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FEDERAL ENERGY MANAGEMENT PROGRAM

Guideline for Water and Energy Considerations During Federal Data Center Consolidations

Prepared for the U.S. Department of Energy
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FEMP
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Careful examination of consolidation options and their impact on energy and water efficiency should be part of the evaluation process when deciding which assets to consolidate and where applications will be hosted. Consolidation presents data center owners with opportunities to employ industry energy efficiency best practices to lower both capital and operating costs, while ensuring sustainability through reduced energy and water use. This guideline will assist Federal agencies in making key data center consolidation or optimization decisions.

Introduction

To address the proliferation of computational applications and resulting costs within the Federal government, the Office of Management and Budget (OMB), early in 2010, established the "Federal Data Center Consolidation Initiative" (FDCCI), a government-wide initiative aimed at optimizing computational capability within Federal Agencies. The FDCCI was designed to reduce the overall operational cost and energy use in Federal data centers, consolidate the number of Federal data centers, and reduce overall IT assets, their supporting infrastructure, material, and manpower. Through this initiative, Federal agencies have developed consolidation plans that focus on various aspects of the overall problem: virtualization, consolidation, outsourcing & decommissioning, etc. (optimization). Developing and following these plans can lead to important gains in how the Federal government's computational needs are met.

Since excessive energy and water use represent operating costs that can be reduced, and as excessive use runs counter to the Federal government's sustainability goals, the Federal Energy Management Program (FEMP) funded the Lawrence Berkeley National Laboratory to develop this guideline to provide information to assist Federal agencies in making key data center consolidation or optimization decisions.

What are the desirable energy related attributes of data centers that are, or will become, a consolidation hub?

Following a successful consolidation, improvements in the following attributes and indicators will be evident:

- Overall energy use for a given computational workload will be reduced
- Average PUE (Power Usage Effectiveness) will have improved over pre-consolidation values Real time monitoring equipment and integrated controls will be installed and help to drive further improvements
- Legacy equipment will be replaced and applications virtualized on new equipment where possible
- Average utilization will be improved (factors of 5-10 improvement are common)
- Energy required for storage systems will be optimized (idle discs where possible)
- Workloads will be migrated to well-managed, energy efficient, cloud providers (internal or external) where possible
- Small server rooms, server closets, etc. will be eliminated to the extent possible by consolidating in energy efficient data centers
- Reliability will be increased by centrally managing the data center
- Environmental conditions for air cooled systems and temperatures for liquid cooled systems will be managed to take advantage of manufacturer's ratings and to maximize free cooling
- Energy Star equipment will be provided where available. Energy performance will be a selection criterion in all purchases.

- Unnecessary redundancy and backup will be eliminated
- Heat produced by IT equipment will be beneficially used where possible
- Future growth (or reduction) is scalable in an energy efficient manner
- Staff is trained for energy efficiency awareness/ Data Center Energy Practitioner (DCEP) qualified through DOE's DCEP Program is available
- Fewer staff are required to manage the systems
- Infrastructure redundancy will be optimized taking advantage of redundancy in the network, other back up available, and locating IT resources based upon risk

Guidelines for considering energy and water use:

Following consolidation, overall costs for Federal computing centers are expected to be significantly reduced. This includes many cost elements – e.g. real estate, personnel, maintenance, infrastructure capital equipment, licensing fees, virtualization, etc. – and of course the operational costs for energy and water use, which are the focus of this guide. Outlined below are key energy related considerations to help guide consolidation decisions.

Total cost of ownership analysis

Since the cost of electricity and water is high in energy intensive data centers, decisions for consolidation options should be based upon total cost of ownership evaluations. The cost of power and cooling over the life of the IT equipment is eclipsing the capital cost of IT equipment. The useful life of infrastructure systems can be 10-20 years; thus, making consolidation decisions when considering the life cycle cost of data centers involved may lead to different consolidation decisions. The true cost of a consolidation option can be compared by considering the lifetime operating cost (including energy, water use, maintenance, etc.) along with capital and maintenance costs. Guidance for determining total cost of ownership for a data center is provided by the Green Grid, a data center industry association.

Use of metrics

Energy and water use metrics for data centers have been evolving. The PUE metric defined by the Green Grid is a measure of infrastructure efficiency:

$$PUE = \frac{Total\ Data\ Center\ Power\ or\ Energy}{IT\ Equipment\ Power\ or\ Energy}$$

At minimum, metering to determine total data center power or energy use and the IT equipment power or energy use will be required. Ideally, this information will be displayed in real time for the data center

operator's use. An explanation of PUE reporting at various accuracy levels is provided in the Green Grid white paper: "Recommendations for Measuring and Reporting Overall Data Center Efficiency."[1]

PUE does not consider the efficiency of IT equipment. In fact, if IT equipment efficiency improves, it is possible that PUE will worsen if infrastructure systems are not able to scale with the IT loads. A goal of consolidation should be to incorporate infrastructure systems whose energy use adjusts with IT energy use. For example, if IT equipment energy use is decreased due to virtualization or other measures, infrastructure energy use should also decrease.

Other metrics developed by the Green Grid include Water Utilization Effectiveness (WUE), Carbon Usage Effectiveness (CUE), and Energy Reuse Effectiveness (ERE). Ideally, consolidated centers would be designed or have the capability to optimize water consumption and utilize the heat produced by the IT equipment. The metrics could be used to set goals for the design of the consolidation center. Use of these metrics will provide a measure of how well these strategies are implemented in consolidated centers, and they can be used to track performance over time.[2]

To determine these metrics, appropriate metering will need to be provided. These metrics could be used (where applicable) to inform consolidation decisions by comparing design and /or operation alternatives for various consolidation options. For example, centers being considered for consolidation could be located where there would be a use for the heat that would otherwise be wasted – e.g. heating for office space. In these cases, the energy reuse effectiveness metric can be used in combination with the PUE metric to compare sites.

These metrics can help inform decisions on consolidation based upon relative performance of existing data centers. The metrics can facilitate comparison, help identify better performing centers that can be used for consolidation, and help set targets for further improvement.

Baseline of IT assets

Inventorying IT assets is a first step to baseline existing IT equipment and its energy use. The baseline determines the number of physical IT devices and their energy use, installed applications, utilization, and age of equipment. Commercially available tools can perform an automated inventory and supply much, if not all, of the information that will characterize the IT equipment in use. This information can help inform:

- Candidates for virtualization. By virtualizing many applications onto a single physical device, many devices can be decommissioned, reducing energy and freeing up space, power, and cooling. Tools that measure processor utilization can help identify virtualization candidates.

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[1] This is available through the Green Grid website: .thegreengrid.org/~/media/WhitePapers/Data%20Center%20Metrics%20Task%20Force%20Recommendations%20V2%205-17-2011.pdf?lang=en.

[2] Complete definitions of these metrics can be found on the Green Grid website.thegreengrid.org/

- Decommissioning unused equipment. Studies have shown that IT equipment may be turned on while not performing any useful work. Yet, they are using nearly as much power as they do when processing – especially for older equipment.
- Refreshing of IT equipment. Refreshing equipment will provide exponential improvement in computational ability. Modern equipment is also more likely to have efficient power supplies and advanced power management capabilities. Refreshing equipment in combination with virtualization will allow a greater number of devices to be decommissioned. Purchasing Energy Star equipment when available is required.
- The opportunity to install servers capable of being cooled with warm air or liquid. ASHRAE and the IT manufacturers have published guidelines for warm air or liquid cooling. Use of such equipment can significantly reduce the data center infrastructure cost and result in lower operating cost.

Energy baseline

For consolidation efforts, it is important to understand the energy performance of the existing IT and Infrastructure Systems. Obtaining a baseline of data center energy performance using the DC Pro tool suite developed by the DOE Advanced Manufacturing Office (AMO) provides a starting point to understand energy use in data centers. The DC Pro profiling tool documents the current PUE of the center, which can then be used to compare energy performance among centers involved in the consolidation. Once the PUE is known, it can also be tracked over time as consolidation takes place. The DC Pro tools provide recommended efficiency measures and a projection of PUE improvement once the efficiency measures are adopted. This information can help to determine better data center consolidation candidates to optimize energy use.

To assist data center operators and to provide assurance that energy assessors have the necessary qualifications to evaluate data centers, the DCEP program was developed. This program qualifies individuals to perform energy assessments for data centers through a combination of educational and experience requirements, taking and passing a standardized training curriculum, and receiving refresher training. DCEP qualified individuals are trained on the use of the DC Pro tools and data center best practices. Data centers undergoing consolidation can benefit from having DCEP qualified staff involved with the project.

The following web link provides information on the DOE resources:
eere.energy.gov/manufacturing/datacenters/

Cloud First

Adopting a "Cloud First" philosophy by evaluating the cost and feasibility of hosting applications in a central "cloud," either within the Agency or external to the Agency, can lead to significant energy and cost reductions. Potential savings can be determined by comparing the life cycle cost of various consolidation options to the cost of internal or external cloud solutions. Consolidating to central data centers does not guarantee that the operation will be more efficient; however, efficiencies in larger, well managed centers generally are better. For hosting within an agency, it is more cost effective to implement

efficiency measures as part of the consolidation activity. If the cloud service is hosted by another company or physically hosted in a co-location facility, the host has a financial incentive to improve operation efficiency due to competition with other providers. The energy cost for these types of service providers is passed on to their customers either directly or indirectly by being built into their lease rates, so there is a business driver for energy efficiency. Agencies should require energy performance reporting from their cloud providers in order to compare to the baseline.

Geographic location

With currently available IT equipment, weather conditions can greatly influence the energy efficiency of data center cooling. Today, when consolidation options are considered, climate and its influence on energy efficiency should be considered. Locations where free cooling can be provided much of the year will result in lower energy costs. Consolidation hubs should be selected to maximize free cooling by considering the site location, air or liquid cooling options, and use of environmentally tolerant IT equipment.

The Green Grid organization has published maps and a calculator to help determine the number of hours of free cooling available in the US for any desired operating conditions.[3] An example of one such map is provided below

[3] The Green Grid free cooling tool is available here: thegreengrid.org/Global/Content/Tools/NAmericanFreeCoolingTool

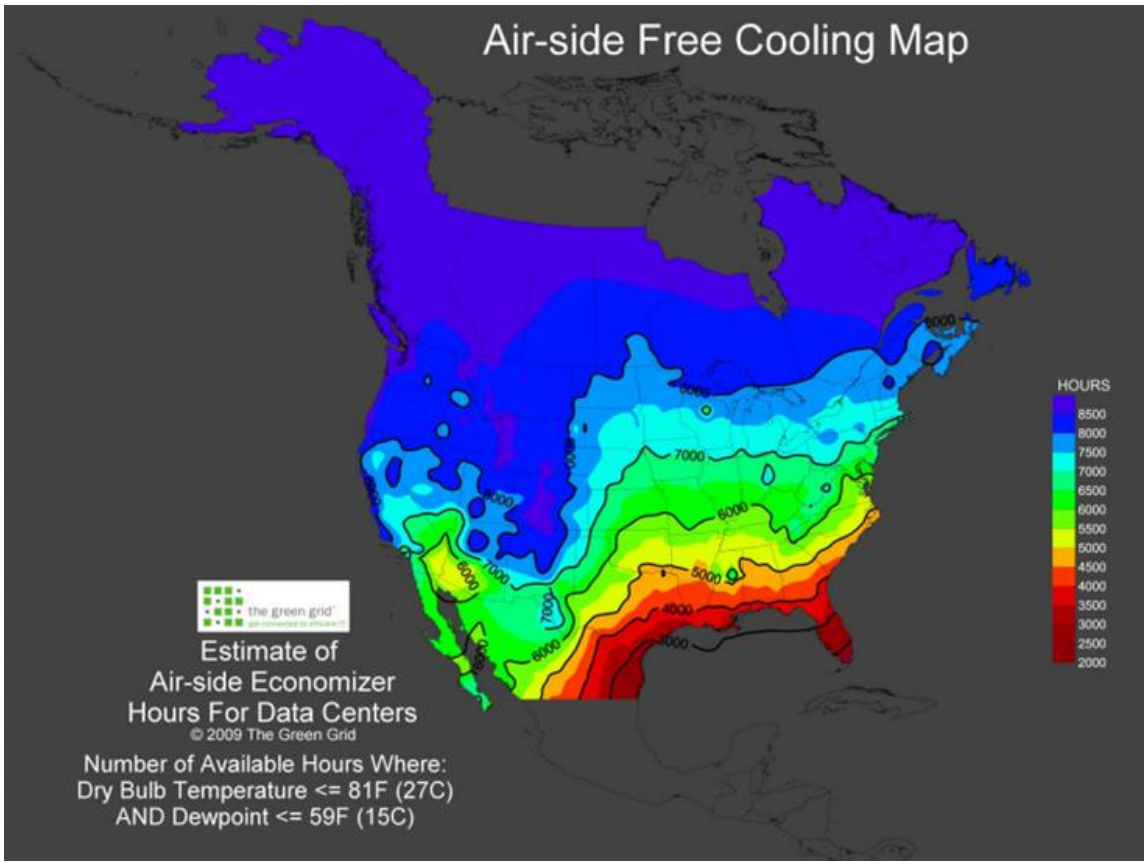

Figure 1: Example of maps provided in the Green Grid tool.

Use of environmentally tolerant IT equipment

ASHRAE, in conjunction with IT equipment suppliers, develops guidelines for thermal conditions required to support reliable operation of air or liquid cooled IT equipment. These guidelines include allowable temperature ranges that are quite high compared to traditional practice. Manufacturers design their equipment to meet or exceed ASHRAE guidelines for various thermal "classes." Cooling system energy use can be dramatically reduced by specifying equipment that is designed to the higher thermal classes' requirements for either air or liquid cooled systems. The highest allowable ranges allow for cooling with 45°C (113°F) air or liquid. By using free cooling strategies using IT equipment designed for these conditions, the need for compressor based cooling in virtually all U.S. locations is eliminated.

Timing consolidations to match refresh cycles

Coordinating data center consolidation with equipment refresh cycles can enable several energy efficiency measures. In addition to the typical efficiency improvement in each successive generation of IT equipment, additional virtualization capacity may be provided and as described below, new equipment can be installed to enable better cooling efficiency.

Improving air management

When existing IT equipment is relocated, or when all new IT equipment is provided in a consolidation effort, opportunity exists to install the equipment with optimal air management (i.e. separation of hot and cool areas). With good air management, the temperature of the air supplied to the IT equipment can be raised because mixing with the hot return air will have been eliminated. Following the latest ASHRAE thermal guidelines will allow for greater efficiency while maintaining reliability. Once the air supply temperature is raised, the cooling systems will not need to work as hard. For example, air temperatures could be set higher and chilled water temperatures could be reset to higher values, and/or chilled water pumps could be operated at slower speeds increasing the efficiency of the chilled water plant. Also, air flow could be adjusted to better meet the needs of the IT equipment. Often, good air management allows a reduction in air flow which can be accomplished with variable speed fans, if equipped, or by turning off unneeded constant speed computer room air conditioners.

Cooling system efficiency

By taking advantage of best practices (e.g. use of free cooling, ASHRAE allowable limits, etc.) cooling systems can be simplified. This should lead to a reduction or elimination of compressor based cooling (e.g. chillers, DX units, in-row coolers, etc.) for many consolidation hubs. This has an added benefit of improving reliability when compressor based systems are eliminated.

Consolidating server closets

In most Federal agencies, as in the private sector, "server closets" have been added over a number of years due to various factors (space availability, proximity to workers, insufficient data center space, etc.). According to industry estimates, the number of servers located in non-data center spaces is about equal to those in controlled data centers. Consolidating servers into centrally managed data centers creates the opportunity to reduce overall energy use because of better performing infrastructure, along with potential virtualization opportunities. Other benefits include improved security, ease of data back-up, and the ability to manage the assets with less staff.

Monitoring energy efficiency progress

Consolidation presents an opportunity to baseline energy use before changes occur, and to follow energy performance of the consolidated data center from day one. A monitoring system is critical to understanding current operations and for discovering additional energy efficiency measures. The content of Data Center Information Management (DCIM) systems varies; however, they are being widely adopted. These systems often include graphical "dashboards" to readily visualize data center performance through key metrics such as real time PUE (power), average PUE (energy), or utilization. Additional system level monitoring provides insight into the efficiency of the various infrastructure systems. Electrical power meters should be provided to measure actual consumption which can then be put into a visual, graphical display for each of the major end use categories:

- IT equipment
- Power distribution losses (UPS, transformers)

- HVAC (fans, pumps, chillers, etc.)
- Standby generator losses
- Lighting
- Other

In addition, environmental monitoring and control will provide information on the effectiveness and efficiency of the HVAC systems.

Review backup and disaster recovery requirements

Data center systems are often designed with redundant and backup equipment to provide assurance for continued operation if one component fails or if there is an interruption to site power. Similarly, IT equipment often has dual power supplies in case one fails. In other cases, entire data centers are backed up by other data centers. All of the extra equipment to provide this assurance consumes energy around the clock. During consolidation is a good time to review the level of backup required by examining the criticality of the processing and fail over mechanisms. For example, if a server failure mechanism is to fail over to another server, servers could be purchased without dual power supplies and the service level would not be affected. Similarly, if some systems need UPS backup and some do not; they could be separated thereby saving the capital cost of the UPS as well as the on-going energy cost for losses in the UPS system. If some equipment was deemed critical enough to warrant back up, it could be separated into critical and noncritical areas and backed up accordingly. In this case the data center could be designed and operated with a mixture of reliability (Uptime Institute TEIR levels).

Modular build-out - build only what is needed with ability to expand

When consolidating, there is an opportunity to move to a modular approach to power delivery and cooling. Often, the IT equipment is added over time and the full power and cooling capability is not needed until much later. By planning for a modular build out, capital cost can be deferred while also minimizing energy use. This can be accomplished in various ways: efforts could involve the use of commercially available modular systems such as in row coolers, or a modular approach could include thoughtful design using more conventional building systems. Containerized data centers represent another option, and enable a modular approach to growth. However, the efficiency of their power and cooling systems varies, so if containers are contemplated, their energy performance needs to be examined. By providing power and cooling in a segmented fashion, capital costs can be limited to only the amount needed - yet provision for future growth can be planned through the addition of modules. This approach can minimize both initial capital cost and, if an efficient design is employed, operational (energy and water) cost throughout the entire building life cycle.

Water use considerations

Data center cooling systems often require large quantities of water that require chemical treatment. In many locations, water is scarce and/or expensive. In these situations use of dry coolers (closed systems), or use of free air cooling could be attractive. Consideration of water availability, treatment requirements, and their cost is an important consideration that should be included in consolidation plans. There could

be a tradeoff between energy and water use. For example, implementing a cooling system that uses evaporative cooling only in a dry climate can dramatically reduce energy use at the expense of water use. Using "dry coolers", however, will minimize water use and may introduce an energy penalty. Dry coolers are not as energy efficient as evaporative coolers and will increase electrical energy use. This less efficient, more energy-intensive cooling could shift the water consumption problem to the power plant. Fossil fuel electrical power plants typically consume large amounts of water for cooling. This means that increased energy use at the data center will result in increased water use at the power plant. If various locations are considered for consolidation, the availability and cost of water and its treatment along with the cooling options' water and energy use need to be considered.

Electrical power grid and utility services

When considering various locations for data center consolidation, the availability, reliability, and power quality of the local electrical utility should be considered. For example, in locations where power can be supplied from two independent substations reliability will be improved. Capacity for load growth as a result of the consolidation should be explored with the local utility. Consolidating to locations that can provide or expand capacity using renewable energy should be considered. Many utilities offer incentives for improved energy efficiency compared to standard practice such as virtualization or other IT load reduction actions.

New construction or retrofit

Energy efficiency strategies are generally applicable for both new construction and retrofit. However, the cost of implementing certain strategies may be prohibitive in certain retrofits, whereas they could be easily implemented at a low cost as part of a new construction project. For example, use of waste heat can be more easily integrated in a new construction project. Life cycle cost for implementation of energy saving measures should be a key decision factor in evaluating consolidation alternatives. The high capital and operating costs of electrical and cooling systems for energy intensive data centers, compared to the cost of the building shell, means that they often dominate in a new construction facility life cycle cost evaluation.

Weighing relative importance in consolidation decisions

There are many competing factors that impact the energy use and carbon footprint in data centers. How would one weigh the various considerations described in this guide? Energy use is affected by many factors - IT hardware assets, utilization and virtualization levels, levels of redundancy, site geographical location, cooling solutions, electrical distribution (redundancy, UPS, medium voltage vs. high voltage), etc. Furthermore, the ability to operate the center efficiently requires sufficient monitoring and the ability to manage the IT and infrastructure.

In order to compare various consolidation options, a ranking criterion is proposed. Figure 2 provides a method to quantify the relative importance of major considerations. Federal agencies can determine their preferred weighting and assign points to each item considering the characteristics of their data centers within the range of the worst to best. Naturally the criterion needs to be based upon total site points using the weighting that the Agency defines. A suggested weighting is shown below:

No	**Parameter**	**Range of points to allocate**	**Worst**	**Best**	**Data center points**
1	PUE	10	3	1	
2	Provision for on-site generation	3	none	all	
3	Energy source	7	Std Utility	renewable	
4	Location – ASHRAE climate zones	5	zone 1	zone 8	
5	Air side economizer hours	6	0	8760	
6	Waterside economizer hours	4	0	8760	
7	Expansion capacity-infrastructure	5	none	300%	
8	Expansion capacity - IT density	6	none	300%	
9	Expansion capacity - DC space	4	none	300%	
10	Cooling system efficiency - kW/ton	4	1.3	0.3	
11	UPS	5	on line double conversion redundant	none or offline	
12	Virtualization potential	5	none	100%	
13	Monitoring and IT energy management potential	5	none	100%	
14	Air management –aisle containment	3	None	100% or liquid-cooled	
15	IT intake air temperature	3	65degF	115degF	
16	Liquid cool percentage	5	none	100%	
17	Variable speed drives	2	none	all	

Figure 2: Proposed criteria ranking method

Modeling data centers

Commercially available software allows modeling of various power and cooling options to see the energy effects of various design options. Existing data centers can be modeled relatively quickly and then "what if" scenarios can be examined for various consolidation options. If consolidation into a new facility is planned, modeling tools can similarly evaluate the relative efficiency of various design options.

Alternative financing of data center energy projects

Federal agency budgeting often becomes a barrier to implementing energy efficiency projects, even if there are reasonable returns on investment. Fortunately there are alternative financing vehicles that Federal Agencies can employ. Energy Service Performance Contracts (ESPCs) and Utility Energy Service Contracts (UESCs) can pay for energy efficiency projects through the energy and related costs saved by the projects. These alternative finance arrangements can enable consolidation projects to proceed and more quickly realize energy savings. The Federal Energy Management Program can assist in facilitating alternative finance solutions.

ESPC and UESC contractors are beginning to enter into data center efficiency contracts. They are most willing to fund the replacement of equipment with known efficiency and operating hours with new equipment of known efficiency such as lights or chillers. Generally these measures are low risk. The contracts are performance contracts that require the contractors to provide a guarantee of performance that result in a costs savings. Due to the constant changes in electrical load in most data centers, the measurement of energy use must be carefully defined to allow for the verification of savings. The contracts have funding thresholds of $1 million or more, and may extend for up to 25 years.

Resources

For more information, please visit:

- FEMP website: eere.energy.gov/femp/program/data_center.html
- LBNL website: lbl.gov/datacenters.html

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