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M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 5.0

Data Center Addendum Version 1.0

Disclaimer

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List of Acronyms

AC	Alternating current
A/C	Air conditioning
AHU	air handling unit
ASHRAE	American Society of Heating Refrigeration and Air-Conditioning Engineers
BAS	Building automation system
CHW	Chilled water
CW	Condenser water
CRAC	Computer room air conditioner
CRAH	Computer Room Air Handler
DC	1. Direct current 2. Data center
DOE	U.S. Department of Energy
DX	Direct expansion. Refers to cooling systems that run refrigerant through the cooling coils, instead of chilled water. CRACs are DX.
ECM	Energy conservation measure (or water conservation measure)
EMCS	Energy management control system
ESPC	energy savings performance contract
FEMP	Federal Energy Management Program
HVAC	Heating, ventilation, air-conditioning
HX	Heat exchanger
IDIQ	indefinite delivery indefinite quantity
IT	Information technology
M&V	Measurement and verification
PDU	Power distribution unit

PF	Power factor
PUE	Power usage effectiveness
RRP	Risk, Responsibility, and Performance (Matrix)
TES	Thermal energy storage
UPS	Uninterruptible power supply
VFD	Variable frequency drive.
VSD	Variable speed drive

Executive Summary

Data centers are becoming increasingly prevalent, with significant growth of these energy intensive facilities and systems. The Energy Independence and Security Act of 2007 (Pub. L 110-140) initially added section 17112 to Title 42 of the United States Code (USC) describing requirements for energy efficiency for data center buildings, including "…advance the design and implementation of efficiency technologies to the maximum extent economically practical…" (42 USC 17112(b)(2)(F)). The Energy Act of 2020 (Pub. L 116-260) added language specifically directing federal agencies to consider energy efficient data center strategies (Title 42 USC Section 8253(h).

Data centers have unique attributes and potential energy conservation measures that may be applicable when evaluating them for energy efficiency improvements. As such, this supplement was developed to augment the Federal Energy Management Program's Measurement and Verification Guidelines for Performance-Based Contracts. Measurement and verification of energy conservation measure (ECM) performance are the key required components of energy savings performance contracts (ESPCs) and may be useful when developing utility energy service contracts (UESCs).

Where appropriate or applicable, this document highlights additional considerations for data centers when evaluating facilities for energy performance contracts (i.e., ESPCs, or UESCs). It also provides additional ECMs that may be applicable when evaluating data centers, and guidance for these additional ECMs. This resource assists in developing site-specific M&V plans and evaluating unique operational and performance characteristics for data centers.

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1 Introduction

This document is an addendum to M&V Guidelines: Measurement and Verification for Performance-Based Contracts, Version 5.0 (M&V Guidelines 5.0), Prepared for the U.S. Department of Energy Federal Energy Management Program, September 2024.

The above listed document is herein referred to as the “parent document” or “M&V Guidelines 5.0.”

This addendum repeats all the major section headings of the parent document and provides additional material and considerations specific to data centers where needed.

The introduction (Section 1) of the parent document stands as is.

This addendum provides additional material to address measurement and verification (M&V) for energy conservation measures (ECMs) implemented in data centers. It is up to personnel at the site or facility to review and determine the best M&V option for each ECM or project application in order to mitigate risk and balance cost and rigor. Refer to M&V Guidelines 5.0, section 5 – *Selecting an M&V Approach* for more information.

Some ECMs described in the parent document do not apply to data centers. Others do apply, either directly or with some modification. This addendum references all ECMs in the parent document and adds new ECMs that apply to data centers.

2 Overview of M&V

Refer to M&V Guidelines 5.0, section 2.0 Overview of M&V.

Data centers differ from most occupied facilities in several important ways. They typically have some of the following characteristics:

- Operate continuously
- Require constant cooling
- Exhibit high energy intensity from IT load density, consuming a large amount of energy compared to most commercial buildings
- Mission-critical, often equipped with redundancies including uninterruptible power supplies and backup generators
- Segregated areas for cool air and warm air (hot aisle/cold aisle), as the temperatures in these areas are usually more extreme than are found in occupied environments
- Meter and monitor devices to manage energy consumption and system performance, including power usage, flow rates, and environmental conditions.

The above factors may have an impact on the selected M&V approach and option for proposed ECMs.

3 Risk and Responsibility in M&V

Refer to M&V Guidelines 5.0, section 3.0 Risk and Responsibility in M&V.

There are several specific considerations for data centers that may need to be addressed within the RRP Matrix. They are located in the following sections and include:

1. Financial

    a. Major changes in facility. Clarify responsibilities in the event of a premature facility closure, loss of funding, or other major change(s). ***Specify changes in IT space, use, etc***.

2. Operational

    b. Load: Clarify whether equipment loads are to be measured or stipulated and what impacts will be if they change. ***Specify IT loads.***

3. Performance

    a. Equipment performance: Clarify who is responsible for initial and long-term performance, how it will be verified, and what will be done if performance does not meet expectations. ***Specify any up-time IT/Data Center requirements*** (e.g., power usage effectiveness, up-time requirements).

4 Detailed M&V Methods

Section 4 stands as-is in the parent document, with the following additions.

4.2. Option A – Retrofit Isolation with Key Parameter(s) Measurement

4.2.1. Approach to Option A

4.2.1.2. Estimates

Among the sources of information listed in the parent document for efficiency estimates, these two appear:

Manufacturers' data or standard tables (such as lighting tables used in utility demand-side management programs).

> Manufacturers of variable-efficiency equipment typically quote a single efficiency value for a given device that corresponds to a single, standard operating condition. This value is often not representative of long-term operating efficiency as the equipment's operation is characterized by "efficiency curves" representing a range of efficiency across operating conditions.

Manufacturers' curves, such as pump, fan, and chiller performance curves.

> Be aware that equipment manufacturers' curves may likewise apply to a standard operating condition. For example, a chiller efficiency curve may correspond to a specific chilled water supply temperature, condenser water temperature and chiller load factor. These temperatures and loads will be different in actual operation, which will change the dimensions and shape of efficiency curve.

Manufacturers' equipment performance data and curves should be corrected for actual operating conditions.

4.3. Option B – Retrofit Isolation with All Parameter Measurement

M&V Option B in Section 4.3 focuses on measurement of performance and operational factors at the component or system level, using short-term, periodic, or continuous measurement of all relevant parameters.

Data centers typically have target temperature and humidity requirements that must be maintained all day, year-round. Leveraging energy management control systems (EMCS) can support meeting project performance requirements and savings guarantees. Continuous measurements (e.g., every 15, 30, or 60 minutes) of all relevant parameters can help ensure that performance and savings are met. Additionally, monthly or quarterly reviews of EMCS trend data can allow issues to be spotted and managed more frequently than only during annual M&V activities.

4.4. Option C - Whole Facility Measurement

Section 4.4. states “Option C models are sometimes not highly predictive of actual whole facility energy consumption”. This is due to the variability in energy use common to occupied buildings (e.g., occupant behavior patterns, seasonality, equipment setbacks, plug loads). In this case, adjustments to the baseline will likely increase the cost of performing M&V.

Data centers tend to provide more homogeneous and stable operating environments with less diverse support systems than those of typical occupied commercial facilities. Also, being mission-critical facilities, they are more likely to have metered sub-systems. Option C may be more readily applicable in a data center context and therefore bears consideration. Key parameters under M&V Option C include monitoring and documenting the installed and operational load of the data center and updating the models accordingly.

4.5. Option D – Calibrated Simulation

4.5.2. Simulation Software

Section 4.5.2 refers to two common energy simulation programs, eQUEST and EnergyPlus. These are well-suited for analyzing occupied facilities, establishing baseline consumption and determining proposed savings.

Data centers, on the other hand, are not always easy to model in software – especially the air side as it is relatively easy to get misleading output if specific space and airflow characteristics are not appropriately input, based on observed or measured conditions. Confer with an experienced data center modeler before developing a model and trusting model results.

5 Selecting an M&V Approach

Refer to M&V Guidelines 5.0, section 5.0 Selecting an M&V Approach.

Data centers typically support mission critical activities, with stringent performance requirements and 24/7 operations. Depending on ECMs chosen, M&V for data center ECMs may be relatively straight forward due to continuous and constant facility operation. However, there are several unique considerations with data centers when considering an M&V approach for ECMs included in the proposed project. They include:

- Complexity of ECM or System. Data centers not only impact the HVAC and BAS/EMCS but also may impact or interact with the IT equipment, which must be considered when determining the M&V approach.
- Sampling. Depending on the risk tolerance or critical nature of the specific system(s) and expected variability in operation or savings, a greater sample size(s) may be warranted.

6 Guidance for Specific ECMs

This section provides general M&V guidelines for data center related ECMs that may be implemented under energy performance contracts and other energy conservation projects. Data center related ECMs described in this section are organized by DOE ESPC IDIQ Technology Categories, as shown in Table 6-1, with the suggested M&V option. There are nine new data center-specific ECMs included in this addendum, which represent some of the more prominent energy savings measures that apply to these types of facilities. For DOE ESPC IDIQ Technology Categories for which a data center specific ECM is not applicable, it is noted as such.

Table 6-1. Summary of Included ECMs and Proposed M&V Options for Data Centers

Technology Category	ECM	M&V Option
Building Automation Systems (BAS)/Energy Management Control Systems (EMCS)	ECM: Implementing EMCS Control Sequences	B
	ECM: Optimize EMCS Sensor Location	B
	ECM: Optimize Air Management	B
	ECM: Networked CRAC, CRAH, and AHU Controls	B or C
Heating, Ventilation, and Air Conditioning (HVAC) Improvements	ECM: Variable Air Volume Conversion	A or B
	ECM: Heat Recovery Systems	B
	ECM: Replace Self-Contained Air Conditioning with Chilled Water	A
	ECM: Air-Side Economizer	B
	ECM: Humidity Control	B
	ECM: Water-Side Economizer	B
	ECM: Effective Cooling Towers	B
	ECM: Lighting Controls	A
Electric Motors and Drives	ECM: Premium Efficiency Motors	A or B
	ECM: Variable Speed Pumping	A or B
Electrical Peak Shaving/Load Shifting	ECM: Thermal Energy Storage (TES)	B
Energy Related Process Improvements	ECM: Energy-Efficient IT Equipment	B
	ECM: Efficient Uninterruptible Power Supply (UPS)	A
Commissioning	ECM: Retro-commissioning / Recommissioning	B

6.1 Boiler Plant Improvements

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.2 Chiller Plant Improvements

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.3 Building Automation Systems (BAS) / Energy Management Control Systems (EMCS)

The parent document does not make a distinction between installation/upgrade of the EMCS itself, and implementation of energy-efficient control sequences once the EMCS is in place. Making this distinction is useful for data centers, so this is reflected in the ECM description.

6.3.1 ECM: Energy Management Control System

This ECM stands as is in the parent document, including with recommending Option B (Retrofit Isolation with all Parameter Measurement), and adds the following data center considerations.

Data Center Considerations

An EMCS for a data center differs in many ways from an EMCS for occupied spaces. Data centers use a relatively large amount of energy and are typically mission-critical facilities. As such, investments in a robust data center EMCS can often be economically justified.

A data center EMCS has two major functions: monitoring of and active control of data center support systems. Energy savings derive from changes to the active control schemes while adhering to the critical system operational limits.

This measure is applicable whether or not a working EMCS already exists. If one does not exist, then the data center support system equipment probably runs with local, “on-board” controls. In either case, this measure calls for both:

- Installation of a functioning EMCS.
- Changes to existing support system equipment control sequences in order to reduce energy use.

Table 6-2 provides an outline of potential changes to control points.

Table 6-2. Data Center EMCS Control Points Outline

Cooling System	Potential Control Point Changes
Air side [direct expansion (DX) or chilled water (CHW)]	
Cooling air temp & humidity	Maintain no tighter range of temperature and humidity than recommended range for the air entering the IT equipment in guidance such as ASHRAE Thermal Guidelines for Air Cooling[1].
Cooling air flow rate	Vary the air flow rate to match the IT equipment demand.
Air-side economizer	Operate the air side economizer to maximize energy savings.
Air-side evaporative cooling	Operate the air side evaporative cooling to maximize energy savings.
CHW Plant	
All equipment	Stage on/off as required and vary speed as needed to meet load.
Chillers	Maintain and reset the CHW supply temperature.
Cooling towers	Maintain and reset the CW supply temperature.
CHW distribution	Vary pressure and flow to minimize pump energy use.
CW distribution	Vary pressure and flow to minimize pump energy use.
Water-side Economizer	Operate the water side economizer to maximize energy savings.
TES plant	Operate the TES plant to maximize energy cost savings.
Water-Cooled DX	
CW supply temperature	Maintain and reset the CW supply temperature.
CW flow rate	Vary pressure and flow to minimize pump energy.
IT Power Chain	Controls tend to be intrinsic to power chain devices.
Backup generator	Generator engine heater thermostatic control.
Renewable energy sources	Scheduling renewable energy sources.
Lighting System	
Lighting controls	Control the data center lights to minimize energy use.
Heating System	Data centers tend not to have space heating systems.

[1] https://www.ashrae.org/file%20library/technical%20resources/bookstore/supplemental%20files/therm-gdlns-5th-r-e-refcard.pdf

The parameters to measure during the M&V process depend on the systems affected by the new controls. The following list of examples expands on the one provided in the parent document, adding parameters relevant to data centers.

- IT equipment power demand and energy use
- Support system equipment runtime and operational status
- Support system equipment power demand and energy use
- Air temperature and humidity set points/ranges and resets
- Supply air temperature, return air temperature and humidity, actual
- Air pressure and flow set-points and resets
- Air pressure and flow rate, actual
- Water temperature set-points and resets
- Supply and return water temperatures, actual
- Water pressure and flow set-points and resets
- Water pressure and flow rate, actual
- Outside air temperature & humidity

6.3.2 ECM: Optimize EMCS Sensor Location

ASHRAE's Thermal Guidelines for Data Processing Environments (5th Edition 2021) provides guidelines for specific ranges of temperature and humidity for cooling air entering IT equipment. These ranges are warmer than the range used for cooling occupied spaces, but appropriate for data center cooling. These warmer ranges allow the data center cooling system to run more efficiently. This measure involves programming the cooling system set points to produce cooling air in the selected range.

CRACs/CRAHs and AHUs are typically designed with on-board, stand-alone controls. Temperature and humidity sensors are located in the return air opening of the unit, and the CRAC/CRAH or AHU adjusts the supply air temperature and humidity in order to maintain the return air set-points.

This ECM requires moving the temperature and humidity control sensors to a location that better represents the air entering the IT equipment and ensuring that the sensors are calibrated. The ability to maintain the desired target air condition for all IT equipment inlets depends on good air management; see ECM 6.3.3: "Air Management."

6.3.2.1 M&V Plan Description

M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended to validate ECM performance for the post-installation and performance periods through continuous measurement (e.g., every 15, 30, or 60 minutes) of all relevant parameters. Under this strategy, post-installation and ongoing performance is evaluated by collecting and monitoring key parameters through the EMCS or sub-metering.

6.3.2.2 M&V Option Selection Rationale

Energy savings vary based on many parameters including existing equipment efficiency, cooling load, heating load, part-load HVAC performance, and runtime hours. Changes to the IT load and intake air temperature and humidity will probably affect performance of the cooling system, which is in turn affected by outside air temperature and humidity. Due to the multiple interactions between HVAC equipment and building load it is recommended to develop a representative baseline energy analysis model to evaluate the savings from the installation of a control system to optimize the performance and runtime of the HVAC equipment. For performance period M&V activities, Option B is recommended to ensure persistence of savings over the contract period by monitoring all parameters.

Identify:

- IT equipment that will be affected by this ECM; and
- cooling system(s) that serve the selected IT equipment.

To successfully execute M&V, quantify the sum of the power draw of the targeted IT equipment and the power draw of the entire cooling system(s) serving said IT equipment, as a function of:

- temperature and humidity of the air entering the IT equipment, and
- changes in outside air temperature and humidity.

Baseline Period

- Measure the parameters in Table 6-3 for the duration of the baseline period, using EMCS data where available. Operate the cooling system with its baseline temperature and humidity control set-points, even if the control sensors do not represent IT equipment intake conditions. This period needs to include changes in the total IT equipment power demand as well as changes in outside air temperature and humidity in order to represent the baseline system energy use.
- Extrapolate to a full year of energy use for baseline operation. Compare to other historical meter data, if available, to ensure that the baseline is accurately characterized.

Post-Installation Period

- Verify that the cooling system is now controlling the IT equipment inlet air condition, keeping it within the selected ASHRAE target range.

- Measure the post-installation parameters in Table 6-3 using EMCS trend data. This measurement period needs to include changes in the total IT equipment power demand as well as changes in outside air temperature and humidity. A measurement period of 15 or 30 days is recommended.
- Extrapolate to a full year of energy use for post-installation operation.
- Confirm that new (higher) setpoint temperatures are being achieved and energy savings are being realized as compared to the baseline conditions.

Performance Period

- Measure the performance period parameters in Table 6-3 using EMCS trend data. Any changes in the total IT equipment power demand as well as changes in outside air temperature and humidity should be documented.
- Confirm that new (higher) setpoint temperatures are being achieved and energy savings continue to be realized as compared to the baseline conditions.

6.3.2.3 M&V Performance Assurance Activities

- Verify installation of control hardware and operational parameters remain unchanged.
- Monitor and verify that IT equipment intake air conditions stay within the selected ASHRAE range.
- Verify that spaces are achieving desired heating and cooling set points.
- Perform post-installation short-term measurements and use the EMCS trending data during the performance period to demonstrate energy savings.
- Verify that the system remains set up and is recording relevant trend logs.
- Annual review of EMCS trend logs to validate ECM performance.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Verify that operators have received training in operating the new system.
- Ensure customer witnessing of M&V activities.

Table 6-3. M&V Parameters for ECM: Optimize EMCS Sensor Location

Parameter	Period	Population	Activity
	IT Equipment Total Power Demand		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of IT equipment targeted by ECM.	Continuous trends from EMCS
Performance	Post-Installation	90/10 or 80/20	Continuous trends from EMCS
Performance	Performance	90/10 or 80/20	Continuous trends from EMCS
	Temperature & Humidity of Air Entering IT Equipment		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of IT equipment targeted by ECM.	Continuous trends from EMCS
Performance	Post-Installation	90/10 or 80/20	Continuous trends from EMCS
Performance	Performance	90/10 or 80/20	Continuous trends from EMCS
	Cooling System Total Power Draw		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of cooling system(s) serving IT equipment targeted by ECM.	Continuous trends from EMCS
Performance	Post-Installation	90/10 or 80/20	Continuous trends from EMCS
Performance	Performance	90/10 or 80/20	Continuous trends from EMCS
	Outside Air Temperature & Humidity		
Performance	Baseline	At each geographical facility location	Continuous trends from EMCS
Performance	Post-Installation	At each geographical facility location	Continuous trends from EMCS
Performance	Performance	At each geographical facility location	Continuous trends from EMCS

6.3.3 ECM: Optimize Air Management

In data centers, the ideal air-based cooling system (from an energy efficiency perspective) is one that:

- delivers the precise flow rate of cooling air that is needed, and no more
- delivers all cooling air directly to the intake openings of the IT equipment without allowing any of it to bypass the equipment

- collects all exhaust air directly from the IT equipment without allowing any of it to short-circuit back to the intake openings
- provides a minimally restrictive path for air flow.

The intent of this ECM is to have the cooling system come as close to this ideal as is practical via physical barriers between the air supplied to, and returned from, the IT equipment.

The intent of this ECM is to have the same target temperature and humidity and flow rate for the air entering the IT equipment, both before and after the retrofit. (Depending on how poor air management is prior to the retrofit, not all of the IT equipment may be receiving air in the target range.) Changing the target range of the air entering the IT equipment is the subject of ECM 6.3.2: "ASHRAE Thermal Guidelines."

6.3.3.1 M&V Plan Description

M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended to validate ECM performance through continuous measurement (e.g., every 15, 30, or 60 minutes) of relevant parameters. Some considerations include:

- Improved air management techniques may result in reduced supply fan energy if the fans operate with automatic speed control or if one or more CRACs/CRAHs or AHUs can be idled if less air flow is needed.
- The performance of the cooling system is affected by outside air temperature and humidity.

6.3.3.2 M&V Option Selection Rationale

Identify:

- The IT equipment that will be affected by this ECM.
- The cooling system(s) that serve the selected IT equipment.

To successfully execute M&V, quantify the sum of the power draw of the targeted IT equipment and the power draw of the entire cooling system(s) serving said IT equipment, which is a function of both the temperature and humidity of the air entering the IT equipment and changes in outside air temperature and humidity.

Baseline Period

- The parameters in Table 6-4 will be measured continuously during the baseline, using EMCS data where available. The period of time chosen should be sufficient to capture changes in the cooling load, as well as in outside air temperature and humidity.
- Extrapolate to a full year of energy use for baseline operation. Compare to historic meter data if available.

Post-Installation Period

- Verify the installation of air management solutions.
- Measure the post-installation parameters in Table 6-4 using EMCS data. The aim is to show that the cooling system is using less power to handle a given cooling load at given outside air conditions. This measurement period should include changes in the cooling load and outside air temperature and humidity. A measurement period of 15 or 30 days is recommended.
- Extrapolate to a full year of energy use for post-installation operation. Confirm that the ECM performs as specified and has potential to achieve expected energy savings as compared to the baseline.

Performance Period

- Measure the performance period parameters in Table 6-4 using EMCS data. The aim is to show that the cooling system is using less power to handle a given cooling load at given outside air conditions. Any changes in the cooling load and outside air temperature and humidity should be documented.
- Confirm energy savings are being realized.

6.3.3.3 M&V Performance Assurance Activities

Before Starting M&V Measurements

- Obtain customer approval of all parameters to be measured.

After the Post-Installation Measurements and during the Performance Period

- Train staff on the principles of good air management and how to sustain them.
- Ensure customer witnessing of M&V activities.

Table 6-4. M&V Parameters for ECM: Optimize Air Management

Parameter	Period	Population	Activity
	IT Equipment Total Power Demand		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of IT equipment targeted by ECM.	Continuous trends from EMCS
Performance	Post-Installation	90/10 or 80/20	Continuous trends from EMCS
Performance	Performance	90/10 or 80/20	Continuous trends from EMCS
	Temperature & Humidity of Air Entering IT Equipment		

Parameter	Period	Population	Activity
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of IT equipment targeted by ECM.	Continuous trends from EMCS
Performance	Post-Installation	90/10 or 80/20	Continuous trends from EMCS
Performance	Performance	90/10 or 80/20	Continuous trends from EMCS
	Cooling System Total Power Draw		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of cooling system(s) serving IT equipment targeted by ECM.	Continuous trends from EMCS
Performance	Post-Installation	90/10 or 80/20	Continuous trends from EMCS
Performance	Performance	90/10 or 80/20	Continuous trends from EMCS
	Outside Air Temperature & Humidity		
Performance	Baseline	At each geographical facility location	Continuous trends from EMCS
Performance	Post-Installation	At each geographical facility location	Continuous trends from EMCS
Performance	Performance	At each geographical facility location	Continuous trends from EMCS

6.3.4 ECM: Networked Computer Room Air Conditioning, Computer Room Air Handling and Air Handling Unit Controls

Computer Room Air Conditioning (CRAC) units, computer room air handling (CRAH) units and air handling units (AHUs) are typically self-contained, complete with an on-board control system and air temperature and humidity sensors. The sensors' calibrations may drift over time. In a data center with many CRAC units, CRAH units or AHUs, it is not unusual to find some units humidifying while others are dehumidifying. There may also be significant differences in supply air temperatures; both situations waste energy. Controlling all CRAC and/or CRAH units and AHUs from a central controller based upon a common set of sensors avoids this. If communications among the units and the controller are lost, the units can revert to a common set of setpoints and modes.

6.3.4.1 M&V Plan Description

M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended to validate ECM performance through continuous measurement (e.g., every 15, 30, or 60 minutes) of relevant parameters. M&V Option C (Whole Facility Measurement) may be applied to this ECM, if available metering is in place and data center energy consumption is isolated, by comparing the total power demand of CRAC units, CRAH units or AHUs with the thermal loads placed on them.

6.3.4.2 M&V Option Selection Rationale

Identify the CRAC units, CRAH units or AHUs to be networked. To successfully execute M&V, quantify the power demand of CRAC units, CRAH units or AHUs as a function of their sensible and latent cooling loads. Savings are determined through analysis of these data as independent variables that affect energy consumption. If Option C is selected, once savings are established in the first performance year(s), the M&V process may be switched to a retrofit isolation technique such as Option A or B.

Baseline Period

- Utilize at least 12 (and preferably 24 or more) months of pre-installation utility data to establish the baseline and capture seasonal variation.
- The parameters in Table 6-5 will be measured continuously during the baseline. The chosen period should adequately capture changes in sensible and latent cooling loads.

Post-Installation Period

- Verify the correct installation of the new control sensor network. Verify that control sensors are calibrated.
- Measure the post-installation parameters in Table 6-5. The aim is show that the CRAC units, CRAH units or AHUs are demanding less power to handle a given total sensible and latent cooling load and have the potential to achieve energy savings. The measurement period should adequately capture changes in sensible and latent cooling loads. A measurement period of 15 or 30 days is recommended.
- Extrapolate to a full year of energy use for post-installation operation. Confirm ECM performance and potential to achieve energy savings as compared to the baseline.

Performance Period

- Measure the performance period parameters in Table 6-5. The aim is to show that the CRAC units, CRAH units or AHUs are demanding less power to handle a given total sensible and latent cooling load. This period should include any changes in sensible and latent cooling loads.
- At least 9 (preferably 12) months of performance period data should be used to calculate annual savings.
- Confirm energy savings are being realized.

6.3.4.3 M&V Performance Assurance Activities

Before Starting M&V Measurements

- Obtain customer approval of all parameters to be measured.

After the Post-Installation Measurements and during the Performance Period

- Verify that the CRAC unit, CRAH unit or AHU networked controls remain unchanged, and trend logs are being recorded.
- Ensure customer witnessing of M&V activities.

Table 6-5. M&V Parameters for ECM: Networked CRAC unit, CRAH unit or AHU Controls

Parameter	Period	Population	Activity
	CRAC units, CRAH units or AHUs Supply and Return Air Temperature & Humidity		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of CRAC units, CRAH units or AHUs targeted by this ECM.	Continuous trends.
Performance	Post-Installation	Same population as baseline.	Continuous trends.
Performance	Performance	Same population as baseline.	Continuous trends.
	CRAC units, CRAH units or AHUs Air Flow Rate		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of CRAC units, CRAH units or AHUs targeted by this ECM.	Continuous trends.
Performance	Post-Installation	Same population as baseline.	Continuous trends.
Performance	Performance	Same population as baseline.	Continuous trends.
	CRAC units, CRAH units or AHUs Supply Fan Power Draw		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of CRAC units, CRAH units or AHUs targeted by this ECM.	Continuous trends.
Performance	Post-Installation	Same population as baseline.	Continuous trends.
Performance	Performance	Same population as baseline.	Continuous trends.
	CRAC units, CRAH units or AHUs Humidifier Power Draw		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of CRAC units, CRAH units or AHUs targeted by this ECM.	Continuous trends.

Parameter	Period	Population	Activity
Performance	Post-Installation	Same population as baseline.	Continuous trends.
Performance	Performance	Same population as baseline.	Continuous trends.

6.4 Heating, Ventilating, and Air Conditioning (HVAC) Improvements

6.4.1 ECM: Variable Air Volume Conversion

This ECM stands as is in the parent document, with these additional considerations on data center applications.

Data Center Considerations

The design of the air side of data center cooling systems is typically different than the design of the air side of systems that serve occupied space. The intent of this measure is to transition from the existing fan speed control scenario to one that is more energy-efficient, while delivering the required air flow rate and pressure at the points of use. Table 6-6 provides several fan speed control scenarios to improve energy efficiency.

The IT equipment itself is typically equipped with internal cooling fans that can change speed in response to the equipment's internal temperature. Ideally, the data center cooling system should deliver the same amount of air that the equipment fans are moving (though in practice this is rarely achieved).

The simplest CRACs/CRAHs and AHUs are equipped with constant-speed fans. It is up to the data center designer to select the appropriate size and number of CRACs/CRAHs and AHUs and configure the air flow path to provide the optimum air flow at peak load conditions. At off-peak times, the CRAC/CRAH and AHU fans deliver more air than is necessary.

Some CRACs/CRAHs and AHUs have variable speed fans that are controlled to provide a constant air pressure difference at a selected point in the air flow path. The point selected may or may not "see" pressure changes as the IT equipment fans ramp up and down. This fan speed control scheme does not provide the capability to directly control the temperature of the air entering the IT equipment (see 6.3.2 ECM: Optimize EMCS Sensor Location). Fan speed can be set to provide a specified inlet temperature at the rack top in the cold aisle.

The intent of this measure is to provide CRAC/CRAH and AHU fan speed control if it does not yet exist, and optionally, to add an automatic fan speed control scheme.

Any reduction in fan speed compared to the pre-retrofit situation (all else being equal) will save energy, given the exponential relationship between fan speed and fan power demand.

If the existing fans do not have variable speed capability (i.e., they run at full speed) and yet they are not supplying enough air to meet current requirements, then adding speed control alone will not help provide more air.

Variable frequency drives (VFDs) are not 100% efficient, and their efficiency falls off at slower speeds. Adding a VFD to a fan comes with an energy cost that must be weighed against the potential savings.

Table 6-6. Fan Speed Control Scenarios

Scenario	Fixed Geometry Flow Path?[2]	Variable Speed Capability?	Runs at Constant Speed?	Flow/Pressure at Point(s) of Use	How to Save Energy
1	Yes	No	Yes	The fan system runs continuously at full speed. Manual dampers or the number, location and/or openings of perforated floor tiles are set to provide the desired air flows.	If the flow is restricted in all branches by manually adjusted dampers, then implement Scenario 2, reduce the flow restrictions, and reduce the fan speed to provide the desired air flows.
2	Yes	Yes	Yes	Fan speed and dampers or the number, location and/or openings of perforated floor tiles are manually set to provide the desired air flows at a constant operating condition.	If the manual dampers and the fan speed are already set to provide the required air flows at the points of use with the least fan power demand, there is no advantage to implementing automatic speed control.
3	No	No	Yes	Manual dampers or the number, location and/or openings of perforated floor tiles are set to restrict maximum possible air flow. Automatic dampers modulate to maintain the desired air flow at the points of use. The fan "rides its curve" as the resistance to flow varies.	Scenarios 4 and 5 provide more efficient solutions.
4	No	Yes	Yes	Fan speed is manually set to provide the desired air flow at the points of use, at the maximum demand condition. At less than maximum demand, the fan works against the modulating dampers and/or floor tiles.	Scenario 5 offers a more efficient solution.

[2] Fixed geometry flow path: A path that does not automatically change physical dimensions during operation, i.e., one that does not have any automatically modulating control dampers.

Scenario	Fixed Geometry Flow Path?[2]	Variable Speed Capability?	Runs at Constant Speed?	Flow/Pressure at Point(s) of Use	How to Save Energy
5	No	Yes	No	Sensors provide feedback to the fan. Fan speed varies to provide the desired air flow over a range of demands. Fan fighting against damper/tile restriction is minimized.	This is the most energy-efficient fan speed control scheme. For further savings, look to ECMs that reduce the air flow requirement at the points of use, or increase the efficiency of the fan and fan motor.

6.4.1.1 M&V Plan Description

For fixed-geometry systems (Scenarios 1 & 2 in Table 6-6), M&V Option A (Retrofit Isolation with Key Parameter Measurement) is suitable. The fan systems run at a steady state, so all that is needed are spot measurements of the baseline and post-retrofit fan power demand.

For variable-geometry systems (Scenarios 3, 4, and 5 in Table 6-6), M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended. In these systems, the air flow requirements at the points of use are assumed to vary. The fan power demand will vary in response, in ways that are not always predictable via simple formulas.

6.4.2 ECM: Heat Recovery Systems

In the parent document, this ECM addresses heat recovery units. HRUs are designed to transfer heat between incoming and outgoing ventilation air streams, in order to save heating and cooling costs while maintaining ventilated outside air flow.

Data Center Considerations

Data centers need continuous cooling, so it is counter-productive to warm incoming ventilation air. In hot weather, pre-cooling incoming ventilation air with outgoing exhaust air can provide a marginal benefit.

There is a much larger heat recovery opportunity present in data centers, though. Data centers shed a relatively large amount of low-grade heat. If there is a nearby need for this type of heat – such as conditioned or occupied space during cold weather, or an industrial process – it may be possible to modify the data center cooling system to redirect the waste heat and thereby offset the source heat energy otherwise being used.

The rest of this ECM description assumes an air-to-air heat exchanger between a data center and another space.

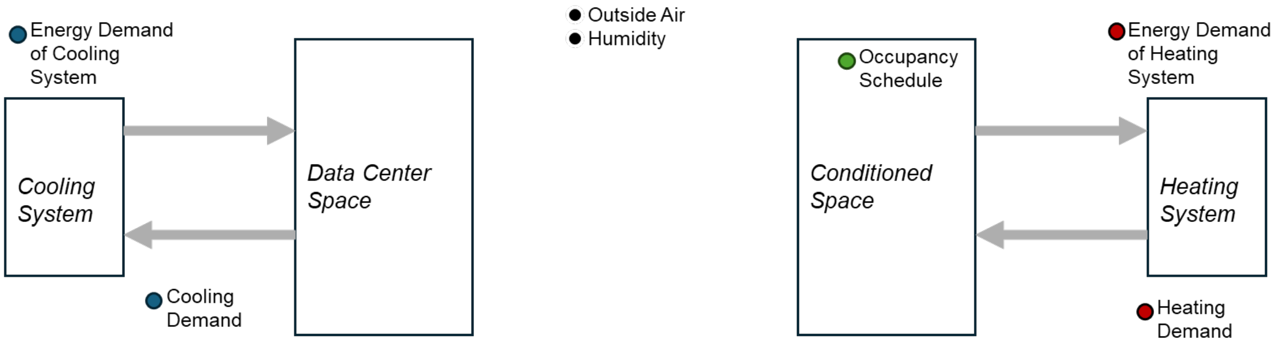

Figure 6-1. Before Installation of Heat Recovery System

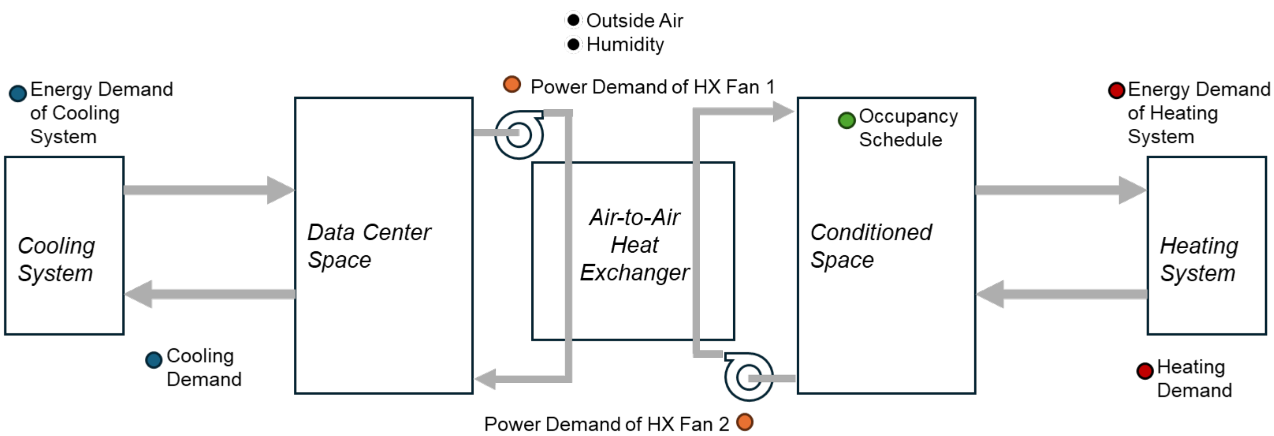

Figure 6-2. After Installation of Heat Recovery System

6.4.2.1 M&V Plan Description

M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended, as the performance of the heat recovery system will depend on outside air conditions and the schedule of the conditioned or occupied space.

6.4.2.2 M&V Option Selection Rationale

Identify:

- The data center space that heat will be extracted from to serve space.
- The cooling system(s) that serve the identified data center space.
- The space that will receive heat from the data center.
- The heating system(s) that serve the identified space.

To successfully execute M&V, quantify the power draw (and tower water use if applicable) of the data center cooling system, the conditioned or occupied space heating system, and the heat exchanger fans as a function of:

- Changes in data center cooling load and space heating load; and
- Changes in outside air temperature and humidity.

Baseline Period

- During the baseline period, the data center cooling system and the space heating system are separate and independent.
- Applicable parameters for the identified data center cooling system and space heating system (see Table 6-7) will be measured continuously during the baseline period for an appropriate amount of time to establish the baseline. Measurements should be made during cold weather, when there is a demand for heating in the space and across varying loads on both systems, along with changes in outside air temperature and humidity.
- Create the baseline energy use profile of the respective heating and cooling systems for the identified spaces.
- Extrapolate to a full year of energy use for baseline operation. Compare to historic meter data if available.

Post-Installation Period

- Verify that the heat exchanger and controls have been installed and commissioned.
- Measure the post-installation parameters in Table 6-7. The aim is to show to what extent the sum of the power demand of the data center cooling system, space heating system, and heat exchanger fans is reduced compared to baseline when conditions are favorable. Measurements should be made during cold weather, when there is a demand for heating in the space, and across varying loads on both systems, along with changes in outside air temperature and humidity.
- Extrapolate to a full year of energy use for post-installation operation. Confirm ECM performs as specified and has the potential to generate expected energy savings.

Performance Period

- Measure the performance period parameters in Table 6-7. The aim is to show that the installed heat exchangers continue to reduce cooling and heating loads of the linked heating and cooling systems. Measurements should be made across varying loads on both systems, along with changes in outside air temperature and humidity.

- Confirm that the installed heat exchangers continue to meet performance requirements and yield expected annual savings.

6.4.2.3 M&V Performance Assurance Activities

Before Starting M&V Measurements

- Check the heat recovery calculations to verify that there is significant energy savings potential.
- Obtain customer approval of all parameters to be measured.

After the Post-Installation Measurements and during the Performance Period

- Continue to monitor the performance of the heat recovery system.
- Ensure customer witnessing of M&V activities.

Table 6-7. M&V Parameters for ECM: Heat Recovery

Parameter	Period	Population	Activity
	Cooling System Total Power Demand		
Performance	Baseline	100% of cooling systems serving data center space targeted by this ECM.	Continuous trends.
Performance	Post-Installation	Same as baseline.	Continuous trends.
Performance	Performance	Same as baseline.	Continuous trends.
	Cooling System Thermal Load		
Performance	Baseline	100% of cooling systems serving data center space targeted by this ECM.	Continuous trends.
Performance	Post-Installation	Same as baseline.	Continuous trends.
Performance	Performance	Same as baseline.	Continuous trends.
	Heating System Power Demand		
Performance	Baseline	100% of heating systems serving space targeted by this ECM.	Continuous trends.
Performance	Post-Installation	Same as baseline.	Continuous trends.
Performance	Performance	Same as baseline.	Continuous trends.
	Heating System Thermal Load		

Parameter	Period	Population	Activity
Performance	Baseline	100% of heating systems serving space targeted by this ECM.	Continuous trends.
Performance	Post-Installation	Same as baseline.	Continuous trends.
Performance	Performance	Same as baseline.	Continuous trends.
	Heat Exchanger Fans Power Demand		
Performance	Baseline	n/a	n/a
Performance	Post-Installation	100% of HX fans.	Spot measurement, assuming fans are constant speed & flow when running. If variable speed, continuous trends.
Performance	Performance	100% of HX fans.	Spot measurement, assuming fans are constant speed & flow when running. If variable speed, continuous trends.
	Heat Exchanger Fans Runtime		
Performance	Baseline	n/a	n/a
Performance	Post-Installation	100% of HX fans.	Continuous trend.
Performance	Performance	100% of HX fans.	Continuous trend.
	Outside Air Temperature & Humidity		
Performance	Baseline	At facility.	Continuous trends.
Performance	Post-Installation	At facility.	Continuous trends.
Performance	Performance	At facility.	Continuous trends.

6.4.3 ECM: Replace Self-Contained Air Conditioning with Chilled Water

This ECM stands as-is in the parent document, with these additional notes on data center applications.

Data Center Considerations

The standard method for cooling data centers uses indoor “precision cooling units,” installed in the same space as the IT equipment or directly adjacent to it. There are two main types:

- Direct-expansion (DX) computer room air conditioners (CRACs). The two main subtypes are air-cooled CRACs and water-cooled CRACs.

- Chilled water (CHW) computer room air handlers (CRAHs). These units receive cooling water from a chilled water plant.

Many data centers are also successfully cooled with more typical DX air conditioners or CHW air handlers. CHW cooling tends to be more energy efficient than DX.

This measure involves the installation of a CHW system to provide cooling to an existing area that is currently cooled with DX technology.

6.4.4 ECM: Air Source Heat Pumps

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.4.5 ECM: Air-Side Economizer

Data center cooling systems have a relatively high air flow rate. Air-side economizers for data centers, needing to accommodate these high flow rates, tend to be physically large. Retrofitting an air side economizer to an existing data center cooling system may not be practical. When there is an opportunity, however, installing an economizer can save significant energy by taking advantage of cool air. Air-side evaporative cooling works in the same way. The maximum allowable air temperature for data center cooling purposes is typically much higher than needed for occupied space, typically 80 F at the face of the IT rack per ASHRAE thermal guidelines. This means the economizer can operate for more hours than those serving occupied spaces.

If the data center is served by packaged A/C units located outside the building, there may be add-on air-side economizers available from the manufacturer. Alternatively, the package units can be replaced with units that have air-side economizers.

If the data center is served by indoor CRACs/CRAHs and AHUs located at the edge of the data center space, or adjacent to the data center, it may be possible to custom-build an air-side economizer that serves multiple CRACs/CRAHs or AHUs simultaneously. Alternatively, since air-side economizers are a standard option for many CRACs/CRAHs, older units may be replaced with newer, economizer-equipped units.

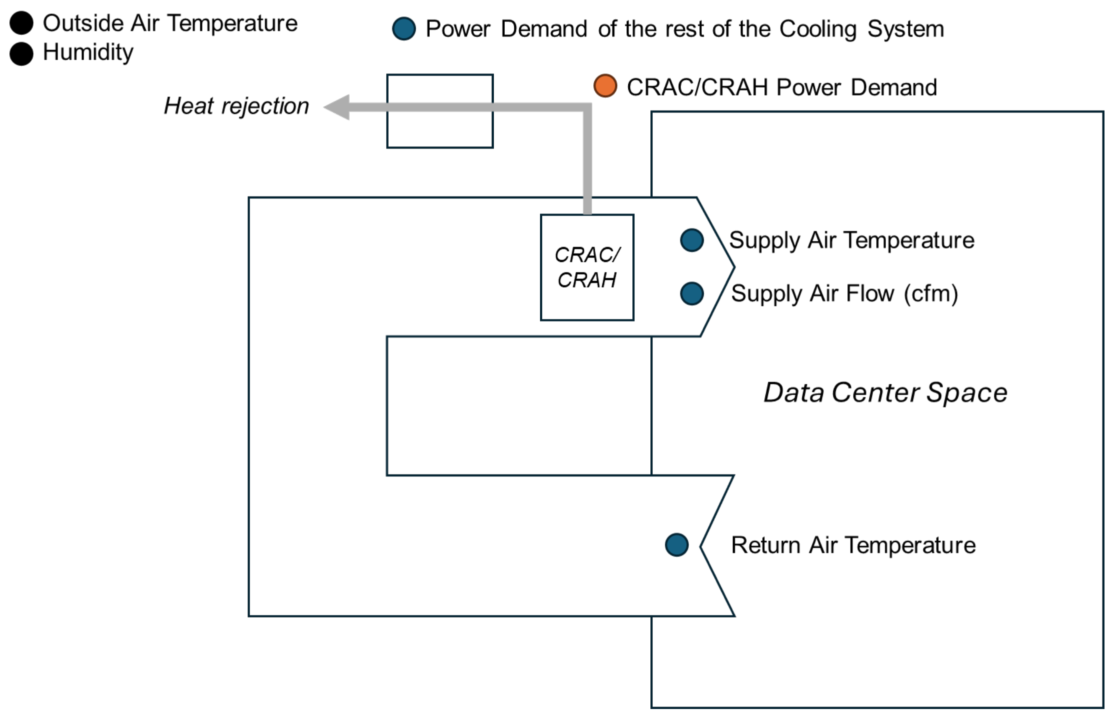

Figure 6-3. Before Installation of Air-Side Economizer

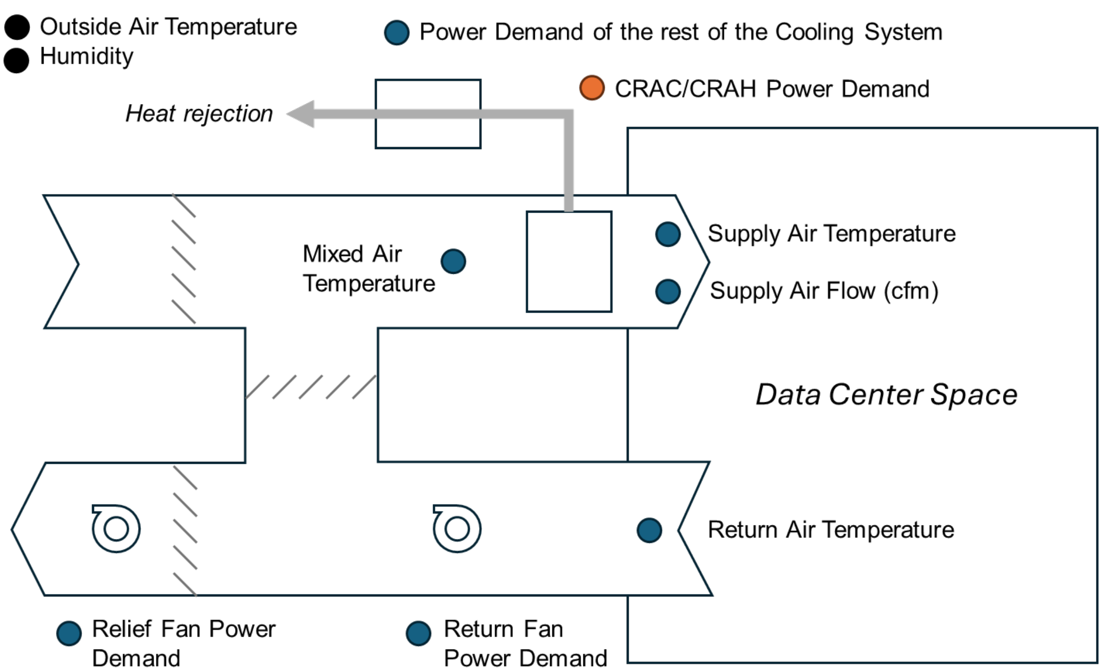

Figure 6-4. After Installation of Air-Side Economizer

6.4.5.1 M&V Plan Description

M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended throughout the performance period.

- The air-side economizer will reduce the thermal load placed on the cooling system, which in turn affects the cooling system efficiency.
- The performance of the cooling system is also affected by outside air temperature and humidity.

6.4.5.2 M&V Option Selection Rationale

To successfully execute M&V, quantify the power draw of the cooling systems as a function of:

- changes in IT equipment load; and
- changes in outside air temperature and humidity.

Baseline Period

- In the baseline period, the air-side economizer is not present. The cooling system power demand is still expected to vary with outside air conditions, just not as dramatically as after the economizer is installed. The baseline measurement period should include spans of both warm and cool weather.
- The applicable parameters shown in Table 6-8 will be metered continuously during the baseline measurement period. This period needs to include changes in the cooling load, as well as outdoor air temperature and humidity, in order to create a representative energy use profile of the cooling system.
- Extrapolate to a full year of energy use for baseline operation. Compare to historic meter data if available.

Post-Installation Period

- Verify the air-side economizer(s) are installed, complete with controls and commissioned. Verify that the cooling compressor turns off when the economizer is on.
- Measure the post-installation parameters in Table 6-8. The aim is to determine the extent to which the installed economizers are providing energy savings. This verification period should include changes in the cooling load and outdoor air temperature and humidity.
- Extrapolate to a full year of post-installation operation. Confirm that the ECM performs as specified and has the potential to generate expected energy savings.

Performance Period

- Measure the performance period parameters in Table 6-8. This period should include changes in the cooling load and outdoor air temperature and humidity.
- Confirm that the installed economizers are supporting reductions in cooling system energy use and expected annual savings are realized.

6.4.5.3 M&V Performance Assurance Activities

Before Starting M&V Measurements

- Obtain customer approval of all parameters to be measured.

After the Post-Installation Measurements and during the Performance Period

- Ensure that staff are trained in the proper operation of the new system. If maintenance is neglected, air-side economizers are particularly susceptible to failure, which can result in increased cooling load and energy demand.
- Ensure customer witnessing of M&V activities.

Table 6-8. M&V Parameters for ECM: Air Side Economizer

Parameter	Period	Population	Activity
	CRAC/CRAH/AHU Supply Air Temperature and Return Air Temperature & Humidity		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of CRACs/CRAHs/AHUs to be served by the new economizer(s).	Continuous trends.
Performance	Post-Installation	Same as baseline.	Continuous trends.
Performance	Performance	Same as baseline.	Continuous trends.
	CRAC/CRAH/AHU Supply Air Flow Rate		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of CRACs/CRAHs/AHUs to be served by the new economizer(s).	Continuous trends.
Performance	Post-Installation	Same as baseline.	Continuous trends.
Performance	Performance	Same as baseline.	Continuous trends.
	CRAC/CRAH/AHU Supply Fan Power Draw and Humidifier Power Draw		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or	Continuous trends.

Parameter	Period	Population	Activity
		80/20) of CRACs/CRAHs/AHUs to be served by the new economizer(s).	
Performance	Post-Installation	Same as baseline.	Continuous trends.
Performance	Performance	Same as baseline.	Continuous trends.
	Economizer Mixed Air Temperature		
Performance	Baseline	n/a.	n/a.
Performance	Post-Installation	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of new economizers.	Continuous trends.
Performance	Performance	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of new economizers.	Continuous trends.
	Economizer Return/Relief Fan Power Draw		
Performance	Baseline	n/a.	n/a.
Performance	Post-Installation	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of new economizers.	Continuous trends.
Performance	Performance	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of new economizers.	Continuous trends.
	Outside Air Temperature & Humidity		
Performance	Baseline	At facility.	Continuous trends.
Performance	Post-Installation	At facility.	Continuous trends.
Performance	Performance	At facility.	Continuous trends.

6.4.6 ECM: Humidity Control

If ASHRAE guidelines are followed regarding data center cooling air temperature and humidity (see ECM: Optimize EMCS Sensor Location) and, given the climate zone in which the data center is located, the need for humidification can possibly be eliminated entirely. In this case, this ECM calls for disabling or removing the humidifiers. If the need for humidification is not eliminated, this ECM calls for installing higher efficiency (adiabatic) humidifiers.

Many air units also feature active dehumidification, in which cooling output is high and reheaters are activated. The option is rarely needed and may be disabled, or the fuses on the reheaters can be removed.

6.4.6.1 M&V Plan Description

M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended, as the duty cycle of the humidifiers depends on outside air conditions. If there is no air-side economizer, then humidity in the data center space will tend to not swing as wide and rapidly as the outside humidity, but there is typically still an effect.

6.4.6.2 M&V Option Selection Rationale

Identify the humidifiers to be targeted by this ECM. If there is a large quantity of humidifiers, use 90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) to select a representative sample for M&V.

To successfully execute M&V, quantify the power draw of the humidifiers as a function of:

- changes in the temperature and humidity of the air entering the IT equipment (within the acceptable target range); and
- changes in outside air temperature and humidity.

Baseline Period

- The parameters in Table 6-9 will be metered continuously during the baseline measurement period. This period should include changes in the temperature and humidity of the air entering the IT equipment (within the acceptable target range), as well as the outside air, in order to create a representative energy use profile of the baseline system.
- Extrapolate to a full year of energy use for baseline operation. Compare to historic meter data if available.

Post-Installation Period

- Verify that the humidifiers have been disabled/removed, or that new, high-efficiency humidifiers have been installed.
- Verify that the temperature and humidity of the air entering the IT equipment continues to remain within its target range.
- Measure the post-installation parameters in Table 6-9. The aim is to show that the target range of air temperature and humidity of the air entering the IT equipment is being maintained, with less humidifier energy use, for a given outside air condition. This period should include changes in the temperature and humidity of the air entering the IT equipment (within the acceptable target range), as well as the outside air. A measurement period of 15 or 30 days is recommended.

- Extrapolate to a full year of energy use for post-installation operation. Confirm ECM performs as specified and has the potential to generate expected energy savings.

Performance Period

- Measure the performance period parameters in Table 6-9. The aim is to show that the target range of air temperature and humidity of the air entering the IT equipment is being maintained, with less humidifier energy use, for a given outside air condition. This period should include changes in the temperature and humidity of the air entering the IT equipment (within the acceptable target range), as well as the outside air.
- Confirm that a reduction in humidifier energy use is being achieved and expected annual savings are realized.

6.4.6.3 M&V Performance Assurance Activities

Before Starting M&V Measurements

- Obtain customer approval of all parameters to be measured.

After the Post-Installation Measurements and during the Performance Period

- If the humidifiers have not been entirely removed/disabled, continue to monitor their energy use.
- Revisit the need for humidity control as IT equipment is refreshed.
- Ensure customer witnessing of M&V activities.

Table 6-9. M&V Parameters for ECM: Humidity Control

Parameter	Period	Population	Activity
	CRAC/CRAH/AHU Humidifier Power Draw		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of CRACs/CRAHs/AHUs that will be subject to this ECM.	Continuous trends.
Performance	Post-Installation	Same as Baseline.	Continuous trends.
Performance	Performance	Same as Baseline.	Continuous trends.
	CRAC/CRAH/AHU Reheater Power Draw		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of CRACs/CRAHs/AHUs that will be subject to this ECM.	Continuous trends.
Performance	Post-Installation	Same as Baseline.	Continuous trends.
Performance	Performance	Same as Baseline.	Continuous trends.

Parameter	Period	Population	Activity
	Temperature & Humidity of Air Entering IT Equipment		
Performance	Baseline	Points that represent the condition of the air entering the IT equipment served by the selected population of CRACs/CRAHs/AHUs.	Continuous trends.
Performance	Post-Installation	Same as Baseline.	Continuous trends.
Performance	Performance	Same as Baseline.	Continuous trends.
	Outside Air Temperature & Humidity		
Performance	Baseline	At facility.	Continuous trends.
Performance	Post-Installation	At facility.	Continuous trends.
Performance	Performance	At facility.	Continuous trends.

6.4.7 ECM: Water-Side Economizer

This ECM stands as-is in the parent document, with these additional notes.

This measure is applicable to a water-cooled chilled water plant, i.e., a plant that includes water-cooled chillers and cooling towers. During periods of low wet bulb temperature (often during shoulder seasons or at night during the peak cooling season), the cooling towers can produce water temperatures low enough to pre-cool the chilled water returning from the facility, effectively removing a portion of the load from the energy-intensive chillers. During the lowest wet bulb periods, the towers may be able to cool the chilled water return to the chilled water supply temperature set-point, allowing the chillers to be shut off entirely. The air handlers see the same chilled water supply temperature at all times, allowing them to maintain the required temperature and humidity requirements. This “free” cooling also offers an additional level of redundancy by providing a non-compressor cooling solution when conditions allow.

For the most efficient operation, specify a low approach temperature, low pressure-drop heat exchanger, and low pressure drop piping on both sides of the heat exchanger.

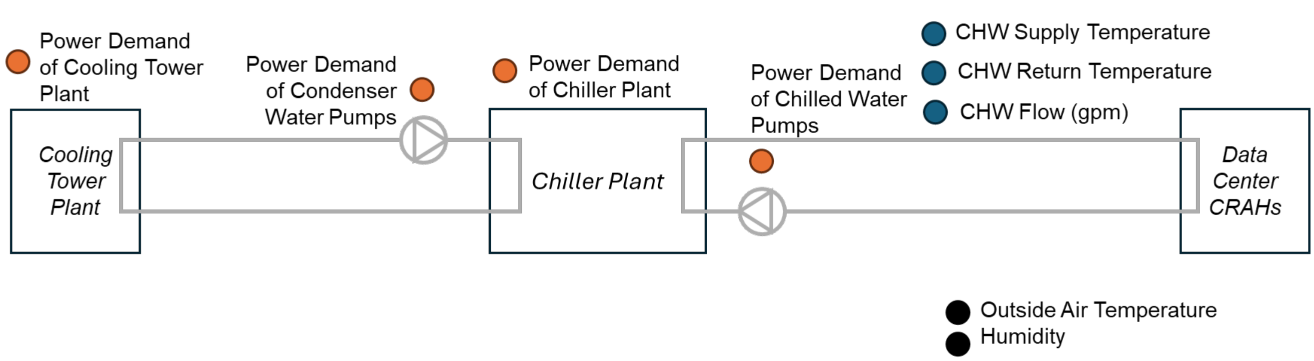

Figure 6-5. Before Installation of Water-Side Economizer

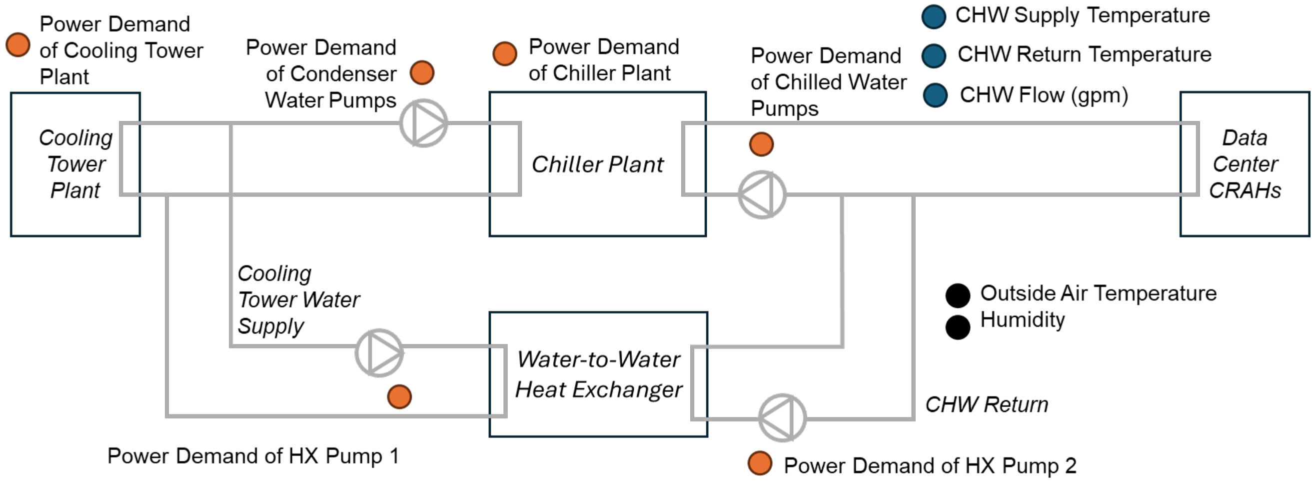

Figure 6-6. After Installation of Water-Side Economizer

6.4.7.1 M&V Plan Description

M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended because the performance of the chilled water plant depends on:

- cooling load on the plant
- chilled water supply temperature
- quantity, capacity, and staging sequence for the cooling towers, chillers, and pumps
- outside air temperature and humidity
- control sequence for the water-side economizer.

6.4.7.2 M&V Option Selection Rationale

To successfully execute M&V, quantify the total power draw of the chilled water plant as a function of the total cooling load on the plant and outside air temperature and humidity (wet bulb temperature).

Baseline Period

- Applicable parameters from Table 6-10 will be metered continuously during the baseline measurement period. The measurement period should be adequate to capture changes in the plant's cooling load and outside air wet bulb temperature in order to create a representative energy use profile of the baseline system.
- Extrapolate to a full year of energy use for baseline operation. Compare to historic meter data if available.

Post-Installation Period

- Verify that the water-side economizer and controls have been properly installed and commissioned.
- Measure the post-installation parameters in Table 6-10. The aim is to show that the water-side economizer can reduce the total chilled water plant power demand when the outside air wet bulb temperature is low enough. Any changes in the plant's cooling load and outside air wet bulb temperature should be documented in order to account for this in the post-installation system.
- Extrapolate to a full year of energy use for post-installation operation. Confirm ECM performs as specified and has the potential to generate expected energy savings are being realized.

Performance Period

- Measure the performance period parameters in Table 6-10. The aim is to show that the water-side economizer continues to reduce the total chilled water plant power demand when the outside air wet bulb temperature is low enough. Any changes in the plant's cooling load and outside air wet bulb temperature should be documented.
- Confirm that the installed water-side economizer continues to meet performance requirements, reduce power draw, and yield expected annual savings during the performance period.

6.4.7.3 M&V Performance Assurance Activities

Before Starting M&V Measurements

- Obtain customer approval of all parameters to be measured.

After the Post-Installation Measurements and during the Performance Period

- Train staff in the proper operation of the water-side economizer. This type of system is often disabled due to lack of understanding of its operating principles.
- Continue monitoring the economizer performance to determine energy savings due to the water-side economizer and the effectiveness of the heat exchanger.
- Ensure customer witnessing of M&V activities.

Table 6-10. M&V Parameters for ECM: Water-Side Economizer

Parameter	Period	Population	Activity
	Total Power Draw of Chillers, Cooling Towers, CHW Pumps, CW Pumps		
Performance	Baseline	Existing CHW plant that water-side economizer will be added to.	Continuous trends.
Performance	Post-Installation	CHW plant with water side-economizer.	Continuous trends.
Performance	Performance	CHW plant with water side-economizer.	Continuous trends.
	Temperature of Plant Chilled Water Supply, Chilled Water Return		
Performance	Baseline	Existing CHW plant that water-side economizer will be added to.	Continuous trends.
Performance	Post-Installation	CHW plant with water-side economizer.	Continuous trends.
Performance	Performance	CHW plant with water-side economizer.	Continuous trends.
	Total Flow Rate of Chilled Water Delivered by Plant		
Performance	Baseline	Existing CHW plant that water-side economizer will be added to.	Continuous trends.
Performance	Post-Installation	CHW plant with water-side economizer.	Continuous trends.
Performance	Performance	CHW plant with water-side economizer.	Continuous trends.
	Total Power Draw of Heat Exchanger Pumps		
Performance	Baseline	N/A.	N/A.
Performance	Post-Installation	Heat exchanger pumps.	Continuous trends.
Performance	Performance	Heat exchanger pumps.	Continuous trends.
	Heat Exchanger Effectiveness		
Performance	Baseline	N/A.	N/A.
Performance	Post-Installation	Monitor control sequence to confirm design setpoints/sequences achieved.	Continuous trends.
Performance	Performance	Monitor control sequence to confirm setpoints/sequences still in place.	Continuous trends.
	Outside Air Temperature & Humidity		
Performance	Baseline	At facility.	Continuous trends.
Performance	Post-Installation	At facility.	Continuous trends.
Performance	Performance	At facility.	Continuous trends.

6.4.8 ECM: Effective Cooling Towers

In a typical water-cooled chilled water plant, cooling tower electric energy use is a small portion of the overall plant consumption. Furthermore, the lower the condenser water (CW) temperature produced by the cooling towers, the more efficiently the energy-intensive chillers will run, and the more hours of operation of the water-side economizer. Therefore, implementing more effective cooling towers – even if the towers themselves use more energy post-retrofit – can reduce the overall chilled water plant energy.

Cooling towers are large water consumers. Decreasing water use by increasing the cycles of concentration can save a significant amount of water. Alternative cooling tower water treatment can allow higher cycles of concentration.

Measures that enable cooling towers to produce colder water include:

Increase Cooling Tower Capacity	Cooling tower plants are typically sized to handle the peak design load at the 99% wet bulb condition. Oversizing the cooling tower plant allows it to reject heat to the environment more efficiently at all load and wet bulb conditions, with less fan energy, and produce lower CW temperatures.
Install a Low Approach Temperature Cooling Tower	Every cooling tower can produce a water temperature that approaches but is never lower than the ambient wet bulb temperature. The difference between these two temperatures is called the “approach” temperature. During operation, the approach temperature will vary as a result of several factors – the tower water flow rate, the temperature of the water entering the tower, the current wet bulb temperature, the cooling tower fan speed, etc. To allow comparisons between different tower models, manufacturers report the approach temperature at a single, specific operating condition. This nominal condition may not be the same from one manufacturer to the next, so exercise care when making comparisons. A tower with a smaller approach temperature is more efficient and enjoys the same advantages of an oversized tower. A low approach temperature tower is often created merely by oversizing the tower but can also be created by a different design without increasing the physical dimensions of the unit.
Convert Cooling Towers from Series Staging to Parallel Staging	By operating as many cooling towers as possible at all times, the amount of water to be cooled is distributed across a greater number of towers. This decreases the amount of heat rejection required by each tower, which in turn reduces the required fan speed. This translates directly to fan energy savings, and a closer approach temperature can be achieved. Care must be taken so that no tower is starved for water flow.

In some climates it may be possible to cool the data center year-round with cooling towers only, eliminating the need to run any chillers.

6.4.8.1 M&V Plan Description

M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended because the performance of the chilled water plant depends on:

- cooling load on the plant
- entering and leaving condenser water temperatures
- quantity, capacity, and staging sequence for the cooling towers, chillers, and pumps
- outside air temperature and humidity
- any new temperature setpoint (if any) for water leaving the cooling towers.

6.4.8.2 M&V Option Selection Rationale

Quantify the total power demand of the chilled water plant, including the selected towers, as a function of:

- The total cooling load on the plant
- The outside air temperature and humidity
- The temperature set-point for water leaving the cooling towers.

Baseline Period

- The parameters listed in Table 6-11 will be metered continuously during the baseline measurement period. This period should be adequate to capture changes in the plant's total cooling load, as well as outside air temperature and humidity, in order to create a representative energy use profile of the baseline system.
- Extrapolate to a full year of energy use for baseline operation. Compare to historic meter data if available.

Post-Installation Period

- Verify that the new cooling towers and/or cooling tower control sequences have been installed and commissioned.
- Measure the post-installation parameters in Table 6-11. The aim is to show that the total power demand of the chilled water plant has been reduced for a given total cooling load, given outside air condition and condenser water temperature. This verification period should include changes in the plant's total cooling load, as well as outside air temperature and humidity.
- Extrapolate to a full year of energy use for post-installation operation. Confirm ECM performs as specified and has the potential to generate expected energy savings.

Performance Period

- Measure the performance period parameters in Table 6-11. The aim is to show that the total power demand of the chilled water plant has been reduced for a given total cooling load, given outside air condition and condenser water temperature. Any changes in the plant's total cooling load, as well as outside air temperature and humidity should be documented.
- Confirm that the installed cooling towers continue to meet performance requirements, reduce power demand, and yield expected annual savings during the performance period.

6.4.8.3 M&V Performance Assurance Activities

Before Starting M&V Measurements

- Obtain customer approval of all parameters to be measured.

After the Post-Installation Measurements and during the Performance Period

- Continue to monitor chilled water plant operation.
- Ensure customer witnessing of M&V activities.

Table 6-11. M&V Parameters for ECM: Effective Cooling Towers

Parameter	Period	Population	Activity
	Total Power Draw of Chillers, Cooling Towers, CHW Pumps, CW Pumps		
Performance	Baseline	Selected chilled water plant.	Continuous trends.
Performance	Post-Installation	Selected chilled water plant.	Continuous trends.
Performance	Performance	Selected chilled water plant.	Continuous trends.
	Temperature of Plant Chilled Water Supply, Chilled Water Return		
Performance	Baseline	Selected chilled water plant.	Continuous trends.
Performance	Post-Installation	Selected chilled water plant.	Continuous trends.
Performance	Performance	Selected chilled water plant.	Continuous trends.
	Total Flow Rate of Chilled Water Delivered by Plant		
Performance	Baseline	Selected chilled water plant.	Continuous trends.
Performance	Post-Installation	Selected chilled water plant.	Continuous trends.
Performance	Performance	Selected chilled water plant.	Continuous trends.
	Temperature of Water Leaving the Cooling Towers		
Performance	Baseline	Cooling towers targeted by this ECM.	Continuous trends.

Parameter	Period	Population	Activity
Performance	Post-Installation	Same population as Baseline.	Continuous trends.
Performance	Performance	Same population as Baseline.	Continuous trends.
	Outside Air Temperature & Humidity		
Performance	Baseline	At facility.	Continuous trends.
Performance	Post-Installation	At facility.	Continuous trends.
Performance	Performance	At facility.	Continuous trends.

6.5 Lighting Improvements

ECM: Lighting and ECM: Lighting Controls stand as-is in the parent document, with these additional considerations.

Data Center Considerations

Typical characteristics of data centers include that they:

- Run continuously and may be occupied at any time of day or week
- Are sparsely occupied
- Are typically not daylit
- Can be dark when unoccupied
- Do not require uniform area illumination when occupied. Task or zone lighting is an effective approach.
- Have appropriate fixture placement, aligned or located to illuminate the IT aisles.

6.6 Building Envelope Modifications

6.6.1 ECM: Building Envelope Improvements

This ECM stands as-is in the parent document, with these additional considerations for data center applications.

Data Center Considerations

Data centers vary from occupied commercial spaces in many ways that can result in deviations from the typical building envelope benefits and recommendations. As some examples, data centers:

- Have high internal loads that require constant cooling

- Often implement air side economizing or similar airflow approaches to help remove IT equipment heat gains, when outside conditions allow
- Typically, do not have windows
- Typically, they have segregated regions of warm and cold air. The temperatures in both regions are usually more extreme than found in occupied spaces.
- May have warm or cold regions adjacent to the inside surface of the envelope, depending on the data center design. If the outside surface of the envelope is colder than the inside surface, then a poorly insulated envelope helps save cooling energy. If the outside surface of the envelope is warmer than the inside surface, then a well-insulated envelope helps save cooling energy.

6.7 Chilled Water, Hot Water, and Steam Distribution Systems

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.8 Electric Motors and Drives

6.8.1 ECM: Premium Efficiency Motors

This ECM stands as is in the parent document, with these additional considerations.

Data Center Considerations

In a data center, a premium efficiency motors ECM would apply to the cooling system – the fans in the CRAC units, CRAH units, AHUs and cooling tower(s), and the pumps in water-cooled DX and CHW systems. Motor ECMs may include even higher efficiency electronically commutated motors; “right-sizing” a motor from an under- or over-loaded condition and adding variable speed/variable frequency capability. Other energy saving measures can be applied to fan and pump systems, for example:

- Minimize resistance to air flow and water flow.
- In the air-side system, minimize bypass and recirculation.
- In CRACs and CRAHs with belt-driven fans, replacing the fans with plug fans and direct-drive electronically commutated motors.

6.8.1.1 M&V Plan Description

Option A is appropriate for the simplest type of fan/pump systems. See scenarios 1 and 2 in Table 6-12.

In scenarios 3, 4, and 5, Option A may give misleading results. This is because the elements of a fan/pump system – the variable frequency drive (VFD)/variable speed drive (VSD) (if present), the motor, and the fan/pump itself – have non-linear efficiency curves. In a fan/pump system with a varying load profile, the system efficiency can vary significantly. In instances where this ECM contributes a significant portion of the savings for the project or the customer desires additional rigor for savings, Option B may be used to verify savings.

Table 6-12. M&V Options for Different Fan/Pump Speed Control Scenarios for Data Centers

Scenario	Fixed Geometry Flow Path?[3]	Has Variable Speed Capability?	Runs at Constant Speed?	Flow/Pressure at Point(s) of Use	Recommended M&V Option
1	Yes	No	Yes	The fan/pump system runs continuously at full speed. Manual dampers/valves or the number, location and/or openings of perforated floor tiles are set to provide the desired flows.	Option A
2	Yes	Yes	Yes	Fan/pump speed and manual dampers/valves or perforated tiles are set to provide the desired flows at a constant operating condition.	Option A
3	No	No	Yes	Manual dampers/valves or perforated tiles (location, opening density) are set to limit the maximum flow. Automatic dampers/valves modulate to maintain desired flows at the points of use. The fan/pump "rides its curve" as the resistance to flow varies.	Option A or B
4	No	Yes	Yes	Fan/pump speed is manually set to provide the desired flows at the maximum demand condition. At less than maximum demand, the fan/pump works against restricting dampers/valves.	Option A or B
5	No	Yes	No	Sensors provide feedback to the fan/pump. Fan/pump speed varies to provide the desired flows/pressures over a range of demands. Fan/pump fighting against restriction is minimized.	Option A or B

The parameters to measure during the M&V process depend on the systems affected by the fan/pump speed controls. The following list should be monitored:

- IT equipment power demand and energy use
- Support system equipment runtime and operational status

[3] Fixed geometry flow path: A path that does not automatically change physical dimensions during operation, i.e., one that does not have any automatically modulating control dampers/valves.

- Support system equipment power demand and energy use.

6.8.2 ECM: Variable Speed Pumping

This ECM stands as is in the parent document, with these additional considerations for data center applications.

Data Center Considerations

The intent of this measure is to provide pump speed control if it does not yet exist, and optionally, to add an automatic pump speed control scheme.

Any reduction in pump speed compared to the pre-retrofit situation (all else being equal) should save energy, given the exponential relationship between pump speed and pump power demand.

If the existing pumps do not have variable speed capability (i.e., they run at full speed) and yet they are not supplying enough water to meet current requirements, then adding speed control alone will not help provide more water.

Variable frequency drives (VFDs) are not 100% efficient, and their efficiency falls off at slower speeds. Adding a VFD to a pump comes with an energy cost that must be weighed against the potential savings.

The intent of this measure is to transition from the existing pump speed control scenario to one that is more energy-efficient, while delivering the same water flow rate and pressure required at the points of use. See Table 6-13 for typical pump speed control scenarios and associated energy savings strategies.

Table 6-13. Pump Speed Control Scenarios

Scenario	Fixed Geometry Flow Path?[4]	Pump Has Variable Speed Capability?	Pump Runs at Constant Speed?	Flow/Pressure at Point(s) of Use	How Energy Can Be Saved
1	Yes	No	Yes	The pump system runs continuously at full speed. Manual valves are set to provide the desired flows.	If the flow is restricted in all branches by manually adjusted valves, then implement Scenario 2, reduce the flow restrictions, and reduce the pump speed to provide the desired flows.

[4] Fixed geometry flow path: A path that does not automatically change physical dimensions during operation, i.e., one that does not have any automatically modulating control valves.

Scenario	Fixed Geometry Flow Path?[4]	Pump Has Variable Speed Capability?	Pump Runs at Constant Speed?	Flow/Pressure at Point(s) of Use	How Energy Can Be Saved
2	Yes	Yes	Yes	Pump speed and valves are manually set to provide the desired flows at a constant operating condition.	If the valves and pump speed are set to provide the required flows at the points of use with the least pump power demand, there is no advantage to implementing automatic speed control.
3	No	No	Yes	Manual valves are set to restrict maximum possible flow. Automatic valves modulate to maintain desired flows at the points of use. The pump "rides its curve" as the resistance to flow varies.	Scenarios 4 and 5 provide more efficient solutions.
4	No	Yes	Yes	Pump speed is manually set to provide the desired flows at the points of use, at the maximum demand condition. At less than maximum demand, the pump works against the modulating valves.	Scenario 5 offers a more efficient solution.
5	No	Yes	No	Sensors provide feedback to the pump. Pump speed varies to provide the desired flows over a range of demands. Pump fighting against valve restriction is minimized.	This is the most energy efficient pump speed control scheme. For further savings, look at ECMs that reduce the flow requirement at the points of use, or increase the efficiency of the pump and pump motor.

6.8.2.1 M&V Plan Description

For fixed-geometry systems (Scenarios 1 & 2 in Table 6-13), M&V Option A is suitable. The pump systems run at a steady state, so all that is needed are spot measurements of the baseline and post-retrofit pump power demand.

For variable-geometry systems (Scenarios 3, 4, and 5 in Table 6-13), M&V Option B (Retrofit Isolation with All Parameter Measurement) is recommended. In these systems, the water flow requirements at the points of use are assumed to vary. The pump power demand will vary in response, in ways that are not always predictable via simple formulas.

6.9 Refrigeration

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.10 Distributed Generation

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.11 Renewable Energy Systems

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.12 Energy/Utility Distribution Systems

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.13 Water and Wastewater Conservation Systems

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.14 Electrical Peak Shaving/Load Shifting

6.14.1 ECM: Battery Energy Storage Systems

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.14.2 ECM: Thermal Energy Storage (TES)

This ECM stands as is in the parent document, with these additional notes regarding data center applications.

Data Center Considerations

Typical characteristics of data centers include:

- Typically operate continuously, so the chilled water plant must be sized such that it can charge the TES while simultaneously meeting the cooling demand of the data center.
- Tend to have a large cooling load, so chilled water TES tanks for data centers tend to be large as well. Capacities of one million gallons and more are not unusual.
- The total annual chilled water plant energy use may be higher after this ECM is implemented, but the aim is to reduce energy cost (via shifting load during periods of higher energy and/or demand charges).
- TES may add energy resilience in data center applications.

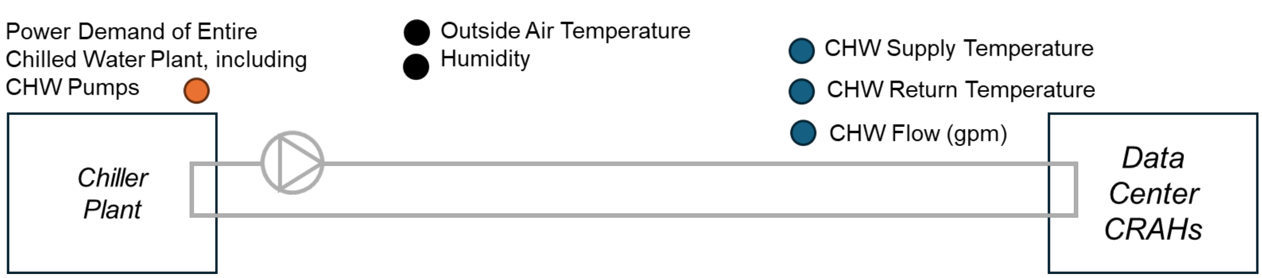

Figure 6-7. Before Installation of Thermal Energy Storage

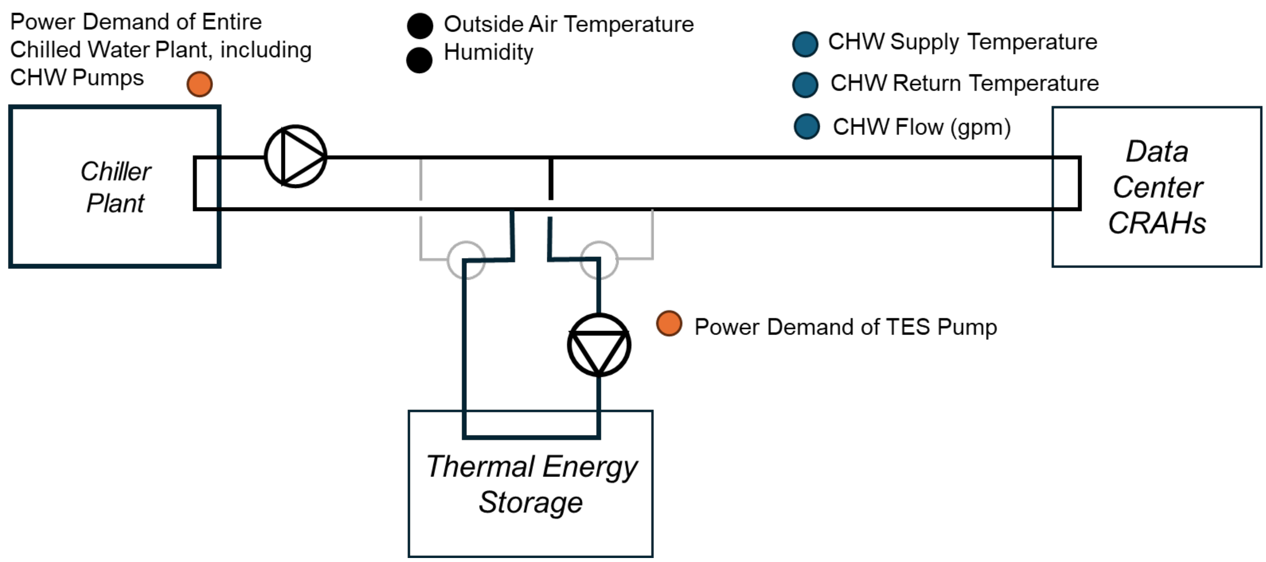

Figure 6-8. After Installation of Thermal Energy Storage: Charge Cycle

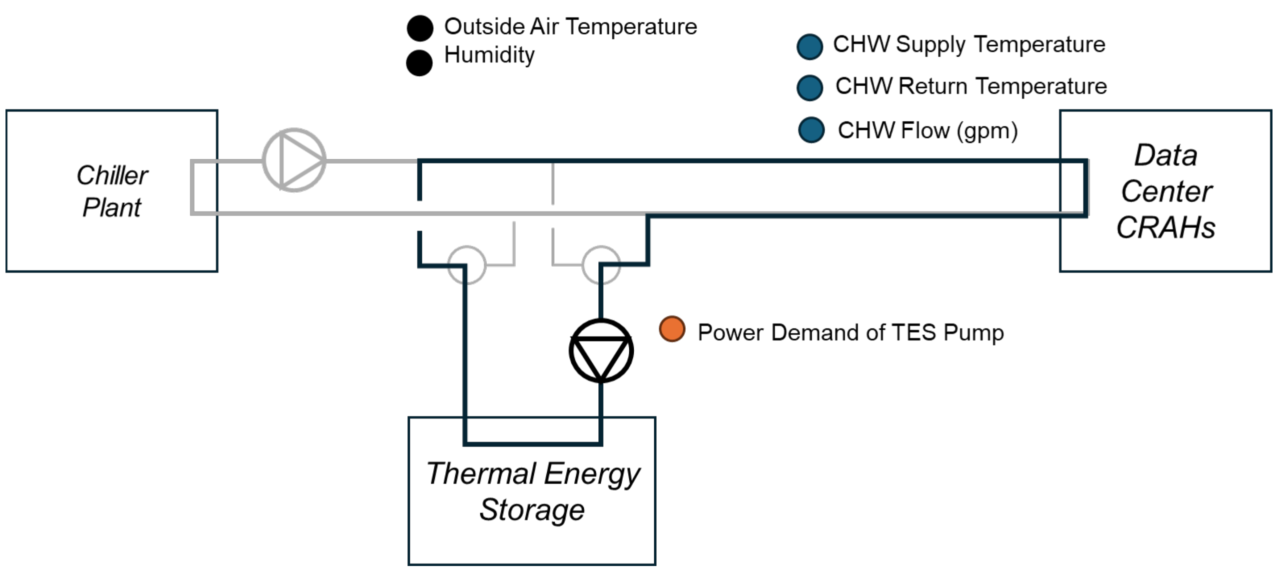

Figure 6-9. After Installation of Thermal Energy Storage: Discharge Cycle

6.15 Energy Cost Reduction Through Rate Adjustments

6.15.1 ECM: Dispatchable Load Management

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.16 Energy Related Process Improvements

6.16.1 ECM: Air Compressor and Vacuum Pump Improvements

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.16.2 ECM: Grid-Interactive Efficient Building (GEB)

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

6.16.3 ECM: Energy-Efficient IT Equipment

The focus of this measure is to improve the energy efficiency of IT equipment in data centers, such that a given computational result can be accomplished with less electrical input. Some ways that IT equipment energy efficiency can be increased:

- Eliminate redundant power supplies
- Upgrade to high efficiency power supplies
- Replace servers with more energy efficient processors
- Eliminate operational servers no longer in use
- Implement server virtualization
- Enable power management features on servers.

6.16.3.1 M&V Plan Description

M&V Option B (Retrofit Isolation with Key Parameter(s) Measurement) is recommended. As a best practice, conduct a baseline assessment of the computational needs to ensure that the new IT system can handle the load (e.g., to prevent slow computing). Assuming the computation load does not increase, this ECM will reduce IT equipment power draw. This reduction will probably also reduce:

- The energy loss in the IT equipment power chain; and
- The energy use of the cooling system. Cooling system performance is affected by outside air temperature and humidity.

6.16.3.2 M&V Option Selection Rationale

Identify:

- The IT equipment that will be affected by this ECM
- The components of the electric power chain that serve the selected IT equipment

- The cooling system(s) that serve the selected IT equipment.

To successfully execute M&V, quantify:

- The computational load of the selected IT equipment. How this is measured will depend on the type of work the IT equipment is performing
- The power draw of the selected IT equipment
- The power loss in the electric power chain serving the selected IT equipment
- The power draw of the entire cooling system(s) serving the selected IT equipment
- Outside air temperature and humidity.

Where multiple pieces of identical equipment are to be installed, it is often more cost-effective to perform the key parameter measurements on a random sample of the installed equipment.

Baseline Period

- Measure the parameters in Table 6-14 for the duration of the baseline. Ensure that the baseline conditions are properly defined to support the validity of savings estimates. This period needs to include changes in the total IT equipment power demand as well as changes in outside air temperature and humidity, in order to create a representative energy use profile of the baseline system.
- Extrapolate to a full year of energy use for baseline operation. Compare to historic meter data if available.

Post-Installation Period

- Verify the ECM(s) have been implemented for the selected IT equipment.
- Measure the post-installation parameters listed in Table 6-14. This period needs to include changes in the total IT equipment power demand as well as changes in outside air temperature and humidity. A measurement period of 15 or 30 days is recommended.
- Confirm that the installed IT equipment/systems continue to meet performance requirements, power draw is being reduced, and energy savings are being realized.
- Extrapolate to a full year of energy use for post-installation operation.

Performance Period

- Verify that the installed equipment is still operational.

- Measure the performance period parameters in Table 6-14. This period needs to include changes in the total IT equipment power demand as well as changes in outside air temperature and humidity.
- Confirm that the installed IT equipment/systems continue to meet performance requirements, reduce power draw, and yield expected annual savings during the performance period.

6.16.3.3 M&V Performance Assurance Activities

Before Starting M&V Measurements

- Obtain customer approval of all parameters to be measured.

After the Post-Installation Measurements and during the Performance Period

- Continue to monitor IT equipment computational efficiency.
- Ensure customer witnessing of M&V activities.

Table 6-14. M&V Parameters for ECM: Energy Efficient IT Equipment

Parameter	Period	Population	Activity
	IT Equipment Computational Output		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of all IT equipment targeted by ECM.	Continuous trends.
Performance	Post-Installation	Same population as Baseline.	Continuous trends.
Performance	Performance	Same population as Baseline.	Continuous trends.
	IT Equipment Total Power Demand		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of all IT equipment targeted by ECM.	Continuous trends.
Performance	Post-Installation	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of all IT equipment targeted by ECM.	Continuous trends.
Performance	Performance	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of all IT equipment targeted by ECM.	Continuous trends.
	Power Loss in Electric Power Chain		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of all IT equipment targeted by ECM.	Continuous trends.

Parameter	Period	Population	Activity
Performance	Post-Installation	Same population as Baseline.	Continuous trends.
Performance	Performance	Same population as Baseline.	Continuous trends.
	Cooling System Total Power Draw		
Performance	Baseline	Entire cooling system(s) serving IT equipment targeted by ECM.	Continuous trends.
Performance	Post-Installation	Entire cooling system(s) serving IT equipment targeted by ECM.	Continuous trends.
Performance	Performance	Entire cooling system(s) serving IT equipment targeted by ECM.	Continuous trends.
	Outside Air Temperature & Humidity		
Performance	Baseline	At the facility.	Continuous trends.
Performance	Post-Installation	At the facility.	Continuous trends.
Performance	Performance	At the facility.	Continuous trends.

6.16.4 ECM: Efficient Uninterruptible Power Supply (UPS)

The focus of this measure is to improve the energy efficiency of UPS in data centers. A more efficient UPS system may be implemented in several ways:

- replacement with a more efficient unit
- installation of a switching UPS (also known as a UPS with “eco-mode”) that bypasses the rectifier and inverter during normal operation
- installation of a modular UPS of smaller systems that each can run at higher load factors for higher efficiency
- shutting down modules that are unneeded while maintaining the required level of redundancy.

6.16.4.1 M&V Plan Description

M&V Option A (Retrofit Isolation with Key Parameter(s) Measurement) is appropriate for this ECM, as the performance of the UPS is defined simply as the ratio between its output power and input power. The estimated parameters, once established, are typically assumed to remain constant over the entire post-installation and performance period.

6.16.4.2 M&V Option Selection Rationale

Identify the UPS units targeted by this ECM. To successfully execute M&V, quantify the UPS input (power demand) as a function of UPS output (load) across a range of loads. See Table 6-15 for recommended parameters for UPS systems.

If the UPS has been eliminated, simply measure the power demand of the IT power chain downstream of the point formerly occupied by the UPS.

Baseline Period

- UPS input and output will be metered continuously during the baseline (see Table 6-15). This period should include changes in load (the UPS output) in order to create a representative energy use profile of the baseline UPS.
- Extrapolate to a full year of energy use for baseline operation. Compare to historic meter data if available.

Post-Installation Period

- Verify the UPS ECM has been implemented correctly.
- Measure the UPS input and output of new UPS modules (see Table 6-15). The aim is to show that the new UPS has less power loss for a given power output, compared to the baseline. This measurement period should include changes in load (the UPS output). A measurement period of 15 or 30 days is recommended.
- Extrapolate to a full year of energy use for post-installation operation. Confirm energy savings are being realized.

Performance Period

- Verify that the installed UPS is still operational.
- Measure the UPS input and output of affected UPS modules (see Table 6-15). The aim is to verify that the new UPS continues to show a reduction in power loss for a given power output.
- Confirm that the installed UPS continues to meet performance requirements and yields expected annual savings during the performance period.

6.16.4.3 M&V Performance Assurance Activities

Before Starting M&V Measurements

- Obtain customer approval of all parameters to be measured.

After the Post-Installation Measurements and during the Performance Period

- Continue to monitor UPS efficiency.
- Ensure customer witnessing of M&V activities.

Table 6-15. M&V Parameters for ECM: Efficient UPS System

Parameter	Period	Population	Activity
	UPS Input Power and UPS Output Power		
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20) of affected UPS modules.	Continuous trends.
Performance	Post-Installation	Same population as baseline.	Continuous trends.
Performance	Performance	Same population as baseline.	Continuous trends.

6.17 Commissioning

6.17.1 ECM: Retro-Commissioning / Recommissioning

This ECM stands as is in the parent document, with these additional notes.

Data Center Considerations

This ECM involves a recommissioning or retro-commissioning of selected data center support systems.

This ECM is similar to 6.3.1 ECM: Building Automation Systems (BAS) / Energy Management Control Systems (EMCS), but includes equipment repairs, performing overdue maintenance, removing unused operational servers and re-calibrations.

6.17.2 ECM: Monitoring-Based Commissioning

No data center specific additions are applicable to this ECM. Refer to M&V Guidelines 5.0.

Glossary

These are additions to the parent document.

Term	Definition
Electric Power Chain	In a data center, this refers to the series of electric power conditioning and transformation devices between the utility power feed to the facility and the IT equipment. This typically consists of transformers, a UPS system, and Power Distribution Units (PDUs). There is usually an electric power loss incurred in each device.
Support System	In a data center, this refers to any system that helps provide the necessary operating conditions. The main ones are the cooling system and the electric power chain. The lights are also considered a support system.

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