Self-benchmarking Guide for Data Center Infrastructure: Metrics, Benchmarks, Actions

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Table of Contents

1. Introduction

Purpose

This guide describes energy efficiency metrics and benchmarks that can be used to track the performance of and identify potential opportunities to reduce energy use of data center HVAC and electrical systems..

Target audience

This guide is primarily intended for personnel who have responsibility for managing energy use in existing data centers – including facilities managers, energy managers, and their engineering consultants. Additionally, data center designers may also use the metrics and benchmarks described in this guide for goal-setting in new construction or major renovation.

What this guide does

This guide provides the following information:

- An outline of the benchmarking process.
- A set of performance metrics for the whole building as well as individual systems. For each metric, the guide provides a definition, performance benchmarks, and potential actions that can be inferred from evaluating this metric.
- A list and descriptions of the data required for computing the metrics

This guide builds on prior data center benchmarking studies supported by the California energy Commission. Much of the benchmarking data are drawn from the LBNL data center benchmarking database that was developed from these studies. Additional benchmark data were obtained from engineering experts including facility designers and energy managers. This guide also builds on recent research supported by the U.S. Department of Energy's Save Energy Now program.

What this guide does not do

This guide does not address IT efficiency and productivity metrics. While the energy benchmarking approach described in this guide can be used to identify potential efficiency opportunities in HVAC and electrical systems, this guide does not in and of itself constitute an energy audit procedure or checklist. (However, benchmarking may be used as part of an energy audit procedure, or to help prioritize areas for more in-depth audits). This guide does not describe detailed measurement procedures and how to calculate savings from the potential actions identified. The reader is encouraged to use the U.S. Department of Energy's DC Pro tool suite to conduct a more in-depth analysis of data center efficiency.

Structure of this guide

Section 2 outlines the benchmarking process and how to use this guide in this context. Users should start here.

Sections 3 through 6 describe the performance metrics and how to use them. A summary of the metrics is provides at the beginning of each section. Users can use these sections as a reference manual, to prioritize which metrics to evaluate, and determine data requirements.

Section 7 provides a list of the data required for computing the metrics and brief guidance on how to obtain the data.

Section 8 lists references.

Definitions

A **Performance Metric** is a unit of measure used to assess performance; e.g. Cooling System Efficiency (kW/ton).

A **Performance Benchmark** is a particular value of the metric that is used as a point of comparison; e.g. 0.8 is “good practice” for Cooling System Efficiency.

2. Benchmarking Process

Set benchmarking goals

- *Identify purpose of benchmarking – baselining, identifying actions, comparison to portfolio, etc.*
- *Determine extent of facility and systems to be evaluated.*

Prioritize metrics

- *Use metrics/data template*
- *Prioritize based on goals and available resources*

Identify required data and develop data collection plan

- *Use metrics/data template*
- *Identify source (EMCS, drawings, temporary meters, etc.), measurement period and frequency, responsible person for each data item.*

Obtain and install monitoring equipment

- *Utility lending libraries may be good source for monitoring equipment.*

Collect data

- *Check equipment and ensure that data is being collected as intended.*

Analyze data and compute metrics

- *Use spreadsheets and metrics/data template to convert raw data into metrics.*

Benchmark metrics and identify potential actions

- *Compare metrics to benchmark values provided in this guide. Identify potential actions based on benchmark results.*

Create follow-up action plan

- *Identify which actions can be implemented immediately and which require more detailed audit.*

Share results

- *Share and compare results with peer organizations.*
- *Add results to benchmarking databases.*

3. Overall Infrastructure Efficiency

ID	Name	Priority
A1	Power Usage Effectiveness	1

A1: Power Usage Effectiveness (PUE)

Description:

This metric is the ratio of the total data center energy use to total IT energy use. The total energy use includes all energy types supplied to the datacenter (electricity, fuel, district chilled water, etc.). All the energy data values in the ratio are converted to common units. For all-electric data centers, PUE can be calculated using site energy. For data centers that also have other forms of energy (e.g. fuel, district chilled water) PUE should be calculated based on source energy.

Units: Dimensionless

For an all-electric data center:
PUE = dA1 ÷ dA2
where:
dA1: Annual Electrical Energy Use (kWh)
dA2: Annual IT Electrical Energy Use (kWh)

For data centers that also have other types of energy:
PUE = (dA1 + dA3 + dA4 + dA5) ÷ dA2
where:
dA1: Annual Electrical Energy Use (Source MMBTU)
dA2: Annual IT Electrical Energy Use (Source MMBTU)
dA3: Annual Fuel Energy Use (Source MMBTU)
dA4: Annual District Steam Energy Use (Source MMBTU)
dA5: Annual District Chilled Water Energy Use (Source MMBTU)

Note: To calculate source energy, site energy should be multiplied by the source factor for each energy type. For national average source factors for different energy types, see: http://www.energystar.gov/ia/business/evaluate_performance/site_source.pdf.

See section 7 for more information on the data items.

Benchmarks:

Standard	Good	Better
2.0	1.4	1.1

This metric can be benchmarked relative to other facilities in the LBNL database, although the LBNL database contains PUE based on power rather than annual energy. For the LBNL dataset, the average PUE value is 1.83.

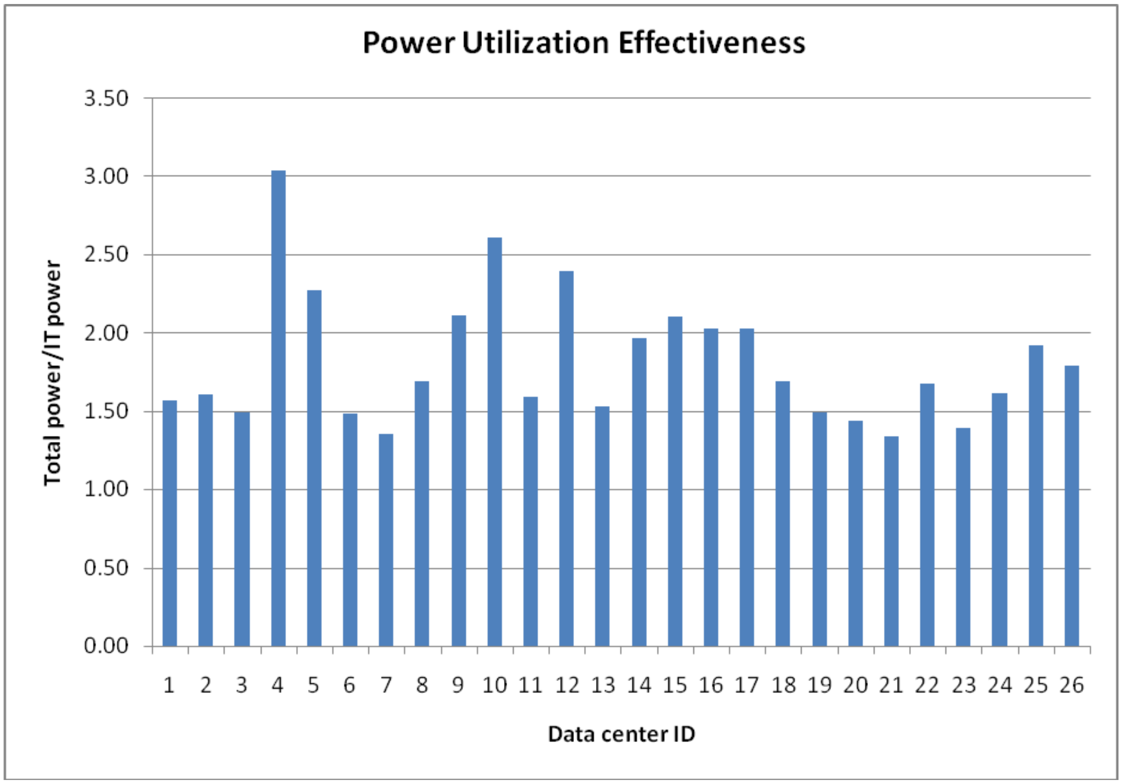

Figure 1. Power Usage Effectiveness metric for data centers in the LBNL database. Note that these PUE values are based on power, not energy.

Actions Inferred:

This metric provides an overall measure of the infrastructure efficiency i.e. higher values relative to the peer group suggest higher potential to improve the efficiency of the infrastructure systems (HVAC, power distribution, lights) and vice versa. Note that it is not a measure of IT efficiency.

Special Considerations:

Since this metric does not account for the efficiency of the IT itself, it is important to note that if a data center has a low PUE, there may still be major opportunities to reduce overall energy use through IT efficiency measures such as virtualization, etc. The ability to decrease PUE is also affected by climate (e.g. free cooling offers much greater potential in cooler climates).

4. Environmental Conditions & Air Management Metrics

ID	Name	Priority
B1	Supply Temperature	1
B2	Humidity Range at IT inlet	1
B3	Return Temperature Index	1

B1: Supply Temperature:

Description:

This metric is the airflow weighted average of the supply air temperature in the data center.

Units: °F

B1 = dB1
where:
dB1: Supply air temperature (airflow weighted average)

See section 7 for more information on the data items

Benchmarks:

Standard	Good	Better
≤ 60 °F	61-74 °F	>= 75 °F

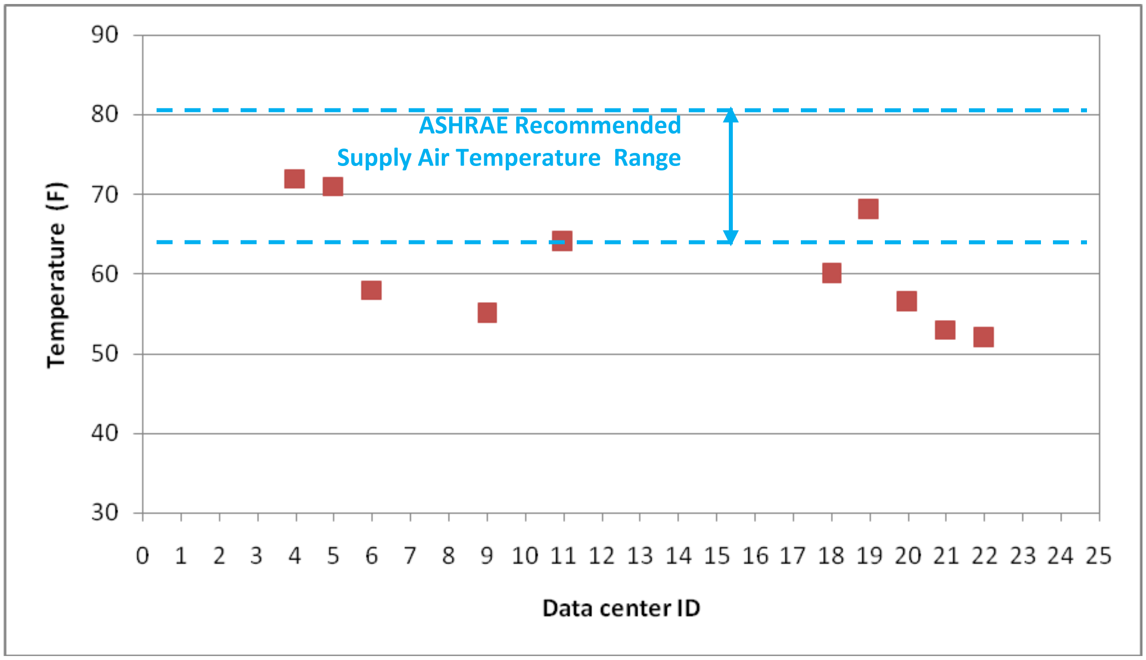

Figure 2. Measured supply temperature for data centers in the LBNL database

Actions Inferred:

A low supply air temperature indicates the potential for improving a data center's air management and increase the supply air temperature. Higher supply air temperatures allow HVAC cooling systems to operate more efficiently. Additionally, higher supply air temperatures provide more opportunity to implement free cooling strategies.

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) guidelines [ASHRAE 2008] provide a range of allowable and recommended supply temperatures and humidity at the inlet to the IT equipment. The recommended temperature range is between a lower end of 64.4°F and an upper end of 80.6 °F. The allowable temperature range is between 50 °F and 95 °F. Operating the data center at server inlet air temperatures above the recommended range may cause internal, variable speed server fans to operate at higher speeds and consume more power. The effect of increasing server inlet temperature on server fan power should be carefully weighed against potential data center HVAC system energy savings.

Supply air temperatures can oscillate significantly over time as Computer Room Air Conditioning (CRAC) unit compressors cycle on/off. This metric is intended to be taken as an average value over a representative period of time.

Special Considerations:

Temperature and humidity affect the reliability and life of IT equipment. Any changes to the air management and temperature and humidity settings should be evaluated with metrics such as the Rack Cooling Index (RCI) (Herrlin 2005), which can be used to assess the thermal health of the IT equipment.

Consult with IT equipment manufacturer on maximum inlet supply temperatures. Avoid pushing internal fans to operate at high speeds consuming more power. The effect of increasing server inlet temperature on server fan power should be carefully weighed against potential data center HVAC system energy savings.

B2: Relative Humidity Range at IT Inlet

Description:

This metric is the range of the IT equipment inlet air humidity setpoints.

Units: % RH

B2 = dB3 to dB4
where:
dB3: Low end IT equipment inlet air relative humidity setpoint
dB4: High end IT equipment inlet air relative humidity setpoint

Another way to view this metric is as a single %RH setpoint +/- deadband value. The difference in the high and low end humidity setpoints equals the deadband multiplied by two.

See section 7 for more information on the data items

Benchmarks:

Standard	Good	Better
40%-55%	25%-60%	No control

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) guidelines [ASHRAE 2008] provide a range of allowable and recommended supply temperatures and humidity at the inlet to the IT equipment. The recommended humidity range is between a lower end defined as a minimum dew point of 42°F and the upper end set at 60% relative humidity and 59°F dewpoint. The allowable relative humidity range is between 20%-80% and 63°F maximum dewpoint.

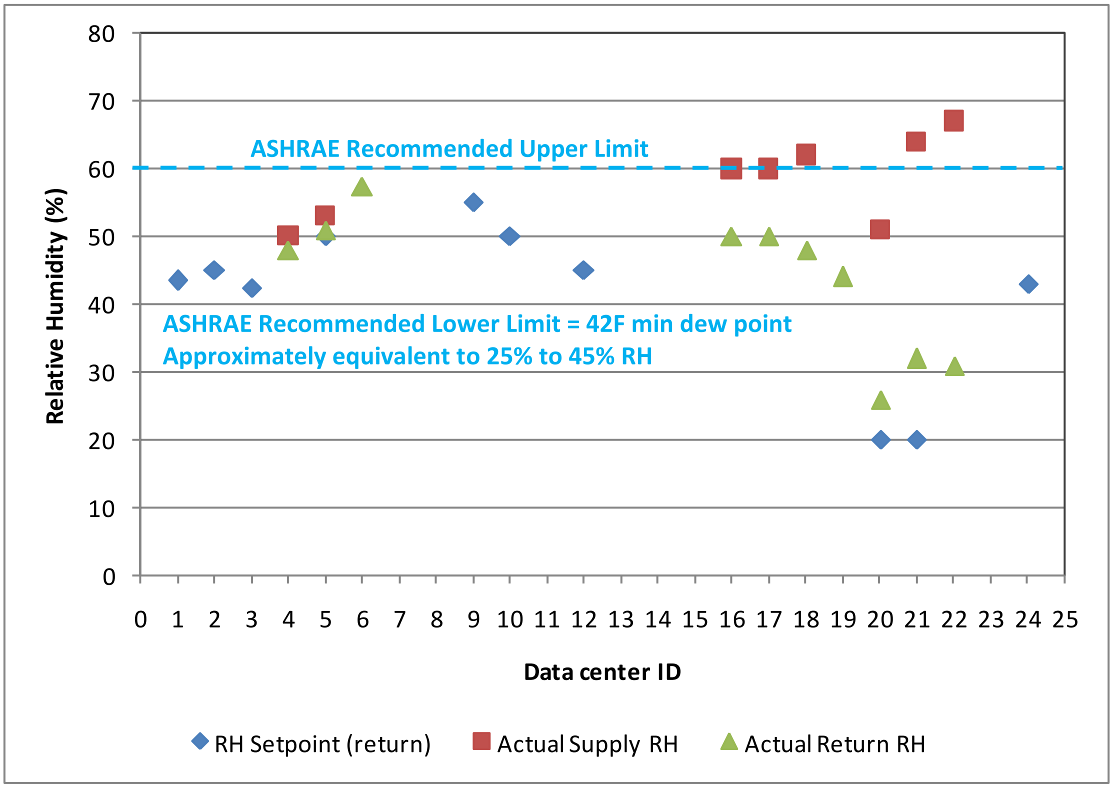

Figure 3. Return air relative humidity setpoints, measured supply and return relative humidity for for data centers in the LBNL database

Actions Inferred:

A small relative humidity setpoint range suggests opportunities to reduce energy use, by reducing the active humidification and dehumidification. Centralized active control of the humidification units reduces conflicting operations between individual units, thereby improving the energy efficiency. Many data centers operate well without active humidity control. Humidity control is important for physical media like tape storage, and generally not critical for the rest of the data center equipment. For data centers with air-side economizers, tight humidity control can severely limit the number of hours of free cooling. See discussion of metrics C3 and C4.

Special Considerations:

Due to variations in HVAC equipment control, a wide %RH setpoint range does not necessarily reflect the actual %RH range experienced in the data center. Ideally, the %RH range would be measured over a representative time period to gain an accurate account of the actual energy use devoted to humidity control.

Temperature and humidity can affect the reliability and life of IT equipment. Any changes to the air management and temperature and humidity settings should be evaluated with metrics such as the Rack Cooling Index (RCI) (Herrlin 2005), which can be used to assess the thermal health of the IT equipment. Studies by LBNL and the Electrostatic Discharge Association suggest that humidity may not need to be as tightly controlled.

B3: Return Temperature Index

Description:

This metric is a measure of the energy performance of the air management scheme (Herrlin 2007). The primary purpose of improving air management is to isolate hot and cold airstreams. This allows elevating both the supply and return temperatures and maximizes the difference between them while keeping the inlet temperatures within ASHRAE recommendations. It also allows reduction of the system air flow rate. This strategy allows the HVAC equipment to operate more efficiently. The return temperature index (RTI) is ideal at 100% wherein the return air temperature is the same as the temperature leaving the IT equipment and the supply air temperature is the same as the rack inlet temperature.

Units: %

RTI = ((dB2 – dB1) / (dB6 – dB5)) × 100
where:
dB1: Supply air temperature
dB2: Return air temperature
dB5: Rack inlet mean temperature
dB6: Rack outlet mean temperature

See section 7 for more information on the data items

Benchmarks:

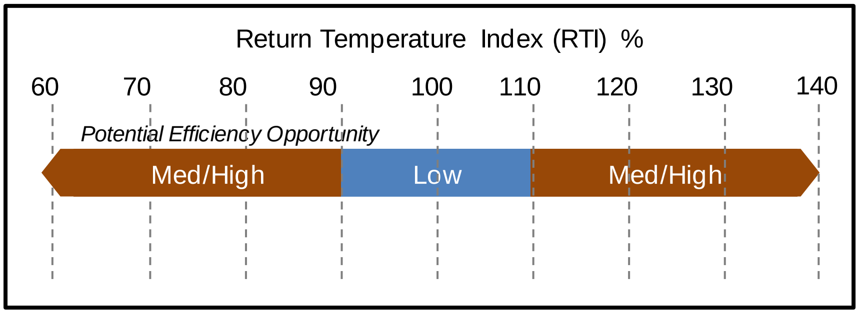

Figure 4. Benchmarks for Return Temperature Index

Actions Inferred:

RTI is also a measure of the excess or deficit of supply air to the server equipment. An RTI value of 100% is ideal. An RTI value of less than 100% indicates that the some of the supply air is by-passing the racks, and a value greater than 100% indicates that there is recirculation of air from the hot aisle. The RTI value can be brought close to ideal (100%) by improving air management.

Special Considerations:

Temperature and humidity affect the reliability and life of IT equipment. Any changes to the air management and temperature and humidity settings should be evaluated with metrics such as the Rack Cooling Index (RCI) (Herrlin 2005), which can be used to assess the thermal health of the IT equipment.

5. Cooling Metrics

ID	Name	Priority
C1	Data Center Cooling System Efficiency	1
C2	Data Center Cooling System Sizing Factor	1
C3	Air Economizer Utilization Factor (full cooling)	1
C4	Air Economizer Utilization Factor (partial cooling)	1
C5	Water Economizer Utilization Factor (full cooling)	1
C6	Water Economizer Utilization Factor (partial cooling)	1
C7	Airflow Efficiency	2

C1: Data Center Cooling System Efficiency

Description:

This metric characterizes the overall efficiency of the cooling system (including chillers, pumps, and cooling towers) in terms of average power input per unit of cooling output.

Units: kW/ton

C1: dC1 ÷ dC2
where:
dC1: Average cooling system power (kW)
dC2: Average cooling load in the data center (tons)

See section 7 for more information on the data items

Benchmarks:

Standard	Good	Better
> 1.0 kW/ton	1.0 - 0.5 kW/ton	< 0.5 kW/ton

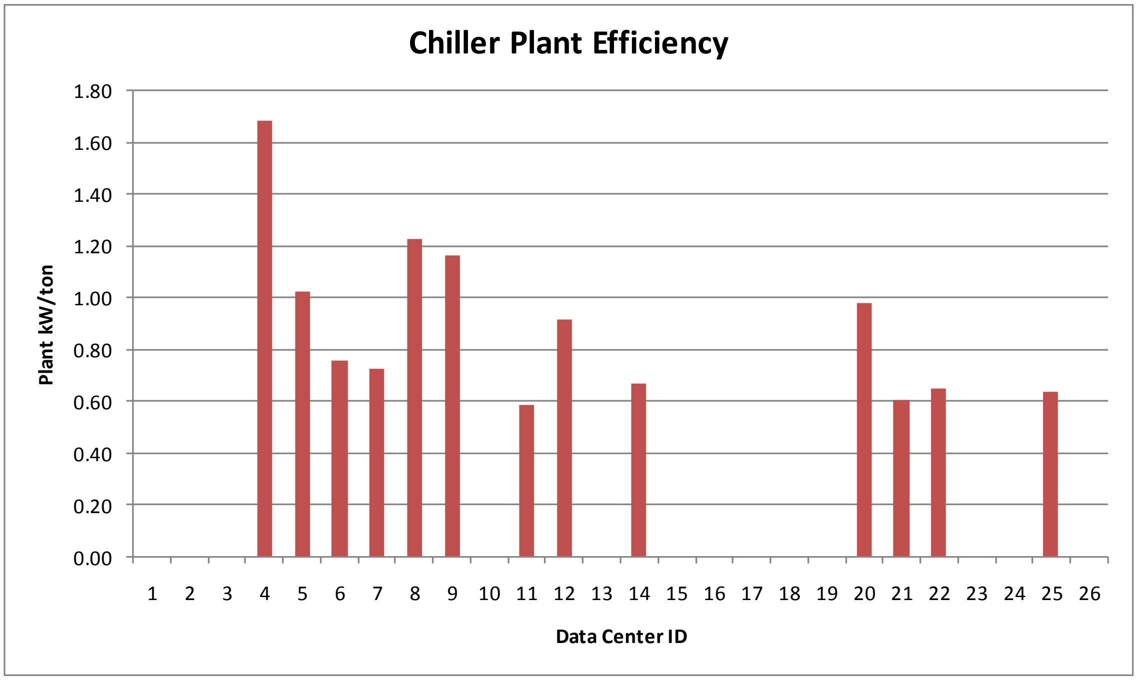

Figure 5. Cooling plant efficiency for datacenters in the LBNL database

Actions Inferred:

There are many efficiency actions that can be used to improve the overall efficiency of the chiller plant. These include:

- Modularization
- High efficiency chillers
- All-variable-speed system
- Premium efficiency motors
- Increased chilled water temperature
- Water-side economizer
- Controls optimization (staging, resets, etc.)

Special Considerations:

For packaged DX/CRAC unit based cooling systems, the supply fan power should not be included in the benchmarking of these systems' efficiency in kW/ton. Fan based efficiency is addressed separately under metric C7.

C2: Cooling System Sizing Factor

Description:

This metric is the ratio of the installed cooling capacity to the peak cooling load.

Units: -

$$C2 = dC3 \div dC4$$

where:

dC3: Installed Chiller Capacity (w/o backup) (tons)
dC4: Peak Chiller Load (tons)

See section 7 for more information on the data items

Benchmarks:

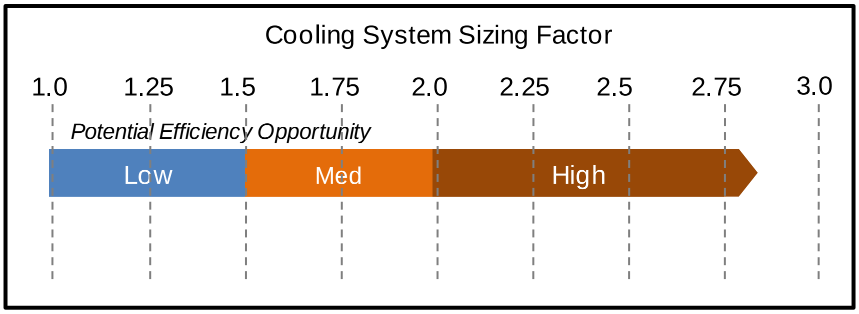

Figure 6. Benchmarks for Cooling System Sizing Factor

Actions Inferred:

A high value for this metric indicates the opportunity to "right-size" the cooling plant and improve part load efficiency. Part load efficiency can also be improved by using a modularized plant design. Also, VFD compressor chillers operate more efficiently around 80% load factor compared to full load. Retrofitting water-cooled chillers with VFDs may improve chiller operating efficiency if they are typically operated at part-load.

C3 and C4: Air Economizer Utilization Factors

Description:

This metric characterizes the extent to which an air-side economizer system is being used to provide "free" cooling. It is defined as the percentage of hours in a year that the economizer system provides either full (C3) or partial (C4) cooling. (i.e. either without any cooling being provided by the chiller plant or with a reduced amount of cooling provided by the chiller plant).

Units: %

$C3 = (dC5 \div 8760) \times 100$
where:
dC5: Air economizer hours (full cooling)

$C4 = (dC6 \div 8760) \times 100$
where:
dC6: Air economizer hours (partial cooling)

See section 7 for more information on the data items

Benchmarks:

The number of hours that the air economizer is being utilized could be compared to the maximum possible for the data center environmental conditions and climate in which the data center is located. This can be determined from simulation analysis. As a point of reference, the table below shows results from simulation analysis for five different data center environmental conditions and five different climate conditions.

Data center environmental conditions modeled for air side economizer analysis

Data Center Air Environmental Conditions	SA DB Temp.	RA DB Temp.	Low %RH Setpt.	Hi %RH Setpt.	Location of RH Sensor	Low DP Temp. Setpt.	Hi DP Temp. Setpt.
DC Condition 1	62	70	40%	55%	RA	44.7	53.2
DC Condition 2	70	84	40%	55%	SA	44.7	53.2
DC Condition 3	70	84	20%	80%	SA	27.0	63.6
DC Condition 4	80	100	40%	55%	SA	53.6	62.4
DC Condition 5	80	100	20%	80%	SA	35.4	73.3

Notes: Air-Side Economizer is modeled with dewpoint lockouts. SA = Supply air; DB = Dry bulb; RA = Return air; DP = Dewpoint; RH = =Relative Humidity.

	Percentage of Year (8760 hours)									
	San Francisco, CA		Houston, TX		Chicago, IL		Phoenix, AZ		Baltimore, MD	
Data Center Air Conditions	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]
DC Condition 1	41%	4%	10%	1%	9%	3%	13%	4%	9%	3%
DC Condition 2	45%	0%	11%	0%	13%	2%	16%	2%	11%	1%
DC Condition 3	91%	7%	46%	2%	53%	5%	75%	6%	53%	4%
DC Condition 4	28%	0%	18%	0%	17%	0%	12%	0%	16%	0%
DC Condition 5	94%	1%	76%	1%	56%	1%	60%	1%	59%	1%

[1] Full cooling hours are those where the outside air drybulb temperature is <= the SAT DB temperature and the outside air dewpoint falls between the low and high data center dewpoint temperature setpoints.

[2] Partial cooling hours are those where the outside air drybulb is > the SAT DB and < RAT DB temperatures and the outside air dewpoint falls between the low and high data center dewpoint temperature setpoints.

Actions Inferred:

A low value for this metric indicates potential for increasing energy savings from using an air-side economizer system. Increasing the supply air temperatures to the data center increases the hours of economizer use. Also, humidity restrictions need to be relaxed to maximize its use (see metric B2). Air-side economizers can provide significant savings if properly designed and controlled. The energy savings from economizer use will vary depending on the climate.

Special Considerations:

Concern over potential degradation from both gaseous contaminants and hygroscopic particles (from outside air), and relaxed humidity controls need to be properly evaluated based on the climate (location) of the data center. Particulate contamination can be significantly reduced by using improved HVAC filters. Most data center equipment is not sensitive to humidity changes, and those that are can be placed in a separately controlled area.

C5 and C6: Water Economizer Utilization Factors

Description:

This metric is the percentage hours in a year that the water side economizer system is used to provide either full, non-compressor based cooling or reduced compressor based cooling of the data center.

Units: %

$C5 = (dC7 \div 8760) \times 100$

where:

dC7: Water economizer hours (full cooling)

$C6 = (dC8 \div 8760) \times 100$

where:

dC8: Water economizer hours (partial cooling)

See section 7 for more information on the data items

Benchmarks:

The number of hours that the water economizer is being utilized can be compared to the maximum possible for the climate in which the data center is located. This can be determined from simulation analysis. As a point of reference, the table below shows results from simulation analysis for five different climates and five chilled water temperature setpoints.

	Percentage of Year (8760 hours)									
	San Francisco, CA		Houston, TX		Chicago, IL		Phoenix, AZ		Baltimore, MD	
Chilled Water Setpoints	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]	100% Cooling Econ. Hrs. [1]	Partial Cooling Econ. Hrs. [2]
CHWST = 44 F; CHWRT = 54 F	1%	9%	3%	8%	32%	15%	1%	14%	21%	18%
CHWST = 48 F; CHWRT = 58 F	2%	21%	6%	11%	38%	15%	2%	23%	28%	18%
CHWST = 48 F; CHWRT = 64 F	2%	54%	6%	20%	38%	24%	2%	41%	28%	28%
CHWST = 52 F; CHWRT = 68 F	6%	74%	10%	23%	44%	26%	9%	49%	36%	28%
CHWST = 56 F; CHWRT = 72 F	15%	77%	14%	26%	50%	28%	20%	49%	43%	28%

Notes: CHWST = Chilled Water Supply Temperature; CHWRT =Chilled Water Return Temperature

[1] Full cooling hours are those where the outside air wetbulb is at least 10 deg. F <= CHWST. (assumes a 10 deg F water-side economizer approach to wetbulb temperature.)

[2] Partial cooling hours are those where the outside air wetbulb is at least 10 deg F < CHWRT and > CHWST + 10 deg. F. (assumes a 10 deg F water-side economizer approach to wetbulb temperature.)

Actions Inferred:

This metric provides information on the energy savings from using an existing water-side economizer system. Increasing the chilled water temperatures allows for more available hours of economizer use. Water-side economizers can provide significant savings if properly designed and controlled.

Special Considerations:

Using water-side economizer removes the concern over particulate contamination from outside air. However, they require pump and tower energy to provide cooling. They are most cost-effective in very dry climates where evaporative cooling is most effective, and air-side economizers may raise concerns about low humidity in the data center..

C7: Airflow Efficiency

Description:

This metric characterizes overall airflow efficiency in terms of the total fan power required per unit of airflow. This metric provides an overall measure of how efficiently air is moved through the data center, from the supply to the return, and takes into account low pressure drop design as well as fan system efficiency. In fact, W/cfm is proportional to the ratio of the total system pressure drop (TSP) to the fan system efficiency ($\eta_{\text{fan syst}}$). That is, W/cfm is proportional to TSP/$\eta_{\text{fan syst}}$.

Units: W/cfm

$C7 = dC9 \times 1000 \div dC10$
where:
dC9: Total fan power (supply and return) (kW)
dC10: Total fan airflow (supply and exhaust) (cfm)

See section 7 for more information on the data items.

Benchmarks:

Standard	Good	Better
0.6 W/cfm	0.3 W/cfm	0.1 W/cfm

There are limited data on airflow efficiency in data centers. The data from the LBNL database suggest that 0.5 W/cfm might be considered a threshold of better practice.

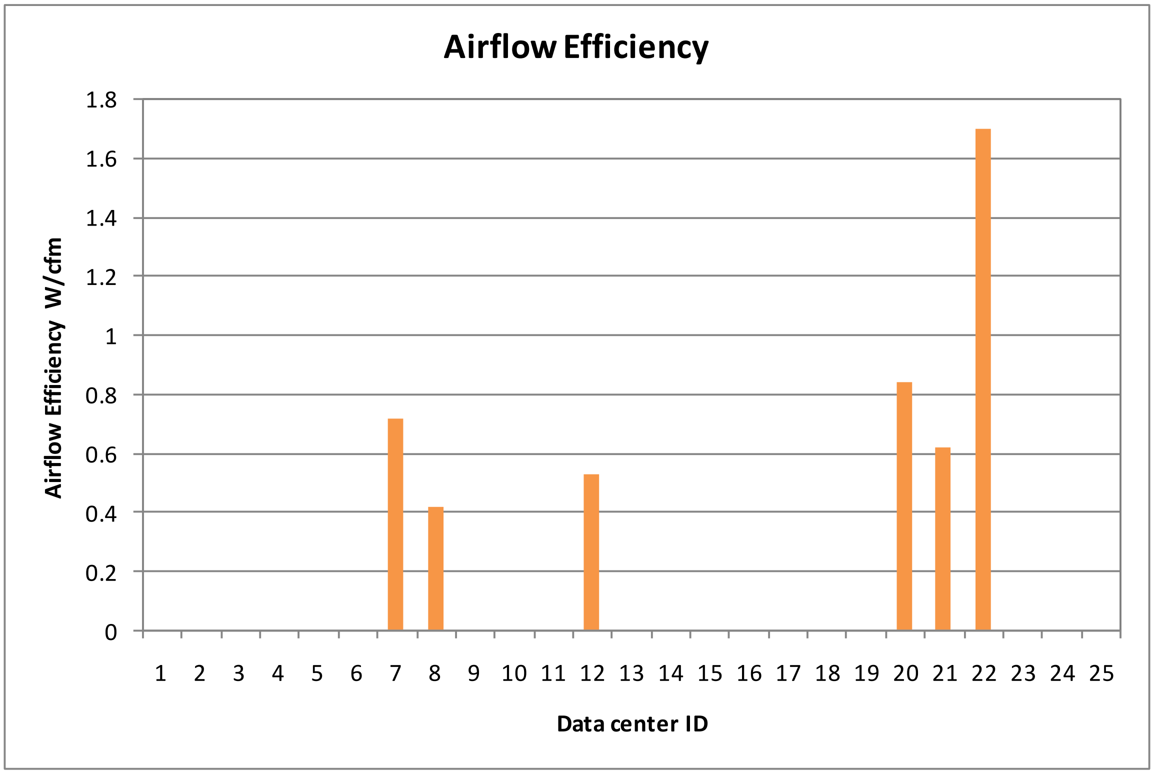

Figure 7. Airflow efficiency for data centers in the LBNL database

Actions Inferred:

A high value of this metric indicates that the fan system (fans, motors, belts, drives) is inefficient and the pressure drops in the airflow distribution system need to be reduced. Improving the design of the duct work can significantly reduce the pressure drop in the system. Additionally, use of low-pressure drop filters and ensuring that filters are clean will reduce overall pressure drop.

Special Considerations:

The airflow efficiency metric indicates the efficiency of the fan system but not whether the air flow rate delivered for cooling is appropriate. It is possible for a cooling system to deliver an excessive volumetric flow rate of air (indicated by a low RTI value) but to do so in an efficient manner as determined by the airflow efficiency metric. This metric is optimally used with consideration given to the RTI metric.

6. Electrical Power Chain Metrics

ID	Name	Priority
E1	UPS Load Factor	1
E2	UPS System Efficiency	1
E3	Lighting Density	3

E1: UPS Load Factor

Description:

This metric is the ratio of the peak load of the uninterruptible power supply (UPS) to the design value of its capacity. This provides a measure of the UPS system over-sizing and redundancy.

Units: Dimensionless

$E1 = dE1 \div dE2$
where:
dE1: UPS average load (kW)
dE2: UPS load capacity (kW)

See section 7 for more information on the data items.

Benchmarks:

Standard	Good	Better
0.4	0.7	0.9

UPS load factors below 0.5 may indicate an opportunity for efficiency improvements, although the extent of the opportunity is highly dependent on the required redundancy level.

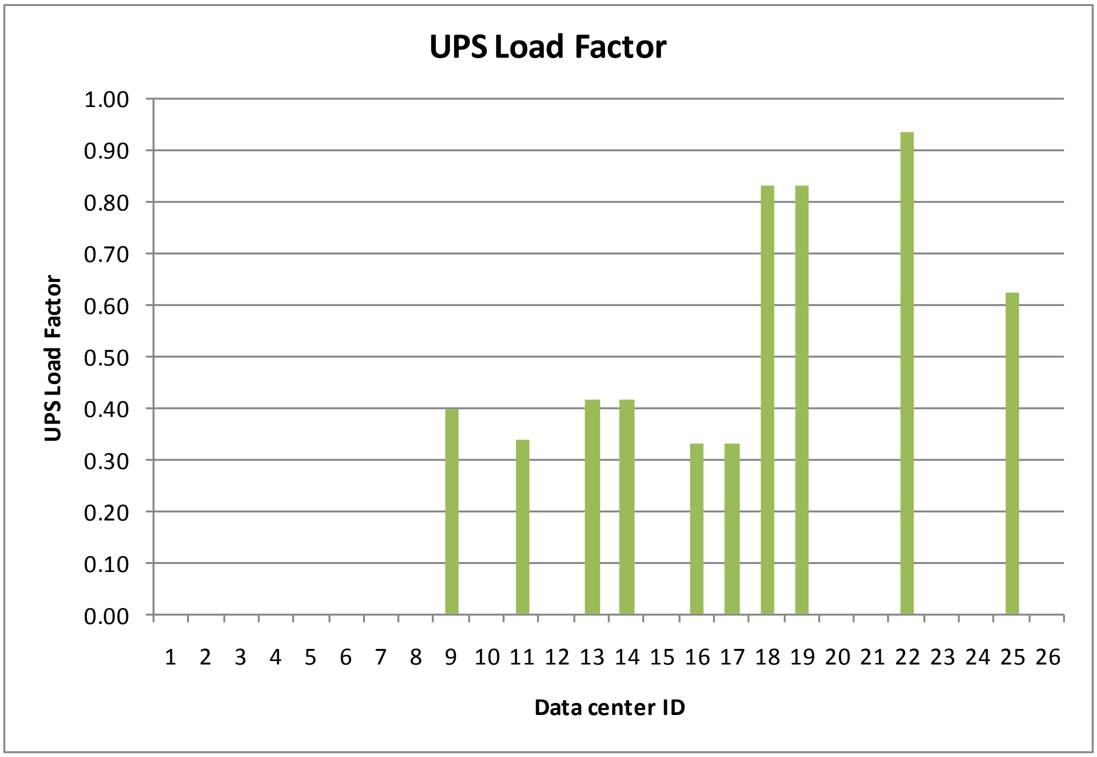

Figure 8. UPS load factor for data centers in the LBNL database

Actions Inferred:

Since UPS efficiency decreases at lower load factors, increasing the load factor can decrease UPS energy losses. The load factor can be improved by several means, including the following:

- Shutdown some UPS modules when Redundancy Level exceeds N+1 or 2N
- Install a scalable/modular UPS
- Install a smaller UPS size to fit present load capacity
- Transfer loads between UPS modules to maximize load factor % per active UPS

E2: Data Center UPS System Efficiency

Description:

This metric is the ratio of the UPS output power to the UPS input power. The UPS efficiency varies depending on its load factor.

Units: %

E2 = (dE4 ÷ dE3) x 100
where:
dE3: UPS input power (kW)
dE4: UPS output power (kW)

See section 7 for more information on the data items

Benchmarks:

Standard	Good	Better
85%	90%	> 95%

The UPS efficiency varies depending on its load factor and therefore the benchmark for this metric depends on the load factor of the UPS system. At UPS load factors below 40% the system usually is highly inefficient due to no load losses. Figure 9 shows the range of UPS efficiencies from factory measurements of different topologies. Figure 10 shows the UPS efficiencies for data centers in the LBNL database. These measurements taken several years ago illustrate that efficiencies vary considerably. Manufacturers claim that improved efficiencies are available today. When selecting UPS systems, it is important to evaluate performance over the expected loading range.

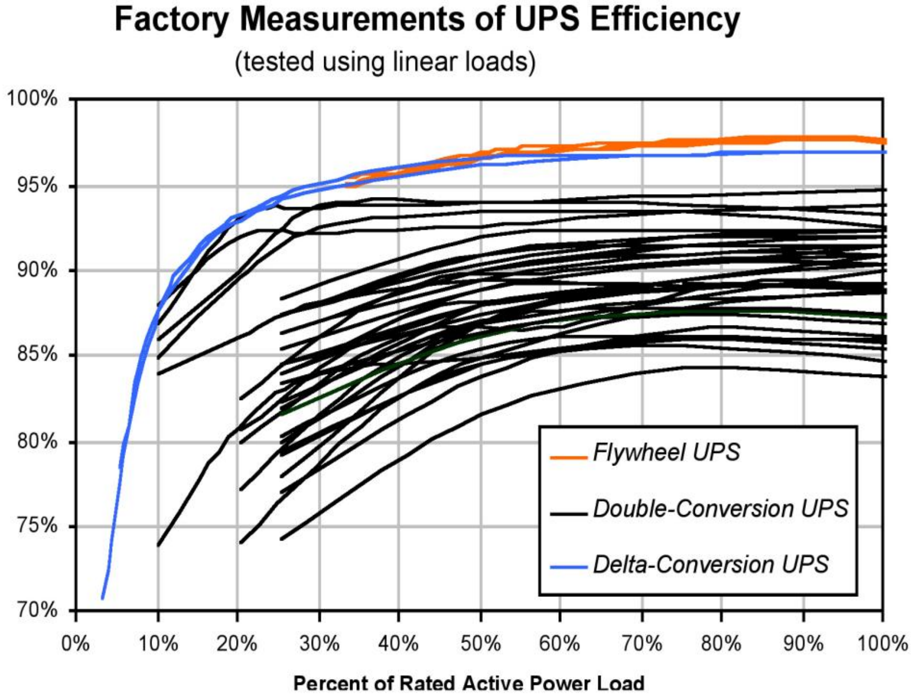

Figure 9. Range of UPS system efficiencies for factory measurements of different topologies

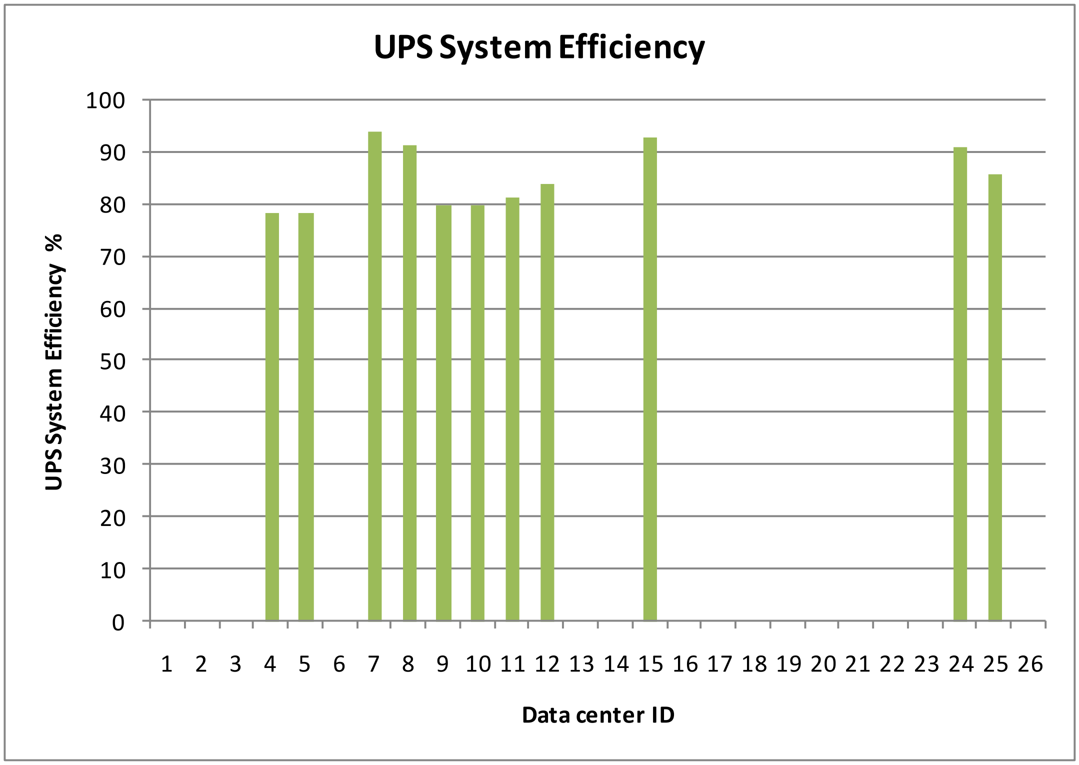

Figure 10. UPS efficiency for data centers in the LBNL database

Actions Inferred:

Selection of more efficient UPS systems, especially the ones that perform well at load factors below 40% improves energy savings. For non-critical IT work by-passing the UPS system using factory-supplied hardware and controls may be an option. Reducing the level of redundancy by using modular UPS systems could also improve the efficiency.

Special Considerations:

In addition to improving the efficiency of the UPS system, efficient transformers and power supplies provide energy savings. Placing the power distribution units and transformers outside the data center room is a strategy that helps reduce the cooling load of the HVAC system.

E3: Data Center Lighting Power Density

Description:

This metric is the ratio of the data center lighting power consumption to the data center area.

Units: W/ft^2

E3 = dE5 × 1000 ÷ dG1
where:
dE5: Data center lighting power (kW)
dG1: Data center area (ft^2)

See section 7 for more information on the data items

Benchmarks:

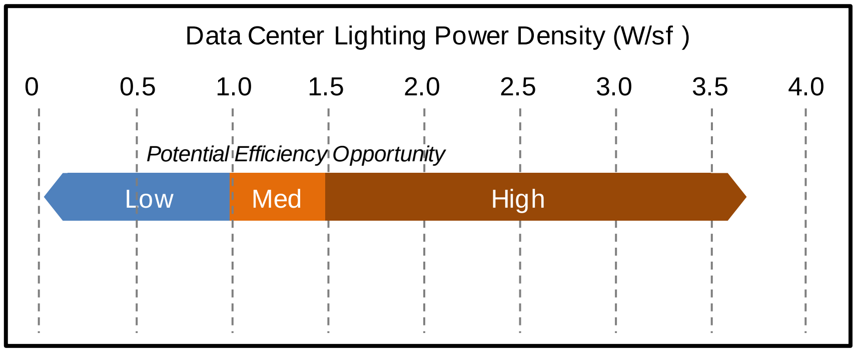

Figure 11. Benchmarks for lighting power density in data centers

Actions Inferred:

The efficiency of the lighting system can be improved by using efficient lamps and ballasts. The use of occupancy sensors to turn off lights in unoccupied aisles can also reduce the overall lighting energy use. For facilities with security issues, LED strip lighting can be used to significantly lower the lighting power density during unoccupied hours while still providing some illumination.

7. Data Required for Performance Metrics

The table below lists the data required for the performance metrics described in sections 3-6.

ID	Data Item	Measurement/Calculation Guidance
General		
dG1	Data Center Area (electrically active)	
dG2	Data Center Location	
dG3	Data Center Type	
dG4	Year of Construction (or major renovation)	
Data Center Energy Data		
dA1	Annual Electrical Energy Use	Meter data or Utility bills
dA2	Annual IT Electrical Energy Use	Measured downstream from PDUs.
dA3	Annual Fuel Energy Use	Meter data or Utility bills
dA4	Annual District Steam Energy Use	Meter data or Utility bills
dA5	Annual District Chilled Water Energy Use	Meter data or Utility bills
Environmental Conditions and Air Management		
dB1	Supply Air Temperature	Measured at supply diffuser/outlet, weighted average by airflow rate
dB2	Return Air Temperature	Measured at return grille/inlet, weighted average by airflow rate
dB3	Low end IT Equipment Inlet Air Relative Humidity Setpoint	Measured at IT equipment air intakes.
dB4	High end IT Equipment Inlet Air Relative Humidity Setpoint	Measured at IT equipment air intakes.
dB5	Rack Inlet Mean Temperature	Average of measurements at different heights and multiple racks
dB6	Rack Outlet Mean Temperature	Average of measurements at different heights and multiple racks
Cooling and Ventilation		
dC1	Average Cooling System Power Consumption	Average power during the time that chiller is on.
dC2	Average Cooling Load	Average load during the time chiller is on. If not directly measured, it can be calculated from flow rate and supply and return temperatures
dC3	Installed Chiller Capacity (w/o backup)	Rated capacity at design conditions
dC4	Peak Chiller Load	Peak over one year
dC5	Air Economizer Hours (full cooling)	Hours without compressor-based cooling
dC6	Air Economizer Hours (partial cooling)	Hours with reduced compressor-based cooling
dC7	Water Economizer Hours (full cooling)	Hours without compressor-based cooling
dC8	Water Economizer Hours (partial cooling)	Hours with reduced compressor-based cooling
dC9	Total Fan Power (Supply and Return)	Use design values if measured values not available
dC10	Total Fan Airflow rate (Supply and Return)	Use design values if measured values not available
Electrical Power Chain		
dE1	UPS Average Load	Average over one year
dE2	UPS Load Capacity	Rated capacity
dE3	UPS Input Power	Average over one year or representative time period
dE4	UPS Output Power	Average over one year or representative time period
dE5	Average Lighting Power	Average over one year or representative time period

8. References & Resources

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