### Advanced Thermostats

###### Description

This measure characterizes the household energy savings from the installation of a new thermostat(s) for reduced heating and cooling consumption through a configurable schedule of temperature setpoints (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, historical and population trends, weather data and forecasts. This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren’t yet established at the level of individual features, but rather at the system level and how it performs overall. Like programmable thermostats, it is not suitable to assume that heating and cooling savings follow a similar pattern of usage and savings opportunity, and so here too this measure treats these savings independently. Note that it is a very active area of ongoing study to better map features to savings value, and establish standards of performance measurement based on field data so that a standard of efficiency can be developed. [[1]](#footnote-1) That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations. Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple programmable thermostats per home does not accrue additional savings.

This measure was developed to be applicable to the following program types:  TOS, NC, RF, DI.

If applied to other program types, the measure savings should be verified.

###### Definition of Efficient Equipment

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the capability to automatically establish and adjust temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to the capability, usability, and sophistication, but at a minimum must be capable of two-way communication[[2]](#footnote-2) and exceed the capabilities of manual and conventional programmable thermostats.

###### Definition of Baseline Equipment

The baseline is either the actual type (manual or programmable) if it is known,[[3]](#footnote-3) or an assumed mix of these two types based upon information available from evaluations or surveys that represent the population of program participants. This mix may vary by program, but as a default, 44% programmable and 56% manual thermostats may be assumed[[4]](#footnote-4).

###### Deemed Lifetime of Efficient Equipment

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat 10 years[[5]](#footnote-5) based upon equipment life only.[[6]](#footnote-6)

###### Deemed Measure Cost

Actual material and labor, and other costs should be used if the implementation method allows[[7]](#footnote-7). If unknown (e.g. through a retail program) the average incremental cost for the new installation measure is assumed to be $175[[8]](#footnote-8).

###### Loadshape

ΔkWh 🡪 Loadshape R10 - Residential Electric Heating and Cooling

ΔkWhheating 🡪 Loadshape R09 - Residential Electric Space Heat

ΔkWhcooling 🡪 Loadshape R08 - Residential Cooling

###### Coincidence Factor

As per the TBD consensus value for Cooling Reduction, the summer peak coincidence factor may, in contrast to programmable thermostats, be non-zero. In the absence of conclusive results from empirical studies on peak savings, it is assumed that the coincidence of advanced thermostat savings with peak is consistent with that of the cooling coincidence with peak. It is therefore consistent with the TRM’s assumptions for Central cooling. Coincidence is calculated 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 system peak hour)

= 68%[[9]](#footnote-9)

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

= 46.6%[[10]](#footnote-10)

Algorithm

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh[[11]](#footnote-11) = ΔkWhheating + ΔkWhcooling

ΔkWhheating = %ElectricHeat \* Elec\_Heating\_Consumption \* Heating\_Reduction \* HF \* Eff\_ISR + (∆Therms \* Fe \* 29.3)

ΔkWhcool = %AC \* ((FLH \* Btu/hr \* 1/SEER)/1000) \* Cooling\_Reduction \* Eff\_ISR

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

|  |  |
| --- | --- |
| **Heating fuel** | **%ElectricHeat** |
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 13%[[12]](#footnote-12) |

Elec\_Heating\_Consumption

= Estimate of annual household heating consumption for electrically heated single-family homes[[13]](#footnote-13). If location and heating type is unknown, assume 15,678 kWh[[14]](#footnote-14)

|  |  |  |
| --- | --- | --- |
| **Climate Zone**  **(City based upon)** | **Electric Resistance**  **Elec\_Heating\_ Consumption**  **(kWh)** | **Electric Heat Pump**  **Elec\_Heating\_ Consumption**  **(kWh)** |
| 1 (Rockford) | 21,741 | 12,789 |
| 2 (Chicago) | 20,771 | 12,218 |
| 3 (Springfield) | 17,789 | 10,464 |
| 4 (Belleville) | 13,722 | 8,072 |
| 5 (Marion) | 13,966 | 8,215 |
| Average | 19,743 | 11,613 |

Heating\_Reduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat

= X.X%

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

|  |  |
| --- | --- |
| **Household Type** | **HF** |
| Single-Family | 100% |
| Multi-Family | 65%[[15]](#footnote-15) |
| Actual | Custom[[16]](#footnote-16) |

Eff\_ISR = Effective In-Service Rate, the percentage of thermostats installed and configured effectively for 2-way communication

|  |  |
| --- | --- |
| **Program Delivery** | **Eff\_ISR** |
| Direct Install | 100% |
| Other | Actual, or XX% |

∆Therms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

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

= 3.14%[[17]](#footnote-17)

29.3 = kWh per therm

%AC = Fraction of customers with thermostat-controlled air-conditioning

|  |  |
| --- | --- |
| **Thermostat control of air conditioning?** | **%AC** |
| Yes | 100% |
| No | 0% |
| Unknown | Actual, or 66%[[18]](#footnote-18) |

FLH = Estimate of annual household full load cooling hours for air conditioning equipment based on location and home type. If location and cooling type are unknown, assume the weighted average.

|  |  |  |  |
| --- | --- | --- | --- |
| **Climate zone**  **(city based upon)** | **FLH**  **(single family) [[19]](#footnote-19)** | **FLH**  **(general multifamily)** [[20]](#footnote-20) | **FLH\_cooling (weatherized multi family)** [[21]](#footnote-21) |
| 1 (Rockford) | 512 | 467 | 243 |
| 2 (Chicago) | 570 | 506 | 263 |
| 3 (Springfield) | 730 | 663 | 345 |
| 4 (Belleville) | 1035 | 940 | 489 |
| 5 (Marion) | 903 | 820 | 426 |
| Weighted average[[22]](#footnote-22) | 629 | 564 | 293 |

Btu/hr = Size of AC unit[[23]](#footnote-23). (Note: One refrigeration ton is equal to 12,000 Btu/hr.)

|  |  |
| --- | --- |
| **Program Delivery** | **Btu/hr** |
| Direct Install (Single Family known, or MF) | Actual |
| Unknown (Single family home only) | 33,600 |

SEER = the cooling equipment’s Seasonal Energy Efficiency Ratio rating (kBtu/kWh)

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

|  |  |
| --- | --- |
| **Cooling System** | **SEER[[24]](#footnote-24)** |
| Air Source Heat Pump | 9.12 |
| Central AC | 8.60 |

1/1000 = kBtu per Btu

Cooling\_Reduction = Assumed percentage reduction in total household cooling energy consumption due to installation of advanced thermostat

= X.X%

For example, a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

ΔkWH = ΔkWhheating + ΔkWhcooling

= 1 \* 20,928\* X.X% \* 100% \* 100% + (0 \* 0.0314 \* 29.3) + 100% \* ((730 \* 33,600 \* 1/9.12)/1000) \* X.X% \* 100%

= XXXX kWh

###### Summer Coincident Peak Demand Savings

ΔkW = (Cooling\_Reduction \* Btu/hr \* (1/EER))/1000 \* CF

Where:

EER = Energy Efficiency Ratio of existing cooling system (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:

EER = (-0.02 \* SEER\_exist2) + (1.12 \* SEER\_exist) [[25]](#footnote-25)

If SEER or EER rating unavailable use:

| **Cooling System** | **EER[[26]](#footnote-26)** |
| --- | --- |
| Air Source Heat Pump | 8.55 |
| Central AC | 8.15 |

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

= 68%[[27]](#footnote-27)

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

= 46.6%[[28]](#footnote-28)

###### Natural Gas Energy Savings

∆Therms = %FossilHeat \* Gas\_Heating\_Consumption \* Heating\_Reduction \* HF \* Eff\_ISR

Where:

%FossilHeat = Percentage of heating savings assumed to be Natural Gas

|  |  |
| --- | --- |
| **Heating fuel** | **%FossilHeat** |
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 87%[[29]](#footnote-29) |

Gas\_Heating\_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below[[30]](#footnote-30).

|  |  |
| --- | --- |
| **Climate Zone**  **(City based upon)** | **Gas\_Heating\_ Consumption**  **(therms)** |
| 1 (Rockford) | 1,052 |
| 2 (Chicago) | 1,005 |
| 3 (Springfield) | 861 |
| 4 (Belleville) | 664 |
| 5 (Marion) | 676 |
| Average | 955 |

Other variables as provided above

For example, a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

∆Therms = 1.0 \* 1005 \* X.X% \* 100% \* 100%

= XX.X therms

###### Water Impact Descriptions and Calculation

N/A

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

N/A

###### Measure Code: RS-HVC-ADTH-V01-160601

1. The ENERGY STAR program discontinued its support for basic programmable thermostats effective 12/31/09, and is presently developing a new specification for ‘Residential Climate Controls’.  [↑](#footnote-ref-1)
2. This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. It is recommended that program implementations incorporate this data into their planning and operation activities to improve understanding of the measure to manage risks and enhance savings results. [↑](#footnote-ref-2)
3. If the actual thermostat is a programmable and it is found to be used in override mode or otherwise effectively being operated like a manual thermostat, then the baseline may be considered to be a manual thermostat [↑](#footnote-ref-3)
4. ComEd Potential Study, 2013 [↑](#footnote-ref-4)
5. Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007 [↑](#footnote-ref-5)
6. Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a number of savings studies that only lasted a single year or less, the longer term impacts should be assessed. [↑](#footnote-ref-6)
7. Including any one-time software integration or annual software maintenance, and or individual device energy feature fees. [↑](#footnote-ref-7)
8. Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure's eligibility criteria are available on units readily available in the market roughly in the range of $200 and $250, excluding the availability of any wholesale or volume discounts. The assumed incremental cost is based on the middle of this range ($225) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption. [↑](#footnote-ref-8)
9. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-9)
10. 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-10)
11. Electrical savings are a function of both heating and cooling energy usage reductions. For heating this is a function of the percent of electric heat (heat pumps) and fan savings in the case of a natural gas furnace. [↑](#footnote-ref-11)
12. Average (default) value of 13% electric space heating from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used. [↑](#footnote-ref-12)
13. 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) and then to electric consumption assuming efficiencies of 100% for resistance and 200% for HP (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-13)
14. Assumption that 1/2 of electrically heated homes have electric resistance and 1/2 have Heat Pump, based on 2010 Residential Energy Consumption Survey for Illinois. [↑](#footnote-ref-14)
15. 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-15)
16. Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations. [↑](#footnote-ref-16)
17. 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-17)
18. 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey; [↑](#footnote-ref-18)
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://ilsag.org/yahoo_site_admin/assets/docs/ComEd_PY2_CACES_Evaluation_Report_2010-10-18.299122020.pdf>, p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in the Appendix providing the appropriate city to use for each county of Illinois. [↑](#footnote-ref-19)
20. Ibid. [↑](#footnote-ref-20)
21. *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015 [↑](#footnote-ref-21)
22. Weighted based on number of residential occupied housing units in each zone. [↑](#footnote-ref-22)
23. Actual unit size required for multi-family building, no size assumption provided because the unit size and resulting savings can vary greatly depending on the number of units. [↑](#footnote-ref-23)
24. Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4. [↑](#footnote-ref-24)
25. 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-25)
26. Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4. [↑](#footnote-ref-26)
27. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-27)
28. 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-28)
29. Average (default) value of 87% electric space heating from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used. [↑](#footnote-ref-29)
30. Values are based on adjusting the average household heating consumption (849 therms) for Chicago based on ‘Table 3-4, Program Sample Analysis, Nicor R29 Res Rebate Evaluation Report 092611\_REV FINAL to Nicor’, calculating inferred heating load by dividing by average efficiency of new in program units in the study (94.4%) and then applying standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24\*0.92) + (0.76\*0.8) = 0.83). This Chicago value was then 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-30)