**State of Illinois**

**Energy Efficiency**

**Technical Reference Manual**

**Ductless Heat Pumps**

**New Measure Requests**

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Table 1 Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **MM/DD/YY** | **Author,Company** | **Summary of Changes** |
| 1 | 11/15/13 | T. Hinck, GDS Associates | Original draft |
|  |  |  |  |

# Summary

This workpaper is designed to lay a foundation for prescribing ductless heat pump (DHP) savings. Heat pumps provide an efficient alternative to other technologies used for heating and cooling spaces. In particular, ductless heat pumps are a flexible option that can be used in many applications where significant energy savings are possible.

However, since there are many unique ductless heat pump applications and many possible existing systems to be replaced, determining savings in a prescriptive way is somewhat complicated. Therefore, only a few of the most basic scenarios are considered here (Specifically electric resistance heating and ducted air-source heat pump systems), which maintains simplicity of the savings algorithm. It is anticipated that future updates will be able to build on this foundation by incorporating additional variables to apply to more situations where ductless heat pumps can achieve savings.

The algorithm we propose is based on the assumption that the DHP unit is *displacing* some of the annual heating load provided by the existing system. This is in contrast to *replacing* the existing system as is usually assumed in other TRM measures. The basic premise is to determine the total annual heat load displaced by the DHP and then use the typical (1/HSPFbase-1/HSPFee) factor to determine savings. Because of the unique operation of ductless heat pumps, determining the heat load displaced poses some difficulty in the measure design.

In order to show that the proposed algorithm calculates realistic savings, we designed an analytical weather-bin-based model5 to calculate the maximum possible heating savings assuming the most efficient application of the DHP unit (displaces as much of the annual load as it possibly can). Then we used the same model to determine minimum savings assuming the DHP unit runs for the same full-load hours as the existing equipment (which displaces far less of the heat load). At both the maximum and minimum values, we show that our proposed algorithm calculates similar savings to the analytical method, which proves that the algorithm is a justified simplification of a complicated situation. Lastly, we compare the savings results of four studies to the savings we calculate in order to show that our calculated savings are within a reasonable range of expected evaluation results 9,10,11.

In order to ensure we’ve calculated conservative savings estimates, we propose to use the percent load displaced variable values that correspond to the minimum savings values. With future IL-specific studies (or others in comparable climates), we may be able to increase the assumed percent load displaced.

Note: Highlighted comments indicate possible future updates – no effect on current submission

Potential future updates. Pending further information:

Mutifamily and C/I versions of the measure should be relatively straight forward.

Replacing less efficient existing ductless heat pumps

Better quantify and capture the possible duct loss savings from installing DHPs. The original inspirations for this measure were other state TRMs that have such measures included (RI, MA, PA). However, the method used for claiming savings in those TRMs appears to be difficult to justify (there is a single deemed savings value for eliminating ducting that applies to all projects regardless of square footage, duct location, or system capacity). Further study is required to determine how the duct-to-ductless savings should be calculated, but we believe that significant savings are achievable and that with the additional research those savings can be estimated prescriptively. Specifically, we think that it should be possible to estimate the savings from not having ductwork as a percentage of the capacity of the system. This update will need to wait until at least the next (2014) TRM update cycle.

Finally, one of the more attractive ductless heat pump applications is in new construction or expansion projects where there is no existing system. Projects can achieve savings by forgoing a ducted system and installing ductless heat pumps instead. The energy savings will require the further study mentioned in the previous paragraph, so this application will also have to wait until the next update cycle. However, because installing ductless heat pumps allows a project to avoid the cost of installing ducts, we anticipate that the savings will be easily justified with attractive incremental first-cost savings values.

## Measure Components Affected

Please check all that apply.

###### Description

###### Definition of Efficient Equipment

###### Definition of Baseline Equipment

###### Deemed Lifetime of Efficient Equipment

###### Deemed Measure Cost

###### Deemed O&M Cost Adjustments

###### Loadshape

###### Coincidence Factor

###### Net To Gross Ratio

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

###### Summer Coincident Peak Demand Savings

###### Natural Gas Savings

###### Water Impact Descriptions and Calculation

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

**Measure code**

## Algorithm and Input Components Affected

### Algorithm / Input 1

### Algorithm / Input 2

## Rationale for the Change

### Methodology

### Sample Size

### Other Rationale

## Please Specify the Proposed Change

Table 2 Summary of Proposed Change

|  |  |  |  |
| --- | --- | --- | --- |
| **ITEM** | **ORIGINAL SPECIFICATION** | **PROPOSED SPECIFICATION** | **CITATION FOR PROPOSED SPECIFICATION** |
| **Ductless heat pumps** | **No existing measure** | **New Measure** |  |

## Author (Company) and Date

T. Hinck (GDS Associates) 11/15/2013

# Components of TRM Measure Characterizations

## Measure 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. Some cooling savings are also possible to achieve if there is an existing air conditioning system. Savings are achieved by displacing some of the heating load currently provided by the existing system and meeting that load with the more efficient ductless heat pump instead. For this reason, the typical approach (using EFLH \* capacity) is likely to understate the heating savings significantly; homeowners have an incentive to utilize the DHP as much as possible and will likely offset all (or nearly all) the home’s heating load 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 (typically window units).

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.A

Add as footnote - A 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.

## 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 requirements of IECC 2012, table C403.2.3(2).This means the unit must meet or exceed 7.7 HSPF (heating mode) and 13 SEER (cooling mode).

Note that savings only apply to the *first* ductless heat pump installed in a residence. Additional heat pumps will achieve additional savings, but not as much as the first one.

Future update: Determine PLD values for additional Ductless Heat Pumps

## 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. 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.1

## Deemed Measure Cost

$4,0002

Note: Compared to installing ducted systems, incremental first costs for installing ductless systems are competitive. If future updates succeed in prescriptively calculating savings for *replacing* whole ducted systems entirely with ductless units, new installations in previously unconditioned spaces are likely to provide very cost effective energy savings and incremental costs should be more carefully quantified.

## Deemed O&M Cost Adjustments

## 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 Central A/C (during utility peak hour)

= 91.5%3

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

= 46.6%4

## Net to Gross Ratio

# Algorithms

## Calculation of Energy Savings

With Ductless heat pumps, there are many variables that change with OAT. The PLD variable is intended to be the “bucket” to capture all these variables in one table. The variables that comprise the single PLD table are: DHP varying capacity over OAT, DHP varying efficiency over OAT, varied operation in different climate zones across the state, and the capacity of the heat pump compared to the capacity of the existing system. All values are weighted by temp bin hours and averaged annually. See the accompanying Excel spreadsheet for a full explanation of how we determined appropriate PLD variable values5.

To verify that the proposed algorithm generates reasonable, conservative savings, we compared the results to metering studies done to measure ductless heat pump savings9, 10, 11.

## Electric Energy Savings

Electric savings

ΔkWh = ΔkWhheat + ΔkWhcool

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

ΔkWhcool = Capacitycool\*(1/SEERbase-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

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% |

It is likely that future research will allow us to increase this value. Also, additional DHPs beyond the first will have to be carefully considered because they may achieve significantly lower savings than the first DHP.

AHHL = Annual Household Heating Load in kWh

|  |  |
| --- | --- |
| Climate Zone | Annual Household Heating Load6 (kWh) |
| 1 (Rockford) | 21,733 |
| 2 (Chicago) | 20,768 |
| 3 (Springfield) | 17,789 |
| 4 (Belleville) | 13,965 |
| 5 (Marion) | 13,962 |
| Average | 21,733 |

Capacitycool = the cooling capacity of the ductless heat pump unit in kBtu/h. Note: 1 Ton = 12 kBtu/h.

= Actual installed

HSPFee = HSPF rating of new equipment

= Actual installed

HSPFbase = HSPF rating of existing equipment

|  |  |
| --- | --- |
| **Existing Equipment Type** | **HSPFbase** |
| Electric resistance heating | 3.14 |
| Ducted Heat Pump | 7.7 |
| All other types, including more ducted systems and potentially including natural gas heat | Future update |

SEERee = SEER rating of new equipment

= Actual installed (Note that if only an EER rating is available, a conversion factor of SEER=1.1\*EER can be used)

SEERbase = SEER rating of existing equipment

= Use actual value. If unknown, see table below

|  |  |
| --- | --- |
| **Equipment Type** | **SEERbase7** |
| PTAC | 11.99-(0.234\*Cap) c |
| PTHP | 11.88-(0.234\*Cap) c |
| SPVAC < 65kBtu/h | 9.9 c |
| SPVHP < 65 kBtu/h | 9.9 c |
| Room A/C with louvered slides <8 kBtu/h | 8.8 |
| Room A/C with louvered slides 8-13.9 kBtu/h | 10.78 c |
| Room A/C with louvered slides 14-19.9 kBtu/h | 8.8 |
| Room A/C with louvered slides > 20 kBtu/h | 9.35 c |
| Room A/C without louvered slides <8 kBtu/h | 9.9 c |
| Room A/C without louvered slides 8-19.9 kBtu/h | 9.35 c |
| Room A/C without louvered slides ≥ 20 kBtu/h | 9.35 c |
| Room A/C Casement-only | 9.57 c |
| Room A/C Casement-slider | 10.45 c |
| Room A/C heat pump with louvered slides < 20 kBtu/h | 9.9 c |
| Room A/C heat pump with louvered slides ≥ 20 kBtu/h | 9.35 c |
| Room A/C heat pump without louvered slides < 14 kBtu/h | 9.35 c |
| Room A/C heat pump without louvered slides ≥ 14 kBtu/h | 8.8 c |
| No existing system | No cooling savings. |
| All other types including ducted air conditioning systems | Future Update |

Cap = the rated cooling capacity of the unit in kBtu/h. If the unit’s capacity is less than 7kBtu/h, use 7kBtu/h in the calculation. If the unit’s capacity is greater than 15kBtu/h, use 15kBtu/h in the calculation.

c. 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.

EFLHcool = Equivalent Full Load Hours for cooling. Depends on location. See table below.

|  |  |
| --- | --- |
| Zone | EFLHcool8 |
| 1 (Rockford) | 816 |
| 2 (Chicago) | 819 |
| 3 (Springfield) | 1001 |
| 4 (Belleville) | 1261 |
| 5 (Marion) | 819 |

Possible Future Updates:

Add a duct savings term to each of the savings algorithms. These represent savings achieved by transitioning from a ducted to a ductless system. Savings result from preventing duct losses and from reducing required fan energy. With additional research, we hope these terms can be determined as a percentage of the existing system capacity. Note that other TRMs have attempted this (RI, MA, and PA, for example) and capturing ducted-to-ductless savings was originally the goal of this workpaper, but the methods used in the other TRMs are very difficult to justify.

## Summer Coincident Peak Demand Savings

ΔkW = ΔkWhcool \*CF

Where: CF value is chosen between:

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

= 91.5%3

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

= 46.6%4

## Natural Gas Savings

None. Note that it is technically possible to displace gas heating with DHP heating, but it is not economically feasible, so it is not considered in this measure proposal.

## Water Impact Descriptions and Calculation

None

## Deemed O&M Cost Adjustment Calculation

# References

1. Copied from footnote 260 of the TRM version 2. Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
2. Review of available online installation costs quoted by HVAC contractors.
3. Copied from footnote 262 of the TRM version 2. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.
4. Copied from footnote 263 of the TRM version 2. 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.
5. See the accompanying excel spreadsheet outlining our method for determining max and min savings potential and how we determined appropriate PLD values.
6. Annual Household Heating Load in kWh was copied from the residential programmable thermostat measure being considered at for inclusion in the TRM.
7. International Energy Conservation Code 2012, table C403.2.3(3). Converted from EER to SEER by multiplying by a factor of 1.1.
8. Copied from footnote 265 of the TRM version 2. Heating and cooling EFLH data based on a series of prototypical small commercial building simulation runs for the Ohio TRM. Values shown are weighted averages across fast food restaurant, full service restaurant, assembly, big box retail, small retail, small office, light industrial and school building models. The prototypes are based on the California DEER study prototypes, modified for local construction practices. Simulations were run using TMY3 weather data for each of the cities listed. Building prototypes used in the energy modeling are described in Appendix A - Prototypical Building Energy Simulation Model Development. The Ohio values were adjusted base on CCD and HDD for IL locations. Further study recommended for IL specific building types.
9. Ecotope Study, prepared for Bonneville Power Administration, “Residential Ductless Mini-Split Heat Pump Retrofit Monitoring,” Monmouth, Oregon, June, 2009.
10. Ecotope Study, Prepared for Bonneville Power Administration, “Ductless Heat Pump Retrofits in Multifamily and Small Commercial Buildings,” December, 2012.
11. KEMA Study, Prepared for NSTAR Electric and Gas Corporation et al. “Ductless Mini Pilot Study,” Middletown, Connecticut, June, 2009

# Stakeholder Comments

## Author (Company) and Date