5.3.8 Ground Source Heat Pump

**Description**

This measure characterizes the installation of a Ground Source Heat Pump under the following scenarios:

1. New Construction:
   1. The installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below in a new home.
   2. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.
2. Time of Sale:
   1. The planned installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below to replace an existing system(s) that does not meet the criteria for early replacement described in section c below.
   2. Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   3. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.
3. Early Replacement/Retrofit:
   1. The early removal of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new high efficiency Ground Source Heat Pump system.
   2. Note the baseline in this case is the existing equipment being replaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   3. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.
   4. The definitions for when an installation can be claimed as an early replacement are provided below. Note if one system (heating or cooling) has failed or does not meet the criteria below but the other system does, then the appropriate new baseline replacement should be used for the unit not meeting early replacement criteria and the existing system efficiency for the unit that does should be used in the algorithm:

|  |  |
| --- | --- |
| **Existing System** | **Early Replacement Criteria** |
| Air Source Heat Pump | SEER <=10 and cost of any repairs <$249 per ton |
| Central Air Conditioner | SEER <=10 and cost of any repairs <$190 per ton |
| Boiler | AFUE <= 75% and cost of any repairs <$709 |
| Furnace | AFUE <= 75% and cost of any repairs <$528 |
| Ground Source Heat Pump | SEER <=10 and cost of any repairs <$249 per ton |

The ENERGY STAR efficiency standards are presented below.

|  |  |  |
| --- | --- | --- |
| ENERGY STAR Requirements (Effective January 1, 2012) | | |
| **Product Type** | **Cooling EER** | **Heating COP** |
| **Water-to-air** | | |
| Closed Loop | 17.1 | 3.6 |
| Open Loop | 21.1 | 4.1 |
| **Water-to-Water** | | |
| Closed Loop | 16.1 | 3.1 |
| Open Loop | 20.1 | 3.5 |
| DGX | 16 | 3.6 |

This measure was developed to be applicable to the following program types:  TOS, NC, EREP.  If applied to other program types, the measure savings should be verified.

**Definition of Efficient Equipment**

In order for this characterization to apply, the efficient equipment must be a Ground Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards effective at the time of installation as detailed above.

**Definition of Baseline Equipment**

For these products, baseline equipment includes Air Conditioning, Space Heating and Water Heating.

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8[[1]](#footnote-1) EER and a Federal Standard electric hot water heater.

To calculate savings with a furnace/central AC baseline, the baseline equipment is assumed to be an 80% AFUE Furnace and central AC meeting the Federal Standard efficiency level; 13 SEER, 11 EER. If a gas water heater, the Federal Standard baseline is calculated as follows[[2]](#footnote-2); for <=55 gallon tanks = 0.675 – (0.0015 \* storage size in gallons) and for tanks >55 gallon = 0.8012 – (0.00078 \* storage size in gallons). For a 40-gallon storage water heater this would be 0.615 EF.

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit, meeting the baselines provided below.

|  |  |
| --- | --- |
| **Unit Type** | **Efficiency Standard** |
| ASHP | 14 SEER, 11.8 EER, 8.2 HSPF |
| Gas Furnace | 80% AFUE |
| Gas Boiler | 82% AFUE |
| Central AC | 13 SEER, 11 EER |

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating, cooling and hot water equipment for the assumed remaining useful life of the existing unit and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above except for Gas Furnace where new baseline assumption is 90% due to pending standard change).

**Deemed Lifetime of Efficient Equipment**

The expected measure life is assumed to be 25 years[[3]](#footnote-3).

For early replacement, the remaining life of existing equipment is assumed to be 8 years[[4]](#footnote-4).

**Deemed Measure Cost**

New Construction and Time of Sale: The actual installed cost of the Ground Source Heat Pump should be used (default of $3957 per ton[[5]](#footnote-5)), minus the assumed installation cost of the baseline equipment ($1936 per ton for ASHP[[6]](#footnote-6) or $2011 for a new baseline 80% AFUE furnace or $3543 for a new 82% AFUE boiler[[7]](#footnote-7) and $2,857[[8]](#footnote-8) for new baseline Central AC replacement).

Early Replacement: The full installation cost of the Ground Source Heat Pump should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1936 per ton for a new baseline Air Source Heat Pump, or $2641[[9]](#footnote-9) for a new baseline 90% AFUE furnace or $3543 for a new 82% AFUE boiler and $2,857 for new baseline Central AC replacement. This future cost should be discounted to present value using the utilities’ discount rate.

**Loadshape**

Loadshape R08 - Residential Cooling (if replacing gas heat and central AC)

Loadshape R09 - Residential Electric Space Heat (if replacing electric heat with no cooling)

Loadshape R10 - Residential Electric Heating and Cooling (if replacing ASHP)

**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 Heat Pumps (during utility peak hour)

= 72%%[[10]](#footnote-10)

CFPJM   = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[[11]](#footnote-11)

**Algorithm**

**Calculation of Savings**

**Electric Energy Savings**

New Construction and Time of Sale (non-fuel switch only):

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings]

= [(FLHcool \* Capacity\_cooling \* (1/SEERbase– (1/EERPL)/1000] + [Elecheat \* FLHheat \* Capacity\_heating \* (1/HSPFbase – (1/COPPL \* 3.412)))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/EFELEC) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

New Construction and Time of Sale (fuel switch only):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh = [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [(FLHcool \* Capacity\_cooling \* (1/SEERbase– (1/EERPL)/1000] + [FLHheat \* Capacity\_heating \* (1/HSPFASHP – (1/COPPL \* 3.412)))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/EFELEC) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

Early replacement (non-fuel switch only)[[12]](#footnote-12):

ΔkWH for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings] + [DHW savings]

= [(FLHcool \* Capacity\_cooling \* (1/SEERexist – (1/EERPL)/1000] + [ElecHeat \* (FLHheat \* Capacity\_heating \* (1/HSPFexist) – (1/COPPL \* 3.412)))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/ EFELEC) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

ΔkWH for remaining measure life (next 17 years):

= [(FLHcool \* Capacity\_cooling \* (1/SEERbase – (1/EERPL)/1000] + [ElecHeat \* (FLHheat \* Capacity\_heating \* (1/HSPFbase) – (1/COPPL \* 3.412)))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/ EFELEC) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

Early replacement - fuel switch only (see illustrative examples after Natural Gas section):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [(FLHcool \* Capacity\_cooling \* (1/SEERexist – (1/EERPL)/1000] + [(FLHheat \* Capacity\_heating \* (1/HSPFASHP – (1/COPPL \* 3.412)))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/ EFELEC) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [(FLHcool \* Capacity\_cooling \* (1/SEERbase – (1/EERPL)/1000] + [(FLHheat \* Capacity\_heating \* (1/HSPFASHP – (1/COPPL \* 3.412)))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/ EFELEC) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

Where:

FLHcool = Full load cooling hours

Dependent on location as below[[13]](#footnote-13):

|  |  |  |
| --- | --- | --- |
| **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[[14]](#footnote-14) | 629 | 564 |

Capacity\_cooling = Cooling Capacity of Ground Source Heat Pump (Btu/hr)

= Actual (1 ton = 12,000Btu/hr)

SEERbase = SEER Efficiency of new replacement baseline unit

|  |  |
| --- | --- |
| **Existing Cooling System** | **SEERbase** |
| Air Source Heat Pump | 14[[15]](#footnote-15) |
| Central AC | 13[[16]](#footnote-16) |
| No central cooling | 13[[17]](#footnote-17) |

SEERexist = SEER Efficiency of existing cooling unit

= Use actual SEER rating where it is possible to measure or reasonably estimate, if unknown assume default provided below:

|  |  |
| --- | --- |
| **Existing Cooling System** | **SEER\_exist** |
| Air Source Heat Pump | 9.12[[18]](#footnote-18) |
| Central AC | 8.60[[19]](#footnote-19) |
| No central cooling | 13 [[20]](#footnote-20) |

SEERASHP = SEER Efficiency of new baseline Air Source Heat Pump unit (for fuel switch)

= 14 [[21]](#footnote-21)

EERPL = Part Load EER Efficiency of efficient GSHP unit[[22]](#footnote-22)

= Actual installed

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

FLHheat = Full load heating hours

Dependent on location as below[[23]](#footnote-23):

|  |  |
| --- | --- |
| **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[[24]](#footnote-24) | 1,821 |

Capacity\_heating = Heating Capacity of Ground Source Heat Pump (Btu/hr)

= Actual (1 ton = 12,000Btu/hr)

HSPFbase =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

|  |  |
| --- | --- |
| **Existing Heating System** | **HSPF\_base** |
| Air Source Heat Pump | 8.2 |
| Electric Resistance | 3.41[[25]](#footnote-25) |

HSPF\_exist =Heating System Performance Factor of existing heating system (kBtu/kWh)

= Use actual HSPF rating where it is possible to measure or reasonably estimate. If unknown assume default:

| **Existing Heating System** | **HSPF\_exist** |
| --- | --- |
| Air Source Heat Pump | 5.44 |
| Electric Resistance | 3.41 |

HSPFASHP =Heating Season Performance Factor for new ASHP baseline unit (for fuel switch)

=8.2 [[26]](#footnote-26)

COPPL = Part Load Coefficient of Performance of efficient unit[[27]](#footnote-27)

= Actual Installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).

ElecDHW = 1 if existing DHW is electrically heated

= 0 if existing DHW is not electrically heated

%DHWDisplaced = Percentage of total DHW load that the GSHP will provide

= Actual if known

= If unknown and if desuperheater installed assume 44%[[28]](#footnote-28)

= 0% if no desuperheater installed

EFELEC = Energy Factor (efficiency) of electric water heater

= Actual. If unknown or for new construction assume federal standard[[29]](#footnote-29):

For <=55 gallons: 0.96 – (0.0003 \* rated volume in gallons)

For >55 gallons: 2.057 – (0.00113 \* rated volume in gallons)

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[[30]](#footnote-30)

= 17.6

Household = Average number of people per household

| **Household Unit Type** | **Household** |
| --- | --- |
| Single-Family - Deemed | 2.56[[31]](#footnote-31) |
| Custom | Actual Occupancy or Number of Bedrooms[[32]](#footnote-32) |

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

Tout = Tank temperature

= 125°F

Tin = Incoming water temperature from well or municiplal system

= 54°F[[33]](#footnote-33)

1.0 = Heat Capacity of water (1 Btu/lb\*°F)

3412 = Conversion from Btu to kWh

Illustrative Examples

New Construction using ASHP baseline:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed with a 50 gallon electric water heater in single family house in Springfield:

ΔkWh = [(FLHcool \* Capacity\_cooling \* (1/SEERbase – (1/EERPL)/1000] + [(FLHheat \* Capacity\_heating \* (1/HSPFbase – (1/COPPL \* 3.412)))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/ EFELEC exist) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

ΔkWh = [(730 \* 36,000 \* (1/14 – 1/19)) / 1000] + [(1754\* 36,000 \* (1/8.2 – 1/ (4.4\*3.412))) / 1000] + [1 \* 0.44 \* (((1/0.945) \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \* 1)/3412)]

= 494 + 3494 + 1328

= 5316 kWh

Early Replacement – non-fuel switch (see example after Natural gas section for Fuel switch):

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed in single family house in Springfield with a 50 gallon electric water heater replacing an existing working Air Source Heat Pump with unknown efficiency ratings:

ΔkWH for remaining life of existing unit (1st 8 years):

= [(730 \* 36,000 \* (1/9.12 - 1/19)) / 1000] + [(1754 \* 36,000 \* (1/5.44 - 1/(4.4 \* 3.412))) / 1000] + [0.44 \* 1 \* (((1/0.945) \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \* 1)/3412)]

= 1498 + 7401 + 1328

= 10,227 kWh

ΔkWH for remaining measure life (next 17 years):

= [(730 \* 36,000 \* (1/14 – 1/28)) / 1000] + [(1967 \* 36,000 \* (1/8.2 – 1/ (4.4 \* 3.412)) / 1000] + [0.44 \* 1 \* (((1/0.945) \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \* 1)/3412)]

= 494 + 3494 + 1328

= 5316 kWh

**Summer Coincident Peak Demand Savings**

New Construction and Time of Sale:

ΔkW = (Capacity\_cooling \* (1/EERbase - 1/EERFL))/1000) \* CF

Early replacement:

ΔkW for remaining life of existing unit (1st 8 years):

= (Capacity\_cooling \* (1/EERexist - 1/EERFL))/1000) \* CF

ΔkW for remaining measure life (next 17 years):

= (Capacity\_cooling \* (1/EERbase - 1/EERFL))/1000) \* CF

Where:

EERbase = EER Efficiency of new replacement unit

|  |  |
| --- | --- |
| **Existing Cooling System** | **EER\_base** |
| Air Source Heat Pump | 11.8[[34]](#footnote-34) |
| Central AC | 11 [[35]](#footnote-35) |
| No central cooling | 11[[36]](#footnote-36) |

EERexist = Energy Efficiency Ratio of existing cooling unit (kBtu/hr / kW)

= Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:

EERexist = (-0.02 \* SEERexist2) + (1.12 \* SEERexist) [[37]](#footnote-37)

If SEER rating unavailable use:

|  |  |
| --- | --- |
| **Existing Cooling System** | **EER\_exist** |
| Air Source Heat Pump | 8.55[[38]](#footnote-38) |
| Central AC | 8.15[[39]](#footnote-39) |
| No central cooling | 11 [[40]](#footnote-40) |

EERFL = Full Load EER Efficiency of ENERGY STAR GSHP unit [[41]](#footnote-41)

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

= 72%%[[42]](#footnote-42)

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

= 46.6%[[43]](#footnote-43)

New Construction or Time of Sale:

For example, a 3 ton unit with Full Load EER rating of 19:

ΔkWSSP = ((36,000 \* (1/11.8 – 1/19))/1000) \* 0.72

= 0.83 kW

ΔkWPJM = ((36,000 \* (1/11 – 1/19))/1000) \* 0.466

= 0.54 kW

Early Replacement:

For example, a 3 ton Full Load 19 EER replaces an existing working Air Source Heat Pump with unknown efficiency ratings in Marion:

ΔkWSSP for remaining life of existing unit (1st 8 years):

= ((36,000 \* (1/8.55 – 1/19))/1000) \* 0.72

= 1.67 kW

ΔkWSSP for remaining measure life (next 17 years):

= ((36,000 \* (1/11.8 – 1/19))/1000) \* 0.72

= 0.83 kW

ΔkWPJM for remaining life of existing unit (1st 8 years):

= ((36,000 \* (1/8.55 – 1/19))/1000) \* 0.466

= 1.08 kW

ΔkWPJM for remaining measure life (next 17 years):

= ((36,000 \* (1/11.8 – 1/19))/1000) \* 0.466

= 0.54 kW

**Natural Gas Savings**

New Construction and Time of Sale with baseline gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claim savings calculated below:

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEbase) – (kWhtoTherm \* FLHheat \* Capacity\_heating \* 1/COPPL)/1000)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below, (electric savings is provided in Electric Energy Savings section):

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEbase) – (kWhtoTherm \* FLHheat \* Capacity\_heating \* 1/(HSPFASHP/3.412))/1000)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

Early replacement for homes with existing gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claim savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEexist) – (kWhtoTherm \* FLHheat \* Capacity\_heating \* 1/(COPPL \* 3.412))/1000)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEbaseER) – (kWhtoTherm \* FLHheat \* Capacity\_heating \* 1//(COPPL \* 3.412))/1000)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEexist) – (kWhtoTherm \* FLHheat \* Capacity\_heating \* 1/HSPFASHP)/1000)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEbaseER) – (kWhtoTherm \* FLHheat \* Capacity\_heating \* 1/HSPFASHP)/1000)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

Gas\_Heating\_Load

= Estimate of annual household heating load[[44]](#footnote-44) for gas furnace heated single-family homes. If location is unknown, assume the average below.

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[[45]](#footnote-45).

| **Climate Zone**  **(City based upon)** | **Gas\_Heating\_Load if Furnace (therms)** [[46]](#footnote-46) | **Gas\_Heating\_Load if Boiler (therms)** [[47]](#footnote-47) |
| --- | --- | --- |
| 1 (Rockford) | 873 | 1275 |
| 2 (Chicago) | 834 | 1218 |
| 3 (Springfield) | 714 | 1043 |
| 4 (Belleville) | 551 | 805 |
| 5 (Marion) | 561 | 819 |
| Average | 793 | 1158 |

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating

= 80% if furnace and 82% if boiler.

AFUEexist = Existing Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4% if furnace and 61.6% [[48]](#footnote-48) if boiler.

AFUEbaseER = Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure

= 90%[[49]](#footnote-49) if furnace and 82% if boiler.

kWhtoTherm = Converts source kWh to Therms

= Hgrid / 100000

Hgrid = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[[50]](#footnote-50). Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses.

3.412 = Converts HSPF to COP

EFGas exist = Energy Factor (efficiency) of existing gas water heater

= Actual. If unknown assume federal standard[[51]](#footnote-51):

For <=55 gallons: 0.675 – (0.0015 \* tank\_size)

For > 55 gallons 0.8012 – (0.00078 \* tank size)

= If tank size unknown assume 40 gallons and EF\_Baseline of 0.615

All other variables provided above

Illustrative Examples *[for illustrative purposes a Heat Rate of 10,000 Btu/kWh is used]*

New construction using gas furnace and central AC baseline, *supported by Gas utility only*:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater is installed in place of a natural gas furnace and 3 ton Central AC unit:

ΔkWH = 0

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEbase) – (kWhtoTherm \* FLHheat \* Capacity\_heating \* 1/(COPPL \* 3.412)/1000)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

= [(1-0) \* ((714/0.80) – (10000/100000 \* 1754 \* 36,000 \* 1/(4.4 \* 3.412))/1000)] + [(1 – 0) \* (0.44 \* (1/ 0.615 \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \* 1) / 100,000)]

= 472 + 70

= 542 therms

Early Replacement fuel switch, *supported by gas and electric utility*:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [(FLHcool \* Capacity\_cooling \* (1/SEERexist – (1/EERPL)/1000] + [(FLHheat \* Capacity\_heating \* (1/HSPFASHP – (1/COPPL \* 3.412)))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/ EFELEC) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

= [(730\* 36,000 \* (1/8.6 - 1/19)) / 1000] + [(1754 \* 36,000 \* (1/8.2 - 1/(4.4 \* 3.412))) / 1000] + [0 \* 0.44 \* (((1/0.904) \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \* 1)/3412)]

= 1673 + 3494 + 0

= 5167 kWh

Continued on next page.

Illustrative Example continued

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings] + [DHW savings]

= [(FLHcool \* Capacity\_cooling \* (1/SEERbase – (1/EERPL)/1000] + [(FLHheat \* Capacity\_heating \* (1/HSPFASHP – (1/COPPL \* 3.412)))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/ EFELEC) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) /3412)]

= [(730 \* 36,000 \* (1/13 – 1/19)) / 1000] + [1754 \* 36,000 \* (1/8.2 – 1/ (4.4 \*3.412)) / 1000] + [0 \* 0.44 \* (((1/0.904) \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \*1)/3412)]

= 638 + 3494 + 0

= 4132 kWh

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEexist) – (kWhtoTherm \* FLHheat \* Capacity\_heating \* 1/HSPFASHP)/1000)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

= [(1-0) \* ((714/0.644) – (10000/100000 \* 1754 \* 36,000 \* 1/8.2)/1000)] + [(1 – 0) \* (0.44 \* (1/ 0.615 \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \* 1) / 100,000)]

= 339 + 70

= 408 therms

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEbaseER) – (kWhtoTherm \* FLHheat \* Capacity\_heating \* 1/HSPFASHP)/1000)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

= [(1-0) \* ((714/0.9) – (10000/100000 \* 1754 \* 36,000 \* 1/8.2)/1000)] + [(1 – 0) \* (0.44 \* (1/ 0.615 \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \* 1) / 100,000)]

= 23 + 70

= 93 therms

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Cost Effectiveness Screening and Load Reduction Forecasting when Fuel Switching**

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch GSHP projects per Section 16-111.5B, changes in site energy use at the customer’s meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the “Electric Energy Savings” and “Natural Gas Savings” sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[[52]](#footnote-52)] + [DHW Savings if gas]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEbase)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

ΔkWh = - [GSHP heating consumption] + [Cooling savings[[53]](#footnote-53)] + [DHW savings if electric]

= - [(FLHheat \* Capacity\_heating \* (1/COPPL \* 3.412))/1000] + [(FLHcool \* Capacity\_cooling \* (1/SEERbase - 1/EERPL))/1000] + [ElecDHW \* %DHWDisplaced \* ((1/EFELEC \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

Illustrative Example of Cost Effectiveness Inputs for Fuel Switching

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings. [Note the calculation provides the annual savings for the first 8 years of the measure life, an additional calculation (not shown) would be required to calculated the annual savings for the remaining life (years 9-25)]:

ΔTherms = [(1 – ElecHeat) \* ((Gas\_Heating\_Load/AFUEexist)] + [(1 – ElecDHW) \* %DHWDisplaced \* (1/ EFGas exist \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

= [(1-0) \* (714/0.644)] + [((1 – 0) \* 0.44 \* (1/ 0.615 \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \* 1) / 100,000)]

= 1109 + 70

= 1179 therms

ΔkWh = - [(FLHheat \* Capacity\_heating \* (1/COPPL \* 3.412))/1000] + [(FLHcool \* Capacity\_cooling \* (1/SEERexist - 1/EERPL))/1000] + [ElecDHW \* %DHWDisplaced \* (((1/EFELEC) \* GPD \* Household \* 365.25 \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

= - [(1754 \* 36,000 \* (1/(4.4 \* 3.412)))/ 1000] + [(730 \* 36,000 \* (1/8.6 - 1/19))/ 1000)] + [0 \* 0.44 \* (((1/0.904) \* 17.6 \* 2.56 \*365.25 \* 8.33 \* (125-54) \* 1)/3412)]

= -4206 + 1673 + 0

= -2533 kWh

**Measure Code: RS-HVC-GSHP-V05-160601**

1. The Federal Standard does not include an EER requirement, so it is approximated with this formula: (-0.02 \* SEER2) + (1.12 \* SEER) Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. [↑](#footnote-ref-1)
2. Minimum Federal Standard as of 4/1/2015;

   http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf [↑](#footnote-ref-2)
3. System life of indoor components as per DOE estimate http://energy.gov/energysaver/articles/geothermal-heat-pumps. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP.

   <http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf> [↑](#footnote-ref-3)
4. Assumed to be one third of effective useful life [↑](#footnote-ref-4)
5. Based on data provided in ‘Results of HomE geothermal and air source heat pump rebate incentives documented by IL electric cooperatives’. [↑](#footnote-ref-5)
6. Based on data provided on Home Advisor website, providing national average ASHP cost based on 2465 cost submittals. <http://www.homeadvisor.com/cost/heating-and-cooling/install-a-heat-pump/> [↑](#footnote-ref-6)
7. Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor (<http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf>). Where efficiency ratings are not provided, the values are interpolated from those that are. [↑](#footnote-ref-7)
8. Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator ([http://www.energystar.gov/ia/business/bulk\_purchasing/bpsavings\_calc/Calc\_CAC.xls](http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html)). While baselines are likely to shift in the future, there is currently no good indication of what the cost of a new baseline unit will be in 6 years. In the absence of this information, assuming a constant federal baseline cost is within the range of error for this prescriptive measure. [↑](#footnote-ref-8)
9. Based on data from Table E.1.1 of Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor. (<http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf>). [↑](#footnote-ref-9)
10. 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)’. <http://www.icc.illinois.gov/downloads/public/edocket/368522.pdf> [↑](#footnote-ref-10)
11. 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-11)
12. The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings). [↑](#footnote-ref-12)
13. 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 Section 3.7 of the TRM providing the appropriate city to use for each county of Illinois. [↑](#footnote-ref-13)
14. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-14)
15. Minimum Federal Standard as of 1/1/2015;

    http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf [↑](#footnote-ref-15)
16. Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200. [↑](#footnote-ref-16)
17. Assumes that the decision to replace existing systems includes desire to add cooling. [↑](#footnote-ref-17)
18. Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4. [↑](#footnote-ref-18)
19. Ibid. [↑](#footnote-ref-19)
20. Assumes that the decision to replace existing systems includes desire to add cooling. [↑](#footnote-ref-20)
21. Minimum Federal Standard as of 1/1/2015;

    http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf [↑](#footnote-ref-21)
22. As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP. [↑](#footnote-ref-22)
23. 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. There is a county mapping table in Section 3.7 of the TRM providing the appropriate city to use for each county of Illinois. [↑](#footnote-ref-23)
24. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-24)
25. Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF. [↑](#footnote-ref-25)
26. Minimum Federal Standard as of 1/1/2015;

    http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf [↑](#footnote-ref-26)
27. As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP. [↑](#footnote-ref-27)
28. Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year (2/3 \* 2/3 = 44%). Based on input from Doug Dougherty, Geothermal Exchange Organization. [↑](#footnote-ref-28)
29. Minimum Federal Standard as of 4/1/2015;

    http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf [↑](#footnote-ref-29)
30. Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission. [↑](#footnote-ref-30)
31. ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 \* 93% evaluation adjustment [↑](#footnote-ref-31)
32. Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts. [↑](#footnote-ref-32)
33. US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL [http://www1.eere.energy.gov/buildings/building\_america/analysis\_spreadsheets.html](http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls) [↑](#footnote-ref-33)
34. The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis refererenced below. [↑](#footnote-ref-34)
35. Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200. [↑](#footnote-ref-35)
36. Assumes that the decision to replace existing systems includes desire to add cooling. [↑](#footnote-ref-36)
37. From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. [↑](#footnote-ref-37)
38. Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4. [↑](#footnote-ref-38)
39. Ibid. [↑](#footnote-ref-39)
40. Assumes that the decision to replace existing systems includes desire to add cooling. [↑](#footnote-ref-40)
41. As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP. [↑](#footnote-ref-41)
42. 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)’. <http://www.icc.illinois.gov/downloads/public/edocket/368522.pdf> [↑](#footnote-ref-42)
43. 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-43)
44. Heating load is used to describe the household heating need, which is equal to (gas consumption \* AFUE ) [↑](#footnote-ref-44)
45. The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes. [↑](#footnote-ref-45)
46. Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD. [↑](#footnote-ref-46)
47. Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611\_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD. [↑](#footnote-ref-47)
48. Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4. [↑](#footnote-ref-48)
49. Assumes that Federal Standard will have been increased to 90% by the time the existing unit would have to have been replaced. [↑](#footnote-ref-49)
50. Refer to EPA eGRID data <http://www.epa.gov/chp/documents/fuel_and_co2_savings.pdf>, page 24 and <http://www.epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_Summary_Tables.pdf>, page 9. Current values are:

    Non-Baseload RFC West: 9,811 Btu/kWh \* (1 + Line Losses)

    Non-Baseload SERC Midwest: 10,511 Btu/kWh \* (1 + Line Losses)

    All Fossil Average RFC West: 10,038 Btu/kWh \* (1 + Line Losses)

    All Fossil Average SERC Midwest: 10,364 Btu/kWh \* (1 + Line Losses) [↑](#footnote-ref-50)
51. Minimum Federal Standard as of 4/1/2015;

    http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf [↑](#footnote-ref-51)
52. Note AFUEbase in the algorithm should be replaced with AFUEexist for early replacement measures. [↑](#footnote-ref-52)
53. Note SEERbase in the algorithm should be replaced with SEERexist for early replacement measures. [↑](#footnote-ref-53)