

## 4.3.8 Controls for Central Domestic Hot Water

### DESCRIPTION

Demand control recirculation pumps seek to reduce inefficiency by combining control via temperature and demand inputs, whereby the controller will not activate the recirculation pump unless both (a) the recirculation loop return water has dropped below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

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

### DEFINITION OF EFFICIENT EQUIPMENT

Re-circulating pump shall cycle on based on (a) the recirculation loop return water dropping below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

### DEFINITION OF BASELINE EQUIPMENT

The base case for this measure category are existing, un-controlled Recirculation Pumps on gas-fired Central Domestic Hot Water Systems.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The effective useful life is 15 years<sup>234</sup>.

### DEEMED MEASURE COST

Incremental Cost: \$1,200<sup>235</sup>

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

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<sup>234</sup> Benningfield Group. (2009). *PY 2009 Monitoring Report: Demand Control for Multifamily Central Domestic Hot Water*. Folsom, CA: Prepared for Southern California Gas Company, October 30, 2009.

<sup>235</sup> Gas Technology Institute. (2014). *1003: Demand-based domestic hot water recirculation Public project report*. Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.

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**Algorithm**


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**CALCULATION OF ENERGY SAVINGS<sup>236</sup>****ELECTRIC ENERGY SAVINGS**Deemed at 651 kWh<sup>237</sup>.**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

$$\Delta\text{Therms} = 55.9^{238} * \text{number of dwelling units}$$

**EXAMPLE**

For example, an apartment building with 53 units:

$$\begin{aligned}\Delta\text{Therms} &= 55.9 * 53 \\ &= 2,962.7 \text{ therms}\end{aligned}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HW\_-CDHW-V01-150601**


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<sup>236</sup> See Illinois\_Statewide\_TRM\_Workpaper\_Demand Control Central DHW for more details

<sup>237</sup> Based on results from the Nicor Gas Emerging Technology Program study, this value is the average kWh saved per pump. Note this value does not reflect savings from electric units but electrical savings from gas-fired units.

<sup>238</sup> Based on results from the Nicor Gas Emerging Technology Program study, this value is the average therms saved per dwelling unit.

### 4.3.9 Heat Recovery Grease Trap Filter

**DESCRIPTION**

A heat recovery grease trap filter combines grease filters and a heat exchanger to recover heat leaving kitchen hoods. As a direct replacement for conventional hood mounted filters in commercial kitchens, they are plumbed to the domestic hot water system to provide preheating energy to incoming water.

This measure was developed to be applicable to the following program types: TOS and RF. If applied to other program types, the measure savings should be verified. For NC projects, this measure may be applicable if code requirements are otherwise satisfied.

**DEFINITION OF EFFICIENT EQUIPMENT**

Grease filters with heat exchangers carrying domestic hot water in kitchen exhaust air ducts.

**DEFINITION OF BASELINE EQUIPMENT**

Kitchen exhaust air duct with constant air flow<sup>239</sup> and no heat recovery.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 15 years.<sup>240</sup>

**DEEMED MEASURE COST**

Full installation costs, including plumbing materials, labor and any associated controls, should be used for screening purposes.

**LOADSHAPE**

Loadshape C01 - Commercial Electric Cooking

**COINCIDENCE FACTOR**

Summer Peak Coincidence Factor for measure is provided below for different building type<sup>241</sup>:

Location	CF
Fast Food Limited Menu	0.32
Fast Food Expanded Menu	0.41
Pizza	0.46
Full Service Limited Menu	0.51
Full Service Expanded Menu	0.36
Cafeteria	0.36
Unknown	0.40

<sup>239</sup> Savings methodology factors are for a constant speed fan.

<sup>240</sup> Professional judgement, consistent with expected lifetime of kitchen demand ventilation controls and other kitchen equipment.

<sup>241</sup>Minnesota 2012 Technical Reference Manual, Electric Food Service\_v03.2.xls, <http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech>

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

For electric hot water heaters:

$$\Delta kWh = \frac{[(Meal/Day * HW/Meal * Days/Year) * lbs/gal * BTU/lb.^{\circ}F * (\Delta T/filter * Qty\_Filter) * 0.00293]}{(\eta_{HeaterElec})}$$

Where:

- Meal/Day = Average number of meals served per day. If not directly available, see Table 1.
- HW/Meal = Hot water required per meal  
 = 3 gal/meal<sup>242</sup>
- Days/Year = Number of days kitchen operates per year. If not directly available, see Table 1.
- Lbs/gal = weight of water  
 = 8.3 lbs/gal
- BTU/lb.°F = Specific heat of water  
 = 1.0
- ΔT/filter = Temperature difference of domestic water across each filter  
 = 5.8°F/filter<sup>243</sup>
- Qty\_Filter = Number of heat recovery grease trap filters installed. If not directly available, see Table 1.

**Commercial Kitchen Load based on Building Type**

Building Type	Meals/Day <sup>244</sup>	Assumed days/Year	Number of Filters <sup>245</sup>
Primary School	400	312	2
Secondary School	600	312	3
Quick Service Restaurant	800	312	5
Full Service Restaurant	780	312	4
Large Hotel	780	356	4
Hospital	800	356	4

- η<sub>HeaterElec</sub> = Efficiency of the Electric water heater.  
 = Actual. If unknown, use the table C404.2 in IECC 2012 (or IECC 2015 if through new

<sup>242</sup> Average dishwashing and faucet water usage taken from Chapter 8, Table 8.3.3 Normalized Annual End Uses of Water in Select Restaurants in Western United States.

<sup>243</sup> Average value based on case studies. Northwinds Sailing, Inc. and North Shore Sustainable Energy, LLC. *Angry Trout Café Kitchen Exhaust Heat Recovery*. Minnesota Department of Commerce, Division of Energy Resources, 2012.

<sup>244</sup> Commercial Kitchen Loads for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL

<sup>245</sup> Each filter is 20 X 20 inches.

construction) to assume values based on code estimates

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

Hours = Hours of operation of kitchen exhaust air fan. If not directly available use:

Building Type	Kitchen Exhaust Fan Annual Operating Hours <sup>246</sup>
Primary School	4,056
Secondary School	4,056
Quick Service Restaurant	5,616
Full Service Restaurant	5,616
Large Hotel	5,340
Hospital	3,916

CF = Summer Peak Coincidence Factor for measure<sup>247</sup>:

Location	CF
Fast Food Limited Menu	0.32
Fast Food Expanded Menu	0.41
Pizza	0.46
Full Service Limited Menu	0.51
Full Service Expanded Menu	0.36
Cafeteria	0.36
Unknown	0.40

**NATURAL GAS SAVINGS**

For natural gas hot water heaters:

$$\Delta Therm = [(Meal/Day * HW/Meal * Days/Year) * lbs/gal * BTU/lb .°F * (\Delta T/filter * Qty_Filter)] / (\eta_{HeaterGas} * 100,000)$$

Where:

$\eta_{HeaterGas}$  = Efficiency of the Gas water heater. If not directly available, use:  
 = Actual. If unknown, use the table C404.2 in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates

Other variables as above

<sup>246</sup> Exhaust Fan Schedules for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL

<sup>247</sup>Minnesota 2012 Technical Reference Manual, [Electric Food Service v03.2.xls](http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech), <http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech>

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

O&M savings may result from reduced filter and hood cleaning frequencies. More research should be done to understand any potential savings and the associated value.

**MEASURE CODE: CI-HW\_-GRTF-V01-160601**

## 4.4 HVAC End Use

Many of the commercial HVAC measures use equivalent full load hours (EFLH) to calculate heating and cooling savings. The tables with these values are included in this section and referenced in each measure.

To calculate the updated EFLHs by building type and climate zone provided below, a TAC Subcommittee utilized building energy models originally developed for ComEd<sup>248</sup>, applying some adjustments and additions for new building type models and mechanical systems. Based on comparisons with available field data from Navigant<sup>249</sup>, the EFLH calculation was finalized by the Subcommittee to be the annual total (heating or cooling) output (in Btu) divided by the 95th percentile hourly peak output (heating or cooling) demand (in Btu/hr). This calculation keeps EFLH independent of modeled systems efficiency (which is utilized in the TRM savings calculation) and buffers EFLH value from hourly variances in the modeling that are not representative of actual buildings. See “EFLH Description 2015-02-11.doc” for further explanation.

The building characteristics can be found in the reference table named “EFLH Building Descriptions Updated 2014-11-21.xlsx”.

Building Type	Heating EFLH				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Assembly	1,787	1,831	1,635	1,089	1,669
Assisted Living	1,683	1,646	1,446	1,063	1,277
College	1,530	1,430	1,276	709	849
Convenience Store	1,481	1,368	1,214	871	973
Elementary School	1,781	1,736	1,531	1,057	1,283
Garage	985	969	852	680	752
Grocery	1,608	1,602	1,404	876	1,047
Healthcare Clinic	1,579	1,620	1,414	963	1,019
High School	1,845	1,857	1,666	1,187	1,388
Hospital - CAV no econ <sup>250</sup>	1,764	1,818	1,549	1,332	1,512
Hospital - CAV econ <sup>251</sup>	1,788	1,853	1,580	1,369	1,555
Hospital - VAV econ <sup>252</sup>	731	695	522	314	340
Hospital - FCU	1,325	1,512	1,232	1,448	1,946
Hotel/Motel	1,761	1,712	1,544	1,056	1,290
Hotel/Motel - Common	1,601	1,626	1,548	1,260	1,323

<sup>248</sup> A full description of the ComEd model development is found in “ComEd Portfolio Modeling Report. Energy Center of Wisconsin July 30, 2010”

<sup>249</sup> <http://www.icc.illinois.gov/downloads/public/edocket/397867.pdf>

<sup>250</sup> Based on model with single duct reheat system with a fixed outdoor air volume.

<sup>251</sup> Based on model with single duct reheat system with airside economizer controls, with constant volume zone reheat boxes and single speed fan motors.

<sup>252</sup> Based on model with single duct reheat system with airside economizer controls, zone VAV reheat boxes and VFD fan motors.

Building Type	Heating EFLH				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Hotel/Motel - Guest	1,758	1,702	1,521	1,018	1,252
Manufacturing Facility	1,048	1,013	939	567	634
MF - High Rise	1,526	1,506	1,373	1,169	1,172
MF - High Rise - Common	1,815	1,762	1,580	1,089	1,406
MF - High Rise - Residential	1,475	1,464	1,330	1,152	1,123
MF - Mid Rise	1,666	1,685	1,450	1,067	1,216
Movie Theater	1,916	1,905	1,718	1,288	1,538
Office - High Rise - CAV no econ	2,020	2,050	1,869	1,252	1,363
Office - High Rise - CAV econ	2,089	2,132	1,960	1,351	1,487
Office - High Rise - VAV econ	1,528	1,558	1,284	759	846
Office - High Rise - FCU	1,118	1,102	952	505	530
Office - Low Rise	1,428	1,425	1,132	692	793
Office - Mid Rise	1,585	1,587	1,342	855	950
Religious Building	1,603	1,504	1,440	1,054	1,205
Restaurant	1,350	1,354	1,216	920	1,091
Retail - Department Store	1,392	1,278	1,200	781	891
Retail - Strip Mall	1,332	1,233	1,090	751	810
Warehouse	1,456	1,357	1,400	875	1,078
Unknown	1,553	1,539	1,369	982	1,139

Equivalent Full Load Hours for Cooling (EFLH<sub>cooling</sub>) :

Building Type	Cooling EFLH				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Assembly	725	796	937	1,183	932
Assisted Living	1,475	1,457	1,773	2,110	1,811
College	475	481	662	746	806
Convenience Store	1,088	1,067	1,368	1,541	1,371
Elementary School	725	764	905	1,142	956
Garage	934	974	1,226	1,582	1,383
Grocery	1,033	1,000	1,236	1,499	1,286
Healthcare Clinic	1,282	1,305	1,519	1,767	1,571
High School	675	721	840	1,060	920
Hospital - CAV no econ	4,166	4,275	4,319	4,692	4,445
Hospital - CAV econ	1,751	1,814	2,120	2,411	2,112
Hospital - VAV econ	1,531	1,592	1,853	2,163	1,876
Hospital - FCU	3,245	3,291	3,451	4,128	3,806
Hotel/Motel	1,233	1,186	1,436	1,274	1,616
Hotel/Motel - Common	2,186	2,103	2,344	1,391	2,651
Hotel/Motel - Guest	1,042	1,019	1,269	1,216	1,418
Manufacturing Facility	1,010	1,055	1,209	1,453	1,273
MF - High Rise	921	845	1,048	1,779	1,099
MF - High Rise - Common	914	839	1,055	2,893	1,132
MF - High Rise - Residential	899	831	1,011	1,569	1,055
MF - Mid Rise	809	767	992	1,119	993
Movie Theater	876	745	1,036	1,178	1,010
Office - High Rise - CAV no econ	1,688	1,708	1,811	1,865	1,725
Office - High Rise - CAV econ	1,454	1,452	1,551	1,568	1,416
Office - High Rise - VAV econ	875	919	1,057	1,275	1,077
Office - High Rise - FCU	1,117	1,170	1,277	1,642	1,412
Office - Low Rise	949	1,010	1,182	1,452	1,281
Office - Mid Rise	883	938	1,072	1,286	1,083
Religious Building	861	817	967	1,159	1,067
Restaurant	1,074	1,134	1,279	1,627	1,325

Building Type	Cooling EFLH				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Retail - Department Store	949	889	1,124	1,367	1,157
Retail - Strip Mall	950	919	1,149	1,351	1,215
Warehouse	357	338	422	647	533
Unknown	1,215	1,221	1,408	1,670	1,480

## 4.4.1 Air Conditioner Tune-up

### DESCRIPTION

An air conditioning system that is operating as designed saves energy and provides adequate cooling and comfort to the conditioned space

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a unitary or split system air conditioner least 3 tons and preapproved by program. The measure requires that a certified technician performs the following items:

- Check refrigerant charge
- Identify and repair leaks if refrigerant charge is low
- Measure and record refrigerant pressures
- Measure and record temperature drop at indoor coil
- Clean condensate drain line
- Clean outdoor coil and straighten fins
- Clean indoor and outdoor fan blades
- Clean indoor coil with spray-on cleaner and straighten fins
- Repair damaged insulation – suction line
- Change air filter
- Measure and record blower amp draw

A copy of contractor invoices that detail the work performed to identify tune-up items, as well as additional labor and parts to improve/repair air conditioner performance must be submitted to the program

### DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be an AC system that that does not have a standing maintenance contract or a tune up within in the past 36 months.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 3 years.<sup>253</sup>

### DEEMED MEASURE COST

The incremental capital cost for this measure is \$35<sup>254</sup> per ton.

### LOADSHAPE

Loadshape C03 - Commercial Cooling

### COINCIDENCE FACTOR

- CF<sub>SSP</sub> = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)  
= 91.3%<sup>255</sup>
- CF<sub>PJM</sub> = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

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<sup>253</sup>ibid.

<sup>254</sup>ibid.

<sup>255</sup> 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.

$$= 47.8\%^{256}$$

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta \text{kWh} = (\text{kBtu/hr}) * [(1/\text{EERbefore}) - (1/\text{EERafter})] * \text{EFLH}$$

Where:

- kBtu/hr = capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).  
=Actual
- EERbefore = Energy Efficiency Ratio<sup>257</sup> of the baseline equipment prior to tune-up  
=Actual
- EERafter = Energy Efficiency Ratio of the baseline equipment after to tune-up  
=Actual
- EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta \text{kW}_{\text{SSP}} = (\text{kBtu/hr} * (1/\text{EERbefore} - 1/\text{EERafter})) * \text{CF}_{\text{SSP}}$$

$$\Delta \text{kW}_{\text{PJM}} = (\text{kBtu/hr} * (1/\text{EERbefore} - 1/\text{EERafter})) * \text{CF}_{\text{PJM}}$$

Where:

- CF<sub>SSP</sub> = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)  
= 91.3%<sup>258</sup>
- CF<sub>PJM</sub> = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)  
= 47.8%<sup>259</sup>

**NATURAL GAS ENERGY SAVINGS**

N/A

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<sup>256</sup>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

<sup>257</sup> In the context of this measure Energy Efficiency Ratio (EER) refers to field-measured steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btuh divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btuh per watt (Btuh/watt). The cooling capacity may be derived using either refrigerant or air-side measurements. The measurement is performed at the outdoor and indoor environmental conditions that are present at the time the tune-up is being performed, and should be normalized using a correction function to the AHRI 210/240 Standard test conditions. The correction function should be developed based on manufacturer's performance data. Care must be taken to ensure the unit is fully loaded and operating at or near steady-state. Generally this requires that the outside air temperature is at least 60°F, and that the unit runs with all stages of cooling enabled for 10 to 15 minutes prior to making measurements

<sup>258</sup> 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.

<sup>259</sup>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

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-ACTU-V03-160601**

## 4.4.2 Space Heating Boiler Tune-up

### DESCRIPTION

This measure is for a non-residential boiler that provides space heating. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. Adjust air flow and reduce excessive stack temperatures, adjust burner and gas input. Check venting, safety controls, and adequacy of combustion air intake. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the facility must, as applicable, complete the tune-up requirements<sup>260</sup> listed below, by approved technician:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 3 years<sup>261</sup>

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<sup>260</sup> Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

<sup>261</sup> Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

**DEEMED MEASURE COST**

The cost of this measure is \$0.83/MBtu/hr<sup>262</sup> per tune-up

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

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**Algorithm**

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**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

$$\Delta \text{Therms} = (\text{Capacity} * \text{EFLH} * (((\text{Effbefore} + \text{Ei}) / \text{Effbefore}) - 1)) / 100,000$$

Where:

Capacity = Boiler gas input size (Btu/hr)  
 = custom

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

Effbefore = Efficiency of the boiler before the tune-up

*Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.*

Ei = Efficiency Improvement of the boiler tune-up measure

100,000 = Converts Btu to therms

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<sup>262</sup>Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

**EXAMPLE**

For example, a 1050 kBtu boiler in a Chicago high rise office records an efficiency prior to tune up of 82% AFUE and a 1.8% improvement in efficiency are tune up:

$$\begin{aligned}\Delta\text{therms} &= (1,050,000 * 2050 * ((0.82 + 0.018) / 0.82 - 1)) / 100,000 \\ &= 473 \text{ Therms}\end{aligned}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-BLRT-V06-160601**

### 4.4.3 Process Boiler Tune-up

#### DESCRIPTION

This measure is for a non-residential boiler for process loads. For space heating, see measure 4.4.2. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. Adjust air flow and reduce excessive stack temperatures, adjust burner and gas input. Check venting, safety controls, and adequacy of combustion air intake. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer.

#### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the facility must, as applicable, complete the tune-up requirements<sup>263</sup> by approved technician, as specified below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel

#### DEFINITION OF BASELINE EQUIPMENT

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months

#### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 3 years<sup>264</sup>

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<sup>263</sup> Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

<sup>264</sup> Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

**DEEMED MEASURE COST**

The cost of this measure is \$0.83/MBtu/hr<sup>265</sup> per tune-up

**DEEMED O&M COST ADJUSTMENTS**

N/A

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

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**Algorithm**

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**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

$$\Delta\text{Therms} = ((\text{Ngi} * 8766 * \text{UF}) / 100) * (1 - (\text{Eff}_{\text{pre}} / \text{Eff}_{\text{measured}}))$$

Where:

Ngi = Boiler gas input size (kBtu/hr)

= custom

UF = Utilization Factor

= 41.9%<sup>266</sup> or custom

Eff<sub>pre</sub> = Boiler Combustion Efficiency Before Tune-Up

= Actual

*Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a*

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<sup>265</sup> Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

<sup>266</sup> Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

*consistent firing rate for pre and post tune-up.*

$Eff_{\text{measured}}$  = Boiler Combustion Efficiency After Tune-Up

= Actual

100 =conversion from kBtu to therms

8766 = hours a year

**EXAMPLE**

For example, a 80% 1050 kBtu boiler is tuned-up resulting in final efficiency of 81.3%:

$$\begin{aligned} \Delta \text{therms} &= ((1050 * 8766 * 0.419) / 100) * (1 - (0.80 / 0.813)) \\ &= 617 \text{ therms} \end{aligned}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-PBTU-V05-160601**

#### 4.4.4 Boiler Lockout/Reset Controls

##### DESCRIPTION

This measure relates to improving combustion efficiency by adding controls to non-residential building heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. Energy is saved by increasing the temperature difference between the water temperature entering the boiler in the boiler's heat exchanger and the boiler's burner flame temperature. The flame temperature remains the same while the water temperature leaving the boiler decreases with the decrease in heating load due to an increase in outside air temperature. A lockout temperature is also set to prevent the boiler from turning on when it is above a certain temperature outdoors.

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

Natural gas customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse linear fashion with outdoor air temperature. Boiler lockout temperatures should be set to 55 °F at this time as well, to turn the boiler off when the temperature goes above a certain setpoint.

##### DEFINITION OF BASELINE EQUIPMENT

Existing boiler without boiler reset controls, any size with constant hot water flow.

##### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 20 years<sup>267</sup>

##### DEEMED MEASURE COST

The cost of this measure is \$612<sup>268</sup>

##### LOADSHAPE

N/A

##### COINCIDENCE FACTOR

N/A

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#### Algorithm

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##### CALCULATION OF SAVINGS

##### ELECTRIC ENERGY SAVINGS

N/A

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<sup>267</sup>CLEAResultreferences the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.

<sup>268</sup> Nexant. Questar DSM Market Characterization Report. August 9, 2006.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS ENERGY SAVINGS

$$\Delta\text{Therms} = \text{Binput} * \text{SF} * \text{EFLH} / (100)$$

Where:

Binput = Boiler Input Capacity (kBtu/hr)  
= custom

SF = Savings factor  
= 8%<sup>269</sup> or custom

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

100 = conversion from kBtu to therms

#### EXAMPLE

For example, a 800 kBtu/hr boiler at a restaurant in Rockford, IL

$$\begin{aligned}\Delta\text{Therms} &= 800 * 0.08 * 1,350 / (100) \\ &= 864 \text{ Therms}\end{aligned}$$

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-BLRC-V03-150601

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<sup>269</sup> Savings factor is the estimate of annual gas consumption that is saved due to adding boiler reset controls. The CLEAResult uses a boiler tuneup savings value derived from Xcel Energy "DSM Biennial Plan-Technical Assumptions," Colorado. Focus on Energy uses 8%, citing multiple sources. Vermont Energy Investment Corporation's boiler reset savings estimates for custom projects further indicate 8% savings estimate is better reflection of actual expected savings.

## 4.4.5 Condensing Unit Heaters

### DESCRIPTION

This measure applies to a gas fired condensing unit heater installed in a commercial application.

This measure was developed to be applicable to the following program types: TOS, NC. 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 is assumed to be a condensing unit heater up to 300 MBH with a Thermal Efficiency > 90% and the heater must be vented, and condensate drained per manufacturer specifications. The unit must be replacing existing natural gas equipment.

### DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be a non-condensing natural gas unit heater at end of life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years<sup>270</sup>

### DEEMED MEASURE COST

The incremental capital cost for a unit heater is \$676<sup>271</sup>

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

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### Algorithm

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### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

N/A

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

#### NATURAL GAS ENERGY SAVINGS

The annual natural gas energy savings from this measure is a deemed value equaling 266 Therms.

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<sup>270</sup>DEER 2008

<sup>271</sup>ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-CUHT-V01-120601**

## 4.4.6 Electric Chiller

### DESCRIPTION

This measure relates to the installation of a new electric chiller meeting the efficiency standards presented below. This measure could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in an existing building (i.e. time of sale). Only single-chiller applications should be assessed with this methodology. The characterization is not suited for multiple chillers projects or chillers equipped with variable speed drives (VSDs).

This measure was developed to be applicable to the following program types: TOS, NC. 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 is assumed to exceed the efficiency requirements defined by the program.

### DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to meet the efficiency requirements within Table 403.2.3(7) of either the 2012 or the 2015 IECC (applicable from 01/01/2016), depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years<sup>272</sup>.

### DEEMED MEASURE COST

The incremental capital cost for this measure is provided below.

Equipment Type	Size Category	Incremental Cost (\$/ton)
Air cooled, electrically operated	All capacities	\$127/ton <sup>273</sup>
Water cooled, electrically operated, positive displacement (reciprocating)	All capacities	\$22/ton <sup>274</sup>
Water cooled, electrically operated, positive displacement (rotary screw and scroll)	< 150 tons	\$351/ton <sup>275</sup>
	>= 150 tons and < 300 tons	\$127/ton
	>= 300 tons	\$87/ton

### LOADSHAPE

Loadshape C03 - Commercial Cooling

<sup>272</sup> 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008 ([http://deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls))

<sup>273</sup> 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008. Calculated as the simple average of screw and reciprocating air-cooled chiller incremental costs from DEER2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation

<sup>274</sup> 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation"

<sup>275</sup> Incremental costs for water-cooled, electrically operated, positive displacement (rotary screw and scroll) from the W017 Itron California Measure Cost Study, accessed via <http://www.energydataweb.com/cpuc/search.aspx>. The data is provided in a file named "MCS Results Matrix – Volume I".

**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.

$$CF_{SSP} = \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)}$$

$$= 91.3\%^{276}$$

$$CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)}$$

$$= 47.8\%^{277}$$

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWH = TONS * ((IPLV_{base}) - (IPLV_{ee})) * EFLH$$

Where:

TONS = chiller nominal cooling capacity in tons (note: 1 ton = 12,000 Btu/hr)  
 = Actual installed

IPLV<sub>base</sub> = efficiency of baseline equipment expressed as Integrated Part Load Value(kW/ton). Chiller units are dependent on chiller type. See Chiller Units, Conversion Values and Baseline Efficiency Values by Chiller Type and Capacity in the Reference Tables section.

IPLV<sub>ee</sub><sup>278</sup> = efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)<sup>279</sup>  
 = Actual installed

EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.

For example, a 100 ton air-cooled electrically operated chiller with IPLV of 14 EER (0.86 kW/ton) and baseline EER of 12.5 (0.96 kW/ton) ,in a low-rise office building in Rockford with a building permit dated on 1/1/2015 would save:

$$\Delta kWH = 100 * ((0.96) - (0.86)) * 949$$

$$= 9,490 \text{ kWh}$$

<sup>276</sup> 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.

<sup>277</sup> 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

<sup>278</sup> Integrated Part Load Value is a seasonal average efficiency rating calculated in accordance with ARI Standard 550/590. It may be calculated using any measure of efficiency (EER, kW/ton, COP), but for consistency with IECC 2012, it is expressed in terms of IPLV here.

<sup>279</sup> Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRnetl.org. <http://www.ahrinet.org/>

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW_{SSP} = \text{TONS} * ((PE_{base}) - (PE_{ee})) * CF_{SSP}$$

$$\Delta kW_{PJM} = \text{TONS} * ((PE_{base}) - (PE_{ee})) * CF_{PJM}$$

Where:

- PE<sub>base</sub> = Peak efficiency of baseline equipment expressed as Full Load (kW/ton)
- PE<sub>ee</sub> = Peak efficiency of high efficiency equipment expressed as Full Load (kW/ton)
- = Actual installed
- CF<sub>SSP</sub> = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)
- = 91.3%
- CF<sub>PJM</sub> = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)
- = 47.8%

For example, a 100 ton air-cooled electrically operated chiller with a full load IPLV of 12 EER ( 1.0 kW/ton) and a baseline full load IPLV 9.56 EER (1.3 kW/ton) would save:

$$\Delta kW_{SSP} = 100 * ((1.3) - (1.0)) * 0.913$$

$$= 27 \text{ kW}$$

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**REFERENCE TABLES**

Chillers Ratings- Chillers are rated with different units depending on equipment type as shown below

Equipment Type	Unit
Air cooled, electrically operated	EER
Water cooled, electrically operated, positive displacement (reciprocating)	kW/ton
Water cooled, electrically operated, positive displacement (rotary screw and scroll)	kW/ton

In order to convert chiller equipment ratings to IPLV the following relationships are provided

$$\text{kW/ton} = 12 / \text{EER}$$

$$\text{kW/ton} = 12 / (\text{COP} \times 3.412)$$

$$\text{COP} = \text{EER} / 3.412$$

$$\text{COP} = 12 / (\text{kW/ton}) / 3.412$$

$$\text{EER} = 12 / \text{kW/ton}$$

$$\text{EER} = \text{COP} \times 3.412$$

2012 IECC Baseline Efficiency Values by Chiller Type and Capacity

TABLE C403.2.3(7)  
 MINIMUM EFFICIENCY REQUIREMENTS:  
 WATER CHILLING PACKAGES\*

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2010		AS OF 1/1/2010 <sup>b</sup>				TEST PROCEDURE <sup>c</sup>
			FULL LOAD	IPLV	PATH A		PATH B		
					FULL LOAD	IPLV	FULL LOAD	IPLV	
Air-cooled chillers	< 150 tons	EER		≥ 10.4					AHRI 550/590
	≥ 150 tons	EER	≥ 9.562	16	≥ 9.562	≥ 12.500	NA	NA	
Air cooled without condenser, electrical operated	All capacities	EER	≥ 10.586	≥ 11.782	Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				AHRI 550/590
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	≤ 0.837	≤ 0.696	Reciprocating units shall comply with water cooled positive displacement efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton			≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600	AHRI 550/590
	≥ 75 tons and < 150 tons	kW/ton	≤ 0.790	≤ 0.676	≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.717	≤ 0.627	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540	
	≥ 300 tons	kW/ton	≤ 0.639	≤ 0.571	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.703	≤ 0.669					AHRI 560
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450	
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400	
	≥ 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400	
Air cooled, absorption single effect	All capacities	COP	≥ 0.600	NR	≥ 0.600	NR	NA	NA	AHRI 560
Water cooled, absorption single effect	All capacities	COP	≥ 0.700	NR	≥ 0.700	NR	NA	NA	
Absorption double effect, indirect fired	All capacities	COP	≥ 1.000	≥ 1.050	≥ 1.000	≥ 1.050	NA	NA	
Absorption double effect, direct fired	All capacities	COP	≥ 1.000	≥ 1.000	≥ 1.000	≥ 1.000	NA	NA	

For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

NA = Not applicable, not to be used for compliance; NR = No requirement.

- a. The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 36°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.
- b. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.
- c. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

2015 IECC Baseline Efficiency Values by Chiller Type and Capacity

TABLE C403.2.3(7)  
 WATER CHILLING PACKAGES – EFFICIENCY REQUIREMENTS<sup>a, b, d</sup>

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015		AS OF 1/1/2015		TEST PROCEDURE <sup>c</sup>
			Path A	Path B	Path A	Path B	
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA <sup>a</sup>	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
			≥ 12.500 IPLV		≥ 13.700 IPLV	≥ 15.800 IPLV	
	≥ 150 Tons		≥ 9.562 FL	NA <sup>a</sup>	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 14.000 IPLV	≥ 16.100 IPLV	
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				
Water cooled, electrically operated positive displacement	< 75 Tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	
			≤ 0.630 IPLV	≤ 0.600 IPLV	≤ 0.600 IPLV	≤ 0.500 IPLV	
	≥ 75 tons and < 150 tons		≤ 0.775 FL	≤ 0.790 FL	≤ 0.720 FL	≤ 0.750 FL	
			≤ 0.615 IPLV	≤ 0.586 IPLV	≤ 0.560 IPLV	≤ 0.490 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.680 FL	≤ 0.718 FL	≤ 0.660 FL	≤ 0.680 FL	
			≤ 0.580 IPLV	≤ 0.540 IPLV	≤ 0.540 IPLV	≤ 0.440 IPLV	
	≥ 300 tons and < 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.625 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.520 IPLV	≤ 0.410 IPLV	
≥ 600 tons	≤ 0.620 FL	≤ 0.639 FL	≤ 0.560 FL	≤ 0.585 FL			
≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV				
Water cooled, electrically operated centrifugal	< 150 Tons	kW/ton	≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.695 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.440 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.635 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.400 IPLV	
	≥ 300 tons and < 400 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.595 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.520 IPLV	≤ 0.390 IPLV	
	≥ 400 tons and < 600 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
≥ 600 Tons	≤ 0.570 FL	≤ 0.590 FL	≤ 0.560 FL	≤ 0.585 FL			
≤ 0.539 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV				
Air cooled, absorption, single effect	All capacities	COP	≥ 0.600 FL	NA <sup>a</sup>	≥ 0.600 FL	NA <sup>a</sup>	AHRI 560
Water cooled absorption, single effect	All capacities	COP	≥ 0.700 FL	NA <sup>a</sup>	≥ 0.700 FL	NA <sup>a</sup>	
Absorption, double effect, indirect fired	All capacities	COP	≥ 1.000 FL	NA <sup>a</sup>	≥ 1.000 FL	NA <sup>a</sup>	
			≥ 1.050 IPLV		≥ 1.050 IPLV		
Absorption double effect direct fired	All capacities	COP	≥ 1.000 FL	NA <sup>a</sup>	≥ 1.000 FL	NA <sup>a</sup>	
			≥ 1.000 IPLV		≥ 1.050 IPLV		

- a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.2.3.1 and are only applicable for the range of conditions listed in Section C403.2.3.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.
- b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.
- c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.
- d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

MEASURE CODE: CI-HVC-CHIL-V04-160601

#### 4.4.7 ENERGY STAR and CEE Tier 1 Room Air Conditioner

##### DESCRIPTION

This measure relates to the purchase and installation of a room air conditioning unit that meets either the ENERGY STAR or CEE TIER 1 minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard efficiency ratings presented below:<sup>280</sup>

Product Class (Btu/H)	Federal Standard EER, with louvered sides	Federal Standard EER, without louvered sides	ENERGY STAR EER, with louvered sides	ENERGY STAR EER, without louvered sides	CEE TIER 1 EER
< 8,000	9.7	9	10.7	9.9	11.2
8,000 to 13,999	9.8	8.5	10.8	9.4	11.3
14,000 to 19,999	9.7	8.5	10.7	9.4	11.2
>= 20,000	8.5	8.5	9.4	9.4	9.8

Casement	Federal Standard (EER)	ENERGY STAR (EER)
Casement-only	8.7	9.6
Casement-slider	9.5	10.5

Reverse Cycle - Product Class (Btu/H)	Federal Standard EER, with louvered sides	Federal Standard EER, without louvered sides	ENERGY STAR EER, with louvered sides	ENERGY STAR EER, without louvered sides
< 14,000	N/A	8.5	N/A	9.4
>= 14,000	N/A	8	N/A	8.8
< 20,000	9	N/A	9.9	N/A
>= 20,000	8.5	N/A	9.4	N/A

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

<sup>280</sup> [http://www.energystar.gov/index.cfm?c=roomac.pr\\_crit\\_room\\_ac](http://www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac) and [http://www.cee1.org/resid/seha/rm-ac/rm-ac\\_specs.pdf](http://www.cee1.org/resid/seha/rm-ac/rm-ac_specs.pdf)

Side louvers that extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models.

Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size.

Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.

Reverse cycle refers to the heating function found in certain room air conditioner models.

[http://www.energystar.gov/ia/partners/product\\_specs/program\\_reqs/room\\_air\\_conditioners\\_prog\\_req.pdf](http://www.energystar.gov/ia/partners/product_specs/program_reqs/room_air_conditioners_prog_req.pdf)

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the new room air conditioning unit must meet the ENERGY STAR efficiency standards presented above.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline assumption is a new room air conditioning unit that meets the current minimum federal efficiency standards presented above.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 9 years.<sup>281</sup>

**DEEMED MEASURE COST**

The incremental cost for this measure is assumed to be \$40 for an ENERGY STAR unit and \$80 for a CEE TIER 1 unit.<sup>282</sup>

**LOADSHAPE**

Loadshape C03 - Commercial 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.

$$\begin{aligned} CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} \\ &= 91.3\% \text{ }^{283} \end{aligned}$$

$$\begin{aligned} CF_{PJM} &= \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \\ &= 47.8\% \text{ }^{284} \end{aligned}$$

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**Algorithm**


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**CALCULATION OF SAVINGS****ENERGY SAVINGS**

$$\Delta kWh = (FLH_{RoomAC} * Btu/H * (1/EER_{base} - 1/EER_{ee}))/1000$$

Where:

$$\begin{aligned} FLH_{RoomAC} &= \text{Full Load Hours of room air conditioning unit} \\ &= \text{dependent on location:}^{285} \end{aligned}$$

<sup>281</sup> Energy Star Room Air Conditioner Savings Calculator,

[http://www.energystar.gov/index.cfm?fuseaction=find\\_a\\_product.showProductGroup&pgw\\_code=AC](http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=AC)

[http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure\\_life\\_GDS%5B1%5D.pdf](http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf)

<sup>282</sup> Based on field study conducted by Efficiency Vermont

<sup>283</sup> 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.

<sup>284</sup> 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

Zone	FLH <sub>RoomAC</sub>
1 (Rockford)	253
2-(Chicago)	254
3 (Springfield)	310
4-(Belleville)	391
5-(Marion)	254

Btu/H = Size of unit

= Actual. If unknown assume 8500 Btu/hr<sup>286</sup>

EER<sub>base</sub> = Efficiency of baseline unit

= As provided in tables above

EER<sub>ee</sub> = Efficiency of ENERGY STAR or CEE Tier 1 unit

= Actual. If unknown assume minimum qualifying standard as provided in tables above

For example for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Rockford:

$$\begin{aligned}\Delta\text{kWh}_{\text{ENERGY STAR}} &= (253 * 8500 * (1/9.8 - 1/10.8)) / 1000 \\ &= 20.3 \text{ kWh}\end{aligned}$$

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = \text{Btu/H} * ((1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{ee}}))/1000 * \text{CF}$$

Where:

CF<sub>SSP</sub> = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)  
= 91.3%<sup>287</sup>

CF<sub>PJM</sub> = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)  
= 47.8%<sup>288</sup>

Other variable as defined above

<sup>285</sup> Full load hours for room AC is significantly lower than for central AC. The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008:

[http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117\\_RLW\\_CF%20Res%20RAC.pdf](http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)) to FLH for Central Cooling for the same location (provided by AHRI:

[http://www.energystar.gov/ia/business/bulk\\_purchasing/bpsavings\\_calc/Calc\\_CAC.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)) is 31%. This ratio has been applied to the FLH from the unitary and split system air conditioning measure.

<sup>286</sup> Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

<sup>287</sup> 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.

<sup>288</sup> 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

For example for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Rockford during system peak

$$\begin{aligned}\Delta kW_{\text{ENERGY STAR}} &= (8500 * (1/9.8 - 1/10.8)) / 1000 * 0.913 \\ &= 0.073 \text{ kW}\end{aligned}$$

**FOSSIL FUEL SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-ESRA-V01-120601**

## 4.4.8 Guest Room Energy Management (PTAC & PTHP)

### DESCRIPTION

This measure applied to the installation of a temperature setback and lighting control system for individual guest rooms. The savings are achieved based on Guest Room Energy Management's (GREM's) ability to automatically adjust the guest room's set temperatures and control the HVAC unit for various occupancy modes.

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

### DEFINITION OF EFFICIENT EQUIPMENT

Guest room temperature set point must be controlled by automatic occupancy detectors or keycard that indicates the occupancy status of the room. During unoccupied periods the default setting for controlled units differs by at least 5 degrees from the operating set point. Theoretically, the control system may also be tied into other electric loads, such as lighting and plug loads to shut them off when occupancy is not sensed. This measure bases savings on improved HVAC controls. If system is connected to lighting and plug loads, additional savings would be realized. The incentive is per guestroom controlled, rather than per sensor, for multi-room suites. Replacement or upgrades of existing occupancy-based controls are not eligible for an incentive.

### DEFINITION OF BASELINE EQUIPMENT

Guest room energy management thermostats replace manual heating/cooling temperature set-point and fan On/Off/Auto thermostat controls. Two possible baselines exist based on whether housekeeping staff are directed to set-back (or turn off) thermostats when rooms are not rented.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for GREM is 15 years<sup>289</sup>.

### DEEMED MEASURE COST

\$260/unit

The IMC documented for this measure is \$260 per room HVAC controller, which is the cost difference between a non-programmable thermostat and a GREM<sup>290</sup>.

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

Loadshape C03 - Commercial Cooling

### COINCIDENCE FACTOR

A coincidence factor is not used in the determination of coincident peak kW savings.

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<sup>289</sup> DEER 2008 value for energy management systems

<sup>290</sup> This value was extracted from Smart Ideas projects in PY1 and PY2.

**Algorithm**

**CALCULATION OF SAVINGS**

Below are the annual kWh savings per installed EMS for different sizes and types of HVAC units. The savings are achieved based on GREM’s ability to automatically adjust the guest room’s set temperatures and control the HVAC unit to maintain set temperatures for various occupancy modes. Note that care should be taken in selecting a value consistent with actual baseline conditions (e.g. whether housekeeping staff are directed to set-back/turn-off the thermostats when rooms are unrented). Different values are provided for Motels and Hotels since significant differences in shell performance, number of external walls per room and typical heating and cooling efficiencies result in significantly different savings estimates. Energy savings estimates are derived using a prototypical EnergyPlus simulation of a motel and a hotel<sup>291</sup>. Model outputs are normalized to the installed capacity and reported here as kWh/Ton, coincident peak kW/Ton and Therms/Ton.

**ELECTRIC ENERGY SAVINGS**

Motel Electric Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
1 (Rockford)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	744
		No Housekeeping Setback	1,786
	PTAC w/ Gas Heating	Housekeeping Setback	63
		No Housekeeping Setback	155
	PTHP	Housekeeping Setback	385
		No Housekeeping Setback	986
2 (Chicago)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	506
		No Housekeeping Setback	1,582
	PTAC w/ Gas Heating	Housekeeping Setback	51
		No Housekeeping Setback	163
	PTHP	Housekeeping Setback	211
		No Housekeeping Setback	798
3 (Springfield)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	462
		No Housekeeping Setback	1,382
	PTAC w/ Gas Heating	Housekeeping Setback	65
		No Housekeeping Setback	198
	PTHP	Housekeeping Setback	202

<sup>291</sup> For motels, see S. Keates, ADM Associates Workpaper: “Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)”, 11/14/2013 and spreadsheet summarizing the results: ‘GREM Savings Summary\_IL TRM\_1\_22\_14.xlsx’. In 2014 the hotel models were also run to compile results, rather than by applying adjustment factors to the motel results as had been done in V3.0 of the TRM. The updated values can be found in ‘GREM Savings Summary (Hotel)\_IL TRM\_10\_16\_14.xls’.

Motel Electric Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
		No Housekeeping Setback	736
4 (Belleville)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	559
		No Housekeeping Setback	1,877
	PTAC w/ Gas Heating	Housekeeping Setback	85
		No Housekeeping Setback	287
	PTHP	Housekeeping Setback	260
		No Housekeeping Setback	1,023
5 (Marion-Williamson)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	388
		No Housekeeping Setback	1,339
	PTAC w/ Gas Heating	Housekeeping Setback	81
		No Housekeeping Setback	274
	PTHP	Housekeeping Setback	174
		No Housekeeping Setback	682

Hotel Electric Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
1 (Rockford)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	204
		No Housekeeping Setback	345
	PTAC w/ Gas Heating	Housekeeping Setback	121
		No Housekeeping Setback	197
	PTHP	Housekeeping Setback	152
		No Housekeeping Setback	253
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	177
		No Housekeeping Setback	296
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	94
		No Housekeeping Setback	148
2 (Chicago)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	188
		No Housekeeping Setback	342
	PTAC w/ Gas Heating	Housekeeping Setback	119

Hotel Electric Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
	PTHP	No Housekeeping Setback	195
		Housekeeping Setback	145
	Central Hot Water Fan Coil w/ Electric Resistance Heating	No Housekeeping Setback	250
		Housekeeping Setback	161
	Central Hot Water Fan Coil w/ Gas Heating	No Housekeeping Setback	294
		Housekeeping Setback	92
	No Housekeeping Setback	147	
3 (Springfield)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	182
		No Housekeeping Setback	291
	PTAC w/ Gas Heating	Housekeeping Setback	123
		No Housekeeping Setback	197
	PTHP	Housekeeping Setback	145
		No Housekeeping Setback	233
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	153
		No Housekeeping Setback	240
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	94
		No Housekeeping Setback	146
4 (Belleville)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	182
		No Housekeeping Setback	308
	PTAC w/ Gas Heating	Housekeeping Setback	125
		No Housekeeping Setback	199
	PTHP	Housekeeping Setback	146
		No Housekeeping Setback	240
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	152
		No Housekeeping Setback	255
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	95
		No Housekeeping Setback	147
5 (Marion-Williamson)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	171
		No Housekeeping Setback	295
	PTAC w/ Gas Heating	Housekeeping Setback	122
		No Housekeeping Setback	199

Hotel Electric Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
	PTHP	Housekeeping Setback	140
		No Housekeeping Setback	235
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	141
		No Housekeeping Setback	243
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	92
		No Housekeeping Setback	146

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Motel Coincident Peak Demand Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Coincident Peak Demand Savings (kW/Ton)
1 (Rockford)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.17
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.17
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.17
2 (Chicago)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.06
		No Housekeeping Setback	0.17
	PTAC w/ Gas Heating	Housekeeping Setback	0.06
		No Housekeeping Setback	0.17
	PTHP	Housekeeping Setback	0.06
		No Housekeeping Setback	0.17
3 (Springfield)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.07
		No Housekeeping Setback	0.17
	PTAC w/ Gas Heating	Housekeeping Setback	0.07
		No Housekeeping Setback	0.17
	PTHP	Housekeeping Setback	0.07
		No Housekeeping Setback	0.17
4 (Belleville)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.10
		No Housekeeping Setback	0.28
	PTAC w/ Gas Heating	Housekeeping Setback	0.10
		No Housekeeping Setback	0.28
	PTHP	Housekeeping Setback	0.10
		No Housekeeping Setback	0.28
5 (Marion-Williamson)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.21
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.21
	PTHP	Housekeeping Setback	0.08

Motel Coincident Peak Demand Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Coincident Peak Demand Savings (kW/Ton)
		No Housekeeping Setback	0.21

Hotel Coincident Peak Demand Savings				
Climate Zone (City based upon)	Heating Source	Baseline	Coincident Peak Demand Savings (kW/Ton)	
1 (Rockford)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08	
		No Housekeeping Setback	0.11	
	PTAC w/ Gas Heating	Housekeeping Setback	0.08	
		No Housekeeping Setback	0.11	
	PTHP	Housekeeping Setback	0.08	
		No Housekeeping Setback	0.11	
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	0.05	
		No Housekeeping Setback	0.08	
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	0.05	
		No Housekeeping Setback	0.08	
	2 (Chicago)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.07
			No Housekeeping Setback	0.11
PTAC w/ Gas Heating		Housekeeping Setback	0.07	
		No Housekeeping Setback	0.11	
PTHP		Housekeeping Setback	0.07	
		No Housekeeping Setback	0.11	
Central Hot Water Fan Coil w/ Electric Resistance Heating		Housekeeping Setback	0.05	
		No Housekeeping Setback	0.07	
Central Hot Water Fan Coil w/ Gas Heating		Housekeeping Setback	0.05	
		No Housekeeping Setback	0.07	
3 (Springfield)		PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
			No Housekeeping Setback	0.11
	PTAC w/ Gas Heating	Housekeeping Setback	0.08	
		No Housekeeping Setback	0.11	

Hotel Coincident Peak Demand Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Coincident Peak Demand Savings (kW/Ton)
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.07
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.07
4 (Belleville)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08
5 (Marion-Williamson)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08

**NATURAL GAS ENERGY SAVINGS**

For PTACs with gas heating:

Motel Natural Gas Energy Savings		
Climate Zone (City based upon)	Baseline	Gas Savings (Therms/Ton)
1 (Rockford)	Housekeeping Setback	30
	No Housekeeping Setback	71
2 (Chicago)	Housekeeping Setback	20
	No Housekeeping Setback	62
3 (Springfield)	Housekeeping Setback	17
	No Housekeeping Setback	52
4 (Belleville)	Housekeeping Setback	21
	No Housekeeping Setback	70
5 (Marion-Williamson)	Housekeeping Setback	13
	No Housekeeping Setback	47

Hotel Natural Gas Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Gas Savings (Therms/Ton)
1 (Rockford)	PTAC w/ Gas Heating	Housekeeping Setback	3.6
		No Housekeeping Setback	6.4
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	3.6
		No Housekeeping Setback	6.4
2 (Chicago)	PTAC w/ Gas Heating	Housekeeping Setback	3.0
		No Housekeeping Setback	6.5
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	3.0
		No Housekeeping Setback	6.5
3 (Springfield)	PTAC w/ Gas Heating	Housekeeping Setback	2.6
		No Housekeeping Setback	4.1
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	2.6
		No Housekeeping Setback	4.1
4 (Belleville)	PTAC w/ Gas Heating	Housekeeping Setback	2.5
		No Housekeeping Setback	4.8
	Central Hot Water Fan Coil	Housekeeping Setback	2.5

Hotel Natural Gas Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Gas Savings (Therms/Ton)
	w/ Gas Heating	No Housekeeping Setback	4.8
5 (Marion-Williamson)	PTAC w/ Gas Heating	Housekeeping Setback	2.1
		No Housekeeping Setback	4.2
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	2.1
		No Housekeeping Setback	4.2

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-GREM-V05-150601**

## 4.4.9 Heat Pump Systems

### DESCRIPTION

This measure applies to the installation of high-efficiency air cooled, water source, ground water source, and ground source heat pump systems. This measure could apply to replacing an existing unit at the end of its useful life, or installation of a new unit in a new or existing building.

This measure was developed to be applicable to the following program types: TOS NC. 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 is assumed to be a high-efficiency air cooled, water source, ground water source, or ground source heat pump system that exceeds the energy efficiency requirements of the 2012 or 2015 (applicable from 01/01/2016) International Energy Conservation Code (IECC), depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

### DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air cooled, water source, ground water source, or ground source heat pump system that meets the energy efficiency requirements of the 2012 or 2015 IECC, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015). Note the Time of Sale baseline is assumed to be IECC 2015. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.<sup>292</sup>

### DEEMED MEASURE COST

For analysis purposes, the incremental capital cost for this measure is assumed as \$100 per ton for air-cooled units.<sup>293</sup> The incremental cost for all other equipment types should be determined on a site-specific basis.

### LOADSHAPE

Loadshape C05 - Commercial 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.

CF<sub>SSP</sub> = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)  
= 91.3%<sup>294</sup>

CF<sub>PJM</sub> = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)  
= 47.8%<sup>295</sup>

<sup>292</sup>Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

<sup>293</sup> Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California.

<sup>294</sup> 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.

<sup>295</sup> Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

For units with cooling capacities less than 65 kBtu/hr:

$$\Delta \text{kWh} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\text{Annual kWh Savings}_{\text{cool}} = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{SEER}_{\text{base}}) - (1/\text{SEER}_{\text{ee}})] * \text{EFLH}_{\text{cool}}$$

$$\text{Annual kWh Savings}_{\text{heat}} = (\text{kBtu/hr}_{\text{heat}}) * [(1/\text{HSPF}_{\text{base}}) - (1/\text{HSPF}_{\text{ee}})] * \text{EFLH}_{\text{heat}}$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta \text{kWh} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\text{Annual kWh Savings}_{\text{cool}} = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{EFLH}_{\text{cool}}$$

$$\text{Annual kWh Savings}_{\text{heat}} = (\text{kBtu/hr}_{\text{heat}})/3.412 * [(1/\text{COP}_{\text{base}}) - (1/\text{COP}_{\text{ee}})] * \text{EFLH}_{\text{heat}}$$

Where:

- $\text{kBtu/hr}_{\text{cool}}$  = capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).  
 = Actual installed
- $\text{SEER}_{\text{base}}$  = Seasonal Energy Efficiency Ratio of the baseline equipment  
 = SEER from tables below, based on the applicable IECC on the date of the building permit (if unknown assume IECC 2015).
- $\text{SEER}_{\text{ee}}$  = Seasonal Energy Efficiency Ratio of the energy efficient equipment.  
 = Actual installed
- $\text{EFLH}_{\text{cool}}$  = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.
- $\text{HSPF}_{\text{base}}$  = Heating Seasonal Performance Factor of the baseline equipment  
 = HSPF from tables below, based on the applicable IECC on the date of the building permit (if unknown assume IECC 2015).
- $\text{HSPF}_{\text{ee}}$  = Heating Seasonal Performance Factor of the energy efficient equipment.  
 = Actual installed. If rating is COP,  $\text{HSPF} = \text{COP} * 3.413$
- $\text{EFLH}_{\text{heat}}$  = heating mode equivalent full load hours are provided in section 4.4 HVAC End Use.
- $\text{EER}_{\text{base}}$  = Energy Efficiency Ratio of the baseline equipment  
 = EER from tables below, based on the applicable IECC on the date of the building permit (if unknown assume IECC 2015).. For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:<sup>296</sup>  

$$\text{EER} = (-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$$
- $\text{EER}_{\text{ee}}$  = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual  $\text{EER}_{\text{ee}}$  is unknown, assume the conversion from SEER to EER as provided above.

over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year  
<sup>296</sup> Based on 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.

	= Actual installed
kBtu/hr <sub>heat</sub>	= capacity of the heating equipment in kBtu per hour.
	= Actual installed
3.412	= Btu per Wh.
COP <sub>base</sub>	= coefficient of performance of the baseline equipment
	= COP from tables below, based on the applicable IECC on the date of the building permit (if unknown assume IECC 2015). If rating is HSPF, COP = HSPF / 3.413
COP <sub>ee</sub>	= coefficient of performance of the energy efficient equipment.
	= Actual installed

Minimum Efficiency Requirements: 2012 IECC

TABLE C403.2.3(2)  
 MINIMUM EFFICIENCY REQUIREMENTS:  
 ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE <sup>a</sup>
Air cooled (cooling mode)	< 65,000 Btu/h <sup>2</sup>	All	Split System	13.0 SEER	AHRI 210/240
			Single Packaged	13.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h <sup>2</sup>	All	Split System	13.0 SEER	
			Single Packaged	13.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h <sup>2</sup>	All	Split System	10.0 SEER	
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 10.7 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	
Water source (cooling mode)	< 17,000 Btu/h	All	86°F entering water	11.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	12.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	12.0 EER	
Ground water source (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.2 EER	
		All	77°F entering water	13.4 EER	
Water-source water to water (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	
			59°F entering water	16.3 EER	
Ground water source Brine to water (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	
Air cooled (heating mode)	< 65,000 Btu/h <sup>2</sup>	—	Split System	7.7 HSPF	AHRI 210/240
		—	Single Package	7.7 HSPF	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h <sup>2</sup> (cooling capacity)	—	Split System	7.4 HSPF	
		—	Single Package	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h <sup>2</sup>	—	Split System	6.8 HSPF	

(continued)

TABLE C403.2.3(2)—continued  
 MINIMUM EFFICIENCY REQUIREMENTS:  
 ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE*
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.3 COP	AHRI 340/360
			17°F db/15°F wb Outdoor Air	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.2 COP	
			17°F db/15°F wb Outdoor Air	2.05 COP	
Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.2 COP	ISO 13256-1
Ground water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.6 COP	
Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.1 COP	
Water-source water to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO 13256-2
		—	50°F entering water	3.1 COP	
Ground source brine to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

Minimum Efficiency Requirements: 2015 IECC

TABLE C403.2.3(2)  
 MINIMUM EFFICIENCY REQUIREMENTS:  
 ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE <sup>a</sup>
				Before 1/1/2016	As of 1/1/2016	
Air cooled (cooling mode)	< 65,000 Btu/h <sup>b</sup>	All	Split System	13.0 SEER <sup>c</sup>	14.0 SEER <sup>c</sup>	AHRI 210/240
			Single Package	13.0 SEER <sup>c</sup>	14.0 SEER <sup>c</sup>	
Through-the-wall, air cooled	≤ 30,000 Btu/h <sup>b</sup>	All	Split System	12.0 SEER	12.0 SEER	
			Single Package	12.0 SEER	12.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h <sup>b</sup>	All	Split System	11.0 SEER	11.0 SEER	
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 12.0 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 11.8 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 10.7 IEER	10.6 EER 11.6 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	10.4 EER 11.4 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 10.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	9.3 EER 9.4 IEER	
Water to Air: Water Loop (cooling mode)	< 17,000 Btu/h	All	86°F entering water	12.2 EER	12.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	13.0 EER	13.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	13.0 EER	13.0 EER	
Water to Air: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	18.0 EER	18.0 EER	ISO 13256-1
Brine to Air: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering water	14.1 EER	14.1 EER	ISO 13256-1
Water to Water: WaterLoop (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	10.6 EER	ISO 13256-2
Water to Water: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.3 EER	16.3 EER	
Brine to Water: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	12.1 EER	

(continued)

TABLE C403.2.3(2)—continued  
 MINIMUM EFFICIENCY REQUIREMENTS:  
 ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE <sup>d</sup>
				Before 1/1/2016	As of 1/1/2016	
Air cooled (heating mode)	< 65,000 Btu/h <sup>b</sup>	—	Split System	7.7 HSPF <sup>c</sup>	8.2 HSPF <sup>c</sup>	AHRI 210/240
		—	Single Package	7.7 HSPF <sup>c</sup>	8.0 HSPF <sup>c</sup>	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h <sup>b</sup> (cooling capacity)	—	Split System	7.4 HSPF	7.4 HSPF	
		—	Single Package	7.4 HSPF	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h <sup>b</sup>	—	Split System	6.8 HSPF	6.8 HSPF	
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb outdoor air	3.3 COP	3.3 COP	
		—	17°F db/15°F wb outdoor air	2.25 COP	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb outdoor air	3.2 COP	3.2 COP	
		—	17°F db/15°F wb outdoor air	2.05 COP	2.05 COP	
Water to Air: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.3 COP	4.3 COP	ISO 13256-1
Water to Air: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.7 COP	3.7 COP	
Brine to Air: Ground Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.2 COP	3.2 COP	
Water to Water: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	3.7 COP	ISO 13256-2
Water to Water: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.1 COP	3.1 COP	
Brine to Water: Ground Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	2.5 COP	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

- a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
- b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.
- c. Minimum efficiency as of January 1, 2015.

For example a 5 ton cooling unit with 60 kbtu heating, an efficient EER of 14, and an efficient HSPF of 9, at a restaurant in Chicago with a building permit dated before 1/1/2016 saves:

$$\begin{aligned} \Delta kWh &= [(60) * [(1/13) - (1/14)] * 1134] + [(60) * [(1/7.7) - (1/9)] * 1354] \\ &= 1898 \text{ kWh} \end{aligned}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{CF}$$

Where CF value is chosen between:

$$\begin{aligned} \text{CF}_{\text{SSP}} &= \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} \\ &= 91.3\%^{297} \end{aligned}$$

$$\begin{aligned} \text{CF}_{\text{PJM}} &= \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \\ &= 47.8\%^{298} \end{aligned}$$

For example a 5 ton cooling unit with 60 kbtu heating, an efficient EER of 14, and an efficient HSPF of 9 saves:

$$\begin{aligned} \Delta kW &= [(60) * [(1/13) - (1/14)] * .913] \\ &= 0.3 \end{aligned}$$

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-HPSY-V04-160601**

<sup>297</sup> 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.

<sup>298</sup> 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

#### 4.4.10 High Efficiency Boiler

##### DESCRIPTION

To qualify for this measure the installed equipment must be replacement of an existing boiler at the end of its service life, in a commercial or multifamily space with a high efficiency, gas-fired steam or hot water boiler. High efficiency boilers achieve gas savings through the utilization of a sealed combustion chamber and multiple heat exchangers that remove a significant portion of the waste heat from flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, some of the flue gasses condense and must be drained.

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

##### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a boiler used 80% or more for space heating, not process, and boiler AFUE, TE (thermal efficiency), or Ec (combustion efficiency) rating must be rated greater than or equal to 85% for hot water boilers and 81% for steam boilers.

##### DEFINITION OF BASELINE EQUIPMENT

Dependent on when the unit is installed and whether the unit is hot water or steam. The baseline efficiency source is the Energy Independence and Security Act of 2007 with technical amendments from Federal Register, volume 73, Number 145, Monday, July 28, 2008 for boilers <300,000 Btu/hr and is Final Rule, Federal Register, volume 74, Number 139, Wednesday, July 22, 2009 for boiler ≥300,000 Btu/hr.

Hot water boiler baseline:

Year	Efficiency
Hot Water <300,000 Btu/hr < June 1, 2013 <sup>299</sup>	80% AFUE
Hot Water <300,000 Btu/hr ≥ June 1, 2013	82% AFUE
Hot Water ≥300,000 & ≤2,500,000 Btu/hr	80% TE
Hot Water >2,500,000 Btu/hr	82% Ec

<sup>299</sup> The Federal baseline for boilers <300,000 btu/hr changes from 80% to 82% in September 2012. To prevent a change in baseline mid-program, the increase in efficiency is delayed until June 2013 when a new program year starts.

Steam boiler baseline:

Year	Efficiency
Steam <300,000 Btu/hr < June 1, 2013 <sup>300</sup>	75% AFUE
Steam <300,000 Btu/hr ≥ June 1, 2013	80% AFUE
Steam - all except natural draft ≥300,000 & ≤2,500,000 Btu/hr	79% TE
Steam - natural draft ≥300,000 & ≤2,500,000 Btu/hr	77% TE
Steam - all except natural draft >2,500,000 Btu/hr	79% TE
Steam - natural draft >2,500,000 Btu/hr	77% TE

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 20 years<sup>301</sup>

**DEEMED MEASURE COST**

The incremental capital cost for this measure depends on efficiency as listed below<sup>302</sup>

Measure Tier	Incr. Cost, per unit
ENERGY STAR® Minimum	\$1,470
AFUE 90%	\$2,400
AFUE 95%	\$3,370
AFUE ≥ 96%	\$4,340
Boilers > 300,000 Btu/hr with TE (thermal efficiency) rating	Custom

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

<sup>300</sup> Ibid.

<sup>301</sup> The Technical support documents for federal residential appliance standards: [http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/pdfs/fb\\_fr\\_tsd/appendix\\_e.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf) Note that this value is below the 20 years used by CA's DEER and the range of 20-40 year estimate made by the Consortium for Energy Efficiency in 2010

<sup>302</sup> Average of low and high incremental cost based on Nicor Gas program data for non-condensing and condensing boilers. Nicor Gas Energy Efficiency Plan 2011 - 2014, May 27, 2011 \$1,470 for ≤ 300,000 Btu/hr for non-condensing hydronic boilers >85% AFUE & \$3,365 for condensing boilers > 90% AFUE. The exception is \$4,340 for AFUE ≥ 96% AFUE which was obtained from extrapolation above the size range that Nicor Gas Energy Efficiency Plan provided for incremental cost.

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

$$\Delta\text{Therms} = \text{EFLH} * \text{Capacity} * ((\text{EfficiencyRating}(\text{actual}) - \text{EfficiencyRating}(\text{base})) / \text{EfficiencyRating}(\text{base})) / 100,000$$

Where:

- EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use
- Capacity = Nominal Heating Input Capacity Boiler Size (Btu/hr) for efficient unit not existing unit  
 = custom Boiler input capacity in Btu/hr
- EfficiencyRating(base) = Baseline Boiler Efficiency Rating, dependant on year and boiler type. Baseline efficiency values by boiler type and capacity are found in the Definition of Baseline Equipment Section
- EfficiencyRating(actual) = Efficient Boiler Efficiency Rating use actual value

Measure Type	Actual AFUE
ENERGY STAR® Minimum	85%
AFUE 90%	90%
AFUE 95%	95%
AFUE ≥ 96%	≥ 96%
Custom	Value to one significant digit i.e. 95.7%

**EXAMPLE**

For example, a 150,000 btu/hr water boiler meeting AFUE 90% in Rockford at a high rise office building , in the year 2012

$$\begin{aligned} \Delta\text{Therms} &= 2,089 * 150,000 * (0.90-0.80)/0.80 / 100,000 \text{ Btu/Therm} \\ &= 392 \text{ Therms} \end{aligned}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-BOIL-V05-150601**

## 4.4.11 High Efficiency Furnace

### DESCRIPTION

This measure covers the installation of a high efficiency gas furnace in lieu of a standard efficiency gas furnace in a commercial or industrial space. High efficiency gas furnaces achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, most of the flue gasses condense and must be drained. Furnaces equipped with ECM fan motors can save additional electric energy

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

Time of sale:

- a. The installation of a new high efficiency, gas-fired condensing furnace in a commercial location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system.

Early replacement:

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (<\$528)<sup>303</sup>.
- All other conditions will be considered Time of Sale.

The Baseline AFUE of the existing unit replaced:

- If the AFUE of the existing unit is known and  $\leq 75\%$ , the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is  $>75\%$ , the Baseline AFUE = 80%.
- If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
- If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a furnace with input energy less than 225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating and fan electrical efficiency exceeding the program requirements:

### DEFINITION OF BASELINE EQUIPMENT

Time of Sale: Although the current Federal Standard for gas furnaces is an AFUE rating of 78%, based upon review of available product in the AHRI database, the baseline efficiency for this characterization is assumed to be 80%. The baseline will be adjusted when the Federal Standard is updated.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life. As discussed above we estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%

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<sup>303</sup> The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

**DEFINITION OF MEASURE LIFE**

The expected measure life is assumed to be 16.5 years<sup>304</sup>  
 Remaining life of existing equipment is assumed to be 5.5 years<sup>305</sup>.

**DEEMED MEASURE COST**

Time of Sale: The incremental capital cost for this measure depends on efficiency as listed below<sup>306</sup>:

AFUE	Installation Cost	Incremental Install Cost
80%	\$2011	n/a
90%	\$2641	\$630
91%	\$2727	\$716
92%	\$2813	\$802
93%	\$3049	\$1,038
94%	\$3286	\$1,275
95%	\$3522	\$1,511
96%	\$3758	\$1,747

Early Replacement: The full installation cost is provided in the table above. The assumed deferred cost (after 5.5 years) of replacing existing equipment with a new baseline unit is assumed to be \$2876<sup>307</sup>. This cost should be discounted to present value using the utilities’ discount rate.

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \text{Heating Savings} + \text{Cooling Savings} + \text{Shoulder Season Savings}$$

Where:

$$\text{Heating Savings} = \text{Brushless DC motor or Electronically commutated motor (ECM)}$$

<sup>304</sup> Average of 15-18 year lifetime estimate made by the Consortium for Energy Efficiency in 2010.

<sup>305</sup> Assumed to be one third of effective useful life

<sup>306</sup> Based on data from 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](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.

<sup>307</sup> \$2641 inflated using 1.91% rate.

= 418 kWh<sup>308</sup>

Cooling Savings = Brushless DC motor or electronically commutated motor (ECM) savings during cooling season

If air conditioning = 263 kWh

If no air conditioning = 175 kWh

If unknown (weighted average)= 241 kWh<sup>309</sup>

Shoulder Season Savings = Brushless DC motor or electronically commutated motor (ECM) savings during shoulder seasons

= 51 kWh

**EXAMPLE**

For example, a blower motor in a low rise office building where air conditioning presence is unknown:

$$\begin{aligned} \Delta\text{kWh} &= \text{Heating Savings} + \text{Cooling Savings} + \text{Shoulder Season Savings} \\ &= 418 + 241 + 51 \\ &= 710 \text{ kWh} \end{aligned}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

For units that have evaporator coils and condensing units and are cooling in the summer in addition to heating in the winter the summer coincident peak demand savings should be calculated. If the unit is not equipment with coils or condensing units, the summer peak demand savings will not apply.

$$\Delta\text{kW} = (\text{CoolingSavings}/\text{HOURSyear}) * \text{CF}$$

Where:

HOURSyear = Actual hours per year if known, otherwise use hours from Table below for building type<sup>310</sup>.

Building Type	HOURSyear
Assembly	2150
Assisted Living	4373
College	1605
Convenience Store	2084
Elementary School	3276
Garage	2102
Grocery	2096
Healthcare Clinic	1987
High School	3141

<sup>308</sup> To estimate heating, cooling and shoulder season savings for Illinois, VEIC adapted results from a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin. This study included effects of behavior change based on the efficiency of new motor greatly increasing the amount of people that run the fan continuously. The savings from the Wisconsin study were adjusted to account for different run hour assumptions (average values used) for Illinois. See: FOE to IL Blower Savings.xlsx.

<sup>309</sup> The weighted average value is based on assumption that 75% of buildings installing BPM furnace blower motors have Central AC.

<sup>310</sup> Hours per year are estimated using the eQuest models as the total number of hours the cooling system is operating for each building type.

Hospital - VAV econ	2788
Hospital - CAV econ	2881
Hospital - CAV no econ	8760
Hospital - FCU	8729
Manufacturing Facility	2805
MF - High Rise	4237
MF - Mid Rise	2899
Hotel/Motel – Guest	4479
Hotel/Motel - Common	8712
Movie Theater	2120
Office - High Rise - VAV econ	2038
Office - High Rise - CAV econ	4849
Office - High Rise - CAV no econ	5682
Office - High Rise - FCU	3069
Office - Low Rise	2481
Office - Mid Rise	1881
Religious Building	2830
Restaurant	3350
Retail - Department Store	2528
Retail - Strip Mall	2266
Warehouse	770
Unknown	2718

CF =Summer Peak Coincidence Factor for measure is provided below for different building types<sup>311</sup>:

HVAC Pumps	CF
Assembly	48.3%
Assisted Living	52.9%
College	14.2%
Convenience Store	57.1%
Elementary School	33.3%
Garage	61.9%
Grocery	47.5%
Healthcare Clinic	61.9%
High School	28.8%
Hospital - VAV econ	57.6%
Hospital - CAV econ	61.5%
Hospital - CAV no econ	64.8%
Hospital - FCU	60.9%
Manufacturing Facility	43.3%
MF - High Rise - Common	43.7%
MF - Mid Rise	24.3%
Hotel/Motel - Guest	62.9%
Hotel/Motel - Common	64.6%

<sup>311</sup> Coincidence Factors are estimated using the eQuest models..

HVAC Pumps	CF
Movie Theater	41.9%
Office - High Rise - VAV econ	43.2%
Office - High Rise - CAV econ	48.3%
Office - High Rise - CAV no econ	50.3%
Office - High Rise - FCU	46.2%
Office - Low Rise	47.4%
Office - Mid Rise	42.8%
Religious Building	43.3%
Restaurant	48.8%
Retail - Department Store	50.5%
Retail - Strip Mall	52.8%
Warehouse	22.5%
Unknown	42.4%

**EXAMPLE**

For example, a blower motor in an low rise office building where air conditioning presence is unknown:

$$\begin{aligned} \Delta kW &= (241 / 2481) * 0.474 \\ &= 0.05 \text{ kW} \end{aligned}$$

**NATURAL GAS ENERGY SAVINGS**

Time of Sale:

$$\Delta \text{Therms} = \text{EFLH} * \text{Capacity} * ((\text{AFUE}(\text{eff}) - \text{AFUE}(\text{base})) / \text{AFUE}(\text{base})) / 100,000 \text{ Btu/Therm}$$

Early replacement<sup>312</sup>:

$\Delta$ Therms for remaining life of existing unit (1st 5.5 years):

$$\Delta \text{Therms} = \text{EFLH} * \text{Capacity} * ((\text{AFUE}(\text{eff}) - \text{AFUE}(\text{exist})) / \text{AFUE}(\text{exist})) / 100,000 \text{ Btu/Therm}$$

$\Delta$ Therms for remaining measure life (next 11 years):

$$\Delta \text{Therms} = \text{EFLH} * \text{Capacity} * ((\text{AFUE}(\text{eff}) - \text{AFUE}(\text{base})) / \text{AFUE}(\text{base})) / 100,000 \text{ Btu/Therm}$$

Where:

- EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use
- Capacity = Nominal Heating Input Capacity Furnace Size (Btu/hr) for efficient unit not existing unit  
 = custom Furnace input capacity in Btu/hr
- AFUE(exist) = Existing Furnace Annual Fuel Utilization Efficiency Rating

<sup>312</sup> 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).

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

If unknown, assume 64.4 AFUE%<sup>313</sup>.

AFUE(base) = Baseline Furnace Annual Fuel Utilization Efficiency Rating, dependant on year as listed below:

Dependent on program type as listed below<sup>314</sup>:

Program Year	AFUE(base)
Time of Sale	80%
Early Replacement	90%

AFUE(eff) = Efficient Furnace Annual Fuel Utilization Efficiency Rating.

= Actual. If Unknown, assume 95%<sup>315</sup>

**EXAMPLE**

For example, a 150,000 btu/hr 92% efficient furnace at a low rise office building in Rockford, in the year 2012

$$\Delta\text{Therms} = 1428 * 150,000 * ((0.92-0.80)/0.80) / 100,000$$

$$= 321 \text{ Therms}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-FRNC-V06-160601**

<sup>313</sup> Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

<sup>314</sup> Though the Federal Minimum AFUE is 78%, there were only 50 models listed in the AHRI database at that level. At AFUE 79% the total rises to 308. There are 3,548 active furnace models listed with AFUE ratings between 78 and 80.

<sup>315</sup> Minimum ENERGY STAR efficiency after 2.1.2012.

## 4.4.12 Infrared Heaters (all sizes), Low Intensity

### DESCRIPTION

This measure applies to natural gas fired low-intensity infrared heaters with an electric ignition that use non-conditioned air for combustion

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

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a natural gas heater with an electric ignition that uses non-conditioned air for combustion

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard natural gas fired heater warm air heater.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years<sup>316</sup>

### DEEMED MEASURE COST

The incremental capital cost for this measure is \$1716<sup>317</sup>

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

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### Algorithm

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### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

N/A

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

#### NATURAL GAS ENERGY SAVINGS

The annual natural gas energy savings from this measure is a deemed value equaling 451 Therms<sup>318</sup>

<sup>316</sup>ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

<sup>317</sup>Ibid.

<sup>318</sup>Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011. These deemed values should be compared to PY evaluation and revised as necessary.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-IRHT-V01-120601**

## 4.4.13 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

### DESCRIPTION

A PTAC is a packaged terminal air conditioner that cools and sometimes provides heat through an electric resistance heater (heat strip). A PTHP is a packaged terminal heat pump. A PTHP uses its compressor year round to heat or cool. In warm weather, it efficiently captures heat from inside your building and pumps it outside for cooling. In cool weather, it captures heat from outdoor air and pumps it into your home, adding heat from electric heat strips as necessary to provide heat.

This measure characterizes:

- a) Time of Sale: the purchase and installation of a new efficient PTAC or PTHP.
- b) Early Replacement: the early removal of an existing PTAC or PTHP from service, prior to its natural end of life, and replacement with a new efficient PTAC or PTHP unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life. The measure is only valid for non-fuel switching installations – for example replacing a cooling only PTAC with a PTHP can currently not use the TRM.

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 is assumed to be PTACs or PTHPs that exceed baseline efficiencies.

### DEFINITION OF BASELINE EQUIPMENT

Time of Sale: the baseline conditions is provided in the Federal Baseline reference table provided below.

Early Replacement: the baseline is the existing PTAC or PTHP for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.<sup>319</sup>

Remaining life of existing equipment is assumed to be 5 years<sup>320</sup>

### DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this equipment is estimated to be \$84/ton.<sup>321</sup>

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unknown assume \$1,047 per ton<sup>322</sup>.

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be \$1,039 per ton<sup>323</sup>. This cost should be discounted to present value using the utilities' discount rate.

<sup>319</sup> Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

<sup>320</sup>Standard assumption of one third of effective useful life.

<sup>321</sup> DEER 2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation

<sup>322</sup> Based on DCEO – IL PHA Efficient Living Program data.

<sup>323</sup> Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

**LOADSHAPE**

Loadshape C03 - Commercial 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.

$$\begin{aligned} CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} \\ &= 91.3\% \text{ }^{324} \end{aligned}$$

$$\begin{aligned} CF_{PJM} &= \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \\ &= 47.8\% \text{ }^{325} \end{aligned}$$

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**Algorithm**


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**CALCULATION OF SAVINGS****ELECTRIC ENERGY SAVINGS**

Electric savings for PTACs and PTHPs should be calculated using the following algorithms

**ENERGY SAVINGS**

Time of Sale:

$$\text{PTAC } \Delta \text{kWh}^{326} = \text{Annual kWh Savings}_{\text{Scool}}$$

$$\text{PTHP } \Delta \text{kWh} = \text{Annual kWh Savings}_{\text{Scool}} + \text{Annual kWh Savings}_{\text{Sheat}}$$

$$\text{Annual kWh Savings}_{\text{Scool}} = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{EFLH}_{\text{cool}}$$

$$\text{Annual kWh Savings}_{\text{Sheat}} = (\text{kBtu/hr}_{\text{heat}})/3.412 * [(1/\text{COP}_{\text{base}}) - (1/\text{COP}_{\text{ee}})] * \text{EFLH}_{\text{heat}}$$

Early Replacement:

$$\Delta \text{kWh for remaining life of existing unit (1}^{\text{st}} \text{ 5 years)} = \text{Annual kWh Savings}_{\text{Scool}} + \text{Annual kWh Savings}_{\text{Sheat}}$$

$$\text{Annual kWh Savings}_{\text{Scool}} = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{exist}}) - (1/\text{EER}_{\text{ee}})] * \text{EFLH}_{\text{cool}}$$

$$\text{Annual kWh Savings}_{\text{Sheat}} = (\text{kBtu/hr}_{\text{heat}})/3.412 * [(1/\text{COP}_{\text{exist}}) - (1/\text{COP}_{\text{ee}})] * \text{EFLH}_{\text{heat}}$$

$$\Delta \text{kWh for remaining measure life (next 10 years)} = \text{Annual kWh Savings}_{\text{Scool}} + \text{Annual kWh Savings}_{\text{Sheat}}$$

$$\text{Annual kWh Savings}_{\text{Scool}} = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{EFLH}_{\text{cool}}$$

<sup>324</sup> 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.

<sup>325</sup> 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

<sup>326</sup> There are no heating efficiency improvements for PTACs since although some do provide heating, it is always through electric resistance and therefore the COP<sub>base</sub> and COP<sub>ee</sub> would be 1.0.

$$\text{Annual kWh Savings}_{\text{heat}} = (\text{kBtu/hr}_{\text{heat}})/3.412 * [(1/\text{COP}_{\text{base}}) - (1/\text{COP}_{\text{ee}})] * \text{EFLH}_{\text{heat}}$$

Where:

- $\text{kBtu/hr}_{\text{cool}}$  = capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).  
= Actual installed
- $\text{EFLH}_{\text{cool}}$  = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use:
- $\text{EFLH}_{\text{heat}}$  = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use
- $\text{EER}_{\text{exist}}$  = Energy Efficiency Ratio of the existing equipment  
= Actual. If unknown assume 8.1  $\text{EER}^{327}$
- $\text{EER}_{\text{base}}$  = Energy Efficiency Ratio of the baseline equipment; see the table below for values.  
= Based on applicable IECC code on date of building permit (if unknown assume IECC 2015).

Copy of Table C403.2.3(3): Minimum Efficiency Requirements: Electrically operated packaged terminal air conditioners, packaged terminal heat pumps

Equipment Type	IECC 2012 Minimum Efficiency	IECC 2015 Minimum Efficiency
PTAC (Cooling mode) New Construction	13.8 – (0.300 x Cap/1000) EER	14.0 – (0.300 x Cap/1000) EER
PTAC (Cooling mode) Replacements	10.9 – (0.213 x Cap/1000) EER	10.9 – (0.213 x Cap/1000) EER
PTHP (Cooling mode) New Construction	14.0 – (0.300 x Cap/1000) EER	14.0 – (0.300 x Cap/1000) EER
PTHP (Cooling mode) Replacements	10.8 – (0.213 x Cap/1000) EER	10.8 – (0.213 x Cap/1000) EER
PTHP (Heating mode) New Construction	3.2 – (0.026 x Cap/1000) COP	3.2 – (0.026 x Cap/1000) COP
PTHP (Heating mode) Replacements	2.9 – (0.026 x Cap/1000) COP	2.9 – (0.026 x Cap/1000) COP

“Cap” = The rated cooling capacity of the project in Btu/hr. If the units capacity is less than 7000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit’s capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculations.

Replacement unit shall be factory labeled as follows “MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS”, Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm) in width.

- $\text{EER}_{\text{ee}}$  = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual  $\text{EER}_{\text{ee}}$  is unknown, assume the following conversion from SEER to EER for calculation of peak savings<sup>328</sup>:  $\text{EER} = (-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$

<sup>327</sup> 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;  $\text{EER} = 10 - (0.16 * 12,000/1,000) = 8.1$ .

<sup>328</sup> Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy

	= Actual installed
kBtu/hr <sub>heat</sub>	= capacity of the heating equipment in kBtu per hour.
	= Actual installed
3.412	= Btu per Wh.
COP <sub>exist</sub>	= coefficient of performance of the existing equipment
	= Actual. If unknown assume 1.0 COP for PTAC units and 2.6 COP <sup>329</sup> for PTHPs.
COP <sub>base</sub>	= coefficient of performance of the baseline equipment; see table above for values.
COP <sub>ee</sub>	= coefficient of performance of the energy efficient equipment.
	= Actual installed

**EXAMPLE:**

Time of Sale (assuming new construction baseline):

For example a 1 ton PTAC with an efficient EER of 12 at a guest hotel in Rockford with a building permit dated before 1/1/2016 saves:

$$= [(12) * [(1/10.2) - (1/12)] * 1,042$$

$$= 184 \text{ kWh}$$

Early Replacement (assuming replacement baseline for deferred replacement in 5 years):

For example a 1 ton PTHP with an efficient EER of 12, COP of 3.0 at a guest hotel in Rockford replaces a PTAC unit (with electric resistance heat) with unknown efficiency.

$\Delta$ kWh for remaining life of existing unit (1<sup>st</sup> 5years)

$$= (12 * (1/8.1 - 1/12) * 1,042) + (12/3.412 * (1/1.0 - 1/3.0) * 1,758)$$

$$= 502 + 4,122$$

$$= 4,624 \text{ kWh}$$

$\Delta$ kWh for remaining measure life (next 10 years)

$$= (12 * (1/8.3 - 1/12) * 1,042) + (12/3.412 * (1/1.0 - 1/3.0) * 1,758)$$

$$= 465 + 4,122$$

$$= 34,587 \text{ kWh}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Time of Sale:

$$\Delta kW = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{CF}$$

Early Replacement:

$$\Delta kW \text{ for remaining life of existing unit (1}^{\text{st}} \text{ 5years)} = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{exist}}) - (1/\text{EER}_{\text{ee}})] * \text{CF}$$

Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

<sup>329</sup>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; COP = 2.9 - (0.026 \* 12,000/1,000) = 2.6

$$\Delta kW \text{ for remaining measure life (next 10 years)} = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{CF}$$

Where:

$$\begin{aligned} \text{CF}_{\text{SSP}} &= \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} \\ &= 91.3\%^{330} \end{aligned}$$

$$\begin{aligned} \text{CF}_{\text{PJM}} &= \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \\ &= 47.8\%^{331} \end{aligned}$$

#### EXAMPLE

Time of Sale:

For example a 1 ton replacement cooling unit with no heating with an efficient EER of 12 saves:

$$\begin{aligned} \Delta kW_{\text{SSP}} &= (12 * (1/10.2 - 1/12) * 0.913) \\ &= 0.16 \text{ kW} \end{aligned}$$

For example a 1 ton PTHP with an efficient EER of 12, COP of 3.0 replacing a PTAC unit with unknown efficiency saves:

$\Delta kW$  for remaining life of existing unit (1<sup>st</sup> 5 years):

$$\begin{aligned} \Delta kW_{\text{SSP}} &= 12 * (1/8.1 - 1/12) * 0.913 \\ &= 0.44 \text{ kW} \end{aligned}$$

$\Delta kW$  for remaining measure life (next 10 years):

$$\begin{aligned} \Delta kW_{\text{SSP}} &= 12 * (1/8.3 - 1/12) * 0.913 \\ &= 0.41 \text{ kW} \end{aligned}$$

#### NATURAL GAS ENERGY SAVINGS

N/A

#### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

#### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

**MEASURE CODE: CI-HVC-PTAC-V07-160601**

<sup>330</sup> 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.

<sup>331</sup> 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

## 4.4.14 Pipe Insulation

### DESCRIPTION

This measure provides rebates for installation of  $\geq 1''$  or  $\geq 2''$  fiberglass, foam, calcium silicate or other types of insulation with similar insulating properties to existing bare pipe on straight piping as well as other pipe components such as elbows, tees, valves, and flanges for all non-residential installations.

Default per linear foot savings estimates are provided for the both exposed indoor or above ground outdoor piping distributing fluid in the following system types (natural gas fired systems only):

- Hydronic heating systems (with or without outdoor reset controls), including:
  - boiler systems that do not circulate water around a central loop and operate upon demand from a thermostat (“non-recirculation”)
  - systems that recirculate during heating season only (“Recirculation – heating season only”)
  - systems recirculating year round (“Recirculation – year round”)
- Domestic hot water
- Low and high-pressure steam systems
  - non-recirculation
  - recirculation - heating season only
  - recirculation - year round

Process piping can also use the algorithms provided but requires custom entry of hours.

Minimum qualifying nominal pipe diameter is 1.” Indoor piping must have at least 1” of insulation and outdoor piping must have at least 2” of insulation and include an all-weather protective jacket. New advanced insulating materials may be thinner and savings can be calculated with 3E Plus.

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

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

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is installing pipe wrap insulation to a length of pipe. Indoor piping must have at least 1” of insulation (or equivalent R-value) and outdoor piping must have at least 2” of insulation (or equivalent R-value) and include an all-weather protective jacket. Minimum qualifying pipe diameter is 1.” Insulation must be continuous and contiguous over fittings that directly connect to straight pipe, including elbows and tees.<sup>332</sup>

### DEFINITION OF BASELINE EQUIPMENT

The base case for savings estimates is a bare pipe. Pipes are required by new construction code to be insulated but are still commonly found uninsulated in older commercial buildings.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.<sup>333</sup>

### DEEMED MEASURE COST

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means<sup>334</sup> pricing

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<sup>332</sup> ASHRAE Handbook—Fundamentals, 23.14; Hart, G., “Saving energy by insulating pipe components on steam and hot water distribution systems”, *ASHRAE Journal*, October 2011

<sup>333</sup> Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. [http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure\\_life\\_GDS%5B1%5D.pdf](http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf)

<sup>334</sup> RS Means 2008. Mechanical Cost Data, pages 106 to 119

reference materials may be used.<sup>335</sup> The following table summarizes the estimated costs for this measure per foot of insulation added and include installation costs:

Insulation Thickness		
	1 Inch (Indoor)	2 Inches (Outdoor)
Pipe- RS Means #	220719.10.5170	220719.10.5530
Jacket- RS Means #	220719.10.0156	220719.10.0320
Jacket Type	PVC	Aluminum
Insulation Cost per foot	\$9.40	\$13.90
Jacket Cost per foot	\$4.57	\$7.30
<b>Total Cost per foot</b>	<b>\$13.97</b>	<b>\$21.20</b>

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

$$\begin{aligned} \Delta \text{therms per foot}^{336} &= [((Q_{\text{base}} - Q_{\text{eff}}) * \text{EFLH}) / (100,000 * \eta_{\text{Boiler}})] * \text{TRF} \\ &= [\text{Modeled or provided by tables below}] * \text{TRF} \\ \Delta \text{therms} &= (L_{\text{sp}} + L_{\text{oc,i}}) * \Delta \text{therms per foot} \end{aligned}$$

Where:

- EFLH = Equivalent Full Load Hours for Heating
- = Actual or defaults by building type provided in Section 4.4, HVAC end use

<sup>335</sup> RS Means 2010: "for fittings, add 3 linear feet for each fitting plus 4 linear feet for each flange of the fitting"

<sup>336</sup>This value comes from the reference table "Savings Summary by Building Type and System Type." The formula and the input tables in this section document assumptions used in calculation spreadsheet "Pipe Insulation Savings 2013-11-12.xlsx"

For year round recirculation or domestic hot water:

= 8,766

For heating season recirculation, hours with the outside air temperature below 55°F:

Zone	Hours
Zone 1 (Rockford)	5,039
Zone 2 (Chicago)	4,963
Zone 3 (Springfield)	4,495
Zone 4 (Belleville/	4,021
Zone 5 (Marion)	4,150
Zone 1 (Rockford)	5,039

- $Q_{base}$  = Heat Loss from Bare Pipe (Btu/hr/ft)  
 = Calculated where possible using 3E Plusv4.0 software. For defaults see table below
- $Q_{eff}$  = Heat Loss from Insulated Pipe (Btu/hr/ft)  
 = Calculated where possible using 3E Plusv4.0 software. For defaults see table below
- 100,000 = conversion factor (1 therm = 100,000 Btu)
- $\eta_{Boiler}$  = Efficiency of the boiler being used to generate the hot water or steam in the pipe  
 = Actual or if unknown use default values given below:  
 = 81.9% for water boilers <sup>337</sup>  
 = 80.7% for steam boilers, except multifamily low-pressure <sup>338</sup>  
 = 64.8% for multifamily low-pressure steam boilers <sup>339</sup>
- TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from  $\Delta$ therms/ft tables below <sup>340</sup>  
 = See table below for base TRF values by pipe location  
 May vary seasonally such as: TRF[summer] \* summer hours + TRF[winter] \* winter hours where TRF values reflecting summer and winter conditions are apportioned by the hours for those conditions. TRF may also be adjusted by building specific balance temperature and operating hours above and below that balance temperature. <sup>341</sup>

<sup>337</sup> Average efficiencies of units from the California Energy Commission (CEC).

<sup>338</sup> Ibid.

<sup>339</sup> Katrakis, J. and T.S. Zawacki. "Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers". ASHRAE V99, pt. 2, 1993.

<sup>340</sup> Thermal regain for *residential* pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012 and Andrews, John, Better Duct Systems for Home Heating and Cooling, U.S. Department of Energy, 2001. Recognizing the differences between residential and commercial heating systems, the factors have been adjusted based on professional judgment. This factor would benefit from additional study and evaluation.

<sup>341</sup> Thermal Regain Factor\_4-30-14.docx

Pipe Location	Assumed Regain	TRF, Thermal Regain Factor
Outdoor	0%	1.0
Indoor, heated space	85%	0.15
Indoor, semi- heated, (unconditioned space, with heat transfer to conditioned space. E.g.: boiler room, ceiling plenum, basement, crawlspace, wall)	30%	0.70
Indoor, unheated, (no heat transfer to conditioned space)	0%	1.0
Location not specified	85%	0.15
Custom	Custom	1 – assumed regain

$L_{sp}$  = Length of straight pipe to be insulated (linear foot)  
 = actual installed ((linear foot)

$L_{oc,l}$  = Total equivalent length of the other components (valves and tees) of pipe to be insulated  
 = Actual installed (linear foot). See table “Equivalent Length of Other Components – Elbows and Tees” for equivalent lengths.

The heat loss estimates ( $Q_{base}$  and  $Q_{eff}$ ) were developed using the 3E Plus v4.0 software program.<sup>342</sup> The energy savings analysis is based on adding 1-inch (indoor) or 2-inch (outdoor) thick insulation around bare pipe. The thermal conductivity of pipe insulation varies by material and temperature rating; to obtain a typical value, a range of materials allowed for this measure were averaged. For insulation materials not in the table below, use 3E Plusv4.0 software to calculate  $Q_{base}$  and  $Q_{eff}$ .

Insulation Type	Conductivity (Btu.in / hr.ft <sup>2</sup> .°F @ 75F)	Max temp (°F)
Polyethylene foam	0.25	200
Flexible polyurethane-based foam	0.27	200
Fiberglass	0.31	250
Melamine foam	0.26	350
Flexible silicon foam	0.40	392
Calcium silicate	0.40	1200
Cellular glass	0.31	400
Average conductivity of all these materials (Btu.in / hr.ft <sup>2</sup> .°F @ 75°F)	0.31	

<sup>342</sup> 3E Plus is a heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association).

The pipe fluid temperature assumption used depends upon both the system type and whether there is outdoor reset controls:

System Type	Fluid temperature assumption (°F)
Hot Water space heating with outdoor reset - Non recirculation	145
Hot Water space heating without outdoor reset - Non recirculation	170
Hot Water space heating with outdoor reset – Recirculation heating season only	145
Hot Water space heating without outdoor reset – Recirculation heating season only	170
Hot Water space heating with outdoor reset – Recirculation year round	130
Hot Water space heating without outdoor reset – Recirculation year round	170
Domestic Hot Water	125
Low Pressure Steam	225
High Pressure Steam	312

Illinois Statewide Technical Reference Manual - 4.4.14 Pipe Insulation

	Indoor Insulation, Hot Water	Indoor Insulation, Low Pressure Steam	Indoor Insulation, High Pressure Steam	Domestic Hot Water	Outdoor Insulation, Hot Water	Outdoor Insulation, Low Pressure Steam	Outdoor Insulation, High Pressure Steam
Insulation thickness (inch)	1	1	1	1	2	2	2
Temperature, Fluid in Pipe (°F)	170 (w/o reset) 145 (w/ reset heat) 130 (w/reset year)	225	312	125	170 (w/o reset) 145 (w/ reset heat) 130 (w/reset year)	225	312
Av. steam pressure (psig)	n/a	10.9	82.8	n/a	n/a	10.9	82.8
Operating Time (hrs/yr)	2,746 (non-recirc) 5,039 (recirc heating season) 8,760 (recirc year round)						
Ambient Temperature (°F) <sup>343</sup>	75	75	75	75	48.6	48.6	48.6
Wind speed (mph) <sup>344</sup>	0	0	0	0	9.4	9.4	9.4
Pipe parameters							
Pipe material	Copper	Steel	Steel	Copper	Copper	Steel	Steel
Pipe size for Heat Loss Calc	2"	2"	2"	2"	2"	2"	2"
Outer Diameter, Pipe, actual	2.38"	2.38"	2.38"	2.38"	2.38"	2.38"	2.38"
Heat Loss, Bare Pipe (from 3EPlus) (Btu/hr.ft)	114 (w/o reset) 78 (w/ reset heat) 58 (w/reset year)	232	432	52	460 (w/o reset) 363 (w/ reset heat) 306 (w/reset year)	710	1101
Insulation parameters							
Outer diameter, insulation	4.38"	4.38"	4.38"	4.38"	4.38"	4.38"	4.38"
Average Heat Loss, Insulation (from 3EPlus) (Btu/hr.ft)	24 (w/o reset) 17 (w/ reset heat) 13 (w/reset year)	40	70	13.25	21 (w/o reset) 16 (w/ reset heat) 13 (w/reset year)	32	52

<sup>343</sup> DOE Weather Data.

[http://apps1.eere.energy.gov/buildings/energyplus/weatherdata/4\\_north\\_and\\_central\\_america\\_wmo\\_region\\_4/1\\_usa/USA\\_IL\\_Aurora.Muni.AP.744655\\_TMY3.stat](http://apps1.eere.energy.gov/buildings/energyplus/weatherdata/4_north_and_central_america_wmo_region_4/1_usa/USA_IL_Aurora.Muni.AP.744655_TMY3.stat) Ibid.

<sup>344</sup> Ibid.

	Indoor Insulation, Hot Water	Indoor Insulation, Low Pressure Steam	Indoor Insulation, High Pressure Steam	Domestic Hot Water	Outdoor Insulation, Hot Water	Outdoor Insulation, Low Pressure Steam	Outdoor Insulation, High Pressure Steam
<b>Annual Energy Savings</b>							
Boiler / Water Heater efficiency	81.9%	80.7% (64.8% for MF)	80.7%	67%	81.9%	80.7% (64.8% for MF)	80.7%
Annual Gas Use, Base Case (therms/yr/ft)	3.8 (w/o reset)	7.9 (non recirc)	14.7 (non recirc)	6.76	15.4 (w/o reset)	24.1 (non recirc)	37.5 (non recirc)
	4.8 (w/ reset heat)	14.5 (recirc heat)	27.0 (recirc heat)		22.5 (w/ reset heat)	44.3 (recirc heat)	68.7 (recirc heat)
	6.2 (w/reset year)	25.2 (recirc year)	46.9 (recirc year)		32.7 (w/reset year)	77.0 (recirc year)	119.5 (recirc year)
Annual Gas Use, Measure case (therms/yr/ft)	0.8 (w/o reset)	1.4 (non recirc)	2.4 (non recirc)	1.73	0.7 (w/o reset)	1.1 (non recirc)	1.8 (non recirc)
	1.1 (w/ reset heat)	2.5 (recirc heat)	4.4 (recirc heat)		1.0 (w/ reset heat)	2.0 (recirc heat)	3.2 (recirc heat)
	1.4 (w/reset year)	4.4 (recirc year)	7.6 (recirc year)		1.4 (w/reset year)	3.4 (recirc year)	5.6 (recirc year)
Annual Gas Savings (therms/yr/ft)	3.0 (w/o reset)	6.5 (non recirc)	12.3 (non recirc)	5.0	14.7 (w/o reset)	23.1 (non recirc)	35.7 (non recirc)
	3.7 (w/ reset heat)	12.0 (recirc heat)	22.6 (recirc heat)		21.4 (w/ reset heat)	42.3 (recirc heat)	65.5 (recirc heat)
	4.8 (w/reset year)	20.8 (recirc year)	39.3 (recirc year)		31.3 (w/reset year)	73.6 (recirc year)	113.9 (recirc year)

Heat = heating season only, year = year round

Values below must be multiplied by the appropriate Thermal Regain Factor (TRF). All variables were the same except for hours of operation in the calculation of the default savings per foot for the various building types and applications as presented in the table below:

**Savings Summary for Indoor pipe insulation by System Type and Building Type (Δtherms per foot)  
 (continues for 3.5 pages)**

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Indoor	Hot Water Space Heating with outdoor reset – non-recirculation	Assembly	1.32	1.36	1.21	0.81	1.24
		Assisted Living	1.25	1.22	1.07	0.79	0.95
		College	1.13	1.06	0.95	0.53	0.63
		Convenience Store	1.10	1.01	0.90	0.65	0.72
		Elementary School	1.32	1.29	1.13	0.78	0.95
		Garage	0.73	0.72	0.63	0.50	0.56
		Grocery	1.19	1.19	1.04	0.65	0.78
		Healthcare Clinic	1.17	1.20	1.05	0.71	0.75
		High School	1.37	1.38	1.23	0.88	1.03
		Hospital - CAV no econ	1.31	1.35	1.15	0.99	1.12
		Hospital - CAV econ	1.33	1.37	1.17	1.01	1.15
		Hospital - VAV econ	0.54	0.51	0.39	0.23	0.25
		Hospital - FCU	0.98	1.12	0.91	1.07	1.44
		Hotel/Motel	1.31	1.27	1.14	0.78	0.96
		Hotel/Motel - Common	1.19	1.21	1.15	0.93	0.98
		Hotel/Motel - Guest	1.30	1.26	1.13	0.75	0.93
		Manufacturing Facility	0.78	0.75	0.70	0.42	0.47
		MF - High Rise	1.13	1.12	1.02	0.87	0.87
		MF - High Rise - Common	1.35	1.31	1.17	0.81	1.04
		MF - High Rise - Residential	1.09	1.08	0.99	0.85	0.83
		MF - Mid Rise	1.23	1.25	1.07	0.79	0.90
		Movie Theater	1.35	1.33	1.24	0.94	1.12
		Office - High Rise - CAV no econ	1.50	1.52	1.38	0.93	1.01
		Office - High Rise - CAV econ	1.55	1.58	1.45	1.00	1.10
		Office - High Rise - VAV econ	1.13	1.15	0.95	0.56	0.63
Office - High Rise - FCU	0.83	0.82	0.71	0.37	0.39		

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Office - Low Rise	1.06	1.06	0.84	0.51	0.59
		Office - Mid Rise	1.17	1.18	0.99	0.63	0.70
		Religious Building	1.19	1.11	1.07	0.78	0.89
		Restaurant	1.00	1.00	0.90	0.68	0.81
		Retail - Department Store	1.03	0.95	0.89	0.58	0.66
		Retail - Strip Mall	0.99	0.91	0.81	0.56	0.60
		Warehouse	1.08	1.01	1.04	0.65	0.80
		Unknown	1.15	1.14	1.01	0.73	0.84
	Hot Water Space Heating without outdoor reset – non-recirculation	Assembly	1.96	2.00	1.79	1.19	1.83
		Assisted Living	1.84	1.80	1.58	1.16	1.40
		College	1.67	1.56	1.40	0.78	0.93
		Convenience Store	1.62	1.50	1.33	0.95	1.06
		Elementary School	1.95	1.90	1.68	1.16	1.40
		Garage	1.08	1.06	0.93	0.74	0.82
		Grocery	1.76	1.75	1.54	0.96	1.15
		Healthcare Clinic	1.73	1.77	1.55	1.05	1.11
		High School	2.02	2.03	1.82	1.30	1.52
		Hospital - CAV no econ	1.93	1.99	1.69	1.46	1.65
		Hospital - CAV econ	1.96	2.03	1.73	1.50	1.70
		Hospital - VAV econ	0.80	0.76	0.57	0.34	0.37
		Hospital - FCU	1.45	1.65	1.35	1.58	2.13
		Hotel/Motel	1.93	1.87	1.69	1.16	1.41
		Hotel/Motel - Common	1.75	1.78	1.69	1.38	1.45
		Hotel/Motel - Guest	1.92	1.86	1.66	1.11	1.37
		Manufacturing Facility	1.15	1.11	1.03	0.62	0.69
		MF - High Rise	1.67	1.65	1.50	1.28	1.28
		MF - High Rise - Common	1.99	1.93	1.73	1.19	1.54
		MF - High Rise - Residential	1.61	1.60	1.46	1.26	1.23
MF - Mid Rise	1.82	1.84	1.59	1.17	1.33		

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Movie Theater	1.99	1.96	1.83	1.39	1.66
		Office - High Rise - CAV no econ	2.21	2.24	2.04	1.37	1.49
		Office - High Rise - CAV econ	2.29	2.33	2.14	1.48	1.63
		Office - High Rise - VAV econ	1.67	1.70	1.40	0.83	0.93
		Office - High Rise - FCU	1.22	1.21	1.04	0.55	0.58
		Office - Low Rise	1.56	1.56	1.24	0.76	0.87
		Office - Mid Rise	1.73	1.74	1.47	0.94	1.04
		Religious Building	1.75	1.65	1.58	1.15	1.32
		Restaurant	1.48	1.48	1.33	1.01	1.19
		Retail - Department Store	1.52	1.40	1.31	0.85	0.97
		Retail - Strip Mall	1.46	1.35	1.19	0.82	0.89
		Warehouse	1.59	1.49	1.53	0.96	1.18
		Unknown	1.70	1.68	1.50	1.07	1.25
	Hot Water with outdoor reset	All buildings, Recirculation heating season only (Hours below 55F)	3.73	3.68	3.33	2.98	3.08
	Hot Water w/o outdoor reset	All buildings, Recirculation heating season only (Hours below 55F)	5.51	5.43	4.92	4.40	4.54
	Hot Water with outdoor reset	All buildings, Recirculation year round (All hours)	4.79	4.79	4.79	4.79	4.79
	Hot Water w/o outdoor reset	All buildings, Recirculation year round (All hours)	9.58	9.58	9.58	9.58	9.58
	Domestic Hot Water	DHW circulation loop	5.02	5.02	5.02	5.02	5.02
	LP Steam – non-recirculation	Assembly	4.25	4.36	3.89	2.59	3.97
		Assisted Living	4.01	3.92	3.44	2.53	3.04
		College	3.64	3.40	3.04	1.69	2.02
		Convenience Store	3.52	3.26	2.89	2.07	2.32
		Elementary School	4.24	4.13	3.64	2.52	3.05
		Garage	2.34	2.31	2.03	1.62	1.79
		Grocery	3.83	3.81	3.34	2.08	2.49
		Healthcare Clinic	3.76	3.85	3.36	2.29	2.42
		High School	4.39	4.42	3.96	2.82	3.30

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Hospital - CAV no econ	4.20	4.33	3.69	3.17	3.60
		Hospital - CAV econ	4.25	4.41	3.76	3.26	3.70
		Hospital - VAV econ	1.74	1.65	1.24	0.75	0.81
		Hospital - FCU	3.15	3.60	2.93	3.44	4.63
		Hotel/Motel	4.19	4.07	3.67	2.51	3.07
		Hotel/Motel - Common	3.81	3.87	3.68	3.00	3.15
		Hotel/Motel - Guest	4.18	4.05	3.62	2.42	2.98
		Manufacturing Facility	2.49	2.41	2.23	1.35	1.51
		MF - High Rise	4.52	4.46	4.07	3.46	3.47
		MF - High Rise - Common	5.38	5.22	4.68	3.23	4.17
		MF - High Rise - Residential	4.37	4.34	3.94	3.41	3.33
		MF - Mid Rise	4.94	4.99	4.30	3.16	3.60
		Movie Theater	4.33	4.26	3.98	3.03	3.61
		Office - High Rise - CAV no econ	4.81	4.88	4.45	2.98	3.24
		Office - High Rise - CAV econ	4.97	5.07	4.66	3.21	3.54
		Office - High Rise - VAV econ	3.64	3.71	3.06	1.81	2.01
		Office - High Rise - FCU	2.66	2.62	2.27	1.20	1.26
		Office - Low Rise	3.40	3.39	2.69	1.65	1.89
		Office - Mid Rise	3.77	3.78	3.19	2.03	2.26
		Religious Building	3.82	3.58	3.43	2.51	2.87
		Restaurant	3.21	3.22	2.89	2.19	2.60
		Retail - Department Store	3.31	3.04	2.86	1.86	2.12
		Retail - Strip Mall	3.17	2.94	2.59	1.79	1.93
		Warehouse	3.46	3.23	3.33	2.08	2.56
		Unknown	3.70	3.66	3.26	2.34	2.71
	LP Steam	All buildings, Recirculation heating season only (Hours below 55F)	11.99	11.81	10.70	9.57	9.88
	LP Steam	All buildings, Recirculation year round (All hours)	20.84	20.84	20.84	20.84	20.84
	HP Steam – non-	Assembly	8.02	8.22	7.34	4.89	7.49

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
	recirculation	Assisted Living	7.56	7.39	6.49	4.77	5.73
		College	6.87	6.42	5.73	3.18	3.81
		Convenience Store	6.65	6.14	5.45	3.91	4.37
		Elementary School	8.00	7.79	6.87	4.75	5.76
		Garage	4.42	4.35	3.82	3.05	3.38
		Grocery	7.22	7.19	6.30	3.93	4.70
		Healthcare Clinic	7.09	7.27	6.35	4.32	4.57
		High School	8.28	8.34	7.48	5.33	6.23
		Hospital - CAV no econ	7.92	8.16	6.95	5.98	6.79
		Hospital - CAV econ	8.03	8.32	7.09	6.14	6.98
		Hospital - VAV econ	3.28	3.12	2.35	1.41	1.53
		Hospital - FCU	5.95	6.79	5.53	6.50	8.73
		Hotel/Motel	7.91	7.69	6.93	4.74	5.79
		Hotel/Motel - Common	7.18	7.30	6.95	5.65	5.94
		Hotel/Motel - Guest	7.89	7.64	6.83	4.57	5.62
		Manufacturing Facility	4.70	4.55	4.22	2.55	2.84
		MF - High Rise	6.85	6.76	6.16	5.25	5.26
		MF - High Rise - Common	8.15	7.91	7.09	4.89	6.31
		MF - High Rise - Residential	6.62	6.57	5.97	5.17	5.04
		MF - Mid Rise	7.48	7.57	6.51	4.79	5.46
		Movie Theater	8.16	8.04	7.52	5.71	6.80
		Office - High Rise - CAV no econ	9.07	9.20	8.39	5.62	6.12
		Office - High Rise - CAV econ	9.38	9.57	8.80	6.06	6.67
		Office - High Rise - VAV econ	6.86	6.99	5.76	3.41	3.80
		Office - High Rise - FCU	5.02	4.95	4.27	2.27	2.38
		Office - Low Rise	6.41	6.40	5.08	3.11	3.56
		Office - Mid Rise	7.12	7.12	6.03	3.84	4.27
		Religious Building	7.20	6.75	6.46	4.73	5.41
	Restaurant	6.06	6.08	5.46	4.13	4.90	

			Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
Location	System Type	Building Type	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Retail - Department Store	6.25	5.74	5.39	3.51	4.00
		Retail - Strip Mall	5.98	5.54	4.89	3.37	3.63
		Warehouse	6.53	6.09	6.29	3.93	4.84
		Unknown	6.97	6.91	6.14	4.41	5.11
	HP Steam	All buildings, Recirculation heating season only (Hours below 55F)	22.62	22.28	20.18	18.05	18.63
	HP Steam	All buildings, Recirculation year round (All hours)	39.32	39.32	39.32	39.32	39.32

**Savings Summary for Outdoor pipe insulation by System Type and Building Type ( $\Delta$ therms per foot)  
 (continues for 3.5 pages)**

			Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
Location	System Type	Building Type	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Outdoor	Hot Water Space Heating with outdoor reset – non-recirculation	Assembly	7.58	7.77	6.94	4.62	7.08
		Assisted Living	7.14	6.98	6.13	4.51	5.42
		College	6.49	6.07	5.41	3.01	3.60
		Convenience Store	6.28	5.80	5.15	3.70	4.13
		Elementary School	7.56	7.36	6.50	4.49	5.44
		Garage	4.18	4.11	3.61	2.88	3.19
		Grocery	6.82	6.80	5.96	3.72	4.44
		Healthcare Clinic	6.70	6.87	6.00	4.09	4.32
		High School	7.83	7.88	7.07	5.03	5.89
		Hospital - CAV no econ	7.49	7.71	6.57	5.65	6.41
		Hospital - CAV econ	7.59	7.86	6.70	5.81	6.60
		Hospital - VAV econ	3.10	2.95	2.22	1.33	1.44
		Hospital - FCU	5.62	6.42	5.23	6.14	8.26
		Hotel/Motel	7.47	7.26	6.55	4.48	5.47
		Hotel/Motel - Common	6.79	6.90	6.57	5.34	5.61

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Hotel/Motel - Guest	7.46	7.22	6.45	4.32	5.31
		Manufacturing Facility	4.45	4.30	3.98	2.41	2.69
		MF - High Rise	6.48	6.39	5.83	4.96	4.97
		MF - High Rise - Common	7.70	7.48	6.70	4.62	5.96
		MF - High Rise - Residential	6.26	6.21	5.64	4.89	4.77
		MF - Mid Rise	7.07	7.15	6.15	4.53	5.16
		Movie Theater	7.71	7.60	7.10	5.40	6.43
		Office - High Rise - CAV no econ	8.57	8.70	7.93	5.31	5.78
		Office - High Rise - CAV econ	8.86	9.04	8.32	5.73	6.31
		Office - High Rise - VAV econ	6.48	6.61	5.45	3.22	3.59
		Office - High Rise - FCU	4.75	4.67	4.04	2.14	2.25
		Office - Low Rise	6.06	6.05	4.80	2.94	3.36
		Office - Mid Rise	6.73	6.73	5.70	3.63	4.03
		Religious Building	6.80	6.38	6.11	4.47	5.11
		Restaurant	5.73	5.75	5.16	3.90	4.63
		Retail - Department Store	5.91	5.42	5.09	3.31	3.78
		Retail - Strip Mall	5.65	5.23	4.62	3.19	3.44
		Warehouse	6.18	5.76	5.94	3.71	4.57
		Unknown	6.59	6.53	5.81	4.17	4.83
		Hot Water Space Heating without outdoor reset – non-recirculation	Assembly	9.59	9.83	8.77	5.85
	Assisted Living		9.04	8.83	7.76	5.70	6.86
	College		8.21	7.68	6.85	3.80	4.56
	Convenience Store		7.95	7.34	6.52	4.68	5.22
	Elementary School		9.56	9.32	8.22	5.68	6.89
	Garage		5.28	5.20	4.57	3.65	4.04
	Grocery		8.63	8.60	7.54	4.70	5.62
	Healthcare Clinic		8.47	8.70	7.59	5.17	5.47
	High School		9.90	9.97	8.94	6.37	7.45
Hospital - CAV no econ	9.47		9.76	8.31	7.15	8.11	
Hospital - CAV econ	9.60	9.95	8.48	7.35	8.34		

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Hospital - VAV econ	3.93	3.73	2.80	1.68	1.82
		Hospital - FCU	7.11	8.12	6.61	7.77	10.45
		Hotel/Motel	9.45	9.19	8.29	5.67	6.92
		Hotel/Motel - Common	8.59	8.73	8.31	6.76	7.10
		Hotel/Motel - Guest	9.44	9.13	8.16	5.47	6.72
		Manufacturing Facility	5.63	5.44	5.04	3.05	3.40
		MF - High Rise	8.19	8.08	7.37	6.27	6.29
		MF - High Rise - Common	9.74	9.46	8.48	5.85	7.54
		MF - High Rise - Residential	7.92	7.86	7.14	6.18	6.03
		MF - Mid Rise	8.94	9.05	7.78	5.73	6.53
		Movie Theater	9.76	9.61	8.99	6.83	8.14
		Office - High Rise - CAV no econ	10.84	11.01	10.03	6.72	7.32
		Office - High Rise - CAV econ	11.21	11.44	10.52	7.25	7.98
		Office - High Rise - VAV econ	8.20	8.36	6.89	4.07	4.54
		Office - High Rise - FCU	6.00	5.91	5.11	2.71	2.84
		Office - Low Rise	7.67	7.65	6.08	3.72	4.25
		Office - Mid Rise	8.51	8.52	7.21	4.59	5.10
		Religious Building	8.61	8.07	7.73	5.66	6.47
		Restaurant	7.25	7.27	6.53	4.94	5.85
		Retail - Department Store	7.47	6.86	6.44	4.19	4.78
		Retail - Strip Mall	7.15	6.62	5.85	4.03	4.35
		Warehouse	7.81	7.29	7.52	4.69	5.78
		Unknown	8.34	8.26	7.35	5.27	6.11
	Hot Water with outdoor reset	All buildings, Recirculation heating season only (Hours below 55F)	21.38	21.06	19.07	17.06	17.61
	Hot Water without outdoor reset	All buildings, Recirculation heating season only (Hours below 55F)	27.05	26.64	24.13	21.58	22.28
	Hot Water with outdoor reset	All buildings, Recirculation year round (All hours)	31.30	31.30	31.30	31.30	31.30
	Hot Water without outdoor reset	All buildings, Recirculation year round (All hours)	47.02	47.02	47.02	47.02	47.02
	LP Steam – non-	Assembly	15.01	15.38	13.73	9.15	14.02

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
	recirculation	Assisted Living	14.14	13.82	12.15	8.93	10.73
		College	12.85	12.01	10.72	5.95	7.13
		Convenience Store	12.44	11.49	10.20	7.32	8.17
		Elementary School	14.96	14.58	12.86	8.88	10.78
		Garage	8.27	8.14	7.15	5.71	6.32
		Grocery	13.51	13.46	11.80	7.36	8.79
		Healthcare Clinic	13.26	13.61	11.88	8.09	8.56
		High School	15.50	15.60	13.99	9.97	11.66
		Hospital - CAV no econ	14.82	15.27	13.01	11.19	12.70
		Hospital - CAV econ	15.02	15.57	13.27	11.50	13.06
		Hospital - VAV econ	6.14	5.84	4.39	2.64	2.85
		Hospital - FCU	11.13	12.71	10.35	12.16	16.35
		Hotel/Motel	14.80	14.38	12.97	8.87	10.84
		Hotel/Motel - Common	13.45	13.66	13.00	10.58	11.12
		Hotel/Motel - Guest	14.77	14.29	12.78	8.56	10.52
		Manufacturing Facility	8.80	8.51	7.89	4.77	5.32
		MF - High Rise	15.97	15.76	14.37	12.23	12.26
		MF - High Rise - Common	18.99	18.44	16.53	11.39	14.71
		MF - High Rise - Residential	15.43	15.31	13.92	12.05	11.75
		MF - Mid Rise	17.43	17.63	15.17	11.16	12.72
		Movie Theater	15.27	15.05	14.07	10.69	12.73
		Office - High Rise - CAV no econ	16.97	17.22	15.70	10.51	11.45
		Office - High Rise - CAV econ	17.55	17.91	16.47	11.35	12.49
		Office - High Rise - VAV econ	12.83	13.09	10.79	6.37	7.11
		Office - High Rise - FCU	9.40	9.26	8.00	4.25	4.45
		Office - Low Rise	12.00	11.97	9.51	5.82	6.66
		Office - Mid Rise	13.32	13.33	11.28	7.18	7.98
		Religious Building	13.47	12.64	12.10	8.86	10.13
		Restaurant	11.34	11.38	10.21	7.73	9.16
		Retail - Department Store	11.69	10.74	10.08	6.56	7.48

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Retail - Strip Mall	11.19	10.36	9.15	6.31	6.80
		Warehouse	12.23	11.40	11.77	7.35	9.05
		Unknown	13.05	12.93	11.50	8.25	9.57
	LP Steam	All buildings, Recirculation heating season only (Hours below 55F)	42.33	41.69	37.76	33.78	34.86
	LP Steam	All buildings, Recirculation year round (All hours)	73.59	73.59	73.59	73.59	73.59
	HP Steam – non-recirculation	Assembly	23.24	23.81	21.26	14.16	21.70
		Assisted Living	21.89	21.40	18.80	13.82	16.61
		College	19.90	18.60	16.60	9.22	11.04
		Convenience Store	19.26	17.79	15.79	11.33	12.65
		Elementary School	23.16	22.57	19.91	13.75	16.69
		Garage	12.80	12.60	11.08	8.84	9.78
		Grocery	20.91	20.83	18.26	11.39	13.61
		Healthcare Clinic	20.53	21.07	18.39	12.53	13.25
		High School	23.99	24.15	21.66	15.43	18.05
		Hospital - CAV no econ	22.94	23.64	20.14	17.32	19.66
		Hospital - CAV econ	23.25	24.10	20.54	17.80	20.22
		Hospital - VAV econ	9.51	9.03	6.79	4.08	4.42
		Hospital - FCU	17.24	19.67	16.02	18.82	25.31
		Hotel/Motel	22.90	22.27	20.08	13.74	16.77
		Hotel/Motel - Common	20.81	21.15	20.13	16.38	17.21
		Hotel/Motel - Guest	22.87	22.13	19.78	13.24	16.28
		Manufacturing Facility	13.63	13.18	12.21	7.38	8.24
		MF - High Rise	19.85	19.59	17.86	15.20	15.24
		MF - High Rise - Common	23.60	22.92	20.55	14.16	18.28
		MF - High Rise - Residential	19.18	19.03	17.30	14.98	14.61
	MF - Mid Rise	21.67	21.92	18.86	13.87	15.81	
	Movie Theater	23.64	23.29	21.78	16.55	19.71	
Office - High Rise - CAV no econ	26.27	26.66	24.30	16.28	17.73		
Office - High Rise - CAV econ	27.16	27.72	25.49	17.57	19.33		

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
			Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Office - High Rise - VAV econ	19.87	20.26	16.70	9.87	11.00
		Office - High Rise - FCU	14.54	14.33	12.38	6.57	6.89
		Office - Low Rise	18.58	18.53	14.72	9.00	10.31
		Office - Mid Rise	20.61	20.64	17.46	11.12	12.36
		Religious Building	20.85	19.56	18.72	13.71	15.67
		Restaurant	17.55	17.61	15.81	11.96	14.18
		Retail - Department Store	18.10	16.63	15.61	10.16	11.58
		Retail - Strip Mall	17.32	16.04	14.17	9.77	10.53
		Warehouse	18.93	17.65	18.21	11.37	14.02
		Unknown	20.20	20.01	17.80	12.77	14.81
		HP Steam	All buildings, Recirculation heating season only (Hours below 55F)	65.53	64.54	58.45	52.29
HP Steam	All buildings, Recirculation year round (All hours)	113.92	113.92	113.92	113.92	113.92	

For insulation covering elbows and tees that connect straight pipe, a calculated surface area will be assumed based on the dimensions for fittings given by ANSI/ASME B36.19. The surface area is then converted to an equivalent length of pipe that must be added to the total length of straight pipe in order to calculate total savings. Equivalent pipe lengths are given in 1" increments in pipe diameter for simplicity. In the case of pipe diameters in between full inch diameters, the closest equivalent length should be used. The larger pipe sizes mostly apply to steam header piping, which has the most heat loss per foot.

**Calculated Surface Areas of Elbows and Tees**

Nominal Pipe Diameter	Calculated Surface Area (ft)	
	90 Degree Elbow <sup>345</sup>	Straight Tee <sup>346</sup>
1"	0.10	0.13
2"	0.41	0.39
3"	0.93	0.77
4"	1.64	1.21
5"	2.57	1.77
6"	3.70	2.44

<sup>345</sup> Based on the dimensions for diameter, long radius, and short radius given by ANSI/ASME 36.19

<sup>346</sup> Based on the center to face and diameter dimensions given by ANSI/ASME B36.19

Nominal Pipe Diameter	Calculated Surface Area (ft)	
	90 Degree Elbow <sup>345</sup>	Straight Tee <sup>346</sup>
8"	6.58	3.95
10"	10.28	5.98
12"	14.80	8.34

**Equivalent Length of Other Components – Elbows and Tees (L<sub>oc</sub>)**

Nominal Pipe Diameter	Equivalent Length of Other Components (ft)	
	90 Degree Elbow	Straight Tee
1"	0.30	0.38
2"	0.66	0.63
3"	1.01	0.84
4"	1.40	1.03
5"	1.76	1.22
6"	2.13	1.41
8"	2.91	1.75
10"	3.65	2.13
12"	4.44	2.50

For insulation around valves or flanges, a surface area from ASTM standard C1129-12 will be assumed for 2" pipes. For 1" pipes, which weren't included in the standard, a linear-trended value will be used. The surface area is then converted to an equivalent length of either 1" or 2" straight pipe that must be added to the total length of straight pipe in order to calculate total savings.

**Calculated Surface Areas of Flanges and Valves**

Valves					Flanges				
Class (psi)	150	300	600	900	Class (psi)	150	300	600	900
NPS (in)	ft <sup>2</sup>	ft <sup>2</sup>	ft <sup>2</sup>	ft <sup>2</sup>	NPS (in)	ft <sup>2</sup>	ft <sup>2</sup>	ft <sup>2</sup>	ft <sup>2</sup>
1	0.69	1.8	1.8	2.4	1	0.36	0.36	0.4	1.23
2	2.21	2.94	2.94	5.2	2	0.71	0.84	0.88	1.54
2.5	2.97	3.51	3.91	6.6					
3	3.37	4.39	4.69	6.5	3	1.06	1.32	1.36	1.85
4	4.68	6.06	7.64	9.37	4	1.44	1.83	2.23	2.64
6	7.03	9.71	13.03	15.8	6	2.04	2.72	3.6	4.37
8	10.3	13.5	18.4	23.8	8	2.92	3.74	4.89	6.4
10	13.8	18	26.5	32.1	10	3.68	4.8	6.93	8.47

Valves				
12	16.1	24.1	31.9	41.9

Flanges				
12	5.01	6.34	7.97	10.43

**Equivalent Length of Other Components - Flanges and Valves (L<sub>oc</sub>)**

ANSI Class (psi)	Equivalent Length of Other Components (ft)			
	1" Valve	1" Flange	2" Valve	2" Flange
150	3.56	1.05	3.56	1.14
300	4.73	1.05	4.73	1.35
600	4.73	1.16	4.73	1.42
900	8.37	3.57	8.37	2.48

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-PINS-V04-160601**