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U.S. DEPARTMENT OF ENERGY

Small Data Centers, Big Energy Savings: An Introduction for Owners and Operators

FINAL REPORT

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Introduction: Small Data Centers

Significant untapped energy efficiency potential exists within small data centers (under 5,000 square feet of computer floor space). While small on an individual basis, these data centers collectively house more than half of all servers (Shehabi et al 2016) and consume about 40 billion kWh per year. Owners and operators of small data centers often lack the resources to assess, identify and implement energy-saving opportunities. As a result, energy performance for this category of data centers has been below average.

The purpose of this brief guide is to present opportunities for small data center owners and operators that generally make sense and do not need expensive assessment and analysis to justify. Recommendations presented in this report range from very simple measures that require no capital investment and little ongoing effort to those that do need some upfront funds and time to implement. Data centers that have implemented these measures have experienced typical savings of 20 to 40%. The energy efficiency measures presented have been shown to work with no impact on IT equipment reliability, when implemented carefully and appropriately. Do make sure to take the appropriate precautions when considering these measures at your own data centers. Check the IT equipment intake air temperatures to make sure they are prudent, for example, to ensure no negative reliability impacts.

In addition to covering the most-common energy-saving opportunities, this guide notes the value of training for personnel involved in data center operations and management. References are also provided for further information.

Simplest Measures

Turn off unused ("comatose" or "zombie") servers

An estimated 20-30% of servers in data centers are consuming power, cooling, and space, but not doing any useful work (Koomey, 2017). An idle server consumes roughly 50% of the power as at full load, but about 75% of the power of a server operating at an average load of 25% utilization (Clinger, 2017). To better manage server usage and utilization, create and regularly update a server hardware and application inventory that will help you track the number of applications running on each server. Mapping applications to the physical servers on which they are running helps identify unused servers and opportunities for consolidation. Just make sure to move any remaining data or workloads to other servers before shutting down equipment (see page 8 for consolidation and virtualization).

Improve server power management

Power management saves energy by turning off power or switching equipment to low-power modes when not in use. Check for power management options that come with your server models and ensure that power management is enabled. Most servers are shipped with it enabled and most users disable it, often unnecessarily. ENERGY STAR servers are shipped with three categories of power management enabled (Clinger, 2017a). Lastly, consider built-in or add-in cards that enable servers to be powered on or off remotely.

Improve air management

Airflow management is conceptually simple and can be relatively easy to implement. The main challenge is ensuring that the cool air from the data center's cooling equipment gets to the air inlet of the IT gear, without getting mixed with the hot air exhausted from the back; and ensuring that hot air going back to the cooling equipment does not mix with the cold air (see Figure 1). This can be done by clearing clutter from the desired airflow path, blocking off bypass and recirculation airflow paths within and between the racks and the raised floor. When good airflow management is in place, savings can be realized through two measures: raising temperature setpoints (see below) and reducing air-flow rates (variable-speed drives, covered on page 10, play a key role here). There is a broad range of air-management strategies that span the range of complexity and cost; for example, containment of cold or hot aisles is a very effective approach, but this technique requires greater investment (Lin et al, 2013).

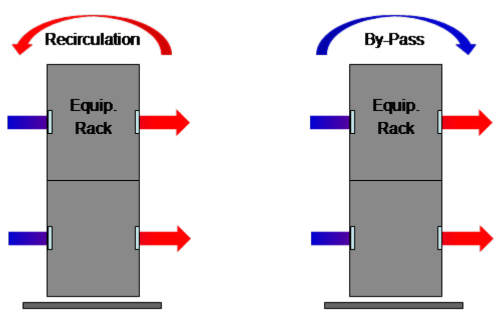

Figure 1. *End view of rows showing undesirable recirculation and by-pass air around IT racks.*

Increase temperature setpoints to deliver air towards the high end of the ASHRAE recommended range

ASHRAE temperature guidelines allow much broader operating ranges than those commonly used, allowing the air temperature at the IT equipment inlet to be raised—up to 80°F or higher—which can considerably reduce cooling energy usage compared to the inlet temperatures of 65-70°F that are commonly seen. See Figure 2 and ASHRAE 2015 for further information. Note that many Computer-Room Air Conditioners (CRACs) and Computer-Room Air Handlers (CRAHs) control their temperatures based on return air; these CRAC/H setpoints will be much higher than the IT inlet temperature. Improving air management (see page 6) should be done first because it will make this measure much more effective. In chilled-water systems, if raising the air temperature also enables raising the chilled water temperature, a 1°F rise in the chilled water temperature typically results in a 2% reduction in chiller energy.

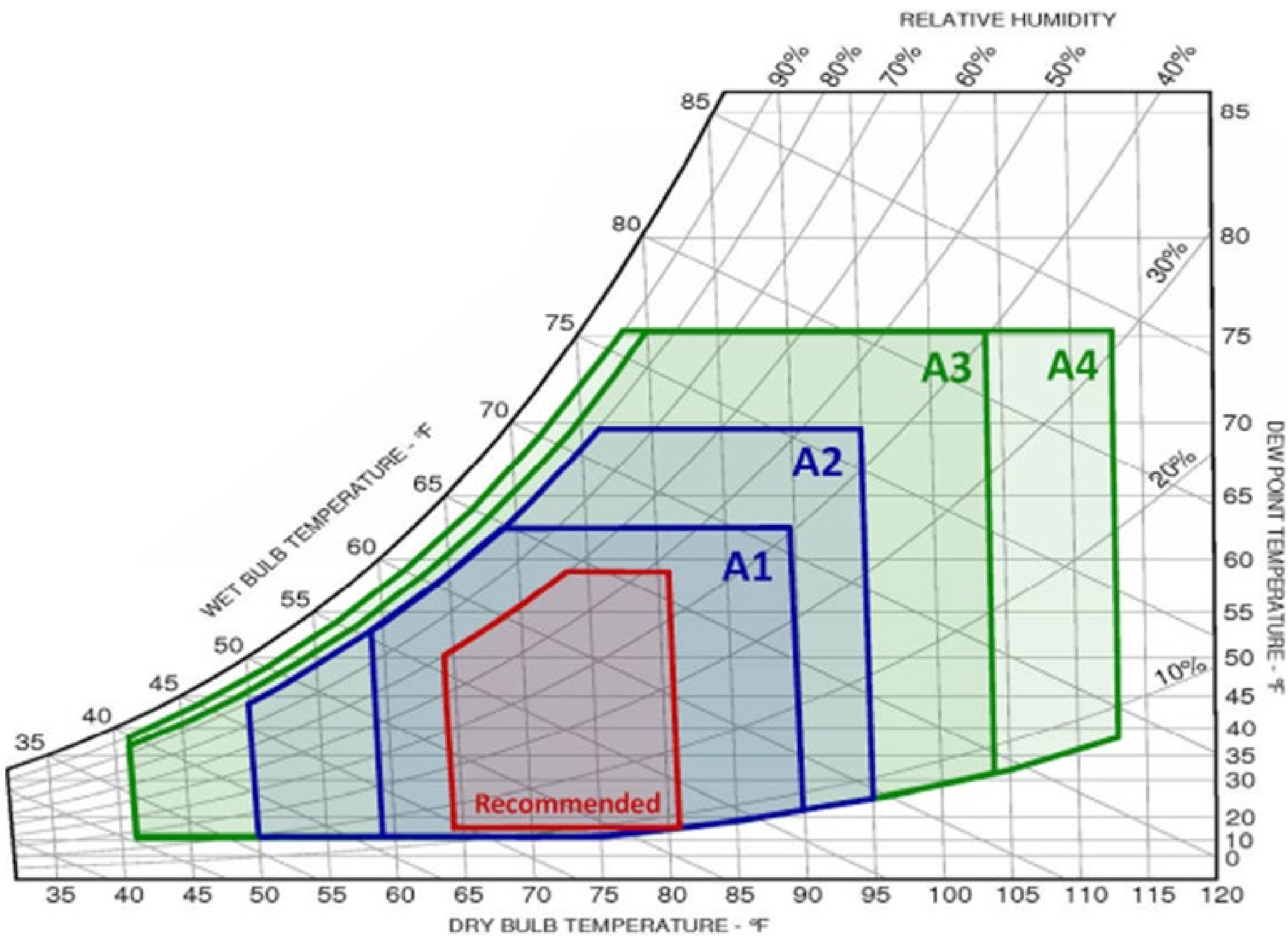

Figure 2. *ASHRAE 2015 Thermal Guidelines for Recommended and Allowable temperature and humidity of the air entering the IT equipment, represented on a psychrometric chart. The ASHRAE recommended range, typically used for normal operation to ensure IT equipment reliability, is 64.4 to 80.6°F air temperature and humidity from 15.8°F to 59°F dewpoint temperature and maximum 60% relative humidity. The allowable categories A1 through A4, with wider temperature and humidity ranges, are for specifying conditions where IT equipment will still function properly, though with potentially reduced reliability.*

Turn off active humidity control

Significant energy savings can result from reducing humidification and from the over-cooling and reheat typically involved in active dehumidification (see Sorell 2017 and ASHRAE 2015 for further information). ASHRAE humidity guidelines, (expanded in 2015 on the low end to about 8% relative humidity—see Figure 2), allow much broader operating ranges than those commonly used (typically 45-55% relative humidity of the return air to the CRAC/H units) . As a result, active humidity control is seldom required and large energy and water savings are possible by limiting or eliminating such control.

Minimize Uninterruptible Power Supply (UPS) requirements

Redundancy is a strong driver of energy inefficiency. Risk-averse IT managers often overdesign redundancy into their systems, when in fact many IT applications can be shut down if there is a power disturbance and restarted without adverse effects. Analyzing your power backup requirements can help you eliminate capital costs for unnecessary or oversized redundant power supplies or Uninterruptible Power Supply (UPS) equipment. It can also help you save energy lost in power conversion in those devices as well as energy to cool them. Anything that needs high reliability should be a candidate for moving to a larger data center or cloud solution. For applications that do require UPS, ENERGY STAR units (see link on page 12) should be purchased.

Still Simple, a Little More Work

Refresh the oldest IT equipment with new high-efficiency equipment

Establish server refresh policies that account for increases in generation-on-generation computational ability, energy efficiency, and power management improvements. The savings in energy and software costs will often justify a faster refresh than expected (e.g. a year sooner than the typical 3-5 year rate).Consider ENERGY STAR servers, (see link in Section 7) high-temperature tolerant servers, and power supplies with higher efficiencies than ENERGY STAR requirements (see link to 80 PLUS). When purchasing new equipment, servers with solid-state drives (SSD), rather than hard disk drives, could be considered, as they feature faster speeds, are generally considered to be more reliable, and consume less power. New equipment typically has much more computing power than older equipment, which facilitates consolidation and virtualization, covered in the next section. Note that IT equipment also includes storage and networking equipment, and when refreshing this equipment, ENERGY STAR certified units should be purchased (see ENERGY STAR Storage and Networking links on page 12).

Consolidate and virtualize applications

Typical servers in server rooms and closets run at very low utilization levels (5-15% on average), while drawing roughly 75% of their peak power on average. Consolidating multiple applications on a smaller number of servers accomplishes the same amount of computational work, and the same level of performance, with much lower energy consumption. Virtualization is a proven method for consolidating applications, allowing multiple applications to run in their own environments on shared servers. Increasing server utilization reduces both the number of servers required to run a given number of applications and the overall server energy use.

Higher-Level Investment, but Very Cost-Effective

Move to higher-efficiency internal or external data center or to the cloud

Distributed server rooms are typically not very energy efficient. If a central data center is available, you may be able to save energy and reduce your utility bill by moving your servers, or their applications, to that location. When a data center is not available, many organizations are moving their equipment to co-location or their applications to cloud facilities (public or private cloud facilities both typically provide much better efficiencies than on-premise server rooms). Data centers, co-location and cloud facilities typically offer better security, redundancy, and efficiency than is usually available in server rooms. In order to assess whether to move hardware or software to another location, one needs to include the cost of the actual move and to compare the ongoing total cost (hardware, software, and operation, including labor, space, power, and cooling) between the options.

Implement IT and infrastructure power monitoring

Power monitoring identifies the energy use and efficiencies of the various components in the electrical distribution and cooling systems. While power monitoring by itself will not save energy, it can help identify energy saving opportunities. Power meters can be installed at the panels serving the cooling units, or directly on IT and HVAC equipment. See Figure 3 for examples of meters. Another alternative is to read IT power from the UPS display, and to estimate cooling power from the nameplate, taking into account unit efficiency and operating hours. Often power distribution products will have built-in monitoring capability. See Mahdavi and Greenberg 2017 for more information. A key metric is the Power Usage Effectiveness (PUE), which is the ratio of total data center energy to IT input energy (with the "overhead" being electrical distribution losses plus cooling power usage). Monitor and strive to lower your PUE: over 2 shows significant room for improvement; 1.5 is good; 1.2 or lower is excellent.

Figure 3. *Examples of power meters, sensors, and displays.*

Install Variable-Speed Drives on cooling system fans

If your server room is cooled with a CRAH or CRAC unit, then it is highly likely that the unit has a constant-speed fan, and that it provides more airflow than your IT equipment needs. Units with variable speed drives (VSDs; often also called Variable-Frequency Drives or VFDs) have the capability of providing only the amount of air that is required by the IT equipment. Fan power scales roughly with the cube of the flow; thus a 20% reduction in flow (easily possible in most data centers) results in about 50% savings in fan power. To maximize potential energy savings, coordinate the implementation of airflow management measures and airflow isolation systems with the installation of variable-speed drives on the cooling unit fans. See page 6 for air management suggestions. Ideally the fan speed should be dynamically controlled to maintain IT inlet temperature within the recommended range. See Greenberg 2013 for further information. See also Figure 4 from another case study.

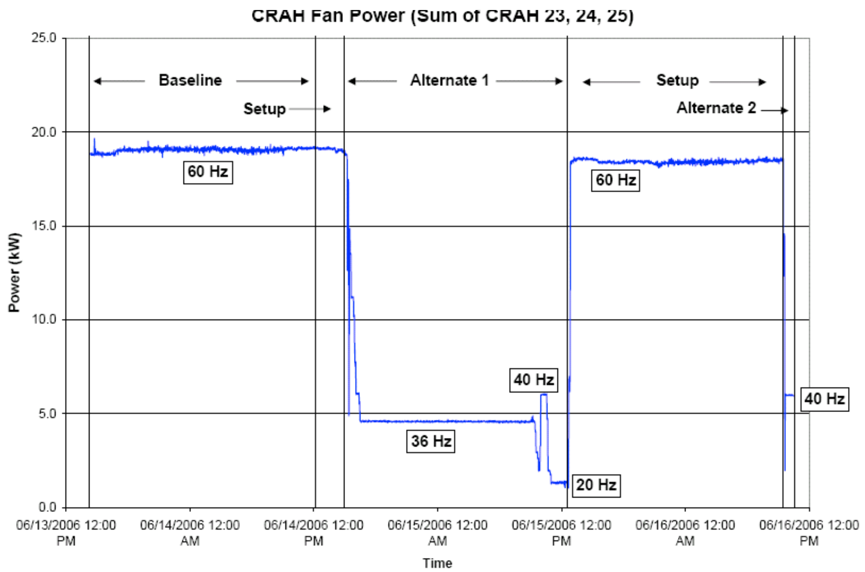

Figure 4. *Case study of savings using Variable-Speed Drives on fans ("Alternate 1").*

Install rack and/or row-level cooling

If you are installing a new server room or buying new racks, consider local cooling, also known as in-rack and in-row cooling because it refers to a cooling system located in that rack or row. Another highly efficient option is a Rear Door Heat Exchanger (RDHX), in which a coil is installed directly on the rear (exhaust) section of the server rack (see Figure 5). Condenser (Tower) water, chilled water, or refrigerant is run through the coils to passively absorb the exhaust heat and provide the needed cooling. Air circulation through the cooling coil is typically provided by the internal server fans.

Figure 5. *Rack with rear-door heat exchanger. Courtesy Coolcentric.*

Use an air-side economizer

An air-side economizer simply draws in outside air for cooling when conditions are suitable. See Figure 6. Server rooms with exterior walls or roof are a pre-requisite for air-side economizers. This could be in the form of an exhaust fan removing heat in one portion of the room and an opening in another location allowing cool, outside air to enter; or it could be in the form of a fan coil or CRAC/H with air-side economizer capability. Depending on the climate zone in which the server closet is located, this strategy can save a significant amount of energy by reducing the energy use of the compressor that would otherwise be needed for cooling.

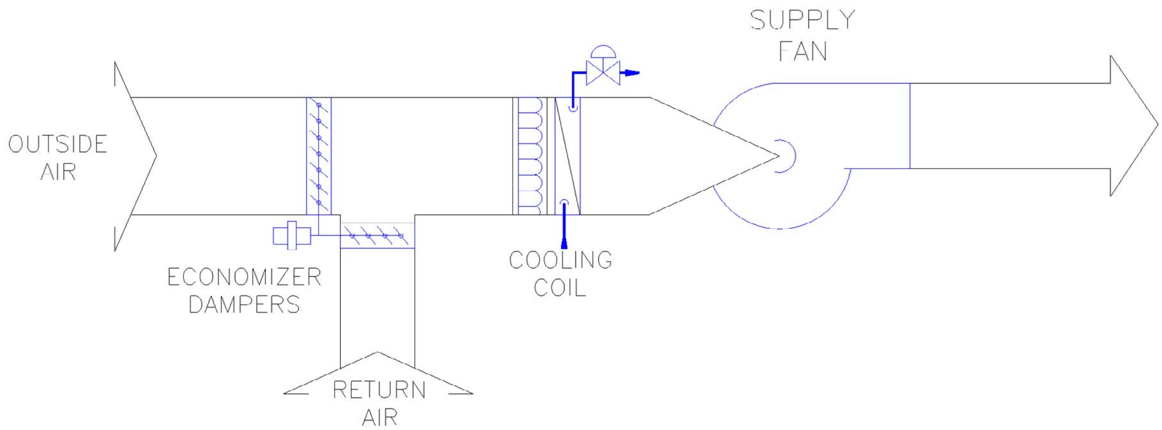

Figure 6. *Schematic drawing of a typical air-side economizer.*

Implement dedicated room cooling (vs. using building cooling)

Install cooling equipment solely for the use of the room, so that the building system does not have to operate around the clock. If a retrofit is in order, installing dedicated cooling equipment (like a packaged air conditioning unit) for your server room(s) can result in significant energy savings. Specify a high-efficiency unit with a high SEER rating and outside-air economizer (see above).

Training for IT and Facility Staff

Improve energy-efficiency awareness by training IT and facilities staff

On-going training is important to keep up with the rapid evolution of technologies and solutions in the data center realm. Have your IT and facilities staff attend webinars or training events offered by utility companies, ASHRAE, FEMP, the Center of Expertise for Energy Efficiency in Data Centers, and other efficiency advocates, to take full advantage of best practices. See links for more information. A more comprehensive option is the Data Center Energy Practitioner (DCEP) training program, which certifies energy practitioners qualified to evaluate the energy status and efficiency opportunities in data centers. Federal data center operators should note that in the recently issued Data Center Optimization Initiative there is a requirement for DCEPs to help with energy management in all data centers.

List of Abbreviations

ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers

CRAC: Computer Room Air Conditioner

CRAH: Computer Room Air Handler

DCEP: Data Center Energy Practitioner

DCOI: Data Center Optimization Initiative

HVAC: Heating, Ventilating, and Air Conditioning

IT: Information Technology

PUE: Power Usage Effectiveness

RDHX: Rear-Door Heat Exchanger

SEER: Seasonal Energy-Efficiency Ratio

SSD: Solid-State Drive

UPS: Uninterruptible Power Supply

VFD: Variable Frequency Drive

VSD: Variable Speed Drive

References and Links

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), Thermal Guidelines for Data Processing Environments, 4th Edition, 2015. This book, number 1 in the ASHRAE Datacom Series, is the definitive guide to temperature and humidity requirements in data centers.

Center of Expertise (CoE) for Energy Efficiency in Data Centers:
https://datacenters.lbl.gov/
Through the supply of technical support, tools, best practices, analyses, and the introduction of technologies, the DOE-led CoE helps federal agencies and other organizations implement data center energy efficiency projects. The CoE, located at the Lawrence Berkeley National Laboratory, partners with key public and private stakeholders to further efficiency efforts.

Clinger, John, 2017. Personal email to Steve Greenberg, 3 January.

Clinger, John, 2017a. Personal email to Steve Greenberg. 3 January. In brief the ENERGY STAR power management requirements are:
Processor – Dynamic voltage and frequency scaling, reduced power states when core or socket not in use both enabled by default
OS/hypervisor – OS power management enabled by default
BIOS – any power management features in BIOS enabled by default.

Data Center Energy Practitioner (DCEP):
https://datacenters.lbl.gov/DCEP
This is the official webpage for the DCEP program, including program description, training schedule, signup options, and a listing of all qualified DCEPs.

Data Center Optimization Initiative:
https://datacenters.cio.gov/
DCOI was established in the Office of Management and Budget (OMB) memorandum M-16-19 dated August 1, 2016, and includes a number of energy efficiency requirements for federal data centers.

ENERGY STAR Equipment: The following four links are to locations on the ENERGY STAR website where information on, and listings of energy-efficient data center related equipment (3 types of equipment on the IT side, one on the power distribution side) can be found.

ENERGY STAR Networking Equipment:
https://www.energystar.gov/productfinder/product/certified-large-network-equipment

ENERGY STAR Servers:
https://www.energystar.gov/productfinder/product/certified-enterprise-servers/results

ENERGY STAR Storage:
https://www.energystar.gov/productfinder/product/certified-data-center-storage/results

ENERGY STAR Uninterruptible Power Supplies:
https://www.energystar.gov/productfinder/product/certified-uninterruptible-power-supplies/results

FEMP's Data Center Energy Efficiency Series
http://eere.energy.gov/femp/training
This is the main website for all of the Federal Energy Management Program training.

Greenberg, Steve, 2013. "Variable-Speed Fan Retrofits for Computer-Room Air Conditioners". Prepared by the Lawrence Berkeley National Laboratory for the Federal Energy Management Program. Available at
https://datacenters.lbl.gov/resources/variable-speed-fan-retrofits-computer-room-air-conditioners
This case study documents three retrofits to existing constant-speed fans in computer-room air conditioners (CRACs), all located in California. The retrofits included down-flow, water-cooled CRACs, up-flow, water-cooled units; and down-flow, air-cooled units.

Koomey, Jon, 2017. Personal email with Steve Greenberg. 21 March.

Lin, Paul, Victor Avelar, and John Niemann 2013. "Implementing Hot and Cold Air Containment in Existing Data Centers", APC White Paper 153.
Available at http://www.schneiderelectric.com/en/download/document/APC_VAVR-8K6P9G_EN/
This paper investigates the constraints, reviews available containment methods, and provides recommendations for determining the best containment approach.

Mahdavi, Rod, and Steve Greenberg, 2017. "Data Center Metering and Resource Guide" Available at
https://datacenters.lbl.gov/resources/data-center-metering-and-resource-guide
This guide helps data center owners and operators implement a metering system that allows their organizations to gather the necessary data for effective decision-making and energy-efficiency improvements. Focus is on the necessary data to calculate the power usage effectiveness (PUE) metric.

Shehabi, A., Smith, S.J., Horner, N., Azevedo, I., Brown, R., Koomey, J., Masanet, E., Sartor, D., Herrlin, M., Lintner, W. 2016. United States Data Center Energy Usage Report. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-1005775.
Available at https://datacenters.lbl.gov/resources/united-states-data-center-energy-usage
This report estimates historical data center electricity consumption back to 2000, relying on previous studies and historical shipment data, and forecasts consumption out to 2020 based on new trends and the most recent data available.

Sorell, Vali, 2017. "Humidity Control in Data Centers", Report by Syska Hennessy Group for the Lawrence Berkeley National Laboratory. Available at https://datacenters.lbl.gov/resources/Humidity_Control_in_Data_Centers
This report reviews the evolution of humidity control in data centers and makes recommendations on how to meet the current humidity control requirements in an energy-efficient manner.

80 Plus Power Supplies:
https://plugloadsolutions.com/80PlusPowerSupplies.aspx
This site describes and lists power supplies that meet a range of stringent efficiency specifications.

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