### Ductless Heat Pumps

**Description**

This measure is designed to calculate electric savings for supplementing existing electric HVAC systems with ductless heat pumps. Existing systems can include: electric resistance heating or ducted air-source heat pumps. For ducted air source heat pumps, cooling savings are also possible if there is an existing air conditioning system.

Savings are achieved by displacing some of the heating or cooling load currently provided by the existing system and meeting that load with the more efficient ductless heat pump instead. The offset of the home’s heating load is likely for the milder heating periods. The limitations on heating offset increase as the outdoor temperature drops, because the DHP capacity decreases, and the point-source nature of the heater is less able to satisfy heating loads in remote rooms.

For cooling, the proposed savings calculations are aligned with those of typical replacement systems. In most cases, the DHP is expected to replace (rather than offset) a comparable amount of cooling in homes with electric resistance heat—at a much higher efficiency than the previously used cooling.

In order for this measure to apply, the control strategy for the heat pump is assumed to be chosen to maximize savings per installer recommendation.[[1]](#footnote-1)

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**

In order for this characterization to apply, the new equipment must be a high-efficiency, variable-capacity (typically “inverter-driven” DC motor) ductless heat pump system that exceeds the current Federal Standard. This means the unit must meet or exceed 8.2 HSPF (heating mode) and 14 SEER (cooling mode)[[2]](#footnote-2).

This measure only applies to the *first* ductless heat pump installed in a residence[[3]](#footnote-3).

**Definition of Baseline Equipment**

In order for this characterization to apply, baseline equipment must include a permanent electric resistance heating source or a ducted air-source heat pump. For multifamily buildings, each residence must have existing individual heating equipment. Multifamily residences with central heating do not qualify for this characterization. Existing cooling equipment is assumed to be standard efficiency. Note that in order to claim cooling savings, there must be an existing air conditioning system.

**Deemed Lifetime of Efficient Equipment**

The expected measure life is assumed to be 18 years[[4]](#footnote-4).

**Deemed Measure Cost**

The incremental cost for this measure is provided below:

|  |  |
| --- | --- |
| **Unit Size** | **Incremental Cost[[5]](#footnote-5)** |
| 1-Ton | $3,000 |
| 1.5-Ton | $3750 |
| 2-Ton | $4,500 |

**Loadshape**

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. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

CFSSP = Summer System Peak Coincidence Factor for ASHP (during utility peak hour)

= 72%%[[6]](#footnote-6)

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

= 46.6%[[7]](#footnote-7)

**Algorithms**

**Calculation of Savings**

**Electric Energy Savings**

Electric savings

ΔkWh = ΔkWhheat + ΔkWhcool

ΔkWhheat = PLD\*AHHL\*HF\*(1/HSPFexist-1/HSPFee)\*3.413

ΔkWhcool = Capacitycool\*HF\*(1/SEERexist-1/SEERee)\*EFLHcool

Where:

PLD = Percent Load Displaced. The average total annual heating load displaced from the existing heating system and now provided by the ductless heat pump[[8]](#footnote-8)

For a first DHP installed in a given home.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **PLD5** | | |
| Climate zone | 1-ton unit | 1.5-ton unit | 2-ton unit |
| Rockford | 26% | 39% | 39% |
| Chicago | 27% | 40% | 42% |
| Springfield | 31% | 47% | 48% |
| Belleville | 30% | 45% | 48% |
| Marion | 31% | 46% | 50% |

AHHL = Annual Household Heating Load in kWh[[9]](#footnote-9)

|  |  |  |
| --- | --- | --- |
| **Climate Zone** | **Annual Household**  **Heating Load Resistance (kWh)** | **Annual Household Heating Load ASHP (kWh)** |
| 1 (Rockford) | 21,741 | 25,578 |
| 2 (Chicago) | 20,771 | 24,436 |
| 3 (Springfield) | 17,789 | 20,928 |
| 4 (Belleville) | 13,722 | 16,144 |
| 5 (Marion) | 13,966 | 16,431 |
| Average | 19,743 | 23,227 |

HF = Household factor, to adjust heating consumption for non-single-family households.

|  |  |
| --- | --- |
| **Household Type** | **HF** |
| Single-Family | 100% |
| Multi-Family | 65%[[10]](#footnote-10) |
| Actual | Custom[[11]](#footnote-11) |

Capacitycool = the cooling capacity of the ductless heat pump unit in kBtu/hr[[12]](#footnote-12).

= Actual installed

HSPFee = HSPF rating of new equipment

= Actual installed

HSPFexist = HSPF rating of existing equipment

| **Existing Equipment Type** | **HSPFbase** |
| --- | --- |
| Electric resistance heating | 3.41[[13]](#footnote-13) |
| Air Source Heat Pump | 5.44[[14]](#footnote-14) |

SEERee = SEER rating of new equipment

= Actual installed[[15]](#footnote-15)

SEERexist = SEER rating of existing equipment

= Use actual value. If unknown, see table below

|  |  |
| --- | --- |
| **Equipment Type** | **SEERexist[[16]](#footnote-16)** |
| PTAC | 7.4 SEER |
| PTHP | 7.4 SEER |
| SPVAC < 65kBtu/hr | 9.0 SEER |
| SPVHP < 65 kBtu/hr | 9.0 SEER |
| Room AC | 7.0 SEER |
| Ducted ASHP | 13.0 SEER |
| No existing system | No cooling savings. |

EFLHcool = Equivalent Full Load Hours for cooling. Depends on location. See table below[[17]](#footnote-17).

| **Climate Zone**  **(City based upon)** | **FLHRoomAC** |
| --- | --- |
| 1 (Rockford) | 220 |
| 2 (Chicago) | 210 |
| 3 (Springfield) | 319 |
| 4 (Belleville) | 428 |
| 5 (Marion) | 374 |
| Weighted Average[[18]](#footnote-18) | 248 |

For example, installing a 1.5-ton (heating and cooling capacity) ductless heat pump unit rated at 8 HSPF and 14 SEER in a single-family home in Chicago to displace electric baseboard heat and replace a window air conditioner, savings are:

ΔkWhheat = 40% x 20,771kWh x 100% x (1/3.41 – 1/8) x 3.413 = 4,771kWh

ΔkWhcool = 18 x 100% x (1/7 – 1/14) x 210 = 270kWh

ΔkWh = 4,771 + 270 = 5,041kWh

**Summer Coincident Peak Demand Savings**

ΔkW = (Capacity\_cooling \*HF\* (1/EER\_exist - 1/EER\_ee))) \* CF

Where:

EER\_exist = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)

= Use actual EER rating otherwise:

| **Equipment Type** | **EERexist** |
| --- | --- |
| PTAC | 8.1EER[[19]](#footnote-19) |
| PTHP | 8.1EER[[20]](#footnote-20) |
| SPVAC < 65kBtu/hr | 9.9 EER [[21]](#footnote-21) |
| SPVHP < 65 kBtu/hr | 9.9 EER[[22]](#footnote-22) |
| Room AC | 7.7 EER[[23]](#footnote-23) |
| Ducted ASHP | 11.2 EER [[24]](#footnote-24) |
| No existing system |  |

EER\_ee = Energy Efficiency Ratio of new ductless Air Source Heat Pump (kBtu/hr / kW)

= Actual, If not provided convert SEER to EER using this formula:

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

= 72%%[[25]](#footnote-25)

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

= 46.6%[[26]](#footnote-26)

**Natural Gas Savings**

N/A

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code: RS-HVC-DHP-V03-150601**

1. The whole purpose of installing ductless heat pumps is to conserve energy, so the installer can be assumed to be capable of recommending an appropriate controls strategy. For most applications, the heating setpoint for the ductless heat pump should be at least 2F higher than any remaining existing system and the cooling setpoint for the ductless heat pump should be at least 2F cooler than the existing system (this should apply to all periods of a programmable schedule, if applicable). This helps ensure that the ductless heat pump will be used to meet as much of the load as possible before the existing system operates to meet the remaining load. Ideally, the new ductless heat pump controls should be set to the current comfort settings, while the existing system setpoints should be adjusted down (heating) and up (cooling) to capture savings. [↑](#footnote-ref-1)
2. 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-2)
3. Additional heat pumps will achieve additional savings, but not as much as the first one. [↑](#footnote-ref-3)
4. Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007 [↑](#footnote-ref-4)
5. *Ductless Heat Pumps for Residential Customers in Connecticut*,  Swift, Joseph R and Rebecca A. Meyer, The Connecticut Light & Power Company, 2010 ACEEE Summer Study on Energy Efficiency in Buildings (2-292) [↑](#footnote-ref-5)
6. 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-6)
7. 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-7)
8. PLD values calculated in “DHP Savings Model 12-31-13.xls”. To verify that the proposed algorithm generates reasonable savings, we compared the results to metering studies done to measure ductless heat pump savings.

   Ecotope Study, prepared for Bonneville Power Administration, “Residential Ductless Mini-Split Heat Pump Retrofit Monitoring,” Monmouth, Oregon, June, 2009.

   Ecotope Study, Prepared for Bonneville Power Administration, “Ductless Heat Pump Retrofits in Multifamily and Small Commercial Buildings,” December, 2012.

   KEMA Study, Prepared for NSTAR Electric and Gas Corporation et al. “Ductless Mini Pilot Study,” Middletown, Connecticut, June, 2009 [↑](#footnote-ref-8)
9. Values in table are based on converting an average household heating load (834 therms) for Chicago based on ‘Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013 to an electric heat load (divide by 0.03413) to electric resistance and ASHP heat load (resistance load reduced by 15% to account for distribution losses that occur in furnace heating but not in electric resistance while ASHP heat is assumed to suffer from similar distribution losses) (see ‘Household Heating Load Summary Calculations\_11062013.xls’). Finally these values were adjusted to a statewide average using relative HDD assumptions 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-9)
10. Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% reduction factor is applied to MF homes with electric resistance, based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes [↑](#footnote-ref-10)
11. Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations. [↑](#footnote-ref-11)
12. 1 Ton = 12 kBtu/hr [↑](#footnote-ref-12)
13. Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF. [↑](#footnote-ref-13)
14. This is from the ASHP measure which estimated HSPF based on finding the average HSPF/SEER ratio from the AHRI directory data (using the least efficient models – SEER 12 and SEER 13) – 0.596, and applying to the average nameplate SEER rating of all Early Replacement qualifying equipment in Ameren PY3-PY4. This estimation methodology appears to provide a result within 10% of actual HSPF. [↑](#footnote-ref-14)
15. Note that if only an EER rating is available, a conversion factor of SEER=1.1\*EER can be used [↑](#footnote-ref-15)
16. Converted from EER using formula EER = 1.1 SEER [↑](#footnote-ref-16)
17. Residential EFLH for room AC [↑](#footnote-ref-17)
18. Weighted based on number of residential occupied housing units in each zone. [↑](#footnote-ref-18)
19. Same EER as PTAC recycling. Estimated using the IECC building energy code up until year 2003 (p107; https://law.resource.org/pub/us/code/ibr/icc.iecc.2000.pdf) and assuming a 1 ton unit; EER = 10 – (0.16 \* 12,000/1,000) = 8.1. [↑](#footnote-ref-19)
20. Same method to calculate EER as PTAC recycling. Estimated using the IECC building energy code up until year 2003 (p107; https://law.resource.org/pub/us/code/ibr/icc.iecc.2000.pdf) and assuming a 1 ton unit; EER = 10 – (0.16 \* 12,000/1,000) = 8.1. [↑](#footnote-ref-20)
21. The quoted efficiency rating in the IECC was given in EER and was translated to SEER using a conversion factor of SEER=1.1\*EER. [↑](#footnote-ref-21)
22. Ibid. [↑](#footnote-ref-22)
23. Same EER as Window AC recycling. Based on Nexus Market Research Inc, RLW Analytics, December 2005; “Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report.” [↑](#footnote-ref-23)
24. 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. Note this is appropriate for single speed units only. [↑](#footnote-ref-24)
25. 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-25)
26. 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-26)