Green Data Center

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What is a green data center? Data center industry stakeholders are discussing definitions in various consortiums and forums, but a publicly obtainable document is not currently available.

One common approach to greening the data center is to extend the U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design[R] (LEED) program. Currently, the LEED Green Building Rating System offers a performance assessment method to document the environmental consciousness of a commercial building in design, construction and operation, but LEED does not directly focus on data centers.

The performance assessment method has certain prerequisites and assigns credits in different categories: site, water, energy, materials and indoor environment. The credits accrued across all categories are added together to generate a single, overall score. The score determines the certification level, where a greater number of credits equate to a higher certification level. (1) Although LEED defines a green building and includes energy efficiency, it is geared towards human and environmental health and does not entirely consider the energy intensive aspect of the data center, which accounts for 1.5% of the U.S. retail electricity. (2) To address the unique energy density in the data center, this article proposes an evaluation system to grade a data center on the entries fulfilled.

The evaluation system consists of two elements, the point structure that determines a grade and the detailed information that describes the documentation requirements which must be adhered to for points. The point structure and detailed information are broken down into five groups: facilities, mechanical, electrical, operations and efficient practices/innovation. Within every group, there are categories, entries and a numbering system.

The point structure contains a certain number of prerequisites in each group that must be fulfilled to be considered for a grade. There are 28 prerequisites out of a possible 130 points; therefore, the prerequisites represent 22% of the total points. Table 1 shows the distribution of points per group.

The grading scale is as follows:

1 = 66% +
2 = 51% - 65%
3 = 36% - 50%
4 = 22% - 35%
5 = Does not meet prerequisites

The evaluation system currently is organized for a new data center, sometimes referred to as a greenfield or grassroots data center. However, the detailed information includes "E only" designations which mean that the specific descriptions and documentation requirements would apply only to existing data centers. For the purposes of this article, the existing data center point structure is not included.

The following pages give the breakdown of the data center energy efficiency evaluation system by group. Each group includes category, alphanumeric number with allocated points, description and documentation headings. As an example, the first group, Facilities, gives points in two categories: Planning as well as Building and Construction. Planning has two prerequisite entries, indicated by PR, and seven optional entries that are assigned an alphanumeric number. In the planning category, G1-1 is a prerequisite and G1-3 is an option. Each entry includes a description, documentation requirements and lists the potential amount of points in the Number column. If the documentation requirements are satisfied, the points are granted.

The intent of the evaluation system is to focus on a single environmental attribute due to the nature of computing in the data center and the scrutiny of data center energy efficiency, as evident in the EPA's report to Congress. (2) The data center evaluation system is not intended to be a green building rating system like LEED or other rating systems that have been established; however, the data center evaluation system could be positioned as a supplement to a recognized building rating system.

In conclusion, the evaluation system provides an initial means to grade the energy efficiency impact of the data center. The evaluation system is in its infancy and the authors acknowledge that more work needs to be done in collaboration with ASHRAE Technical Committee 9.9, Mission Critical Facilities, Technology Spaces and Electronic Equipment and other organizations to create a comprehensive data center energy efficiency evaluation system.

Group	Points	Prerequisites
Mechanical	45	10
Electrical	31	2
Operations	17	8
Facilities	21	5
Efficient Practices	16	4
Totals	130	29

Table 1: Allocation of points in each group.

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Point Structure — **Areas in grey labeled "PR" are pre-requisites that must be completed.**

Mechanical

System Selection

	Evaluate advantages and disadvantages of each air conditioning type based on the following criteria per footprint:		
G2-1	climate	1	PR
G2-2	installation ease	1	PR
G2-3	maintenance and serviceability	1	PR
G2-4	reliability	1	PR
G2-5	scalability	1	PR
G2-6	heat removal capacity per footprint	1	PR
G2-7	Review redundancy options to find the most efficient option that meets availability objectives and install the proper system.	2	
G2-8	Study energy efficiency tradeoffs in operating the air conditioning syste	3	

Cooling System Design

Chose either Chilled Water or Direct Expansion.

Chilled Water System Design

	Choose high efficiency components in the following areas:		
G2-9	Chillers	1	
G2-10	Pumps	1	
G2-11	Fans	1	
G2-12	Check chiller capacity tradeoffs with simulation software	1	
G2-13	Design pump and piping system to control pump head pressure	1	
G2-14	Determine and implement methods to keep the ECWT as low as possible	2	

OR

Direct Expansion System Design

	Choose high efficiency components in the following areas:		
G2-15	Compressors	1	
G2-16	Pumps	1	
G2-17	Fans	1	
G2-18	Ensure proper condenser heat transfer and spacing	1	
G2-19	Design pump, piping system, and fans to control pump head pressure	1	
G2-20	Installing an economizer coil	2	

Closely Coupled

G2-21	Review local cooling options such as liquid, in row, or overhead cooling.	1	PR

Cooling System Maintenance

G2-22	Establish a written process to maintain efficient operation	2	
	at a minimum, include manufacturers guidelines for maintenance of:		
G2-23	compressors	1	
G2-24	pumps	1	
G2-25	fans	1	
G2-26	cooling towers	1	
	Establish a written process for cleaning heat transfer areas of:		

G2-27	Cooling towers	1	
G2-28	Condenser coil faces	1	
G2-29	Humidifiers	1	
G2-30	Condenser and evaporator tubes	1	

Alternative Cooling

Economizer Design

	Determine if an economizer can result in energy savings by looking at:		
G2-31	Weather bin data	1	
G2-32	Reduction in facility cost versus added costs	1	
	Determine which type is suitable		
G2-33	Air side economizer	1	
G2-34	Water side economizer	1	
G2-35	Implement economizer with proper environmental controls	1	PR

Economizer Maintenance

G2-36	Install and use monitoring on all economizers	1	
	Implement a process for calibration and maintenance of:		
G2-37	Temperature and humidity sensors	1	
G2-38	Control systems	1	

Thermal Storage

G2-39	Review the potential for a cooling storage management system	1	
G2-40	Implement a cooling storage management system	3	

Waste Heat

G2-41	Analyze building and calculate waste heat costs	1	PR
G2-42	Implement waste heat recovery system or reuse waste heat	3	
	Totals	45	9

Electrical

System Selection

G3-1	Understand electricity generation and consumption	1	PR
	Verify electrical system design losses:		
G3-2	Voltage conversions	1	
G3-3	Conductor run lengths, gauge, and heating	1	
G3-4	Design redundancy only to the required level	2	
	Choose high efficiency components		
G3-5	CRAC/CRAH motors with variable air volume fans	1	
G3-6	UPS with scalable/modular capacity	1	
G3-7	Other aspects specific to your data center	1	
G3-8	Install monitoring equipment at all points in the electrical network	5	
G3-9	Obtain accurate and detailed electrical meter readings and bills and perform calculations on energy usage and investments	1	

IT Equipment

G3-10	Develop an energy profile	1	
	Choose high efficiency equipment:		
G3-11	Power supplies	2	

G3-12	Multi core processors	2	
G3-13	Dynamic power management	1	
G3-14	Enable power management tools on equipment	1	PR

Alternative Energy

G3-15	Supplement utility with distributed generation	5	
G3-16	Combined heat and power	1	
G3-17	Fuel cells	1	
	Supplement utility with a renewable energy source		
G3-18	Photovoltaic panels	1	
G3-19	Wind	1	
G3-20	Other	1	
	Totals	31	2

Operations

Temperature

G4-1	Optimize the return air set point of the CRAC/CRAH	1	
G4-2	Set higher supply air temperature	1	PR
G4-3	Use a supply side temperature control system	1	

Humidity

G4-4	Choose a system with the least operating costs, but tightest control	1	PR
G4-5	Set minimum relative humidity to lowest allowable level	1	PR
G4-6	Allow larger CRAC/CRAH humidity control tolerance	1	
G4-7	Use dew point humidity control	1	PR
G4-8	Install humidification equipment on make up air units only	1	

Preventative Maintenance

G4-9	Have the data center cleaned regularly by professionals	1	
	Schedule maintenance for CRAC/CRAH units on:		
G4-10	Filters	1	PR
G4-11	Pulleys	1	
G4-12	Belts	1	
	Schedule maintenance for electrical system on:		
G4-13	Electrical connections	1	

Training

G4-14	All employees must complete a training course on energy efficiency and best practices	1	PR
G4-15	Set up an energy improvement employee rewards program	1	PR

Commissioning

G4-16	Ensure infrastructure has been fully engineered and tested	1	PR
G4-17	Check data center vitals and compare to commissioning data	1	
	Totals	17	8

Facilities

Planning

G1-1	Show energy optimization has been a focus since the beginning of the design process	1	PR
G1-2	Involve all stakeholders in the whole design process	1	PR
G1-3	Simulate the data center with CFD software	1	
G1-4	Model the electrical system to analyze efficiencies	1	
	Verify all tradeoffs in design:		
G1-5	High density versus more space	1	
G1-6	UPS loading and redundancy for efficiency	1	
G1-7	Other tradeoffs specific to your data center	1	
G1-8	Design data center to be scalable/modular	1	
G1-9	Compile and frequently update a plan for future growth	1	

Building and Construction

G1-10	Minimize data center envelope losses	1	
	Room design:		
G1-11	Minimize amount of windows	1	
G1-12	Use vapor barriers and insulation on building exterior	1	
G1-13	Use vapor barriers and insulation or equivalent on piping and val	1	
G1-14	Local mechanical plant as close to data center as possible	1	
	Architecture:		
G1-15	At least a 24 in (610 mm) raised floor	1	
G1-16	At least 10 feet (3 m) from raised floor to drop ceiling	1	PR
G1-17	At least 4 feet (1.2 m) from crop ceiling to slab of next floor	1	
	Lighting:		
G1-18	Minimize amount of lighting	1	PR
G1-19	Make all lighting as efficient as possible	1	PR
G1-20	Apply timers and sensors to the lighting	1	
G1-21	Install task lighting for low occupancy areas	1	
	Totals	21	5

Efficient Practices and Innovation

Points

Hot Aisle/Cold Aisle

G5-1	Arrange racks in hot aisle/cold aisle position	1	PR

Perforated Tiles

G5-2	Have perforated tiles properly placed within datacenter	1	
G5-3	Correct amount of perforated tiles based on open area	1	

Raised Floor

G5-4	Seal unnecessary openings in the raised floor	1	PR
G5-5	Minimize under floor blockages from pipes, cables, power whips, etc.	1	PR

Racks

G5-6	Use filler panels in and between racks	1	PR

	G5-7	Use end baffles at the end of every row and over the top barriers	1	
Above Floor				
	G5-8	Utilize overhead cable trays	1	
	G5-9	Duct return airflow back to CRAC/CRAH units	2	
	G5-10	Keep up to date with best practices	1	
Innovation				
	G5-11	Unique engineering solutions to improve energy efficiency	5	
			Totals 16	4

Overall Totals

Possible Criteria	**130**
Criteria Fulfilled	**28**
Total Percent Obtained	**22%**

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Detailed Information

Category	Number	Description	Documentation/Submittal
		Mechanical	
System Selection	G2-1 G2-2 G2-3 G2-4 G2-5 G2-6	Evaluate advantages and disadvantages of the different types and quantities of air conditioning with respect to efficiency and the facilities strategy that considers climate, installation, maintenance, serviceability, reliability, scalability, and heat removal capacity per footprint. Options include chilled water and direction expansion (DX) with air cooled, water cooled, or glycol cooled condensers. Install or retrofit the most efficient air conditioning system according to the stated criteria.	Document the evaluation process and results.
	G2-7	Review redundancy options such as n+1 in the number of components operating in series or parallel, or 2n in the piping arrangement to determine the most efficient operating points while meeting availability objectives.	Document the choices and the rationale.
	G2-8	Study energy efficiency tradeoffs in the operation of the air conditioning system. For example, -Raising the chilled water temperature reduces cooling coil capacity which could raise the air temperature in the data center, resulting in air conditioning unit fans operating at a higher speed to remove the heat. -Raising the chilled water temperature increases the amount of chilled water that must be pumped to the cooling coil to remove a given heat load. -Lowering the condenser water temperature could increase the fan speed in the cooling tower.	Determine the optimum operating point via software simulation or analysis of historical operating data. Document strategies that make the air conditioning system energy efficient.
Chilled Water - Design	G2-9 G2-10 G2-11	Select individual high efficiency components in the air conditioning system: -Chillers – review efficiency as a function of chiller type and size available from ASHRAE 90.1 Energy Standard. -Pumps (chilled water loop, condenser water loop) -Fans (cooling towers, CRAH)	Record make, model, and specifications for the components reviewed and selected. Document the final choice of equipment brand name, make and model; include efficiencies at 20%, 50%, 80% load and the normal expected operating point for the components.
	G2-12	Study chiller capacity based on condenser water in/out temperatures as well as chilled water in/out temperatures.	Record the results of the conditions reviewed via chiller manufacturer computer aided software.
	G2-13	Keep system pump pressure low with regulation valves that modulate water flow to control pump head pressure. The pump and piping must be sized appropriately.	Document piping and pump design.
	G2-14	Study methods to keep the ECWT as low as possible within the acceptable limit of the chiller and keep efficiency at a high level. A possible method includes, but is not limited to, installing a larger cooling tower with increased surface area and free area within the tower fill to reduce the size of the fan motor. Another possibility is to take advantage of wet bulb conditions in the cooling tower system.	Record methods reviewed and document preferred approach.

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Category	Number	Description	Documentation/Submittal
Direct Expansion - Design	G2-15 G2-16 G2-17	Select individual high efficiency components in the air conditioning system: -The number and type of compressors per air conditioning unit (CRAC) -Pumps (fluid cooler loop) -Fans (cooling towers, air-cooled condenser, or fluid cooler)	Record make, model, and specifications for the components reviewed and selected. Document the final choice of equipment brand name, make and model; include efficiencies at 20%, 50%, 80%, 100% load and the normal expected operating point for the components.
	G2-18	Review air cooled condenser heat transfer area and installation spacing to reduce condensing temperatures and avoid air recirculation that raises compressor power consumption.	Document the air-cooled condenser design and installation plans for effective heat removal.
	G2-19	Keep system pump pressure low with regulation valves that modulate flow to control pump head pressure to fluid coolers and cooling towers, dielectrics to keep heat rejection pumping usage small, or manage air-side static pressure. The pump and piping must be sized appropriately.	Document piping, pump design, and fan curves.
	G2-20	Install an economizer coil that can be used to bypass the CRAC heat exchanger when ambient conditions permit the glycol in the fluid cooler to substitute the refrigeration cycle.	Document the make and model of the CRAC and the control strategy for use of the economizer coil.
Closely Coupled	G2-21	Review local cooling options to reduce fan power or air heat load in the data center. Options include, but are not limited to, liquid cooling, in-row cooling, and overhead cooling.	Determine feasibility of implementing options that improve energy efficiency.
Chilled Water and DX - Operation	E only	Maintain an accurate and detailed daily operating log of the air conditioning system including flow rates. Regularly compare the data to the design and initial start-up information to detect problems or inefficient control settings.	Log data in a format that is easy to use for trending and detailed analysis.
	E only	Review the operating performance of the air conditioning system to determine the most energy efficient operating point. Make the necessary adjustments to components, controls, valves, and building automation systems to increase efficiency based on environmental conditions.	Track the difference in operation and efficiency from monitoring before and after any air conditioning system. Note the most efficient operating point based on internal or external environment conditions.

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Category	Number	Description	Documentation/Submittal
Chilled Water and DX – Preventative Maintenance	G2-22 G2-23 G2-24 G2-25 G2-26	Establish a set of processes to adequately maintain efficient operation, reliability, and lifespan of the air conditioning system. At a minimum, compressors should be tested for leaks and pumps properly lubricated.	Document and make available to all trained personnel the written maintenance procedures and schedule for maintenance for all equipment, referencing manufacturers as necessary. Set-up a central repository for all the maintenance activity that can be used for data mining. Obtain one point for written guidelines and additional points for each system in the guidelines.
	E only	Keep good maintenance records that show preventative maintenance actions as well as unscheduled maintenance actions. Identify components with frequent activity.	
	G2-27	For air conditioning systems that use a cooling tower, clean to minimize drops in air and water pressure, have an aggressive water treatment program, and clean the intake strainer.	Document procedures and schedule for cleaning.
	G2-28	For air conditioning systems that use an air cooled condenser, keep the coil faces clean to promote heat transfer efficiency. Blocked fins can increase temperatures, pressures and compressor energy.	
	G2-29	Clean humidifiers and implement a water filtration system to reduce buildup and prevent contamination.	
	G2-30	Clean evaporator and condenser tubes to keep temperatures on the heat transfer surfaces from increasing with scaling and fouling.	
Alternative Cooling – Economizer Design	G2-31	Investigate the weather bin data, including nighttime, to determine if air-side and/or water-side economizers can result in energy savings for the data center.	Document the results of the weather investigation, outlining the potential number of days an economizer can be run.
	G2-32	The potential reduction in facility energy costs should be compared to the potential added costs of building space, reliability, calibration, and maintenance.	Project the economizer capital, installation, and operation costs to determine the payback period based on energy saving.
	G2-33	Select an air-side economizer with dry bulb temperature control (sensible) or temperature and humidity control (enthalpy). Proper analysis and design are necessary to ensure the temperature and humidity meet criteria to partially or fully meet the heat load requirements. - An air-side economizer with a dual enthalpy control system, which actively compares to outside air and return air enthalpy, can optimize economizer operation. - Evaporative cooled air-side economizers that use a direct evaporative cooler to add moisture to the air can further enhance economizer operation.	Record the make and model of economizer and create a mechanical drawing with schematic of its location and arrangement with other equipment.
	G2-34	Water-side economizers should be considered when air supplied to the facility must be kept within tight humidity limits, especially if it offers more free cooling hours than air-side economizers. The water-side economizer heat exchanger, when used with a chiller, should be arranged in series with the condenser water loop to increase the free cooling hours.	
	G2-35	Implement an economizer. Control strategies should be programmed to adjust air damper positions (air-side) or motorized control valves (water-side) based on the environmental sensors used.	Record the operating data and correlate with the controls.

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Category	Number	Description	Documentation/Submittal
Alternative Cooling – Economizer Maintenance	G2-36	Monitoring of air-side and water-side economizer elements must be done to ensure correct operation and to maximize the amount of energy savings.	Record the operating data and correlate with the controls.
	G2-37 G2-38	Calibration and maintenance of air-side temperature and/or humidity sensors as well as water-side motorized control values must be done frequently to ensure proper economizer operation.	Document procedure for calibration and maintenance, referencing manufacturers as necessary.
Alternative Cooling – Thermal Storage	G2-39 G2-40	Run the chiller off-peak and use stored cooled water, ice, or other media during peak energy times of the day to conserve energy when there is a significant difference in energy demand between peak and off-peak hours. The thermal storage can also be used as a reserve in the event of a chiller failure.	Project the thermal storage capital, installation, and operation costs to determine estimated savings of using stored energy over peak demand energy. Include factors such as availability of space for storage media, cooling load profile, rate schedule, and existing equipment in the analysis. Implement a thermal storage system if the analysis is favorable.
	E only	Study the load variation of the data center and match it to a thermal storage system.	Target a 3% decrease in cooling plant consumption from an established baseline.
Alternative Cooling – Waste Heat	G2-41	Review strategies to recover waste heat from building space heating, domestic water heating, absorption or adsorption chillers, or on-site electricity generation. Calculate potential energy savings based on the number of hours-per-year where excess energy is available and whether or not that energy can be used for purposes that would otherwise require purchase.	Document the strategies reviewed and the criteria used to determine feasibility.
	G2-42	Implement a waste heat recovery system.	
Electrical			
System Selection	G3-1	Understand where and how the electricity to be consumed is generated. Energy rates, energy sources, and proximity to clean energy alternatives should be studied.	Document results of the study.
	G3-2 G3-3	Study the voltage (AC, DC, or combination) and electrical distribution delivered to the data center to minimize the number of power conversions and electrical heat losses in the building wiring.	Document the electrical distribution via detailed drawings and one-line schematics. In addition to the typical symbols, include the lengths of the wiring and gauge for service, feeder, and branch circuit conductors.
	G3-4	Redundancy should be designed only up to the required level for availability objectives as extra redundancy has a potential energy efficiency penalty with low loading on the electrical distribution components.	
	G3-5 G3-6 G3-7	Select individual high efficiency components in the electrical distribution at anticipated loads, keeping in mind normal daily operation with redundancy. Look at components that maintain a high efficiency at varying percentage load as components are typically operated well below their full rated load capacities. Some examples, -Premium efficiency fan motors that are efficient with the use of variable air volume (VAV) fans. -UPSs with scalable or modular capacity that are easily expanded if the electrical load increases over time. Systems that incorporate flywheel technologies should be reviewed for efficiency improvement.	Analyze current equipment, new equipment and technologies. Identify the difference in efficiency. Determine costs and payback periods for purchase of new equipment.
	G3-8	Institute an energy management and monitoring program. Install monitoring at all points within the data center electrical network to understand electricity consumption and calculate metrics (e.g., The Green Grid DCE, cooling plant efficiency in kW/ton). Conduct regular or automatic energy assessments as new IT equipment, upgrades, and room changes are done. Do not include office space if shared within the building.	Document the energy management and monitoring strategy.
	E only	Once monitoring is installed, review the output frequently. Look at the trends to make appropriate changes to increase energy efficiency or detect problems.	
	G3-9	Get an accurate and detailed monthly electrical meter reading and energy bill to understand the energy consumption and calculate the return on investment of energy efficiency improvements.	Plot the utility bill and data center energy consumption on the same chart for tracking and trend analysis.

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IT Equipment	G3-10	Develop an energy profile of the infrastructure and IT equipment in the data center.	Generate data center drawing and energy profile.
	G3-11 G3-12 G3-13	Install energy efficient IT equipment that should include the following: -High efficiency power supplies -Multi-core processors -Dynamic power management	Document the energy efficient features of the IT equipment.
	G3-14	Enable power management features that are available on IT equipment.	Record status (enabled/disabled).
	E only	Disconnect unutilized IT equipment.	Document the number and types of equipment eliminated along with an estimate of energy saved.
	E only	Refresh technology periodically to take advantage of the latest IT equipment energy efficiency advancements.	Outline a plan for every 2 years to research new technology, calculate cost versus savings, and implement. Upgrades must be made at least every 5 years.
Alternative Energy	G3-15 G3-16 G3-17	Review applicability and economic benefit of distributed generation technologies such as combined heat and power as well as fuel cells. Install a system to supplement the existing electricity supply.	Document distributed generation technologies researched along with advantages and disadvantages. Determine the ideal type of technology for your environment.
	G3-18 G3-19 G3-20	Review renewable energy options such as wind turbines or photovoltaic panels as a primary energy source with the electricity supply as a supplemental or secondary option.	Document renewable energy sources researched along with advantages and disadvantages. Determine the ideal type of technology for your environment.
		Data Center Operations	
Temperature	G4-1	Optimize the return air set-point of the CRAC and/or CRAH to provide the necessary cooling. Increasing the return set-point above the traditional 70°F can increase the sensible cooling capacity and efficiency of the CRAC/CRAH.	Study and implement if it provides energy efficiency benefits.
	G4-2	Increase the supply air temperature to avoid continuously dehumidifying the air to which moisture must be added. This could potentially avoid the need for reheat elements, although some humidification may be necessary. Increased supply air temperature can also increase chiller efficiency and economizer hours of operation in full or integrated mode.	
	G4-3	Use CRAH/CRAC supply side temperature control to maintain a constant discharge temperature.	Study feasibility of implementing.
Humidity	G4-4	Choose a humidification system that has the least operating costs with tight control over the environment.	Compare humidification systems such as electric and ultrasonic.
	G4-5	Set the relative humidity to the lowest level based on ASHRAE Thermal Guidelines for Data Processing Environments or to a minimum level based on external climate factors.	Study and implement if it provides energy efficiency benefits.
	G4-6 G4-7	Allow a large humidity control tolerance and use dew point control to minimize simultaneous humidification and dehumidification of adjacent CRAC/CRAH units.	
	G4-8	If there is a need for humidification, consider installing humidification equipment on make-up air units used for positive pressurization.	

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Preventative Maintenance	G4-9	Periodic data center cleaning should be done by a qualified, experienced company to optimize equipment efficiency and performance.	Document a plan for data center cleaning.
	G4-10 G4-11 G4-12	Perform regularly, scheduled maintenance on the CRAC and/or CRAH filters, pulleys, and belts. -A filter's air resistance increases as the filter becomes dirty which increases fan static pressure and energy use. Ensure that there are no air bypass pathways. -Pulleys should be adjusted to provide the appropriate CFM based on the fan curve. -Belts should be checked for wear and tear to minimize slipping and debris.	Document a plan to complete CRAC/CRAH maintenance periodically.
	G4-13	Electrical connections with fittings should be checked for damaged or loose connections and hot spots via infrared imaging.	Submit preventative maintenance plan that includes frequency, procedure and information from the manufacturer regarding the proper upkeep of the electrical equipment.
	E only	Inspection of equipment plugs and receptacles should be done to ensure adequate mating and ground continuity.	Document findings and fix deficiencies.
Training	E only	Ensure that the IT and facility operations staff receive education on identification and proper operation of all systems and their energy efficiency features.	Training must be completed with record of training for current employees and plan for training new employees maintained.
	G4-14	Establish policies and educate IT and facility operations staff on data center best practices.	Required part of the training course.
	G4-15	Encourage the IT and facility operations staff to look for and report opportunities for energy improvements.	
Commission	G4-16	Ensure the infrastructure design has been fully engineered and tested.	Document a plan for commissioning to establish a baseline of the mechanical and electrical systems.
	E only	Fully commission and re-commission the air conditioning and electrical systems periodically.	Record the results and indicate which systems may require replacement, timeframe, and costs compared to savings.
	G4-17	Ensure set points are at proper values, sensors and controls are in calibration, airflow is within design tolerance, and regulation valves are functioning correctly.	At a minimum, include in the plan for commissioning.

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Category	Number	Description	Documentation/Submittal
		Facility	
Planning	G1-1	Introduce energy optimization at the earliest possible phase of the design process to minimize operating expenses.	Document a strategy to follow which outlines the continuous need to review the energy consciousness of all aspects of designing and operating the data center.
	G1-2	Involve all IT, facilities, and management in the design process to achieve solutions that save energy while meeting reliability, performance, control, and other business requirements.	Create a data center team that includes the proper representation to achieve energy efficiency objectives in the IT and facility. Implement a change management system.
	G1-3	Use computational fluid dynamics (CFD) to build and simulate the data center. Identify and rectify potential areas of insufficient airflow or inadvertent mixing of air.	Identify the top 5 opportunities to improve; implement at least 2 and document energy savings.
	G1-4	Use electrical system design and simulation software to analyze the efficiency of the proposed distribution and identify improvement opportunities prior to construction or retrofitting.	
	G1-5 G1-6 G1-7	Be aware of tradeoffs in the design process. For example, -Higher densities can create design challenges, however, spreading out systems requires longer conductor runs for the electrical infrastructure. It also increases the total space that must be conditioned, requiring larger chillers and additional fan capacity. -Typical redundancy is accomplished with two units capable of 100% load. Consider redundancy with three or more units capable of 50% load so that the operating load is a larger percentage of the unit load which equates to higher efficiency.	Audit the data center design carefully with regards to energy efficiency and space conservation opportunities.
	G1-8	Design the data center to be scalable and modular to right-size the infrastructure based on the load. Designate a high-density section of the data center with the ability to support high-density loads.	Document the scalable parts of the data center and how these are expandable without construction.
	G1-9	Have a plan for future data center growth and follow it or update as necessary.	
Building and Construction	G1-10	Evaluate the location of the data center to minimize envelope losses from adjacent spaces, walls, doors, floor, and ceiling.	If any of the guidelines cannot be followed, document efficient measures taken to counteract the negative effects.
	G1-11	Avoid windows and skylights to minimize additional heat load from solar gain.	
	G1-12	Use vapor barriers around the exterior of the data center to control moisture exchange. Insulation must be used and should meet energy code minimums.	
	G1-13	Piping and valves that carry chilled water need a vapor barrier to reduce moisture condensed within the insulation that can destroy not only its insulating properties, but also the pipe it is supposed to protect. An alternative option is to keep the supply water temperature above the dew point.	
	G1-14	The mechanical plant should be located as close to the data center as possible to minimize the amount of piping and fluctuations of fluid temperature that can occur.	
	G1-15 G1-16 G1-17	The data center should have at least a 24 inch (610 mm) raised-floor and a 10 feet (3 m) ceiling measured from the top of the raised-floor to a suspended ceiling, if used. The distance from a suspended ceiling to the slab of the next floor should be a minimum of 4 feet (1.2 m).	
	G1-18 G1-19 G1-20 G1-21	For data center lighting, use only the amount absolutely necessary with the most efficient technology. Consider occupancy sensors and time-of-day controls for some or all of the lights. Install task lighting or dimmers for low occupancy areas.	

THE ENERGY EFFICIENT DATA CENTER
Detailed Information

Category	Number	Description	Documentation/Submittal
Efficient Practices and Innovation			
Efficient Practices	G5-1	Hot aisle / Cold aisle	Record the best practices implemented in the data center.
	G5-2	Place perforated panels directly in front of the IT equipment to provide the most direct path for the conditioned air to reach the IT equipment inlets.	
	G5-3	Install the air conditioning manufacturer recommended number of perforated panels to ensure adequate static pressure.	
	G5-4	Seal unnecessary raised-floor openings to prevent the conditioned air from doing no work.	
	G5-5	Minimize under floor blockages (communications cables, power whips, chilled/return water pipes, etc.) that hinder airflow.	
	G5-6	Use filler panels in and between cabinets to block exhaust air from recirculating to the IT equipment inlets.	
	G5-7	Install end of row and over the top barriers to further divide the hot and cold air streams.	
	G5-8	Utilize overhead cable trays to alleviate congestion under the raised-floor.	
	G5-9	Consider using the area between the suspended ceiling and slab of the floor above as a return air space with the appropriate ducting.	
	G5-10	Keep up-to-date with best practices as established by groups like ASHRAE TC 9.9 and The Green Grid.	
Innovation	G5-11	Identify and implement data center energy efficiency break-through improvements that are unique and not categorized in the evaluation system.	Record the innovations implemented in the data center.

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