Information Technology Settings and Strategies for Energy Savings in Commercial Buildings

Overview

Currently, there is no "quick start guide" that helps building owners, energy managers, and information technology (IT) equipment operators save energy in their facilities. This guide is a quick reference that harmonizes previous research and directs readers to in-depth tools, websites, databases, and other information.

Conventional IT equipment and data center spaces can consume more than 100 times the energy of standard office spaces (DOE 2011a) (***www.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf***), so the potential for energy savings is huge. You can use this application guide to reduce your equipment energy consumption in any building with a data center, server closets, or other IT equipment (computers, printers, etc.). Some of these strategies are most effective at the beginning of the design process; others can be implemented at any time and be sequenced as part of the normal procurement and replacement schedule.

For each strategy, ask yourself "Are my IT equipment and infrastructure doing this?". If not, you can take the energy savings numbers provided and determine how much energy your facility could save. Some strategies do not have easily measurable savings, although they have been implemented as "best practices" in many IT equipment and data center spaces.

Conventional Airflow Management
Hot air from server racks freely mixes with cold supply air.

Best Practices Airflow Management
An airtight envelope prevents supply and exhaust air from mixing and allows for waste heat recovery.

Conventional Cable Management
Poor cable management impedes air flow.

Best Practices Cable Management
Proper cable management creates open air paths.

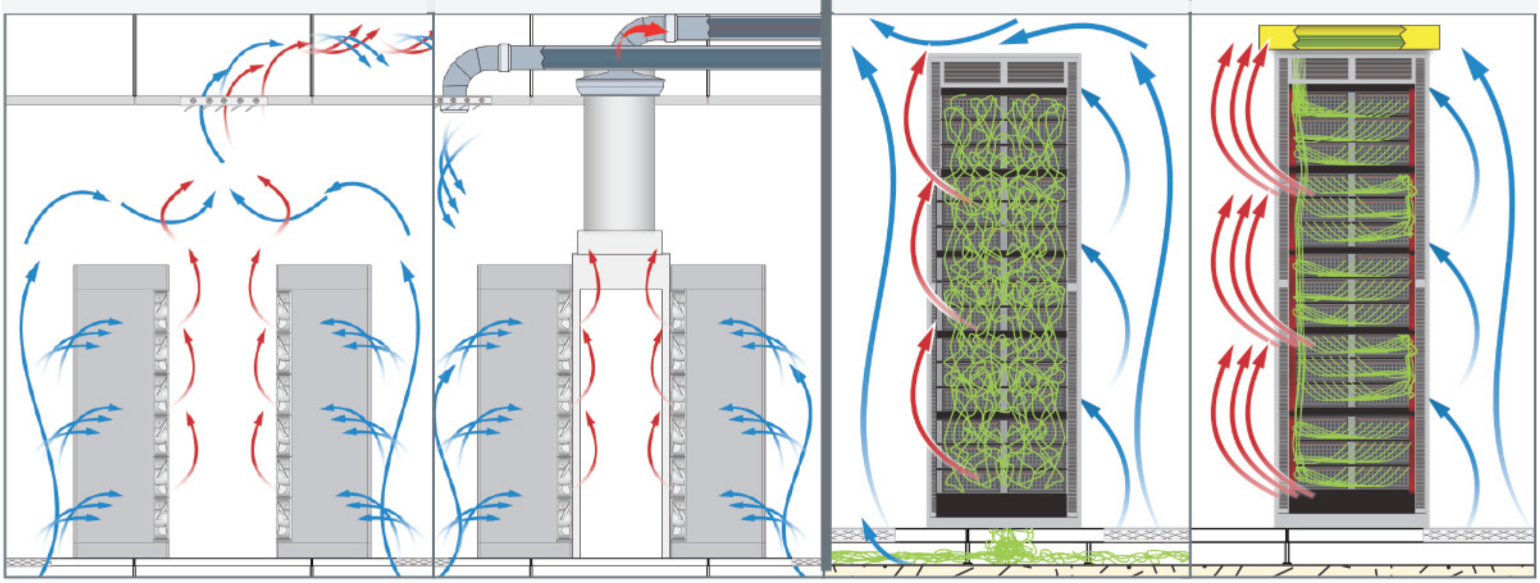

Figure 1. Conventional versus best practices data center. (*Credit: Joshua Bauer, NREL*)

Setting the Stage: Gaining Buy-In From Data Center Operators and Owners

The first important step in reducing data center loads is to gain buy-in from operators and owners. Typically, these people will be concerned about changes to status quo operations and equipment. Operators and owners need to understand the following key benefits of energy efficiency improvements:

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Increasing Uptime

For data center operators, minimizing downtime is a critical concern. By lowering the data center energy load, it can be run off backup generators for longer periods during a power outage, resulting in significantly greater uptime. If the data center energy load is reduced enough, the entire data center (including cooling) can be run off the backup generator.

Reducing cooling and dehumidification demands

Working within ASHRAE guidelines, data centers can be operated at higher temperatures and with greater humidity, yielding significant reductions in cooling and dehumidification loads. In 2008, ASHRAE released environmental guidelines for data communications (Datacom) equipment to expand the recommended environmental envelope (***http://tc99.ashraetcs.org/documents/ASHRAE_Extended_Environmental_Envelope_Final_Aug_1_2008.pdf***). These guidelines recommend a maximum supply air (SA) temperature of 80.6ºF (77ºF in 2004 guidelines), a maximum SA relative humidity (RH) of 60%, and a recommended dew point of 59ºF (55% RH in 2004 guidelines).

In 2008, Intel used an airside economizer to cool 900 heavily utilized production servers with 100% outdoor air (OA) at temperatures up to 90ºF (Intel 2008). No significant increase in server failures occurred. Energy consumption was reduced by 67%, which would yield an annual saving of almost $2.9 million for a 10-MW data center (***www.intel.com/content/www/us/en/data-center-efficiency/data-center-efficiency-xeon-reducing-data-center-cost-with-air-economizer-brief.html***).

Decreasing upfront capital costs

Data centers with smaller energy footprints typically have lower cooling requirements. This allows smaller cooling systems to be used, which can reduce capital costs. Server virtualization can also reduce capital costs because fewer physical servers are needed to meet the same service needs.

For data centers that use on-site renewable energy to offset their energy use, reducing data center loads can reduce capital costs. For example, operators in the National Renewable Energy Laboratory's (NREL) new data center were tasked with meeting computing needs as efficiently as possible to reduce the costs for the photovoltaics (PV) required to offset energy use. NREL saved about $2.2 million in PV costs by reducing data center loads and more than $1.5 million in PV costs by reducing workstation loads.

Improving service while reducing energy bills

The total lifetime energy use costs of IT equipment typically exceed the cost of the original capital investment (Metzger et al. 2011). Retrofits and new construction present opportunities to replace problematic or outdated equipment. By implementing energy-efficient technology, IT equipment operators can use a fraction of the energy to provide a higher level of service. For example, NREL's new data center saves approximately $82,000/year in energy bills compared to its legacy data center.

Complying with institutional and federal policies

Many organizations have institution-wide sustainability objectives for reducing building energy use. This gives IT equipment owners and operators an additional incentive to implement energy efficiency improvements.

For federal agencies, Executive Order 13514, "Federal Leadership in Environmental, Energy, and Economic Performance" (***www.whitehouse.gov/assets/documents/2009fedleader_eo_rel.pdf***), requires electronics stewardship by "implementing best management practices for energy-efficient management of servers and federal data centers" (Obama 2009).

Data Center and Server Room Strategies ▼

Strategies to reduce the energy load of your data center fall into three main categories: (1) procurement and proper implementation, (2) airflow management, and (3) operation.

For additional details about these and other strategies, visit the U.S. Department of Energy's (DOE) website (***www1.eere.energy.gov/industry/datacenters/***) on saving energy in data centers. This site contains a wealth of tools and resources you can use to save energy in your facility.

Procurement and proper implementation strategies

When procuring new equipment, you should obtain the most energy-efficient equipment available that fits your business model. The ENERGY STAR® database (ENERGY STAR 2011a) (***www.energystar.gov/***) can guide your choices for energy-efficient servers. For nonrated equipment, work with manufacturers to find the most efficient option for your needs.

Information Technology Settings and Strategies

Servers

- Decommission broken, unused, and obsolete equipment (e.g., servers running legacy applications) to save energy and increase performance (EPA 2007) (***www.energystar.gov/ia/partners/prod_development/downloads/EPA_Datacenter_Report_Congress_Final1.pdf***).
- Replace legacy servers with blade servers that use variable-speed fans and energy-efficient power supplies.
- Replacing servers can reduce energy use by 54% (ENERGY STAR 2010) (***www.energystar.gov/ia/products/downloads/ES_server_case_study.pdf***).
- Running virtualization software will further reduce energy consumption and support the same workload. Typically, 20 or more virtual machines can be run on one blade server.

Data management

- Use storage area networks to pool storage resources and reduce the hardware that needs to be dedicated to server resources.

Electrical power chain equipment

Before purchasing electrical power chain equipment:

- Use the DOE Data Center Electrical Systems Tool (***www1.eere.energy.gov/industry/datacenters/docs/dcpro_eat.xls***) to assess your equipment. This tool will help you assess the potential savings from efficiency actions in the electrical power chain of a data center, including lighting.

Uninterruptable power supplies

An uninterruptable power supply (UPS) provides power to data center/server room equipment during power outages until the backup generator (BUG) turns on. It also conditions incoming power to protect the connected loads from surges and spikes. An aging and inefficient UPS should be replaced at the end of its service life. When buying a new UPS system, look for these features:

- 95% efficiency
- Scalable design
- Built-in redundancy
- End user serviceable
- Provides enough uptime until the BUG starts
- Can be operated in the efficiency "sweet spot" given your IT infrastructure.

HVAC Equipment

Before purchasing HVAC equipment you should determine whether your climate zone is appropriate for free or evaporative cooling. Figure 2 shows the possible energy savings from airside economizing. To see how much energy savings can be achieved in your location through airside economizing, direct evaporative cooling, and indirect evaporative cooling, refer to Metzger et al. (2011).

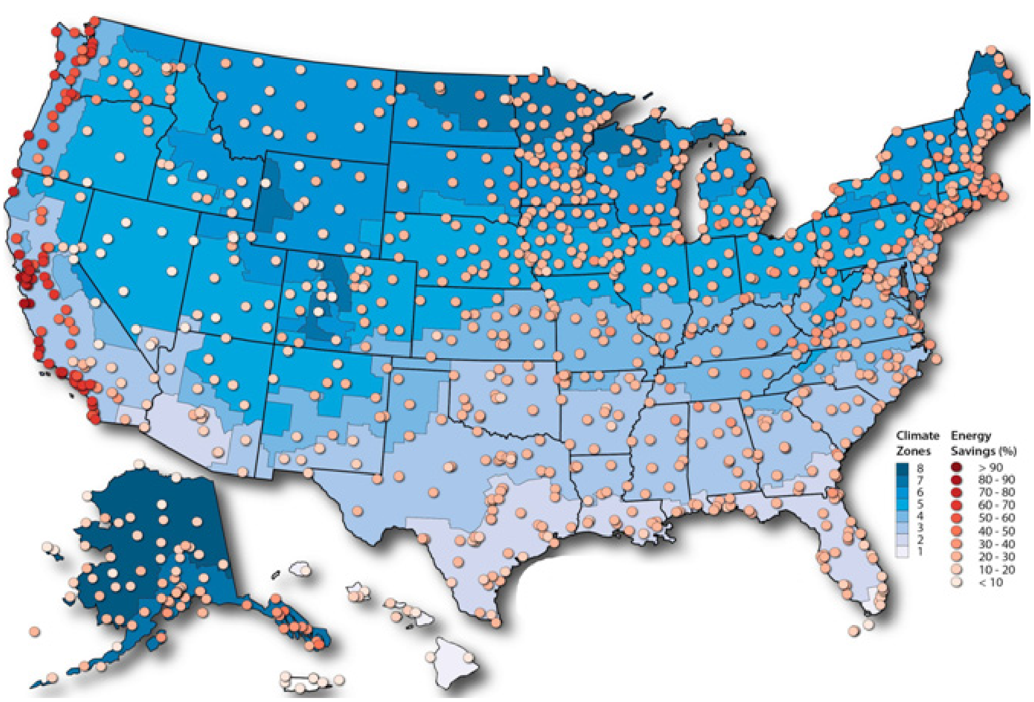

Figure 2 Potential energy savings from using an airside economizer (*Credit: Billy Roberts/NREL*)

Airflow management strategies

Data center equipment requires significant fan and cooling energy. To increase cooling efficiency, you should improve the airflow through your equipment. Before making changes to your facility, use the DOE Data Center Air-Management (AM) Tool (DOE 2011b) (***www1.eere.energy.gov/industry/datacenters/pdfs/am_tool_manual.pdf***) to assess your current airflow management strategies. This tool provides recommendations specific to your data center for improving airflow and reducing fan and chiller energy. Figure 1 illustrates a conventional data center versus one that has implemented the best airflow management practices.

The airflow management retrofit completed at Lawrence Berkeley National Laboratory (LBNL) is a great example of how these strategies can be implemented and still achieve an acceptable payback period (FEMP 2010) (***www1.eere.energy.gov/femp/pdfs/air_flow.pdf***). LBNL used wireless temperature and pressure sensors to monitor the improvements. The retrofit decreased fan energy by 8% and increased cooling capacity by 21%. This, along with other improvements, cost approximately \$12.00/ft^2 and will yield a simple payback of 2–6 years.

Best practices for airflow management include:

- ☐ Replace long power cables with shorter ones.
- ☐ Use cable management practices and cable wraps to secure loose or draped cabling.
- ☐ Remove excess subfloor cabling and wiring.
- ☐ Use commercially available grommets and brush panels to seal cable penetrations in raised floors and racks. This helps cold air flow through—not around—hot data center equipment.
- ☐ Cover all open rack spaces with blanking panels.
- ☐ Procure equipment that has front ventilation.
- ☐ Adopt "clean" practices to prevent dust from clogging server fans and other orifices:
  - ☐ Use antistatic sticky mats at entrances.
  - ☐ Prohibit cardboard, food, and drink.
  - ☐ Clean the room regularly.

    The frequency of cleaning depends on types of activities that take place in the facility. The more contamination introduced into the data center, the more frequently it needs to be cleaned. Some data centers must be cleaned daily, others yearly.
  - ☐ Minimize access.
- ☐ Hot aisle/cold aisle configuration with containment
  - ☐ Configure your racks as hot aisle/cold aisle to reduce fan energy and cooling load. Depending on your existing configuration, this can be an involved process. A hot aisle/cold aisle configuration involves organizing racks into parallel rows with the hot sides of the aisles facing each other. Figure 3 shows a cold aisle in NREL's new data center.

Figure 3 A view down one of the cold aisles in NREL's new data center *(Credit: Dennis Schroeder/NREL PIX 18766)*

- ☐ Ensure cold SA is delivered to the cold aisle sides and that the hot aisle sides are close to return air inlets.
- ☐ Contain the hot aisle in new construction by procuring specialized server racks that form an airtight envelope around it. Ideally, the containment prevents air from leaking from the hot aisle and mixing with the cold SA. Your SA temperature can thus be higher, which will reduce your data center cooling load.

  A contained hot aisle enables you to reuse the waste heat from server equipment to:
- ☐ Preheat incoming OA during cold weather to maintain the cold aisle temperature.
- ☐ Help heat the building through the ventilation system.

  Caution: The equipment may overheat if it draws air from inside the rack. You can prevent this by ensuring that server equipment fans blow from cold to hot. If server equipment is not full rack depth, cowlings can be made that isolate air intakes from the hot aisle (see Figure 4).

Figure 4 Server cowlings force air to flow through, rather than around servers. Left: server with cowling installed. Right: server without cowling installed.
(*Credit: Michael Sheppy/NREL PIX 19936*)

Operation strategies

- ☐ Turn off the lights when the center is unoccupied. This can be accomplished by having a contractor install vacancy sensor light switches and by encouraging good occupant behavior. This strategy reduces lighting and cooling loads.
- ☐ Develop relationships between IT and facilities staff by conducting regular meetings for employees to review the data center's energy performance and adjust operations to maximize energy savings.
- ☐ Building owners, data center managers, and IT staff should make energy consumption a part of total cost of ownership analysis to justify changing data center operations or procuring new IT equipment.

Metering and Benchmarking Data Center Performance ▼

To ensure optimal performance, data center managers should implement energy and environmental metering to benchmark and track performance.

Metered data can be used to troubleshoot problems, fine-tune operations, and as an energy efficiency metric. Power usage effectiveness (PUE) is the industry standard metric for data center energy efficiencies, and is calculated as a ratio (DOE 2011a):

$$\text{PUE} = \frac{\text{Cooling + Power + Equipment}}{\text{Equipment}}$$

PUE metering is best implemented as part of the building management system. Given the current state of technology, average data centers have a PUE of around 2.0; best-in-class data centers have a PUE of around 1.1 (DOE 2011a).The specific equipment needed to calculate PUE will vary based on your data center and the meter vendor. At a minimum, you need to meter:

- ☐ All data center HVAC loads separately from building HVAC loads
- ☐ Data center lighting separately from building lighting
- ☐ Data center miscellaneous loads separately from building miscellaneous loads
- ☐ IT equipment at UPS.

The U.S. Environmental Protection Agency has developed recommendations for measuring PUE (EPA 2011) (***www.energystar.gov/ia/partners/prod_development/downloads/Data_Center_Metrics_Task_Force_Recommendations_V2.pdf***). Figure 5 shows proper meter placement in a data center to measure PUE.

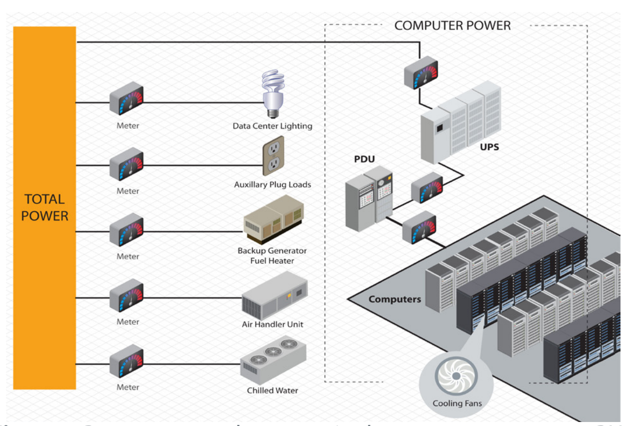

Figure 5 Proper meter placement in data center to measure PUE
(Credit: Marjorie Schott/NREL)

PUE measures only how well an organization has optimized its energy use for data center cooling and power systems. It does not consider efforts to optimize energy use for servers, storage, and network infrastructure. Comparing power per user or power per computation offers a more comprehensive evaluation of overall energy efficiency.

Workstations

Workstation IT equipment such as computers, monitors, phones, printers, fax machines, scanners, and copiers—especially in commercial office buildings—comprises a significant part of a building's total energy load. When procuring new workstation equipment, you should look for pieces that are more energy efficient than legacy equipment and that facilitate the implementation of energy-saving power settings. Given the current state of technology, you should procure a laptop/monitor combination that uses no more than 45 W while in use. Figure 6 is an example of a low-energy workstation.

The following strategies are best practices that should be implemented to cost-effectively reduce equipment energy use without sacrificing functionality. When the following strategies recommend equipment replacement, refer to ENERGY STAR (2011a) (***www.energystar.gov/***) and EPEAT (2006) (***http://www.epeat.net/***) for energy-efficient options.

Note: The savings shown in the following strategies assumes a utility rate of $0.10/kWh and an operating schedule of 10 business hours per day.

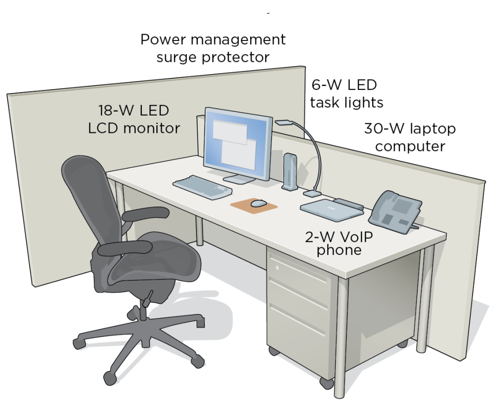

Figure 6 Diagram of an example low-energy workstation (Credit: Matthew Luckwitz/NREL)

Computers

- Replace standard desktop computers with miniature desktop, laptop, or thin client computers (*Savings of as much as $60/year/computer*)
- Disable screensavers and enable computer power management settings

Savings of as much as $50/year/computer with use of the computer management features (ENERGY STAR 2011b) (***www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_low_carbon_join***)

Configure computers to allow users to manually trigger standby or sleep mode via one or more of the following methods:

- The computer power button
- The laptop docking station power button
- Designated keyboard buttons
- A standby icon on the computer desktop
- Other external standby triggering devices.

Monitors

- Replace aging monitors with light-emitting diode (LED) backlit liquid crystal display (LCD) monitors (*Savings of as much as $25/year/monitor* (***www.nrel.gov/docs/fy11osti/49002.pdf***))

Phones

- Replace standard phones with low-power voice over Internet protocol (VoIP) phones (*Savings of $10/year/phone*)

Printers, Copiers, Scanners, and Fax Machines

- Consolidate multiple personal devices into a single multifunction device (*Savings of $15/year/personal device*)
- Enable the power option settings on the multifunction devices to go into standby after 15 minutes of idle time

Conference Room Equipment

Conference rooms are subject to varying use schedules.

- Implement controls that disconnect or turn off equipment when the space is unoccupied. Electrical outlet timers can be used to power down equipment during nonbusiness hours. Occupancy sensors can be used to disconnect power when the rooms are unoccupied during business hours.
- Outfit the space with energy-efficient equipment. LED backlit LCD televisions and energy-efficient projectors should be used for display purposes.

Parasitic Loads

- Implement power management surge protectors at workstations to reduce or eliminate the parasitic loads of equipment during nonbusiness hours

For a detailed process on how to control plug and process loads, refer to Lobato et al. (2011b).

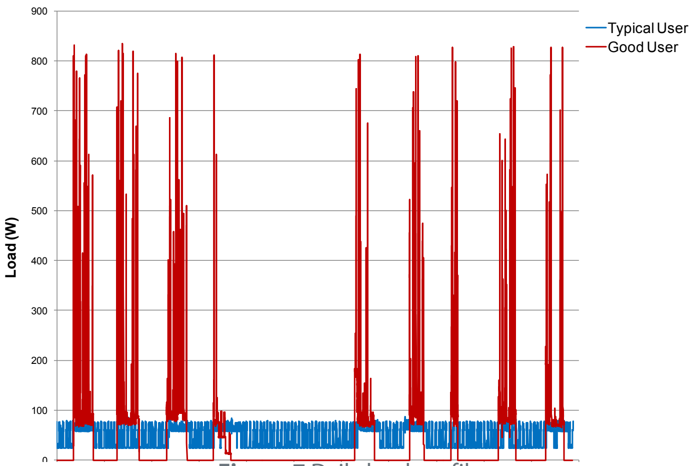

Figure 7 Daily load profile

(Credit: Chad Lobato/NREL)

Educate Users

Figure 7 shows the workstation loads for two example users; let's call them User A ("Good User") and User B ("Typical User"). In this case, User A's job requires them to have additional equipment that User B does not have. As a result, User A has a peak demand that is 10 times higher than that of User B. Despite having more equipment, User A consumes 3.4 kWh/week versus 6.2 kWh/week because User A turns everything off at night. In comparison to User B, User A consumes approximately 45% less energy, saving $69/year. This illustrates the need for user education and the use of standby functionality.

To encourage good workstation power management, you can:

- Send email reminders to encourage good behavior.
- Implement employee IT power management training at orientation.
- Put reminder stickers on monitors and laptop docking stations.

Optimizing IT Settings: NREL Before and After

NREL used simple strategies to cut energy use in its new data center by nearly 1.45 million kWh/year (see Figure 8). Based on NREL's utility rate of $0.06/kWh, this saves the laboratory approximately $82,000/year (Sheppy et al. 2011) (***http://www.nrel.gov/docs/fy12osti/52785.pdf***).

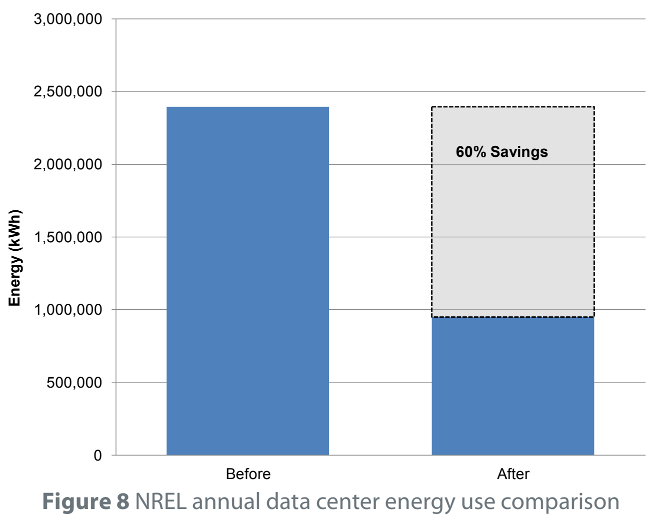

Figure 8 NREL annual data center energy use comparison (Credit: Chad Lobato/NREL)

Before: NREL's Legacy Data Center

NREL's legacy data center used individual servers with a utilization of less than 5%. The UPS and room PDU were 80% efficient or less. Chilled air was created using one multistage chiller unit and a backup single-stage air-conditioning chiller unit, which delivered chilled water to seven computer room air handlers. The cool air was delivered through an underfloor plenum, which was also a passageway for most cables, conduits, and chilled water pipes. This increased the fan energy required to move air between the computer room air handlers and the servers. It also had open hot and cold aisles, which allowed cool SA and hot return air to mix. Additionally, two walls of the data center were floor-to-ceiling exterior windows with southwestern exposure that introduced solar heat gain to the space and required additional cooling.

After: NREL's Research Support Facility Data Center

The data center in NREL's Research Support Facility (RSF) uses blade servers that run virtualized servers. When the total data center power draw is divided among all users, the continuous per-person power consumption rate is 45 W. The UPS and room PDU are 95% efficient. Currently, the UPS is configured with 125 kW worth of batteries and scales in 25-kW increments.

NREL is located in Golden, Colorado, a climate that can use airside economizing to provide most of the data center's cooling needs. The facility was designed use airside economizing and evaporative cooling methods for most of the year and to minimize traditional air-conditioned cooling. It was designed to provide SA of 66°–77°F to the data center with an RH of up to 60%. It is projected to cool the data center for all but 44 hours/year (the hottest and most humid days) without refrigerant-based air-conditioning. The equipment racks are arranged in a hot aisle/cold aisle configuration with hot aisle containment. Waste heat from the hot aisle is extracted for reuse in the building. The new data center is well insulated, largely because it is mostly below grade and has no windows. The measured PUE for NREL's RSF data center is 1.11–1.15, which is extremely low and unique among data centers worldwide.

Energy and cost savings. The RSF cuts energy use by nearly 1.45 million kWh/year with no performance tradeoffs. In fact, the overall level of service has increased. Based on NREL's utility rate of $0.06/kWh, this reduction will save the laboratory approximately $82,000/year (see Figure 9). Breaking down the numbers further, the RSF data center's average total load is 165 kW less than the legacy data center's, resulting in a 60% reduction in overall power. More computing equipment will be added over time to adjust for growth; however, the PUE should remain fairly constant—or even decrease—as the data center operators continually optimize the HVAC and computing systems.

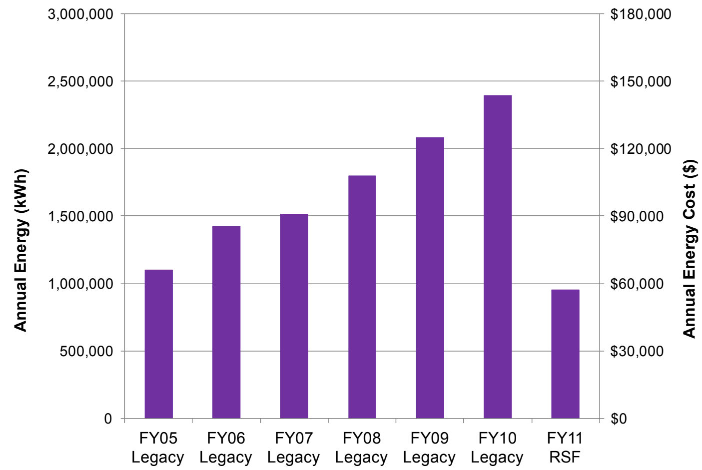

Figure 9 Annual energy and cost comparison between the legacy and RSF data centers
(Credit: Chad Lobato/NREL)

References

ASHRAE. 2008. 2008 ASHRAE Environmental Guidelines for Datacom Equipment: Expanding the Recommended Environmental Envelope. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers. ***http://tc99.ashraetcs.org/documents/ASHRAE_Extended_Environmental_Envelope_Final_Aug_1_2008.pdf***.

DOE. 2011a. Best Practices Guide for Energy-Efficient Data Center Design. Prepared by Rumsey Engineers under contract to the National Renewable Energy Laboratory. ***www.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf***.

DOE. 2011b. DOE Data Center Air-Management (AM) Tool: User's Manual, Version 1.16. Washington, D.C.: U.S. Department of Energy. ***www1.eere.energy.gov/industry/datacenters/pdfs/am_tool_manual.pdf***.

ENERGY STAR. 2010. Energy Savings from ENERGY STAR-Qualified Servers. Prepared by The Cadmus Group, Inc. ***www.energystar.gov/ia/products/downloads/ES_server_case_study.pdf***.

ENERGY STAR. 2011a. ENERGY STAR database. ***http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DC.***

ENERGY STAR. 2011b. Power Manage Computers To Save up to $50 per Computer Annually. ***www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_low_carbon_join***.

EPA. 2007. Report to Congress on Server and Data Center Energy Efficiency: Public Law 109-431. ENERGY STAR Program. ***www.energystar.gov/ia/partners/prod_development/downloads/EPA_Datacenter_Report_Congress_Final1.pdf***.

EPA. 2011. Recommendations for Measuring and Reporting Overall Data Center Efficiency

Version 2 – Measuring PUE for Data Centers. Washington, D.C.: U.S. Environmental Protection Agency. ***www.energystar.gov/ia/partners/prod_development/downloads/Data_Center_Metrics_Task_Force_Recommendations_V2.pdf***.

EPEAT. 2006. EPEAT database. ***www.epeat.net/***.

FEMP. 2010. Data Center Airflow Management Retrofit. Technology Case Study Bulletin: September 2010. ***www1.eere.energy.gov/femp/pdfs/air_flow.pdf***.

Intel. 2008. Reducing Data Center Cost With an Air Economizer. Intel Information Technology. Computer Manufacturing Energy Efficiency. August 2008. ***www.intel.com/content/www/us/en/data-center-efficiency/data-center-efficiency-xeon-reducing-data-center-cost-with-air-economizer-brief.html***.

Lobato, C.; Pless, S.; Sheppy, M.; Torcellini, P. 2011a. Reducing Plug and Process Loads for a Large Scale, Low Energy Office Building: NREL's Research Support Facility; Preprint. Golden, CO: National Renewable Energy Laboratory. ***www.nrel.gov/docs/fy11osti/49002.pdf***.

Lobato, C.; Sheppy, M.; Brackney, L.; Pless, S.; Torcellini, P. 2011b. Selecting a Control Strategy for Miscellaneous Electrical Loads. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-51708. To be published.

Metzger, I.; Rockenbaugh, C.; VanGeet, O.; Dean, J.; Kurnik, C. 2011. Psychrometric Bin Analysis for Alternative Cooling Strategies in Data Centers. Presented at the ASHRAE Annual Conference, 25–29 June 2011, Montreal. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers. In ASHRAE Transactions, ***http://www.techstreet.com/cgi-bin/detail?product_id=1812284***.

Sheppy, M.; Lobato, C.; Van Geet, O.; Pless, S.; Donovan, K.; Powers, Chuck. 2011. Reducing Data Center Loads for a Large-Scale, Low-Energy Office Building: NREL's Research Support Facility. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-52785. ***http://www.nrel.gov/docs/fy12osti/52785.pdf.***

Obama, B. 2009. Executive Order 13514. "Federal Leadership in Environmental, Energy, and Economic Performance." ***www.whitehouse.gov/assets/documents/2009fedleader_eo_rel.pdf***.

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