

DCOI Compliance: A Guide to Improving PUE in U.S. Federal Data Centers

White Paper 250

Revision 2

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Executive summary

The U.S. government's Data Center Consolidation Initiative (DCOI) requires all Federal agencies and departments to achieve and maintain a PUE of ≤ 1.5 for existing "tiered" data centers. New data centers must design and maintain a PUE of ≤ 1.4 . This paper provides an explanation of the PUE metric, lists factors impacting data center efficiency measurements, and describes ways to improve PUE by reducing energy consumption of power and cooling systems supporting the IT. While DCOI policy only applies to the U.S. government, the suggested improvements would be beneficial to any data center.

Introduction

Tiered vs. Non-tiered

The U.S. Government classifies its data centers as being either “tiered” or “non-tiered”. Tiered are defined as those that use each of the following:

- Separate physical space
- UPS
- Independent cooling system
- Backup power generator

All other sites are considered to be non-tiered. Required PUE monitoring applies to tiered sites.

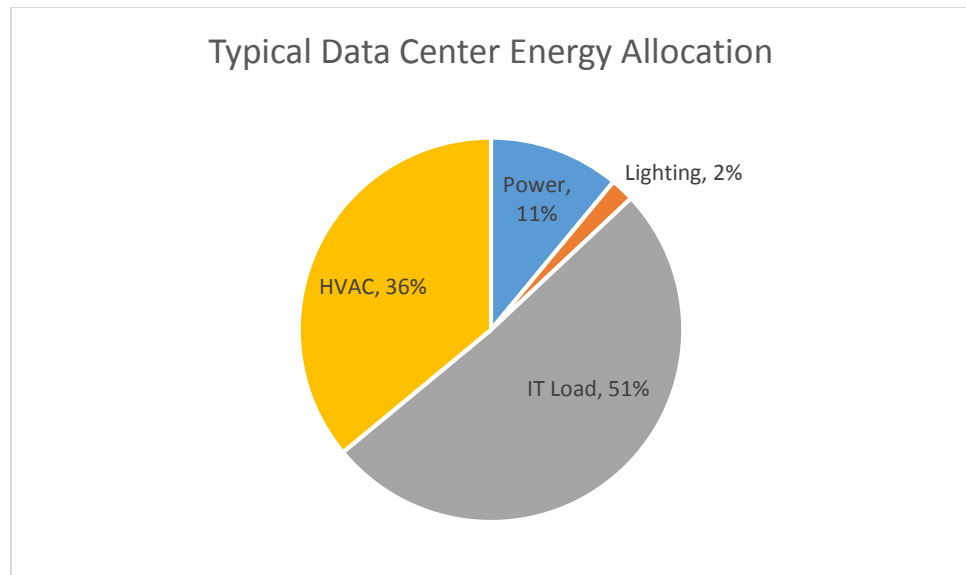
The U.S. Federal Data Center Optimization Initiative, or DCOI, supersedes the Federal Data Center Consolidation Initiative (FDCCI). The FDCCI had promoted the use of Green IT by “reducing the overall energy and real estate footprint of government data centers, reducing the cost of data center hardware, software and operations, increasing the overall security posture of Federal government, and shifting IT investments to more efficient computing platforms and technologies.”¹ DCOI takes this effort a step further by requiring agencies to develop and report on data center strategies to consolidate inefficient infrastructure, optimize existing facilities, achieve cost savings, and transition to more efficient infrastructure such as cloud-based or shared agency IT services.

To enforce compliance, there are several KPIs required that must be regularly reported. There are also certain levels of performance that must be achieved. One such required metric is Power Usage Effectiveness (PUE) which is an indicator of how efficient power and cooling systems are in supporting the IT load of the data center. DCOI requires existing “tiered” data centers (see **sidebar**) to report and maintain a PUE value of 1.5 or less. New data centers must be at 1.4 or less with 1.2 being “encouraged”².

Federal data center stakeholders will have to assess the energy situation within their own particular data centers and then formulate short-term and long-term plans for changes to their existing practices and existing infrastructure. This paper will focus on energy efficiency gains that can be realized through optimization of physical infrastructure (i.e., power and cooling equipment). Physical infrastructure accounts nearly half of the total energy consumption of a typical data center (see Figure 1). Approaches for improving IT equipment efficiency (i.e., servers, storage, telecommunications devices) are NOT within the scope of this paper.

Figure 1

Shows the typical energy allocation in data centers today; reflects a Power Usage Effectiveness (PUE) rating of about 2.



¹ <https://datacenters.cio.gov/>

² https://www.whitehouse.gov/sites/default/files/omb/memoranda/2016/m_16_19_1.pdf

The challenge of improving PUE

Meeting the required PUE levels will be a significant challenge for many existing Federal data centers. Some data centers are saddled with the constraints of outdated facilities (the building that houses the data center), or outdated designs that are not capable of supporting the high densities required for optimum utilization of footprint. They are also faced with existing limits to power capacity and cooling capacities. And virtualization efforts, while lowering overall energy consumption, might have actually made the PUE worse.

The good news on the physical infrastructure side of data center energy consumption, however, is that innovative best practices, utilization of measurement tools, and deployment of modern technology solutions can reduce the data center electric bill by 20-50%. This white paper will discuss the key steps that need to be undertaken in order to achieve the goal of improved data center efficiency and meeting the DCOI PUE performance targets. **White Paper 204**, "[Continuous Monitoring of PUE in Data Centers](#)", describes how to monitor PUE on an on-going basis and discusses the trade-offs of different levels of metering.

How an efficiency assessment and tools can help get started

The first time the efficiency of a data center is measured it should be part of an overall efficiency assessment by experts. In addition to making an efficiency measurement, a data center efficiency assessment typically provides an analysis of the as-built configuration and recommendations regarding efficiency improvement. Ideally, an assessment should provide a mathematical model of the data center as one of its deliverables. A proper assessment can produce the following outputs:

- Identification of problem areas
- Recommendations for quick, inexpensive fixes
- Recommendations for organizing a long term energy efficiency strategy

There are third party companies and some infrastructure vendors like Schneider Electric who offer assessment services that provide these outputs.

Various tools, such as the Schneider Electric Data Center Efficiency Calculator (see **Figure 2**), are available for use for free at <http://tools.apc.com>. These tools are useful for calculation of data center efficiency and carbon footprint rough estimates. The Efficiency Calculator makes it quick and easy to see the impact of implementing a particular power and cooling architecture along with specific efficiency best practices on PUE and energy costs.

Data Center Efficiency Calculator

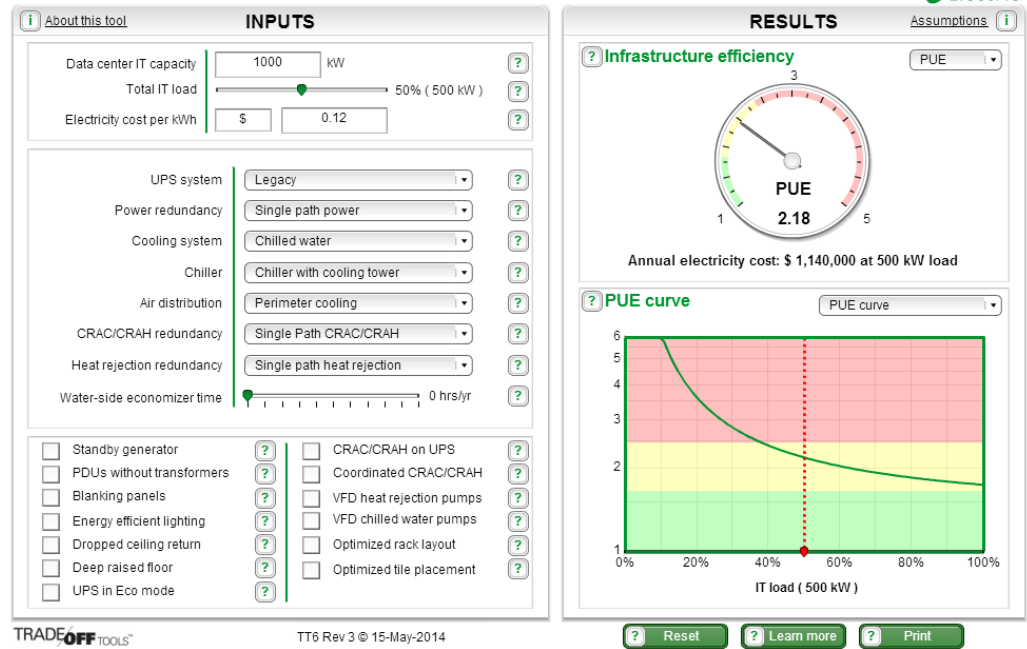


Figure 2

Schneider Electric's free Data Center Efficiency Calculator makes it easy to see the impact of physical infrastructure improvements and change on PUE

Understanding the language of data center efficiency

Data center electrical efficiency is often not planned, monitored, or managed and, as a result, many data centers waste substantial amounts of electricity. Efficiency varies widely across similar data centers, and – even more significant – the actual efficiencies of real installations are well below the practical achievable best-in-class values. In order to address this issue, the industry has largely adopted a common infrastructure efficiency metric in order to compare alternative data center efficiency scenarios. This allows specific data centers to be benchmarked against similar facilities, and to measure progress against internal or external targets, such as DCOI.

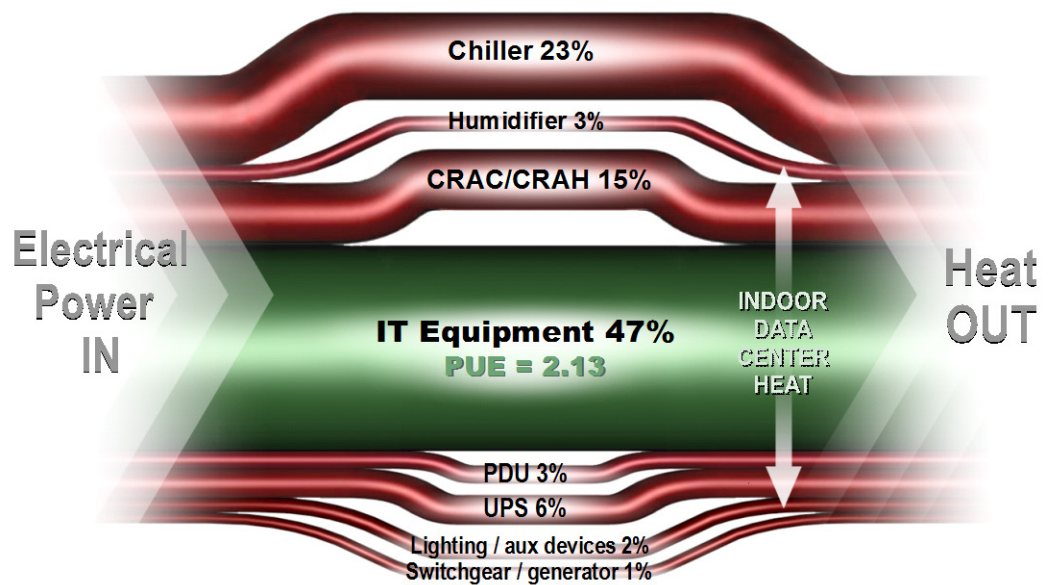
The metric

This commonly-used infrastructure efficiency metric is Power Usage Effectiveness (PUE). It is determined by dividing the total amount of power entering a data center by the amount of power that actually makes it to the data center computer equipment (servers, storage etc.) PUE is expressed as a ratio, with overall efficiency improving as the quotient decreases toward 1. For more information on PUE and efficiency metrics, refer to White Paper 158, [Guidance for Calculation of Efficiency \(PUE\) in Data Centers](#).

Where the power goes

If the “useful” power of the data center (defined by PUE) is the power delivered to the IT loads, where does the rest of the power go? **Figure 3** shows where power flows in a sample data center. Note that virtually all the electrical power feeding the data center ultimately ends up as heat. The data center represented in **Figure 3** is 50% loaded data center, with an “N” configuration for all systems (no redundancy), a traditional uninterruptible power supplies (UPS), as opposed to a new high efficiency UPS, no economizer, perimeter cooling, poor floor layout, poor tile placement. Note that less than half the electrical power feeding this data center actually is delivered to the IT loads. The data center in this example reflects a PUE of 2.1 (47% efficient).

Figure 3
Power in, heat out



The energy consumption of a data center over a period of time is computed using the average of the data center efficiency over that period. Therefore, when we speak about data center infrastructure efficiency (PUE), we really are interested in the average efficiency over a period of time.

PUE measured instantaneously will generally NOT be equal to the annual PUE or, for that matter, to the daily, weekly, or monthly PUE. Single measurements of data center efficiency are inherently inaccurate and should not be used as a basis for benchmarking or efficiency management. For more information on data center energy consumption, see White Paper 154, [Electrical Efficiency Measurement for Data Centers](#)

Factors impacting overall data center efficiency

Conditions in a data center change over time, and this causes the efficiency of the data center to also change over time. Several factors have a major impact on the data center's efficiency:

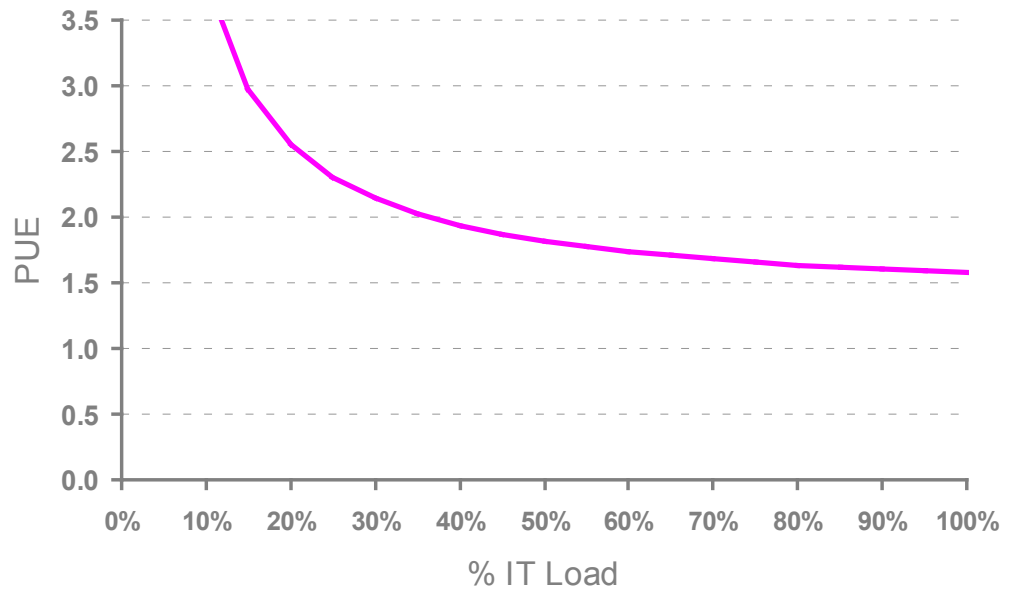
IT load

Power management features, user demand, and automated VM workload management can all cause the IT load to vary moment-to-moment, while the removal and addition of IT equipment by the data center operator causes longer term changes in the IT load. Data centers running low loads are less efficient than data centers running high loads (see **Figure 4**). This is primarily due to fixed losses from the supporting physical infrastructure equipment (e.g., power and cooling). All power and cooling devices have electrical losses (inefficiency) dispersed as heat. A portion of this loss is fixed loss – power consumed regardless of load. At no load (idle), fixed loss is the only power consumed by the device, so 100% of the power consumed is electrical loss (heat) and the device is 0% efficient, doing no useful work. As load increases, the device's fixed loss stays the same and other losses that are tied to the amount of load on the device, collectively called proportional loss, increase in proportion to the amount of load. As load increases, fixed loss becomes a smaller and smaller portion of the total energy used, and as the load decreases, fixed loss becomes a larger portion of total energy used. So it is important to note, PUE can worsen even though overall energy use has been reduced. **If the IT load is reduced – due to consolidation, virtualization, and/or outsourcing – and the physical infrastructure systems are left as they are, PUE will degrade.** For

more information on physical infrastructure power losses, see Schneider Electric **White Paper 113**, [“Electrical Efficiency Modeling for Data Centers”](#).

Figure 4

PUE as a function of IT load



Outdoor conditions

Outdoor conditions are another factor that varies with time and affects data center efficiency. While sunlight, humidity and wind speed can affect efficiency, the most important variable is the outdoor temperature. The efficiency of a typical data center declines as temperature increases. This is because heat rejection systems consume more power when processing the data center heat, and because outdoor heat infiltration into the data center becomes an additional heat load that must be processed.

User configuration and settings

Users take a variety of actions that affect the PUE. Users can change temperature or humidity set points, move or add vented floor tiles, or can fail to clean air filters. These effects are highly variable and depend on the exact design of the power and cooling systems. When the user changes these “settings” – for example, moves a vented floor tile, changes a filter, or changes a temperature set point – the data center design is considered to have been changed and new measurements are required.

Measuring and modeling

Numerous issues exist when attempting to generate an accurate PUE energy efficiency measurement for a data center. These include:

- Certain devices within data centers draw power, but whether their power data should be included in an efficiency calculation is unclear.
- Certain data center subsystems are not present in a given data center (e.g., outdoor lighting or network operations center (NOC)).
- Some subsystems support a mixed-use facility and are shared with other non-data-center functions (for example, cooling towers and chiller plants), so the fraction of power attributable to the data center cannot be directly measured.
- Some subsystems are impractical or costly to instrument (for example, power distribution units (PDUs) due to number of output connections).

- Some power measurement points include loads that are unrelated to a data center but these loads cannot be separated during measurement.

To overcome these problems, the following three-step approach should be implemented:

1. Categorize data center subsystems as either (a) IT load, (b) physical infrastructure, or (c) not included in the calculation.
2. If a subsystem is shared with non-data-center loads, estimate the power using a standardized methodology for that subsystem type.
3. If technical barriers to measurement exist, estimate the power using a standardized methodology for that subsystem type.

For more information on measurement of PUE, refer to **White Paper 158**, “[Guidance for Calculation of Efficiency \(PUE\) in Data Centers](#)”.

Estimate of shared resources

Some data center related devices are a resource that is shared with other entities within a given facility. For example, a data center may share a chiller plant with an office building, or the data center UPS may also provide power to a call center. Even an exact measurement of the energy use of such a shared device is unhelpful in the data center efficiency calculation, because the losses of that device associated with loads other than the data center should not be included in the PUE.

A common approach taken when a device is shared is to simply omit the device from the PUE calculations. This can result in major errors, however, especially if the device is a major energy user such as a chiller. Such an approach invalidates the PUE calculation for bench-marking purposes. A better strategy is to estimate (or indirectly measure) the fraction of the losses of the shared device that are associated with the data center, and then use these losses in the PUE calculations. This approach can yield surprisingly accurate results.

Consider the following example of a shared chiller plant:

1. Measure/estimate the thermal load on the chiller using known electrical losses of all other data center loads. Measure/estimate the chiller efficiency performance. Then use this information to calculate the electrical power the chiller uses for data center loads.
2. Measure/estimate the fractional split of the thermal load between the data center and other loads (using water temp, pressure, pump settings, etc.). Measure the chiller input power, and then allocate the fraction of the chiller power to the data center according to the fractional split.
3. Shut off the non-data center loads on the chiller, and then measure the chiller to determine the chiller power associated with the data center.

These indirect measurements are made during an expert data center energy audit, but can be attempted by sophisticated data center operators. Once the technique is established for a specific data center, it is easy to re-use it over time for efficiency trending.

Estimation of devices impractical to measure

It can be complex, expensive and impractical to measure energy use of some devices. In many cases, indirect measurement and estimation of devices can allow determination of the PUE in a practical and cost-effective manner.

Consider the case of a PDU. In a partially loaded data center, the losses in PDUs can be in excess of 10% of the IT load, with a significant effect on the PUE calculation. Yet most data center operators omit PDU losses in PUE calculations because they are considered too difficult to determine. This can cause a serious error in the PUE calculation.

Fortunately, the losses in a PDU are quite deterministic, in that they can be directly calculated from the IT load if the characteristics of the PDU are provided. The losses of a PDU can therefore be estimated with a high degree of precision if the load is known in watts, amps, or VA. In fact, estimating the losses in this way is typically MORE accurate than using built-in PDU instrumentation.

Once PDU losses are estimated, they are subtracted from the UPS output metering to obtain the IT load, and they are counted as part of the physical infrastructure load in determining the PUE. This simple method improves the accuracy of the PUE calculation when compared to ignoring the PDU losses.

Data center operators need to understand that determining PUE does not require extensive, expensive instrumentation because many losses in a data center can be very effectively estimated by indirect measurement and estimation.

Integration of a mathematical model

A mathematical model is the key to creating a process and system for efficiency management. It is the model that allows understanding of the causes of inefficiency; therefore, the purpose of data center efficiency measurement is to establish the parameters of the efficiency model.

An efficiency model for a data center can be created for an existing data center, or it can be created before a data center is even constructed, if the design and the characteristics of the power, cooling and lighting devices are known. If the model accurately represents the design, the data it provides will be similarly accurate. While the electrical performance of some types of devices, such as lighting, UPS and transformers are very consistent and predictable, many uncertainties exist regarding the as-built performance of devices, such as pumps and air conditioners that cause the model to lose accuracy. This is where measurement can help. For more information on a mathematical model for efficiency management, see **White Paper 154**, [“Electrical Efficiency Measurement for Data Centers”](#).

Data center efficiency best practices

If future data centers are to be more efficient, a number of approaches will have to be implemented. Efficiency optimization must deal with the data center system as a whole (see **Figure 5**). Attempts to optimize the individual inefficiencies will be less effective. The following system-wide practices provide a roadmap for improved data center efficiency:

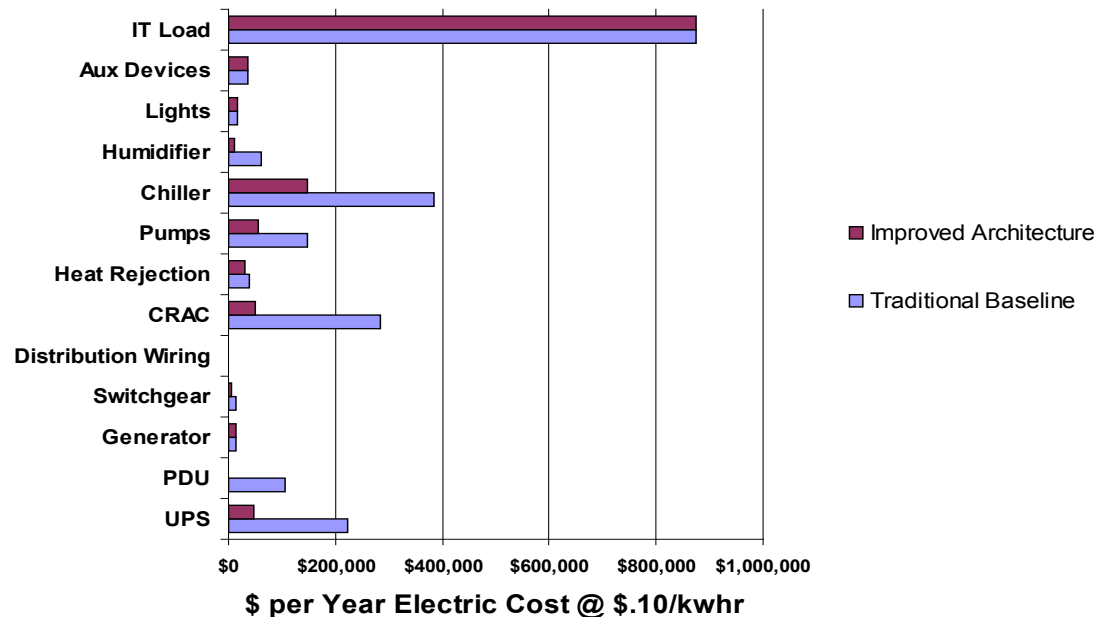
- Powering off unused equipment - Power and cooling equipment that is not needed should not be energized. This includes unused power modules on modular UPSs. These typically can be removed without interrupting power to the load and without requiring specialized personnel.
- Hot aisle / cold aisle arrangement - The rows of racks should be oriented so that the fronts of the servers face each other. In addition, the backs of the rows of racks should also be facing each other. This orientation of rows creates what is known as the “hot aisle / cold aisle” approach to row layout. It helps separate cold supply air with hot return air. Such a layout, if properly organized, can greatly reduce energy losses and also prolong the life of the servers.

- Adding air containment systems to further isolate hot and cold air streams can further improve PUE. Containment of the hot aisle allows increased chilled water temperatures which results in increased economizer hours and significant electrical cost savings. Cooling set points can be set higher while still maintaining a comfortable work environment temperature for people. For existing data centers, however, containing the cold aisle is likely easier to do. Containing the hot aisle also makes it possible to operate the cooling plant in an energy-saving economizer mode for more hours per year than with a cold aisle containment system. Retro-fitting an existing perimeter-cooled, raised floor data center with hot aisle containment system can save 40% in the annual cooling system energy cost corresponding to a 13% reduction in the annualized PUE. See **White Paper 153**, [“Implementing Hot and Cold Aisle Containment in Existing Data Centers”](#) for more information. For new data centers being planned or designed, see **White Paper 135**, [“Impact of Hot and Cold Aisle Containment on Data Center Temperature and Efficiency”](#).
- Operating cooling plants in economizer mode as much as possible. Economizer modes save energy by using outside air during favorable climate conditions to allow refrigerant-based components like chillers and compressors to be shutoff or operated at a reduced capacity. In certain climate conditions, some cooling systems can save over 70% in annual cooling energy costs by operating in economizer mode. This corresponds to a 15% reduction in PUE. **TradeOFF Tool 11**, [“Cooling Economizer Mode PUE Calculator”](#), makes it easy to quickly compare the impact of specific geographies and cooling architectures on PUE, energy cost, and carbon emissions. **White Paper 132**, [“Economizer Modes of Data Center Cooling Systems”](#) describes the different economizer modes and compares their performance against key data center attributes.
- Operating with higher IT inlet temps – With the latest revisions to ASHRAE standard TC9.9 where recommended temperature ranges were increased, there has been industry pressure on operators to raise the IT inlet air temperature set point to higher values. This reduces chiller energy use by increasing the efficiency of the chiller and by allowing it to operate in economizer mode for a longer period of the year. These efficiency gains, however, can be compromised by increased energy use from dry coolers, CRAHs, and from the IT server fans having to spin up faster as a result of the higher server inlet temps. **White Paper 221**, [“The Unexpected Impact of Raising Data Center Temperatures”](#), provides a CAPEX and energy cost analysis of a typical data center to demonstrate the importance of looking at the whole data center holistically inclusive of the IT equipment energy. The impact of raising temperatures on reliability is also considered.
- Tuning redundant systems - Subsystems that must be used below their rated capacity (to support redundancy) should be optimized for their fractional-load efficiency, not for their full-load efficiency. Many modern UPS systems, for example, are now designed to be much more efficient at lower load levels (e.g., 50%) than they used to be capable of.
- Data Center Infrastructure Management tools – DCIM offers capacity management tools to help minimize “stranded capacity” within the data center, allowing the maximum amount of IT equipment to be installed within the gross power and cooling envelope, pushing the system to the highest point on its efficiency curve. An effective capacity management system consists of the tools and rules that allow a data center to operate at a higher density and with smaller safety margins (without compromising safety). For more information on capacity management tools, see **White Paper 150**, [“Power and Cooling Capacity Management for Data Centers”](#).
- Instrumentation to monitor energy consumption - The data center should be instrumented to identify and warn about conditions that generate sub-optimal

electrical consumption, so that energy waste situations can be quickly corrected.

Figure 5

Cost savings of improved architecture broken down by data center subsystem

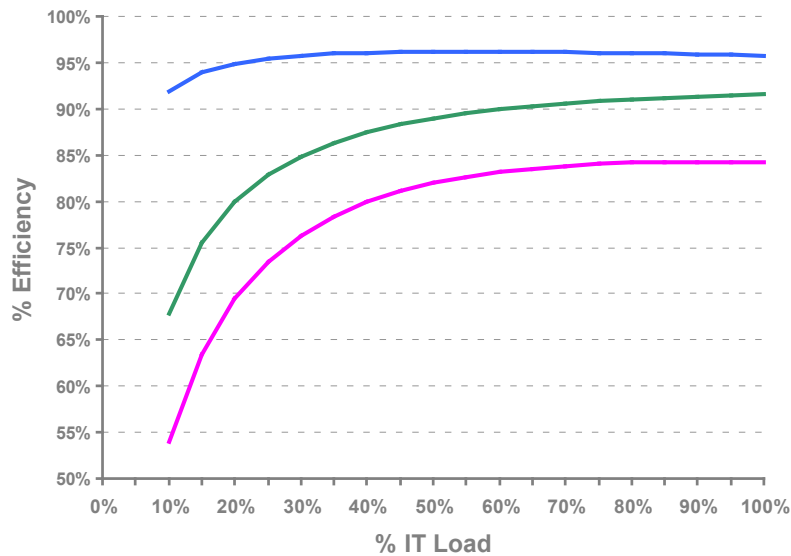


- Scalable power and cooling to enable rightsizing - The use of a scalable power and cooling solution can increase efficiency in smaller data centers or in data centers that are early in their life cycles, as well as defer capital and operating costs until needed. For more information regarding the impact of modularity and scalability, see **White Paper 129**, "[Comparing Data Center Power Distribution Architectures](#)"
- 415/240 V AC power distribution – In North America, sending power to IT loads at 415/240 V AC instead of 208/120 V AC eliminates PDU transformers and their associated losses. In addition to this efficiency gain, the elimination of PDUs reduces copper costs, reduces floor loading and frees up additional space for the IT equipment footprint. For more information on higher voltage distribution, see **White Paper 128**, "[High-Efficiency AC Power Distribution for Green Data Centers](#)".
- High-efficiency UPS - Technologies are now available that substantially increase the efficiency obtainable by UPS systems. **Figure 7** compares efficiencies of high-efficiency UPS to UPS efficiency data published by Lawrence Berkley National Labs³. At 30% load the newest UPS systems pick up over 10% in efficiency when compared to the average of currently installed UPS systems.
- Operating UPS in eco-mode. Many UPSs today offer various energy-saving modes of operation, commonly called "eco-mode". In this mode, the load is typically powered by the bypass path with the UPS inverter only being engaged when the utility mains fail. This results in about a 2% overall data center energy savings making the UPS approximately 99% efficient. **White Paper 157**, "[Eco-mode: Benefits and Risks of Energy-saving Modes of UPS Operation](#)", explains the benefits and concerns that might arise from its use. Situations where these modes are recommended (and not) are also described.

³ LBNL report on UPS efficiency: http://hightech.lbl.gov/documents/UPS/Final_UPS_Report.pdf, Figure 17, page 23. Accessed March 21, 2008.

Figure 7

UPS efficiency as a function of load comparing latest generation UPS to historic published data



- Variable Frequency Drives (VFD) - Many electric motor-driven devices in the data center operate at full speed even when the loads they are supporting require less capacity. Variable frequency drives (VFDs) help to match the output of the fan to the load. The speed control mechanism in these devices helps to maximize efficiency. Fan speed must be adjusted to match the IT load in real time. Both management software and wired and wireless thermal sensors can help in the regulation or control of VFD drives.
- Reference designs – For facility and IT managers in federal data centers, Schneider Electric has created a series of reference design data centers. This is a series of pre-designed data centers that have been optimized to run at high efficiency utilizing existing building and IT room physical infrastructure technologies. Such designs save months in research time and have been pre-tested to perform at the targeted PUE levels.
- Modular, prefabricated solutions - Existing building structures often limit the electrical efficiencies that can be achieved through power and cooling distribution. Manufacturers now offer modular, containerized power and cooling modules that utilize standard power and cooling components, right-sized for the load, and designed to a specific PUE target. Packaged, shipped and installed as a container that plugs into an existing building, these solutions can rapidly increase efficiencies within existing data centers.
- Interior lighting with sensors - High efficiency interior lighting can cut consumption from 1.5 to 3 watts per square foot. Occupancy sensors can increase savings by turning on lights only when the physical space is occupied. Where utility rebates are available, sensors can pay for themselves in less than one year, but most pay for themselves in two to three years without rebates. Savings will vary depending on the area size, type of lighting and occupancy pattern.

Of all of the efficiency techniques available to users (refer to **Table 1** for partial list), right-sizing the physical infrastructure system to the load has the most impact on physical infrastructure electrical consumption. Scalable physical infrastructure solutions that can grow with IT load offer a major opportunity to reduce electrical waste and costs. Right-sizing has the potential to eliminate up to 50% of the electrical bill in real-world installations. The compelling economic advantage of right-sizing is a key reason why the industry has been moving toward modular, scalable physical infrastructure solutions.

Table 1

Range of achievable electrical savings (partial list)

	Energy savings	Guidance	Limitations
Right-size physical infrastructure	10 – 30%	<ul style="list-style-type: none"> • Turn—off unused equipment, remove unused UPS power modules • Using a modular, scalable power and cooling architecture • Savings are greater for redundant systems 	<ul style="list-style-type: none"> • For new designs and some expansions
More efficient air conditioner architecture	7 – 15%	<ul style="list-style-type: none"> • Separate cold and hot airstreams with containment • Shorter air paths require less fan power (when uncontained) • CRAC supply and return temperatures are higher, increasing efficiency, capacity, and preventing dehumidification thereby greatly reducing humidification costs 	<ul style="list-style-type: none"> • Hot aisle containment easier for new designs
Economizer modes of air conditioners	4 – 15%	<ul style="list-style-type: none"> • Many air conditioners offer economizer options • This can offer substantial energy savings, depending on geographic location • Some data centers have air conditioners with economizer modes, but economizer operation is disabled 	<ul style="list-style-type: none"> • For new designs if not present • Difficult to retrofit
More efficient floor layout	5 – 12%	<ul style="list-style-type: none"> • Floor layout has a large effect on the efficiency of the air conditioning system • Involves hot-aisle / cold-aisle arrangement with suitable air conditioner locations (White Paper 122) 	<ul style="list-style-type: none"> • For new designs • Difficult to retrofit
More efficient power equipment	4 – 10%	<ul style="list-style-type: none"> • New best-in-class UPS systems have 70% less losses than legacy UPS at typical loads • Light load efficiency is the key parameter, NOT the full load efficiency • Don't forget that UPS losses must be cooled, doubling their costs 	<ul style="list-style-type: none"> • For new designs or retrofits
Coordinate air conditioners	0 – 10%	<ul style="list-style-type: none"> • Many data centers have multiple air conditioners that actually fight each other • One may actually heat while another cools • One may dehumidify while another humidifies • The result is gross waste • May require a professional assessment to diagnose 	<ul style="list-style-type: none"> • For any data center with multiple air conditioners
Locate vented floor tiles correctly	1 -6%	<ul style="list-style-type: none"> • Many vented tiles are located incorrectly in the average data center or the wrong number are installed • Correct locations are NOT intuitively obvious • A professional assessment can ensure an optimal result • Side benefit - reduced hot spots 	<ul style="list-style-type: none"> • Only for data centers using a raised floor • Easy, but requires expert guidance to achieve best result
Install energy efficient lighting	1 – 3%	<ul style="list-style-type: none"> • Turn off some or all lights based on time of day or motion • Use more efficient lighting technology • Don't forget that lighting power also must be cooled, doubling the cost • Benefit is larger on low density or partly filled data centers 	<ul style="list-style-type: none"> • Most data centers can benefit
Install blanking panels	1 – 2%	<ul style="list-style-type: none"> • Decrease server inlet temperature • Also saves on energy by increasing the CRAC return air temperature • Cheap and easy with new snap-in blanking panels 	<ul style="list-style-type: none"> • For any data center, old or new
Variable Frequency Drives (VFD)	1 – 10%	<ul style="list-style-type: none"> • Replaces fixed speed drives • Enhances performance of chillers and pumps • Appropriate controls needed to match IT load and outdoor conditions 	<ul style="list-style-type: none"> • For data centers operated 24X7X365

Conclusion










The Federal Data Center Optimization Initiative requires all government “Tiered” data centers to achieve a PUE of 1.5 or less for existing facilities and 1.4 or less for new sites. This paper lays out a roadmap for improving PUE enough to meet or exceed these requirements. It begins with an assessment to identify problem areas, quick fixes, and recommendations for a longer term efficiency strategy. The paper identifies many best practices that will make a data center more efficient and lower its PUE. Relevant white papers and TradeOFF tools are referenced to provide an in-depth understanding on many of the practices listed.

About the authors

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-  [Continuous Monitoring of PUE in Data Centers](#)
White Paper 204
-  [Guidance for Calculation of Efficiency \(PUE\) in Data Centers](#)
White Paper 158
-  [Electrical Efficiency Measurement for Data Centers](#)
White Paper 154
-  [Electrical Efficiency Modeling for Data Centers](#)
White Paper 113
-  [Implementing Hot and Cold Aisle Containment in Existing Data Centers](#)
White Paper 153
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White Paper 132
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White Paper 221
-  [Power and Cooling Capacity Management for Data Centers](#)
White Paper 150
-  [Comparing Data Center Power Distribution Architectures](#)
White Paper 129
-  [High Efficiency Power Distribution for Green Data Centers](#)
White Paper 128
-  [Eco-mode: Benefits and Risks of Energy-saving Modes of Data Center UPS Operation](#)
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If you are a customer and have questions specific to your data center project:

Contact your Schneider Electric representative at
www.apc.com/support/contact/index.cfm