4500CFM50
House to duct pressure of 45 Pascals. = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4700 CFM50
$CFM50_{Envelope\ Only}$ = 4500CFM50
House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29
= 387 CFM

$CFM50_{DL\ after}$ = (4700 – 4500) * 1.39
= 278 CFM

Energy Savings:

ΔkWh = ((387 – 278) * 60 * 3986 * 0.75* 0.018) / 1000 / 11

= 32 kWh

[278] Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used) each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/)

[279] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31

Methodology 2: Evaluation of Distribution Efficiency

Determine Distribution Efficiency by evaluating duct system before and after duct sealing using Building Performance Institute "Distribution Efficiency Look-Up Table"

$$\Delta kWh_{cooling} = ((DE_{after} - DE_{before}) / DE_{after})) * FLHcool * BtuH * (1/SEER)/1000$$

Where:

DE_{after} = Distribution Efficiency after duct sealing

DE_{before} = Distribution Efficiency before duct sealing

FLHcool = Full load cooling hours
Dependent on location as below:

Location	Run Hours[280]
Akron	476
Cincinnati	664
Cleveland	426
Columbus	552
Dayton	631
Mansfield	474
Toledo	433
Youngstown	369

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual

SEER = SEER Efficiency of AC unit
= Actual

For example, duct sealing in a house in Akron, with 3-ton SEER 11 central air conditioning and the following duct evaluation results:

DE_{after} = 0.92

DE_{before} = 0.85

Energy Savings:

$$\Delta kWh = ((0.92 - 0.85)/0.92) * 476 * 36000 * (1/11)) / 1000$$

$$= 118.5 \text{ kWh}$$

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh / FLHcool * CF$$

Where:

FLHcool = Full load cooling hours

Dependent on location as below:

[280] Based on Full Load Hour assumptions taken from the ENERGY STAR calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 33% due to assumption that the average air conditioning is oversized by 50% (Neme, Proctor, Nadal, 1999; "National Energy Savings Potential From Addressing Residential HVAC Installation Problems"). Note this approach results in full load hour estimates within 10% of measured estimates from the Energy Center of Wisconsin, May 2008 study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

Location	Run Hours[281]
Akron	476
Cincinnati	664
Cleveland	426
Columbus	552
Dayton	631
Mansfield	474
Toledo	433
Youngstown	369

CF = Summer Peak Coincidence Factor for measure
= 0.5[282]

Space Heating Savings Calculation

Methodology 1: Modified Blower Door Subtraction

$\Delta MMBTU = ((CFM50_{DL\ before} - CFM50_{DL\ after}) * 60 * 24 * HDD * 0.018) / 1,000,000 / \eta Heat$

Where:

$CFM50_{DL\ before}$ = Duct Leakage rate before duct sealing
= calculated as above

$CFM50_{DL\ after}$ = Duct Leakage rate after duct sealing
= calculated as above

HDD = Heating Degree Days (60° base temperature) for location[283]

Location	Heating Degree Days (60°F base temperature)
Akron	4,848
Cincinnati	3,853
Cleveland	4,626
Columbus	4,100
Dayton	4,430
Toledo	4,482
Youngtown	4,887

$\eta Heat$ = Average Net Heating System Efficiency (Equipment Efficiency * Distribution Efficiency) [284]
= actual recorded

[281] Based on Full Load Hour assumptions taken from the ENERGY STAR calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 33% due to assumption that the average air conditioning is oversized by 50% (Neme, Proctor, Nadal, 1999; "National Energy Savings Potential From Addressing Residential HVAC Installation Problems"). Note this approach results in full load hour estimates within 10% of measured estimates from the Energy Center of Wisconsin, May 2008 study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

[282] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

[283] The 10 year average annual heating degree day value, using a balance point for heating equipment use of 60 degrees was calculated for each location based on data obtained from http://www.engr.udayton.edu/weather/. The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers.

[284] The System Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.
If there are more than one heating systems, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.

Note for homes with electric heat (resistance or heat pump), follow the MMBTU formula above and convert to kWh by multiplying by 293.1. For heat pumps the equipment efficiency used in the above algorithm should be the Coefficient Of Performance or COP (i.e. divide HSPF by 3.412, e.g. HSPF 7.7 is COP of 2.26).

For example, duct sealing in a house in Akron with a 80% AFUE natural gas furnace and the following blower door test results:

Before: $CFM50_{Whole\ House}$ = 4800 CFM50
$CFM50_{Envelope\ Only}$ = 4500CFM50
House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4700 CFM50
$CFM50_{Envelope\ Only}$ = 4500CFM50
House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29
= 387 CFM

$CFM50_{DL\ after}$ = (4700 – 4500) * 1.39
= 278 CFM

Energy Savings:

ΔMMBTU = ((387 - 278) * 60 * 24 * 4848 * 0.018) / 1,000,000 / 0.80

= 17.1 MMBtu

Methodology 2: Evaluation of Distribution Efficiency

$$\Delta MMBTUfossil\ fuel = ((DE_{after} - DE_{before}) / DE_{after})) * MMBTU_{heat}$$

Where:

DE_{after} = Distribution Efficiency after duct sealing

DE_{before} = Distribution Efficiency before duct sealing

$MMBTU_{heat}$ = Heating energy consumption

= 71.2 MMBtu[285]

For example, duct sealing in a fossil fuel heated house in Akron with the following duct evaluation results:

DE_{after} = 0.92

DE_{before} = 0.85

Energy Savings:

ΔMMBTU = ((0.92 – 0.85)/0.92) * 71.2

= 5.42 MMBtu

[285] Assumption based on review of Ohio State average home heating output (based on gas utility data)

ΔMMBTUelectric = $((DE_{after} - DE_{before}) / DE_{after})) * FLHheat * BtuH * (1/COP * 3.413)/1000$

Where:

FLHheat = Full load heating hours
Dependent on location as below:

Location	Run Hours[286]
Akron	1576
Cincinnati	1394
Cleveland	1567
Columbus	1272
Dayton	1438
Mansfield	1391
Toledo	1628

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual

COP = Coefficient of Performance of electric heating system[287]

For example, duct sealing in a heat pump (HSPF 6.8) heated house in Akron with the following duct evaluation results:

DE_{after} = 0.92

DE_{before} = 0.85

Energy Savings:

ΔkWh = ((0.92 – 0.85)/0.92) * 1576 * 36000 * (1/6.8)/1000

= 635 kWh

Water Impact Descriptions and Calculation
n/a

Deemed O&M Cost Adjustment Calculation
n/a

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[286] Heating EFLH extracted from simulations conducted for Duke Energy, OH Joint Utility TRM, October 2009; "Technical Reference Manual (TRM) for Ohio Senate Bill 221Energy Efficiency and Conservation Program and 09-512-GE-UNC"
[287] Note that the HSPF of a heat pump is equal to the COP * 3.413.

ENERGY STAR Windows (Time of Sale)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure describes the purchase of ENERGY STAR Windows meeting the minimum requirement for the North region[288] (u factor ≤ 0.30), at natural time of replacement or new construction. This does not relate to a window retrofit program.

Definition of Efficient Equipment
To qualify for this measure, the new window must meet ENERGY STAR criteria for the North region (u factor ≤ 0.30). There is no minimum criterion for Solar Heat Gain Coefficient (SHGC) for windows in the North region, so an assumed typical SHGC of 0.30 for a u-0.30 window is used (this is also the minimum criteria for the federal tax credit).

Definition of Baseline Equipment
The baseline window is assumed to be a standard double pane window with vinyl sash, (u-0.49, SHGC-0.58).

Deemed Savings for this Measure

NOTE: These savings are all per 100 square feet of windows

	Average Annual KWH Savings per unit	Average Summer Coincident Peak kW Savings per unit	Average Annual Fossil Fuel heating fuel savings (MMBTU) per unit	Average Annual Water savings per unit
Heating Savings (Electric Resistance)	302	n/a	n/a	n/a
Heating Savings (Heat Pump)	237	n/a	n/a	n/a
Heating Savings (Fossil Fuel)	n/a	n/a	1.84	n/a
Cooling Savings (Central AC)	126	0.063	n/a	n/a

Deemed Lifetime of Efficient Equipment
The measure life is assumed to be 25 years[289].

Deemed Measure Cost
The incremental cost for this measure is assumed to be $150 per 100 square feet of windows[290].

Deemed O&M Cost Adjustments
n/a

Coincidence Factor
The summer peak coincidence factor for this measure is assumed to be 0.5[291].

[288] Energy Star Qualification Criteria; http://www.energystar.gov/ia/partners/prod_development/archives/downloads/windows_doors/WindowsDoorsSkylightsProgRequirements7Apr09.pdf
[289] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf
[290] Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007
[291] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

REFERENCE SECTION

Calculation of Savings

Energy Savings [292]

Heating kWh Savings (Electric Resistance) = 302 kWh per 100 square feet window area

Heating kWh Savings (Heat Pump COP 2.0) = 237 kWh per 100 square feet window area

Cooling kWh Savings = %CoolKWHSav * (FLHcool * BtuH * (1/SEER))/1000

Where:

%CoolKWHSav = Percentage of cooling energy savings per 100 square feet of window
= 7%[293]

FLHcool = Full load cooling hours
= 552[294]

BtuH = Size of equipment in Btuh
= 36,000[295]

SEER = Assumed SEER efficiency of central AC unit
= 11[296]

Cooling kWh Savings = 0.07 * (552 * 36000 * (1/11))/1000

= 126 kWh per 100 square feet window area

Summer Coincident Peak Demand Savings

ΔkWcooling = %CoolKWSav * BtuH * (1/EER)/1000 * CF

Where:

%CoolKWSav = Percentage of cooling energy savings per 100 square feet of window
= 3.7%[297]

EER = Assumed EER Efficiency of central AC unit
= 10.5 [298]

CF = Summer Peak Coincidence Factor for measure
= 0.5[299]

ΔkWcooling = 0.037 * 36000 * (1/10.5)/1000 * 0.5

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[292] Savings for this measure are based on REMRate modeling of a typical home in Columbus, Ohio climate with electric resistance or air source heat pump (COP 2.0), and assuming SEER 11 air conditioning.

[293] REMRate analysis indicated that installing Energy Star windows in a home in Columbus OH would reduce cooling consumption by 7% per 100 square feet of window.

[294] Based on Full Load Hour assumptions for Columbus OH (used as proxy for the State) taken from the ENERGY STAR calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 33% due to assumption that the average air conditioning is oversized by 50% (Neme, Proctor, Nadal, 1999; "National Energy Savings Potential From Addressing Residential HVAC Installation Problems").

[295] Assumption of typical central AC unit capacity.

[296] VEIC estimate of existing unit efficiency, based on minimum federal standard prior to 2006 of SEER 10, and SEER 13 after 2006.

[297] REMRate analysis indicated that installing Energy Star windows in a home in Columbus OH would reduce cooling design loads by 3.7% per 100 square feet of window.

[298] Converting 11 SEER to 10.5 EER using algorithm EER = (SEER * 0.37) + 6.43 (based on Roberts and Salcido, Architectural Energy Corporation, Feb 2008; "Peak Electric Demand Calculations in the REM/Rate Home Energy Rating Software and REM/Design Home Energy Analysis Software").

[299] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p32

= 0.063 kW per 100 square feet of windows

Fossil Fuel Impact Descriptions and Calculation

Heating MMBtu Savings (Fossil Fuel) = 2.17 MMBtu per 100 square feet window area [300]

Water Impact Descriptions and Calculation
n/a

Deemed O&M Cost Adjustment Calculation
n/a

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[300] Savings for this measure are based on REMRate modeling of a typical home in Columbus, Ohio climate with a 72% AFUE natural gas furnace, and assuming SEER 11 air conditioning. 72% AFUE is estimated based on in 2000, 40% of furnaces purchased in Ohio were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process). Assuming typical efficiencies for condensing and non condensing furnace and duct losses, the average heating system efficiency is estimated as follows:
$(0.4*0.92) + (0.6*0.8) * (1-0.15) = 0.72$

Residential Two Speed / Variable Speed Pool Pumps (Time of Sale)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure describes the purchase and installation of an efficient two-speed or variable speed residential pool pump motor in place of a standard single speed motor of equivalent horsepower.

Definition of Efficient Equipment
The high efficiency equipment is a two-speed or variable speed residential pool pump.

Definition of Baseline Equipment
The baseline efficiency equipment is assumed to be a single speed residential pool pump.

Deemed Savings for this Measure

	Average Annual KWH Savings per unit	Average Summer Coincident Peak kW Savings per unit	Average Annual Fossil Fuel heating fuel savings (MMBTU) per unit	Average Annual Water savings per unit
Two Speed	440	1.13	n/a	n/a
Variable Speed	1170	1.73	n/a	n/a

Deemed Lifetime of Efficient Equipment
The estimated useful life for a variable speed pool pump is 10 years.

Deemed Measure Cost
The incremental cost is estimated to be $175 for a two speed motor and $750 for a variable speed motor[301].

Deemed O&M Cost Adjustments
n/a

Coincidence Factor
The coincidence factor for this measure is assumed to be 0.83[302].

REFERENCE SECTION

Calculation of Savings

Energy Savings [303]

$$\Delta kWh = kWh_{Base} - kWh_{Efficient}$$

Where:

kWh_{Base} = assumed annual kWh consumption for standard single speed pump motor in a cool climate (100 days[304])
= 1,380 kWh

[301] Based on review of Lockheed Martin pump retail price data, July 2009.
[302] Based on Efficiency Vermont's coincidence factor for pool pumps; in the absence of empirical evaluation data, this was based on market feedback about the typical run pattern for pool pumps showing that most people will run pump during the day, and set timer to turn pump off during the night.
[303] Energy Consumption provided in: Consortium for Energy Efficiency, June 2009; "Pool Pump Exploration Memo"
[304] Assumes pool operation between Memorial Day and Labor Day.

$kWh_{Efficient}$ = assumed annual kWh consumption for efficient pump motor in a cool climate (100 days)

$kWh_{Two\ Speed}$ = 940 kWh

$kWh_{Variable\ Speed}$ = 210 kWh

$\Delta kWh_{Two\ Speed}$ = 1380 - 940
= 440 kWh

$\Delta kWh_{Variable\ Speed}$ = 1380 - 210
= 1170 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = (kW_{Base} - kW_{Efficient}) * CF$$

Where[305]:

kW_{Base} = Assumed connected load of standard single speed pump motor
= 2.3 kW

$kW_{Efficient}$ = Weighted average connected load of efficient pump motor

$kW_{Two\ Speed}$ = 0.94 kWh

$kW_{Variable\ Speed}$ = 0.21 kWh

CF = Summer Peak Coincidence Factor for measure
= 0.83[306]

$\Delta kW_{Two\ Speed}$ = (2.3 – 0.94) * 0.83
= 1.13 kW

$\Delta kW_{Variable\ Speed}$ = (2.3 – 0.21) * 0.83
= 1.73 kWh

Fossil Fuel Impact Descriptions and Calculation
n/a

Water Impact Descriptions and Calculation
n/a

Deemed O&M Cost Adjustment Calculation
n/a

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[305] Connected loads calculated by dividing daily consumption by run hours. Data provided in: Consortium for Energy Efficiency, June 2009; "Pool Pump Exploration Memo"

[306] Based on Efficiency Vermont's coincidence factor for pool pumps; in the absence of empirical evaluation data, this was based on market feedback about the typical run pattern for pool pumps showing that most people will run pump during the day, and set timer to turn pump off during the night.

Residential Premium Efficiency Pool Pump Motor (Time of Sale)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure describes the purchase and installation of a residential 1.5HP premium efficiency single speed pool pump motor in place of a standard single speed motor of equivalent horsepower.

Definition of Efficient Equipment
The high efficiency equipment is a residential 1.5HP premium efficiency single speed pool pump motor.

Definition of Baseline Equipment
The baseline efficiency equipment is a residential 1.5HP standard single speed motor pool pump motor.

Deemed Savings for this Measure

	Average Annual KWH Savings per unit	Average Summer Coincident Peak kW Savings per unit	Average Annual Fossil Fuel heating fuel savings (MMBTU) per unit	Average Annual Water savings per unit
Premium Efficiency Motor	409	0.58	n/a	n/a

Deemed Lifetime of Efficient Equipment
The estimated useful life for a pump is 10 years.

Deemed Measure Cost
The incremental cost for this measure is assumed to be $50[307].

Deemed O&M Cost Adjustments
n/a

Coincidence Factor
The coincidence factor for this measure is assumed to be 0.83[308].

REFERENCE SECTION

Calculation of Savings

Energy Savings

$$kWh_{Base} = (HP * LF_{Base} * 0.746) / \eta Pump_{Base} * Hrs/day_{Base} * Days/yr$$
$$kWh_{Eff} = (HP * LF_{Eff} * 0.746) / \eta Pump_{Eff} * Hrs/day_{Eff} * Days/yr$$

$$\Delta kWh = kWh_{Base} - kWh_{Eff}$$

Where [309]

HP = Horsepower of motors

[307] Franklin Energy Services; "FES- M4 – HE Swimming Pool Pumps – Residential"
[308] Based on Efficiency Vermont's coincidence factor for pool pumps; in the absence of empirical evaluation data, this was based on market feedback about the typical run pattern for pool pumps showing that most people will run pump during the day, and set timer to turn pump off during the night.
[309] All assumptions from First Energy's Residential Swimming Pool Pumps memo unless otherwise stated.

	= 1.5
LF_{Base}	= Load factor of baseline motor
	= 0.66
LF_{Eff}	= Load factor of efficient motor
	= 0.65
$\eta Pump_{Base}$	= Efficiency of premium efficiency motor
	= 0.325
$\eta Pump_{Eff}$	= Efficiency of premium efficiency motor
	= 0.455
Hrs/day	= Assumed hours of pump operation per day
	= 6 [310]
Days/yr	= Assumed number of days pool in use
	= 100 days[311]

kWh_{Base} = (1.5 * 0.66 * 0.746) / 0.325 * 6 * 100
= 1,363 kWh

$kWh_{Efficient}$ = (1.5 * 0.65 * 0.746) / 0.455 * 6 * 100
= 959 kWh

ΔkWh = 1363 - 959
= 404 kWh

Summer Coincident Peak Demand Savings

$$kW_{Base} = (HP * LF_{Base} * 0.746) / \eta Pump_{Base}$$
$$kW_{Eff} = (HP * LF_{Eff} * 0.746) / \eta Pump_{Eff}$$

$$\Delta kW = (kW_{Base} - kW_{Eff}) * CF$$

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.83[312]

kW_{Base} = (1.5 * 0.66 * 0.746) / 0.325
= 2.27 kW

kW_{Eff} = (1.5 * 0.65 * 0.746) / 0.455
= 1.60 kW

ΔkW = (2.27 – 1.60) * 0.83

= 0.56 kW

Fossil Fuel Impact Descriptions and Calculation
n/a

[310] Consortium for Energy Efficiency, June 2009; "Pool Pump Exploration Memo"
[311] Assumes pool operation between Memorial Day and Labor Day.
[312] Based on Efficiency Vermont's coincidence factor for pool pumps; in the absence of empirical evaluation data, this was based on market feedback about the typical run pattern for pool pumps showing that most people will run pump during the day, and set timer to turn pump off during the night.

Water Impact Descriptions and Calculation
n/a

Deemed O&M Cost Adjustment Calculation
n/a

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Water Heaters (Time of Sale)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
This measure describes the purchase and installation of an efficient water heater meeting or exceeding Energy Star criteria[313] for the water heater category.

Definition of Efficient Equipment
The minimum efficiency Energy Star qualification criteria[314] by category are:

Water Heater Type	*Energy Factor*
Gas Storage	0.67
Gas Condensing	0.80
Gas Tankless (Whole house)	0.82

Definition of Baseline Equipment
New 50 gallon conventional gas storage water heater rated at the federal minimum 0.58 EF.

Deemed Savings for this Measure

$$\text{Savings } \Delta\text{MMBtu} = 180 * (1/\text{EF}_{\text{Base}} - 1/\text{EF}_{\text{Eff}})$$

Deemed Lifetime of Efficient Equipment
The measure life is assumed to be 13 years[315]

Deemed Measure Cost

Water Heater Type	*Incremental Cost*[316]
Gas Storage (0.67EF)	$400
Gas Storage Condensing (0.80EF)	$685[317]
Gas Tankless (Whole house 0.82EF)	$605[318]

Deemed O&M Cost Adjustments
There is no justification at this time for O&M cost adjustments.

Coincidence Factor
n/a

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313 http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters

314 Though the current standard is 0.62 As of Sept 1 2010 the gas storage specification will change on 9/1/2010, requiring a higher energy factor. The more stringent criteria will save a typical family nearly 15% over a standard model.

315 For all water heaters, life expectancy will depend on local variables such as water chemistry and homeowner maintenance. There is currently insufficient data to determine tankless water heaters lifetimes. Preliminary data show lifetimes up to 20 years are possible. This value attempts to capture the weighted average lifetime of this category in aggregate and is supported by the findings http://www.aceee.org/consumerguide/WH_LCC_1107.pdf

316 We started with the EPA Energy Star Water Heater criteria final analysis for cost data and because of the age of the report we looked and compared the cost and ranges to current market prices. We found that the cited cost (or the middle of the high and low values provided) were on target for the Gas Storage categories, but that the average of the high and low ranges was too high for the tankless category. For this reason the low end of the cited range was used for the tankless category.

317 This value comes from the middle of the range ($1985) of installed costs from the above source minus the $865 installed cost of the baseline. These units are only recently on the market and a review of available pricing support this number.

318 Uses the same $865 cost baseline, but market review indicated that the incremental cost should be calculated from the low end of the price cited in the source ($1470)

REFERENCE SECTION

Calculation of Savings
Savings are determined using Energy Factor assumptions, applying the proportion of consumption used for water heating.

Energy Savings

$\Delta MMBtu = BtuHW_{USAGE} * (1 - EF_{Base} / EF_{Eff})$

Where:

$BtuHW_{USAGE}$ = typical household hot water consumption in therms per year
= 180[319]

EF_{Base} = Energy Factor for the baseline equipment
= 0.58

EF_{Eff} = Energy Factor for the efficient equipment
= actual installed

For example for a new tankless unit rated at AFUE 0.82 the savings would be calculated as follows:

$\Delta MMBtu = 180 * (0.82-0.58)/0.58$
= 54

Summer Coincident Peak Demand Savings
n/a

Water Impact Descriptions and Calculation
n/a

Deemed O&M Cost Adjustment Calculation
n/a

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[319] Average Daily household hot water usage from 2001 Residential Energy Consumption Survey.

Programmable Thermostats (Time of Sale, Direct Install)

Official Measure Code (Measure Number: X-X-X-X (Program name, End Use)

Description
Programmable Thermostats can save energy through the advanced scheduling of time-of-day and/or day-of-week setbacks to control heating and cooling setpoints. Typical usage reduces the heating setpoint during times of the day when occupants are usually not at home (work hours), keeping the home at a cooler temperature in the winter reduces heat losses relative to a higher temperature.

Definition of Efficient Equipment
Programmable Thermostat

Definition of Baseline Equipment
Standard, non-programmable thermostat for central heating system (baseboard electric is excluded from this characterization.

Deemed Savings for this Measure

	Average Annual KWH Savings per unit	Average Summer Coincident Peak kW Savings per unit	Average Annual Fossil Fuel heating fuel savings(MMBTU) per unit	Average Annual Water savings per unit
Residential	n/a[320]	n/a	4.8	n/a

Deemed Lifetime of Efficient Equipment
The lifetime of this measure is assumed to be 15 years in accordance with the EPA's determination of the lifetime of the thermostats.

Deemed Measure Cost
The incremental cost for the purchase of a programmable thermostat shows significant variation, but is typically on the order of $35 based upon current retail market prices. Measures directly installed through retrofit programs should use the actual material, and labor costs.

Deemed O&M Cost Adjustments
n/a

Coincidence Factor
n/a

[320] The referenced study only evaluated heating savings and did not address savings during the cooling season. We do not believe it is appropriate to assume a similar pattern of savings from setting your thermostat down during the heating season and up during the cooling season. A literature review could not find any appropriate defensible source of cooling savings from programmable thermostats