Calculation and M&V Guidelines

ComEd® Energy Efficiency Program Retro-Commissioning (RCx) Flex and Monitoring-Based Commissioning (MBCx) Offerings

Effective January 1, 2026 - December 31, 2026

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Contents

1. Introduction

1.1. Overview

This document is for the ComEd® Energy Efficiency Program, Nicor Gas, Peoples Gas, and North Shore Gas RCx offering Service Providers' use in preparing required RCx offering deliverables and supporting calculation files. The goal of this document is to standardize the calculation methods used by providers and to ensure that those calculation methods provide accurate energy and cost savings information to both the RCx offering and the RCx offering participants. Use of these guidelines will also decrease time investment in review and revisions for both Resource Innovations and the Service Provider.

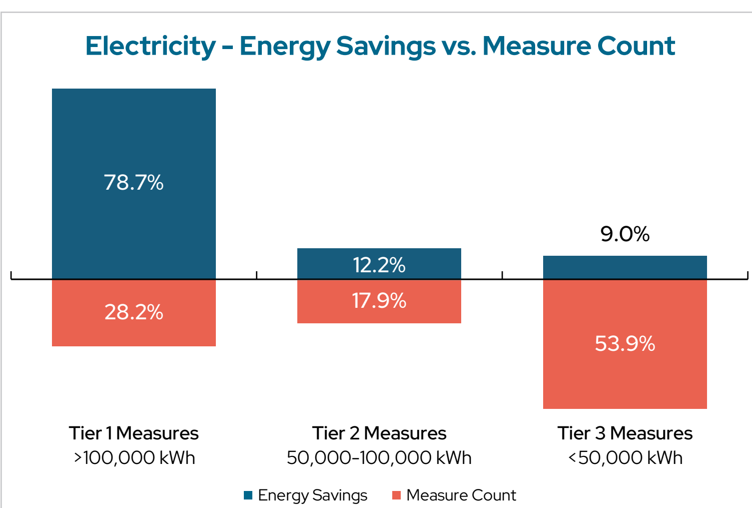
1.2. Measure Tiers

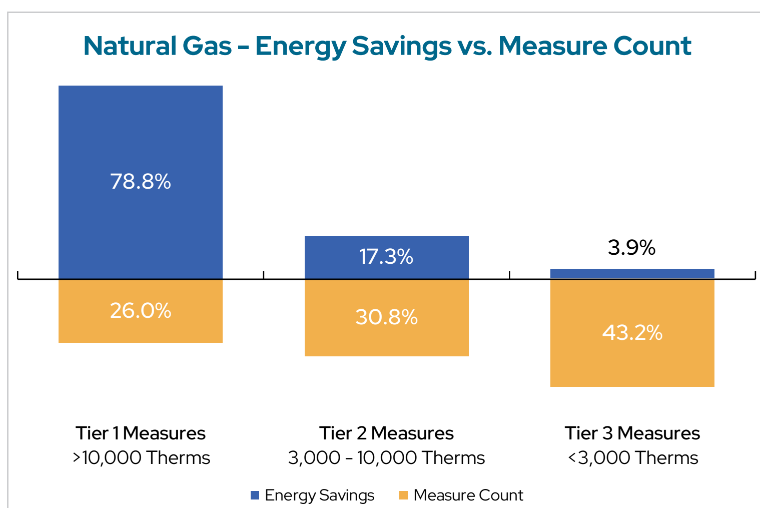
The RCx offering specifies three tiers (or categories) of measures in order to differentiate between large, medium and small measures. Service Provider calculations as well as measurement and verification (M&V) efforts are to be focused on Tier 1 (Large) measures since those measures account for the great majority of the RCx offering's total impacts. Table 1 summarizes how measures are categorized.

Table 1. Measure Tiers

Measure Category	Thresholds	M&V Methodology
Tier 1	Over 100,000 kWh per year OR Over 10,000 therms per year	Data collection (spot measurements and/or trends) is required. Minimum sample size is specified in **Table 3** and **Table 4**
Tier 2	Measures below all the Tier 1 thresholds and above Tier 3 thresholds	Use of RCx Offering-Provided Calculators is strongly encouraged. Tier 1 data collection requirements apply to measures that do not use RCx Offering-Provided Calculators.
Tier 3	Below 50,000 kWh per year OR Below 3,000 therms per year	Use of RCx Offering-Provided Calculators is strongly encouraged. Tier 1 data collection requirements apply to measures that do not use RCx Offering-Provided Calculators.

Measure tiers are defined at a strategy level. For example, if multiple measures are identified which implement one energy conservation strategy (the same strategy applied to the same type of equipment, e.g. several AHU scheduling measures) and their total impacts are greater than 10,000 therms per year or 100,000 kWh per year, then all of those measures will be subject to the Tier 1 calculation and M&V requirements.





2. General Requirements

The following guidelines apply to all calculations (Tier 1, Tier 2 and Tier 3 measures) presented for the RCx offering:

2.1. Calculation Guidelines

- Calculate system or equipment baseline energy consumption and monthly peak demand before estimating energy savings.
- Use measured data and/or trended data to support both the pre- and post-installation energy savings calculations. Guidance and requirements for measured and trended data are provided in this document.
- Present calculations in a clear, easy-to-follow format.
- Clearly state and explain assumptions used in the calculation in the Diagnostic and Calculation (D&C) Plan.
- Consider latent cooling effects wherever cooling savings are identified.
- Present calculations in spreadsheet format unless written pre-approval is provided by Resource Innovations.
- Identify the final implementation date for each measure in order to aid in M&V data gathering efforts. The date should occur after all fine-tuning and iterations of the measure have been completed.

2.2. Weather Data

All weather sensitive measures will use Typical Meteorological version x (TMYx) data unless prior approval is given by Resource Innovations. TMYx data is available for download from the Service Provider Portal or Climate One Buildings (**https://climate.onebuilding.org/WMO_Region_4_North_and_Central_America/USA_United_States_of_America/index.html#IDIL_Illinois-**).

Service Providers will use TMYx data from the weather site nearest to the project location unless the building is within 8 miles of Lake Michigan; then please use the selection criteria below to account for lake-effect weather conditions:

- Buildings located in downtown Chicago area recommend using TMYx data from Chicago Meigs Field-Northerly Island
- Recommend using TMYx data from Midway or Waukegan stations for other buildings whichever is closer

The program standard calculators include TMYx data for Midway (MDW), O'Hare (ORD), Waukegan (UGN), Aurora (AUZ), Joliet (JOT), Rockford (RFD), and Chicago Meigs Field-Northerly Island.

The preferred method for analysis is to process data into outdoor air temperature bins of 1, 2, or 5 degrees, depending of level of accuracy required. For example, a change in economizer setpoint from 62° to 68° OAT would require 1 or 2° bins to accurately represent the operating hours.

2.3. Determining Peak Demand Savings

Using blended rates for input, both customer average demand savings and ComEd peak demand savings can be determined by the RCx offering-provided standard calculators. However, in cases where demand rates are available, peak demand savings will be determined through two separate metrics:

1. **Customer Average Demand Savings** – The customer's average demand savings is used to determine the monetary impacts on the customer's utility bill. To determine when peak billing demand occurs during each month, historical interval data and monthly peak demand data will be reviewed by the Service Provider. For each measure and for each month of the year, determine demand savings which reduce the monthly peak demand. The customer's demand monetary cost savings which result from each measure will be determined by considering site-specific time-of-day and seasonal demand rates.
2. **ComEd Peak Demand Savings** – Peak demand savings are reported for each measure and defined for summertime peak capacity evaluation by ComEd.

a. Non-weather-sensitive measures: The ComEd Peak Demand Savings is the expected average demand (kW) reduction between 1 pm and 5 pm Central Standard Time on all business days from June 1 through August 31. Business days are defined as all weekdays that are not federal holidays.

b. Weather-sensitive measures: The ComEd Peak Demand Savings is to be estimated by determining the average demand savings under the weather conditions in Table 2 and during the same time constraints as defined for non-weather-sensitive measures (see above).

Table 2. Weather Conditions for Peak Demand Savings

Weather Conditions 1–5 pm	
Average Dry Bulb Temp.	**Average Relative Humidity**
82	58%

2.4. Energy Cost Savings

The Energy Cost Savings is the annual reduction in energy costs through the energy and demand savings realized by implementing a measure. This Energy Cost Savings must be estimated using the incremental cost of energy and demand (or next unit cost in $/kWh or $/kW) calculated from the customer's electricity bills. Eligible customers for the RCx offering must use ComEd, Nicor Gas, Peoples Gas or North Shore Gas delivery services; however, a customer may use another supplier. It is the Service Provider's responsibility to obtain electricity bills from the Customer or supplier as appropriate.

The incremental cost of energy is calculated by adding up all charges which are billed on a per-kWh basis. The incremental cost of demand is calculated by summing all charges which are billed on a per-kW basis. Further, the incremental costs of energy and demand may fluctuate based on the time of year, on-peak/off-peak periods, etc. Therefore, it is the Service Provider's responsibility to select the most appropriate incremental cost(s) to use considering when energy savings will be realized for a particular measure. The use of blended rates (i.e., the ratio of total annual energy costs ($) and annual energy consumption (kWh)) for determining energy cost savings is not permitted.

2.5. Trending Requirements

Trending of key parameters is typically required (see **3.3. Calculation Input Priority – Tier 1 Measures** and **4.4. Calculation Input Priority – Tier 2 and Tier 3 Measures** sections). The following guidelines apply where trending is required. Note that if there are any safety concerns (e.g. high voltage equipment, dangerous locations, poor equipment condition, etc.), the Service Provider should contact Resource Innovations to determine the appropriate data or assumptions to use in lieu of the preferred data.

Trending Period

- Weather sensitive measures: collect trend data for key parameters covering a range of operating conditions for a minimum of two weeks. Local outdoor air dry bulb temperature should also be trended contemporaneously with other parameters.
- Non-weather sensitive measures: collect trend data for key parameters covering at least 1 week during typical operating conditions.

Documentation

- Provide the RCx offering with raw trend data files for records. Service Provider should analyze and process trend data into weather bins (2 or 5 degree bins are typical) and this data should be used to calculate energy savings. Note any non-typical operating conditions included in the trend period such as holidays or building shut-downs.

Trend Interval

- When trending temperature, humidity, enthalpy, pressure, VFD speed, or light levels: Trend interval of 15 to 60 minutes.
- When trending equipment amperage or on/off status: Trend interval no longer than the cycle time of equipment.

Power Measurements Accompanying Trends

- Three phase power measurements are no longer required by the program because of safety concerns.
- If the equipment has a VFD or integrated display (e.g. chiller), take a picture of the display showing motor speed, amps, volts and if available: kW and power factor. The power measurements should be synchronized with a known building automation system (BAS) data point, e.g. equipment speed or % load. Collect data at 3 operating loads, in order to better understand the relationship of power vs. load.
- When spot measurements are taken, document date, time of day, value of related BAS data point and outside air temperature (OAT) in order to synchronize spot measurements with a BAS data point taken at the same time.

2.6. Equipment and Seasonal Data Collection Limitations

Due to RCx offering timelines, some data collection limitations may exist for some retro-commissioning measures. The following guidelines will be followed by the Service Providers when reporting savings for these measures. This section applies to both heating and cooling measures. This section does not imply flexibility for Service Providers to delay the data collection process for other reasons.

Equipment List

Provide documentation supporting installed equipment capacity (Motor HP, Tons, CFM, GPM, etc.). The following sources are listed in order of program preference beginning with the highest preference.

1. Picture or PDF copy of mechanical equipment schedules (as-built)
2. Pictures of equipment nameplates or equipment list compiled by the customer
3. Manufacturer's technical specifications or cut sheets that best match the equipment make/model

Investigation and Verification Data Quality

Where seasonal equipment operation will not allow appropriate data collection as required by the RCx offering, Service Providers will document limitations in the D&C Plans summarizing data collection approach. In the D&C plans, Service Providers will detail the preferred data collection plan and summarize reasons for any changes to the proposed plan. Service Providers will report savings based on best available data including engineering assumptions as required.

1. BAS trend history
2. Data loggers
3. Functional tests and equipment spot measurements to simulate post-install operation during Verification Phase (as feasible and allowed by customer). Provide mechanical drawings with design sequence of operation if available
4. Screenshots of BAS graphics including setpoints and reset schedules
5. Screenshots of control logic or equipment schedules

With Resource Innovations' prior approval the following may be considered for Tier 3 measures.

1. Operator logs
2. Operator interview

3. Tier 1 (Large) Measure Requirements

3.1. Applicable IPMVP Guidelines – Tier 1 measures

Service Providers will generally follow Option A: Retrofit Isolation: Key Parameter Measurement or Option B: All Parameter Measurement of IPMVP Concepts and Options for Determining Energy and Water Savings, Volume 1. This document is available online at **www.evo-world.org**. Trending requirements are provided for specific measures in **Appendix B. M&V Guidelines for Common Measures** of this document.

3.2. Sampling – Tier 1 Measures

Where a measure involves multiple, similar equipment, sampling is allowed. Equipment is deemed similar for sampling purposes if:

1. Equipment type and size are similar, or
2. Equipment is controlled in a similar way, or
3. Operating schedule and equipment loading are similar; e.g. AHU schedule for different floors, same setback schedule for different floors, same supply air setpoint for air handling units (AHU), etc.

If Service Providers are uncertain about how the equipment is deemed similar in a project, Service Providers shall consult with Resource Innovations.

Required sample sizes are categorized in two groups:

Group	Equipment	Sample Size Table	Sample Size Confidence and Precision
Group A	Large or system level equipment - AHUs, chillers, boilers, large pumps, etc. Additionally any equipment with complex controls	Table 3	80% confidence interval, 20% precision levels (assuming coefficient of variance equal to 0.75)
Group B	Small or zone level equipment - terminal boxes, radiant heaters, small zone level pumps, etc.	Table 4	80% confidence interval, 20% precision levels (assuming coefficient of variance equal to 0.5)

If obtaining the required sample size is too cost-prohibitive for a project, Service Providers shall consult with Resource Innovations.

Table 3. Required Sample Sizes (Group A – large or system level equipment)

Population Size	Required Sample
<6	Total population
7-8	6
9	7
10-12	8
13-14	9
15-17	10
18-20	11
21-24	12
25-28	13
29-33	14
34-40	15
41-48	16

Population Size	Required Sample
49-58	17
59-72	18
73-91	19
>91	20

Table 4. Required Sample Sizes (Group B – small or zone level equipment)

Population Size	Required Sample
<6	Total population
7-9	5
10-13	6
14-19	7
20-27	8
30-49	9
50-110	10
>110	11

3.3. Calculation Input Priority – Tier 1 Measures

The preference for the source of inputs is provided, beginning with the highest preference.

1. Use measured data:
   a. For key parameters which vary depending on ambient conditions, time of day, etc. In this case, collect at least two weeks of trended data (see **2.5. Trending Requirements**) and develop a correlation between outdoor air conditions and measured data in order to predict operation over the course of a typical year using TMY3 weather data (see **2.2. Weather Data** section).
   b. For parameters which do not vary significantly or whose value does not greatly impact the energy savings. In this case, take a picture of the VFD showing amps, speed, volts and if available, kW and power factor.
   c. If power can be measured safely, take a spot measurement of true RMS power or use a read-out from equipment controller or BAS. Use equipment specifications from the equipment manual, nameplate, or equipment schedules.
2. Use a default value provided by Resource Innovations. Guidance for calculation inputs for several common variables is provided in **Appendix A. Calculation Inputs for Common Variables** of this document (motor load factor, motor and VFD efficiencies, fan, pump, chilling and heating equipment efficiencies).

4. Tier 2 (Medium) and Tier 3 (Small) Measure Requirements

4.1. Applicable IPMVP Guidelines – Tier 2 and Tier 3 Measures

Service Providers will generally follow Option A: Retrofit Isolation: Key Parameter Measurement of IPMVP Concepts and Options for Determining Energy and Water Savings, Volume 1. This document is available online at **www.evo-world.org**.

4.2. Sampling - Tier 2 and Tier 3 Measures

Where a measure involves many pieces of similar equipment, sampling is allowed. Equipment is deemed similar for sampling purposes if:

1. Equipment type and size are similar, including part load performance if applicable or;
2. Equipment is controlled in a similar way, or;
3. Operating schedule and equipment loading are similar;

Some examples include variable air volume (VAV) boxes located in the same orientation, units serving the same side of the building (if solar load affects operation), same supply air setpoint for air handling units (AHU), etc.

If Service Providers are uncertain about how the equipment is deemed similar in a project, Service Providers shall consult with Resource Innovations. Required sample sizes are specified in Table 5 based on a 80% confidence interval, 20% precision levels (assuming coefficient of variance equal to 0.5). The Service Provider shall follow Table 5 to obtain the minimum number of samples.

Table 5. Required Sample Sizes

Population Size	Required Sample
<6	Total population
7-9	5
10-13	6
14-19	7
20-27	8
30-49	9
50-110	10
>110	11

4.3. Use of RCx Offering-Provided Calculators – Tier 2 and Tier 3 Measures

A RCx offering-provided calculation spreadsheet is available for the 11 measures listed below. For measures using the RCx offering-provided calculators, general requirements for spot measurement, trending, and functional testing typically do not apply. Instead, Service Providers will follow Data collection requirements specified for each measure in the individual measure calculator.

1. Implement or optimize air-side, dry-bulb economizer controls; Optimize air-side enthalpy economizer controls.
2. Reduce ventilation (outside air volume)
3. Implement duct static pressure reset or reduce static pressure setpoint
4. Reset condenser water entering temperature based on outdoor air temperature
5. Reset chilled water temperature based on outdoor air temperature
6. Schedule chilled water or hot water pumps
7. Schedule air handler
8. Reduce or reset pump differential pressure setpoint
9. Schedule lights
10. Night setback
11. Optimize AHU operation during unoccupied hours

If a recommended energy conservation strategy meets the measure criteria specified under Assumptions in the individual measure calculator, and if its impacts at the site are less than or equal to 100,000 kWh per year or 10,000 therms per year, Service Providers **should** use a RCx offering-provided calculation tool.

If savings are greater than the Tier 1 threshold of 100,000 kWh or 10,000 therms, the standard calculators may be used if trend data is collected, included in the standard calculator tool, and the model parameters are adjusted to replicate trend data collected.

4.4. Calculation Input Priority – Tier 2 and Tier 3 Measures

The preference for the source of inputs is provided, beginning with the highest preference.

1. Use measured data:
   a. For key parameters which vary depending on ambient conditions, time of day, etc. In this case, collect at least two weeks of trended data (see **2.5. Trending Requirements**) and develop a correlation between outdoor air conditions and measured data in order to predict operation over the course of a typical year using TMY3 weather data (see **2.2. Weather Data** section).
   b. For parameters which do not vary significantly or whose value does not greatly impact the energy savings, take a picture of the VFD showing amps, speed, volts and if available, kW and power factor.
   c. If power can be measured safely, take a spot measurement of true RMS power or use a read-out from equipment controller or BAS.
2. Use equipment specifications from the equipment manual, nameplate, or equipment schedules.
3. Use a default value provided by Resource Innovations. Guidance for calculation inputs for several common variables is provided in **Appendix A. Calculation Inputs for Common Variables** of this document (motor load factor, motor and VFD efficiencies, fan, pump, chilling and heating equipment efficiencies).

Appendix A. Calculation Inputs for Common Variables

A.1. Use of this Appendix

Service Providers will consult this Appendix when the variables included in this Appendix are part of the measure energy savings calculation. Service Providers will consider site specific operation factors.

A.2. ASHRAE Fan Curves

Where estimations of fan power or change in fan power are made, Service Providers will reference the ASHRAE fan curves from ASHRAE 90.1. This reference should be utilized for all HVAC fan measures involving a change in flow. The fan curves are replicated in Figure 1 for reference. Note that for each type of fan and control, there is a minimum turndown ratio, as given in Table 6. An additional table of power fraction as a function of CFM ratio is given in **Table 7** for reference.

Table 6. Minimum Fan Turndown Ratios

Fan Type – Control	Min. Turndown
Air-Foil or Backward – Inclined – Damper Control	45%
Air-Foil or Backward – Inclined – Inlet Vanes	30%
Forward-Curved – Damper Control	20%
Forward – Curved – Inlet Vanes	20%
Vane-Axial – Variable Pitch Blades	20%
Variable Speed Drive	20%

Figure 1. ASHRAE Fan Curves

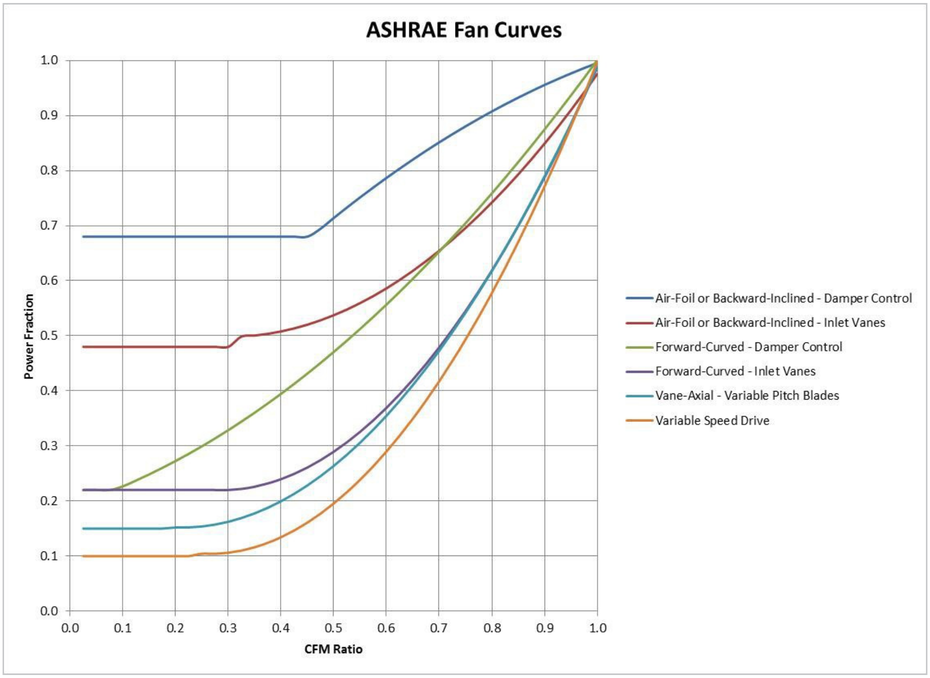


Table 7. Fan Power Fraction as a Function of CFM Ratio from ASHRAE Fan Curves

	Power Fraction					
CFM Ratio	Air - Foil or Backward - Inclined - Damper Control	Air - Foil or Backward - Inclined - Inlet Vanes	Forward - Curved - Damper Control	Forward - Curved - Inlet Vanes	Vane - Axial - Variable Pitch Blades	Variable Speed Drive
0.20			0.27	0.22	0.15	0.10
0.25			0.30	0.22	0.15	0.10
0.30		0.50	0.33	0.22	0.16	0.11
0.35		0.50	0.36	0.23	0.18	0.12
0.40		0.51	0.39	0.24	0.20	0.13
0.45	0.68	0.52	0.43	0.26	0.23	0.16
0.50	0.71	0.54	0.47	0.29	0.26	0.20
0.55	0.75	0.56	0.51	0.33	0.31	0.24
0.60	0.79	0.59	0.56	0.37	0.35	0.29
0.65	0.82	0.62	0.60	0.42	0.41	0.35
0.70	0.85	0.65	0.65	0.48	0.47	0.42
0.75	0.88	0.70	0.70	0.54	0.54	0.49
0.80	0.91	0.74	0.76	0.62	0.62	0.58
0.85	0.93	0.79	0.82	0.70	0.70	0.67
0.90	0.96	0.85	0.87	0.79	0.79	0.77
0.95	0.98	0.91	0.94	0.88	0.89	0.88
1.00	1.00	0.98	1.00	0.99	0.99	1.00

A.3. Pump and Fan Equations

For applications where a change in pump or fan operation is being recommended and the ASHRAE fan curves are not applicable, the Service Provider should use the pump and fan equations to determine savings. These calculations determine pump or fan power based on flow and static pressure developed by the device and the device efficiency. The pump and fan equations are provided in Table 8.

The Service Provider should use the equations in Table 8 to calculate energy savings when the affected fans and pumps' operation is pressure dependent before and after the implementation. For example, calculating the fan energy savings by reducing the duct static pressure in a VAV system.

Table 8. Pump and Fan Equations

Pump Equation	$Bhp = \frac{\dot{Q}(\text{gpm}) \cdot \Delta P(\text{psi})}{1714 \cdot \eta_{pump}}$
Fan Equation	$Bhp = \frac{\dot{Q}(\text{CFM}) \cdot \Delta P(\text{in. w.g.})}{6356 \cdot \eta_{fan}}$
Conversion from Bhp to $kW_{electric}$	$kW_{electric} = \frac{Bhp^{*}\ 0.746(\text{kW/hp})\ {}^{*}85\%\ \text{load factor}}{\eta_{motor}\eta_{VFD}}$
Conversion from Motor Nameplate HP to $kW_{electric}$	$kW_{electric} = \frac{HP^{*}\ 0.746(\text{kW/hp})\ {}^{*}70\%\ \text{load factor}}{\eta_{motor}\eta_{VFD}}$ *If measured load factor is available, please use instead of 70%

A.4. Affinity Laws, Fans and Pumps

If affinity laws apply to the measure calculation, and the ASHRAE fan curves or the pump or fan equations cannot be used, Service Providers will consult the following guidelines. The affinity laws for fans and pumps are provided in Table 9 and Table 10 below. In practice, losses within the system decrease savings from theoretical. Service Providers will use an exponent of **2.5** instead of the theoretical value of 3 for the flow vs. power relationship. Service Providers will use an exponent of **1.3** instead of the theoretical value of 1.5 for the pressure vs. power relationship. This results in a conservative estimate when calculating energy savings by accounting for other losses within the system.

Table 9. Fan Laws[1]

Fan Affinity Laws:	Fan Affinity Laws (Modified by Resource Innovations):
$N \propto Q \propto \sqrt{P} \propto \sqrt[3]{W}$ Where: N = rotational speed Q = volume airflow rate P = total pressure W = power	$Q_2 = Q_1 * \frac{N_2}{N_1}$
	$P_2 = P_1 * \left(\frac{N_2}{N_1}\right)^2$
	$W_2 = W_1 * \left(\frac{N_2}{N_1}\right)^{2.5}$ $W_2 = W_1 * \left(\frac{P_2}{P_1}\right)^{1.3}$

1. Assumes constant fan size and gas density

Source: 2008 ASHRAE Handbook: HVAC Systems and Equipment (pg. 20.4, Table 2)

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Table 10. Pump Affinity Laws[2]

Centrifugal Pump Affinity Laws:	Centrifugal Pump Affinity Laws (Modified by Resource Innovations):
$N \propto Q \propto \sqrt{H} \propto \sqrt[3]{W}$ Where: N = rotational speed Q = flow rate H = head W = power	$Q_2 = Q_1 * \frac{N_2}{N_1}$
	$H_2 = H_1 * \left(\frac{N_2}{N_1}\right)^2$
	$W_2 = W_1 * \left(\frac{N_2}{N_1}\right)^{2.5}$ $W_2 = W_1 * \left(\frac{H_2}{H_1}\right)^{1.3}$

2. Assumes constant impeller size

Source: 2008 ASHRAE Handbook: HVAC Systems and Equipment (pg. 43.7, Table 1)

A.5. Motor Power

Service Providers will take true RMS spot power readings on motors involved in calculations. True RMS spot power measurements will include power factor measurements. Table 11 provides other default values for motors for use in limited cases where true RMS power readings are not available in the Investigation and Verification Phases.

Table 11. Other Default Values

RCx Offering Default Values, Motors	
Motor Load Factor when using nameplate HP	70%
Motor Load Factor when using design BHP	85%
Heating Equipment Load Factor	70%
Power Factor	85%

Service Providers will obtain motor nameplate information for motors involved in calculations. When motor efficiency is not available, motor efficiency is assumed to be Energy Policy Act (EPAct) standard efficiency from Table 12.

Table 12. NEMA Threshold Full-Load Nominal Efficiency Values for Energy-Efficient Motors[3]

Nominal Full Load Efficiency for Enclosed Motors				
hp	3600 rpm	1800 rpm	1200 rpm	900 rpm
1	72.5	82.5	80.0	74.0
1.5	82.5	84.0	85.5	77.0
2	84.0	84.0	86.5	82.5
3	85.5	87.5	87.5	84.0
5	87.5	87.5	87.5	85.5
7.5	88.5	89.5	89.5	85.5
10	89.5	89.5	89.5	88.5
15	90.2	91.0	90.2	88.5
20	90.2	91.0	90.2	89.5
25	91.0	92.4	91.7	89.5

Nominal Full Load Efficiency for Enclosed Motors				
hp	3600 rpm	1800 rpm	1200 rpm	900 rpm
30	91.0	92.4	91.7	91.0
40	91.7	93.0	91.7	91.0
50	92.4	93.0	93.0	91.7
60	93.0	93.6	93.0	91.7
75	93.0	94.1	93.6	93.0
100	93.6	94.5	93.6	93.0
125	94.5	94.5	94.1	93.6
150	94.5	95.0	94.1	93.6
200	95.0	95.0	95.0	94.1
250	95.4	95.0	95.0	94.5
300	95.4	95.4	95.0	–
350	95.4	95.4	95.0	–
400	95.4	95.4	–	–
450	95.4	95.4	–	–
500	95.4	95.8	–	–

3. Motor classes from 1 to 200 hp for 3600, 1800, and 1200 rpm motors are covered by efficiency standards contained in the Energy Policy Act of 1992.
Source: NEMA Standard MG1 (Table 12-10)

A.6. Fan Efficiency

Service Providers will consult the fan performance curves for the fan in consideration to determine the efficiency at given operating conditions.

In the Investigation and Verification Phases, actual performance curves or measurements must be used. If unavailable, Service Providers will consult with Resource Innovations.

A.7. Pump Efficiency

Service Providers will consult the pump performance curves for the pump in consideration to determine the pump efficiency at given operating conditions.

In the Investigation and Verification Phases, actual performance curves or measurements must be used. If unavailable, Service Providers will consult with Resource Innovations.

Table 13. Bell & Gossett Pump Centrifugal Pump Efficiency

		Head (ft)									
		20		40		60		80		100	
		hp	eff (%)	hp	eff (%)	hp	eff (%)	hp	eff (%)	hp	eff (%)
	100	1	58	2	69	5	59	5	51	7.5	56
	500	5	72	7.5	84	15	79	20	71	20	75
	1000	7.5	79	15	79	25	80	30	84	40	86
	1500	15	73	25	77	40	80	50	80	60	85
	2000	15	76	40	62	50	79	60	82	75	81
GPM	2500	–	–	40	77	75	63	100	65	100	72

		Head (ft)									
		20		40		60		80		100	
		hp	eff (%)	hp	eff (%)	hp	eff (%)	hp	eff (%)	hp	eff (%)
	3000	–	–	50	73	75	75	100	82	100	86
	3500	–	–	60	70	100	71	100	81	125	84
	4000	–	–	60	78	100	74	125	78	150	81
	4500	–	–	75	73	125	72	125	84	150	86
	5000	–	–	100	75	125	72	150	77	200	81

Source: Bell & Gossett product selection software – Least expensive option is selected

A.8. VFD Efficiency

Calculations should assume a turndown percentage limit of 20 percent (at 12Hz) unless manufacturer specifications indicate otherwise.

Calculations involving VFD equipped fans, pumps, or compressors will account for VFD efficiency. Since efficiency varies with VFD speed, the efficiency at the most common operating speed will be used. The Service Provider will obtain equipment-specific VFD efficiency if available. Where that is not available, the Service Provider will use values shown in Table 14.

Table 14. VFD Efficiency

Design Speed, %	Efficiency
0	88
20	91
40	94
60	97
80	98
100	98

A.9. Heating and Cooling Equipment Efficiencies

For measures which result in a change in chiller efficiency (e.g. chilled water temperature reset), Service Providers will measure or trend chiller performance over multiple operating conditions. The largest available range of representative operating conditions from shoulder period (spring/fall) loading to peak summer conditions should be obtained.

For measures which do not result in a change in the efficiency of the heating or cooling equipment, Service Providers will use manufacturer specified part load ratings for the equipment. Service Providers will include a reference to the website or specific document source for the rated values used. When this information is not available, Service Providers will reference Table 15 or **Table 16** where applicable. Part load efficiencies (IPLV) from Table 15 should be selected based on the approximate age of the building and the chiller type. Efficiencies from **Table 16** should be selected for heating equipment based on the age of the building.

A.10. District Energy

District Energy is defined as chilled water, steam and/or hot water produced in a remote centralized location and distributed via a network of pipes. The equipment used to produce District Energy is owned and operated by another party, who sells District Energy to customer(s).

District Energy Calculation Methodology

1. Cost Savings
   a. Cost savings for District Energy will be calculated based on incremental cost, similar to the electricity and natural gas cost saving calculations for other Energy Conservation Measures (ECM).
2. Energy Saving
   a. Enwave Chicago Customers: Chilled water plant efficiency is assumed to be 0.58 kW/ton (excludes customer chilled water pumps).
   b. For Building to Building, or Building to Tenant District Energy Sales/Campus District Energy, please refer to the guidance provided in Table 15 Water Chilling Packages Minimum Efficiency Requirements ASHRAE 90.1

Table 15. Water Chilling Packages Minimum Efficiency Requirements ASHRAE 90.1

Equipment Type	Standard Year	Size Category	Min. Efficiency	
			Full Load	Part Load
Air Cooled, with Condenser, Electrically Operated	**2010**	<150 tons	9.562 EER	12.500 IPLV
		>15 tons	9.562 EER	12.750 IPLV
	2001 / 2004 / 2007	All Capacities	2.80 COP	3.05 IPLV
	1989 / 1999	<150 tons	2.70 COP	2.80 IPLV
		>15 tons	2.50 COP	2.50 IPLV
Air Cooled, without Condenser, Electrically Operated	**2010**	Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller efficiency requirements		
	2001 / 2004 / 2007	All Capacities	3.10 COP	3.45 IPLV
	1989 / 1999	All Capacities	3.10 COP	3.20 IPLV
Water Cooled, Electrically Operated, Positive Displacement (Rotary Screw and Scroll)	**2010**	<75 tons	Path A: 0.780 kW/Ton Path B: 0.800 kW/Ton	Path A: 0.630 kW/Ton Path B: 0.600 kW/Ton
		≥75 tons and <150 tons	Path A:0.775 kW/Ton Path B: 0.790 kW/Ton	Path A: 0.615 kW/Ton Path B: 0.586 kW/Ton
		≥150 tons and <300 tons	Path A: 0.680 kW/Ton Path B: 0.718 kW/Ton	Path A: 0.580 kW/Ton Path B: 0.540 kW/Ton
		≥300 tons	Path A: 0.620 kW/Ton Path B: 0.639 kW/Ton	Path A: 0.540 kW/Ton Path B: 0.490 kW/Ton
	2001 / 2004 / 2007	<150 tons	4.45 COP	5.20 IPLV
		≥150 tons and <300 tons	4.90 COP	5.60 IPLV
		≥300 tons	5.50 COP	6.15 IPLV
	1989 / 1999	<150 tons	3.80 COP	3.90 IPLV
		≥150 tons and <300 tons	4.20 COP	4.50 IPLV
		≥300 tons	5.20 COP	5.30 IPLV

Equipment Type	Standard Year	Size Category	Min. Efficiency	
			Full Load	Part Load
Water Cooled, Electrically Operated, Positive Displacement (Reciprocating)	**2010**	Reciprocating units must comply with water-cooled positive displacement efficiency requirements		
	2001 / 2004 / 2007	All Capacities	4.20 COP	5.05 IPLV
	1999*	All Capacities	3.80 COP	3.90 IPLV
Water Cooled, Electrically Operated, Centrifugal	**2010**	<150 tons	Path A: 0.634 kW/Ton Path B: 0.639 kW/Ton	Path A: 0.596 kW/Ton Path B: 0.450 kW/Ton
		≥150 tons and <300 tons	Path A:0.634 kW/Ton Path B: 0.639 kW/Ton	Path A: 0.596 kW/Ton Path B: 0.450 kW/Ton
		≥300 tons and <600 tons	Path A: 0.576 kW/Ton Path B: 0.600 kW/Ton	Path A: 0.549 kW/Ton Path B: 0.400 kW/Ton
		≥600 tons	Path A: 0.570 kW/Ton Path B: 0.590 kW/Ton	Path A: 0.539 kW/Ton Path B: 0.400 kW/Ton
	2001 / 2004 / 2007	<150 tons	5.00 COP	5.25 IPLV
		≥150 tons and <300 tons	5.55 COP	5.90 IPLV
		≥300 tons	6.10 COP	6.40 IPLV
	1999*	<150 tons	3.80 COP	3.90 IPLV
		≥150 tons and <300 tons	4.20 COP	4.50 IPLV
		≥300 tons	5.20 COP	5.30 IPLV

*Not referenced in ASHRAE Standard 90.1-1989

Sources: ASHRAE Standard 90.1-1989 (pg. 100, Table 10-7); ASHRAE Standard 90.1-1999 (pg. 29, Table 6.2.1C); ASHRAE Standard 90.1-2001 (pg. 29, Table 6.2.1C); ASHRAE Standard 90.1-2004 (pg. 47, Table 6.8.1C); ASHRAE Standard 90.1-2007 (pg. 47, Table 6.8.1C); ASHRAE Standard 90.1-2010 (pg. 60, Table 6.8.1C)

Table 16. Heating Equipment Minimum Efficiency Requirements ASHRAE 90.1

Equipment Type	Standard Year	Size Category	Min. Efficiency
Warm Air Furnace, Gas-Fired	**1999 / 2001 / 2004 / 2007 / 2010**	<225,000 Btu/h	78% AFUE or 80% Et
		≥225,000 Btu/h	80% Ec*Et for 1999
Warm Air Duct Furnaces, Gas-Fired	**1999 / 2001 / 2004 / 2007 / 2010**	All Capacities	80% Ec
	1999	All Capacities	78% Et
Warm Air Unit Heaters, Gas-Fired	**2001 / 2004 / 2007 / 2010**	All Capacities	80% Ec
	1999	All Capacities	78% Et
Boilers, Gas-Fired, Hot Water	**1999 / 2001 / 2004 / 2007 / 2010**	<300,000 Btu/h	80% AFUE
	1989	<300,000 Btu/h	68% AFUE

Equipment Type	Standard Year	Size Category	Min. Efficiency
Boilers, Gas-Fired, Steam	**1999 / 2001 / 2004 / 2010**	<300,000 Btu/h	75% AFUE
	1989	<300,000 Btu/h	68% AFUE
Boilers, Gas-Fired	**2001 / 2004 / 2007 / 2010**	≥300,000 Btu/h and ≤2,500,000 Btu/h	75% Et
	1999	≥300,000 Btu/h and ≤2,500,000 Btu/h	80% Ec
	1989	≥300,000 Btu/h	75% Ec
Boilers, Gas-Fired, Hot Water, Not Packaged	**1999 / 2001 / 2004 / 2007 / 2010**	>2,500,000 Btu/h and <8,000,000 Btu/h	80% Ec
Boilers, Gas-Fired, Steam, Not Packaged	**1999 / 2001 / 2004 / 2007 / 2010**	>2,500,000 Btu/h and <8,000,000 Btu/h	80% Ec
Boilers, Gas-Fired, Hot Water, Packaged	**1999 / 2001 / 2004 / 2007 / 2010**	>2,500,000 Btu/h	80% Ec
Boilers, Gas-Fired, Hot Water, Packaged	**1999 / 2001 / 2004 / 2007 / 2010**	>2,500,000 Btu/h	80% Ec

Sources: ASHRAE Standard 90.1-1989 (pg. 101, Table 10-8 and 10-9); ASHRAE Standard 90.1-1999 (pg. 31, Table 6.2.1E and 6.2.1F); ASHRAE Standard 90.1-2001 (pg. 31, Table 6.2.1E and 6.2.1F); ASHRAE Standard 90.1-2004 (pg. 49, Table 6.8.1E and 6.8.1F); ASHRAE Standard 90.1-2007 (pg. 50, Table 6.8.1E and 6.8.1F); ASHRAE Standard 90.1-2010 (pg. 63, Table 6.8.1E and 6.8.1F);

Et= thermal efficiency

Ec=combustion efficiency (100% less flue losses).

Appendix B. M&V Guidelines for Common Measures

B.1. Use of Guidelines

Measurement and verification (M&V) guidelines for several common measures are provided in this Appendix. The Service Provider will consider site specific conditions, equipment configurations and facility requirements when using these guidelines. When site specific limitations prevent the collection of specified data, the Service Provider will note clearly that the data was unavailable and explain the estimation method used to address the omission.

These guidelines describe the M&V methods appropriate for the Investigation Phase and Verification Phase.

B.2. Common Measure Descriptions

The following measure descriptions relate to the M&V requirements as detailed in **Table 17** below. The RCx offering understands that there are many variations to these common measures, but has defined the measures as listed here for the purpose of standardizing the M&V requirements. The Service Provider will make recommendations based on improving the performance of the system at each site and will utilize these guidelines if the measure complies with the measure description below.

- **Calibrate sensor/t-stat**: Includes many different applications.
- **Chilled Water Temperature Reset**: Increase or reset the chilled water supply temperature (CHWST) during low building cooling loads to decrease chiller electricity consumption. Savings result from increase in chiller efficiency, but penalties for increased pumping energy and/or AHU fan increase need to be accounted for

  When to (and not to) use the standard measure calculator:

  ✓ If the proposed CHWST resets based on outside air dry bulb temperature.

  × If the proposed CHWST resets based on CHWRT.

  × When there are more than four affected chillers.

  × When there are more than eight pairs of chilled water pumps.

- **Condenser Water Temperature Reset**: Reset the condenser water (CW) temperature in order to improve chiller efficiency. The approach temperature for the specific cooling tower must be considered to ensure that cooling tower approach temperature will still be maintained with the new CW reset, or excessive fan energy may result.

  When to (and not to) use the standard measure calculator:

  ✓ If the current condenser water entering temperature (CWET) is fixed.

  × When the proposed CWET resets above the existing setpoint.

  × When all of the cooling tower fans are constant speed or two-speed (i.e. no VFD).

  × When there are more than four affected chillers.

  × When there are more than eight cooling tower fans.

- **Duct Static Pressure (DSP) Reset**: Reset or reduce static pressure setpoint on VAV systems to achieve fan energy savings.

  When to (and not to) use the standard measure calculator:

  ✓ The proposed reset schedule is based on outdoor air dry bulb conditions.

  × The proposed reset schedule is based on zone dampers/valves position.

  × The proposed reset schedule is based on return air temperature.

- **Improve Economizer Dry Bulb Temperature/Enthalpy Setpoints**: Includes repairing outside air damper failed in closed position, repairing poorly calibrated outdoor air damper position, or optimizing economizer setpoints. Cooling savings result from inappropriate outdoor air volume during economizer hours.

When to (and not to) use the standard measure calculator:

✓ Adjust economizer setpoint higher or lower than the existing setpoint.

× The economizer control strategy changed from dry bulb to enthalpy, or vice versa.

- **Night setback**: Setback energy savings (heating and/or cooling) based on heat transfer through exterior surfaces (UAdT).

  When to (and not to) use the standard measure calculator:

  × Energy savings are greater than the Tier 1 threshold values for kWh or Therms

  × The space being setback does not have exterior walls or roof.

- **Optimize AHU operation during unoccupied hours**: Optimizes unoccupied sequence of operation to reduce AHU cycling, closed OA dampers, utilize economizer for free cooling.
- **Reduce Minimum Outside Air Flow**: Repair outside air damper failed in open position or adjust the minimum outside air fraction back to design value from an excessive value. Cooling and heating savings result from decrease in excess outdoor air volume.

  When to (and not to) use the standard measure calculator:

  ✓ The outside air damper is stuck open.

  ✓ The space type/occupancy density permanently changed from the original design.

  × The affected AHUs use economizer strategies other than fixed dry bulb or differential dry bulb.

- **Reduce or reset pump differential pressure setpoint:** Reset or reduce pump static pressure setpoint for variable speed systems.

  When to (and not to) use the standard measure calculator:

  ✓ The proposed reset schedule is based on outdoor air dry bulb conditions.

  × The proposed reset schedule is based on zone valves position.

  × The proposed reset schedule is based on return water temperature.

- **Schedule AHUs**: Scheduling of specific AHU to achieve energy savings in both fan and heating/cooling energy.
- **Schedule all HVAC Equipment for Building Use**: Schedule entire building HVAC for use including chillers, boilers, AHUs, pumps and fans. With or without temperature setbacks.
- **Schedule chilled water or hot water pumps**: Scheduling heating and cooling pumps based on OAT and/or time of day.
- **Schedule Lighting**: Use existing lighting control to improve lighting schedule.

  When to (and not to) use the standard measure calculator:

  ✓ Lighting count or lighting density is known.

  × Need to install new lighting control equipment.

Table 17 applies to measures when custom calculators are used.

Table 17: M&V Guidelines for Common Measures

Measure Name	Nameplate Info[1]	Provide Documentation	Power Measurement	Trend[2]	Verification Plan
1. Duct Static Pressure Reset	• Supply fans motors (include motor HPs and efficiencies)	• Presence of fan VFD • AHU operation schedule from BAS • Maximum design supply CFM	• If the supply fan has a VFD obtain pictures of the VFD display at several load factors (at least 3) showing Amps, Speed and kW if available • If no VFDs are present, fan power will be estimated using a motor load factor of 70% and fan speed or IGV position	• Duct static pressure • Supply fan kW if available through the BAS • Supply fan VFD speed or damper position • SAT	• Repeat trending • Repeat spot measurement (at least one load factor) • Trend control variable (e.g. high limit, zone demand, OAT, or etc.)
2. Supply Air Temperature Reset	• Supply fans motors (include motor HPs and efficiencies) • Return fans motors (include motor HPs and efficiencies)	• Presence of fan VFD • Presence of air side economizer and setpoint • AHU operation schedule from BAS • Heating and cooling efficiency from manufacturer • CAV or VAV system	• If the supply and return fans have VFDs, obtain pictures of the VFD display at several load factors (at least 3) showing Amps, Speed and kW if available • If no VFDs are present, fan power will be estimated using a motor load factor of 70% and fan speed or IGV position	• SAT • SAT Setpoint • RAT • OAT • MAT • Supply fan VFD speed or damper position • Return fan VFD speed or damper position	• Repeat trending • Document new SAT reset schedule from BAS • Trend control variable (e.g. zone demand, OAT, or etc.)
3. Reduce Minimum Outside Air Flow	N/A	• OA damper and fan control sequences from BAS • Heating and cooling efficiency from manufacturer specs • Code required OA volume • Design OA volume (CFM) • CAV or VAV air system • AHU operation schedule from BAS	N/A	• OAT and OA enthalpy • RAT and RA enthalpy (If RA is used as the control variable) • MAT • SAT • Supply fan VFD speed or damper position • OA CFM or OA damper position	• Repeat trending • If OA control sequence is modified, document new control sequence from BAS

1. Nameplate information on both the load (fan or pump) and the drive power (motor) are required. Load nameplate includes: model, size (diameter), speeds (for fans), flow-rate, total pressure generated. Drive power nameplate includes: motor horsepower (HP), efficiency, revolutions per minute (RPM), full load amperes (FLA), power factor and service factor.

2. For guidelines on trending requirements, see the **Trending Requirements** section of this document.

Measure Name	Nameplate Info[1]	Provide Documentation	Power Measurement	Trend[2]	Verification Plan
4. Improve Economizer Temperature/ Enthalpy Setpoints	N/A	• CAV or VAV air system • Economizer control sequence from BAS • Cooling efficiency from manufacturer • AHU operation schedule from BAS • Design OA volume (CFM)	N/A	• OAT and OA enthalpy • RAT and RA enthalpy (If RA is used as the control variable) • MAT • SAT • Supply fan VFD speed or damper position • OA CFM or OA damper position • Economizer setpoint	• Repeat trending • Document new economizer control from BAS
5. Chilled Water (CHW) Temperature Reset	• CHW pumps (include motor HPs and efficiencies)	• CAV or VAV air system • Presence of CHW pump VFD • Presence of air or water side economizer • CHW setpoint or reset from BAS • Chiller operation schedule from BAS • Chiller performance data including varying Chilled Water Supply Temperature	• If the chiller has an integrated display or VFD, obtain pictures of the display at several load factors (at least 3) showing amps, speed, volts and kW if available • If the CHW pumps have VFDs obtain pictures of the VFD display at several load factors (at least 3) showing Amps, Speed and kW if available • If no VFDs are present, CHW pump power will be estimated using a motor load factor of 70% and equipment speed or IGV position	• If available, collect information available from the Chiller display and trends: % speed/load, operating kW, amps, volts, power factor • CHW supply and return temps • CHW pump speed (and pump kW if available through the BAS) • Supply airflow (CFM) or supply fan speed • OAT	• Repeat trending • Document new CHW reset schedule from BAS
6. Condenser Water (CW) Temperature Reset	• CW pumps (include motor HPs and efficiencies) • CT fans (include motor HPs and efficiencies)	• Presence of CT fan VFD • Presence of water side economizer • CW setpoint or reset from BAS • Chiller performance data including varying Entering Condenser-Water Temperature • CT operation schedule and seasonal shut down and start up	• If the chiller has an integrated display or VFD, obtain pictures of the display at several load factors (at least 3) showing amps, speed, volts and kW if available • If the CT fans and pumps have a VFD obtain pictures of the VFD display at several load factors (at least 3) showing Amps, Speed and kW if available • If no VFDs are present, CT fan and pump power will be estimated using a motor load factor of 70% and equipment speed or IGV position	• ECWT • OA WB • Chiller amperage or kW if available through the BAS • CT fan kW if available through the BAS, speed (if VFD) or on/off status	• Repeat trending • Document new CW reset schedule from BAS

Measure Name	Nameplate Info[1]	Provide Documentation	Power Measurement	Trend[2]	Verification Plan
7. Schedule Building HVAC System for Building Use	• All affected equipment (include motor HPs and efficiencies)	• Previous 24 months utility usage data • Previous 12 months utility interval data • Current equipment schedules from BAS • Nighttime temp setbacks from BAS	• Chiller • Supply fan, return fan, pumps • If the fans and pumps have a VFD obtain pictures of the VFD display at several load factors (at least 3) showing Amps, Speed and kW if available • If no VFDs are present, fan and pump power will be estimated using a motor load factor of 70% and equipment speed or IGV position	• Chiller amperage or kW if available through the BAS • Supply fan VFD speed or damper position • CHW and HW pump amperage or kW if available through the BAS • OAT • Return fan VFD speed or damper position • Other major equipment affected	• Repeat trending • Document new equipment schedule from BAS
8. Schedule Lighting	• Fixture ballasts • Lamps	• Number of fixtures by space • Current lighting schedule from controller • Observations of unoccupied lighting use (or trended light levels)	N/A	N/A	• Document new lighting schedule from controller • Observe unoccupied use (or trend light levels)
9. Calibrate Sensor/Tstat	• Dependent on measure	• Note if related system is CV or VAV • Presence of VFDs on related pumps • Presence of air or water side economizers related in system	• Independent calibrated sensor reading and concurrent BAS reading	• Trend sensor reading from BAS • Other variables dependent on measure	• Repeat spot measurement • Repeat trending • Other actions dependent on measure
10. Schedule AHU(s) for Space Use	• Supply fans motors (include motor HPs and efficiencies) • Return fans motors (include motor HPs and efficiencies)	• Presence of fan VFD • Presence of air side economizer and setpoint • CAV or VAV system • AHU operating schedule from BAS • SAT setpoint from BAS • Heating and cooling equipment efficiency from manufacturer	• Supply fan and return fan • If the fans have a VFD obtain pictures of the VFD display at several load factors (at least 3) showing Amps, Speed and kW if available • If no VFDs are present, fan power will be estimated using a motor load factor of 70% and fan speed or IGV position	• SAT • RAT • MAT • OAT • Supply fan VFD speed or damper position • Return fan VFD speed or damper position	• Repeat trending • Document new equipment schedule from BAS
11. Pump Pressure Reset	• Pump motors (include motor HPs and efficiencies)	• Presence of VFD • Pump operation schedule from BAS • Pump design GPM • Pump design differential pressure	• If the supply fan has a VFD obtain pictures of the VFD display at several load factors (at least 3) showing Amps, Speed and kW if available	• Pump kW if available through the BAS • Pump flow • Pump VFD speed or valve position • Supply temperature • Return temperature • Pump differential pressure	• Repeat trending • Repeat spot measurement (at least one load factor)