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USER GUIDE FOR IMPLEMENTING ECBC 2017 IN DATA CENTRES

Complying With the Energy Conservation Building Code and Higher Rating Levels

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Users Guide for Implementing ECBC 2017 in Data Centres

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1. Introduction

This guide serves as a supplement to the 2017 Energy Conservation Building Code (ECBC), which is intended to provide minimum requirements for design and construction of energy-efficient buildings in India.

The purpose of this supplemental guide is to help users identify standards in the 2017 ECBC that pertain specifically to data centres and to offer notes and suggestions for implementation. Additionally, this guide directs users to resources, including the U.S. Department of Energy's Center for Expertise (CoE) for Energy Efficiency in Data Centers (https://datacenters.lbl.gov/). The CoE website provides helpful tools and other resources that can assist users in achieving desired energy efficiency results.

This guide covers energy efficiency measures under four broad categories:

1. Room Cooling
2. Chiller Plant
3. Electrical
4. IT Hardware & Management

2. Code Compliance and Performance Levels

This guide summarizes the ECBC 2017 standards relevant to data centres as outlined by the Bureau of Energy Efficiency (BEE), Ministry of Power. This guide includes standards for each measure type at the various ECBC tiers ("ECBC Compliant", "ECBC+", and "SuperECBC").

In the case of measures for which the Bureau of Energy Efficiency (BEE), Ministry of Power, did not define standards for compliance with the ECBC, ECBC+, or SuperECBC standards, additional requirements are provided. This guide aims to help users identify which ECBC tier they will seek for compliance, as well as provide guidance on how compliance can be achieved.

This guide contains a section for each measure type (e.g., Air Management). Each section provides guidance, tips, and resources to help users achieve a given efficiency level for the measures. Information on verifying compliance with these standards is outside the scope of this guide but can be found in the 2017 ECBC Guide.

Each section begins with a table listing the requirements for each of three efficiency levels.

- **Level I:** ECBC Compliant and any recommended additional requirements.
- **Level II**: ECBC+ and any recommended additional requirements.
- **Level III**: SuperECBC and any recommended additional requirements.

Note that Level II, and Level III requirements are the same as their lower-level requirements except where higher efficiencies or additional requirements are specified. The table below provides an example of the format for each of the sections that follow.

Format of Compliance Level Tables in this Guide

Level I	Level II	Level III
ECBC Compliant *Reference to ECBC 2017 Section Number if applicable.* *Listed requirements to achieve ECBC Compliant level.* **Recommended Additional Requirements** *Additional requirements (if any) to achieve this level, that are not directly addressed by ECBC 2017.*	**ECBC+** *Reference to ECBC 2017 Section Number if applicable.* *Listed requirements to achieve ECBC+ level.* **Recommended Additional Requirements** *Additional requirements (if any) to achieve this level, that are not directly addressed by ECBC 2017.*	**SuperECBC** *Reference to ECBC 2017 Section Number if applicable.* *Listed requirements to achieve SuperECBC level.* **Recommended Additional Requirements** *Additional requirements (if any) to achieve this level, that are not directly addressed by ECBC 2017.*

Each table is followed by Tips and Best Practices for meeting or exceeding the requirements or achieving operational efficiencies. Each section also includes Resources or citations to various sources of information on the measures, their energy performance, or implementation.

3. Room Cooling

The measure types in this section address cooling at the data centre room level.

CRAC Efficiency

ECBC 2017 formally adopted energy efficiency requirements for Computer Room Air Conditioners (CRACs) and condensing units serving data centres.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 Section 5.2.2.4: ✓ Minimum Net Sensible Coefficient of Performance (NSCOP) rating of 2.5, regardless of capacity, for both downflow & upflow. **Recommended Additional Requirements**	**ECBC+** Same as ECBC compliant **Recommended Additional Requirements** Same as Level I, plus: ✓ Minimum Net Sensible Coefficient of Performance (NSCOP) rating of 3.0, regardless of capacity or air flow direction.	**SuperECBC** Same as ECBC compliant **Recommended Additional Requirements** Same as Level II, plus: ✓ Minimum Net Sensible Coefficient of Performance (NSCOP) rating of 3.1, regardless of capacity or air flow direction.

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✓ CRACs/air handlers shall be equipped with variable-speed fans. ✓ Minimum Net Sensible Coefficient of Performance (NSCOP) rating of 2.5, regardless of capacity or air flow direction.		

Tips and Best Practices

CRAC Efficiency

- A CRAC manufacturer's efficiency rating applies to the entire CRAC as a single package.
- The rating is determined by operating the CRAC at standard conditions (specific air temperature and humidity, air flow rate, and fan pressure drop) in a laboratory setting.
- A manufacturer can achieve a particular rating with different choices and arrangement of the components – fans, motors, compressor, coils, and air filters.
- The actual operating efficiency of a CRAC when put into service can be better or worse than its rating, depending on how it is installed and operated. An NSCOP of 3.5 can be achieved with a return air temperature of 38°C or higher.

CRAC Options

- Some options – such as refrigerant economizing coils – may offer significant efficiency gains that are not reflected in the rating. CRAC efficiency ratings are typically determined with all options removed.
- Consider water-cooled condensers instead of air-cooled.

CRAC Retrofits

- For already-installed CRACs, some manufacturers (e.g., Stulz, Vertiv) offer efficiency retrofits. A popular retrofit for downflow units is replacing the fan with an underfloor, direct-drive, ECM plug fan.

Measuring Actual Operating Efficiency

- A data centre owner with an interest in energy efficiency will want to know how the actual operating efficiency of his CRACs compare to the manufacturer's rating. The difference can be significant, depending on how far the real-world operating conditions vary from the standard test conditions. See the Metering & Monitoring section below.

Air Handlers

- CRACs are the most common form of data centre cooling system, but they are not the only solution, nor are they always the most efficient solution.
- Air handlers served by a chilled-water system are another solution for data centre cooling. The term "air handler" covers purpose-built Computer Room Air Handlers (CRAHs) and generic units. The latter can easily be adapted to data centre use. In addition to offering better overall system efficiency, air handlers can incorporate air-side economizers. See the Air-Side Economizing section below.

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- ECBC 2017 does not specify performance criteria for whole air handlers or for an entire chilled-water cooling system (chiller plant plus air handlers). Nonetheless, if the designer of a chilled-water cooling system follows the criteria for the components as described in the following sections, the result will be an efficient system.

CRAHs

- The closer the cooling coil can be placed relative to the source of heat (the IT hardware), the shorter the cooling air loop needs to be and the more efficient the cooling system can be.
- In-row CRAHs have the same form factor as IT hardware racks and are designed to be placed in the rack rows. They circulate cooling air directly to neighbouring racks.

Applicable to CRACs and Air Handlers

- See the Air Management, Temperature & Humidity Control, and Fan Systems sections below.

Other Solutions

- Rear door heat exchangers are cooling coils that attach to the rear of server racks. This is a “fanless” solution, as it relies on the server fans to the push warm air through the coil.
- “Liquid cooling” can dispense with air flow entirely. For example, cooling fluid can be brought into direct contact with the server CPUs.

Resources

Variable-Speed Fan Retrofits for Computer-Room Air Conditioners. Report, 2013. Steve Greenberg, Lawrence Berkeley National Laboratory. This case study documents three retrofits to existing constant-speed fans in computer-room air conditioners (CRACs), all located in California: first, a forty year-old, 6,000 ft2 data center located at the Lawrence Berkeley National Laboratory (LBNL) in Berkeley, with down-flow, water-cooled CRACs; second, a three year-old, 1,000 ft2 data center owned by NetApp in Sunnyvale, with up-flow, water-cooled units; and, third, a twelve year-old, 1300 ft2 data center owned by the Electric Power Research Institute (EPRI) in Palo Alto, with down-flow, air-cooled units. Link.

Pumped Refrigerant Economizers for Use in Computer Rooms. Report, 2015. Mark Alatorre, California Energy Commission. California’s Building Energy Efficiency Standards require the mechanical cooling equipment serving a computer room to be equipped with either an integrated air-side economizer or an integrated water-side economizer. Pumped refrigerant economizing uses the same concept for energy savings, in that it bypasses the compressor for mechanical cooling by using a pump to move the refrigerant through the evaporator and condenser. Link.

Liquid Cooling. Reports, 2010-2019. Center of Expertise for Energy Efficiency in Data Centers. This website provides links to reports that address the subject of liquid cooling in data centers. Link.

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Air Management

While ECBC 2017 did not formally adopt air management related standards for data centres, in most data centres there is plenty of room for improvement in air management.

The following recommended requirements apply to data centre rooms with an IT design load greater than 100 kVA. Data centre rooms with an IT design load of 100 kVA or less currently have no recommended requirements for air management.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 does not address this level.	**ECBC+** ECBC 2017 does not address this level.	**SuperECBC** ECBC 2017 does not address this level.
Recommended Additional Requirements - None -	**Recommended Additional Requirements** ✓ No more than 30% extra supply air relative to IT airflow. ✓ IT inlet temperature at any point no more than 4˚C higher than the cooling system supply air temperature.	**Recommended Additional Requirements** ✓ No more than 15% extra supply air relative to IT airflow. ✓ IT inlet temperature at any point no more than 2˚C higher than the cooling system supply air temperature. ✓ Automatic variable air flow control.

Tips and Best Practices

General

The intent of air management is to deliver cooling air directly to the IT hardware, and then return the warmed air directly to the cooling coils with as little mixing as possible. Superior air management is achieved by ducting the supply air, the return air, or both. In such ducted systems, the direction of air flow in the CRAC or air handler is of little concern.

However, if an unducted system is in place, then downflow units serving cold air to the space under a false floor are recommended. Warm air naturally tends to rise, assisting the fans in units that discharge downwards and draw warm return air from above.

Level I requirements should be attainable with the following measures:

- Server racks arranged to create hot & cold aisles.
- No gaps between server racks.
- Blanking plates placed in empty server slots in each rack.

Level II requirements should be attainable with the addition of:

- Medium containment. Example: Ceiling plenum return.

Level III requirements should be attainable with the addition of:

- Full containment. Example: Enclosed hot aisles, ducted return.

Other Solutions

- Heat recovery. In some cases, the heat removed from a data centre can be directed to nearby uses rather than simply rejecting it to the environment. The NREL report in the Additional Resources section at the end of this Guide provides an example.
- Liquid cooling. “Liquid cooling” dispenses with air flow entirely. Instead, cooling fluid is brought into direct contact with the server CPUs.
- Fan speed control. Fan speed control can assist air management. (See the Fans Systems section below.)

Resources

The Air Management Tool. Software tool, 2014. Lawrence Berkeley National Laboratory. The Air Management Tool was developed to accelerate energy savings in data centres without affecting the thermal IT equipment environment by assessing the data centre air-management status. Based on user input, the tool provides air management recommendations and the potential for reducing the supply airflow rate and increasing the supply air temperature without affecting the thermal equipment environment. Link.

The Air Management Estimator. Software tool, 2017. Lawrence Berkeley National Laboratory, ANCIS. The Air Management Estimator is a simplified version of the Air Management Tool that uses the same engine. The input options in this tool have been reduced in favor of increased clarity. Link.

Demonstration: Portable Air Management Measurement Tools. Report, 2018. Magnus Herrlin, Steve Greenberg, Lawrence Berkeley National Laboratory. This demonstration involves two inexpensive, portable measurement tools for assessing air management in small data centres (<5,000ft^2 or <464m^2) on a limited, temporary basis. Access to simple, inexpensive tools for implementing and tracking air management is imperative in such environments. Besides evaluating the accuracy of the temperature measurements, this report also includes an evaluation of the ease of use of the tools. Link.

Air Management in Small Data Centers. Report, 2016. Magnus Herrlin, Lawrence Berkeley National Laboratory. Randall Cole, Pacific Gas & Electric Company. This report focuses on improving air management in small data centres due to the great potential for collective energy savings. To implement air management, key environmental parameters need to be monitored. Complex and simple tools are described. Due to many barriers in small data centres it would help to provide utility incentives for rapidly deployable “packages” of air management measures that require only marginal customization. Such packages were developed based on computer modeling. The report also outlines the process to select the packages, calculate the energy savings, determine the cost of the packages, and establish the rebates. Link.

Air Management Webinar. Slides, 2018. Magnus Herrlin, Lawrence Berkeley National Laboratory. From Magnus Herrlin’s April 12, 2018 Federal Energy Management Program (FEMP) presentation on air management. The presentation covers basic air management “best practices” and detection and correction of common problems. The importance and key goals and results with air management are reviewed in some detail. Link.

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Liquid Cooling. Reports, 2010-2019. Center of Expertise for Energy Efficiency in Data Centers. This website provides links to reports that address the subject of liquid cooling in data centers. Link.

Temperature & Humidity Control

ECBC 2017 formally adopted energy efficiency requirements for temperature and humidity control. Mechanical heating and cooling equipment in all buildings shall be installed with controls to manage the temperature inside the conditioned zones. BEE also outlines identical requirements for ECBC+ and SuperECBC, which apply in both cases to buildings with a built area of greater than 20,000 m^2. Note that the reset requirements do not apply to buildings in warm, humid climate zones.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 Section 5.2.3.2: ✓ Each floor or building block shall be installed with at least one control to manage the temperature. ✓ Separate thermostat control shall be in each computer room of educational.	**ECBC+** ECBC 2017, Sections 5.2.4.1 - 5.2.4.3: In addition to ECBC Compliant: ✓ Centralized demand shedding controls shall have capabilities to be disabled by facility operators and be manually controlled by a central point by facility operators to manage cooling set points. ✓ Supply air temperature reset capabilities. Controls shall reset the supply air temperature to at least 25% of the difference between the design supply air temperature and the design room air temperature. ✓ Chilled water systems with a design capacity>350 kWr supplying chilled water to comfort conditioning systems shall have controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outdoor air temperature. ✓ Exceptions: Controls to automatically reset chilled water temperature shall not be required where the supply temperature reset controls causes improper operation of equipment. **Recommended Additional Requirements** ✓ CRACs/air handlers shall operate on fixed supply air temperature	**SuperECBC** Same as ECBC+ **Recommended Additional Requirements** Same as Level II, plus: ✓ CRACs/air handlers shall have the ability to control supply air dewpoint temperature as well as supply air relative humidity, to conform with the ASHRAE Recommended range. ✓ All CRAC/air handler operating modes (supply air temperature & humidity setpoints, actual supply air temperature and humidity, de-humidification status, reheat status) shall be monitored from a central monitoring system. See Metering and Monitoring section below.

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	control, not return air temperature control. ✓ CRACs/air handlers shall have the ability to provide supply air at the upper limit of the ASHRAE recommended temperature/humidity range. This means systems support high supply air temperature (26/27˚C) and return air temperature (38/40˚C). *See additional Tip below.* ✓ CRACs/air handlers shall be equipped with variable-speed fans. See CRAC Efficiency section above. ✓ Cooling system controls shall prevent simultaneous humidification & dehumidification by multiple units serving the same space.	

Tips and Best Practices

General

- “Floor or building block” refers to a data centre room.
- “Design room air temperature” refers to allowable IT hardware inlet air temperature & humidity.
- For fan speed control options, see the Fan Systems section below.
- Variable cooling capacity (multi-stage compressor) CRACs are recommended. Supply air temperature tends to oscillate widely with single-stage compressors, making supply air temperature control more difficult.
- CRACs are typically autonomous, each one operating with its own on-board controls. This can lead to a situation where adjacent CRACs are fighting each other. For example, one CRAC may be humidifying, and its neighbour is simultaneously dehumidifying. This consumes energy to no purpose. Fighting can be avoided by installing a centralized control system.

Air Temperature Control

- Default CRAC/CRAH controls are commonly set up to maintain a constant return air temperature and a constant air flow. In this case, the supply air temperature cannot also be simultaneously controlled – it will be a result of the cooling load encountered. Yet, to meet the acceptable range of IT hardware inlet temperature, it is more to the point to control supply air temperature. If the CRACs/CRAHs are set up to control their return air temperature, then the aim is to select return air temperature setpoints and air flow rates that provide an acceptable range of IT hardware inlet temperatures during operation.
- If a CRAC/air handler is controlling its supply air temperature, and also controlling its fan speed to maintain a differential air pressure setpoint, then the return air temperature cannot also be simultaneously controlled – it will be a result of the cooling load encountered. The return air temperature range (38/40˚C) cited under Level II Recommended Additional Requirements in the above table is not a setpoint, but rather a target upper range.

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- With improved air management and use of the upper end of the ASHRAE recommended supply air temperature range, return air temperatures significantly higher than the rating condition are possible. This in turn results in higher capacity and efficiency from a given CRAC unit, or higher capacity from a given air handler cooling coil.
- Some controls are set up to maintain an IT hardware inlet temperature setpoint rather than CRAC/air handler supply or return air temperature. This is the most accurate way to ensure the hardware is receiving the correct air condition, but attention must also be directed to proper air management. Poor air management can force the CRAC/air handler to produce a lower supply air temperature (requiring more energy) in order to meet the IT hardware inlet setpoint.

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Resources

Data Center Efficiency & IT Equipment Reliability at Wider Operating Temperature and Humidity Ranges. Report, 2012. Steve Strutt, Chris Kelley, Harkeeret Singh, Vic Smith, Green Grid. Many data centres can realize overall operational cost savings by leveraging looser environmental controls within the wider range of supported temperature and humidity limits as established by equipment manufacturers. Link.

2015 Thermal Guidelines for Data Processing Environments, 4th Edition. Guide, 2015. ASHRAE Technical Committee 9.9.

IT equipment environmental requirements are often mismatched with adjacent equipment requirements or with facility operating conditions. How can HVAC equipment manufacturers and installers, data center designers, and facility operators find common solutions and standard practices that facilitate IT equipment interchangeability while preserving industry innovation?

Thermal Guidelines for Data Processing Environments provides a framework for improved alignment of efforts among IT equipment hardware manufacturers (including manufacturers of computers, servers, and storage products), HVAC equipment manufacturers, data center designers, and facility operators and managers.

This guide covers five primary areas:

1. Equipment operating environment guidelines for air-cooled equipment
2. Environmental guidelines for liquid-cooled equipment
3. Facility temperature and humidity measurement
4. Equipment placement and airflow patterns
5. Equipment manufacturers' heat load and airflow requirement reporting

This fourth edition of Thermal Guidelines features updated information as well as new discussions on topics such as increasing energy efficiency by allowing reduced moisture levels with minimum risk of electrostatic discharge. The guide provides groundbreaking, vendor-neutral information that will empower data center designers, operators, and managers to better determine the impact of varying design and operation parameters. The book comes with a removable reference card with helpful information for facility managers and others. The reference card may also be accessed online. Link.

2016 Errata to Thermal Guidelines for Data Processing Environments, 4th Edition. Guide, 2016. ASHRAE Technical Committee 9.9. Link.

Humidity Control in Data Centers. Report, 2017. Vali Sorell, Syska Hennessey. Magnus Herlin, Lawrence Berkeley National Laboratory. This report reviews the evolution of humidity control in data centers and makes recommendations on how to meet the current humidity control requirements in an energy-efficient manner. Guidance on the use of evaporative cooling is also provided. Link.

Fan Systems

ECBC 2017 provides requirements for fan mechanical efficiency and fan motor efficiency at the ECBC Complaint, ECBC+ and SuperECBC levels. These efficiencies are only one aspect of fan systems; other considerations are addressed in the Tips section below.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 Section 5.3: ✓ Supply, exhaust, and return or relief fans with motor power exceeding 0.37 kW shall meet or exceed: • Fan mechanical efficiency of 60%. • Motor efficiency IE2, as per IS 12615. Exception: ✓ Fans in un-ducted air conditioning unit where fan efficiency has already been taken in account to calculate the efficiency standard of the unit.	**ECBC+** Same as ECBC Compliant, except: • Fan mechanical efficiency of 65%. • Motor efficiency IE3, as per IS 12615.	**SuperECBC** Same as ECBC+, except: • Fan mechanical efficiency of 70%. • Motor efficiency IE4, as per IS 12615. ECBC 2017, Section 5.2.5.1: ✓ Fans in Variable Air Volume (VAV) systems shall have controls or devices that will result in fan motor demand of no more than 30% of their design wattage at 50% of design airflow based on manufacturer's certified fan data.

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Tips and Best Practices

Fan Power

An electric fan system consists of a variable speed controller (optional), the motor, the transmission (belt, gearbox, or direct drive), and the fan. The power demand of the fan system depends on the amount of air it is moving, the resistance to the air flow, and the efficiency of each system component.

Air Flow Rate

If the air flow rate can be reduced, fan energy will be saved. To reduce the air flow and still successfully handle the cooling load, the temperature difference between the supply and return air (the “delta-T”) must increase.

Pressure Drop

The power required by a fan increases with the resistance (the “pressure drop”) experienced by its air flow, and the pressure drop tends to increase exponentially with the air flow rate. Significant energy savings are realized by minimizing resistance to flow throughout the air flow loop. To consider:

- **Air Filters.** Select low pressure drop filters.
- **False Floor Height.** A minimum of 600mm clear height is recommended.

Floor Tiles

Avoid an overly restricted false floor. This can be caused by not enough perforated tiles, or perforations that are too small.

- **Pressure setpoint.** CRACs and air handlers with variable speed fans are typically controlled to maintain a constant pressure setpoint in the underfloor space. The setpoint needs to be high enough to successfully deliver cooling air to the IT hardware but setting it too high wastes energy.
- **Ducts.** Ducts with a large cross-section and gentle bends offer less flow resistance.
- **Air balancing.** If the air distribution system has multiple branches, it may have balancing dampers installed. During commissioning, make sure that at least one of the dampers is wide open.

Component Efficiency

The greater the efficiency of each fan system component, the less power is required.

- **Variable Speed Drive.** Electrically Commutated Motors (ECMs) currently provide the highest efficiency variable speed control capability. Variable Frequency Drives (VFDs) are also popular.
- **Fan Motor.** Required fan motor efficiencies are specified in the table above.
- **Transmission.** A direct drive (motor shaft bolted directly to the fan shaft) is 100% efficient. Belt drives and gearboxes are less efficient. A direct drive (motor shaft bolted directly to the fan shaft) is 100% efficient. Belt drives and gearboxes are less efficient.
- **Fan.** Required fan efficiencies are specified in the table above.

Fan Speed Control

ECBC 2017 formally adopted energy efficiency requirements for fan control at the SuperECBC level only. The requirements apply to CRACs/air handlers with a mechanical cooling capacity exceeding 18 kWr. Fan speed control offers possible energy savings in two ways:

- The fan is set to a fixed speed that yields the desired constant air flow rate, without needing to choke the air flow path to fight against full fan speed. Systems that control to a constant differential pressure setpoint (like most data centres) fit this description.
- An automatic control scheme is implemented, that varies the air flow rate depending on the thermal load. This minimizes fan energy.

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Speed control does not guarantee efficient operation. Either of these methods will function even if the air flow path is overly restrictive, or more air is being moved than is necessary, or if the fan system components are inefficient.

Resources

Air Movement & Control Association, Asia. Website, current. AMCA International. Mission: "To promote the Health and Growth of the Industries covered by its Scope and the Members of the Association consistent with the interests of the Public." Link.

Demonstration of Intelligent Control and Fan Improvements in Computer Room Air Handlers. Report, 2012. Henry Coles, Steve Greenberg, Lawrence Berkeley National Laboratory. Corinne Vita, Vigilent. Computer room air handlers (CRAHs) at a Digital Realty Trust data centre were retrofitted with improved efficiency fans and controlled by a central control system provided by Vigilent. The resulting efficiency improvements were analysed in this report. Link.

Air-Side Economizing

As stated in ECBC 2017, requirements for economizers apply only to buildings with a built-up area greater than 20,000 square meters.

For applicability to data centres, we take the ECBC 2017 requirements for economizers to apply only to data centres with a total IT load capacity greater than 100 kVA.

Level I	Level II	Level III
ECBC Compliant *See Recommended Additional Requirements.* **Recommended Additional Requirements** ✓ Use of air-side economizer for ECBC compliance is waived.	**ECBC+** ECBC 2017 Section 5.3.3.1: Each cooling system shall include at least one of the following: ✓ An air economizer capable of modulating outside-air and return-air dampers to supply 50% of the design supply air quantity as outside-air. ✓ A water or pumped refrigerant economizer. (*See Water-Side Economizer section below.*) Exceptions: ✓ Projects in warm-humid climate zones are exempt. ✓ Projects with only daytime occupancy in the hot-dry climate zones are exempt. ✓ Individual ceiling mounted fan systems is less than 3,200 liters per second exempt. ECBC 2017 Sections 5.3.3.2-5.3.3.4:	**SuperECBC** Same as ECBC+. **Recommended Additional Requirements** If an air economizer is selected instead of a water-side economizer, then it shall be: ✓ Capable of modulating outside-air and return-air dampers to supply 100% of the design supply air quantity as outside-air. Exceptions: None.

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	✓ Economizers shall be capable of providing partial cooling even when additional mechanical cooling is required to meet the cooling load. ✓ Air economizer shall be equipped with controls: • That allow dampers to be sequenced with the mechanical cooling equipment and not be controlled by only mixed air temperature. • Capable of automatically reducing outdoor air intake to the design minimum outdoor air quantity when outdoor air intake will no longer reduce cooling energy usage. • Capable of adjustable high-limit shutoff at a temperature below the return-air temperature or return-air enthalpy. **Recommended Additional Requirements** ✓ The exception for daytime occupancy is removed, as the data centre is assumed to be continuously operated.	

Tips and Best Practices

- Higher return air temperatures made possible by improved air management can in turn greatly increase the number of economizer hours for air-side economizers.

Resources

Reducing Data Center Cost with an Air Economizer. Report, 2008. Don Atwood, John Miner, Intel. To challenge established industry assumptions regarding data center cooling, Intel IT conducted a proof of concept (PoC) test that used an air economizer to cool production servers with 100 percent outside air at temperatures of up to 90 degrees Fahrenheit (F). Link.

Impact of Air Filtration on the Energy and Indoor Air Quality of Economizer-based Data Centers in the PG&E Territory. Report, 2009. Srirupa Ganguly, Arman Shehabi, William Tschudi, Ashok Gadgil, Lawrence Berkeley National Laboratory. A significant portion of the energy in data centers is currently dedicated to provide cooling for the server equipment. Data centers must provide continuous air conditioning to address high internal heat loads (heat release from computer servers) and maintain indoor temperatures within recommended operating levels for computers. Air-side economizers, which bring in large amounts of outside air to cool internal loads when weather conditions are favorable, could save cooling energy. However, this technology is not widely adopted because the climate dependant energy savings from air-side economizers are expressed only qualitatively. Further, the lifecycle costing of this system is not well understood. A major barrier to economizer implementation is the fear of increasing pollutants levels in the data center

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during economizer cycle, and the fear that these pollutants could affect computer server reliability High efficiency HVAC filters are suggested as an option to effectively reduce particulate contamination inside the data center. Further, the energy implication of using improved filters in an air-side economizer system is also discussed. Strategies to reduce this economizer implementation barrier are explored in this study. Pollutants of concern are measured in a data center enabled with economizer operation while using air filtration of varying levels of efficiency. Link.

4. Chiller Plant

The measure types in this section address the different components of a chilled water plant.

Chillers

Of all the components in a chilled water plant, the chillers typically draw the most power. ECBC 2017 provides efficiency requirements for chillers at ECBC Compliant, ECBC+, and SuperECBC levels.

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Level I

ECBC Compliant

ECBC 2017 Section 5.2.2.1:

- ✓ Chillers shall meet or exceed the minimum efficiency requirements presented under ANSI/ AHRI 550/ 590 conditions.
- ✓ Requirements of **both** COP and IPLV shall be met.

Water Cooled Chillers

Chiller Capacity (kWr)	COP	IPLV
<260	4.7	5.8
≥ 260 & < 530	4.9	5.9
≥ 530 & < 1,050	5.4	6.5
≥ 1,050 & <1,580	5.8	6.8
≥ 1,580	6.3	7.0

Air Cooled Chillers

Chiller Capacity (kWr)	COP	IPLV
<260	2.8	3.5
≥ 260	3.0	3.7

- ✓ The application of an air-cooled chiller is allowed in all buildings with cooling load < 530 kW.
- ✓ For buildings with cooling load ≥ 530 kW, the capacity of air-cooled chiller(s) is restricted to 33% of the total installed chilled water capacity

Level II

ECBC+

ECBC 2017 Section 5.2.2.1:

- ✓ Chillers shall meet or exceed the minimum efficiency requirements presented under ANSI/ AHRI 550/ 590 conditions.
- ✓ Requirements of **either** COP or IPLV shall be met.

Water Cooled Chillers

Chiller Capacity (kWr)	COP	IPLV
<260	5.2	6.9
≥ 260 & < 530	5.8	7.1
≥ 530 & < 1,050	5.8	7.5
≥ 1,050 & <1,580	6.2	8.1
≥ 1,580	6.5	8.9

Air Cooled Chillers

Chiller Capacity (kWr)	COP	IPLV
<260	3.0	4.0
≥ 260	3.2	5.0

- ✓ The application of an air-cooled chiller is allowed in all buildings with cooling load < 530 kW.
- ✓ For buildings with cooling load ≥ 530 kW, the capacity of air-cooled chiller(s) is restricted to 33% of the total installed chilled water

Level III

SuperECBC

ECBC 2017 Section 5.2.2.1:

- ✓ Chillers shall meet or exceed the minimum efficiency requirements presented under ANSI/ AHRI 550/ 590 conditions.
- ✓ Requirements of **either** COP or IPLV shall be met.

Water Cooled Chillers

Chiller Capacity (kWr)	COP	IPLV
<260	5.8	7.1
≥ 260 & < 530	6.0	7.9
≥ 530 & < 1,050	6.3	8.4
≥ 1,050 & <1,580	6.5	8.8
≥ 1,580	6.7	9.1

Air Cooled Chillers

Chiller Capacity (kWr)	COP	IPLV
<260	N/A	N/A
≥ 260	N/A	N/A

- ✓ The application of an air-cooled chiller is allowed in all buildings with cooling load < 530 kW.
- ✓ For buildings with cooling load ≥ 530 kW, the capacity of air-cooled chiller(s) is restricted to 33% of the total installed chilled water capacity

unless the authority having jurisdiction mandates the application of air-cooled chillers. ✓ Minimum efficiency requirements under BEE Standards and Labeling Program for chillers shall take precedence over requirements outlined above. **Recommended Additional Requirements** ✓ Air-cooled chillers above 530 kWr shall have COP of 3.2 **and** IPLV of 4.0.	capacity unless the authority having jurisdiction mandates the application of air-cooled chillers. ✓ Minimum efficiency requirements under BEE Standards and Labeling Program for chillers shall take precedence over requirements outlined above.	unless the authority having jurisdiction mandates the application of air-cooled chillers. ✓ Minimum efficiency requirements under BEE Standards and Labeling Program for chillers shall take precedence over requirements outlined above.

Tips and Best Practices

- ECBC encourages larger chiller plants to be water-cooled chiller plants as they are generally cost effective.
- Chillers designed at different temperatures shall also be rated at AHRI-550-590 to show ECBC compliance. (AHRI-551-591 is the same standard, in SI units.)
- Chiller performance is required to be compliant at the rating conditions stated, but the chiller will be selected, and the chiller plant optimized, for the actual weather data and operation for the site.
- For plants dedicated to data centres, much higher chilled-water temperatures are possible than at the standard rating conditions. These higher temperatures allow both significantly higher chiller efficiency and higher cooling capacity than would be possible at the standard conditions with the same chiller.
- Higher chilled-water temperatures allow more hours of operation from water-side economizers. (See Water-Side Economizing section below.) Extending this concept, it is possible to design the data centre with a cooling water temperature high enough that the chillers can be eliminated entirely, and cooling towers alone will suffice. In order for this to work, the peak annual outdoor wet-bulb temperature and the cooling tower approach temperature must be low enough to produce the desired cooling water temperature.
- Other design elements to consider: Variable speed chillers, multiple chillers staged to meet load, lowest possible condenser water temperature setpoint.

Resources

ANSI/AHRI Standard 551/591 (SI): Performance Rating Of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle. Standard, 2011, SI units. Link.

ANSI/AHRI Standard 551/591 (SI) Errata Sheet. Standard, 2016. Link.

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Cooling Towers

Cooling towers reject the heat collected by the chilled water system. The power required by the cooling tower fans is relatively modest, but efficiency gains can be realized. ECBC 2017 provides cooling tower requirements.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 Section 5.3.2: ✓ Equipment Type: Open circuit cooling tower fans. ✓ Rating Condition: 35°C entering water 29°C leaving water 24°C WB outdoor air ✓ Efficiency: 0.017 kW/kWr or 0.31 kW/l/s	**ECBC+** Same as ECBC Compliant, plus: ✓ Cooling tower fans shall be variable speed. **Recommended Additional Requirements** ✓ Cooling tower efficiency shall be 0.012 kW/kWr or 0.17 kW/l/s.	**SuperECBC** Same as ECBC+. **Recommended Additional Requirements** Same as Level II.

Tips and Best Practices

- Cooling tower performance is required to be compliant at the rating conditions stated, but the actual weather data and plant design for the site must be used in the cooling tower selection and overall chiller plant optimization.

Resources

Best Management Practice #10: Cooling Tower Management. Online guide, current. US DOE EERE. The thermal efficiency and longevity of the cooling tower and equipment depend on the proper management of recirculated water. Link.

Pump Systems

ECBC 2017 provides efficiency requirements for chilled water and condenser water pumps at the ECBC Complaint, ECBC+ and SuperECBC levels.

Other considerations for pump systems are addressed in the Tips section below.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 Section 5.3.1:	**ECBC+** Same as ECBC Compliant, plus:	**SuperECBC** Same as ECBC+, plus:

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✓ Chilled Water Pump (Primary and Secondary) (maximum): 18.2 W/kWr with VFD on secondary pump. ✓ Condenser Water Pump (maximum): 17.7 W/kWr. ✓ Pump Efficiency (minimum): 70%. ECBC 2017 Section 5.3.4.1: ✓ HVAC pumping systems having a total pump system power exceeding 7.5 kW shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to an extent which is lesser or equal to the limit, where the limit is set by the larger of: (a) 50% of the design flow rate, or (b) the minimum flow required by the equipment manufacturer for proper operation of the chillers or boilers.	✓ Chilled Water Pump (Primary and Secondary) (maximum): 16.9 W/kWr with VFD on secondary pump. ✓ Condenser Water Pump (maximum): 16.5 W/kWr. ✓ Pump Efficiency (minimum): 75%.	✓ Chilled Water Pump (Primary and Secondary) (maximum): 14.9 W/kWr with VFD on secondary pump. ✓ Condenser Water Pump (maximum): 14.6 W/kWr. ✓ Pump Efficiency (minimum): 85%.

Tips and Best Practices

Standard Condition

All pump systems shall be designed for site water-flow rate and shall be rated at pump power/chiller tonnage as per AHRI condition.

Pump Power

An electric pump system consists of a variable speed controller (optional), the motor, the transmission (typically direct drive), and the pump. The power demand of the pump system depends on the amount of water it is moving, the resistance to the water flow, and the efficiency of each system component.

Water Flow Rate

If the water flow rate can be reduced, pump energy will be saved. To reduce the water flow and still successfully handle the cooling load, the temperature difference between the supply and return water (the “delta-T”) must increase.

Pressure Drop

The power required by a pump increases with the resistance (the “pressure drop”, or “head”) experienced by its water flow, and the pressure drop tends to increase exponentially with the water flow rate. Significant energy savings are realized by minimizing resistance to flow throughout the water loop. To consider:

- Filters and suction diffusers. Select low pressure drop filters. After commissioning, consider removing suction diffusers for additional energy savings. Designing the system to have relatively long, straight inlets to the pumps will help ensure smooth inlet flow.

- Flow and pressure control valves. Select low pressure drop flow control valves. Implementing a variable flow system can remove the need for pressure control valves, providing additional energy savings.
- Pressure setpoint. Variable speed pumps are typically controlled to maintain a constant pressure setpoint at the far end of the loop. The setpoint needs to be high enough to successfully deliver cooling water to its destination but setting it too high wastes energy.
- Piping. Pipes with a large cross-section and gentle bends offer less flow resistance.
- Balancing valves. If the water distribution system has multiple branches, it will likely have balancing valves. During commissioning, make sure that at least one of the valves is wide open.

Component Efficiency

The table above specifies required overall pump system efficiency in terms of power required per unit of cooling provided, as well as pump efficiencies. The required overall pump system values can be attained by focusing on the efficiency of each pump system component.

- Variable Speed Drive. Electrically Commutated Motors (ECMs) currently provide the highest efficiency variable speed control capability. Variable Frequency Drives (VFDs) are also popular.
- Pump Motor. Select the highest efficiency pump motor that is practical.
- Transmission. Cooling system pumps are typically direct drive (motor shaft bolted directly to the pump shaft). This is 100% efficient.
- Pump. Required pump efficiencies are specified in the table above. Select pumps to provide their rated efficiency at the most prevalent operating condition (flow and pressure) anticipated in your system. The pump system efficiencies (W/kWr) in the above table all assume the same pumping head (30 m for chilled water pumps, and 24 m for condenser water pumps). It is possible to design each of these systems with respectively lower heads, resulting in lower W/kWr values.

Pump Speed Control

Variable flow hydronic systems with a total pump power of more than 7.5 kW are subject to an energy efficiency requirement; see the above table. Pump speed control offers possible energy savings in two ways:

- The pump is set to a fixed speed that yields the desired constant water flow rate, without needing to choke the water flow path to fight against full pump speed. Systems that control to a constant differential pressure setpoint fit this description.
- An automatic control scheme varies the water flow rate depending on the thermal load.

Speed control does not guarantee efficient operation. The water flow path still can be overly restrictive. More water can be moved than is necessary. The pump system components can still be inefficient. The W/kWr efficiency requirements in the table above guard against these inefficiencies.

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Variable Flow Systems

Primary-only variable flow chilled water loop. Chilled water distribution systems are commonly designed as two linked loops – a primary, constant-flow loop to circulate water through the evaporator barrel of the chillers, and a secondary, variable flow loop to circulate water through the cooling coils. A more efficient arrangement is to have a single variable flow loop that serves both purposes. Care must be taken to ensure the minimum flow required by the chillers is always met.

Resources

HVAC Chilled Water Distribution Schemes. Guide. A Bhatia, Continuing Education and Development, Inc. A chilled water system is a cooling system in which chilled water is circulated throughout the building or through cooling coils in an HVAC system in order to provide space cooling. The principal objectives of chilled water pumping system selection and design are to provide the required cooling capacity to each load, to promote the efficient use of refrigeration capacity in the plant, and to minimize pump energy consumption subject to whatever budgetary constraints may apply. Link.

Chiller Plants - Performance Approach

Buildings may show compliance by optimizing the total system efficiency for the chiller plant instead of the individual components covered by the prescriptive requirements. This alternate compliance approach can apply to central chilled-water plants in all building types. The total installed capacity per kW of refrigeration load shall be less than or equal to the maximum thresholds specified below.

Equipment that can be included in central chilled-water plant for this alternate approach are chillers, chilled water pumps, condenser water pumps, and the cooling tower fan.

Compliance checks will be based on annual hourly simulation.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 Section 5.4: ✓ Water Cooled Chill Plant Maximum Threshold (kW/kWr) of 0.26.	**ECBC+** ECBC 2017 Section 5.4: ✓ Maximum Threshold (kW/kWr) of 0.23.	**SuperECBC** ECBC 2017 Section 5.4: ✓ Maximum Threshold (kW/kWr) of 0.20.

Tips and Best Practices

Recommendation is for overall chiller-plant performance. Overall average chiller-plant performance (kW/kWr) should not be greater than the sum of individual component design performance.

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Resources

Design Brief: Chiller Plant Efficiency. Guide. Energy Design Resources. Chilled water-based cooling systems are frequently used to air condition large office buildings or campuses that encompass multiple buildings. They represent a large investment from the perspective of first cost, physical space they require within the building, as well as energy and maintenance cost. Yet despite these fiscal and spatial impacts, many chiller plants do not reach their potential from the standpoint of energy efficiency. Link.

Chilled Water Plant Design Guide. Guide, 2009. Energy Design Resources. Target audience: Mechanical engineers who design, redesign or retrofit chilled water plants. The guide provides engineering information on how to estimate plant loads; details on chillers, towers and other plant equipment; system piping arrangements and configurations; controls; design approaches; contract documents; and commissioning. While design engineers are the primary audience, the guide also provides useful information for operation and maintenance personnel, mechanical contractors, and building managers. Link.

Water-Side Economizing

As stated in ECBC 2017, requirements for economizers apply only to buildings with a built-up area greater than 20,000 square meters.

For applicability to data centres, we take the ECBC 2017 requirements for economizers to apply only to data centres with a total IT load capacity greater than 100 kVA.

The term “water-side economizer” applies to both water and pumped refrigerant economizers.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 Section 5.3.3.1: Each cooling system shall include at least one of the following: ✓ An air economizer. (*See Air-Side Economizing section above.*) ✓ A water economizer capable of providing 50% of the expected system cooling load at outside air temperatures of 10°C dry-bulb/7.2°C wet-bulb and below. Exceptions: ✓ Projects in warm-humid climate zones are exempt.	**ECBC+** Same as ECBC Compliant. **Recommended Additional Requirements** If a water-side economizer is selected instead of an air-side economizer, then it shall be: ✓ Capable of providing 100% of the expected system cooling load at outside air temperatures of 10°C dry-bulb/7.2°C wet-bulb and below. Exceptions: None.	**SuperECBC** Same as ECBC+. **Recommended Additional Requirements** Same as Level II.

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✓ Projects with only daytime occupancy in the hot-dry climate zones are exempt. ✓ Individual ceiling mounted fan systems is less than 3,200 liters per second exempt. ECBC 2017 Sections 5.3.3.2-5.3.3.4: ✓ Economizers shall be capable of providing partial cooling even when additional mechanical cooling is required to meet the cooling load. **Recommended Additional Requirements** ✓ The exception for daytime occupancy is removed, as the data centre is assumed to be continuously operated.		

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Tips and Best Practices

Increased chilled-water temperatures made possible with data centre operation (especially with higher return air temperatures noted above) greatly increase the number of economizer hours for water-side economizers.

Resources

Waterside Economizing in Data Centers: Design and Control Considerations. Guide, 2009. Jeff Stein, ASHRAE. Free cooling was not common in data centers in the past for a variety of reasons including the philosophy that data center cooling should be designed for maximum reliability and not for energy efficiency. Recently times have changed. Energy and sustainability are more important to many data center owners now and sophisticated owners and designers know that free cooling can provide a good return on investment while still maintaining adequate reliability. Many data centers are being designed or retrofitted with airside economizers, waterside economizers, and even “wet bulb” economizers (direct evaporative coolers). This paper briefly compares airside and waterside economizers, then briefly compares the two types of waterside economizers (CRAC and chiller plant) and then focuses on design and control considerations for chiller plant waterside economizers serving data centers. Link.

Data Center Economizer Cooling with Tower Water. Report, 2012. Henry Coles, Steve Greenberg, California Energy Commission. A prototype computer equipment rack-level cooling device with two heat exchangers was demonstrated to illustrate an energy efficient cooling capability. This unique device was designed and constructed by APC by Schneider Electric to operate with higher-temperature cooling water, so that it can support many more hours of free cooling compared to traditional systems that utilize chilled water. Link.

5. Electrical

The measure types in this section address the different components of the data centre electrical system.

Diesel Generators

ECBC 2017 formally adopted energy efficiency requirements for diesel generators. The requirements apply to diesel generator sets in buildings greater than 20,000 square meters of built-up area.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 Section 7.2.3: ✓ Minimum 3 stars rating.	**ECBC+** ECBC 2017 Section 7.2.3: ✓ Minimum 4 stars rating.	**SuperECBC** ECBC 2017 Section 7.2.3: ✓ Minimum 5 stars rating.

Tips and Best Practices

Typical generators include heaters to help ensure starting and minimize engine stress when called to load rapidly after starting. Ensure that the heaters have thermostats and, in the case of generators backing up a UPS systems, they are set to temperatures (e.g.,20 C) consistent with generators that can be allowed to warm up for 30-60 seconds before the transfer switch puts them under load (rather than the typical emergency generator that is expected to start and be placed under full load in under 10 seconds; the latter temperature setpoints are typically in the 40C range).

Resources

Diesel Generators: Improving Efficiency and Emission Performance in India. Report, 2014. Shakti Sustainable Energy Foundation. While India's power sector struggles to provide extensive, uninterrupted and reliable grid supply, diesel generator sets assume great importance as preferred power back-up in prominent sectors like agriculture, construction, industry, households, and other commercial applications. Link.

Amendment to Schedule 18 for Diesel Generator Sets. Standard, 2016. Bureau of Energy Efficiency, India. This schedule specifies the star labeling requirements for various classifications for the application, rating and performance of single/three phase Diesel Generating sets consisting of a Reciprocating Internal Combustion (RIC) engine driven by diesel as fuel, Alternating Current (a.c.) generator, any associated control gear, switchgear and auxiliary equipment. Link.

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Metering & Monitoring

ECBC 2017 Section 7.2.4 specifies formal requirements for metering and monitoring. Requirements are provided for ranges of electric service capacity to the building. Some ranges overlap.

The lower part of Table 7-3 in Section 7.2.4 states "Mandatory requirement for building type over the requirement stated above: Data centers". This is taken to mean that all the items listed in Table 7-3 as Not Required in the 100-250 kVA range, are required for data centres.

As provided in the ECBC, all electrical metering must be permanently installed.

Recommended additional requirements are provided for Levels II & III in the following table. They are provided for three ranges of IT load capacity.

The requirements of each level are cumulative, i.e., the requirements of the lower levels apply unless more stringent requirements are listed at the higher levels. The same applies to the requirements at the higher IT load capacity ranges within each level: e.g., if monitoring is required at Level II, 100-250 kVA, it is also required at Level II for centres with a load capacity greater than 250 kVA.

Level I	Level II	Level III
ECBC Compliant	ECBC+	SuperECBC
ECBC 2017 Section 7.2.4: **Service 65 kVA and less:** ✓ Energy (kWh) **Service >65 to 1000 kVA:** ✓ Energy (kWh) ✓ Demand (kW) ✓ Total Power Factor or, alternatively, kVARh **Service >1000 kVA:** ✓ Energy (kWh) ✓ Demand (kVA) ✓ Total Power Factor ✓ Current in each phase and the neutral ✓ Voltage between phases and between each phase and neutral ✓ Total Harmonic Distortion (THD) as percent of total current **Service 120 kVA and greater:** ✓ HVAC system and components	Same as ECBC Compliant. Recommended Additional Requirements **IT load capacity 100 to 250 kVA:** ✓ Data Centre Total kWh & kW ✓ IT Equipment Total kWh & kW ✓ UPS Input kW ✓ UPS Output kW ✓ IT hardware inlet air temperature at the top of every 3rd rack in every cold aisle **IT load capacity >250 kVA:** ✓ Cooling System Total Cooling Load kWr ✓ Power Usage Effectiveness (PUE) measured as per Green Grid Level 1 guidelines	Same as ECBC+. Recommended Additional Requirements **IT load capacity 100 to 250 kVA:** Same as Level II, plus: ✓ Electric power draw of each IT rack (kW) ✓ UPS Room Cooling System Power Draw (kW) ✓ Supply Air Temperature Setpoint for every CRAC/air handler ✓ Actual Supply Air Temperature for every CRAC/air handler ✓ Cooling System Total Cooling Load kWr ✓ Power Usage Effectiveness (PUE) measured as per Green Grid Level 1 guidelines ✓ Power Usage Effectiveness (PUE) for mechanical systems, Green Grid Level 2 or 3 ✓ Power Usage Effectiveness (PUE) for electrical systems, Green Grid Level 2 or 3. **IT load capacity >250 kVA:**

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✓ Interior and Exterior Lighting ✓ Plug loads ✓ Renewable power source ✓ Domestic hot water		Same as Level II, plus: ✓ Electric power draw of each IT rack (kW) ✓ Water consumption in cooling system (if applicable) ✓ CRAC/air handler air filter status ✓ Battery Room and UPS Room temperature & humidity ✓ UPS Room Cooling System Load (kWr) ✓ All data shall be available in real time in an automated data centre infrastructure management (DCIM) system.

Tips and Best Practices

Metering and monitoring of data centre energy does not directly result in energy-efficient operation, but it is an enabling technology that allows the data centre operator to track and improve performance. Real-time tracking of key metrics such as PUE and cooling kW/kWr alerts the operator to critical issues that bear on energy performance.

Derived Metrics

Monitoring the points listed in the table above allows the monitoring system to automatically calculate additional metrics. Recommend metrics:

Level II

IT load capacity <100 kVA

- Data Centre Total Electric Capacity Utilization
- Alarm for CRAC/air handler supply air temperature set point breach

IT load capacity 100 to 250 kVA

- UPS Efficiency (Output kW/Input kW)

IT load capacity >250 kVA

- Cooling System Percent Load
- Cooling System Efficiency kW/kWr

Level III

IT load capacity 100 to 250 kVA

- Electric capacity utilization of each rack
- Cooling System Percent Load
- Cooling System Efficiency kW/kWr

IT load capacity >250 kVA

- UPS Room Cooling System Efficiency (kW/kWr)

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Resources

Data Centre Metering & Resource Guide. Guide, 2017. Rod Mahdavi, Steve Greenberg, US DOE EERE. This Guide intends to help data centre owners and operators implement a metering system that allows their organizations to gather the necessary data for effective decision-making and energy-efficiency improvements. Link.

Practical Considerations for Metering and Power Usage Effectiveness. Slides, 2017. Dale Sartor, Lawrence Berkeley National Laboratory. From Dale Sartor's August 17, 2017 presentation on metering and Power Usage Effectiveness (PUE) while participating in FEMP's Energy Exchange Data Center Panel. Link.

PUE: A Comprehensive Examination of the Metric. Report, 2014. Victor Avelar, Dan Azevedo, Alan French, Green Grid. Allows executives to gain a high level of understanding of the concepts surrounding PUE, while providing in-depth application knowledge and resources to those implementing and reporting data center metrics. Link.

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Uninterruptible Power Supply (UPS)

ECBC 2017 adopted requirements for UPSs for all ECBC levels. Requirements for UPSs apply to all buildings.

Level I	Level II	Level III
ECBC Compliant ECBC 2017 Section 7.2.7: ✓ UPS modules with kVA <20 shall have minimum efficiency of 90.2% at 100% load. ✓ UPS modules with 20 <= kVA <=100 shall have minimum efficiency of 91.9% at 100% load. UPS modules with kVA > 100 shall have minimum efficiency of 93.8% at 100% load.	**ECBC+** Same as ECBC Compliant. **Recommended Additional Requirements** ✓ UPS modules with kVA <=100 shall have minimum efficiency of 94.5% in the 40-70% load range. ✓ UPS modules with kVA > 100 shall have minimum efficiency of 96% in the 40-70% load range.	**SuperECBC** Same as ECBC+. **Recommended Additional Requirements** Same as Level II.

Tips and Best Practices

- The BIS/IEC 62040-3 standard will be followed as the test method for UPS performance.
- The overall UPS system efficiency should be considered, not just the UPS modules.
- The UPS system efficiency should be optimized (selected and operated) over the range of actual loads in the data centre. For example, for a double-fed system, the

UPS will typically not be loaded over 40%, so the efficiency of the modules as well as the number in operation are important for overall efficiency.

- Efficiency can be further improved by selecting and operating in “eco-mode” or equivalent (where the UPS operates in bypass under normal conditions and switches to inverter operation when needed and before the load is dropped). Careful coordination of electrical system components needs to be part of successful eco-mode operation.

Resources

IEC 62040-3:2011: Uninterruptible power systems (UPS) - Part 3: Method of specifying the performance and test requirements. Standard, 2011. International Electrotechnical Commission. IEC 62040-3:2011 applies to movable, stationary and fixed electronic uninterruptible power systems (UPS) that deliver single or three phase fixed frequency AC output voltage not exceeding 1000 VAC and that incorporate an energy storage system, generally connected through a DC link. Link.

Data Center Electrical Power Chain Tool. Software tool, 2010. Lawrence Berkeley National Laboratory, EYP Mission Critical Facilities. This Excel-based tool designed to help data centre owners assess the potential savings from efficiency actions in the electrical power chain of a data centre (transformers, generators, UPSs, PDUs, power supplies). Link.

6.IT Hardware & IT Management

ECBC 2017 does not address IT hardware or management.

IT Hardware & Utilization

This section provides recommended requirements for IT hardware and IT management at three performance levels. Six measure types are presented.

Level I	Level II	Level III
Efficiency Ratings for Servers and Data Storage Equipment		
[placeholder]	[placeholder, Energy Star?]	[placeholder, Energy Star?]
Processors		
No recommended requirement.	Percentage of processors no older than N-2 Generation: >60%	Percentage of processors no older than N-1 Generation: >60%

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Power Supplies		
80 Plus Silver or below for more than 75% of all server hardware.	**80 Plus Gold** or better for more than 75% of all server hardware.	**80 Plus Platinum** or better for more than 75% of all server hardware.
Power Type		
Power Input Type: Any	Power Input Type: Any	Power Input Type: High Voltage Direct Current (HVDC)
Server Utilization		
CPU load 10 – 20%	CPU load >20% - 40%	CPU load > 40%
Server Virtualization		
10% - 20% Virtualization	>20% – 40% Virtualization	>40% Virtualization

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Tips and Best Practices

Efficiency Ratings for Servers and Data Storage Equipment

Does an India-specific rating system already exist? If not, should another rating system be adopted?

Processors

The advancement of processor technologies has also brought significant improvement in the CPU power efficiency curve, with achievement of greater computing power at lower electricity consumption. If the data centre has a large percentage of older generation of hardware then it is a safe assumption that the same output can be achieved at a lower energy consumption with a newer generation of processor (subject to the workload supporting the newer generation of processor and OS).

Processor generation percentage is measured as follows.

T_H = total number of processors

N = current processor generation

T_N = total number of processors of current generation

T_{N-1} = total number of processors of N-1 generation

T_{N-2} = total number of processors of N-2 generation

T_P = percentage of processors

For Level I there is no recommended number for T_P

For Level II, the recommended number for T_P is greater than 60% for

$T_P = (T_N / T_H) + (T_{N-1} / T_H) + (T_{N-2} / T_H)$

For Level III, the recommended number for T_P is greater than 60% for

$T_P = (T_N / T_H) + (T_{N-1} / T_H)$

Power Supplies

Most IT hardware in the data centre operates at voltages in the 1.2v to 12v range. Voltage from the UPS/Outlet therefore must be stepped down from line voltage (e.g.,220v) AC to the lower voltages needed for the IT hardware.

Power supply in the IT hardware has a significant impact on the overall power consumption of the equipment in the data centre. Industry has gravitated to a few standards around this, the common ones being 80PLUS, ENERGY STAR v2, etc. For the purpose of this document, we are referencing 80PLUS as a base.

Power Type

The electric power chain in data centres typically involves a conversion of current from alternating to direct and back again in the UPS, and from alternating to direct again in the IT hardware power supply. There are also typically several step-downs of voltage by the time the power reaches the IT hardware. Each of these conversions and step-downs is less than 100% efficient.

Providing direct current from the UPS to the IT power supplies can eliminate some of these inefficiencies and provide additional benefits.

The adoption of direct current power as well as higher voltages such as 380v DC increases reliability improves power quality and eliminates the need for complex synchronization circuits associated with multi-source AC distribution.

Server Utilization

Need a standard method for measuring weighted average CPU load across a data centre.

Server Virtualization

Server virtualization is a tool to increase server utilization and reliability and should be implemented as appropriate.

Resources

Energy Efficiency Guidelines and Best Practices in Indian Datacenters. Report, 2010. Bureau of Energy Efficiency, India. This manual contains the following:

- Information about the latest trends & technologies in data centres and its associated systems
- The best practices adopted in various data centres for improving energy efficiency levels.
- Case studies elucidating the technical details and the financial benefits of adopting certain measures for higher energy efficiency.
- Guidelines for setting up energy efficient data centres.
- Key indicators to assess the performance of existing systems.

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- Information to set section-wise targets for energy conservation goals.

Link.

Accelerating Energy Efficiency in Indian Data Centers: Final Report for Phase I Activities. Report, 2016. Suprotim Ganguly, Sanyukta Raje, Satish Kumar, Confederation of Indian Industry. Dale Sartor, Steve Greenberg, Lawrence Berkeley National Laboratory. This report documents Phase 1 of the "Accelerating Energy Efficiency in Indian Data Centers" initiative to support the development of an energy efficiency policy framework for Indian data centers. The initiative is being led by the Confederation of Indian Industry (CII), in collaboration with Lawrence Berkeley National Laboratory (LBNL)-U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, and under the guidance of Bureau of Energy Efficiency (BEE). It is also part of the larger Power and Energy Efficiency Working Group of the US-India Bilateral Energy Dialogue. The initiative consists of two phases: Phase 1 (November 2014 – September 2015) and Phase 2 (October 2015 – September 2016). Link.

Small Data Centers, Big Energy Savings: An Introduction for Owners and Operators. Guide, 2017. Steve Greenberg, Magnus Herrlin, Lawrence Berkeley National Laboratory.

Significant untapped energy efficiency potential exists within small data centers (under 5,000 square feet of computer floor space). While small on an individual basis, these data centers collectively house more than half of all servers (Shehabi et al 2016) and consume about 40 billion kWh per year. Owners and operators of small data centers often lack the resources to assess, identify and implement energy-saving opportunities. As a result, energy performance for this category of data centers has been below average.

The purpose of this brief guide is to present opportunities for small data center owners and operators that generally make sense and do not need expensive assessment and analysis to justify. Recommendations presented in this report range from very simple measures that require no capital investment and little ongoing effort to those that do need some upfront funds and time to implement. Data centers that have implemented these measures have experienced typical savings of 20 to 40%. The energy efficiency measures presented have been shown to work with no impact on IT equipment reliability, when implemented carefully and appropriately. Do make sure to take the appropriate precautions when considering these measures at your own data centers. Check the IT equipment intake air temperatures to make sure they are prudent, for example, to ensure no negative reliability impacts.

In addition to covering the most-common energy-saving opportunities, this guide notes the value of training for personnel involved in data center operations and management. References are also provided for further information.

Link.

80 PLUS Power Supply Certification. Website, current. Plug Load Solutions. Power supplies are the devices that power computer, servers and data center devices. They convert AC power from electric utilities into DC power used in most electronics. The 80 PLUS® performance specification requires power supplies in computers and servers to be 80% or greater energy efficient at 10, 20, 50 and 100% of rated load with a true power factor of 0.9 or greater. This makes an 80 PLUS certified power supply substantially more efficient than typical power supplies. Link.

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380 Vdc Architectures for the Modern Data Center. Report, 2013. EMerge Alliance. Presents an overview of the case for the application of 380 VDC as a vehicle for optimization and simplification of the critical electrical system in the modern data center. Specifically, this paper presents currently available architectures consistent with ANSI/BICSI 002-2011 and the EMerge Alliance Data/Telecom Center Standard Version 1.0. Link.

Optimizing Resource Utilization of a Data Center. Report, 2016. Xiang Sun, Nirwan Ansari, Ruopeng Wang, IEEE. To provision IT solutions with reduced operating expenses, many businesses are moving their IT infrastructures into public data centers or start to build their own private data centers. Data centers can provide flexible resource provisioning in order to accommodate the workload demand. In this paper, we present a comprehensive survey of most relevant research activities on resource management of data centers that aim to optimize the resource utilization. Link.

Analyzing Utilization Rates in Data Centers for Optimizing Energy Management. Report, 2012. Michael Pawlish, Aparna Varde, Stefan Robila, Montclair State University. Explores academic data center utilization rates from an energy management perspective with the broader goal of providing decision support for green computing. Link.

Data Center Case Study: How Cisco IT Virtualizes Data Center Application Servers. Report, 2007. Cisco Systems Inc. Deploying virtualized servers produces significant cost savings, lowers demand for data center resources, and reduces server deployment time. Link.

Implementing and Expanding a Virtualized Environment. Report, 2010. Bill Sunderland, Steve Anderson, Intel. In 2005, Intel IT began planning, engineering, and implementing a virtualized business computing production environment as part of our overall data center strategy. Link.

Data Center IT Efficiency Measures. Guide, 2015. NREL. The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. Link.

7. Additional Resources

DC Pro. Online tool, current. Lawrence Berkeley National Laboratory. This 10-screen online tool estimates current and potential PUE and energy use distribution without sub-metering. DC Pro also provides tailored recommended actions to start the improvement process. An especially valuable output of this tool is an estimated Power Usage Effectiveness (PUE) metric. Link.

PUE Estimator. Online tool, current. Lawrence Berkeley National Laboratory. This 1-screen online tool is a simplified version of DC Pro. The PUE Estimator only asks questions that affect the PUE calculation, and it does not provide potential PUE or recommended actions. Link.

Data Center Best Practices Guide. Guide, 2012. Integral Group Inc, Lawrence Berkeley National Laboratory. Data centers can consume 100 to 200 times as much electricity as standard office spaces. With such large power consumption, they are prime targets for energy efficient design measures that can save money and reduce electricity use. However, the critical nature of data center loads elevates many design criteria -- chiefly reliability and high power density capacity – far above efficiency. Short design cycles often leave little time

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to fully assess efficient design opportunities or consider first cost versus life cycle cost issues. This can lead to designs that are simply scaled up versions of standard office space approaches or that reuse strategies and specifications that worked “good enough” in the past without regard for energy performance. This Data Center Best Practices Guide has been created to provide viable alternatives to inefficient data center design and operating practices and address energy efficiency retrofit opportunities. Link.

ASHRAE 90.4-2016: Energy Standard for Data Centers. Standard, 2016. ASHRAE. Link.

Best Practices Guide for Energy-Efficient Data Center Design. Guide, 2011. William Lintner, Bill Tschudi, Otto VanGeet, US DOE EERE. This guide provides an overview of best practices for energy-efficient data center design which spans the categories of Information Technology (IT) systems and their environmental conditions, data center air management, cooling and electrical systems, on-site generation, and heat recovery. Link.

Data Center Knowledge. Website, current Informa. From the website: "Data Center Knowledge is a leading online source of daily news and analysis about the data center industry." Link.

Energy Star: Data Center Equipment. Website, current US Energy Star Program. Data centers are often thought of as large standalone structures run by tech giants. However, it is the smaller data center spaces located in almost every commercial building – such as localized data centers, server rooms and closets – that can also waste a lot of energy. Here are the best resources to help you save energy in your data center – be it large or small. Link.

Reducing Data Center Loads for a Largescale, Low-energy Office Building: NREL’s Research Support Facility. Report, 2011. Michael Sheppy, Chad Lobato, Otto Van Geet, Shanti Pless, Kevin Donovan, Chuck Powers, NREL. In June 2010, the National Renewable Energy Laboratory (NREL) completed construction on the new 220,000-square foot (ft2) Research Support Facility (RSF) which included a 1,900-ft2 data center (the RSF will expand to 360,000 ft2 with the opening of an additional wing December, 2011). The project’s request for proposals (RFP) set a whole-building demand-side energy use requirement of a nominal 35 kBtu/ft2 per year. On-site renewable energy generation offsets the annual energy consumption. The original “legacy” data center had annual energy consumption as high as 2,394,000 kilowatt-hours (kWh), which would have exceeded the total building energy goal. As part of meeting the building energy goal, the RSF data center annual energy use had to be approximately 50% less than the legacy data center’s annual energy use. This report documents the methodology used to procure, construct, and operate an energy-efficient data center suitable for a net-zeroenergy-use building. Link.

Best Practices for Data Centers: Lessons Learned from Benchmarking 22 Data Centers. Report, 2006. Steve Greenberg, Evan Mills, Bill Tschudi, Lawrence Berkeley National Laboratory. Peter Rumsey, Rumsey Engineers. Bruce Myatt, EYP Mission Critical Facilities. Over the past few years, the authors benchmarked 22 data center buildings. From this effort, we have determined that data centers can be over 40 times as energy intensive as conventional office buildings. Studying the more efficient of these facilities enabled us to compile a set of “best-practice” technologies for energy efficiency. These best practices include: improved air management, emphasizing control and isolation of hot and cold air streams; rightsizing central plants and ventilation systems to operate efficiently both at inception and as the data center load increases over time; optimized central chiller plants, designed and controlled to maximize overall cooling plant efficiency, central air-handling

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units, in lieu of distributed units; “free cooling” from either air-side or water-side economizers; alternative humidity control, including elimination of control conflicts and the use of direct evaporative cooling; improved uninterruptible power supplies; high-efficiency computer power supplies; on-site generation combined with special chillers for cooling using the waste heat; direct liquid cooling of racks or computers; and lowering the standby losses of standby generation systems. Link.

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Appendix A: Glossary

AHRI	Air-conditioning, Heating, and Refrigeration Institute.
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers.
BEE	Bureau of Energy Efficiency, Indian Ministry of Power.
BMS	Building Management System.
CoE	Center of Expertise for Energy Efficiency in Data Centers, http: //data centers.lbl.gov.
COP	Coefficient of Performance. For cooling equipment this is defined as the ratio of total cooling provided (including latent cooling, and ignoring fan motor heat), to electrical input power, at a given rating condition. Both the cooling and the input power are expressed in the same units, yielding a dimensionless number.
CRAC	Computer Room Air Conditioner. A Direct-Expansion (DX) system for providing temperature and humidity control in data centres.
CRAH	Computer Room Air Handler. A chilled-water system for providing temperature and humidity control in data centres.
ECBC	Energy Conservation Building Code.
ECM	Electrically Commutated Motor.
kVAR	Kilo-Volt-Amps, Reactive.
kVARh	Kilo-Volt-Amp Hours, Reactive.
kW	Kilowatt
kWh	Kilowatt-hour
Net Sensible Cooling Capacity	= Total gross cooling capacity - latent cooling capacity – fan power
NSCOP	Net Sensible Coefficient of Performance. The ratio of Net Sensible Cooling provided (which is equal to total cooling, minus latent cooling, minus fan input power) to electrical input power, at a given rating condition. See also COP and SCOP. Resources for NSCOP: **AHRI Standard 1361 (SI), 2017 Standard for Performance Rating of Computer and Data Processing Room Air Conditioners.** Link. **ASHRAE Standard 127-2012 Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners.** Link.

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PDU	Power Distribution Unit.
PUE	Power Usage Effectiveness, ratio of total building energy to IT equipment energy.
SCOP	Sensible Coefficient of Performance. The ratio of Sensible Cooling provided (which is equal to total cooling minus latent cooling) to electrical input power, at a given rating condition. See also COP and NSCOP.
UPS	Uninterruptible Power Supply.
VAV	Variable Air Volume.
VFD	Variable Frequency Drive.

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