

Energy Efficiency and Availability Management in Consolidated Data Centers

Abstract

The Federal Data Center Consolidation Initiative (FDCCI) was driven by the recognition that growth in the number of Federal data centers was an inefficient use of Federal resources. Consolidation offers the prospect of expanding information technology benefits while reducing their costs to align with declining budget forecasts. Each consolidated data center will manage a larger portion of the Government’s information technology portfolio resulting in proportionately higher mission impact from any infrastructure failure. Similarly, each consolidated data center will have a larger responsibility for minimizing environmental impact and power costs. FDCCI goals will be fully realized only if adequate planning and execution results in high-availability energy-efficient data centers. This paper discusses concepts and tools for planning and managing high-availability energy-efficient consolidated data centers.

Federal Data Center Consolidation Initiative

The Federal Government was an early and aggressive adopter of information technology to improve operational efficiency, effectiveness, and service to citizens. Figure 1 demonstrates a compound annual growth rate of 6.5% in Federal information technology spending¹ from fiscal year 2001 to 2010. Fiscal year 2012 and 2013 budgets project a decline in Federal information

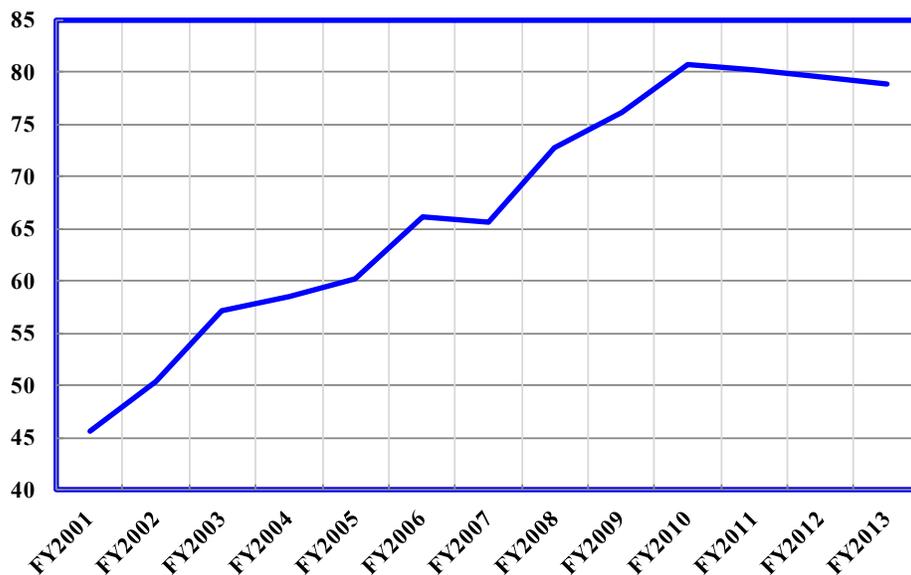


Figure 1: Federal information technology spending (\$billion) by fiscal year

technology spending even as demands on agencies increase.

The Federal Government has been challenged to manage its information technology investments more effectively in legislation such as the Clinger/Cohen Act and guidance such as OMB Circular A-130. More recently the U.S. Chief Information Officer (CIO) launched the Federal Data Center Consolidation Initiative² (FDCCI) to reduce environmental impact, reduce cost, and improve security. The FDCCI was driven by the recognition that growth in Federal data centers from 432 in 1998 to 2094 in 2010 was an inefficient use of Federal resources. Consolidation offers the prospect of expanding information technology benefits while reducing their costs to align with declining budget forecasts.

Each consolidated data center manages a larger portion of the Government's information technology portfolio resulting in higher mission impact from any infrastructure failure ... and larger responsibility for minimizing environmental impact and energy costs.

The FDCCI was incorporated into the U.S. CIO's *25 Point Implementation Plan to Reform Federal Information Technology Management*³ comprising two of the 25 points: complete detailed implementation plans to consolidate at least 800 data centers by 2015; create a government-wide marketplace for data center availability. FDCCI is also a key element in the U.S. CIO's strategy for maximizing the return on investment of Federal information technology⁴.

Each consolidated data center will manage a larger portion of the Government's information technology portfolio resulting in proportionately higher mission impact from any infrastructure failure. Similarly, each consolidated data center will have a larger responsibility for minimizing environmental impact and energy costs. FDCCI goals will be fully realized only if adequate planning and execution results in high-availability energy-efficient data centers. This paper discusses concepts and tools for planning and managing high-availability energy-efficient consolidated data centers

Energy efficient data centers

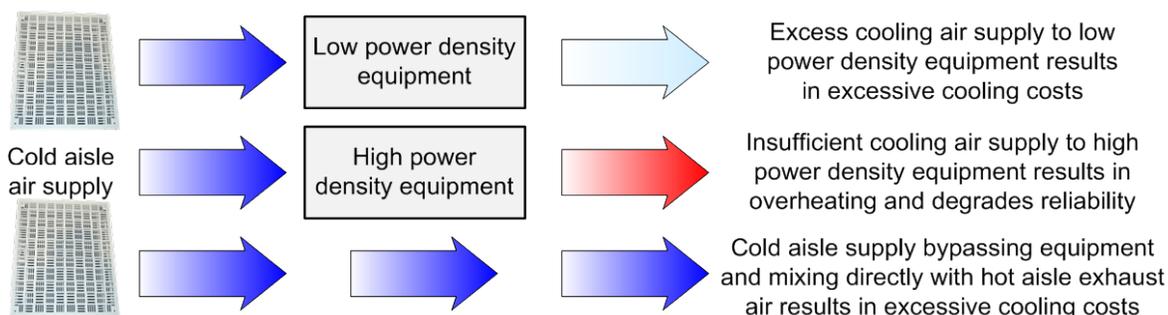
The keys to minimizing energy cost and environmental impact during consolidation are to match the cooling air supply to the heat load at every point in the data center, and to eliminate paths for cold air to bypass equipment and mix with warm exhaust air.

The U.S. Department of Energy National Renewable Energy Laboratory published a comprehensive guide⁵ for building a new data center or renovating an existing data center infrastructure. The guide addresses selecting information technology, environmental standards, cooling systems, and electrical systems.

Most data center managers have already made significant progress transitioning to energy efficient information technology and implementing virtualization to optimize technology utilization and reduce equipment energy demand. As most consolidations will take place in data centers less than ten years old, there will be few cost effective options for modifying electrical or cooling systems.

The keys to minimizing energy cost and environmental impact during consolidation are to match the cooling air supply to the heat load at every point in the data center, and to eliminate paths for cold air to bypass equipment and mix with warm exhaust air. Figure 2 illustrates the three issues to be avoided.

Figure 2: Three issues commonly encountered in data centers



Excess cooling air supply to low power-density equipment results in excessive cooling costs because the equipment does not produce enough heat to make use of the cooling air capacity. Cold air enters the exhaust stream in the hot aisle served no useful purpose. Insufficient cooling air supply to high power-density equipment results in overheating and degrades reliability because the cooling air supply does not have adequate capacity to remove generated heat. Cold aisle supply air bypassing equipment and mixing directly with hot aisle exhaust air, results in excessive cooling costs because the cooling capacity of the supply air is not used for its intended purpose.

Simple and well known as these principles are, few data centers leverage them effectively. Many data centers' power usage effectiveness⁶ (PUE = total facility power / information technology equipment power⁷) exceeds 2.5 implying 2.5 kW of power are delivered to the facility for each 1 kW of power used by the information technology equipment.

The *Uptime Institute 2012 Data Center Industry Survey*⁸ found an average PUE of 1.8 to 1.89 with 9% reporting PUE \geq 2.5 in responses from 1,100 data center owners and operators. Industry averages are likely higher than 1.89 because of the selective survey population and the 29% of enterprises

that do not measure PUE. Reducing PUE from 2.5 to 1.5 cuts the power bill and environmental impact 40% with no mission impact.

The first step in planning an energy-efficient consolidation is to perform an energy audit⁹ of the target data center. Factory-trained professional data center assessors evaluate data center cooling, power, and air handling systems; rack configurations, locations, and heat load; vent tile placement; air duct impedance; vapor barriers; temperature profiles; and air mixing. The audit deliverable includes a detailed report of data center cooling characteristics including a baseline of how the data center is operating with regard to heat rejection from sensitive heat generating computer equipment and heating load versus available cooling capacity.

The assessment applies Computational Fluid Dynamics (CFD) modeling to identify data center cooling problems, recommend solutions, and assess the data center's capability to tolerate failure scenarios. The audit includes an under floor pressure and air flow map, thermal plane map (Figure 3), and specific improvement recommendations.

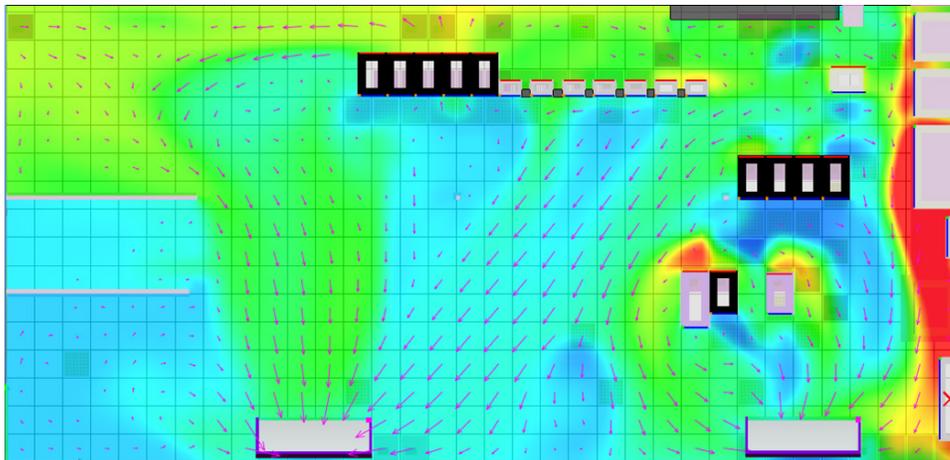


Figure 3: Energy audits evaluate heat sources and cooling to optimize power usage effectiveness¹⁰

The results of the audit drive the PUE improvement plan for existing and consolidation equipment that balances implementation cost with power reduction. The plan considers a broad range of approaches including lighting switch motion sensors, high efficiency lighting, improved hot and cold aisle air containment, environmental sensors which can provide feedback to a central management system that can dynamically adjust the cooling system and humidification, air-side and water-side economizers.

Figure 4 illustrates techniques for avoiding issues illustrated in Figure 2. Individual racks should be loaded with similar equipment and located in the same aisle as other racks with similar power density. Air vent floor tiles are placed to match supply to heat load. This results in uniform cooling of equipment and effective utilization of cooling capacity in each aisle. Occasionally heat load mismatches are unavoidable and must be compensated for by rack air removal units, rack air distribution units, or even rack cooling units.

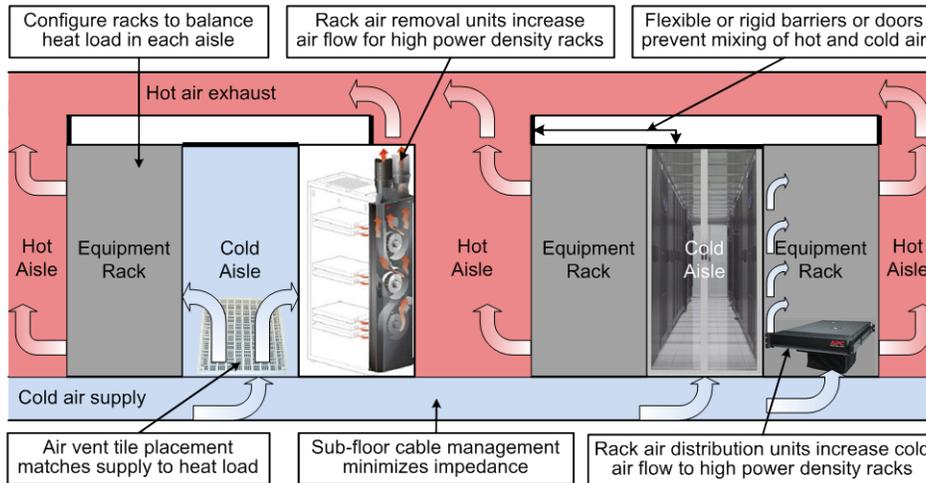


Figure 4: techniques for avoiding data center cooling issues

Preventing cold air from bypassing equipment requires panels covering all unfilled rack space, insulation filling cable sub-floor access openings, and flexible or rigid barriers and doors isolating cold aisles. Minimizing impedance to air flow by managing sub-floor and rack cabling reduces energy consumed by the fans moving supply and exhaust air.

The most aggressive approach to managing cooling air flow inside the data center is the use of prefabricated modules with factory installed racks, cabling, technology components, and air flow management requiring only power, telecommunications, and cooling hookups. In a 2009 video¹¹, Google showcased a new data center housing 45,000 servers in prefabricated shipping container modules (Figure 5) installed in a warehouse quality facility. Google achieved¹² PUE = 1.13 over their global data centers and 1.06 in specific data centers.



Figure 5: Google prefabricated modular data center¹³

Data center software products facilitate planning rack configurations and data center floor layout. They provide an accurate estimate of space, power, and cooling requirements. They enable facility

preparation, sequence planning and scheduling for installation, and establish the configuration management baseline prior to consolidation.

With a detailed plan in place, original data center racks can be reconfigured to both resolve extant power usage issues and accommodate consolidation equipment. The plan ensures that in addition to reduced costs associated with operating from a smaller number of data centers, residual data centers will be operated at optimal PUE.

Managing high availability data centers

With consolidation completed the task shifts to maintaining both the energy efficiency and availability of the consolidated data center. One of the innovations of recent years has been the introduction of data center infrastructure management (DCIM) software¹⁴ to manage the data center infrastructure in much the same way that network management software (e.g., IBM Tivoli, HP OpenView, CA Technologies, CiscoWorks) manages information technology components. By automating the monitoring and control of the data center infrastructure, DCIM improves availability, maintains optimum PUE, and reduces the data center labor force.

By automating the monitoring and control of the data center infrastructure, DCIM improves availability, maintains optimum PUE, and reduces the data center labor force.

DCIM technology enables remote monitoring (Figure 6) and control of data center power, cooling, and air handling systems. Installing DCIM also enables more detailed trending analysis, system health monitoring, environment monitoring, and alarm monitoring for more fine grained management of generators, power conditioning units, fuel levels, transfer switches, UPS battery banks and controls, pumps, and enclosures. DCIM controls on compatible power, cooling, and air handling units enables efficient response to trending towards control limits. Monitoring extends to CPU temperatures and fan speeds to detect problems before they impact information technology performance. Most modern servers provide built-in sensors at these levels.

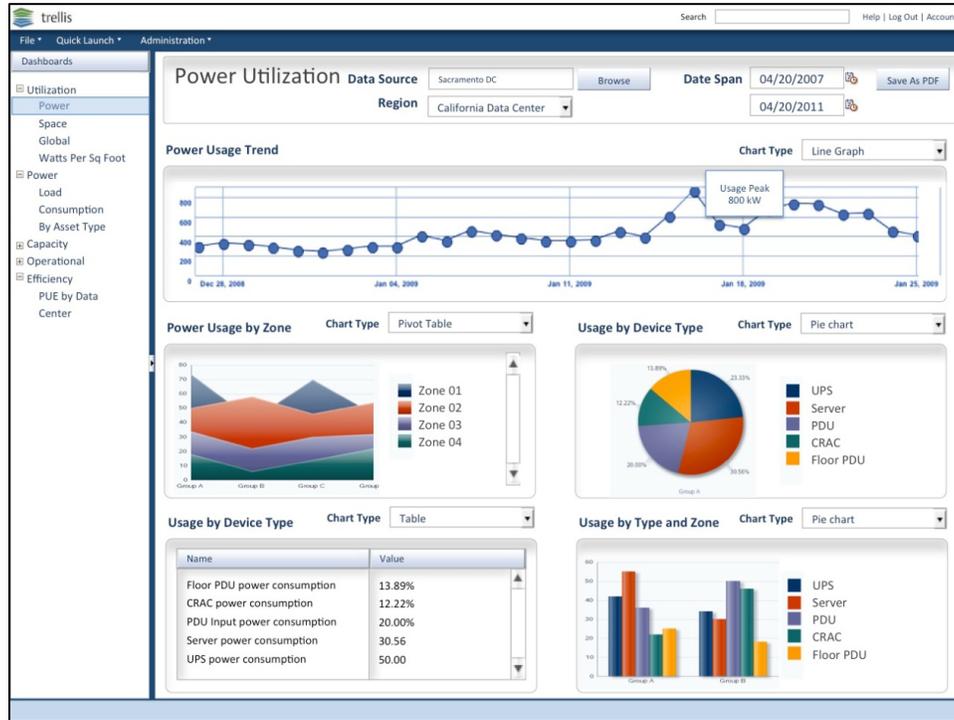


Figure 6 DCIM collects, aggregates and presents critical data and alerts¹⁵

Onsite technicians must access equipment rooms only to install, remove, maintain, or relocate equipment. This reduces the number of personnel located on site in the data center offices; reduces the staff required to monitor and manage data center systems, especially during non-prime shifts; reduces heat load from equipment room lighting; and reduces heat load associated with entry, presence, and egress from equipment rooms.

High availability data centers are all built with redundant backup systems¹⁶ so the failure of a component does not impact operations and so they can continue operating in the absence of external utilities. However, an undetected and unresolved component failure leaves the data center with a single point of failure. Automated monitoring ensures that component failures are identified via alerts as soon as they occur, enabling data center staff to initiate resolution in a timely manner.

For example, if a cooling system pump fails the backup pump sustains operations. Operators may not be aware of the primary pump failure until they perform a system inspection leaving the cooling system with a single point of failure. A DCIM would alert operators as soon as the pump fails, minimizing the time to repair. DCIM also helps prevent human error such as failing to replenish diesel generator fuel tanks depleted during routine testing.

Maintaining proper temperature and humidity is essential to reliable operation of data center located IT equipment and to effective cooling and PUE. DCIM software monitors temperature and humidity sensors and controls temperature and humidity at multiple points in data centers to ensure they remain within specified limits consistent with manufacturer requirements. As technology is refreshed, equipment is moved, or new capabilities are added to the data center, continuous environmental monitoring alerts operators to emerging hot spots or excess cooling enabling timely resolution.

Most data centers experience daily and weekly cyclical computing loads based on user work schedules. Modern information technology equipment can be configured to respond to load variations by shutting down CPUs and hard drives and/or reducing fan speeds. This reduces power consumption and heat load potentially resulting in a mismatch with cooling supply air. Only continuous monitoring can detect these inefficiencies and provide the basis for implementing control responses, such as air supply dampers, to dynamically match cooling supply to heat load.

DCIM systems provide data center operators and managers with the information and control they need to ensure all backup systems are available when needed and cooling is properly matched to heat load. The result is a high availability data center supporting high availability information technology with minimum energy costs and minimum environmental impact.

¹ *Report on Information Technology (IT) Spending for the Federal Government*, www.whitehouse.gov.

² Vivek Kundra, *Memorandum to Chief Information Officers*, February 26, 2010.

³ Vivek Kundra, *25 Point Implementation Plan to Reform Federal Information Technology Management*, www.whitehouse.gov, December 9, 2010.

⁴ Steven VanRoekel, *Federal Information Technology FY 2013 Budget Priorities: Doing More With Less, and Doing More with Less By Consolidating Nearly 1,000 Data Centers*, www.whitehouse.gov, October 07, 2011.

⁵ National Renewable Energy Laboratory, *Best Practices Guide for Energy-Efficient Data Center Design*, <http://www1.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf>, March 2011.

⁶ The Green Grid, *Green Grid Data Center Power Efficiency Metrics: PUE and DCIE*, www.thegreengrid.org, 2008.

⁷ It is instructive to note that installing energy-efficient information technology equipment and implementing virtualization reduce data center energy consumption but do not impact PUE.

⁸ Matt Stansberry, Julian Kudritzki, *Uptime Institute 2012 Data Center Industry Survey*, uptimeinstitute.com.

⁹ For example, see cooling assessments at EmersonNetworkPower.com. The use of Emerson Network Power images and references does not imply any endorsement of Emerson Network Power products or services.

¹⁰ Image courtesy of Emerson Network Power, Liebert Services.

¹¹ www.youtube.com/watch?v=zRwPSFpLX8I

¹² www.google.com/about/datacenters/inside/efficiency/power-usage.html#

¹³ www.youtube.com/watch?v=zRwPSFpLX8I

¹⁴ Forrester Research, Inc., *Market Overview: Data Center Infrastructure Management Solutions*, March 29, 2012, Updated: April 3, 2012.

¹⁵ Image courtesy of Emerson Network Power, Liebert Services.

¹⁶ Uptime Institute, LLC, *Data Center Site Infrastructure Tier Standard: Operational Sustainability*, uptimeinstitute.com, 2010.