### Air Sealing

###### Description

Thermal shell air leaks are sealed through strategic use and location of air-tight materials. Leaks are detected and leakage rates measured with the assistance of a blower-door. The algorithm for this measure can be used when the program implementation does not allow for more detailed forecasting through the use of residential modeling software.

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

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 using a blower door. The baseline condition of a building upon first inspection significantly impacts the opportunity for cost-effective energy savings through air-sealing.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.[[1]](#footnote-1)

###### Deemed Measure Cost

The actual capital cost for this measure should be used in screening.

###### Loadshape

|  |
| --- |
| Loadshape R08 - Residential Cooling |
| Loadshape R09 - Residential Electric Space Heat |
| Loadshape R10 - Residential Electric Heating and Cooling |

###### 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%[[2]](#footnote-2)

CFSSP = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[[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

ΔkWh = ΔkWh\_cooling + ΔkWh\_heating

Where:

ΔkWh\_cooling = If central cooling, reduction in annual cooling requirement due to air sealing

= [(((CFM50\_existing - CFM50\_new)/N\_cool) \* 60 \* 24 \* CDD \* DUA \* 0.018) / (1000 \* ηCool)] \* LM

CFM50\_existing = Infiltration at 50 Pascals as measured by blower door before air sealing.

= Actual

CFM50\_new = Infiltration at 50 Pascals as measured by blower door after air sealing.

= Actual

N\_cool = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

=Dependent on exposure:[[5]](#footnote-5)

| **Climate Zone** | **Exposure** | **N-Factor** |
| --- | --- | --- |
| Zone 2 | Well Shielded | 22.2 |
| Normal | 18.5 |
| Exposed | 16.7 |
| Zone 3 | Well Shielded | 25.8 |
| Normal | 21.5 |
| Exposed | 19.4 |

60 \* 24 = Converts Cubic Feet per Minute to Cubic Feet per Day

CDD = Cooling Degree Days

= Dependent on location[[6]](#footnote-6):

|  |  |
| --- | --- |
| **Climate Zone (City based upon)** | **CDD 65** |
| 1 (Rockford) | 820 |
| 2 (Chicago) | 842 |
| 3 (Springfield) | 1,108 |
| 4 (Belleville) | 1,570 |
| 5 (Marion) | 1,370 |

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [[7]](#footnote-7)

0.018 = Specific Heat Capacity of Air (Btu/ft3\*°F)

1000 = Converts Btu to kBtu

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

= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following[[8]](#footnote-8):

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

LM = Latent multiplier to account for latent cooling demand[[9]](#footnote-9)

|  |  |
| --- | --- |
| Climate Zone (City based upon) | LM |
| 1 (Rockford) | 3.3 |
| 2 (Chicago) | 3.2 |
| 3 (Springfield) | 3.5 |
| 4 (St Louis, MO) | 3.4 |
| 5 (Paducah, KY) | 3.5 |

ΔkWh\_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

= (((CFM50\_existing - CFM50\_new)/N\_heat) \* 60 \* 24 \* HDD \* 0.018) / (ηHeat \* 3,412)

N\_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone, building height and exposure level:[[10]](#footnote-11)

|  | **# Stories:** | **1** | **1.5** | **2** | **3** |
| --- | --- | --- | --- | --- | --- |
| Zone 2 | Well Shielded | 22.2 | 20.0 | 17.8 | 15.5 |
| Normal | 18.5 | 16.7 | 14.8 | 13.0 |
| Exposed | 16.7 | 15.0 | 13.3 | 11.7 |
| Zone 3 | Well Shielded | 25.8 | 23.2 | 20.6 | 18.1 |
| Normal | 21.5 | 19.4 | 17.2 | 15.1 |
| Exposed | 19.4 | 17.4 | 15.5 | 13.5 |

HDD = Heating Degree Days

= Dependent on location:[[11]](#footnote-12)

|  |  |
| --- | --- |
| **Climate Zone**  **(City based upon)** | **HDD 65** |
| 1 (Rockford) | 6,569 |
| 2 (Chicago) | 6,339 |
| 3 (Springfield) | 5,497 |
| 4 (Belleville) | 4,379 |
| 5 (Marion) | 4,476 |

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below[[12]](#footnote-13):

|  |  |  |  |
| --- | --- | --- | --- |
| **System Type** | **Age of Equipment** | **HSPF Estimate** | **ηHeat (Effective COP Estimate)= (HSPF/3.413)\*0.85** |
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| 2006 - 2014 | 7.7 | 1.92 |
| 2015 on | 8.2 | 2.40 |
| Resistance | N/A | N/A | 1 |

3412 = Converts Btu to kWh

For example, a well shielded, 2 story single family home in Chicago with 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), has pre and post blower door test results of 3,400 and 2,250:

ΔkWh = ΔkWh\_cooling + ΔkWh\_heating

= [((((3,400 – 2,250) / 22.2) \* 60 \* 24 \* 842 \* 0.75 \* 0.018) / (1000 \* 10.5)) \* 3.5] + [((3,400 – 2,250) / 17.8)) \* 60 \* 24 \* 6339 \* 0.018 / (1.92 \* 3,412)]

= 283 + 1620

= 1,903 kWh

ΔkWh\_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms \* Fe \* 29.3

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

= 3.14%[[13]](#footnote-14)

29.3 = kWh per therm

For example, a well shielded, 2 story single family home in Chicago with a gas furnace with system efficiency of 70%, has pre and post blower door test results of 3,400 and 2,250 (see therm calculation in Natural Gas Savings section:

ΔkWh = 152 \* 0.0314 \* 29.3

= 140 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = (ΔkWh\_cooling / FLH\_cooling) \* CF

Where:

FLH\_cooling = Full load hours of air conditioning

= Dependent on location[[14]](#footnote-15):

|  |  |  |
| --- | --- | --- |
| **Climate Zone**  **(City based upon)** | **Single Family** | **Multifamily** |
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |

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

= 68%[[15]](#footnote-16)

CFSSP = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[[16]](#footnote-17)

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

= 46.6%[[17]](#footnote-18)

Other factors as defined above

For example, a well shielded, 2 story single family home in Chicago with 10.5 SEER central cooling and a heat pump with COP of 2.0, has pre and post blower door test results of 3,400 and 2,250:

ΔkWSSP = 283 / 570 \* 0.68

= 0.34 kW

ΔkWPJM = 283 / 570 \* 0.466

= 0.23 kW

###### Natural Gas Savings

If Natural Gas heating:

ΔTherms = (((CFM50\_existing - CFM50\_new)/N\_heat) \* 60 \* 24 \* HDD \* 0.018) / (ηHeat \* 100,000)

Where:

N\_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone, building height and exposure level[[18]](#footnote-19):

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **# Stories:** | **1** | **1.5** | **2** | **3** |
| Zone 2 | Well Shielded | 22.2 | 20.0 | 17.8 | 15.5 |
| Normal | 18.5 | 16.7 | 14.8 | 13.0 |
| Exposed | 16.7 | 15.0 | 13.3 | 11.7 |
| Zone 3 | Well Shielded | 25.8 | 23.2 | 20.6 | 18.1 |
| Normal | 21.5 | 19.4 | 17.2 | 15.1 |
| Exposed | 19.4 | 17.4 | 15.5 | 13.5 |

HDD = Heating Degree Days

= dependent on location[[19]](#footnote-20):

|  |  |
| --- | --- |
| **Climate Zone**  **(City based upon)** | **HDD 65** |
| 1 (Rockford) | 6,569 |
| 2 (Chicago) | 6,339 |
| 3 (Springfield) | 5,497 |
| 4 (Belleville) | 4,379 |
| 5 (Marion) | 4,476 |

ηHeat = Efficiency of heating system

= Equipment efficiency \* distribution efficiency

= Actual[[20]](#footnote-21). If not available use 70%[[21]](#footnote-22).

Other factors as defined above

For example, a well shielded, 2 story single family home in Chicago with a gas furnace with system efficiency of 70%, has pre and post blower door test results of 3,400 and 2,250:

ΔTherms = ((3,400 – 2,250)/17.8) \* 60 \* 24 \* 6339 \* 0.018) / (0.7 \* 100,000)

= 152 therms

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: RS-SHL-AIRS-V04-150601

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007 [↑](#footnote-ref-1)
2. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-2)
3. Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’. [↑](#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. N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and exposure of the home to wind (impacts of stack effect based on height of building will not be significant because of reduced delta T during the cooling season) , based on methodology developed by Lawrence Berkeley Laboratory (LBL). [N-factor](http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html#94011122) values copied from J. Krigger, C. Dorsi; “Residential Energy: Cost Savings and Comfort for Existing Buildings”, p284. [↑](#footnote-ref-5)
6. National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F. [↑](#footnote-ref-6)
7. This factor's source is: Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31. [↑](#footnote-ref-7)
8. 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-8)
9. Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”. [↑](#footnote-ref-9)
10. N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location, height of building (stack effect) and exposure of the home to wind, based on methodology developed by Lawrence Berkeley Laboratory (LBL). [N-factor](http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html#94011122) values copied from J. Krigger, C. Dorsi; “Residential Energy: Cost Savings and Comfort for Existing Buildings”, p284. [↑](#footnote-ref-11)
11. National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F. The base temperature was selected to account for the fact that homes receiving airsealing efforts are likely to be more leaky homes where the inside and outside air temperature is more consistent and therefore is more likely to require heating as temperatures drop below 65 degrees. Using this base temperature also reconciles the resulting savings estimates with the results of more sophisticated modeling software. [↑](#footnote-ref-12)
12. 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 means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps. [↑](#footnote-ref-13)
13. 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-14)
14. Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting”, <http://ilsag.org/yahoo_site_admin/assets/docs/ComEd_PY2_CACES_Evaluation_Report_2010-10-18.299122020.pdf> p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. [↑](#footnote-ref-15)
15. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-16)
16. Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’. [↑](#footnote-ref-17)
17. 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-18)
18. N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location, height of building (stack effect) and exposure of the home to wind, based on methodology developed by Lawrence Berkeley Laboratory (LBL). [N-factor](http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html#94011122) values copied from J. Krigger, C. Dorsi; “Residential Energy: Cost Savings and Comfort for Existing Buildings”, p284. [↑](#footnote-ref-19)
19. National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in “Statistical Analysis of Historical State-Level Residential Energy Consumption Trends,” 2004.. [↑](#footnote-ref-20)
20. Ideally, the System Efficiency should 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. [↑](#footnote-ref-21)
21. 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> )

    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) \* (1-0.15) = 0.70 [↑](#footnote-ref-22)