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WP-0 v0	WHITE PAPER LIBRARY NAVIGATION GUIDE This presentation provides recommended white paper reading lists by interest area, from fundamentals to best practices to hot topics.
WP-1000 v0	Schneider Electric White Paper App: Download Instructions and FAQs With millions of downloads every year, Schneider Electric's fact-based, vendor-neutral white papers are a highly respected information source. Schneider Electric's white paper library can now be conveniently stored, read and updated on your smart phone or tablet. This paper explains how to download and install the App for both iOS (e.g., iPhone, iPad, iPod Touch) and Android (e.g., Samsung Infuse, Motorola Zoom) devices.
WP-164 v1	TCO Analysis of a Traditional Data Center vs. a Scalable, Prefabricated Data Center Standardized, scalable, pre-assembled, and integrated data center facility power and cooling modules provide a "total cost of ownership" (TCO) savings of 30% compared to traditional, built-out data center power and cooling infrastructure. Avoiding overbuilt capacity and scaling the design over time contributes to a significant percentage of the overall savings. This white paper provides a quantitative TCO analysis of the two architectures, and illustrates the key drivers of both the capex and opex savings of the improved architecture.
WP-165 v0	Types of Prefabricated Modular Data Centers Data center systems or subsystems that are pre-assembled in a factory are often described with terms like prefabricated, containerized, modular, skid-based, pod-based, mobile, portable, self-contained, all-in-one, and more. There are, however, important distinctions between the various types of factory-built building blocks on the market. This paper proposes standard terminology for categorizing the types of prefabricated modular data centers, defines and compares their key attributes, and provides a framework for choosing the best approach(es) based on business requirements.
WP-132 v0	Economizer Modes of Data Center Cooling Systems In certain climates, some cooling systems can save over 70% in annual cooling energy costs by operating in economizer mode, corresponding to over 15% reduction in annualized PUE. However, there are at least 17 different types of economizer modes with imprecise industry definitions making it difficult to compare, select, or specify them. This paper provides terminology and definitions for the various types of economizer modes and compares their performance against key data center attributes.
WP-206 v0	Overload Protection in a Dual-Corded Data Center Environment In a dual-corded environment, the loss of power on one path will cause the load to transfer to the other path, which can create an overload condition on that path. This can lead to a situation where the failure of one path leads to the failure of both paths. This paper explains the problem and how to solve it, and provides a set of rules to ensure that a dual-path environment provides the expected fault tolerance.
WP-195 v0	Fundamentals of Managing the Data Center Life Cycle for Owners Just as good genes do not guarantee health and well-being, a good design alone does not ensure a data center is well-built and will remain efficient and available over the course of its life span. For each phase of the data center's life cycle, proper care and action must be taken to continuously meet the business needs of the facility. This paper describes the five phases of the data center life cycle, identifies key tasks and pitfalls, and offers practical advice to facility owners and management.
WP-153 v0	Implementing Hot and Cold Air Containment in Existing Data Centers Containment solutions can eliminate hot spots and provide energy savings over traditional uncontained data center designs. The best containment solution for an existing facility will depend on the constraints of the facility. While ducted hot aisle containment is preferred for highest efficiency, cold aisle containment tends to be easier and more cost effective for facilities with existing raised floor air distribution. This paper investigates the constraints, reviews all available containment methods, and provides recommendations for determining the best containment approach.
WP-163 v2	Prefabricated Power and Cooling Modules for Data Centers Standardized, pre-assembled and integrated data center facility power and cooling modules are at least 60% faster to deploy, and provide a first cost savings of 13% or more compared to traditional data center power and cooling infrastructure. Facility modules, also referred to in the data center industry as containerized power and cooling plants, allow data center designers to shift their thinking from a customized "construction" mentality to a standardized "site integration" mentality. This white paper compares the cost of both scenarios, presents the advantages and disadvantages of each, and identifies which environments can best leverage the facility module approach.
WP-107 v3	How Data Center Infrastructure Management Software Improves Planning and Cuts Operational Costs Business executives are challenging their IT staffs to convert data centers from cost centers into producers of business value. Data centers can make a significant impact to the bottom line by enabling the business to respond more quickly to market demands. This paper demonstrates, through a series of examples, how data center infrastructure management software tools can simplify operational processes, cut costs, and speed up information delivery.
WP-170 v0	Avoiding Common Pitfalls of Evaluating and Implementing DCIM Solutions While many who invest in Data Center Infrastructure Management (DCIM) software benefit greatly, some do not. Research has revealed a number of pitfalls that end users should avoid when evaluating and implementing DCIM solutions. Choosing an inappropriate solution, relying on inadequate processes, and a lack of commitment / ownership / knowledge can each undermine a chosen toolset's ability to deliver the value it was designed to provide. This paper describes these common pitfalls and provides practical guidance on how to avoid them.
WP-129 v3	Comparing Data Center Power Distribution Architectures Significant improvements in efficiency, power density, power monitoring, and reconfigurability have been achieved in data center power distribution, increasing the options available for data centers. This paper compares five power distribution approaches including panelboard distribution, field-wired PDU distribution, factory-configured PDU distribution, floor-mount modular power distribution, and modular busway, and describes their advantages and disadvantages. Guidance is provided on selecting the best approach for specific applications and constraints.
WP-142 v2	Data Center Projects: System Planning Planning of a data center physical infrastructure project need not be a time consuming or frustrating task. Experience shows that if the right issues are resolved in the right order by the right people, vague requirements can be quickly translated into a detailed design. This paper outlines practical steps to be followed that can cut costs by simplifying and shortening the planning process while improving the quality of the plan.
	Choosing the Optimal Data Center Power Density The choice of IT rack power densities has a direct impact on the capital cost of the data center. There are significant savings in developing a data center with an average rack power density of at least 5 kW per rack, however, densities higher than ~15 kW per

WP-156 v0	rack show no further relevant savings. This white paper analyzes these costs and presents a flexible architecture to accommodate a well-specified density, and discusses the importance of operational policies in enforcing the specification.
 WP-147 v0	Data Center Projects: Advantages of Using a Reference Design It is no longer practical or cost-effective to completely engineer all aspects of a unique data center. Re-use of proven, documented subsystems or complete designs is a best practice for both new data centers and for upgrades to existing data centers. Adopting a well-conceived reference design can have a positive impact on both the project itself, as well as on the operation of the data center over its lifetime. Reference designs simplify and shorten the planning and implementation process and reduce downtime risks once up and running. In this paper reference designs are defined and their benefits are explained.
 WP-160 v1	Specification of Modular Data Center Architecture There is a growing consensus that conventional legacy data center design will be superseded by modular scalable data center designs. Reduced total cost of ownership, increased flexibility, reduced deployment time, and improved efficiency are all claimed benefits of modular scalable designs. Yet the term "modular", when and where modularity is appropriate, and how to specify modularity are all poorly defined. This paper creates a framework for modular data center architecture and describes the various ways that modularity can be implemented for data center power, cooling, and space infrastructure and explains when the different approaches are appropriate and effective.
 WP-197 v0	Facility Operations Maturity Model for Data Centers An operations & maintenance (O&M;) program determines to a large degree how well a data center lives up to its design intent. The comprehensive data center facility operations maturity model (FOMM) presented in this paper is a useful method for determining how effective that program is, what might be lacking, and for benchmarking performance to drive continuous improvement throughout the life cycle of the facility. This understanding enables on-going concrete actions that make the data center safer, more reliable, and operationally more efficient. NOTE: The complete FOMM is embedded in the Resources page at the end of this paper.
 WP-166 v0	Practical Considerations for Implementing Prefabricated Data Centers Implementing prefabricated modular data centers results in well-understood benefits including speed of deployment, predictability, scalability, and lifecycle cost. The process of deploying them – from designing the data center, to preparing the site, to procuring the equipment, to installation – is quite different than that of a traditional data center. This paper presents practical considerations, guidance, and results that a data center manager should expect from such a deployment.
 WP-136 v1	High Efficiency Indirect Air Economizer-based Cooling for Data Centers Of the various economizer (free cooling) modes for data centers, using fresh air is often viewed as the most energy efficient approach. However, this paper shows how indirect air economizer-based cooling produces similar or better energy savings while eliminating risks posed when outside fresh air is allowed directly into the IT space.
 WP-171 v1	Considerations for Owning versus Outsourcing Data Center Physical Infrastructure When faced with the decision of upgrading an existing data center, building new, or leasing space in a retail colocation data center, there are both quantitative and qualitative differences to consider. The 10-year TCO may favor upgrading or building over outsourcing, however, this paper demonstrates that the economics may be overwhelmed by a business' sensitivity to cash flow, cash cross-over point, deployment timeframe, data center life expectancy, regulatory requirements, and other strategic factors. This paper discusses how to assess these key factors to help make a sound decision.
 WP-196 v0	Essential Elements of Data Center Facility Operations 70% of data center outages are directly attributable to human error according to the Uptime Institute's analysis of their "abnormal incident" reporting (AIR) database1. This figure highlights the critical importance of having an effective operations and maintenance (O&M;) program. This paper describes unique management principles and provides a comprehensive, high-level overview of the necessary program elements for operating a mission critical facility efficiently and reliably throughout its life cycle. Practical management tips and advice are also given.
 WP-135 v3	Impact of Hot and Cold Aisle Containment on Data Center Temperature and Efficiency Both hot-air and cold-air containment can improve the predictability and efficiency of traditional data center cooling systems. While both approaches minimize the mixing of hot and cold air, there are practical differences in implementation and operation that have significant consequences on work environment conditions, PUE, and economizer mode hours. The choice of hot-aisle containment over cold-aisle containment can save 43% in annual cooling system energy cost, corresponding to a 15% reduction in annualized PUE. This paper examines both methodologies and highlights the reasons why hot-aisle containment emerges as the preferred best practice for new data centers.
 WP-173 v0	Power and Cooling Guidelines for Deploying IT in Colocation Data Centers Some prospective colocation data center tenants view power and cooling best practices as constraining. However, an effective acceptable use policy can reduce downtime due to thermal shutdown and human error, reduce stranded capacity, and extend the life of the initial leased space, avoiding the cost of oversized reserved space. This paper explains some of the causes of stranded power, cooling, and space capacity in colocation data centers and explains how high-density rack power distribution, air containment, and other practices improve availability and efficiency. Examples of acceptable use policies that address these issues are provided.
 WP-68 v1	Cooling Strategies for IT Wiring Closets and Small Rooms Cooling for IT wiring closets is rarely planned and typically only implemented after failures or overheating occur. Historically, no clear standard exists for specifying sufficient cooling to achieve predictable behavior within wiring closets. An appropriate specification for cooling IT wiring closets should assure compatibility with anticipated loads, provide unambiguous instruction for design and installation of cooling equipment, prevent oversizing, maximize electrical efficiency, and be flexible enough to work in various shapes and types of closets. This paper describes the science and practical application of an improved method for the specification of cooling for wiring closets.
 WP-207 v0	Design and Specification for Safe and Reliable Battery Systems for Large UPS A properly designed UPS battery solution is important for safe and reliable operation. This paper describes the main components and functions of a battery system, and discusses the reasons why vendor pre-engineered battery solutions are optimal. In cases where pre-engineered solutions don't meet the requirements, vendor-engineered solutions are next best. If third party custom battery solutions must be used, design guidelines are provided to ensure a safe and reliable design.
 WP-159 v0	How Overhead Cabling Saves Energy in Data Centers Placing data center power and data cables in overhead cable trays instead of under raised floors can result in an energy savings of 24%. Raised floors filled with cabling and other obstructions make it difficult to supply cold air to racks. The raised floor cable cutouts necessary to provide cable access to racks and PDUs result in a cold air leakage of 35%. The cable blockage and air leakage problems lead to the need for increased fan power, oversized cooling units, increased pump power, and lower cooling set points. This paper highlights these issues, and quantifies the energy impact.
 WP-157 v3	Eco-mode: Benefits and Risks of Energy-saving Modes of UPS Operation Many newer UPS systems have an energy-saving operating mode known as "eco-mode" or by some other descriptor. Nevertheless, surveys show that virtually no data centers actually use this mode, because of the known or anticipated side-effects. Unfortunately, the marketing materials for these operating modes do not adequately explain the cost / benefit tradeoffs. This paper shows that eco-mode provides a reduction of approximately 2% in data center energy consumption and explains the various limitations and concerns that arise from eco-mode use. Situations where these operating modes are recommended and contra-indicated are also described.
 WP-174 v0	Practical Options for Deploying IT Equipment in Small Server Rooms and Branch Offices Small server rooms and branch offices are typically unorganized, insecure, hot, unmonitored, and space constrained. These conditions can lead to system downtime or, at the very least, lead to "close calls" that get management's attention. Practical experience with these problems reveals a short list of effective methods to improve the availability of IT operations within small server rooms and branch offices. This paper discusses making realistic improvements to power, cooling, racks, physical security, monitoring, and lighting. The focus of this paper is on small server rooms and branch offices with up to 10kW of IT load.
 WP-154 v2	Electrical Efficiency Measurement for Data Centers Data center electrical efficiency is rarely planned or managed. The unfortunate result is that most data centers waste substantial amounts of electricity. Today it is both possible and prudent to plan, measure, and improve data center efficiency. In addition to reducing electrical consumption, efficiency improvements can gain users higher IT power densities and the ability to install more IT equipment in a given installation. This paper explains how data center efficiency can be measured, evaluated, and modeled, including a comparison of the benefits of periodic assessment vs. continuous monitoring.

 WP-175 v1	<u>Preparing the Physical Infrastructure of Receiving Data Centers for Consolidation</u> The consolidation of one or more data centers into an existing data center is a common occurrence. This paper gives examples of what is becoming a standard architecture for preparing the physical infrastructure in the receiving data center. This approach allows for shorter timelines and high efficiency while avoiding the commonly expected difficulties and complexities often experienced with consolidation projects.
 WP-7 v0	<u>Maximizing Uptime in Mission-Critical Facilities</u> As technology reaches into every corner of our world, the importance of, and reliance on, your mission critical facility reaches new heights. Uptime is no longer a lofty goal, it is an absolute necessity. However, uptime is not a product that you specify with the design of your facility, install, and then forget about. A facility designed to 99.99% of availability will not achieve / maintain that number, unless we fully understand the many factors that affect uptime. Maximum Uptime is a philosophy. It begins with the planning of your facility, and remains a continuous process through every step of design, construction, commissioning, operations, failure analysis, and recommissioning.
 WP-139 v0	<u>Cooling Entire Data Centers Using Only Row Cooling</u> Row cooling is emerging as a practical total cooling solution for new data centers due to its inherent high efficiency and predictable performance. Yet some IT equipment in data centers appears incompatible with row cooling because it is not arranged in neat rows due to the nature of the equipment or room layout constraints, suggesting the ongoing need for traditional perimeter cooling to support these loads. This paper explains how a cooling system comprised only of row coolers, with no room cooling system, can cool an entire data center, including IT devices that are not in neat rows.
 WP-114 v1	<u>Implementing Energy Efficient Data Centers</u> Electricity usage costs have become an increasing fraction of the total cost of ownership (TCO) for data centers. It is possible to dramatically reduce the electrical consumption of typical data centers through appropriate design of the network-critical physical infrastructure and through the design of the IT architecture. This paper explains how to quantify the electricity savings and provides examples of methods that can greatly reduce electrical power consumption.
 WP-177 v2	<u>Determining the Power, Cooling, and Space Capacities when Consolidating Data Centers</u> When planning the consolidation of multiple data centers into existing data center(s), it is often difficult to establish the various capacities and capabilities of each site's physical infrastructure. This information is a key input to deciding which site(s) will become the "receiving" data center(s). This paper describes how to specify these requirements in standard terms and how to establish current conditions and future capabilities of each data center involved in a consolidation project.
 WP-118 v4	<u>Virtualization and Cloud Computing: Optimized Power, Cooling, and Management Maximizes Benefits</u> IT virtualization, the engine behind cloud computing, can have significant consequences on the data center physical infrastructure (DCPI). Higher power densities that often result can challenge the cooling capabilities of an existing system. Reduced overall energy consumption that typically results from physical server consolidation may actually worsen the data center's power usage effectiveness (PUE). Dynamic loads that vary in time and location may heighten the risk of downtime if rack-level power and cooling health are not understood and considered. Finally, the fault-tolerant nature of a highly virtualized environment could raise questions about the level of redundancy required in the physical infrastructure. These particular effects of virtualization are discussed and possible solutions or methods for dealing with them are offered.
 WP-150 v3	<u>Power and Cooling Capacity Management for Data Centers</u> High density IT equipment stresses the power density capability of modern data centers. Installation and unmanaged proliferation of this equipment can lead to unexpected problems with power and cooling infrastructure including overheating, overloads, and loss of redundancy. The ability to measure and predict power and cooling capability at the rack enclosure level is required to ensure predictable performance and optimize use of the physical infrastructure resource. This paper describes the principles for achieving power and cooling capacity management.
 WP-200 v0	<u>Impact of Leading Power Factor on Data Center Generator Systems</u> IT devices may exhibit electrical input current with a characteristic called "leading power factor". This situation may cause back-up generators to become unstable and shut down. Furthermore, a data center that is operating correctly for a long time may suddenly develop a problem as the IT load changes over time, or during an unusual event. This means that it is important to understand the margin of safety and correct for this condition before it happens. This paper explains the problem, why and how it occurs, and how to detect and correct it.
 WP-2 v0	<u>Top 10 Mistakes in Data Center Operations: Operating Efficient and Effective Data Centers</u> How can you avoid making major mistakes when operating and maintaining your data center(s)? The key lies in the methodology behind your operations and maintenance program. All too often, companies put immense amounts of capital and expertise into the design of their facilities. However, when construction is complete, data center operations are an afterthought. This whitepaper explores the top ten mistakes in data center operations.
 WP-104 v3	<u>Classification of Data Center Infrastructure Management (DCIM) Tools</u> Data centers today lack a formal system for classifying software management tools. As a result, confusion exists regarding which management systems are necessary and which are optional for secure and efficient data center operation. This paper divides the realm of data center management tools into four distinct subsets and compares the primary and secondary functions of key subsystems within these subsets. With a classification system in place, data center professionals can begin to determine which physical infrastructure management tools they need – and don't need – to operate their data centers.
 WP-126 v1	<u>An Improved Architecture for High-Efficiency, High-Density Data Centers</u> Data center power and cooling infrastructure worldwide wastes more than 60, 000, 000 megawatt-hours per year of electricity that does no useful work powering IT equipment. This represents an enormous financial burden on industry, and is a significant public policy environmental issue. This paper describes the principles of a new, commercially available data center architecture that can be implemented today to dramatically improve the electrical efficiency of data centers.
 WP-42 v4	<u>Ten Cooling Solutions to Support High-density Server Deployment</u> High-density servers offer a significant performance per watt benefit. However, depending on the deployment, they can present a significant cooling challenge. Vendors are now designing servers that can demand over 40 kW of cooling per rack. With most data centers designed to cool an average of no more than 2 kW per rack, innovative strategies must be used for proper cooling of high-density equipment. This paper provides ten approaches for increasing cooling efficiency, cooling capacity, and power density in existing data centers.
 WP-103 v0	<u>How Monitoring Systems Reduce Human Error in Distributed Server Rooms and Remote Wiring Closets</u> Surprise incidences of downtime in server rooms and remote wiring closets lead to sleepless nights for many IT managers. Most can recount horror stories about how bad luck, human error, or just simple incompetence brought their server rooms down. This paper analyzes several of these incidents and makes recommendations for how a basic monitoring system can help reduce the occurrence of these unanticipated events.
 WP-158 v2	<u>Guidance for Calculation of Efficiency (PUE) in Data Centers</u> Before data center infrastructure efficiency can be benchmarked using PUE or other metrics, there must be agreement on exactly what power consumptions constitute IT loads, what consumptions constitute physical infrastructure, and what loads should not be counted. Unfortunately, commonly published efficiency data is not computed using a standard methodology, and the same data center will have different efficiency ratings when different methodologies are applied. This paper explains the problem and describes a standardized method for classifying data center loads for efficiency calculations.
 WP-210 v0	<u>Single Phase UPS Management, Maintenance, and Lifecycle</u> "How long will my battery last?" and "what is the best practice for maintaining my UPS?" are very common questions posed from UPS owners. Few realize there is more to the UPS than just battery back-up; and that, like all electronics it has a life expectancy. Many of the factors that affect battery life also affect UPS electronics. Some factors may be controlled by taking some preventative measures or simply adjusting some basic UPS settings. This whitepaper discusses the key factors that influence both battery and UPS life; and provides some simple recommendations and guidelines to help you manage your single phase UPS to maximize the life and overall availability.
	<u>Choosing Between Room, Row, and Rack-based Cooling for Data Centers</u> Latest generation high density and variable density IT equipment create conditions that traditional data center cooling was never intended to address. Building traditional systems that can provide sufficient and immediate Room and Rack-based cooling

WP-130 v2	intended to address, resulting in cooling systems that are oversized, inefficient, and unprecise. Room, row, and rack-based cooling methods have been developed to address these problems. This paper describes these improved cooling methods and provides guidance on when to use each type for most next generation data centers.
 WP-161 v1	Allocating data center energy costs and carbon to IT users Are complicated software and instrumentation needed to measure and allocate energy costs and carbon to IT users? Or can we get by with simple, low cost methods for energy cost and carbon allocation? How precise do we need to be? This paper provides an overview of energy cost and carbon allocation strategies and their precision. We show that it is both easy and inexpensive for any data center, large or small, new or old, to get started allocating costs and carbon, but the expense and complexity escalate and ROI declines when excessive precision is specified.
 WP-127 v3	A Quantitative Comparison of High Efficiency AC vs. DC Power Distribution for Data Centers This paper presents a detailed quantitative efficiency comparison between the most efficient DC and AC power distribution methods, including an analysis of the effects of power distribution efficiency on the cooling power requirement and on total electrical consumption. The latest high efficiency AC and DC power distribution architectures are shown to have virtually the same efficiency, suggesting that a move to a DC-based architecture is unwarranted on the basis of efficiency.
 WP-155 v0	Calculating Space and Power Density Requirements for Data Centers The historic method of specifying data center power density using a single number of watts per square foot (or watts per square meter) is an unfortunate practice that has caused needless confusion as well as waste of energy and money. This paper demonstrates how the typical methods used to select and specify power density are flawed, and provides an improved approach for establishing space requirements, including recommended density specifications for typical situations.
 WP-134 v2	Deploying High-Density Pods in a Low-Density Data Center Simple and rapid deployment of self-contained, high-density pods within an existing or new low-density data center is possible with today's power and cooling technology. The independence of these high-density pods allow for predictable and reliable operation of high-density equipment without a negative impact on the performance of existing low-density power and cooling infrastructure. A side benefit is that these high-density pods operate at much higher electrical efficiency than conventional designs. Guidance on planning design, implementation, and predictable operation of high-density pods is provided.
 WP-116 v2	Standardization and Modularity in Data Center Physical Infrastructure Failure to adopt modular standardization as a design strategy for data center physical infrastructure (DCPI) is costly on all fronts: unnecessary expense, avoidable downtime, and lost business opportunity. Standardization and its close relative, modularity, create wide-ranging benefits in DCPI that streamline and simplify every process from initial planning to daily operation, with significant positive effects on all three major components of DCPI business value – availability, agility, and total cost of ownership.
 WP-151 v0	Review of Four Studies Comparing Efficiency of AC and DC Distribution for Data Centers DC is proposed for use in data centers as an alternative to AC distribution primarily based on publicized claims of efficiency improvements and energy savings. This paper shows that the most widely cited values for quantitative improvements are wrong and grossly overstate the efficiency differences between AC and DC, and that the latest AC and DC systems provide effectively the same efficiency. This paper compares the results of four different publicized studies and explains the assumptions and mistakes that have led to erroneous but widely circulated beliefs about the efficiency benefits of DC power distribution.
 WP-29 v6	Rack Powering Options for High Density Alternatives for providing electrical power to high density racks in Data Centers and Network Rooms are explained and compared. Issues addressed include quantity of feeds, single-phase vs. three-phase, number and location of circuit breakers, overload, selection of plug types, selection of voltage, redundancy, and loss of redundancy. The need for the rack power system to adapt to changing requirements is identified and quantified. Guidelines are defined for rack power systems that can reliably deliver power to high density loads while adapting to changing needs.
 WP-143 v1	Data Center Projects: Growth Model Long term data center or network room capacity planning may seem impossible in the face of evolving IT technology and business requirements. Nevertheless, data center facilities have a lifetime that may span many generations of IT equipment, so planning – or lack of planning – can have a large impact on the effectiveness of investments. Many unnecessary costs can be avoided with simple planning strategies, and even uncertainty itself can be incorporated into a plan. This paper shows a simple and effective way to develop a capacity plan for a data center or network room.
 WP-43 v3	Dynamic Power Variations in Data Centers and Network Rooms The power requirement required by data centers and network rooms varies on a minute by minute basis depending on the computational load. This magnitude of this variation has grown and continues to grow dramatically with the deployment of power management technologies in servers and communication equipment. This variation gives rise to new problems relating to availability and management.
 WP-6 v4	Determining Total Cost of Ownership for Data Center and Network Room Infrastructure An improved method for measuring total cost of ownership (TCO) of data center and network room physical infrastructure and relating these costs to the overall Information Technology infrastructure is described, with examples. The cost drivers of TCO are quantified. The largest cost driver is shown to be unnecessary unabsorbed costs resulting from the oversizing of the infrastructure.
 WP-176 v1	Energy Savings Performance Contracts for Federal Data Center Consolidation The cost of operating and maintaining federal agency data centers is extremely high. Mandates and initiatives have been put in place to address these costs through energy conservation, but with budgets already strained, the initial capital investment can be a daunting hurdle. This paper describes energy savings performance contracts (ESPCs), explains how to use them as an alternative financing option for consolidation projects, and provides examples.
 WP-128 v2	High-Efficiency AC Power Distribution for Green Data Centers The use of 240 volt power distribution for data centers saves floor space, simplifies power cabling, saves capital cost, reduces weight, and increases electrical efficiency. This paper describes the various configurations for this distribution architecture and quantifies the benefits for the optimal configuration. Note: The methods in this paper only apply in North America and are for problems that are unique to North America.
 WP-131 v1	Improved Chilled Water Piping Distribution Methodology for Data Centers Chilled water remains a popular cooling medium; however leaks in the piping systems are a threat to system availability. High density computing creates the need to bring chilled water closer than ever before to the IT equipment, prompting the need for new high reliability piping methods. This paper discusses new piping approaches which can dramatically reduce the risk of leakage and facilitate high density deployment. Alternative piping approaches and the advantages over traditional piping systems are described.
 WP-44 v4	Improving Rack Cooling Performance Using Airflow Management Blanking Panels Unused vertical space in open frame racks and rack enclosures creates an unrestricted recycling of hot air that causes equipment to heat up unnecessarily. The use of airflow management blanking panels can reduce this problem. This paper explains and quantifies the effects of airflow management blanking panels on cooling system performance.
 WP-141 v1	Data Center Projects: Project Management In data center design/build projects, flaws in project management and coordination are a common – but unnecessary – cause of delays, expense, and frustration. The ideal is for project management activities to be structured and standardized like interlocking building blocks, so all parties can communicate with a common language, avoid responsibility gaps and duplication of effort, and achieve an efficient process with a predictable outcome. This paper presents a framework for project management roles and relationships that is understandable, comprehensive, and adaptable to any size project.
 WP-92 v2	Comparison of Static and Rotary UPS Much confusion exists among data center professionals when deciding whether to deploy static or rotary Uninterruptible Power Supplies (UPS) in their data centers. This paper defines both static and rotary UPS architectures, points out similarities and differences, and analyzes the advantages and disadvantages of each in data center environments.
 WP-127 v4	Energy Efficient Cooling for Data Centers: A Close-Coupled Row Solution The trend of increasing heat densities in data centers has held consistent with advances in computing technology for many years. As power density increased, it became evident that the degree of difficulty in cooling these higher power loads was also increasing. In recent years, traditional cooling system design has proven inadequate to remove concentrated heat loads (20 kW per rack and

	higher). This has driven an architectural shift in data center cooling. The advent of a newer cooling architecture designed for these higher densities has brought with it increased efficiencies for the data center. This article discusses the efficiency benefits of row-based cooling compared to two other common cooling architectures.
 WP-19 v3	Raised Floors vs Hard Floors for Data Center Applications Raised floors were once a standard feature of data centers, but over time a steadily growing fraction of data centers are built on hard floors. Many of the traditional reasons for the raised floor no longer exist, and some of the costs and limitations that a raised floor creates are avoidable by using hard-floor designs. This paper discusses factors to consider when determining whether a data center should use a raised floor or a hard floor design.
 WP-4 v0	The Importance of Critical Site Documentation and Training All studies of downtime in mission-critical environments come to the same conclusion: human error is a leading cause. The most effective way to fight this threat to your business is with the double-edged sword of documentation and training. Properly trained facility personnel understand how the infrastructure works, how to operate and maintain it safely, and how to respond when the equipment does not function as expected. Thorough, accurate, and readily accessible documentation is both the foundation of this knowledge and the means to implement it. The establishment of a comprehensive documentation and training program is a crucial, but rarely achieved goal. This white paper describes the proper methodology for building an effective, organized program that addresses the special requirements of critical environments.
 WP-58 v2	Humidification Strategies for Data Centers and Network Rooms The control of humidity in Information Technology environments is essential to achieving high availability. This paper explains how humidity affects equipment and why humidity control is required. Quantitative design guidelines for existing and new computing installations are discussed. Alternative methods to achieve desired humidity are described and contrasted. The difficult issue of how and where humidity should be measured is explained. The hidden costs associated with over-humidification are described.
 WP-49 v2	Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms Avoidable mistakes that are routinely made when installing cooling systems and racks in data centers or network rooms compromise availability and increase costs. These unintentional flaws create hot-spots, decrease fault tolerance, decrease efficiency, and reduce cooling capacity. Although facilities operators are often held accountable for cooling problems, many problems are actually caused by improper deployment of IT equipment outside of their control. This paper examines these typical mistakes, explains their principles, quantifies their impacts, and describes simple remedies.
 WP-61 v0	Electrical Distribution Equipment in Data Center Environments IT professionals who are not familiar with the concepts, terminology, and equipment used in electrical distribution, can benefit from understanding the names and purposes of equipment that support the data center, as well as the rest of the building in which the data center is located. This paper explains electrical distribution terms and equipment types and is intended to provide IT professionals with useful vocabulary and frame of reference.
 WP-117 v1	Data Center Physical Infrastructure: Optimizing Business Value To stay competitive in today's rapidly changing business world, companies must update the way they view the value of their investment in data center physical infrastructure (DCPI). No longer are simply availability and upfront cost sufficient to make adequate business decisions. Agility, or business flexibility, and low total cost of ownership have become equally important to companies that will succeed in a changing global marketplace.
 WP-145 v1	The Top 9 Mistakes in Data Center Planning Why do so many data center builds and expansions fail? This white paper answers the question by revealing the top 9 mistakes organizations make when designing and building new data center space, and examines an effective way to achieve success through the Total Cost of Ownership (TCO) approach.
 WP-179 v1	Data Center Temperature Rise During a Cooling System Outage The data center architecture and its IT load significantly affect the amount of time available for continued IT operation following a loss of cooling. Some data center trends such as increasing power density, warmer supply temperatures, the "right-sizing" of cooling equipment, and the use of air containment may actually increase the rate at which data center temperatures rise. However, by placing critical cooling equipment on backup power, choosing equipment with shorter restart times, maintaining adequate reserve cooling capacity, and employing thermal storage, power outages can be managed in a predictable manner. This paper discusses the primary factors that affect transient temperature rise and provides practical strategies to manage cooling during power outages.
 WP-55 v3	The Different Types of Air Distribution for IT Environments There are nine basic approaches to distribute air in data centers and network rooms. These approaches vary in performance, cost, and ease of implementation. These approaches are described along with their various advantages. The proper application of these air distribution types is essential knowledge for Information Systems personnel as well as Facilities Managers.
 WP-182 v0	The Use of Ceiling-Ducted Air Containment in Data Centers Ducting hot IT-equipment exhaust to a drop ceiling can be an effective air management strategy, improving the reliability and energy efficiency of a data center. Typical approaches include ducting either individual racks or entire hot aisles and may be passive (ducting only) or active (include fans). This paper examines available ducting options and explains how such systems should be deployed and operated. Practical cooling limits are established and best-practice recommendations are provided.
 WP-63 v6	AC vs DC Power Distribution for Data Centers DC power distribution has been proposed as an alternative to AC power distribution in data centers, but misinformation and conflicting claims have confused the discussion. A detailed analysis and model show that many of the benefits commonly stated for DC distribution are unfounded or exaggerated. This paper explains why high efficiency AC will likely emerge as the dominant choice for data center power distribution.
 WP-46 v7	Cooling Strategies for Ultra-High Density Racks and Blade Servers Rack power of 10 kW per rack or more can result from the deployment of high density information technology equipment such as blade servers. This creates difficult cooling challenges in a data center environment where the industry average rack power consumption is under 2 kW. Five strategies for deploying ultra-high power racks are described, covering practical solutions for both new and existing data centers.
 WP-140 v1	Data Center Projects: Standardized Process As the design and deployment of data center physical infrastructure moves away from art and more toward science, the benefits of a standardized and predictable process are becoming compelling. Beyond the ordering, delivery, and installation of hardware, any build or upgrade project depends critically upon a well-defined process as insurance against surprises, cost overruns, delays, and frustration. This paper presents an overview of a standardized, step-by-step process methodology that can be adapted and configured to suit individual requirements.
 WP-121 v1	Airflow Uniformity Through Perforated Tiles in a Raised-Floor Data Center Perforated tiles on a raised floor often deliver substantially more or less airflow than expected, resulting in inefficiencies and even equipment failure due to inadequate cooling. In this paper, the impact of data center design parameters on perforated tile airflow is quantified and methods of improving airflow uniformity are discussed. This paper was written jointly by APC and IBM for the ASME InterPACK '05 conference.
 WP-119 v1	Creating Order from Chaos in Data Centers and Server Rooms Data center professionals can rid themselves of messy racks, sub-standard under floor air distribution, and cable sprawl with a minimum of heartache and expense. Whether the data center mess is created over years of mismanagement or whether the cable-choked data center is inherited, solutions for both quick fixes and longer term evolutionary changes exist. This paper outlines several innovative approaches for dealing with the symptoms of chaos and for eliminating the root causes of disorder.
 WP-90 v1	Essential Standby Generator System Requirements for Next Generation Data Centers Effective standby generator system installations must address the known problems and challenges relating to current and past designs. This paper presents a categorized and prioritized overview of generator system challenges and the requirements needed to overcome them.
	Types of Electrical Meters in Data Centers There are several different types of meters that can be designed into a data center, ranging from high precision power quality meters to embedded meters (i.e. in a UPS or PDU). Each has different core functions and applications. This white paper provides guidance

WP-172 v1	on the types of meters that might be incorporated into a data center design, explains why they should be used, and discusses the advantages and disadvantages of each. Example data centers are presented to illustrate where the various meters are likely to be deployed.
 WP-120 v2	Guidelines for Specification of Data Center Power Density Conventional methods for specifying data center density are ambiguous and misleading. Describing data center density using Watts / ft2 or Watts / m2 is not sufficient to determine power or cooling compatibility with high density computing loads like blade servers. Historically there is no clear standard way of specifying data centers to achieve predictable behavior with high density loads. An appropriate specification for data center density should assure compatibility with anticipated high density loads, provide unambiguous instruction for design and installation of power and cooling equipment, prevent oversizing, and maximize electrical efficiency. This paper describes the science and practical application of an improved method for the specification of power and cooling infrastructure for data centers.
 WP-124 v1	Preventive Maintenance Strategy for Data Centers In the broadening data center cost-saving and energy efficiency discussion, data center physical infrastructure preventive maintenance (PM) is sometimes neglected as an important tool for controlling TCO and downtime. PM is performed specifically to prevent faults from occurring. IT and facilities managers can improve systems uptime through a better understanding of PM best practices. This white paper describes the types of PM services that can help safeguard the uptime of data centers and IT equipment rooms. Various PM methodologies and approaches are discussed. Recommended practices are suggested.
 WP-86 v0	Estimating a Data Center's Electrical Carbon Footprint Data center carbon emissions are a growing global concern. The U.S. Environmental Protection Agency (EPA) cites data centers as a major source of energy consumption in the United States. The EPA has set an efficiency target for government data centers: a 20% reduction in carbon footprint by 2011. European Union (EU) members have agreed to cut their combined emissions of greenhouse gases to 8% below the 1990 level by 2012. Data center owners will be increasingly challenged to report their carbon emissions. This paper introduces a simple approach, supported by free web-based tools, for estimating the carbon footprint of a data center anywhere in the world.
 WP-199 v0	How to Fix Hot Spots in the Data Center Data center operators take a variety of actions to eliminate hot spots. Some of these actions result in short term fixes but may come with an energy penalty and some actions may even create more hot spots. Airflow management is an easy and cost effective way to permanently eliminate hot spots while saving energy and can avoid the capital expense of adding more cooling units. This paper describes the root cause of hot spots, recommends methods to identify them, reviews the typical actions taken, and provides the best practices to eliminate them.
 WP-27 v3	Efficiency and Other Benefits of 208 Volt Over 120 Volt Input for IT Equipment Decisions made regarding the distribution of 208V or 120V power to IT equipment can significantly impact overall efficiency of the data center. This paper explores the voltage connection options of 208 volt (V) and 120V for servers in North America and considers the efficiency implications of these choices. This same discussion applies to the use of 200V vs. 100V in Japan.
 WP-48 v1	Comparing Availability of Various Rack Power Redundancy Configurations Transfer switches and dual-path power distribution to IT equipment are used to enhance the availability of computing systems. Statistical availability analysis techniques suggest large differences in availability are expected between the various methods commonly employed. This paper examines various electrical architectures for redundancy that are implemented in today's mission-critical environments. The availability analyses of these various scenarios are then performed and the results are presented. The analysis identifies which approach provides the best overall performance, and how alternatives compare in performance and value.
 WP-144 v1	Data Center Projects: Establishing a Floor Plan A floor plan strongly affects the power density capability and electrical efficiency of a data center. Despite this critical role in data center design, many floor plans are established through incremental deployment without a central plan. Once a poor floor plan has been deployed, it is often difficult or impossible to recover the resulting loss of performance. This paper provides structured floor plan guidelines for defining room layouts and for establishing IT equipment layouts within existing rooms.
 WP-102 v3	Monitoring Physical Threats in the Data Center Traditional methodologies for monitoring the data center environment are no longer sufficient. With technologies such as blade servers driving up cooling demands and regulations such as Sarbanes-Oxley driving up data security requirements, the physical environment in the data center must be watched more closely. While well understood protocols exist for monitoring physical devices such as UPS systems, computer room air conditioners, and fire suppression systems, there is a class of distributed monitoring points that is often ignored. This paper describes this class of threats, suggests approaches to deploying monitoring devices, and provides best practices in leveraging the collected data to reduce downtime.
 WP-5 v0	A Practical Guide to Disaster Avoidance in Mission-Critical Facilities A disaster preparedness plan is crucial to organizations operating in 24/7/365 environments. With zero disruption the goal, management must carefully evaluate and mitigate risks to the physical infrastructure that supports the mission-critical facility. While business continuity planning typically addresses Information Technology, this paper reviews and discusses the requirements of the facility's infrastructure as part of a comprehensive business continuity disaster plan. Without a proper disaster mitigation plan for the facility's infrastructure, the overall business continuity plan is built on a risky foundation. If a natural, human, or technological disaster strikes your facility, are you and your infrastructure prepared? Does your organization have procedures in place to prepare for severe winter storms, earthquakes, tornados, hurricanes, or other disasters? Surviving tomorrow's disaster requires planning today.
 WP-108 v3	Making Large UPS Systems More Efficient As energy resources become scarcer and more expensive, electrical efficiency is becoming a more important performance factor in the specification and selection of large UPS systems. There are three subtle but significant factors that can materially affect a company's cost of operating a UPS system and particularly the electrical bill. Unfortunately, the people who specify systems often fail to recognize these factors, which leads to increased costs to the owner because operational efficiencies are not correctly considered. This paper discusses the common errors and misunderstandings in evaluating UPS efficiency. UPS efficiency curves are explained, compared, and their cost implications quantified.
 WP-40 v3	Cooling Audit for Identifying Potential Cooling Problems in Data Centers The compaction of Information Technology equipment and simultaneous increases in processor power consumption are creating challenges for data center managers in ensuring adequate distribution of cool air, removal of hot air and sufficient cooling capacity. This paper provides a checklist for assessing potential problems that can adversely affect the cooling environment within a data center.
 WP-18 v1	The Seven Types of Power Problems Many of the mysteries of equipment failure, downtime, software and data corruption, are often the result of a problematic supply of power. There is also a common problem with describing power problems in a standard way. This white paper will describe the most common types of power disturbances, what can cause them, what they can do to your critical equipment, and how to safeguard your equipment, using the IEEE standards for describing power quality problems.
 WP-125 v2	Strategies for Deploying Blade Servers in Existing Data Centers When blade servers are densely packed, they can exceed the power and cooling capacities of almost all traditional data centers. This paper explains how to evaluate the options and select the best power and cooling approach for a successful and predictable blade deployment.
 WP-98 v0	The Role of Isolation Transformers in Data Center UPS Systems Most modern UPS systems do not include the internal transformers that were present in earlier designs. This evolution has increased efficiency while decreasing the weight, size, and raw materials consumption of UPS systems. In the new transformerless UPS designs, the transformers are optional and can be placed in the best location to achieve a required purpose. In older designs, transformers were typically installed in permanent positions where they provided no benefit, reduced system efficiency, or were not optimally located. This paper considers the function of transformers in UPS systems, when and how transformers should be used, and how the absence of internal transformers in newer UPS designs frequently improves data center design and performance.
	Guidelines for Specification of Data Center Criticality / Tier Levels A framework for benchmarking a future data center's operational performance is essential for effective planning and decision making. Currently available criticality or tier methods do not provide defensible specifications for validating data center performance. An

WP-122 v2	appropriate specification for data center criticality should provide unambiguous defensible language for the design and installation of a data center. This paper analyzes and compares existing tier methods, describes how to choose a criticality level, and proposes a defensible data center criticality specification. Maintaining a data center's criticality is also discussed.
 WP-178 v0	A Framework for Developing and Evaluating Data Center Maintenance Programs Inadequate maintenance and risk mitigation processes can quickly undermine a facility's design intent. It is, therefore, crucial to understand how to properly structure and implement an operations and maintenance (O&M) program to achieve the expected level of performance. This paper defines a framework, known as the Tiered Infrastructure Maintenance Standard (TIMS), for aligning an existing or proposed maintenance program with a facility's operational and performance requirements. This framework helps make the program easier to understand, communicate, and implement throughout the organization.
 WP-250 v0	Guide for Reducing Data Center Physical Infrastructure Energy Consumption in Federal Data Centers In an effort to create a clean energy economy, recent US presidents and congress have issued a series of legislation and executive orders requiring federal agencies to increase energy efficiency and reduce carbon emissions in government facilities. Vivek Kundra, Federal Chief Information Officer, is supporting that effort by establishing a Federal Data Center Consolidation Initiative to help reduce energy consumption in over 1,100 Federal data centers. US Federal data center managers are on a timeline to respond with their final consolidation plan. This paper analyzes the implication of these mandates and offers recommendations for how to improve energy efficiency in Federal data centers. This paper is written for a US-only audience.
 WP-112 v1	Performing Effective MTBF Comparisons for Data Center Infrastructure Mean Time Between Failure (MTBF) is often proposed as a key decision making criterion when comparing data center infrastructure systems. Misleading values are often provided by vendors, leaving the user incapable of making a meaningful comparison. When the variables and assumptions behind the numbers are unknown or are misinterpreted, bad decisions are inevitable. This paper explains how MTBF can be effectively used as one of several factors for specification and selection of systems, by making the assumptions explicit.
 WP-78 v1	Mean Time Between Failure: Explanation and Standards Mean Time Between Failure is a reliability term used loosely throughout many industries and has become widely abused in some. Over the years the original meaning of this term has been altered which has led to confusion and cynicism. MTBF is largely based on assumptions and definition of failure and attention to these details are paramount to proper interpretation. This paper explains the underlying complexities and misconceptions of MTBF and the methods available for estimating it.
 WP-111 v2	Reliability Analysis of the APC InfraStruXure Power System The APC InfraStruXure product line offers an alternative architecture to the central UPS. MTechnology, Inc. used the techniques of Probabilistic Risk Assessment (PRA) to evaluate the reliability of the 40 kW InfraStruXure UPS and PDU with static bypass. The calculations considered the performance of the InfraStruXure in both ideal and real-world conditions. The study also compared the performance of the InfraStruXure architecture to that of a central UPS serving a hypothetical 500 kW critical load in a data center. The results showed that the InfraStruXure architecture was significantly less likely to suffer failure of all loads in the data center, and slightly less likely to experience failure in any one piece of IT equipment. This paper summarizes the key findings of MTechnology's quantitative risk assessment and discusses their implications for facility managers and designers.
 WP-82 v2	Physical Security in Mission Critical Facilities Physical security is critical to achieving availability goals of mission critical facilities. Security of the data center accounts for it's surroundings as well as data processing equipment inside and the systems supporting them. In this paper, systems for providing secure facilities are recommended and best practices for physical security are explained.
 WP-65 v2	Comparing Data Center Batteries, Flywheels, and Ultracapacitors Most data center professionals choose lead-acid batteries as their preferred method of energy storage. However, alternatives to lead-acid batteries are attracting more attention as raw material and energy costs continue to increase and as governments become more vigilant regarding environmental and waste disposal issues. This paper compares several popular classes of batteries, compares batteries to both flywheels and ultracapacitors, and briefly discusses fuel cells.
 WP-62 v1	Powering Single-Corded Equipment in a Dual Path Environment The use of dual power path architecture in combination with IT equipment with dual power supplies and power cords is an industry best-practice. In facilities using this approach there are inevitably some IT devices which have only a single power cord. There are a number of options for integrating single-corded devices into a high availability dual path data center. This paper explains the differences between the various options and provides a guide to selecting the appropriate approach.
 WP-52 v1	Four Steps to Determine When a Standby Generator is Needed for Small Data Centers Small data centers and network rooms vary dramatically in regard to the amount of UPS runtime commonly deployed. This paper describes a rational framework for establishing backup time requirements. Tradeoffs between supplemental UPS batteries and standby generators are discussed, including a total cost of ownership (TCO) analysis to help identify which solution makes the most economic sense. The analysis illustrates that the runtime at which generators become more cost effective than batteries varies dramatically with kW and ranges from approximately 20 minutes to over 10 hours.
 WP-73 v1	Reducing the Hidden Costs Associated with Upgrades of Data Center Power Capacity Scaling the power capacity of legacy UPS systems leads to hidden costs that may outweigh the very benefit that scalability intends to provide. A scalable UPS system provides a significant benefit to the Total Cost of Ownership (TCO) of data center and network room physical infrastructure. This paper describes the drawbacks of scaling legacy UPS systems and how scalable rack-based systems address these drawbacks. The cost factors of both methods are described, quantified and compared.
 WP-138 v1	Energy Impact of Increased Server Inlet Temperature The quest for efficiency improvement raises questions regarding the optimal air temperature for data centers. The ASHRAE TC-9.9 committee has recently adopted an extension of the recommended thermal envelope for server inlet temperature and humidity. A popular hypothesis suggests that total energy demands should diminish as the server inlet temperatures increase. This paper tests that hypothesis through the development of a composite power consumption baseline for a mixture of servers as a function of inlet temperature and applying this data to a variety of cooling architectures.
 WP-57 v5	Fundamental Principles of Air Conditioners for Information Technology Every Information Technology professional who is responsible for the operation of computing equipment needs to understand the function of air conditioning in the data center or network room. This introductory paper explains the function of basic components of an air conditioning system for a computer room. The concepts presented here are a foundation for allowing IT professionals to successfully specify, install, and operate critical facilities.
 WP-109 v1	Reliability Analysis of the APC Symmetra MW Power System This paper is a quantitative reliability analysis of the APC Symmetra MW UPS performed by MTechnology, Inc. (MTech). In contrast to common MTBF calculations based on summing component failure rates, this study used techniques of Probabilistic Risk Assessment (PRA) to calculate the likelihood of over 680,000 potential failure modes. The mathematical method accounts for uncertainty in failure rates and component performance, and provides detailed guidance as to the contribution of each system component to the overall risk of failure. The study included an exhaustive analysis of the system's architecture, component selection, control system, manufacturing practices, and response to internal and external faults. The study also included a detailed review of APC's delta conversion online topology.
 WP-72 v1	Five Basic Steps for Efficient Space Organization within High Density Enclosures Organizing components and cables within high density enclosures need not be a stressful, time consuming chore. In fact, thanks to the flexibility of new enclosure designs, a standard for organizing enclosure space, including power and data cables can be easily implemented. This paper provides a five step roadmap for standardizing and optimizing organization within both low and high density enclosures, with special emphasis on how to plan for higher densities.
 WP-22 v4	Understanding EPO and its Downtime Risks An Emergency Power Off (EPO) system is a control mechanism, formally known as a "disconnecting means." It is intended to power down a single piece of electronic equipment or an entire installation from a single point. EPO is employed in many applications such as industrial processes and information technology (IT). This white paper describes the advantages and disadvantages of EPO for protecting data centers and small IT equipment rooms containing uninterruptible power supply (UPS) systems. Various codes and standards that require EPO are discussed. Recommended practices are suggested for the use of EPO with UPS systems.
	Data Center Physical Infrastructure for Radio Frequency Identification (RFID) Systems

WP-89 v1	Radio frequency identification (RFID) technology helps automate a variety of business processes, improving their efficiencies. It generates a huge volume of data that needs to be filtered, processed and stored, and generally requires its own virtual local area network (VLAN). To gain all the promised benefits and return on investment of RFID, the network must be highly available. The data center physical infrastructure (DCPI) must be assessed for vulnerabilities in power, cooling, physical security, and other CCPI elements. Failing to plan for DCPI can lead to disruption of critical business processes resulting in loss of revenue and competitive advantage. This paper provides an understanding of an RFID network and its components, identifies critical DCPI locations, and explains how to plan for high availability.
WP-26 v1	Hazards of Harmonics and Neutral Overloads This document provides an overview of problems related to harmonic currents, with a specific focus on Information Technology equipment. The way that international regulations solved these problems is described.
WP-56 v3	How and Why Mission-Critical Cooling Systems Differ From Common Air Conditioners Today's technology rooms require precise, stable environments in order for sensitive electronics to operate optimally. Standard comfort air conditioning is ill suited for technology rooms, leading to system shutdowns and component failures. Because precision air conditioning maintains temperature and humidity within a very narrow range, it provides the environmental stability required by sensitive electronic equipment, allowing your business to avoid expensive downtime.
WP-8 v2	Inter-system Ground Noise: Causes and Effects Many power-related problems are the result of Inter-System Ground Noise. This problem cannot be corrected using typical AC-only power protection equipment. The cause and solution of Inter-System Ground Noise problems are described.
WP-1 v7	The different types of UPS systems There is much confusion in the marketplace about the different types of UPS systems and their characteristics. Each of these UPS types is defined, practical applications of each are discussed, and advantages and disadvantages are listed. With this information, an educated decision can be made as to the appropriate UPS topology for a given need.
WP-88 v2	Power and Cooling Considerations for Power-over-Ethernet (PoE) Power-over-Ethernet (PoE) can cut costs by enabling, for the first time, the deployment of a single Ethernet cable for simultaneous access to both power and data. However, lack of a power and cooling plan to support the PoE implementation can result in unanticipated downtime. This paper illustrates which power and cooling factors to consider when safeguarding a PoE investment.
WP-37 v7	Avoiding Costs From Oversizing Data Center and Network Room Infrastructure The physical and power infrastructure of data centers and network rooms is typically oversized by more than 100%. Statistics related to oversizing are presented. The costs associated with oversizing are quantified. The fundamental reasons why oversizing occurs are discussed. An architecture and method for avoiding oversizing is described.
WP-59 v2	The Different Technologies for Cooling Data Centers There are 13 basic heat removal methods to cool IT equipment and to transport unwanted heat to the outdoor environment. This paper describes these fundamental cooling technologies using basic terms and diagrams. 11 of these methods rely on the refrigeration cycle as the primary means of cooling. Pumped refrigerant systems provide isolation between the primary heat removal system and IT equipment. The direct air and indirect air methods rely on the outdoor conditions as the primary means cooling making them more efficient for mild climates. The information in this paper allows IT professionals to be more involved in the specification of precision cooling solutions that better align with IT objectives.
WP-89 v1	Power and Cooling for VoIP and IP Telephony Applications Voice Over IP (VoIP) deployments can cause unexpected or unplanned power and cooling requirements in wiring closets and wiring rooms. Most wiring closets do not have uninterruptible power available, and they do not provide the ventilation or cooling required to prevent equipment overheating. Understanding the unique cooling and powering needs of VoIP equipment allows planning for a successful and cost effective VoIP deployment. This paper explains how to plan for VoIP power and cooling needs, and describes simple, fast, reliable, and cost effective strategies for upgrading old facilities and building new facilities.
WP-38 v1	Harmonic Currents in the Data Center: A Case Study This document provides an overview of how problems related to harmonic neutral currents are mitigated by load diversity, with specific focus on Information Technology data center environments. Detailed measurements of an actual operating data center are presented. This case study illustrates the way that load diversity mitigates harmonic current levels, lowers shared neutral current in multi-wire feeders and branch circuits, and improves total circuit power factor.
WP-36 v1	Data Center VRLA Battery End-of-Life Recycling Procedures Contrary to popular belief, the recycling of lead-acid batteries, which are the most common batteries found in data centers, is one of the most successful recycling systems that the world has ever seen. Reputable battery manufacturers, suppliers, and recycling companies have teamed up to establish a mature and highly efficient lead-acid battery recycling process. This paper reviews battery end-of-life options and describes how a reputable vendor can greatly facilitate the safe disposal and recycling of VRLA lead-acid batteries.
WP-15 v1	Watts and Volt-Amps: Powerful Confusion This note helps explain the differences between Watts and VA and explains how the terms are correctly and incorrectly used in specifying power protection equipment.
WP-149 v1	Ten Errors to Avoid When Commissioning a Data Center Data center commissioning can deliver an unbiased evaluation of whether a newly constructed data center will be an operational success or a failure. Proper execution of the commissioning process is a critical step in determining how the data center operates as an integrated system. The documentation produced as a result of commissioning is also the single, most enduring value added deliverable in a data center's operational life. This paper outlines the ten most common errors that prevent successful execution of the commissioning process.
WP-84 v1	Data Center Physical Infrastructure for Enterprise Wireless LANs Wireless LAN (WLAN) deployments can result in unexpected or unplanned power, cooling, management and security requirements. Most wiring closets do not have uninterruptible power supplies (UPS), and they do not provide adequate ventilation or cooling required to prevent equipment overheating. Understanding the unique data center physical infrastructure (DCPI) requirements of WLAN equipment allows planning for a successful and cost effective deployment. This paper explains how to plan for DCPI while deploying indoor WLANs in small, medium or large enterprise, with emphasis on power and cooling. Simple, fast, reliable, and cost effective strategies for upgrading old facilities or building new facilities are described.
WP-86 v2	Power Protection for Digital Medical Imaging and Diagnostic Equipment Medical imaging and diagnostic equipment (MIDE) is increasingly being networked to Picture Archiving and Communications Systems (PACS), Radiology Information Systems (RIS), Hospital Information Systems (HIS), and getting connected to the hospital intranet as well as the Internet. Failing to implement the necessary physical infrastructure can result in unexpected downtime, and safety and compliance issues, which translates into lost revenue and exposure to expensive litigations, negatively affecting the bottom line. This paper explains how to plan for physical infrastructure when deploying medical imaging and diagnostic equipment, with emphasis on power and cooling.
WP-148 v1	Data Center Projects: Commissioning Failure to properly commission a data center leaves the door wide open for expensive and disruptive downtime that could have been avoided. Integrated commissioning of all physical infrastructure components assures maximum data center performance and justifies the physical infrastructure investment. This paper reviews the desired outputs and identifies the standard inputs of the commissioning data center project step. The commissioning process flow is described and critical success factors are discussed. The commissioning process inputs and outputs are also placed in context with other key data center project process phases and steps.
WP-50 v1	Cooling Solutions for Rack Equipment with Side-to-Side Airflow Equipment with side-to-side airflow presents special cooling challenges in the modern data center. Common rack enclosures and rack layouts are fundamentally incompatible with side-to-side cooling, resulting in equipment that receives supply air of excessive temperature. This paper describes the problem along with several side-effects that are not generally appreciated. Various solutions to the problem are described along with their costs and benefits.
	Preventing Data Corruption in the Event of an Extended Power Outage Data corruption is a common problem in data centers, and it can be prevented by implementing a DC and power protection. Data corruption can be prevented by implementing a DC and power protection. Data corruption can be prevented by implementing a DC and power protection.

	WP-10 v3	Despite advances in computer technology, power outages continue to be a major cause of PC and server downtime. Protecting computer systems with Uninterruptible Power Supply (UPS) hardware is part of a total solution, but power management software is also necessary to prevent data corruption after extended power outages. Various software configurations are discussed, and best practices aimed at ensuring uptime are presented.
	WP-23 v1	Reliability Models for Electric Power Systems This white paper explains the sources of downtime in electric power systems and provides an explanation for site-to-site variations in power availability. The factors affecting power quality from generation to the utilization point are summarized. There is a qualitative description of a model, which can be combined with data to provide a method for estimating down time based on site-related factors.
	WP-93 v1	Fundamental Principles of Generators for Information Technology Every Information Technology professional who is responsible for the operation of computing equipment needs to ensure their data center or network room is prepared for extended utility power outages. Understanding the basic functions and concepts of standby generator systems helps provide a solid foundation allowing IT professionals to successfully specify, install, and operate critical facilities. This paper is an introduction to standby generators and subsystems that power a facility's critical electrical loads when the utility cannot.
	WP-113 v2	Electrical Efficiency Modeling for Data Centers Conventional models for estimating electrical efficiency of data centers are grossly inaccurate for real-world installations. Estimates of electrical losses are typically made by summing the inefficiencies of various electrical devices, such as power and cooling equipment. This paper shows that the values commonly used for estimating equipment inefficiency are quite inaccurate. A simple, more accurate efficiency model is described that provides a rational basis to identify and quantify waste in power and cooling equipment.
	WP-31 v8	Battery Technology for Data Centers and Network Rooms: U.S. Fire Safety Codes Related to Lead Acid Batteries Fire safety regulations and their application to UPS battery installations are reviewed. In some cases, fire codes do not clearly recognize improvements in battery safety resulting from changing battery technology. Valve Regulated Lead Acid (VRLA) batteries are frequently deployed within data centers and network rooms without the need for the elaborate safety systems that are required for Vented (Flooded) Lead Acid batteries. Proper interpretation of the fire codes is essential in the design and implementation of data centers and network rooms.
	WP-16 v1	Protection of RS-232 Serial Connections This white paper explains the special power protection issues related to RS-232 cabling. First, the special vulnerabilities of RS-232 cabling are explained. Then appropriate protection and mitigation techniques are provided.
	WP-83 v2	Mitigating Fire Risks in Mission Critical Facilities This paper provides a clear understanding of the creation, detection, suppression, and prevention of fire within mission critical facilities. Fire codes for Information Technology environments are discussed. Best practices for increasing availability are provided.
	WP-79 v1	Technical comparison of On-line vs. Line-interactive UPS designs UPS systems below 5000VA are available in two basic designs: line-interactive or double-conversion on-line. This paper describes the advantages and disadvantages of each topology and addresses some common misconceptions about real-world application requirements.
	WP-115 v1	Accounting and Tax Benefits of Modular, Portable Data Center Infrastructure Well-informed accounting treatment of data center physical infrastructure (DCPI) assets provides significant opportunities to contribute to improving the financial performance of a business, institution, or organization. Design and manufacturing improvements in modular, scalable UPS systems, power distribution units (PDUs), and computer room air conditioners have not only created technological benefits, but provide entirely new DCPI asset management opportunities with direct and measurable financial benefits.
	WP-3 v1	Calculating Total Power Requirements for Data Centers Part of data center planning and design is to align the power and cooling requirements of the IT equipment with the capacity of infrastructure equipment to provide it. This paper presents methods for calculating power and cooling requirements and provides guidelines for determining the total electrical power capacity needed to support the data center, including IT equipment, cooling equipment, lighting, and power backup.
	WP-123 v1	Impact of High Density Hot Aisles on IT Personnel Work Conditions The use of modern enclosed hot aisles to address increasing power densities in the data center has brought into question the suitability of working conditions in these hot aisle environments. In this paper, it is determined that the additional heat stress imposed by such high density IT environments is of minimal concern.
	WP-21 v1	Neutral Wire Facts and Mythology This Technical Note discusses many common misunderstandings about the function of the neutral wire and its relation to power problems. The subjects of dedicated lines, phase reversal, isolation transformers, and grounding are addressed. Various myths are described and criticized.
	WP-96 v1	A Hidden Reliability Threat in UPS Static Bypass Switches IT managers will be surprised to learn that some medium and high power UPS systems on the market today (rated 50 kW and higher) use undersized static bypass switches despite their negative implications. By using a contactor or a circuit breaker in parallel with SCRs, these static bypass switches are able use smaller, less expensive SCRs that are rated to carry less than full load current continuously. This paper shows that the availability of the UPS system is compromised when undersized static bypass switches are employed in the system. The advantages of fully rated static bypass switches are discussed.
	WP-9 v2	Common Mode Susceptibility of Computers This white paper examines and challenges the claims made in literature regarding the alleged high susceptibility of computers to common mode noise.
	WP-60 v2	Avoiding AC Capacitor Failures in Large UPS Systems Most AC power capacitor failures experienced in large UPS systems are avoidable. Capacitor failures can give rise to UPS failure and can in some cases cause critical load drops on stand-alone and paralleled systems. AC capacitor failures have historically been ascribed to unavoidable random failure or supplier defect. However, recent advances in the science of capacitor reliability analysis show that capacitor failures can be controlled by system design. This paper explains AC capacitor failure mechanisms and demonstrates how UPS designers and specifiers can avoid most common AC capacitor failures and the associated consequences.
	WP-11 v3	Explanation of Cooling and Air Conditioning Terminology for IT Professionals As power densities continue to increase in today's data centers, heat removal is becoming a greater concern for the IT professional. Unfortunately, air conditioning terminology routinely used in the cooling industry is unnecessarily complicated. This complexity makes it difficult and frustrating for IT professionals to specify cooling requirements and even makes it difficult to discuss current cooling system performance with contractors, engineers, and maintenance personnel. This paper explains cooling terms in common language, providing an essential reference for IT professionals and data center operators.
	WP-24 v3	Effect of UPS on System Availability This white paper explains how system availability and uptime are affected by AC power outages and provides quantitative data regarding uptime in real-world environments, including the effect of UPS on uptime.
	WP-87 v2	Grounding and the Use of the Signal Reference Grid in Data Centers Signal reference grids are automatically specified and installed in data centers despite the fact that they are no longer needed by modern IT equipment. Even when installed, they are typically used incorrectly. This paper explains the origins of the signal reference grid, the operating principles and limitations, and why they no longer are needed.
	WP-25 v3	Calculating Total Cooling Requirements for Data Centers This document describes how to estimate heat output from Information Technology equipment and other devices in a data center such as UPS, for purposes of sizing air conditioning systems. A number of common conversion factors and design guideline values are also included.
	WP-81 v2	Site Selection for Mission Critical Facilities When selecting a new site or evaluating an existing site, there are dozens of risk factors that must be considered if optimal availability is to be obtained. Geographic, site-related, building, and economic risks need to be understood and mitigated to lessen the downtime effects on your business. In this paper guidelines are established for selecting a new site or assessing an existing one. Common risks

	that affect the availability of a business are defined and techniques for minimizing these risks are presented.
 WP-35 v4	Battery Technology for Data Centers and Network Rooms: Lifecycle Costs The lifecycle cost of different UPS battery technologies is compared. The costs associated with the purchase of batteries, the infrastructure costs, and the costs associated with inflexibility to meet changing requirements are discussed and quantified.
 WP-33 v5	Battery Technology for Data Centers and Network Rooms: Site Planning The choice of UPS battery technology directly impacts site requirements and the costs for protecting information technology and network environments. This paper will discuss how battery technologies impact site requirements.
 WP-17 v1	Understanding Power Factor, Crest Factor, and Surge Factor This white paper explains the technical terms of power factor, crest factor, and surge factor. The use of these terms in specifying UPS is explained.
 WP-20 v1	The Different Types of AC Power Connectors in North America A confusing array of AC power plugs and receptacles exist to deliver power to various electronic loads. This white paper describes the different types of connectors used to power computer equipment in North America. An illustration guide is provided in the appendix to help identify the various connectors by appearance and size.
 WP-39 v2	Battery Technology for Data Centers and Network Rooms: VRLA Reliability and Safety The Valve Regulated lead-Acid (VRLA) battery is the predominant choice for small and medium-sized Uninterruptible Power Supply (UPS) energy storage. This white paper explores how the technology affects overall battery life and system reliability. It will examine the expected performance, life cycle factors, and failure mechanisms of VRLA batteries.
 WP-30 v12	Battery Technology for Data Centers and Network Rooms: Lead-Acid Battery Options The lead-acid battery is the predominant choice for Uninterruptible Power Supply (UPS) energy storage. Over 10 million UPSs are presently installed utilizing Flooded, Valve Regulated Lead Acid (VRLA), and High Density Modular Battery Cartridges (HDBCMBC) systems. This paper discusses the advantages and disadvantages of these three battery technologies.
 WP-85 v1	Data Line Transient Protection Electrical transients (surges) on data lines can destroy computing equipment both in the business and home office environments. Many users appreciate the risk of power surges but overlook data line surges. This white paper explains how transients are created, how they can have devastating effects on electrical equipment, and how surge suppression devices work to help protect against them.
 WP-75 v3	Comparing UPS System Design Configurations There are five principle UPS system design configurations that distribute power from the utility source of a building to the critical loads of a data center. The selection of the appropriate configuration or combination thereof for a particular application is determined by the availability needs, risk tolerance, types of loads in the data center, budgets, and existing infrastructure. This paper will focus on these five configurations; the advantages and disadvantages of each are discussed. The impact on availability is addressed for each configuration and guidelines are provided for choosing the appropriate design.
 WP-32 v7	Battery Technology for Data Centers and Network Rooms: Environmental Regulations Some lead-acid batteries located in data centers are subject to government environmental compliance regulations. While most commercial battery back-up systems fall below required reporting levels, very large UPS and DC plant batteries may have to comply. Failure to comply can result in costly penalties. Environmental compliance regulations focus on the amount of sulfuric acid and lead in a given location. This paper offers a high level summary of the regulations and provides a list of environmental compliance information resources.
 WP-34 v3	Battery Technology for Data Centers and Network Rooms: Ventilation of Lead-Acid Batteries Lead-acid batteries are the most widely used method of energy reserve. Ventilation systems must address health and safety as well as performance of the battery and other equipment in a room. Valve regulated lead acid (VRLA) batteries and modular battery cartridges (MBC) do not require special battery rooms and are suitable for use in an office environment. Air changes designed for human occupancy normally exceed the requirements for VRLA and MBC ventilation. Vented (flooded) batteries, which release hydrogen gas continuously, require a dedicated battery room with ventilation separate from the rest of the building. This paper summarizes some of the factors and U.S. codes to consider when selecting and sizing a ventilation system for a facility in which stationary batteries are installed.
 WP-76 v1	Modular Systems: The Evolution of Reliability Nature proved early on that in complex systems, modular designs are the ones that survive and thrive. An important contributor to this success is the critical reliability advantage of fault tolerance, in which a modular system can shift operation from failed modules to healthy ones while repairs are made. In data centers, modular design has already taken root in new fault-tolerant architectures for servers and storage systems. As data centers continue to evolve and borrow from nature's blueprints, data center physical infrastructure (DCPI) must also evolve to support new strategies for survival, recovery, and growth.