### Basement Sidewall Insulation

###### Description

Insulation is added to a basement or crawl space. Insulation added above ground in conditioned space is modeled the same as wall insulation. Below ground insulation is adjusted with an approximation of the thermal resistance of the ground. Insulation in unconditioned spaces is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load. Cooling savings only consider above grade insulation, as below grade has little temperature difference during the cooling season.

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**

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

**Definition of Baseline Equipment**

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no basement wall or ceiling insulation.

**Deemed Lifetime of Efficient Equipment**

The expected measure life is assumed to be 25 years.[[1]](#footnote-1)

**Deemed Measure Cost**

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

**Deemed O&M Cost Adjustments**

N/A

**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**

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh\_cooling + ΔkWh\_heating)

Where:

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

= ((((1/R\_old\_AG - 1/(R\_added+R\_old\_AG)) \* L\_basement\_wall\_total \* H\_basement\_wall\_AG \* (1-Framing\_factor)) \* 24 \* CDD \* DUA) / (1000 \* ηCool))) \* ADJBasementCool

R\_added = R-value of additional spray foam, rigid foam, or cavity insulation.

R\_old\_AG = R-value value of foundation wall above grade.

= Actual, if unknown assume 1.0[[5]](#footnote-5)

L\_basement\_wall\_total = Length of basement wall around the entire insulated perimeter (ft)

H\_basement\_wall\_AG = Height of insulated basement wall above grade (ft)

Framing\_factor = Adjustment to account for area of framing when cavity insulation is used

= 0% if Spray Foam or External Rigid Foam

= 25% if studs and cavity insulation[[6]](#footnote-6)

24 = Converts hours to days

CDD = Cooling Degree Days

= Dependent on location and whether basement is conditioned:[[7]](#footnote-7)

|  |  |  |
| --- | --- | --- |
| **Climate Zone**  **(City based upon)** | **Conditioned CDD 65** | **Unconditioned**  **CDD 65[[8]](#footnote-8)** |
| 1 (Rockford) | 820 | 263 |
| 2 (Chicago) | 842 | 281 |
| 3 (Springfield) | 1,108 | 436 |
| 4 (Belleville) | 1,570 | 538 |
| 5 (Marion) | 1,370 | 570 |
| Weighted Average[[9]](#footnote-9) | 947 | 325 |

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

= 0.75 [[10]](#footnote-10)

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following:[[11]](#footnote-11)

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

ADJBasementCool = Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[[12]](#footnote-12).

= 80%

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

= ([((1/R\_old\_AG - 1/(R\_added+R\_old\_AG)) \* L\_basement\_wall\_total \* H\_basement\_wall\_AG \* (1-Framing\_factor)) + ((1/(R\_old\_BG - 1/(R\_added+R\_old\_BG)) \* L\_basement\_wall\_total \* (H\_basement\_wall\_total - H\_basement\_wall\_AG) \* (1-Framing\_factor))] \* 24 \* HDD) / (3,412 \* ηHeat)) \* ADJBasementHeat

Where

R\_old\_BG = R-value value of foundation wall below grade (including thermal resistance of the earth) [[13]](#footnote-13)

= dependent on depth of foundation (H\_basement\_wall\_total – H\_basement\_wall\_AG):

= Actual R-value of wall plus average earth R-value by depth in table below

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Below Grade R-value** |  |  |  |  |  |  |  |  |  |
| **Depth below grade (ft)** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| Earth R-value (°F-ft2-h/Btu) | 2.44 | 4.50 | 6.30 | 8.40 | 10.44 | 12.66 | 14.49 | 17.00 | 20.00 |
| Average Earth R-value (°F-ft2-h/Btu) | 2.44 | 3.47 | 4.41 | 5.41 | 6.42 | 7.46 | 8.46 | 9.53 | 10.69 |
| Total BG R-value (earth + R-1.0 foundation) default | 3.44 | 4.47 | 5.41 | 6.41 | 7.42 | 8.46 | 9.46 | 10.53 | 11.69 |

H\_basement\_wall\_total = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on location and whether basement is conditioned:[[14]](#footnote-14)

| **Climate Zone**  **(City based upon)** | **Conditioned**  **HDD 60** | **Unconditioned**  **HDD 50** |
| --- | --- | --- |
| 1 (Rockford) | 5,352 | 3,322 |
| 2 (Chicago) | 5,113 | 3,079 |
| 3 (Springfield) | 4,379 | 2,550 |
| 4 (Belleville) | 3,378 | 1,789 |
| 5 (Marion) | 3,438 | 1,796 |
| Weighted Average[[15]](#footnote-15) | 4,860 | 2,895 |

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[[16]](#footnote-16)

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

ADJBasementHeat = Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[[17]](#footnote-17).

= 60%

.

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

ΔkWh = (ΔkWh\_cooling + ΔkWh\_heating)

= [((((1/2.25 - 1/(13 + 2.25))\*(20+25+20+25) \* 3 \* (1 - 0)) \* 24 \* 281 \* 0.75)/(1000 \* 10.5)) \* 0.8] + [(((((1/2.25 - 1/(13 + 2.25)) \* (20+25+20+25) \* 3 \* (1-0)) + ((1 / (2.25 + 6.42) – 1 / (13 + 2.25 + 6.42)) \* (20+25+20+25) \* 4 \* (1-0))) \* 24 \* 3079) / (3412 \* 1.92)) \* 0.6]

= (39.4 + 860.9)

= 900.3 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%[[18]](#footnote-19)

29.3 = kWh per therm

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section :

= 78.3 \* 0.0314 \* 29.3

= 72.0 kWh

**Summer Coincident Peak Demand**

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

Where:

FLH\_cooling = Full load hours of air conditioning

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

|  |  |  |
| --- | --- | --- |
| **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 |
| Weighted Average[[20]](#footnote-21) | 629 | 564 |

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

= 68%[[21]](#footnote-22)

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

= 72%%[[22]](#footnote-23)

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

= 46.6%[[23]](#footnote-24)

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

ΔkWSSP = 39.4 / 570 \* 0.68

= 0.047 kW

ΔkWPJM = 39.4 / 570 \* 0.466

= 0.032 kW

**Natural Gas Savings**

If Natural Gas heating:

ΔTherms = [(([((1/R\_old\_AG - 1/(R\_added+R\_old\_AG)) \* L\_basement\_wall\_total \* H\_basement\_wall\_AG \* (1-Framing\_factor) + (1/(R\_old\_BG - 1/(R\_added+R\_old\_BG)) \* L\_basement\_wall\_total \* (H\_basement\_wall\_total - H\_basement\_wall\_AG) \* (1-Framing\_factor)] \* 24 \* HDD) / (ηHeat \* 100,067)] \* ADJBasementHeat

ηHeat = Efficiency of heating system

= Equipment efficiency \* distribution efficiency

= Actual. If unknown assume 72%[[24]](#footnote-25)

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 72% efficient furnace:

= ((1/2.25 - 1/(13 + 2.25)) \* (20+25+20+25) \* 3 \* (1-0) + (1/8.67 - 1/(13 + 8.67)) \* (20+25+20+25) \* 4 \* (1 - 0)) \* 24 \* 3079) / (0.72 \* 100,067) \* 0.60

= 78.3 therms

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code: RS-SHL-BINS-V07-160601**

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. ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991, http://www.ornl.gov/sci/roofs+walls/foundation/ORNL\_CON-295.pdf [↑](#footnote-ref-5)
6. ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1 [↑](#footnote-ref-6)
7. National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F. There is a county mapping table in the Appendix providing the appropriate city to use for each county of Illinois. [↑](#footnote-ref-7)
8. Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year climate normals from NCDC used elsewhere are not available at base temps above 72F. [↑](#footnote-ref-8)
9. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-9)
10. 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-10)
11. 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-11)
12. As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 80%. [↑](#footnote-ref-12)
13. Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook [↑](#footnote-ref-13)
14. National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F for a conditioned basement and 50°F for an unconditioned basement), consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in “Statistical Analysis of Historical State-Level Residential Energy Consumption Trends,” 2004. There is a county mapping table in the front of the TRM providing the appropriate city to use for each county of Illinois. [↑](#footnote-ref-14)
15. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-15)
16. 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-16)
17. As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 60%. [↑](#footnote-ref-17)
18. 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-19)
19. Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting”, <http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd%20EPY2%20Evaluation%20Reports/ComEd_Central_AC_Efficiency_Services_PY2_Evaluation_Report_Final.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. There is a county mapping table in the front of the TRM providing the appropriate city to use for each county of Illinois. [↑](#footnote-ref-20)
20. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-21)
21. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-22)
22. 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-23)
23. 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-24)
24. Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses. [↑](#footnote-ref-25)