### Duct Insulation and Sealing

**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 p.44 of the Energy Conservatory Blower Door Manual; which can be found on the Energy Conservatory website (As of Oct 2014: http://www.energyconservatory.com/sites/default/files/documents/mod\_3-4\_dg700\_-\_new\_flow\_rings\_-\_cr\_-\_tpt\_-\_no\_fr\_switch\_manual\_ce\_0.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](http://www.cee1.org/com/com-lt/com-lt-main.php3)

* 1. Percentage of duct work found within the conditioned space
  2. Duct leakage evaluation
  3. Duct insulation evaluation

This measure was developed to be applicable to the following program types:  RF.

If applied to other program types, the measure savings should be verified.

**Definition of Efficient Equipment**

The efficient condition is sealed duct work throughout the unconditioned or semi-conditioned space in the home. A non‐conditioned space is defined as a space outside of the thermal envelope of the building that is not intentionally heated for occupancy (crawl space, roof attic, etc). A semi-conditioned space is defined as a space within the thermal envelop that is not intentionally heated for occupancy (unfinished basement)[[1]](#footnote-1).

**Definition of Baseline Equipment**

The existing baseline condition is leaky duct work within the unconditioned or semi-conditioned space in the home.

**Deemed Lifetime of Efficient Equipment**

The assumed lifetime of this measure is 20 years[[2]](#footnote-2).

**Deemed Measure Cost**

The actual duct sealing measure cost should be used.

**Loadshape**

|  |
| --- |
| Loadshape R08 - Residential Cooling |
| Loadshape R09 - Residential Electric Space Heat |
| Loadshape R10 - Residential Electric Heating and Cooling (Shell Measures) |

**Coincidence Factor**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

CFSSP = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[[3]](#footnote-3)

CFPJM   = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[[4]](#footnote-4)

**Algorithm**

**Calculation of Savings**

**Electric Energy Savings**

***Methodology 1: Modified Blower Door Subtraction***

1. Determine Duct Leakage rate before and after performing duct sealing:

Duct Leakage (CFM50DL) = (CFM50Whole House – CFM50Envelope Only) \* SCF

Where:

CFM50Whole House = Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential

CFM50Envelope 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.

1. Calculate duct leakage reduction, convert to CFM25DL and factor in Supply and Return Loss Factors

Duct Leakage Reduction (∆CFM25DL) = (Pre CFM50DL – Post CFM50DL) \* 0.64 \* (SLF + RLF)

Where:

0.64 = Converts CFM50 to CFM25[[5]](#footnote-5)

SLF = Supply Loss Factor

= % leaks sealed located in Supply ducts \* 1 [[6]](#footnote-6)

Default = 0.5[[7]](#footnote-7)

RLF = Return Loss Factor

= % leaks sealed located in Return ducts \* 0.5[[8]](#footnote-8)

Default = 0.25[[9]](#footnote-9)

c) Calculate Electric Energy Savings:

ΔkWh = ΔkWhcooling + ΔkWhFan

ΔkWhcooling = ((*∆*CFM25DL/ ((CapacityCool/12,000) \* 400)) \* FLHcool \* CapacityCool \* TRFcool) / 1000 / ηCool

ΔkWhFan = (ΔTherms \* Fe \* 29.3)

Where:

∆CFM25DL = Duct leakage reduction in CFM25

= calculated above

CapacityCool = Capacity of Air Cooling system (Btu/hr)

=Actual

12,000 = Converts Btu/H capacity to tons

400 = Converts capacity in tons to CFM (400CFM / ton)[[10]](#footnote-10)

FLHcool = Full load cooling hours

= Dependent on location as below[[11]](#footnote-11):

|  |  |  |
| --- | --- | --- |
| **Climate Zone**  **(City based upon)** | **FLHcool**  **Single Family** | **FLHcool**  **Multifamily** |
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[[12]](#footnote-12) | 629 | 564 |

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.0 for Semi-Conditioned Spaces[[13]](#footnote-13)

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual. If unknown assume the following[[14]](#footnote-14):

| **Age of Equipment** | **SEER Estimate** |
| --- | --- |
| Before 2006 | 10 |
| After 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

ΔTherms = Therm savings as calculated in Natural Gas Savings

Fe = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[[15]](#footnote-15)

29.3 = kWh per therm

For example, duct sealing in unconditioned space a single family house in Springfield with a 36,000 Btu/H, SEER 11 central air conditioning, an 80% AFUE, 105,000 Btu/H natural gas furnace and the following blower door test results:

Before: CFM50Whole House = 4800 CFM50

CFM50Envelope Only = 4500 CFM50

House to duct pressure of 45 Pascals. = 1.29 SCF (Energy Conservatory look up table)

After: CFM50Whole House = 4600 CFM50

CFM50Envelope Only = 4500 CFM50

House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

CFM50DL before = (4800 – 4500) \* 1.29

= 387 CFM

CFM50DL after = (4600 – 4500) \* 1.39

= 139 CFM

Duct Leakage reduction at CFM25:

∆CFM25DL = (387 – 139) \* 0.64 \* (0.5 + 0.25)

= 119 CFM25

Energy Savings:

ΔkWhcooling = [((119 / ((36,000/12,000) \* 400)) \* 730 \* 36,000 \* 1) / 1000 / 11] + (212 \* 0.0314 \* 29.3)

= 237 + 195

= 432 kWh

Heating savings for homes with electric heat (Heat Pump):

ΔkWhheating  = ((∆CFM25DL /((OutputCapacityHeat/12,000) \* 400)) \* FLHheat \* OutputCapacityHeat \* TRFheat) / ηHeat / 3412

Where:

OutputCapacityHeat = Heating output capacity (Btu/hr) of electric heat

=Actual

FLHheat = Full load heating hours

= Dependent on location as below[[16]](#footnote-16):

| **Climate Zone**  **(City based upon)** | **FLH\_heat** |
| --- | --- |
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[[17]](#footnote-17) | 1,821 |

TRFheat = Thermal Regain Factor for cooling by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[[18]](#footnote-18)

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use[[19]](#footnote-19):

| **System Type** | **Age of Equipment** | **HSPF Estimate** | **COP Estimate** |
| --- | --- | --- | --- |
| Heat Pump | Before 2006 | 6.8 | 2.00 |
| After 2006 - 2014 | 7.7 | 2.26 |
| 2015 on | 8.2 | 2.40 |
| Resistance | N/A | N/A | 1.00 |

3412 = Converts Btu to kWh

For example, duct sealing in unconditioned space in a 36,000 Btu/H 2.5 COP heat pump heated single family house in Springfield with the blower door results described above:

ΔkWhheating = ((119 / ((36,000/12,000) \* 400)) \* 1,754 \* 36,000 \* 1) / 2.5 / 3412

= 734 kWh

***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”

ΔkWh = ((((DEafter – DEbefore) / DEafter) \* FLHcool \* CapacityCool \* TRFcool)/1000 / ηCool) + (ΔTherms \* Fe \* 29.3)

Where:

DEafter = Distribution Efficiency after duct sealing

DEbefore = Distribution Efficiency before duct sealing

FLHcool = Full load cooling hours

= Dependent on location as below[[20]](#footnote-20):

| **Climate Zone**  **(City based upon)** | **FLHcool**  **Single Family** | **FLHcool**  **Multifamily** |
| --- | --- | --- |
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[[21]](#footnote-21) | 629 | 564 |

CapacityCool = Capacity of Air Cooling system (Btu/hr)

=Actual

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.0 for Semi-Conditioned Spaces[[22]](#footnote-22)

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual. If unknown assume[[23]](#footnote-23):

|  |  |
| --- | --- |
| **Age of Equipment** | **SEER Estimate** |
| Before 2006 | 10 |
| After 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

For example, duct sealing in unconditioned space in a single family house in Springfield, with 36,000 Btu/H SEER 11 central air conditioning, an 80% AFUE, 105,000 Btu/H natural gas furnace and the following duct evaluation results:

DEbefore = 0.85

DEafter = 0.92

Energy Savings:

ΔkWhcooling = ((((0.92 – 0.85)/0.92) \* 730 \* 36,000 \* 1) / 1000 / 11) + (212 \* 0.0314 \* 29.3)

= 182 + 195

= 377 kWh

Heating savings for homes with electric heat (Heat Pump):

ΔkWhheating = ((DEafter – DEbefore)/ DEafter)) \* FLHheat \* OutputCapacityHeat \* TRFheat) / ηHeat / 3412

Where:

OutputCapacityHeat = Heating output capacity (Btu/hr) of the electric heat

=Actual

FLHheat = Full load heating hours

= Dependent on location as below[[24]](#footnote-24):

|  |  |
| --- | --- |
| **Climate Zone**  **(City based upon)** | **FLH\_heat** |
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[[25]](#footnote-25) | 1,821 |

TRFheat = Thermal Regain Factor for cooling by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[[26]](#footnote-26)

COP = Coefficient of Performance of electric heating system[[27]](#footnote-27)

= Actual. If not available use[[28]](#footnote-28):

| **System Type** | **Age of Equipment** | **HSPF Estimate** | **COP Estimate** |
| --- | --- | --- | --- |
| Heat Pump | Before 2006 | 6.8 | 2.00 |
| After 2006 - 2014 | 7.7 | 2.26 |
| 2015 on | 8.2 | 2.40 |
| Resistance | N/A | N/A | 1.00 |

For example, duct sealing in unconditioned space in a 36,000 Btu/H, 2.5 COP heat pump heated single family house in Springfield with the following duct evaluation results:

DEafter = 0.92

DEbefore = 0.85

Energy Savings:

ΔkWhheating = ((0.92 – 0.85)/0.92) \* 1,967 \* 36,000 \* 1) / 2.5) / 3412

= 632 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = ΔkWhcooling/ FLHcool \* CF

Where:

FLHcool = Full load cooling hours:

= Dependent on location as below[[29]](#footnote-29):

|  |  |  |
| --- | --- | --- |
| **Climate Zone**  **(City based upon)** | **FLHcool**  **Single Family** | **FLHcool**  **Multifamily** |
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[[30]](#footnote-30) | 629 | 564 |

CFSSP = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[[31]](#footnote-31)

CFPJM = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%[[32]](#footnote-32)

**Natural Gas Savings**

For homes with Natural Gas Heating:

***Methodology 1: Modified Blower Door Subtraction***

ΔTherm = (((∆CFM25DL / (InputCapacityHeat \* 0.0123)) \* FLHheat \* InputCapacityHeat \* TRFheat (ηEquipment / ηSystem)) / 100,000

Where:

∆CFM25DL = Duct leakage reduction in CFM25

InputCapacityHeat = Heating input capacity (Btu/hr)

=Actual

0.0123 = Conversion of Capacity to CFM (0.0123CFM / Btu/hr)[[33]](#footnote-33)

FLHheat = Full load heating hours

=Dependent on location as below[[34]](#footnote-34):

|  |  |
| --- | --- |
| **Climate Zone**  **(City based upon)** | **FLH\_heat** |
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[[35]](#footnote-35) | 1,821 |

TRFheat = Thermal Regain Factor for cooling by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[[36]](#footnote-36)

100,000 = Converts Btu to therms

ηEquipment = Heating Equipment Efficiency

= Actual[[37]](#footnote-37). If not available use 83%[[38]](#footnote-38)

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency \* Pre Distribution Efficiency)[[39]](#footnote-39)

= Actual. If not available use 70%[[40]](#footnote-40)

For example, duct sealing in unconditioned space in a house in Springfield with an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following blower door test results:

Before: CFM50Whole House = 4800 CFM50

CFM50Envelope Only = 4500CFM50

House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

After: CFM50Whole House = 4600 CFM50

CFM50Envelope Only = 4500CFM50

House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

CFM50DL before = (4800 – 4500) \* 1.29

= 387 CFM

CFM50DL after = (4600 – 4500) \* 1.39

= 119 CFM

Duct Leakage reduction at CFM25:

∆CFM25DL = (387 – 139) \* 0.64 \* (0.5 + 0.25)

= 119 CFM25

Energy Savings:

Pre Distribution Efficiency = 1 – (387/4800) = 92%

ηSystem = 80% \* 92% = 74%

ΔTherm = ((119/ (105,000 \* 0.0123)) \* 1,754 \* 105,000 \* 1 \*(0.8/0.74)) / 100,000

= 183 therms

***Methodology 2: Evaluation of Distribution Efficiency***

ΔTherm = ((DEafter – DEbefore)/ DEafter)) \* FLHheat \* InputCapacityHeat \* TRFheat \* (ηEquipment / ηSystem)) / 100,000

Where:

DEafter = Distribution Efficiency after duct sealing

DEbefore = Distribution Efficiency before duct sealing

Other variables as defined above

For example, duct sealing in unconditioned space in a house in Springfield an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following duct evaluation results:

DEafter = 0.92

DEbefore = 0.85

Energy Savings:

ηSystem = 80% \* 85% = 68%

ΔTherm = ((0.92 – 0.85)/0.92) \* 1,754 \* 105,000 \* 1 \* (0.8/0.68)) / 100,000

= 164 therm

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code: RS-HVC-DINS-V06-160601**

1. Definition matches Regain factor discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012 [↑](#footnote-ref-1)
2. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

   [http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure\_life\_GDS%5B1%5D.pdf](http://www.eia.gov/consumption/residential/data/2009/) [↑](#footnote-ref-2)
3. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-3)
4. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year. [↑](#footnote-ref-4)
5. 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the “Can’t Reach Fifty” factor for CFM25; see Energy Conservatory Blower Door Manual). [↑](#footnote-ref-5)
6. Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in “Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements” from <http://www.energyconservatory.com/download/dbmanual.pdf> [↑](#footnote-ref-6)
7. Assumes 50% of leaks are in supply ducts. [↑](#footnote-ref-7)
8. Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than “average” (e.g. pulling return air from a super heated attic), or can be adjusted downward to represent significantly less energy loss (e.g. pulling return air from a moderate temperature crawl space) . More information provided in “Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements” from [http://www.energyconservatory.com/download/dbmanual.pdf](http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12440) [↑](#footnote-ref-8)
9. Assumes 50% of leaks are in return ducts. [↑](#footnote-ref-9)
10. This conversion is an industry rule of thumb; e.g. see http://www.hvacsalesandsupply.com/Linked%20Documents/Tech%20Tips/61-Why%20400%20CFM%20per%20ton.pdf [↑](#footnote-ref-10)
11. Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in the Appendix providing the appropriate city to use for each county of Illinois. [↑](#footnote-ref-11)
12. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-12)
13. Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012. [↑](#footnote-ref-13)
14. These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. [↑](#footnote-ref-14)
15. Fe is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% Fe. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. [↑](#footnote-ref-15)
16. Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL. [↑](#footnote-ref-16)
17. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-17)
18. Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012. [↑](#footnote-ref-18)
19. These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. [↑](#footnote-ref-19)
20. Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in the Appendix providing the appropriate city to use for each county of Illinois. [↑](#footnote-ref-20)
21. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-21)
22. Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012. [↑](#footnote-ref-22)
23. These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. [↑](#footnote-ref-23)
24. Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL. [↑](#footnote-ref-24)
25. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-25)
26. Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012. [↑](#footnote-ref-26)
27. Note that the HSPF of a heat pump is equal to the COP \* 3.413. [↑](#footnote-ref-27)
28. These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. [↑](#footnote-ref-28)
29. Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in the Appendix providing the appropriate city to use for each county of Illinois. [↑](#footnote-ref-29)
30. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-30)
31. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-31)
32. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year. [↑](#footnote-ref-32)
33. Based on Natural Draft Furnaces requiring 100 CFM per 10,000 Btu, Induced Draft Furnaces requiring 130CFM per 10,000Btu and Condensing Furnaces requiring 150 CFM per 10,000 Btu (rule of thumb from [http://contractingbusiness.com/enewsletters/cb\_imp\_43580/](http://ilsag.org/yahoo_site_admin/assets/docs/ComEd_PY2_CACES_Evaluation_Report_2010-10-18.299122020.pdf)). Data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggested that in 2000, 24% of furnaces purchased in Illinois were condensing units. Therefore a weighted average required airflow rate is calculated assuming a 50:50 split of natural v induced draft non-condensing furnaces, as 123 per 10,000Btu or 0.0123/Btu. [↑](#footnote-ref-33)
34. Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL. [↑](#footnote-ref-34)
35. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-35)
36. Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012. [↑](#footnote-ref-36)
37. The Equipment Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

    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. [↑](#footnote-ref-37)
38. This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey: [http://www.eia.gov/consumption/residential/data/2009/xls/HC6.9%20Space%20Heating%20in%20Midwest%20Region.xls](http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf)))

    In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

    (0.24\*0.92) + (0.76\*0.8) = 0.829 [↑](#footnote-ref-38)
39. 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](http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)) or by performing duct blaster testing. [↑](#footnote-ref-39)
40. Estimated as follows: 0.829 \* (1-0.15) = 0.70 [↑](#footnote-ref-40)