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Small Embedded Data Center Program Pilot

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MnTAP Minnesota Technical Assistance Program

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DISCLAIMER

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Executive Summary

A 2016 U.S. DOE-funded study estimated that data centers used about 70 billion kWh of electricity (about 1.8% of the total electricity used in the U.S.).[1] Small embedded data centers (SEDCs) are the server closets and server rooms typically found on site in businesses and offices, and about half of all U.S. servers are located in SEDCs. SEDCs are one of the fastest growing end uses of electrical energy in commercial buildings. By various accounts, as much as one third of the electricity used by SEDCs is unnecessary.[2,3]

This project developed, implemented, and assessed a pilot program targeting SEDCs in Minnesota, with the intent of helping utility programs deliver cost-effective energy savings. This report includes three main tasks:

1. The market characterization of SEDCs in Minnesota,
2. The field study to assess energy use at selected sites and measure savings of installed measures, and
3. The dissemination of the study's results to stakeholders such as businesses, institutions, and utilities throughout Minnesota.

Literature Review

In 2014, the Minnesota Technical Assistance Program (MnTAP) published a CARD-funded white paper that analyzed data center energy efficiency opportunities and challenges in Minnesota. The study covered the full range of data centers, from server closets with a floor area less than 200 square feet to enterprise-class data centers with a floor area greater than 15,000 square feet. We reviewed the MnTAP study along with studies by Natural Resource Defense Council (NRDC) , Cadmus Group , and Lawrence Berkeley National Laboratory to learn from their experiences with this sector.

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[1] Armin Shehabi, S. Smith, D. Sartor, R. Brown, M. Herrlin, J. Koomey, E. Masanet, N. Horner, I. Azevedo, and W. Lintner. 2016. United States Data Center Energy Usage Report. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-1005775 http://eta.lbl.gov/publications/united-states-data-center-energy-usag (retrieved April 28, 2017)

[2] Jon Koomey and Jon Taylor. 2015. "New data supports finding that 30 percent of servers ate 'Comatose', indicating that nearly a third of capital in enterprise data centers is wasted." Anthesis Group, June. http://anthesisgroup.com/wp-content/uploads/2015/06/Case-Study_DataSupports30PercentComatoseEstimate-FINAL_06032015.pdf (retrieved April 28, 2017)

[3] Josh Whitney and Pierre Delforge, 2014. Data Center Efficiency Assessment - Scaling Up Energy Efficiency Across the Data Center Industry: Evaluating Key Drivers and Barriers. NRDC and Anthesis. Issue Paper #IP:14-08-A. August. https://www.nrdc.org/sites/default/files/data-center-efficiency-assessment-IP.pdf (retrieved April 28, 2017)

Based on the literature review, we made the following observations which guided project design and implementation:

- There are already existing utility incentives and rebates that can be applied to data center energy efficiency measures throughout Minnesota.
- The major segments from which to recruit our participating sites are government, schools, healthcare, professional services, and manufacturing.
- Since IT managers have little awareness of their SEDC power draw/energy use and server utilization, we need to develop a protocol to measure and document these aspects of SEDCs without impacting SEDC operations and reliability.
- Most of the measures implemented in SEDCs will likely be IT Environmental Conservation Opportunities (or "ECOs") such as:
    - Server consolidation,
    - Server virtualization,
    - Equipment replacement with ENERGY Uninterruptable Power Supplies (or "UPS") and servers,
    - Data storage management,
    - Migration to the cloud, and
    - Colocation.

Electronic Survey

Project partner Wisconsin Energy Conservation Corporation (WECC) developed an electronic survey to help discern the IT services of SEDCs for various business types in Minnesota and identify opportunities for energy savings. The goals of the survey were to:

- Define the major sectors in Minnesota that employ SEDCs and the common types and sizes of those businesses;
- Assess the nature and variety of SEDCs in Minnesota and the common IT practices employed;
- Survey stakeholder perceptions and gain an understanding of their support network; and
- Determine opportunities and barriers to implementing energy efficiency measures for SEDCs.

Outreach efforts of the project team resulted in 134 responses from around the state, representing a range of data center types from server closets with floor areas less than 200 square feet to enterprise data centers greater than 15,000 square feet. Of the survey responses, 35 were server rooms under 200 to 1,000 square feet (26%) and 47 were data closets under 200 square feet (35%). Since the focus of the study is SEDCs, the discussion is focused on the responses from data closets and server rooms.

Many of the survey respondents had already adopted some energy efficiency measures. Sixty-six percent of respondents replied that server virtualization was in place at their site, while 18% responded no and the remaining 18% did not know. With regard to cloud services and cloud computing, 62% of survey respondents shared they were using some close services, while 33% responded no and 5% did not know. Nearly half (48%) of the respondents had already taken advantage of both virtualization and cloud services. For those that had not, the main barriers to adopting virtualization were cost and maintenance/staffing while the main barriers to adopting cloud services were security and cost.

Utilities throughout Minnesota offer incentives, rebates, and loans that can be applied to data center energy efficiency measures. of incentives, rebates, and loans. These includes measures dealing with IT equipment and cooling, as well as services such as monitoring and consulting. Some are prescriptive based while others are performance based. Of note, only 2% of respondents were aware that utility rebates and incentives were even offered for data centers. The survey found that vendors are an important source of information to SEDC IT managers, and they could have a significant role in both outreach to SEDC IT managers and in advocating for energy efficiency measures. It also suggests that a midstream strategy with incentives to vendors could be very effective.

Field Study

The field study provided a snapshot of the current state of SEDC practice and energy use in Minnesota.

A total of eleven sites representing commercial, institutional, and industrial sectors were recruited to participate in the field study. The sites included a total of 24 SEDCs (10 server rooms and 14 network closets). Nine of the ten sites had dedicated cooling equipment while one remaining site had an exhaust fan that removed the heated air from the server room, typical configurations for SEDCs. We monitored energy use at the sites over several months to acquire a baseline and recommend possible energy efficiency measures. We then worked with IT staff at each of the sites to plan and test experimental strategies to reduce SEDC energy use and performed post-measure monitoring to assess the energy saving impacts.

We identified and verified a number of measures that increase the energy efficiency of SEDCs without introducing the need for large capital expenditures. Most of the measures deal with operational changes that can be performed by IT staff. Table 1 summarizes the measures that were performed at each site and the savings that were measured.

Table 1. Summary Energy Savings from Data Center Measures

Category	Measure	Site	Energy Savings
IT	UPS consolidation	9	438 kWh/yr for consolidating 4 UPSs (<20% load) to 2 UPSs
	Shutting off dormant servers	9	1233 kWh/yr
	Virtualization	7	442 W per Xserve removed or about 9,000 kWh/yr for seven Xserves removed
	Scheduling network switches	6, 8	Site 6: 200 W for powering down a network switch or 1021 kWh/yr if turned off 10 hours

Category	Measure	Site	Energy Savings
			each night during the workweek and all weekend Site 8: 355 kWh/yr for powering down 9 APs for 10 hours every night
	Distributed power management	6, 8	Site 6: 1,388 kWh/yr for 10 hours each night on weekdays and all day on weekends. Site 8: 361 kWh/yr for 10 hours each night on weekdays and all day on weekends.
Cooling	Adjusting the SEDC thermostat set point temperature	1, 2, 5, 9, 10	Site 1: 26,280 kWh/yr from 3°F increase Site 2: 9,636 kWh/yr from 4°F increase Site 5: 6,044 kWh/yr from 3°F increase Site 9: 5,670 kWh/yr from 8°F increase (estimate) Site 10: 1,134 kWh/yr from 9°F increase (estimate)
	Airflow management	11	No post-retrofit data collected
	Cold or hot aisle containment	2, 6	Site 2: Increasing set point temperature 4°F plus cold aisle containment reduced power draw by 1.1 kW or 9,636 kWh/yr Site 6: Replacing a CRAC unit with a 312 W exhaust fan with hot aisle containment produced an estimated reduction of about 1.5 kW or a savings of 13,140 kWh/yr.

Category	Measure	Site	Energy Savings
	Adjusting fan settings on the RTU air handler	4, 7	Site 4: 1,004 kWh over 6 month heating season, with economizing Site 7: 5,577 kWh over 6 month heating season, without economizing

Operational Efficiency Measures

There are opportunities available to achieve energy savings in SEDCs through simple changes in operation based on activity or inactivity. These opportunities are typically overlooked due to the priority of maintaining mission critical services, and the lack of energy management training and awareness of IT staff, building facilities personnel, and the accounting staff who pay the energy bills. Simply put, energy savings can be obtained fairly quickly and at low cost with routine operational changes that have no impact on user needs for IT services. It is possible to achieve energy savings by powering down IT equipment during non-work hours or during times of non-utilization, and this can account for about 60% of the work week (including overnight hours and weekends). IT staff are typically more open to these operational efficiency measures since they avoid the capital expenditures involved with purchasing new equipment. These simple scheduling changes also avoid any downtime in IT services and can be easily implemented and reversed if issues arise.

The best candidates for scheduling changes are network switches. Network switches are found in both server rooms and network closets. Scheduling server status using currently available software already installed on the server can reduce the server power draw during low-utilization periods. During off hours, a bare bones number of physical hosts can be kept awake while the remainder are put on standby. Then when services are in demand, additional hosts can be brought online as needed, without any interruption of service. The magnitude of savings depends on how many servers are placed on standby through scheduling.

Airflow and Cooling Opportunities

For SEDCs with dedicated cooling systems, poor operations translate into energy inefficiencies. Relying on the thermostat set point to deliver cooling often results in overcooling. Monitoring air temperatures at the server inlets can now be done with inexpensive temperature monitors, which allow for more precise and efficient cooling strategies.

Airflow management can reduce cooling loads by minimizing the mixing of cooled and heated air in the server room. This creates more uniform temperatures along the inlet of the server racks and makes it possible to deliver conditioned air in the upper range of the ASHRAE recommended indoor air temperature of 64.4°F to 80.6°F. Hot aisle and/or cold aisle containment can provide significant savings by minimizing airflow.

Equipment Upgrades

Monitoring important operational data ensures that systems are working properly and operations are performed without unnecessary and excessive use of energy. We found that at most sites very little effort was made to monitor energy use, even though it can be easily and inexpensively done.

It is often assumed that energy efficiency improvements are a byproduct of normal equipment upgrades. While this may be true for large data centers with two- to three-year cycles for equipment upgrades, refresh rates for the SEDCs in this study were generally much longer, often two to three times that of larger data centers. Equipment upgrades can bring greater energy efficiency as new models and improved technologies provide more capabilities per unit, and as data center equipment certifications like ENERGY STAR allow for more informed energy choices. With time, equipment refreshes naturally lead to higher energy efficiency.

The following two tables (Table 2 and Table 3) list our suggested energy efficiency measures to reduce the IT and cooling power loads for SEDCs, respectively. Most of the operational measures can be performed immediately at very little cost.

Table 2. Measures to Reduce IT Power Loads in SEDCs

Category	Measure
Simple, No-Cost, or Very-Low-Cost Measures	1. Consolidation: Power down any unused (comatose) servers.
	2. Consolidation: Examine power backup requirements to determine if the UPSs are underutilized and consolidate if possible.
	3. Scheduling: Power down network switches, ports, and/or PoE during non-work hours such as nights, weekends, and holidays.
A Little More Work, But Still Fairly Simple	4. Power Reduction: Refresh IT equipment with high-efficiency ENERGY STAR models.
	5. Power Reduction: Upon UPS refresh, resize UPS to better match power loads of the SEDC to result in UPS utilizations in the range of 60-80%. Replace with ENERGY STAR UPS models.
	6. Power Reduction: Move IT services (applications, storage, etc.) to more energy-efficient external central data center space, co-location, or cloud solutions employing SaaS.

Category	Measure
Higher Investment, But Can Be Cost Effective	7. Consolidation: Reduce the number of physical hosts by employing server virtualization.
	8. Consolidation: Archive unused storage onto tape drives and power down unneeded disk drives.
	9. Scheduling/Consolidation: Perform live migration or DPM on virtualized servers and place unused physical hosts on standby. This could require software upgrade, additional storage, or CPU replacement.

Table 3. Measures to Reduce Cooling Loads in SEDCs

Category	Measure
Simple, No-Cost, or Very-Low-Cost Measures	1. Mechanical System: Increase temperature set points so that server rack inlet temperatures are at the high end of ASHRAE's recommended limit (~77°F).
	2. Airflow management: Install blanking panels and block holes between servers in racks.
	3. Mechanical System: Set air handler fan to AUTO instead of ON (i.e., running continuously), if allowed by code.
	4. Monitoring: Install low-cost Bluetooth temperature monitors to track rack inlet temperatures and SEDC thermostat setpoint.
A Little More Work, But Still Fairly Simple	5. Airflow management: Arrange or orient server racks so that distinct cold aisles and hot aisles are created.
	6. Airflow management: Perform cold aisle and/or hot aisle containment using drapes or other air barriers.
	7. Airflow management: Properly manage server cables by tying or clipping cords together.
Higher Investment, But Can Be Cost Effective	8. Mechanical System: Depending on power load of SEDC (<4 kW), consider installing an exhaust fan in hot aisle (to avoid need for dedicated cooling and provide CHP opportunities with the rest of the building).
	9. Mechanical System: Re-duct supply and return vents to promote rack- and row-level cooling (hot and cold aisles).

Program Recommendations

Utility Implementation

IT staff have the ability to significantly reduce SEDC energy use with currently available tools and techniques; however, IT staff typically lack of awareness and training. Education, incentives, and marketing from utility programs can help spur interest and increase motivation. Another barrier is that, while the effort required to implement operational efficiency measures is relatively small, the absolute magnitude of energy savings per SEDC may be correspondingly low. Savings become truly appreciable through economies of scale. Utility program efforts need to focus on leveraging opportunities where a number of sites are reached to help justify programmatic transactional costs. Another possibility is to package SEDC saving opportunities with other building measures to increase the cost effectiveness of the entire suite of savings.

Institutional Purchasing Policies

All the major manufacturers of data center IT equipment now offer ENERGY STAR certified equipment. Institutional purchasing policies (e.g., for state government, schools, and higher education) should be adjusted to require ENERGY STAR certified data center equipment. Many of these institutions already require ENERGY STAR certified office equipment or computers so adjustments to purchasing policies regarding SEDCs would be minimal. The benefit of an institutional policy is that IT staff would then have to specify ENERGY STAR certified equipment in the their next equipment refresh, despite their typical lack of concern with energy issues as they pertain to mission critical responsibilities.

Cloud Services

Cloud service providers report or estimate power utilization effectiveness (or "PUEs") values in the range of 1.12 to 1.2. The server rooms in this study that had dedicated cooling were closer to 2. For SEDCs to achieve the 1.2 PUE that cloud services might provide would require an average cooling load reduction of 75%. To reduce energy costs, any services that can be migrated to cloud services as a way to reduce IT equipment should be encouraged.

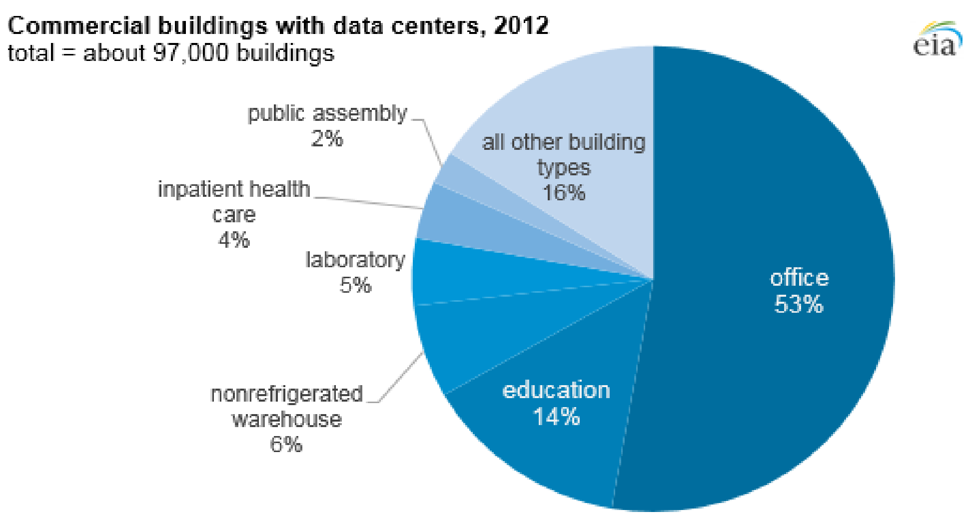
Looking Forward

We observed a shift in how SEDCs and commercial office spaces operate, and this will bring both challenges and opportunities to IT staff and building operations in the coming years. For one, IT workforce will see a shift in responsibilities. As IT services move to the cloud, on-site IT staff roles and responsibilities will be less about providing services and more about maintaining networks and networked equipment. IT staff are a very skilled workforce that contributes enormous benefit to the commercial building sector represents, and emphasis should be placed on identifying opportunities to retain this skilled workforce. One opportunity will come as connected Power over Ethernet (or "PoE") and connected office equipment and buildings systems are introduced into commercial buildings. When this happens on-site IT staff will be needed to perform increased energy management roles of these networked devices. There will also be additional opportunities to expand energy management to new settings that utility efficiency programs do not often target.

Introduction

A 2016 U.S. DOE-funded study estimated that data centers used about 70 billion kWh of electricity (about 1.8% of the total electricity use in the U.S.).[4] Small embedded data centers (SEDCs) are the server closets and server rooms typically found on site in businesses and offices, and about half of all U.S. servers are located in SEDCs. SEDCs are one of the fastest growing end uses of electrical energy in commercial buildings.[5] The U.S. EIA found in the most recent Commercial Building Energy Consumption Survey (CBECS) that "office buildings with data centers use significantly higher computing, cooling, and total electricity intensity (consumption per square foot) than office buildings without data centers. Total electricity intensity in buildings with data centers is 87%, 60%, and 20% higher than in buildings without data centers in the 50,000 square feet or less, 50,001–200,000 square feet, and greater than 200,000 square feet categories, respectively."[6] The 2012 CBECS estimates that about 2% of all commercial buildings, or about 97,000 commercial buildings, contain data centers. Figure 1 shows the breakdown by sector and also defines the diverse and dispersed customer base that must be reached.

Figure 1. Sector Breakdown of Commercial Buildings with Data Centers[7]



4 Armin Shehabi, S. Smith, D. Sartor, R. Brown, M. Herrlin, J. Koomey, E. Masanet, N. Horner, I. Azevedo, and W. Lintner. 2016. United States Data Center Energy Usage Report. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-1005775 http://eta.lbl.gov/publications/united-states-data-center-energy-usag (retrieved April 28, 2017)

5 Jonathan Koomey, 2011. "Growth in Data Center Electricity Use 2005 to 2010," Analytics Press: Oakland, CA. http://www.co.twosides.info/download/Koomey_Johnathon_G-_Growth_In_Data_Center_Electricity_Use_2005_to_2010_2011.pdf

6 EIA. 2016. "Office buildings with data centers use significantly more electricity than other offices." Today in Energy, October 5, 2016. http://www.eia.gov/todayinenergy/detail.php?id=28232 http://www.eia.gov/todayinenergy/detail.php?id=28232

7 U.S. Energy Information Administration, Commercial Buildings Energy Consumption Survey (CBECS)

By various accounts, as much as one third of the electricity used by SEDCs is unnecessary. Unfortunately, when dealing with mission critical services, energy use considerations are typically ignored by SEDC system administrators (sys admins). The principal objective of SEDC sys admins is to provide sufficient server availability and capacity to satisfy their business' operations and needs. A finding from the recent CARD project on data centers performed by one of our partners, the Minnesota Technical Assistance Program (MnTAP), found that small- to medium-sized enterprises were unaware of the energy use of their data centers because no effort had been made to measure it.[8]

In order to address these issues, this project worked to develop, implement, and assess a pilot program that targets SEDCs in Minnesota with the intent of helping utility programs deliver cost-effective energy savings to this target market. The following major steps were defined for the project:

1. An electronic survey to characterize the SEDC market in Minnesota.
2. A field study at selected participant sites to:
    a. Test possible SEDC audit methods,
    b. Measure SEDC power demands using real-time monitoring that would not disrupt mission critical services, and
    c. Evaluate energy efficiency measures and strategies to assess the feasibility of incorporation into Minnesota CIP portfolios.
3. Dissemination of the study's results to stakeholders such as businesses, institutions, and utilities throughout Minnesota.

[8] J. Vanyo, R. Lundquist, and L. Babcock. Energy Conservation Potential at Minnesota Data Centers: Identifying the Opportunity, Minnesota Department of Commerce, Division of Energy Resources, COMM-03192012-53916, November 2014. https://www.cards.commerce.state.mn.us/CARDS/security/search.do?method=showPoup&documentId=%7bE8AF5773-EDEB-4A26-84C2-7C0B537EE593%7d&documentTitle=181490&documentType=6 (retrieved April 28, 2017)

Background

Data Center Basics

To provide various IT needs, companies utilize small embedded data centers (SEDCs), typically a room or rooms with a multitude of servers and network appliances that centralize the IT infrastructure. Servers provide commonly shared services such as data storage and program applications, printing, and email. Disk drives physically store the files and applications employed by the servers and the network. Network appliances include:

- Switches that physically connect the entire network,
- Access points that provide wireless (Wi-Fi) connectivity, and
- Routers that connect to other networks (internet access, VPN).

Telecommunication equipment centralizes the phone system while firewalls protect the network from external intrusion. Most data centers deploy uninterruptible power supplies (UPSs), which utilize batteries as a backup power source in the event of an outage. Depending on the size of the room and the concentration of servers and appliances, data centers can heat up to destabilizing temperatures for the equipment they run. Often air conditioning may be employed to specifically maintain proper equipment operating temperatures in the room.

SEDC Classifications

Shehabi et al. (2016) define two new categories in which data centers can be grouped, avoiding the traditional approach of classifying data centers by size (floor area). The two data center designations are:

1. Internal data centers that are the traditional facilities dedicated to supporting the host businesses or institutions, and
2. Service provider data centers that are remote facilities that provide specialized core services to business and institutional clients via collocation, hosting, and/or cloud services.

According to this classification, SEDCs can be defined as internal data centers and are composed of two types: internal server closets and internal server rooms. Table 4 shows the definitions for these two types of SEDCs.

Table 4. Typical IT Equipment and Site Infrastructure System Characteristics by SEDC Type[9]

SEDC Type	Typical size	Typical infrastructure system characteristics
Internal server closet	< 100 ft^2	Often outside of central IT control (often at a remote location) that has little to no dedicated cooling.
Internal server room	100 – 999 ft^2	Usually under IT control, may have some dedicated power and cooling capabilities.

A special type of server closet is used to provide only network services and will be defined as network closets. Network closets house network switches and patch panels that connect cables directly to individual users providing internet and phone services. They may not contain any data processing computer servers and usually have UPSs to ensure that network services are maintained during power outages. These are also known as intermediate distribution frames (IDFs), which connect to the centralized main distribution frame (MDF) serving as the main server room or data center. In larger offices that occupy more than one floor, the centralized MDF will be on the main floor with one IDF on each of the other floors, all connected back to the MDF or server room.

SEDC Infrastructure

Typically SEDCs are placed in rooms not specifically intended for the purpose of housing a data center. Often they are placed in spare windowless supply rooms within the building, with the IT equipment usually installed in server racks, as shown in Figure 2.

[9] Armin Shehabi, S. Smith, D. Sartor, R. Brown, M. Herrlin, J. Koomey, E. Masanet, N. Horner, I. Azevedo, and W. Lintner. 2016. United States Data Center Energy Usage Report. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-1005775 http://eta.lbl.gov/publications/united-states-data-center-energy-usag (retrieved April 28, 2017)

Figure 2. Server Racks in an SEDC

Power to the server racks comes from the building either through outlets in the wall or hardwired directly into an electrical panel. The power first goes to the UPS(s) before powering the IT equipment. The UPSs are either standalone or rack-mounted (Figure 3 and Figure 4). A UPS stores energy in batteries, which then power the data center during any limited power interruptions. Simply put, it takes the AC electricity from the building, converts it to DC electricity to charge the batteries, and then converts the electricity back to AC to deliver usable electricity to the IT equipment. Some power is lost at the UPS from these two power conversions.

Figure 3. Standalone UPS

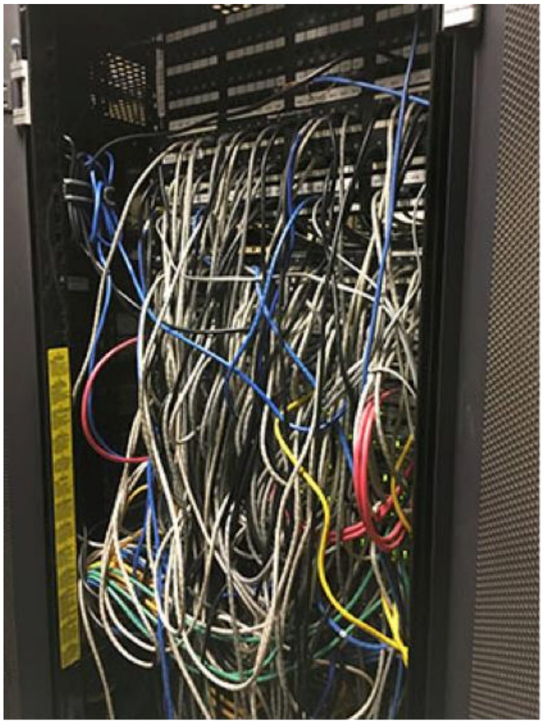
Figure 4. Two Rack-Mounted UPSs

The power from the UPS is then distributed to the equipment mounted in the server racks via power distribution units (PDUs) that function like power strips (Figure 5). All the IT equipment within the racks such as servers, data storage drives (Figure 6), network switches (Figure 7), routers, access points, telecommunications equipment, and firewalls are plugged into the PDUs.

Figure 5. Power Distribution Unit (PDU)

Figure 6. Rack-Mounted Storage Drive and Servers

Figure 7. Network Switches



The power supplies in each of these appliances converts the AC electricity from the UPS into the DC power as it is needed by each of the internal components. Heat is given off from the power supplies and the internal components of the devices as operations are performed. Small internal cooling fans inside heat generating equipment like servers and drives and draw in room air to help exhaust heat from these devices.

SEDCs deal with the waste heat generated by the IT equipment in a number of ways. For server closets, SEDCs may be located in small, confined spaces that are not connected to the building's air distribution system. ASHRAE's recommended indoor air temperature range for data centers is 64.4°F to 80.6°F.[10] The conditioned air from the rest of the building may be sufficient to maintain the operating temperatures of the SEDC within this range. In some situations fans may be required to bring cooler inside air to the space; another option is to install room exhaust fans that remove waste heat to the outside or distribute it to another area in the building that may be able to use the warm air.

When additional cooling is needed, roof top units (RTU) and ductless splits can provide dedicated cooling to the room (Figure 8 and Figure 9). A computer room air-conditioning unit (CRAC) can also be used, especially if the room is specifically designed and constructed to be used as an SEDC (Figure 10). These cooling measures allow thermostatic control of the SEDC air temperature.

Figure 8. Roof Top Unit (RTU)

[10] ASHRAE TC 9.9, 2011. 2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance. ASHRAE: Atlanta, GA.

Figure 9. Ductless Split

Figure 10. Computer Room Air-Conditioning Unit (CRAC)

In larger data centers, airflow measures are usually taken to efficiently deliver the cool, conditioned air to the fronts of the server racks where the cooling fans in the IT appliances draw the air into the devices to cool them. The heated air is exhausted either out the back or through the top of the server rack and then ducted out of the space by the CRAC. This type of airflow management is not typically found in SEDCs. In SEDCs, the cool conditioned air is delivered to the general space and the return ducts are connected to the room either through the building's air distribution system. In some instances ducting from the RTU or CRAC unit draw the heated air from the space. Mixing of the cooled and heated air takes place because of the open-air circulation within the room.

Power Usage Effectiveness (PUE) and Mechanical Load Component (MLC)

Energy Star defines the power utilization efficiency (PUE) as: "a standard industry metric, equal to the total energy consumption of a data center (for all fuels) divided by the energy consumption used for the IT equipment."[11] It provides a measure to compare the power consumption of one data center versus another. A larger PUE means that the data center is consuming power less efficiently. A PUE of 2.0 means that only half the incoming power is used for data processing. Most data centers have a PUE in the range of 1.25 to 3.0 (from a high of 80% efficiency down to 33% efficiency). The Uptime Institute's 2014 Data Center Survey found that the global average PUE of respondents' largest data centers was about 1.7.[12] Benchmarks from Lawrence Berkeley National Laboratory's data center database found that a PUE of 2.0 was standard, 1.4 was good, and 1.1 was better.[13]

While PUE is an effective standard for large standalone data centers, it becomes more problematic to calculate PUEs for SEDCs. Large standalone data centers monitor their energy use while businesses with SEDCs may not even see their energy bills since their utility bills are often included in their rent as tenants. The energy use of SEDCs is not typically submetered and it is difficult to accurately disaggregate the SEDC heating, cooling, and lighting use from the building metered data.

ANSI/ASHRAE Standard 90.4-2016 Energy Standard for Data Centers defines the mechanical load component (MLC) as the sum of all cooling, fan, pump, and heat rejection power divided by the data center information technology equipment (ITE) power. This differs from the PUE in that it does not include other electrical uses in the data center such as lighting and electrical distribution losses.[14] The MLC is a more readily available metric for SEDCs since the power to the HVAC system can be separately submetered at the panel where monitoring the other electrical uses would be problematic. The MLC is the SEDC energy effectiveness metric reported for this project.

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[11] U.S. EPA. 2010. "ENERGY STAR for Data Centers: Scheduled Portfolio Manager Release on June 7, 2010." Energystar.gov. http://www.energystar.gov/ia/partners/prod_development/downloads/DataCenterRating_General.pdf (retrieved April 28, 2017)

[12] Matt Stansberry. 2014. "2014 Data Center Industry Survey." journal.uptimeinstitute.com. https://journal.uptimeinstitute.com/2014-data-center-industry-survey/ (retrieved April 28, 2017)

[13] T. Hong, L. Yang, D. Hill, and W. Feng. 2014. Data and Analytics to Inform Energy Retrofit of High Performance Buildings. Lawrence Berkeley National Laboratory. May. http://escholarship.org/uc/item/0k32878x (retrieved April 28, 2017)

[14] ASHRAE. 2016. ANSI/ASHRAE Standard 90.4-2016, *Energy standard for data centers*. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.

Server Virtualization and Consolidation

In many server rooms, it is not uncommon to find that each application or service provided to the network has its own dedicated physical server. For instance, email services may be provided by their own server, while the financial accounting database application has its own server, and so on. When these applications are not being used, the servers are still powered on even though they are largely dormant, waiting for its next call to action.

Over the past 10 to 15 years, SEDCs have adopted the practice of server virtualization to reduce the number of physical servers needed. Server virtualization allows one physical server to host a number of virtual machines (or guests) that run their own independent operating systems, applications, and system resources. In other words, a number of virtual machines/guests can run on a single physical server, reducing the power demand of the SEDC by removing unneeded single-application dedicated physical servers. In addition to the virtualization software (or hypervisor), the physical server needs to have a CPU that supports virtualization, and sufficient computer resources such as RAM and block storage must be available for all the virtual servers to perform their functions without a performance penalty.

Once virtualization has been implemented, an additional opportunity for dynamic server consolidation is possible through virtual machine live migration. Though the name depends on the vendor, this is a common function available in most enterprise-ready hypervisors. Live migration makes it possible to move running virtual machines from one physical server to another without affecting availability to the network. By using this dynamic hypervisor consolidation, known as distributed power management (DPM), virtual machines can be migrated to fewer hosts (i.e., physical servers) during periods of low resource utilization. During these times the unneeded hosts can be placed on standby to save energy. Hosts can be awakened dynamically as more resources are called for. Thus, rather than having servers running 24/7, some can be put to sleep during off hours such as at night or on weekends and holidays.

Server virtualization, consolidation, and live migration offer the possibility for significant energy savings. A national study by Whitney and Delforge (2014)[15] reports the following:

- 20% to 30% of servers are comatose, yet run 24/7.
- Server utilization is no more than 12% to 18% while the physical servers draw 30%to 60% of their maximum power.
- There is limited and poor deployment of virtualization.

The study suggests that, "Achieving just half of technologically feasible savings could cut electric use by 40% and save U.S. businesses $3.8 billion annually."

[15] Josh Whitney and Pierre Delforge, 2014. Data Center Efficiency Assessment - Scaling Up Energy Efficiency Across the Data Center Industry: Evaluating Key Drivers and Barriers. NRDC and Anthesis. Issue Paper #IP:14-08-A. August. https://www.nrdc.org/sites/default/files/data-center-efficiency-assessment-IP.pdf (retrieved April 28, 2017)

Possible SEDC Energy Savings Measures

Energy efficiency measures for SEDCs fall under two categories: 1) the IT side with equipment and operation opportunities, and 2) the cooling side, if applicable, with equipment, operation, and airflow management. It is estimated that 30% of all servers are "comatose," meaning that they are powered on but not serving any useful information or computing services.[16] Opportunities to consolidate servers and utilize power management during times of low use would provide obvious savings. On the cooling side, SEDCs are often overcooled because of poor air management and poor separation of hot and cold air. According to Magnus Herrlin, program manager for the High Tech Group at Lawrence Berkeley National Lab, "Air management is not a technology that has been widely implemented in smaller data centers."[17]

In order to be implemented, the energy savings need to justify the time and effort of IT staff and also fit within the capital expenditure limits of businesses and institutions. Most importantly, any changes must not negatively impact the reliability of the IT department's mission critical services. Lawrence Berkeley National Laboratory has identified 14 cost-effective measures for improving SEDC energy efficiency, as shown in Table 5.[18]

Table 5. Top 14 Measures to Save Energy in an SEDC

Category	Measure
Simple, No-Cost, or Very-Low-Cost Measures	1. Determine computational functions/turn off any unused servers.
	2. Increase temperature set points to the high end of ASHRAE's recommended limit.
	3. Examine power backup requirements to determine if the UPS is oversized or even needed.
	4. Install blanking panels and block holes between servers in racks to help with airflow management.

[16] Jon Koomey and Jon Taylor. 2015. "New data supports finding that 30 percent of servers ate 'Comatose', indicating that nearly a third of capital in enterprise data centers is wasted." Anthesis Group, June. http://anthesisgroup.com/wp-content/uploads/2015/06/Case-Study_DataSupports30PercentComatoseEstimate-FINAL_06032015.pdf (retrieved April 28, 2017)

[17] Yevgeniy Sverdlik. 2015. "The Problem of Inefficient Cooling in Smaller Data Centers." datacenterknowledge.com. http://www.datacenterknowledge.com/archives/2015/12/04/the-problem-of-inefficient-cooling-in-smaller-data-centers/ (retrieved April 28, 2017)

[18] Mark Bramfitt, Rich Brown, Hoi Ying (Iris) Cheung, Pierre Delforge, Joyce Dickerson, Steve Greenberg, Rod Mahdavi, and William Tschudi. 2012. Improving Energy Efficiency for Server Rooms and Closets. Lawrence Berkeley National Laboratory, October. https://datacenters.lbl.gov/sites/all/files/fact-sheet-ee-server-rooms-3.pdf (retrieved April 28, 2017)

Category	Measure
A Little More Work, But Still Fairly Simple	5. Refresh the oldest equipment with the high-efficiency models.
	6. Move to a more energy-efficient internal or external central data center space, or to co-location or cloud solutions.
	7. Provide energy efficiency awareness training for IT custodial and facility staff.
Higher Investment, But Very Cost Effective	8. Implement server power management.
	9. Consolidate and virtualize applications.
	10. Implement rack/infrastructure power monitoring.
	11. Install variable frequency drives on cooling units.
	12. Install rack- and row-level cooling.
	13. Use air-side economizers.
	14. Install dedicated cooling for the room.

Barriers to Implementing Energy Efficiency Measures

While these fourteen measures have been identified as clear steps to reduce SEDC energy use, barriers exist within the businesses that prevent adoption. These include:

- **The customers' fear of down time of mission critical equipment**. IT staff are particularly conservative in taking any measures that may impact keeping the systems running, which is the primary task of IT staff.
- **The limits to budget and time of IT staff**. Because energy efficiency may not be a priority, management may choose not to spend IT staff and resources on non-mission critical services.
- **The lack of technical expertise in implementing and maintaining energy-efficient hardware and software measures**. Learning new operational approaches or features may require new knowledge and skills that could require training or technical support.
- **The need for data privacy and security**, which may require that servers are located and secured on the premises. Some businesses may be contractually bound by their clients to have their data stored and accessed only on the businesses premises.
- **The presence of split incentives**, where IT staff is concerned with keeping equipment running at all cost while the company accounting staff oversees operating costs. Similarly, in office rental space, the utility bill is often included as part of the buildings rent so the operating cost of the data center are unknown.

- **The cost effectiveness of implementing measures**. Some of these measures have prohibitively large payback periods that are difficult for businesses to justify. Others have savings potentials that are difficult to calculate at all.

Being cognizant of these barriers and obstacles is important when communicating with IT staff in order to foster and drive energy efficiency practices. Based on these issues, this pilot project was designed to: 1.) determine the extent of the barriers; 2.) demonstrate how to deal with the barriers; 3) show that energy savings can be achieved without impacting mission critical services; and 4.) quantify the savings that can be achievable.

Methodology

This project was performed through three main tasks:

1. The market characterization of SEDCs in Minnesota,
2. The field study to assess energy use at selected sites and measure savings of installed measures, and
3. The dissemination of the study's results to stakeholders such as businesses, institutions, and utilities throughout Minnesota.

Task 1: Characterization

Literature Review

A literature review was performed to assess previous data center studies focused on SEDCs and discern the applicability of those studies to the Minnesota market. In 2014, the Minnesota Technical Assistance Program (MnTAP) published a CARD-funded white paper that analyzed data center energy efficiency opportunities and challenges in Minnesota.[19] The study covered the full range of data centers from server closets with a floor area less than 200 ft^2 to enterprise-class data centers with a floor area greater than 15,000 ft^2. We reviewed studies by Natural Resource Defense Council (NRDC)[20,21], Cadmus Group[22,23], and Lawrence Berkeley National

[19] J. Vanyo, R. Lundquist, and L. Babcock. Energy Conservation Potential at Minnesota Data Centers: Identifying the Opportunity, Minnesota Department of Commerce, Division of Energy Resources, COMM-03192012-53916, September 2014.

[20] Drew Bennett and Pierre Delforge, Small Server Rooms, Big Energy Savings: Opportunities and Barriers to Energy Efficiency on the Small Server Room Market, NRDC Issue Paper, February 2012. http://www.nrdc.org/energy/files/Saving-Energy-Server-Rooms-IssuePaper.pdf (retrieved April 28, 2017)

[21] Mark Bramfitt, P.E., and Pierre Delforge, Utility Energy Efficiency Program Design: Server Room Assessments and Retrofit, NRDC, April 11, 2012. http://docs.nrdc.org/energy/files/ene_12041101a.pdf (retrieved April 28, 2017)

[22] Allison Bard, Robert Huang, Mark Bramfitt, Kerstin Rock, and Michelle Lichtenfels, Pacific Gas and Electric Company Small Data Center Market Study, The Cadmus Group, Inc., December 27, 2013, http://www.calmac.org/publications/FINAL_REPORT_PGE_Small_Data_Center_Study.pdf (retrieved April 28, 2017)

[23] Allison Bard, Robert Huang, and Rafael Friedmann, "From Our Closet to Yours: Fashioning Energy Efficiency Programs for Small Data Centers," Proceedings, 2014 ACEEE Summer Study on Energy Efficiency in Buildings, paper 6-232, August 2014. http://aceee.org/files/proceedings/2014/data/papers/6-232.pdf (retrieved April 28, 2017)

Laboratory[24,25] to learn from their experiences with this sector. The literature review is included as Appendix A: Literature Review.

Electronic Survey

The Wisconsin Energy Conservation Corporation (WECC) developed an electronic survey to help discern the IT services that SEDCs currently serve for various business types and identify opportunities for energy savings (Appendix B: Electronic Survey Questions). The goals of the survey were to:

- Define the major sectors in Minnesota that employ SEDCs and the common types and sizes of those businesses;
- Assess the nature and variety of SEDCs used and the common IT practices employed;
- Survey stakeholder perceptions and gain an understanding of their support network; and
- Determine opportunities and barriers to implementing energy efficiency measures.

We solicited survey responses via email using lists from project partners (MnTAP, One Stop Efficiency Shop, and the Foundation) and help from organizations such as the B3 Benchmarking Program, Minnesota Council of Nonprofits, the Minnesota Department of Commerce Division of Energy Resources, the Minnesota Technical Reference Manual Advisory Committee, and the Minnesota Department of Employment and Economic Development.

Phone Interviews

We performed interviews with a number of utilities, both inside and outside of Minnesota, with active data center programs to update information about current programs, program barriers, and future plans. Discussions also took place with experts in the field to keep up-to-date with the latest work and findings.

Task 2: Field Study

The field study provided a snapshot of the current state of SEDC practice and energy usage in Minnesota. We recruited participants from a number of sectors representative of typical SEDC implementations and monitored energy use at the sites for a sufficient period to acquire a baseline and to afford sufficient insight to recommend possible energy efficiency measures.

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[24] H.Y. Iris Cheung, Steve E. Greenberg, Roozbeh Mahdavi, Richard Brown, and William Tschudi. (Lawrence Berkeley National Laboratory, 2013. Energy Efficiency in Small Server Rooms. California Energy Commission. Publication number: CEC-XXX-2013-XXX. http://www.energy.ca.gov/2015publications/CEC-500-2015-052/CEC-500-2015-052.pdf (retrieved April 28, 2017)

[25] Iris (Hoi Ying) Cheung, Steve Greenberg, Roozbeh Mahdavi, Richard Brown, and William Tschudi, "Energy Efficiency in Small Server Rooms: Field Survey and Findings," Proceedings, 2014 ACEEE Summer Study on Energy Efficiency in Buildings, paper 9-109, August 2014. http://aceee.org/files/proceedings/2014/data/papers/9-109.pdf (retrieved April 28, 2017)

Working with IT staff, experimental strategies were planned and tested, and post-measure monitoring was performed, to assess energy savings impacts.

Recruitment

We recruited 11 participants for the study. The test sites were recruited through our electronic survey; outreach efforts from CEE programs and contacts; clients of subcontractor the Foundation; small manufacturing sites enlisted by MnTAP; and referrals from Xcel Energy. The participants were recruited to provide a representation of the spectrum of businesses and institutions that employ SEDCs. IT staff was contacted and all participants signed a Participant Agreement form pledging their cooperation for the duration of the project. Participation included allowing us to monitor their IT energy and cooling energy use, as applicable, for the duration of the study. They also allowed us to take an inventory of their equipment.

Monitoring IT Power Usage

In order to keep the monitoring as non-intrusive as possible, we monitored power to the server racks upstream of the UPS. When the UPS was plugged into an outlet in the wall, we used cables produced by Packet Power (http://www.packetpower.com/) to provide us with one-minute power and energy data. The cables communicate with a gateway that sends the data over the internet to the PacketPower Amazon Web Services (AWS) servers.[26] The internet connection was through a gateway provided by PacketPower and was connected through the host network. The cables were connected in line between the outlet at the wall and the power cord from the UPS. Figure 11 shows a Packet Power cable and Figure 12 shows the gateway. Connecting the cables was done very quickly so that, during the short time that power is removed from the UPS, the UPS was able to power the server and associated IT equipment. We obtained information on the types of plugs used by the UPS and the amps of the current to the UPS from the IT staff to ensure that the cable would connect properly. Figure 13 shows the cables connected at a site.

[26] Amazon Web Services. "Cloud Computing with Amazon Web Services." aws.amazon.com. https://aws.amazon.com/what-is-aws/ (retrieved April 28, 2017)

Figure 11. PacketPower Cable

Figure 12. Packet Power Gateway

Figure 13. Site-Installed Packet Power Cables

If the UPSs are hardwired to the electrical panel, current transformers (CTs) were used to monitor the power at the breakers. CTs can measure the alternating current running through a line via the magnetic field generated by that current. Consequently, CTs can be clamped around the power lines without any disconnection of the lines or disruption of power. When working inside the panel, we hired a licensed electrician to do the installation. We used either an eGauge data logger (https://www.egauge.net/) or a PacketPower data logger to collect the data. The data logger had a built in IP address that could be accessed through host network, or its built-in 4G connection could be used to provide secure internet connectivity. Figure 14 shows the eGauge data logger with CTs ready for site installation and Figure 15 shows the CTs installed in an electrical panel. In addition, if dedicated air conditioning equipment was used to cool the SEDC, we monitored the power to the HVAC equipment using CTs at the panel.

Figure 14. eGauge and 3CT Clamps

Figure 15. Panel-Installed CT Clamps

One-minute interval data was collected from both types of monitoring systems. Dashboards showing the continuous monitoring were accessible for viewing by each of the participants, and the monitoring equipment was kept on site for both the pre- and the post-intervention periods.

Monitoring SEDC Air Temperatures

Typically SEDCs are placed in rooms not necessarily designed for use as a server room or network closet. Consequently these spaces may be either unconditioned or retrofitted with dedicated cooling. Even in instances when dedicated cooling is provided to the space, the space is usually considered small enough that airflow management is not considered. ASHRAE TC 9.9 recommends that inlet air temperature entering the data center equipment be in the range of 64.4°F to 80.6°F (18°C to 27°C).[27]

In order to measure the air distribution within the conditioned server rooms, we obtained Onset HOBO Bluetooth temperature data loggers[28] from Apogee Interactive, which helped with data visualization and analysis (Figure 16).[29]

Figure 16. Onset HOBO MX1101 Data Logger

A number of data loggers were placed at different locations in the server rooms to assess air distribution. These locations included at the room thermostat, the front of the server rack, and inside the server rack (Figure 17, Figure 18, and Figure 19).

[27] ASHRAE TC 9.9. 2015. Thermal Guidelines for Data Processing Environments, Fourth Edition. Atlanta GA: ASHRAE.

[28] Onset. "HOBO Temperature and Relative Humidity Logger for Mobile Devices." Onsetcomp.com. http://www.onsetcomp.com/mx (retrieved April 28, 2017

[29] Apogee Interactive. "About Apogee." apogee.net. http://www.apogee.net/about/ (retrieved April 28, 2017)

Figure 17. Temperature Data Logger at Server Room Thermostat

Figure 18. Data Logger Measuring Server Rack Inlet Temperature

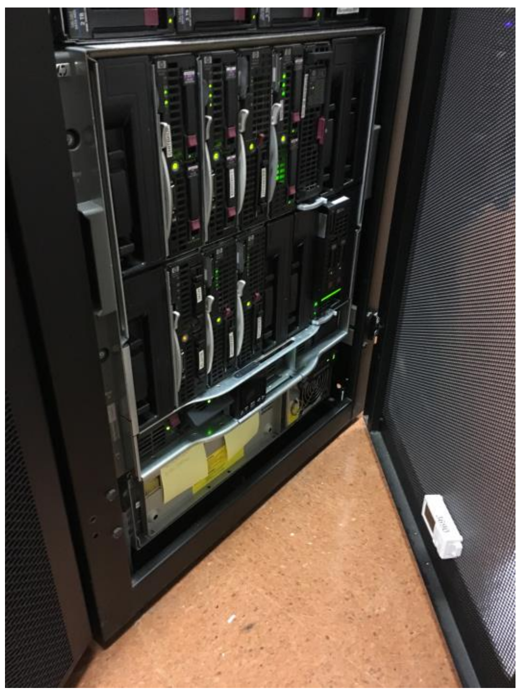
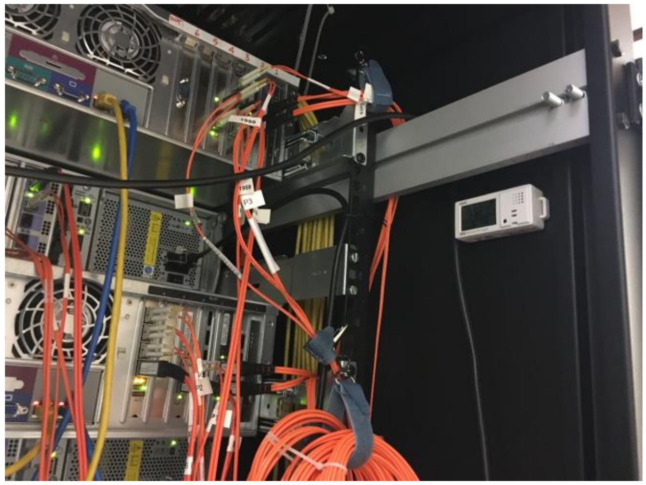


Figure 19. Data Logger Measuring Server Rack Outlet Temperature



Data was collected at one-minute intervals, with smaller intervals of 30 seconds and 15 seconds that were used to assess evidence of short cycling of the cooling units. The data loggers that we used output files in a number of formats including csv and these files can be downloaded to a smart phone via Bluetooth. These files are then sent electronically via email from phone to a host. Based on the data, recommendations for airflow management measures, set point temperature changes, and addressing short-cycling issues can be made.

Energy Efficiency Measures

The diverse and disparate nature of how the project participants situated, equipped, and employed their SEDCs required us to partner with their IT staff to identify and deploy energy efficiency strategies. Using the monitored interval data allowed us to understand the magnitude of the power demands of the SEDCs and also observe patterns of operation. Working closely with IT staff helped us understand their overall objectives, concerns, and constraints. Within this context we also worked to facilitate the process by engaging with the electric utility (Xcel Energy for the majority of participants) to encourage participant implementation via existing utility incentive opportunities. We also provided technical support to participant IT, facilities, and management staff through the efforts of Robert Lysholm of CEE and Matthew Woestehoff of the Foundation, who both lent their IT expertise to the project. Neal Ray of CEE, Gustav Brandstrom of QSE (and formerly of CEE), and Jon Vanyo of MnTAP also served as engineering consultants.

Task 3: Dissemination

At the completion of the project, we performed a webinar for public dissemination of study findings. The target audience for the webinar was Minnesota State staff, utility representatives, and business decision-makers such as IT staff, fiscal officers, building personnel, architectural designers, property manager, and building owners. The webinar content was recorded for later viewing and wider distribution. The Wisconsin Energy Conservation Corporation (WECC) was the lead on this effort.

Results

Literature Review

Based on the reviewed literature described in Appendix A: Literature Review, the following observations can be made:

- Utilities throughout Minnesota offer incentives and rebates that can be applied to data center energy efficiency measures. Table 6 shows the list of incentives, rebates, and loans as reported by MnTAP.[30] The list includes measures dealing with IT equipment and cooling, as well as services such as monitoring and consulting. Some are prescriptive based while others are performance based.

Table 6. Select Minnesota Utilities Data Center Efficiency Initiatives

Utility	Service Territory	Data Center Incentives Offered
Austin Utilities	City of Austin	Prescriptive rebates on cooling equipment, servers, and clients.
Dakota Electric Association	Dakota County	Low interest loans, rebates on cooling equipment, audits, consulting, and monitoring.
Minnesota Power	Northeastern Minnesota	Standard and, performance rebates.
Otter Tail Power Co	Western Minnesota	Grants available for conservation and efficiency improvements based on demand and kwh saved.
Owatonna Public Utilities	Owatonna area	Prescriptive rebates on cooling equipment, servers, and clients.
Rochester Public Utilities	City of Rochester	Prescriptive rebates on cooling equipment, servers, and clients.

[30] J. Vanyo, R. Lundquist, and L. Babcock. Energy Conservation Potential at Minnesota Data Centers: Identifying the Opportunity, Minnesota Department of Commerce, Division of Energy Resources, COMM-03192012-53916, September 2014.

Utility	Service Territory	Data Center Incentives Offered
Xcel Energy	St. Paul/Minneapolis and suburbs	Specific data center efficiency rebate program includes an energy study, cost estimates of measures, and rebates. Study rebates up to 75% or $25,000, and rebates of $400 per kW saved in preapproved projects.

- The Cadmus and NRDC reports (see Appendix A: Literature Review) affirmed our segment approach using IT vendors and other connectors to engage SEDC managers.[31,32] Five of the seven major segments identified by the Cadmus Group as employing SEDCs were identified as likely segments from which to recruit our participating sites. These were government, schools, healthcare, professional services, and manufacturing. The financial services segment would be difficult to recruit from because of security issues and the risk averse nature of their IT services. The high tech and biotech segment would not represent a significantly different segment from the types of professional services companies that we were recruiting. The breadth of segments that we were recruiting from should demonstrate the wide applicability of our findings to typically encountered SEDCs. The vendor and IT manager survey instruments created by the Cadmus Group served as a good model for our instrument tool.
- Since IT managers have little awareness of their power draw/energy use and server utilization, there was a clear need to develop a protocol that allowed us to measure and document these aspects of SEDCS while guaranteeing little to no impact on SEDC operations and reliability. The Packet Power jumper cable was a good solution for monitoring power draw and energy use both pre- and post-measure implementation. A means to assess server utilization needed to be identified and vetted for use in the project.
- It is likely that most of the measures implemented would be IT Environmental Conservation Opportunities (ECOs) such as:
    - Server consolidation,
    - Server virtualization,
    - Equipment replacement with ENERGY STAR UPSs and servers,
    - Data storage management,

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31 Allison Bard, Robert Huang, Mark Bramfitt, Kerstin Rock, and Michelle Lichtenfels, Pacific Gas and Electric Company Small Data Center Market Study, The Cadmus Group, Inc., December 27, 2013. http://www.calmac.org/publications/FINAL_REPORT_PGE_Small_Data_Center_Study.pdf

32 Mark Bramfitt, P.E., and Pierre Delforge, Utility Energy Efficiency Program Design: Server Room Assessments and Retrofit, NRDC, April 11, 2012. http://docs.nrdc.org/energy/files/ene_12041101a.pdf (retrieved April 28, 2017)

- Migration to the cloud, and
- Colocation.

Data from the Packet Power jumper cables would allow us to assess the energy savings.

- HVAC ECOs would be implemented as needed, with scheduling and setpoint temperature adjustment as the main low-cost items considered. Other opportunities would be implemented depending on cost and willingness of the business, and submetering of HVAC equipment would need to be performed for these cases.
- The need for a benchmarking metric for SEDCs was evident since the PUE did not appear to be a good fit for SEDCs. The Lawrence Berkeley National Lab assessment tool[33] would be used as a model for the SEDC on-site audit with additional information considered to help characterize each site. The project goal would be the development of a protocol to assess potential and opportunity and to account for actual savings.
- Because of the issue of split incentives, energy costs and savings are not likely determining factors for IT managers to take action. Some framing and messaging might be needed to persuade IT managers and financial officers to adopt ECOs (e.g. environmental messaging). The messaging would need to be developed as we monitored more sites and obtained data that we could use regarding SEDC energy use and costs. Providing the Foundation with the tools and information necessary to encourage participation would help us develop a program delivery plan. We would also need to work with utilities to identify rebates and incentives that would reduce both the initial costs and capital costs for SEDCs. A prescriptive incentive program appears to be a likely strategy for SEDC customers, and the NRDC[34] supplies a good template for this type of program.

Electronic Survey

The electronic survey was posted online from the middle of April 2015 to the end of May 2015. Appendix B: Electronic Survey Questions shows the survey questions. The outreach efforts of WECC, MnTAP, and CEE resulted in 134 responses that represented a range of data center types from server closets with floor areas less than 200 ft^2 to enterprise data centers greater than 15,000 ft^2. Since the focus of this study is SEDCs, the results discussion will focus on data closets (under 200 ft^2) and server rooms (200 ft^2 to 1,000 ft^2), which accounted for 82 (62%) total surveys, with 47 of those being data closets less than 200 ft^2. Responses came from all over the state. Figure 20 shows the geographical distribution of the responses based on the zip code reported

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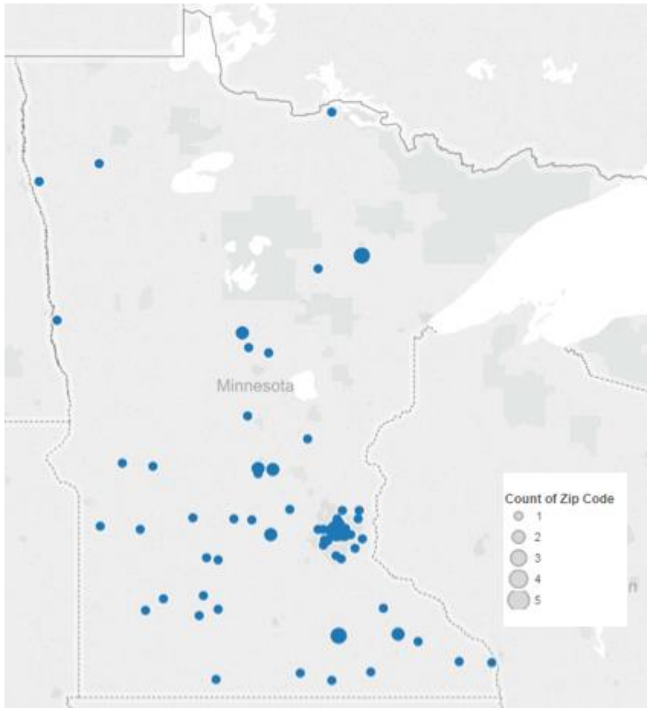
[33] H.Y. Iris Cheung, Steve E. Greenberg, Roozbeh Mahdavi, Richard Brown, and William Tschudi. (Lawrence Berkeley National Laboratory, 2013. Energy Efficiency in Small Server Rooms. California Energy Commission. Publication number: CEC-XXX-2013-XXX. http://www.energy.ca.gov/2015publications/CEC-500-2015-052/CEC-500-2015-052.pdf (retrieved April 28, 2017)

[34] Mark Bramfitt, P.E., and Pierre Delforge, Utility Energy Efficiency Program Design: Server Room Assessments and Retrofit, NRDC, April 11, 2012. http://docs.nrdc.org/energy/files/ene_12041101a.pdf (retrieved April 28, 2017)

by each respondent. A total of 29 responses came from the Twin Cities metro area while the other 53 respondents were located in Greater Minnesota.

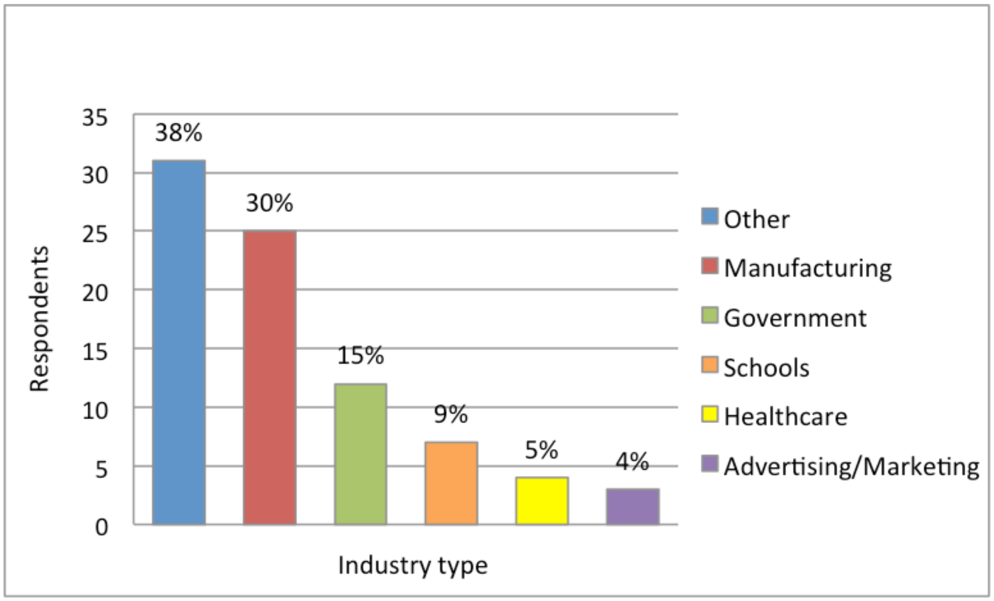
Figure 20. Geographical Distribution of SEDC Survey Responses (By Zip Code)



The industry distribution breakdown for the survey respondents is as follows and is also shown in Figure 21:

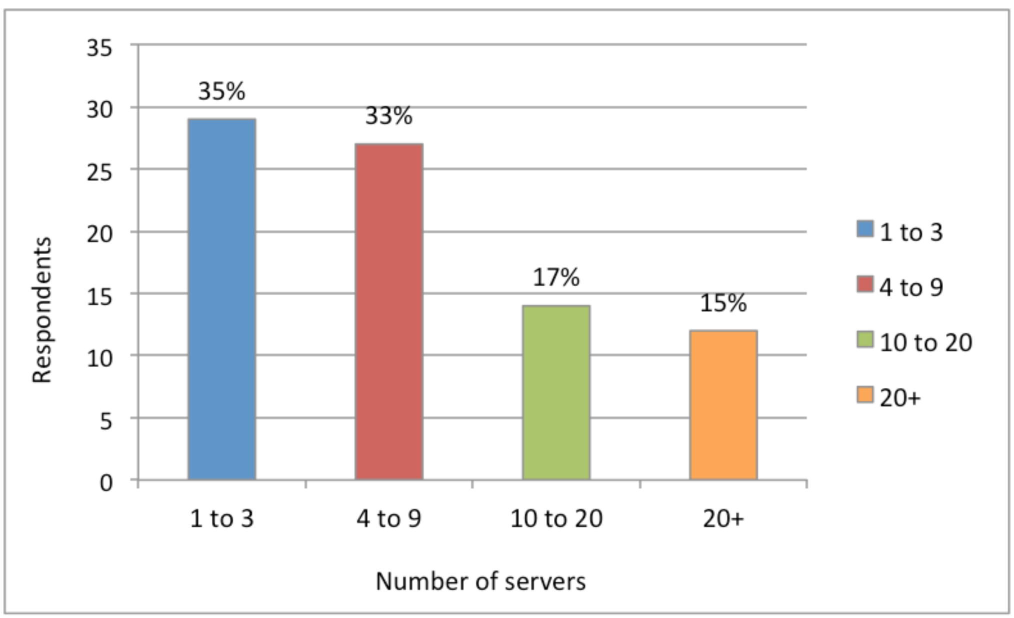
- 30% (n=25) of the respondents were in the manufacturing sector.
- 15% (n=12) of the respondents were government entities.
- 8% (n=14) of respondents were in advertising/marketing, schools, and healthcare.
- Nearly 40% (n=31) of respondents were in a variety of other sectors, including nonprofit, property/real estate, software, research, construction, hospitality, wholesaler, IT consulting, utilities, engineering, RV sales, and telecommunications.

Figure 21. Industry Classification of Survey Respondents (n=82)



The most frequent building type for respondents (35%) was a stand-alone/business building, with 29% of the SEDCs located in a manufacturing facility and 21% of the respondents located in an office complex. A little more than one third of the businesses had one to three servers in their SEDC, and about two-thirds of the businesses used less than 10 servers (Figure 22).

Figure 22. Number of Servers Reported in Business' SEDC (n=82)



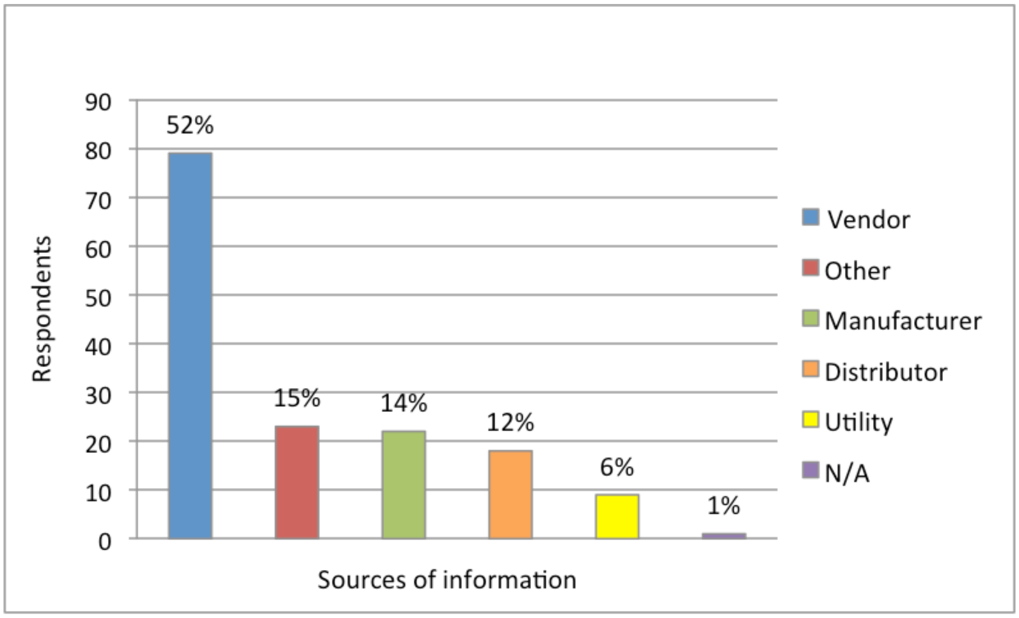
Perhaps a better measure of the size and energy use of SEDCs is the number of server racks found in them. Server racks hold much more equipment than just the physical servers, including UPSs, storage devices, routers, switches, and more, and these pieces of equipment also are also energy consumers. About 50% of the respondents had one server rack in their SEDC, another 38% had between two to four racks, and about 10% had five to nine racks. The industry reports that the average IT refresh cycle is about three years. For SEDCs, 39 of 82 respondents (48%) have servers that are older than this and 88% of the SEDCs have servers with an average age of two years or more. The responses for the timetable of server upgrades showed that 56% of the respondents were not planning upgrades for another year and 24% were not planning an upgrade for at least another three years. The refresh cycle for SEDCs from this sample is more along the lines of five to six years. According to the survey, the main motivation for making server upgrades was dependability.

To gauge the amount of data on SEDC power consumption that might be available to us, we asked our respondents whether they monitored data center power usage or the amount of server utilization. Only 13% said that they monitored their SEDC power usage while 60% monitored server utilization. All the respondents that monitored power usage also monitored server utilization. However, comparing data closets (under 200 ft^2) to server rooms (200 ft^2 to 1,000 ft^2), only 9% of the data closet respondents monitored power usage versus 20% of the server room respondents. Similarly, 51% of the data closet respondents answered that they monitored their server utilization while 71% of the server rooms said that they did not.

Many of the survey respondents had already adopted some energy efficiency measures. Server virtualization was implemented by 66% of the respondents, with 18% responding no and the remaining 18% that they did not know. With regard to cloud services and cloud computing, 62% responded that some cloud services were being used with 33% saying no and 5% not knowing. Nearly half (48%) of the respondents took advantage of both virtualization and cloud services. The main barriers to adopting virtualization were cost and maintenance/staffing while the main barriers to cloud services were security and cost.

We also used the survey to gauge opportunities to influence IT managers to adopt energy efficiency measures for SEDCs. An important finding is that only 2% of respondents were aware that utility rebates and incentives were even offered for data centers. This can be attributed in part to the utilities' data center outreach efforts. Current efforts place an emphasis on large enterprise data centers and the efforts of dedicated account managers and staff to reach out to their larger customers to target greater centralized savings. To gain insight towards resolving the issue of reaching out to the diverse SEDC customer base, we asked IT managers about their trusted sources of information in order to identify effective communications channels. Figure 23 shows the results from this survey question. Responses could be made in more than one category. Vendors clearly are an important source of information and a channel to use to promote data center energy efficiency. Vendors could have a significant role in both outreach to SEDC IT managers and in advocating for energy efficiency measures. It also suggests that a midstream strategy with incentives to vendors could be very effective. As expected, the "Other" category had a range of replies including consultant, peer, and brother.

Figure 23. Trusted Sources of Information for IT Decisions



The electronic survey report is included as Appendix C: Electronic Survey Results

Field Study Participants

Participants were recruited from interest generated by the electronic survey, individual contacts, and referrals from utilities. A total of eleven sites were recruited to participate in the field study. MnTAP recruited three small manufacturing companies, one located in the Twin Cities Metro region and two located in Greater Minnesota. CEE recruited the eight participants representing commercial and institutional sectors, all of them located in the Twin Cities metro area. These participants include two architectural design firms, a healthcare clinic, a law firm, a municipality, a non-profit, and two school districts. The eleven participants represent a variety of data closet uses across sectors that are representative of common SEDC users, based on servers, storage, networking, and telecom. A total of 24 SEDCs (ten server rooms and fourteen IDFs) were located amongst these eleven participants. Table 7 shows the details of each of the participants.

Table 7. Summary of Participants and Their SEDCs

Site	Sector	Server Rooms	Server Room Racks	Intermediate Distribution Frames (IDFs)	Total SEDCs
Site 1	Architectural Design	1	10	3	4
Site 2	Architectural Design	1	3	0	1
Site 3	Healthcare	0	0	5	5
Site 4	Legal Services	1	2	0	1
Site 5	Municipality	1	6	0	1
Site 6	Nonprofit	1	2	2	3
Site 7	School District	1	5	2	3
Site 8	School District	1	9	2	3
Site 9	Manufacturing	1	4	0	1
Site 10	Manufacturing	1	4	0	1
Site 11	Manufacturing	1	2	0	1
Total		10	47	14	24

Of the commercial/institutional sites, three had a single server room while the other five had a main server room that was connected to a number of IDFs. The healthcare facility (Site 3) consisted of five IDFs on each floor of the building. Its primary computing services were provided by an off-site enterprise data center owned and operated by the healthcare provider. All three manufacturing sites had single server rooms.

IT Equipment

We inventoried all the IT equipment in each of the eleven SEDCs, both server rooms and IDFs as part of an initial audit process. The form to collect this information is included in Appendix E: Device Inventory Form. Figure 24 shows the server room of one of the participating sites.

Figure 24. Server Room at Site 5

Table 8 shows the number of IT devices in the server rooms at each site.

Table 8. Participant Server Room IT Equipment Inventory

Site #	Racks	Servers	Storage (SANs)	Switches	UPSs	Routers	Telecom
1	10	16	45	14	1	7	12
2	4	5	1	4	1	1	1
4	2	9	2	9	2		4
5	6	9	9	10	1	5	2
6	2	7	4	2	3	1	1
7	4	8	7	1	4		
8	9	26	10	17	1	5	6
9	4	12	7	10	8		2
10	4	7	1	1	6		
11	2	8	4	4	2		3
Mean	5	11	9	7	3	2	3
Standard Deviation	3	6	13	6	2	3	4
Max	10	26	45	17	8	7	12
Min	2	5	1	1	1	0	0

Site 3 is not included in the table because it does not have a server room.

Figure 25 shows a typical IDF found in the study.

Figure 25. IDF at Site 7

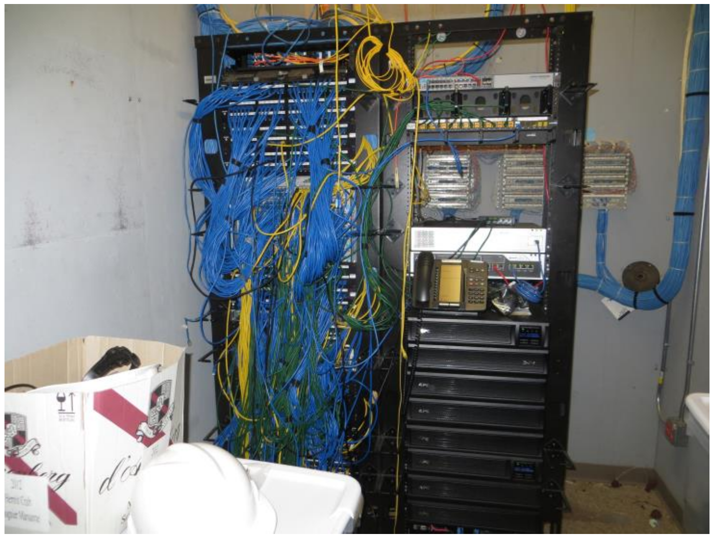


Table 9 shows the IT equipment found in each of the IDFs.

Table 9. Participant IDF IT Equipment Inventory

Site #	Racks	Servers	Storage (SANs)	Switches	UPSs	Routers	Telecom
1	3	1		7	1		
1	3	1		7	1		
1	2	1		6	1		
3	2			4	1	5	
3	1			5	1		
3	1	1		5	1		
3	1			3	1		
3	1			3	1	1	
6	1	1		1	1		
6	2	2	4	1	1	1	
7	2			5	2		2
8	2			9	2		
8	1			6	2	1	
Mean	2	1	0	5	1	1	0
Standard Deviation	1	1	1	2	0	1	1
Max	3	2	4	9	2	5	2
Min	1	0	0	1	1	0	0

Comparing Table 8 and Table 9 illustrates the differences in the functions of server rooms and IDFs. Server rooms contain storage devices and arrays, a larger number of servers, switches, and other IT appliances like tape drives, firewall security, modems, and routers. The typical server room in this study had five racks with 11 servers, seven switches, and nine storage arrays. The typical IDF for this study had only two racks with seven switches. With the exception of one of the IDFs at Site 6, none of the IDFs had any storage devices and six IDFs had servers. The primary functions of the IDFs are to provide internet connectivity to workstations and office equipment and to provide power and data to phones and Wi-Fi access points (APs). Power over Ethernet (PoE) provides low voltage DC power through Cat-5 and Cat-6 Ethernet cable. Even with PoE, the power demand for IDFs will typically be less than for server rooms.

Dedicated Mechanical Load Equipment

Nine of the 10 sites with server rooms had dedicated cooling equipment while one site (Site 6) had an exhaust fan that removed the heated air from their server room (Table 10).

Table 10. Summary of Participants' Dedicated Mechanical Load Equipment

Site	Dedicated Air Conditioning
Site 1	CRAC with under floor air delivery
Site 2	In-Row
Site 4	RTU
Site 5	Three ductless splits
Site 6	Exhaust fan
Site 7	RTU
Site 8	Two ductless splits
Site 9	RTU
Site 10	Three ductless splits
Site 11	CRAC

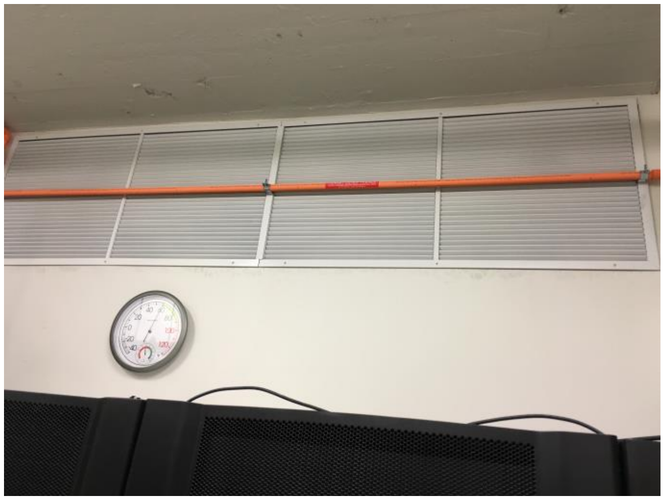
Site 3 is not included in the table because it does not have a server room.

For Site 1, the CRAC is located in an adjacent room and cold air is delivered to the intakes of the server rack via under floor ducting (Figure 26 and Figure 27). The return to the CRAC is located along the back wall above the UPS (Figure 28). A thermostat in the room controls the temperature. Site 11 also uses a CRAC located in an adjacent room, but the room is directly above the data center.

Figure 26. CRAC Unit at Site 1

Figure 27. Under Floor Cold Air Supplies at Site 1

Figure 28. CRAC Return Grilles at Site 1



Site 2 has an in-row CRAC unit (Figure 29). A temperature sensor is connected to the CRAC unit and located at the server rack to control cooling. The server room also has a thermostat that controls baffles in a transfer grille and an exhaust fan in case conditioned air from the rest of the office was needed to cool the server room (Figure 30 and Figure 31).

Figure 29. In Row CRAC at Site 2

Figure 30. Exhaust Fan above Server Room at Site 2

Figure 31. Transfer Grille into Server Room at Site 2

Sites 4, 7, and 9 use RTUs to supply cold air through connected ductwork to the server rooms (Figure 32 and Figure 33).

Figure 32. RTU at Site 7

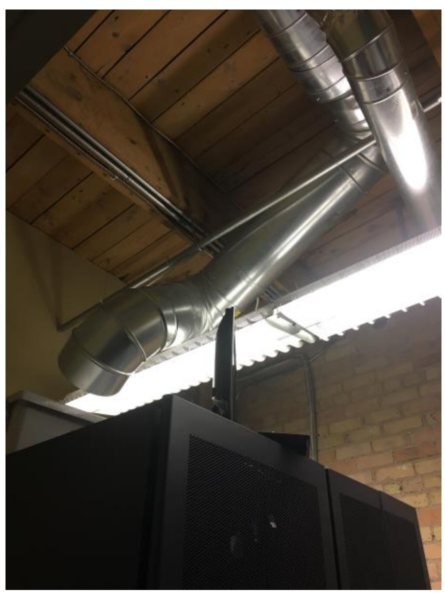
Figure 33. RTU Supply and Return at Site 7

Sites 5, 8, and 10 employ a number of ductless splits that are wall-mounted units located in the room (Figure 34). Cold air is supplied through registers at the top of the unit and the grilles at the bottom of the units draw in the return air.

Figure 34. Ductless Splits at Site 8

The final site with a dedicated mechanical system is Site 6. This site has a small server closet that relied on conditioned air from the rest of the office to provide cooling. Heat generated within the server room is exhausted using a 750 CFM fan and the negative pressure created by the exhaust fan ensure that conditioned air is delivered to the server racks (Figure 35).

Figure 35. Ducting to Exhaust Fan at Site 6



Baseline Energy Use

IT Power Loads

Table 11 shows the average power load for each of the SEDCs measured over the time periods shown. Data was collected at one minute intervals. We monitored the load into the UPSs at all of the sites. The standard deviation (σ) is a measure of the amount of variation of the data around the calculated mean. The range of values enclosed by $\pm 2 * \sigma$ around the mean includes 95% of the data collected (a 95% confidence interval). The coefficient of variation (CV) is the percentage of the standard deviation compared to the calculated mean. It is a measure of the range of variability in the data set. A small CV indicates a narrow spread of data while a large CV indicates a wide fluctuation in the measured data.

Table 11. Average Measured IT Power Loads of the SEDCs

Site #	SEDC Type	Mean Power Load (W)	Standard Deviation (W)	Coefficient of Variation	Time Period
1	Server Room + 4 IDFs	30325	556	1.8%	2/1/16 to 3/31/16
2	Server Room	3194	21	0.7%	8/1/16 to 9/30/16
3	IDF	899	21	2.4%	1/1/16 to 1/31/16
	IDF	559	8	1.5%	12/4/15 to 12/26/15
	IDF	580	2	0.4%	11/12/15 to 12/4/15
	IDF	430	1	0.2%	10/21/15 to 11/12/15
	IDF	507	1	0.3%	9/30/15 to 10/21/15
4	Server Room	3208	81	2.5%	3/1/16 to 6/30/16
5	Server Room	6450	69	1.1%	8/1/16 to 9/30/16
6	Server Room	3799	37	1.0%	5/1/16 to 8/15/16
	IDF	380	2	0.6%	11/1/16 to 12/31/16
	IDF	895	7	0.8%	10/1/16 to 11/30/16
7	Server Room	5931	69	1.2%	6/21/16 to 7/3/16
	IDF	1728	13	0.7%	5/7/16 to 5/31/16
	IDF	853	19	2.2%	5/1/16 to 5/31/16
	IDF	1443	5	0.3%	10/1/16 to 11/6/16

Site #	SEDC Type	Mean Power Load (W)	Standard Deviation (W)	Coefficient of Variation	Time Period
8	Server Room	8305	31	0.4%	3/18/16 to 4/18/16
	IDF	1064	9	0.9%	8/1/16 to 11/30/16
	IDF	1243	5	0.4%	9/1/16 to 11/30/16
9	Server Room	5395	25	0.5%	11/2/15 to 12/6/15
10	Server Room	2256	65	2.9%	1/24/16 - 1/31/16
11	Server Room	2142	32	1.5%	4/1/16 - 4/18/16

The UPS of Site 1 powers both the server room as well s the IDFs located on each of the four floors of the office and a number of outlets throughout the office. All the remaining SEDCs were either server rooms or IDFs. The average load of the nine server rooms was 4520 ± 314 W (95% confidence interval) while the average load of the 12 IDFs was 882 ± 70 W.

An important observation about the power loads of both the server rooms and the IDFs can be discerned from the magnitudes of the CVs. The average CV for the server rooms was 1.3 ± 1.7% and the average CV for the IDFs was 0.9 ± 1.5%. Such a small spread of data for both sets of SEDCs (3.5% and 3%, respectively) indicates that the power loads for all of the sites, independent of data center type, was essentially constant 24/7 even though no site had office hours 24/7. Some sites did report scheduled back-ups during off hours as well as remote server use by staff during evenings and weekends. Figure 36 and Figure 37 show the range of loads for the server rooms and the IDFs, respectively. Both figures clearly show how little variation in power load exists for all the sites and types of SEDCs, as evidenced by the small spread in the standard deviations shown at the top of each bar of data.

Figure 36. Server Room Power Loads

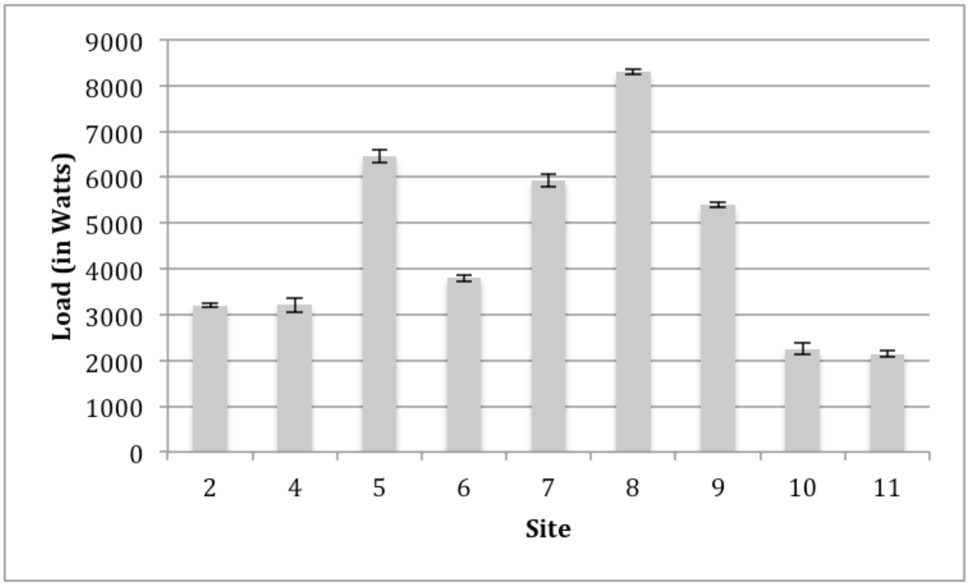


Figure 37. IDF Power Loads

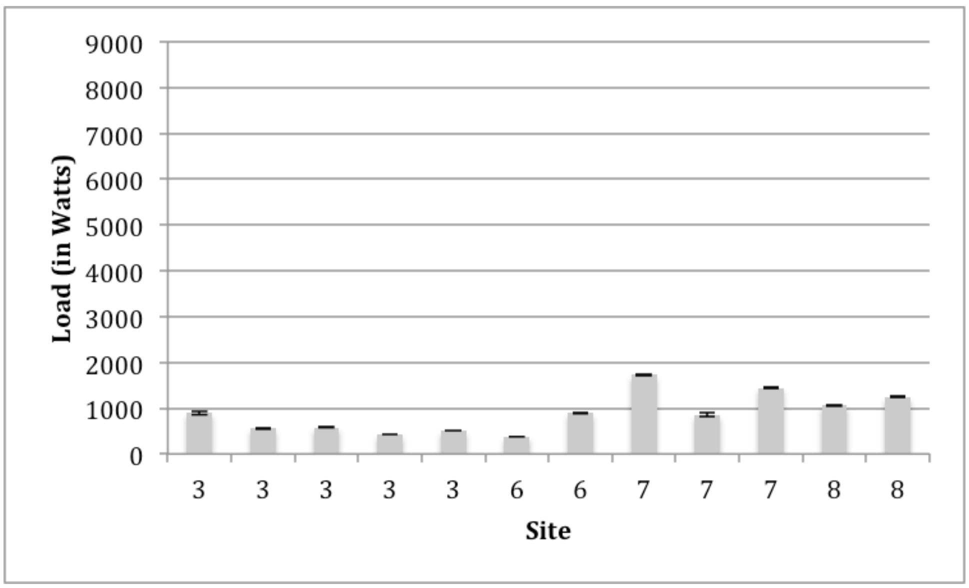
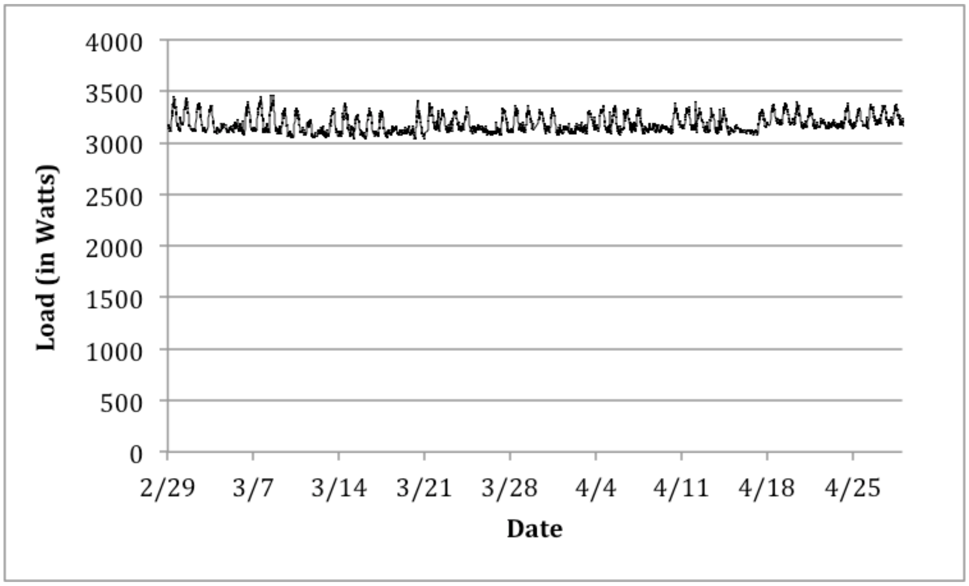


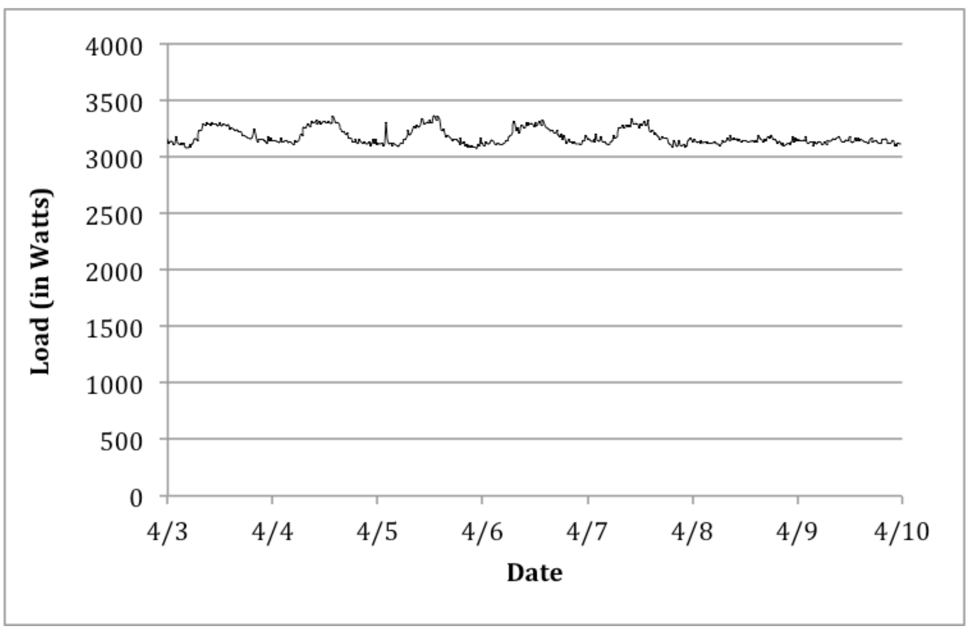
Figure 38 shows an example of the power load for the server room of Site 4, which had one of the highest CVs of 2.5%. The average load for the monitoring period from March 1, 2016, to April 30, 2016, was 3183 ± 163 W. Site 4 was one of participating sites in this project that did not utilize any server virtualization in the server rooms studied. The other was Site 11.

Figure 38. Site 4 Server Room Power Load from 3/1/16 to 4/30/16



The time series data clearly shows the IT activity is highest during the workweek, with much lower activity over the weekends. There clearly is a constant baseload power load of about 3100 W through the two-month monitoring period. At its greatest demand during the week, IT activity is about 300-400 W. Figure 39 shows the load for a typical week in April 2016 for Site 4.

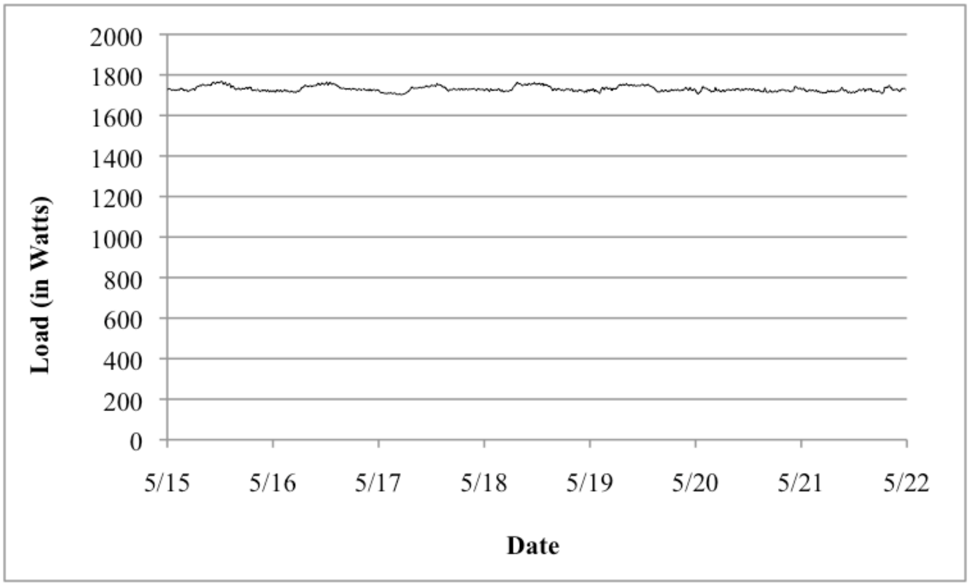
Figure 39. Site 4 Server Room Power Load for the Week of 4/4/16



A similar behavior was observed for the other server rooms to varying degrees, as indicated from the statistical analysis of the data.

As an example of the daily loads on switches in an IDF, Figure 40 shows the power draw of an IDF at Site 7. The average load from May 16, 2016, to May 23, 2016, was 1731 ± 26 W with a CV of 0.8%

Figure 40. Site 7 IDF Power Load for the Week of 5/16/16

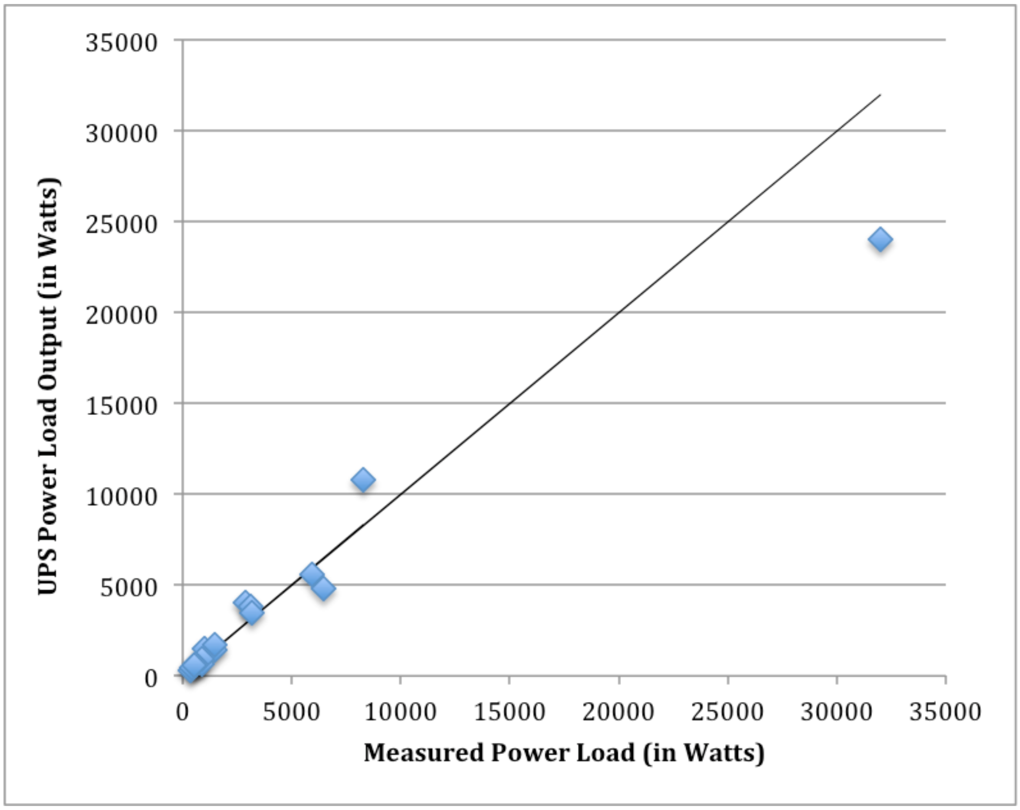


While the data shows some increased power during the weekdays as a result of phones and network activity during the work hours, the load is basically constant 24/7, similar to the server room data.

UPS Power Readings

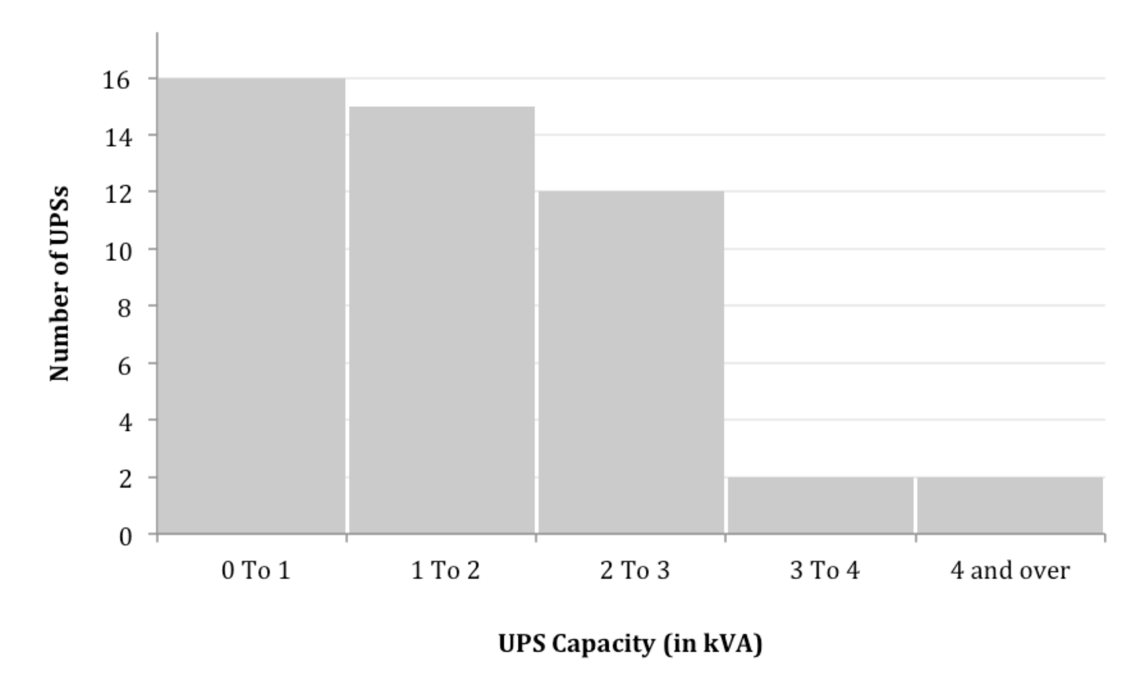
The UPSs in the server rooms also provide information on the power load of the SEDC. The quality of this information varies per UPS. The standalone UPSs often provide a readout display with a numerical value of the load and the percent of the UPS capacity. Rack mounted UPSs often provide only a series of LED indicators that give an approximation of the percent load of the UPS being used. For example, two of five lit LEDs would indicate that 20% to 40% of the UPS load is being drawn by the SEDC. Figure 41 shows a comparison of the amount displayed on the UPS versus the power load measured by our monitoring equipment for each SEDC. Each data point represents a comparison of the two values for each of the sites. The line is where the two values for each site are in exact agreement. The figure shows that for most of the sites the UPS display of SEDC power load is a fairly good measure of the actual power load.

Figure 41. Comparison of Power Load Estimated from UPS Readings with Measured Power Load



Among the 11 sites, there were 40 UPSs ranging from six standalone to 34 rack mounted. Some provided backup of minutes while others provided a backup of up to an hour or more. All six server rooms with a standalone UPS had a dedicated cooling system. The average power load for the 40 UPSs was 7.1 ± 33.6 kVA with a CV of 237%. The standalone UPSs ranged from a capacity of 10 kVA to 96 kVA and were all located in server rooms. The rack mounted UPSs had a capacity of 5 kVA or less with an average load of 2.1 ± 2.0 kVA with a CV of 49%. Figure 42 provides a histogram of the number of UPSs based on their load capacities.

Figure 42. Histogram of Load Capacity of the Rack-Mounted UPSs



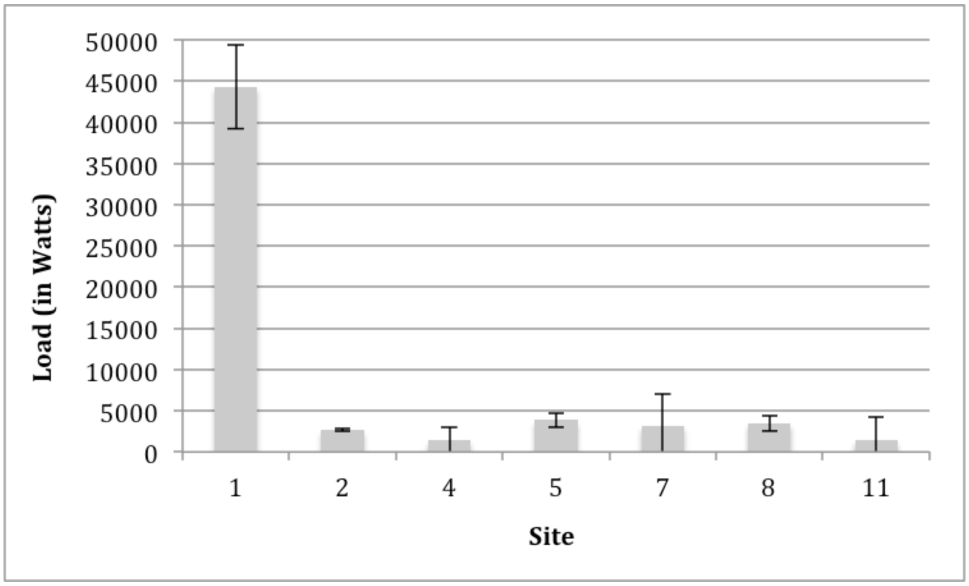
Dedicated Mechanical Equipment Energy Use

The project monitored the power load for seven of the nine server rooms with dedicated cooling systems. Table 12 shows the average loads that were measured. Figure 43 shows the cooling power loads.

Table 12. Average Measured Cooling Power Loads of the SEDCs

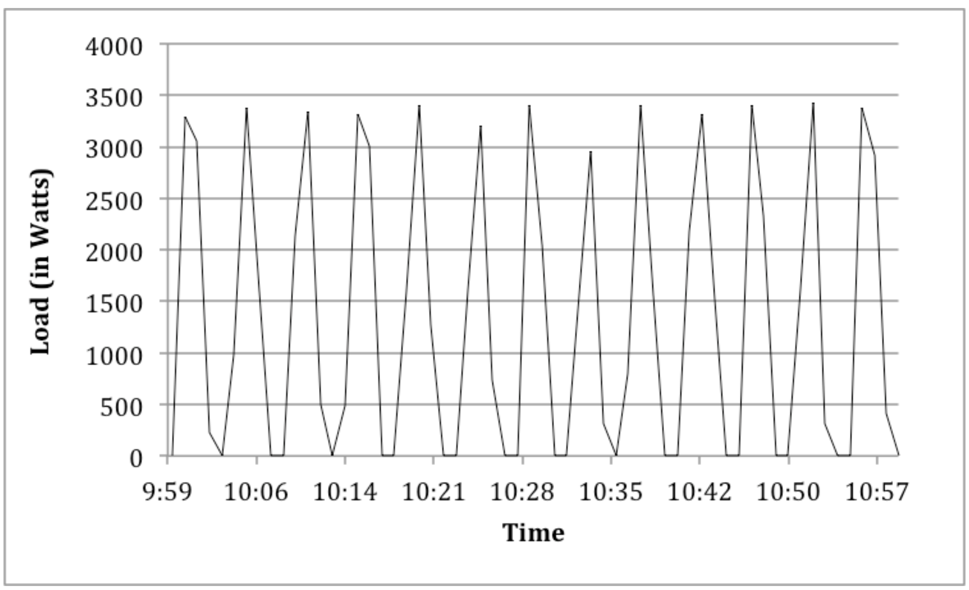
Site #	Cooling System	Mean Power Load (W)	Standard Deviation (W)	Coefficient of Variation	Time Period
1	CRAC with under floor air delivery	44313	2544	5.7%	2/1/16 to 3/31/16
2	In-Row	2655	95	3.6%	8/1/16 to 9/30/16
4	RTU	1377	812	59.0%	4/1/16 to 10/31/16
5	Three ductless splits	3851	424	11.0%	8/1/16 to 9/30/16
7	RTU	3183	1907	59.9%	9/9/16 - 9/18/16
8	Two ductless splits	3488	472	13.5%	3/18/16 to 4/18/16
11	CRAC	1437	1423	99.0%	4/11/16 - 4/18/16

Figure 43. CRAC Power Loads



In contrast to the IT power loads, the cooling loads all show a fairly large CV with a mean of 36 ± 37%. As expected, with the compressor cycling on and off to meet the cooling demand and the air handler fan running either continuously or on-and-off with the compressor, the cooling load fluctuates between a base load value and full cooling load. Figure 44 shows the cooling load for the Site 11 CRAC for a one-hour period (10 am to 11 am) on April 12, 2016.

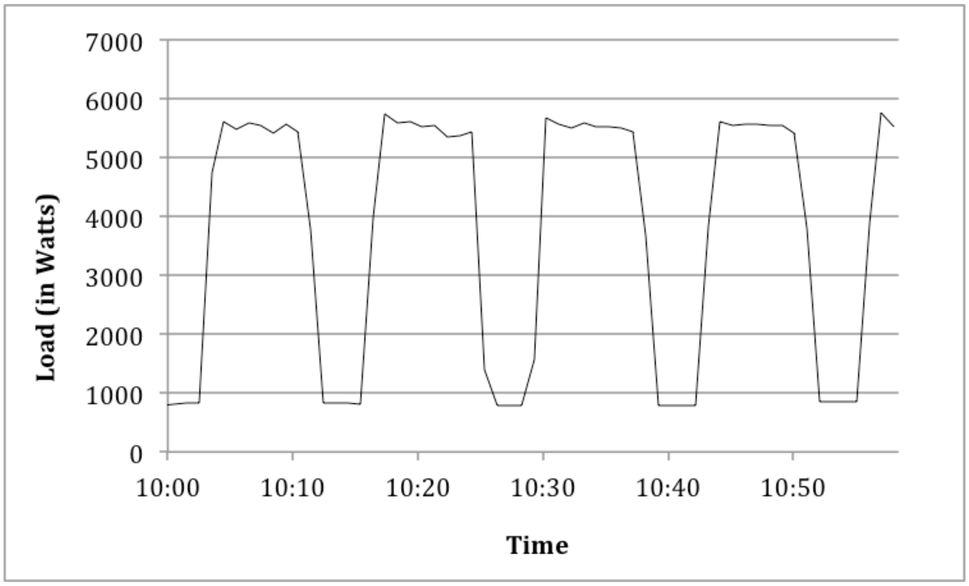
Figure 44. Site 11 CRAC Power Load from 10 am to 11 am on 4/12/16



Notice that there are 13 cycles during this hour with each cycle about 4.6 minutes. The data shows that the CRAC unit is oversized and short cycling.

Figure 45 shows the cooling load for Site 5 from 10 am to 11 am on July 15, 2016.

Figure 45. Site 7 CRAC Power Load from 10 am to 11 am on 7/15/16



There are a little more than four cycles per hour with about 14 minute cycles. The fan is running continuously at about 780 W.

Table 13 shows air temperatures that were monitored at the thermostat and in front of the server racks in some of the SEDCs with CRACs. The industrial sites were not included in this part of the experiment since their data collection periods were already completed by the time that the temperature monitoring equipment was obtained. The average temperature measured at the thermostat was 68.4°F ± 4.1°F with a CV of 3.1% and the average rack inlet temperature was 70.2°F ± 7.9°F with a CV of 5.6%.

Table 13. Air Temperature in SEDCs with Dedicated Cooling

Site #	Temperature at the Thermostat (°F)	Average Rack Inlet Temperature (°F)
1	65.4	66.1
2	68.7	74.2
4	71.3	73.8
5	66.8	67.6
7	68.2	66.4
8	69.7	73.4

The Coefficient of Performance (COP) and the Mechanical Load Component (MLC)

For the sites with dedicated cooling, a comparison of the IT power loads to the cooling loads of the mechanical system allow us to calculate two measures that can be used to characterize the system energy efficiency: the coefficient of performance (COP) and the mechanical load component (MLC) (Table 14). The COP is a common measure for the efficiency of air-conditioning systems and is the ratio of useful cooling provided versus the input of electric energy used in the process. It is assumed that the cooling load for the CRAC at each SEDC is equal to the measured IT load at the site. The electric loads of the CRACs were monitored at the panel. Therefore, the COP for the CRAC will be the ratio of the IT load divided by the power that is drawn by the CRAC. Then larger the value of the COP, the more efficient the system is. Based on the above definition for MLC, the MLC for the SEDCs of this study is the sum of the IT power and the CRAC power load divided by the IT power. The closer the value of the MLC is to one, the more energy efficient is the SEDC based on the dedicated cooling.

Table 14. COP and MLC Results for SEDCs with Dedicated Cooling

Site #	IT power (kW)	Cooling power (kW)	COP	MLC	Time Period
1	31.6	54.3	0.6	2.7	7/18 to 7/25
2	3.2	2.7	1.2	1.8	7/22 to 7/25
4	3.3	2.2	1.5	1.7	7/18 to 7/25
5	4.5	4.4	1.0	2.0	7/18 to 7/25
7	5.9	4.0	1.5	1.7	7/5 to 7/11, 7/29 to 9/8
8	8.3	5.2	1.6	1.6	7/18 to 7/25
11	2.2	1.4	1.5	1.7	4/1 to 4/18
Average	8.4	10.6	1.3	1.9	

The average COP is 1.3 ± 0.4 with a CV of 29% and the average MLC is 1.9 ± 0.4 with a CV of 21%. Based on data provided by Shehabi et al. (2016), the average COPs of a server closet (< 100 ft^2) and server room (100-999 ft^2) for 2014 would be 1.1 and 0.8, respectively, and the average MLCs would be 1.9 and 2.2, respectively. Typically a COP of 3 would be expected for a cooling system in a commercial building. It is likely that more efficient cooling in the SEDCs is possible. For Site 6, which does not have a CRAC but uses an exhaust fan to remove heat from the SEDC and draws in conditioned air from the surrounding office space, the calculated MLC is 1.1.

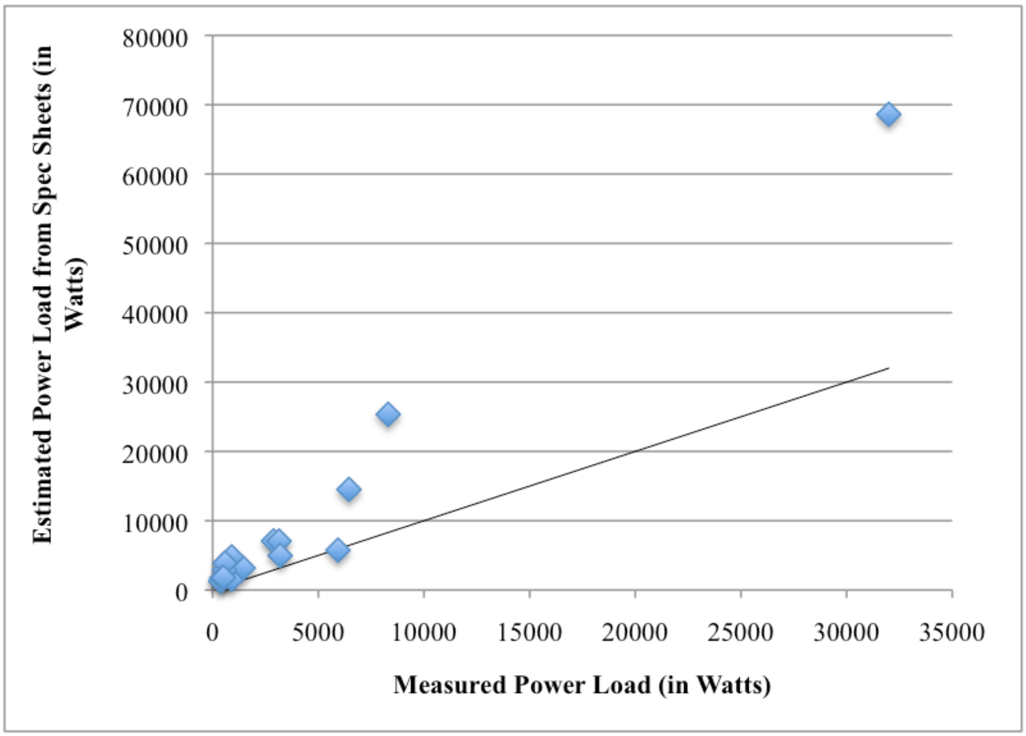
SEDC Audit Approaches

An important goal of this project was to develop an unobtrusive audit process that could characterize the SEDC and provide a measure of its power demands. We tested two approaches: 1.) We performed an inventory of the makes and models of the IT equipment and relied on spec sheets for power data and 2.) We estimated by cataloguing the generic types of IT equipment used, relying on typical equipment power draws to calculate load estimates.

Device Inventory for Predicting IT Power Load

During the initial visits at the sites, we performed an inventory of all the devices that were powered off the UPSs. This IT device inventory served as an initial site audit; the audit form is shown in Appendix E: Device Inventory Form. We hoped that this would provide a non-intrusive approach to estimating the IT load of the SEDC. We obtained the maximum power loads from manufacturer spec sheets and literature for the make and model of each piece of IT equipment. Unfortunately, given the variety of equipment options available, the exact configuration of each piece of IT equipment could only be estimated. At best, this approach will only provide an upper bound of the power loads of the SEDC. Figure 46 shows a comparison of the calculated power loads using the manufacturer's spec sheets with the measured power loads. The line shows the 1:1 plot of the measured power. Data points falling on this line shows exact agreement between the power estimated by the spec sheets and the measured data.

Figure 46. Comparison of Power Load Calculated from Spec Sheets with Measured Power Load



The graph shows that the calculated loads exceed the measured loads in all cases but one. The average over-approximation was 43 ± 50% with a CV of 58%. The approach also does not provide any insights into the relative power loads of different types of equipment because of the unknown levels of over-approximation occurs using the spec sheet data for the specific type of equipment.

A Predictive IT Power Load Audit Tool

In June 2016, Shehabi et al.[35] published a report forecasting data center electricity consumption out to 2020. For their forecast, power load estimates were calculated for the primary data center IT equipment, server (1 processor socket and 2 or more sockets), external storage (hard disk drive or HDD and solid state drive or SSD), and networking (based on data transfer speed per Ethernet port — 100 MB, 1000 MB, 10 GB, and 40 GB). Table 15 shows the estimated power draws of the types of IT equipment they modeled.

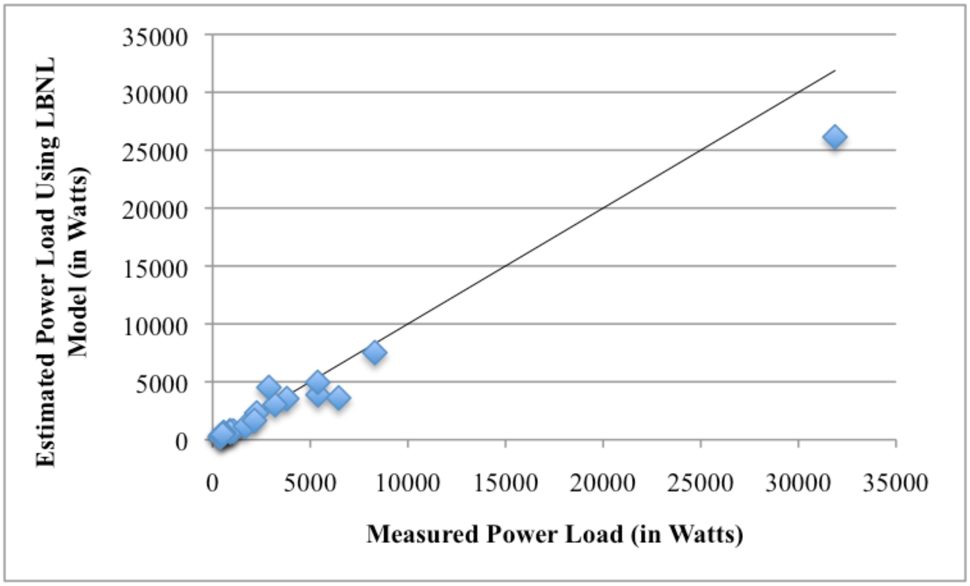
Table 15. Estimated Power Loads of Data Center IT Equipment

IT Equipment	Type	Watts per Type
Servers	1S	118
	2S+	365
	Average	330
External Storage	HDD	9
	SSD	6
Switches	100 MB Ports	1
	1000 MB Ports	2
	10 GB Ports	4
	40 GB Ports	6

Using this as a basis for a predictive load audit process, four additional inputs were added to cover additional devices found in data centers: routers (10 W), modems (6 W), PoE access points (10 W), and PoE phones (4 W). Appendix F: SEDC Estimated Power Audit Sheet provides the predictive load audit form that was used. Audits were performed on 19 of the SEDCs monitored in this project. Figure 47 shows a comparison of the results using the predicate tool with the measured data, with the line again showing the 1:1 plot of the measured power. It should be noted that the measured power loads were the loads drawn by the UPSs. These values will typically be larger than the actual IT equipment power loads since the UPS adds power losses due to power conversion and other functions.

[35] Armin Shehabi, S. Smith, D. Sartor, R. Brown, M. Herrlin, J. Koomey, E. Masanet, N. Horner, I. Azevedo, and W. Lintner. 2016. United States Data Center Energy Usage Report. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-1005775 http://eta.lbl.gov/publications/united-states-data-center-energy-usag (retrieved April 28, 2017)

Figure 47. Comparison of Predictive Audit Tool with Measured Power Load for All SEDCs



Because server rooms and IDFs will be composed of different proportions of the different IT equipment, it is useful to compare the audit predictions for the two different types of SEDCs. Figure 48 and Figure 49 show the comparisons for the server rooms and IDFs, respectively.

Figure 48. Comparison of Predictive Audit Tool with Measured Power Load for the Server Rooms

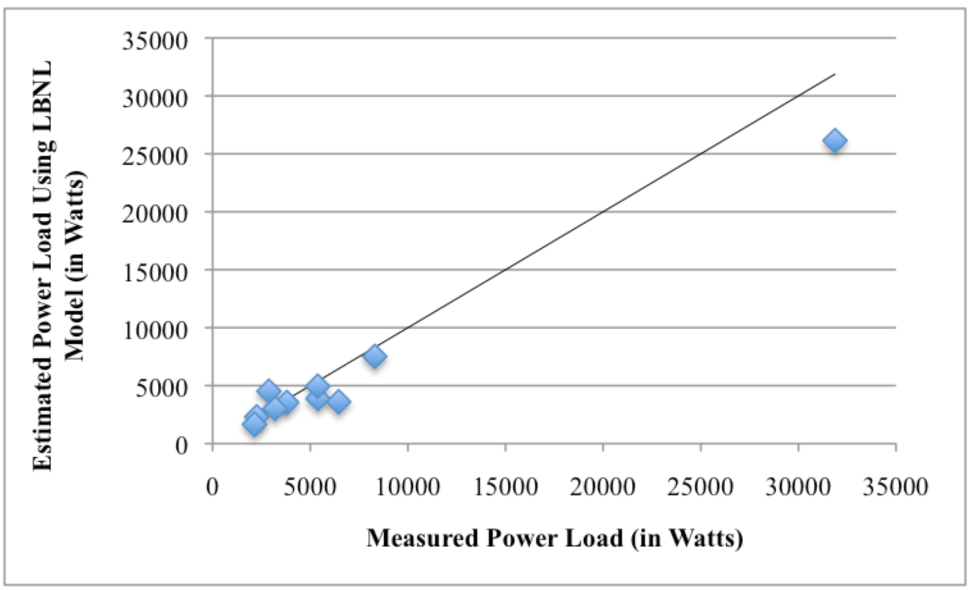
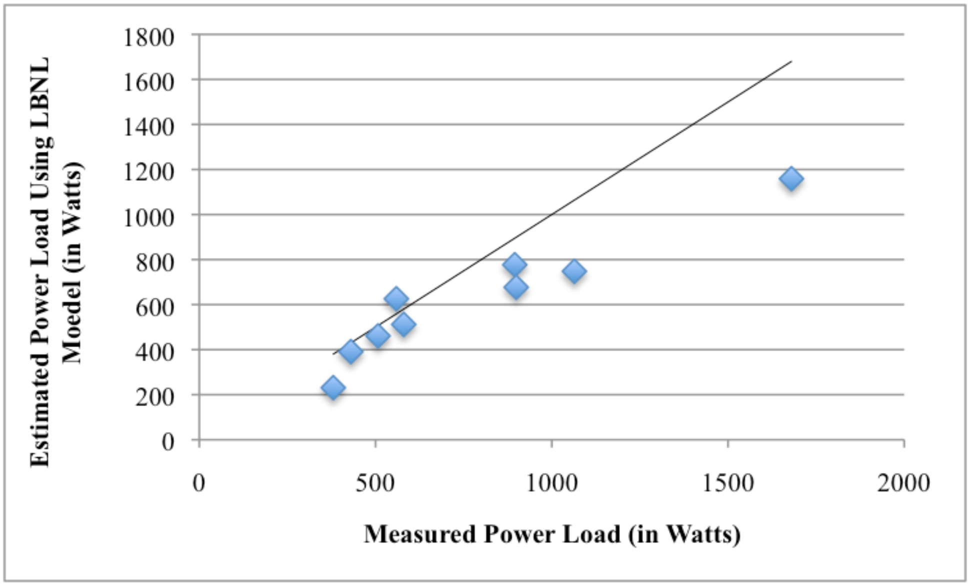
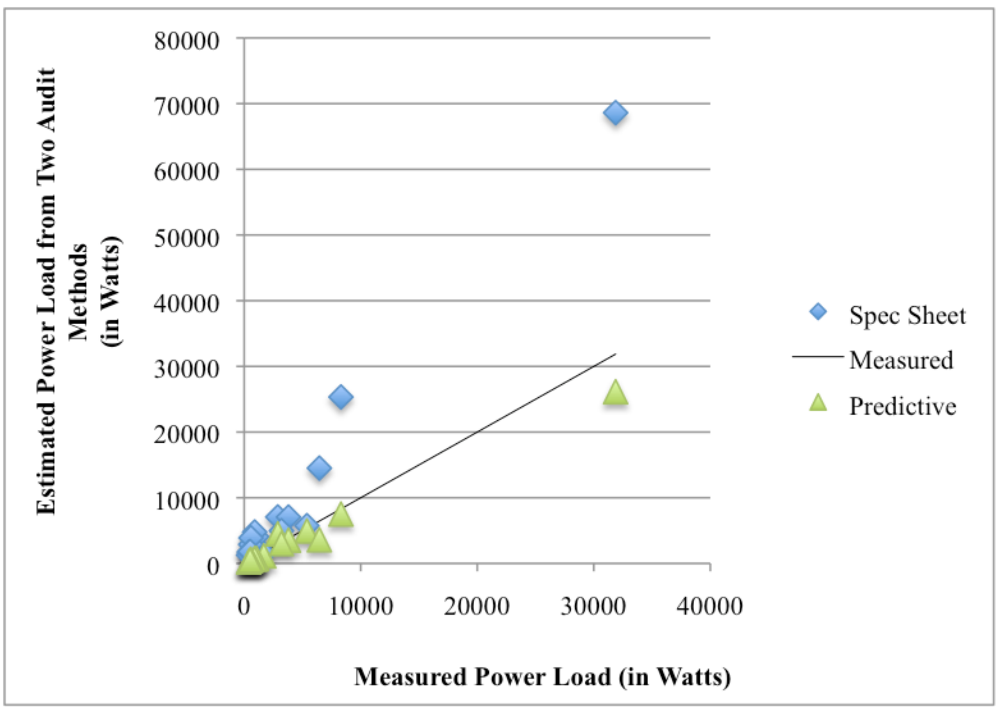


Figure 49. Comparison of Predictive Audit Tool with Measured Power Load for the IDFs



The comparison of the predictive audit tool versus using the spec sheet data is shown in Figure 50. Overall, the predictive tool provides a more consistent agreement with the measured values.

Figure 50. Comparison of Predictive Audit Tool with Spec Sheet Approach



Filling out the predictive audit form is very straightforward; it relies on a visual inspection of the server racks with on-site IT staff to identify and count the specific types of equipment.

An additional benefit of this audit approach is that it provides an estimate of the relative power demands of various IT equipment in the SEDC. Figure 51 and Figure 52 show the estimated power loads for the IT equipment in the audited server rooms and IDFs in this study, respectively.

Figure 51. Estimated Server IT Equipment Power Loads

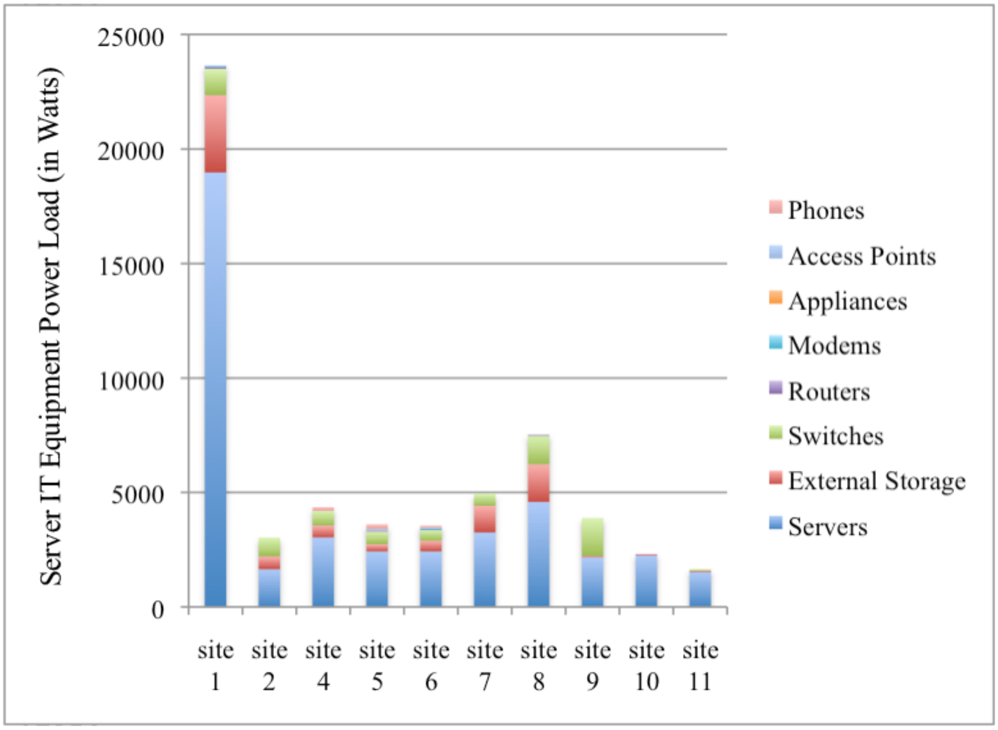


Figure 52. Estimated IDF IT Equipment Power Loads

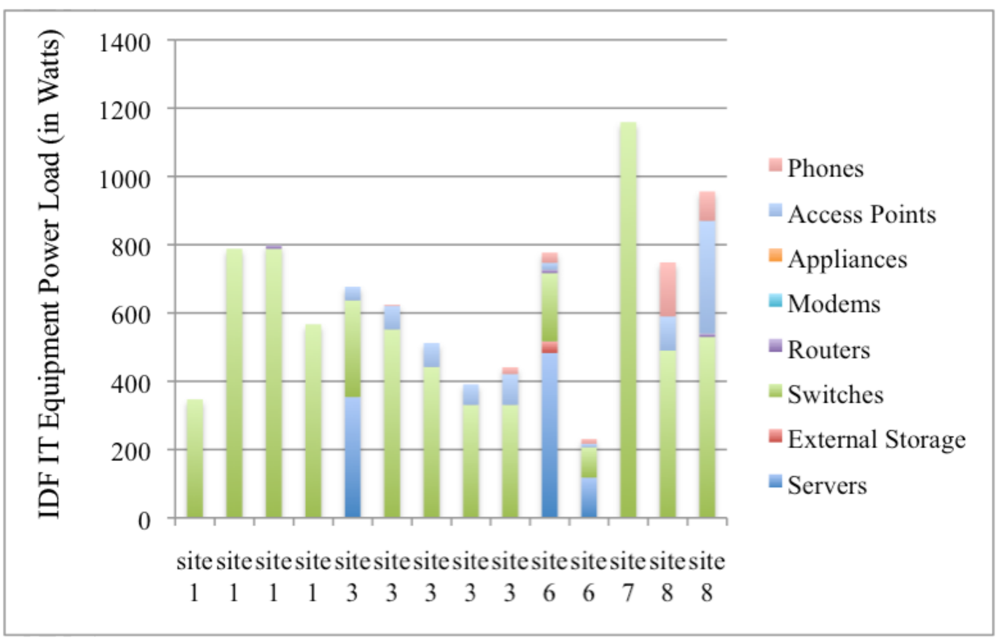


Figure 53 and Figure 54 show the estimated percentage power demands for the IT equipment types in the server rooms and IDFs, respectively.

Figure 53. Estimated Server IT Equipment Power Loads

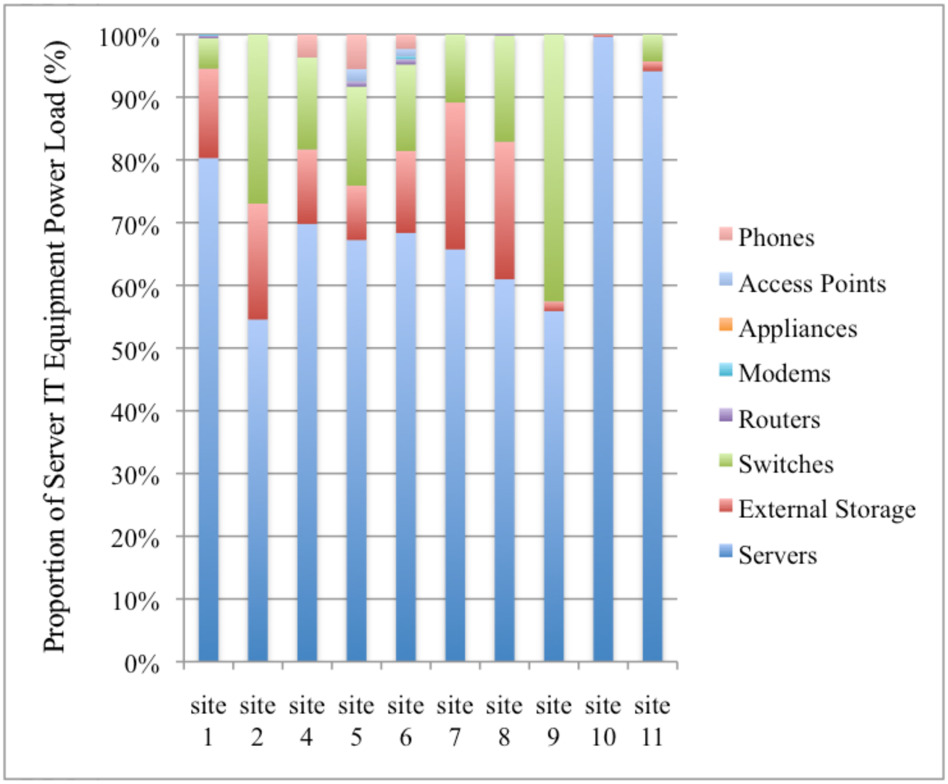
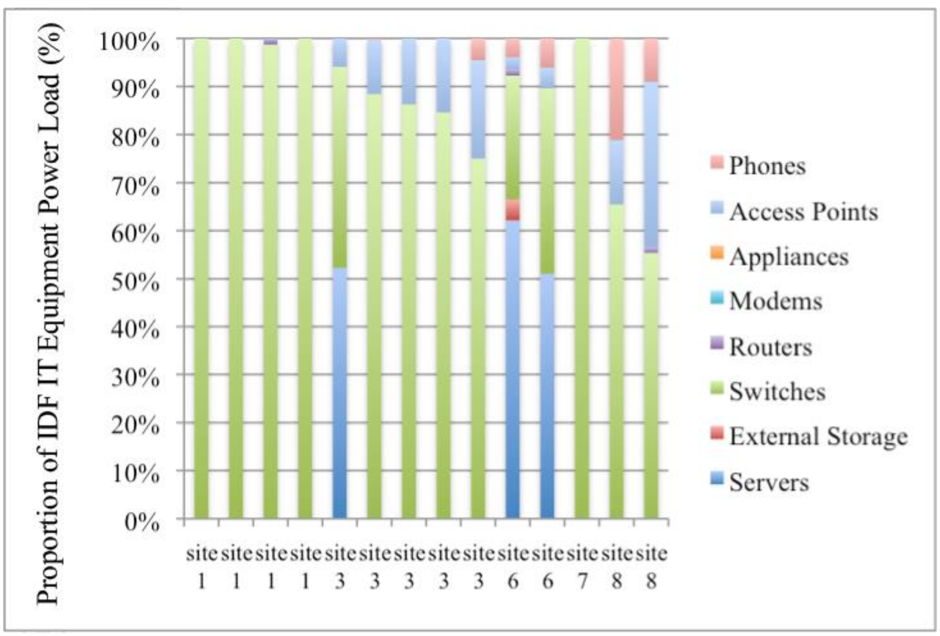


Figure 54. Estimated IDF IT Equipment Power Loads



For the server rooms, the estimates show that servers make up at least 50% of the power load and often more than that, followed by about equal amounts of load for external storage and network switches. The exceptions are Sites 9, 10, and 11, which are the three industrial sites. For the IDFs at these sites, the network servers clearly represent the largest demand for power.

However, it should be a clear that when an IDF also has a server, the server load becomes a high proportion of the total load. These estimates can be used to inform possible opportunities for savings and can help quantify the magnitude of those savings.

Energy Savings Measures

At all eleven sites, IT staff were open to trying energy savings measures as long as mission critical services were not jeopardized. Unfortunately, there was some attrition over the length of the project and Site 3, the healthcare site, withdrew from the project after the baseline characterization. They were in the midst of building a private enterprise data center and could not provide IT staff time to continue partnering on this project. We were able to perform energy savings measures at the remaining 10 sites.

At all remaining sites we emphasized modifications in operational practices as a way to achieve energy savings. Given the constant IT power loads and the need to reduce cooling loads for the SEDCs with dedicated CRACs, modifications in operational practices should produce opportunities for reducing SEDC energy use. Budgetary constraints also limited options that would involve the purchasing of new equipment or software that could achieve energy savings. The following sections describe the specific measures enacted at the remaining 10 participating sites.

Site 1: Adjusting the SEDC Thermostat Set Point Temperature

In the Site 1 SEDC, cold air is provided from under floor supplies, and the return to the CRAC unit is located along a wall that is perpendicular to the server racks and cold air supplies (Figure 55). The thermostat controlling the CRAC is mounted on the wall facing the server rack, which is opposite the last server rack, farthest from the return plenum (server rack #10). In October 2016 temperature data loggers were placed at the thermostat and at various locations on and around the server racks.

Figure 55. Server Racks at Site 1

Initially, the thermostat was set at 65°F (the monitored air temperature at the thermostat was 65.4°F). The air temperature at the third server rack from the return plenum wall (see Figure 46, the far wall) was measured at 62.8 °F, while the inlet temperature of the eight server rack (nearer to the thermostat) was recorded at 69.3°F. The rack inlet temperature across the 10 racks was estimated to be 66.1°F. The average cooling power load for that day (October 25, 2016) was 46.3 ± 6.6 kW with a CV of 7%.

In late December 2016 the thermostat set point was increased and in late January 2017 the air temperature at the thermostat was measured at 68°F. The inlet air temperature at the third server rack increased from 62.8° F to 65.6° F. The inlet temperature of the server rack farthest from the wall (tenth server rack) was measured at 74.9°F while the inlet temperature of the nearest server rack (first rack) was 65.1°F. The rack inlet temperature across the 10 racks was estimated to be 70.0°F. The average cooling power load for that day (January 22, 2017) was 43.3 ± 3.8 kW with a CV of 4%. This represents a savings of about 3.0 ± 5.4 kW from the 3°F increase in set point temperature, or an annual energy savings for 26,280 kWh (and about $2,628 per year assuming a blended rate of 10¢ per kWh).

Site 2: Adjusting CRAC Set Point Temperature and Cold Aisle Containment

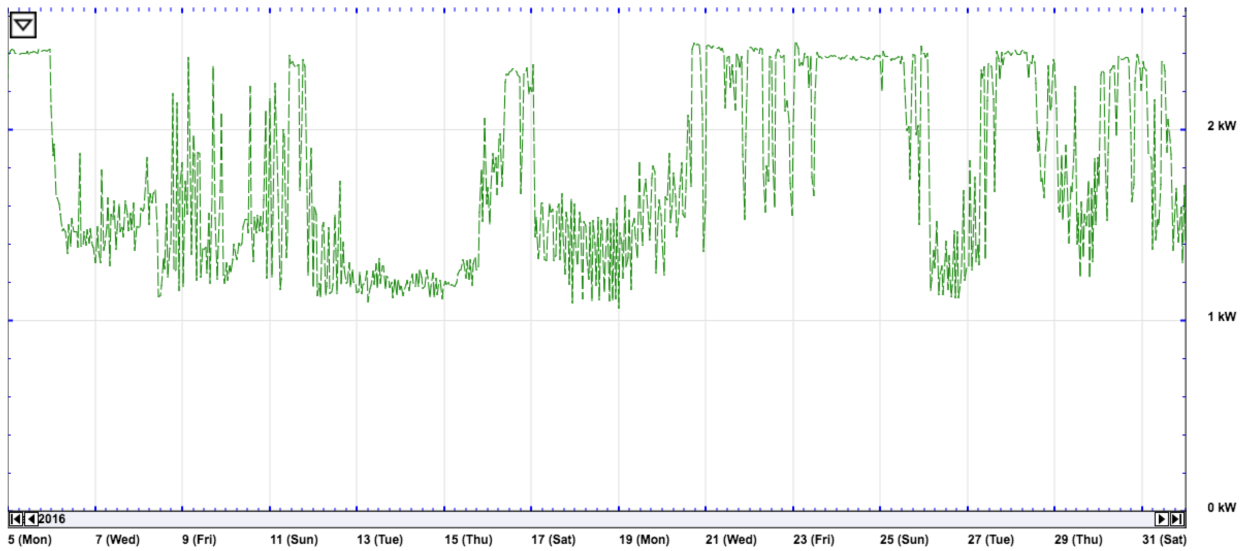
Site 2 had an in-row CRAC. Even though a thermostat was mounted on the wall, a temperature sensor placed in the server rack was connected to the CRAC and was used by the CRAC to call for cooling. The set point for the CRAC was 74°F. Figure 56 shows that the cooling load was fairly level at about 2.6 kW from August thru October, 2016.

Figure 56. Cooling Power Load at Site 2 for 70°F Set Point

However when we monitored the inlet temperatures to the racks, we found that the inlet temperature was actually 70°F. On closer inspection, we found that the temperature sensor for the CRAC had been placed inside the racks where it was indeed measuring 74°F. ASHRAE guidelines for data center air temperatures are for the inlet rack temperatures, not for temperatures inside the racks. Therefore, the CRAC sensor placement should actually be in front of the racks and not inside of them. Because this was not the case, while the CRAC was maintaining a 74°F temperature inside the rack, the sensor was actually causing the CRAC to provide 70°F air to the rack inlet. Hence the true CRAC set point temperature was more like 70°F instead of the 74°F at which it was set.

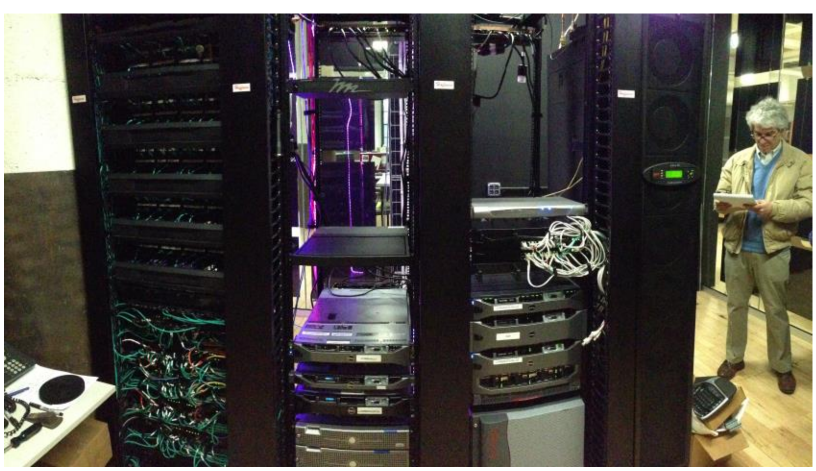
Moving the temperature sensor from inside the server racks to a position in front of the racks effectively changed the set point temperature from 70°F to 74°F. After that the power to the CRAC unit did decrease but showed substantial fluctuation (Figure 57).

Figure 57. Cooling Power Load at Site 2 for 74°F Set Point



The above graph shows that increasing the set point from 70°F to 74°F could provide a savings of up to 50%, reducing the load from a maximum of 2.2 kW to a low of 1.1 kW. Because the servers sit in a room with no airflow management, the observed fluctuation is a likely result of the mixing of the warm air exiting the server racks with the cold supply air from the CRAC and possibly the building HVAC system. Figure 58 shows how the server racks are positioned in the SEDC.

Figure 58. Server Racks and In-Row CRAC at Site 2



To minimize the mixing between the cold supply air and the heated air exiting the racks, we placed rack filler panels in the racks to close off the empty spaces and then placed a temporary enclosure in front of the server racks to create some cold aisle containment. Figure 59 shows the enclosure and Figure 60 shows the filler panels installed in the racks behind the enclosure.

Figure 59. Enclosure Placed in Front of the In-Row CRAC and Server Racks at Site 2

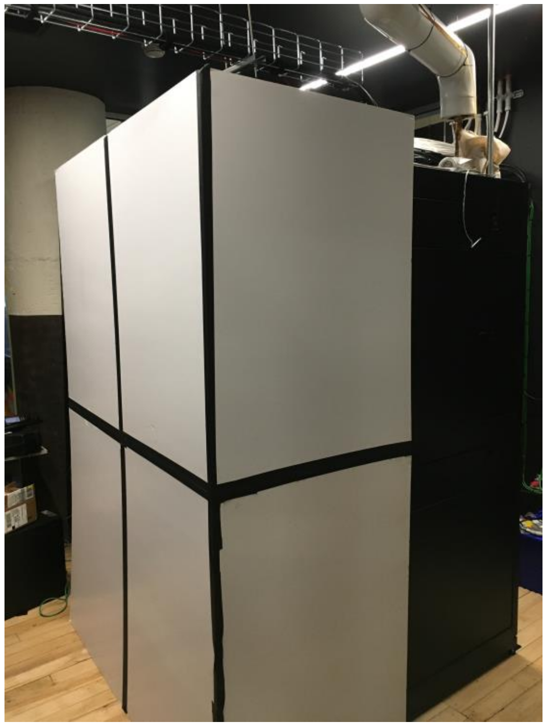
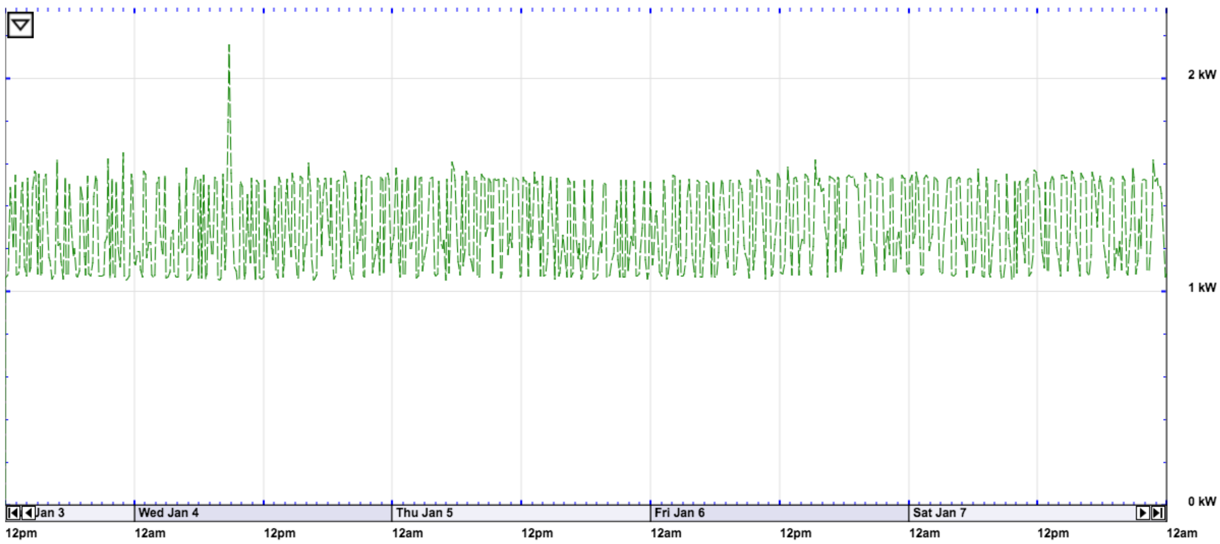


Figure 60. Filler Panels Installed in Site 2 Server Racks

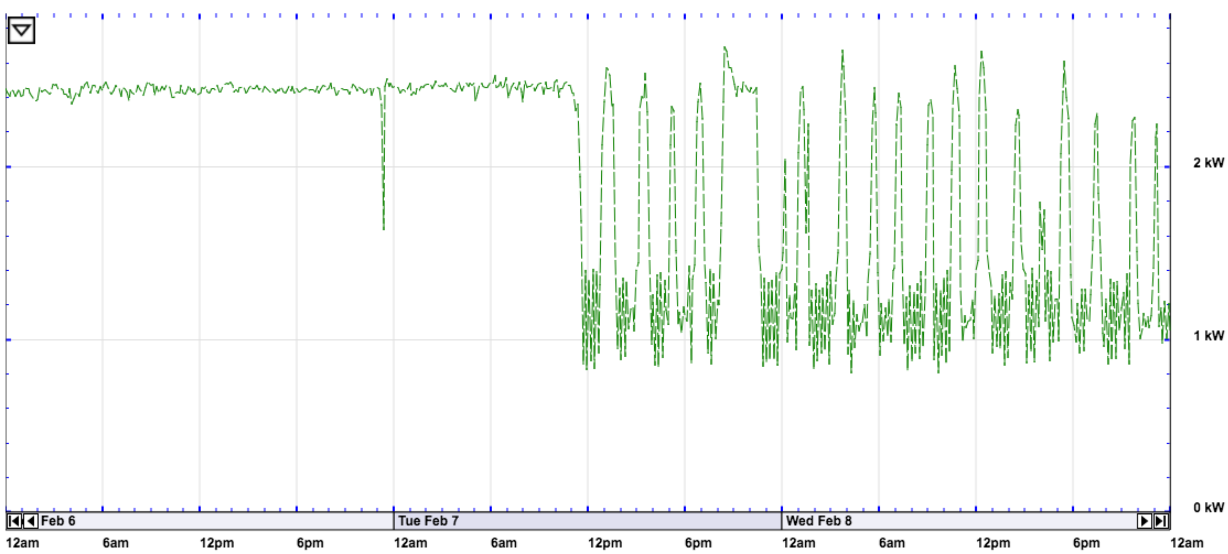
This stabilized the cooling load for nearly a week, as shown in Figure 61.

Figure 61. Cooling Power Load for Site 2 from Jan 3 to Jan 7, 2017



Unfortunately this could not be maintained, as the fluctuations returned. Figure 62 shows the cooling power load from February 6 thru February 8, 2017.

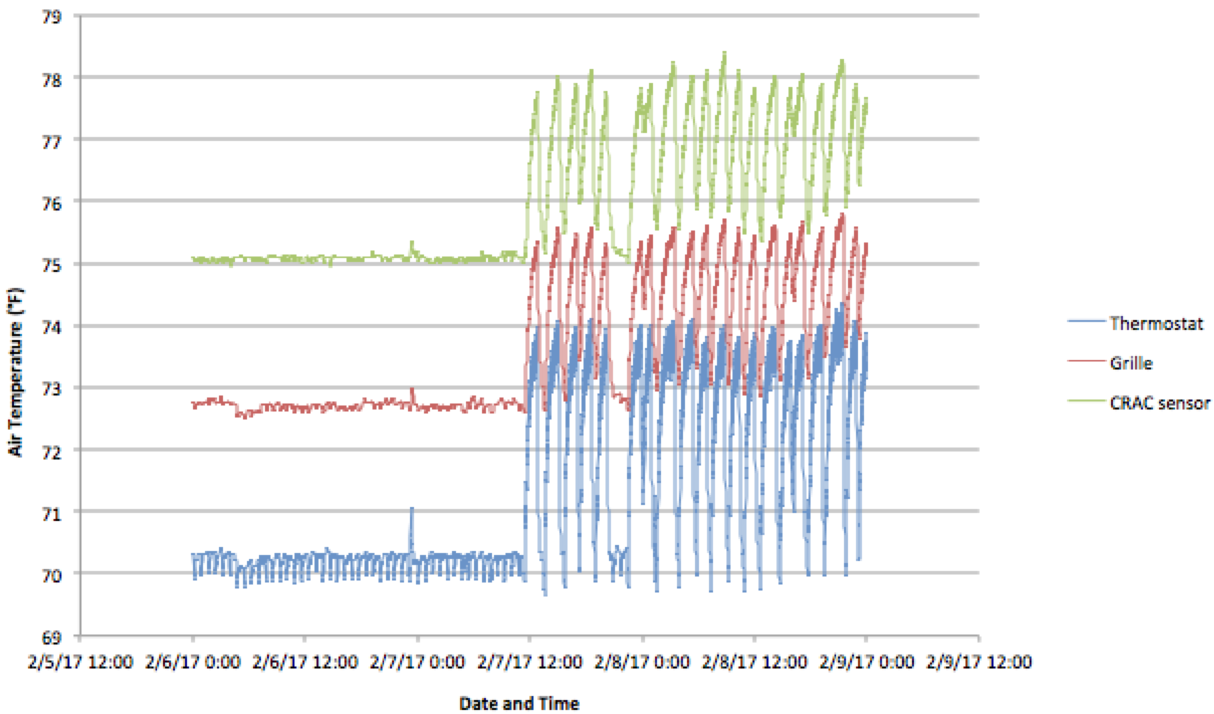
Figure 62. Cooling Power Load for Site 2 from Feb 6 thru Feb 8, 2017



The first half of the graph shows a constant load of about 2.2 kW, which compares to the load before the CRAC set point was changed and the enclosure was added. The second half of the graph looks closer to the behavior we initially obtained with the measures we performed, about 1.1kW, although there is some instability that returns the load to 2.2 kW.

Figure 63 shows the air temperatures that were measured during the same period, located at the wall thermostat in the SEDC, at the CRAC temperature sensor positioned in front of the server racks, and at the transfer grille on the wall behind the server racks.

Figure 63. Air Temperatures Measured Inside the Site 2 SEDC from Feb 6 thru Feb 8, 2017

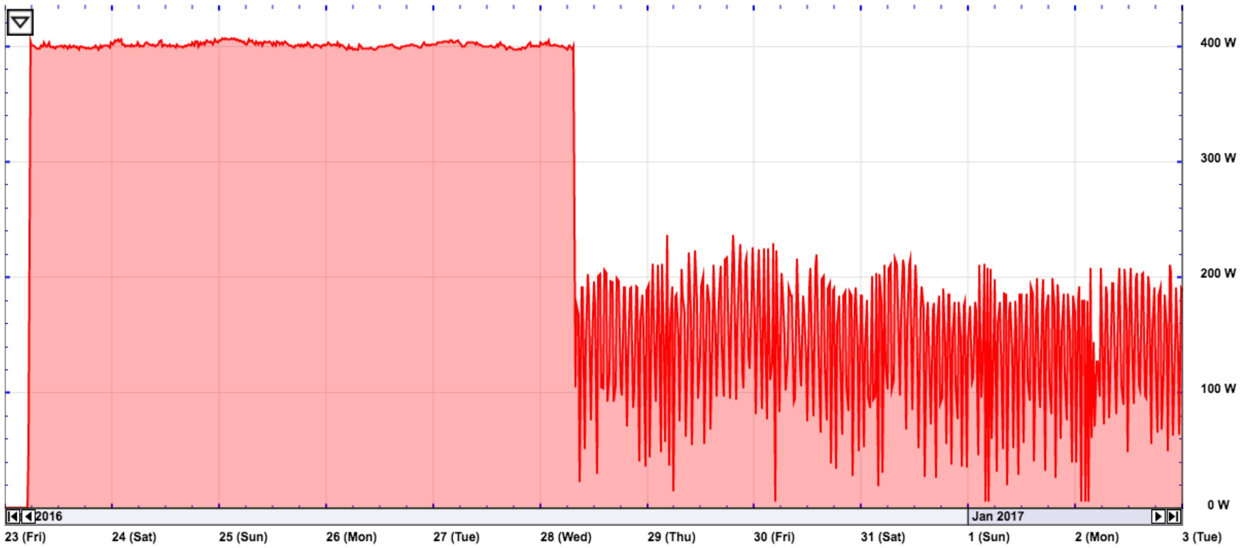


When the load is highest at 2.2 kW, the CRAC temperature sensor is constant at 75°F with a very small dead band. In the second part of the graph, it appears that the CRAC is operating on a 3°F dead band. This suggests that there might be an issue with either the temperature sensor or the CRAC thermostat, or the conditioned air from the surrounding office space is somehow being flushed into the server room, maintaining a 70°F temperature in the space. Further work is needed to gain a clearer understanding of how the system is operating and whether the full savings opportunities can be realized. If a power reduction of 1.1 kW could be maintained year round, the possible annual savings would be about 9,636 kWh or about $964 per year (assuming a blended rate of 10¢ per kWh).

Site 4: Adjusting Settings on the RTU Air Handler

At Site 4, monitoring of the cooling power load showed a constant load of 400W throughout Fall 2016. During that time, the thermostat set point was increased from 71°F to 74°F and there was no change in power load or air temperature. As there was no cooling load to the SEDC, the air handler was run continuously. IT staff changed the fan setting on the thermostat from ON to AUTO, and this resulted in the change in the power draw of the RTU shown in Figure 64.

Figure 64. Cooling Power Load for Site 4 from Dec 23, 2016 to Jan 3, 2017



When the fan was running continuously, the average power load to the RTU was 402 ± 2 W with a CV of 1%. When the fan was set to AUTO, the average power load dropped to 173 ± 107 W with a CV of 62%. For a typical day, the energy savings from changing the fan from ON to AUTO was 5.5 kWh per day, about a 57% reduction in energy use. During the six months of the heating season when no cooling beyond economizing is needed, the energy savings would be 1,004 kWh or about $101 per year (assuming a blended rate of 10¢ per kWh). Additional savings would be obtained during the summer months based on the cycling of the mechanical system and the times when the air handler would be off.

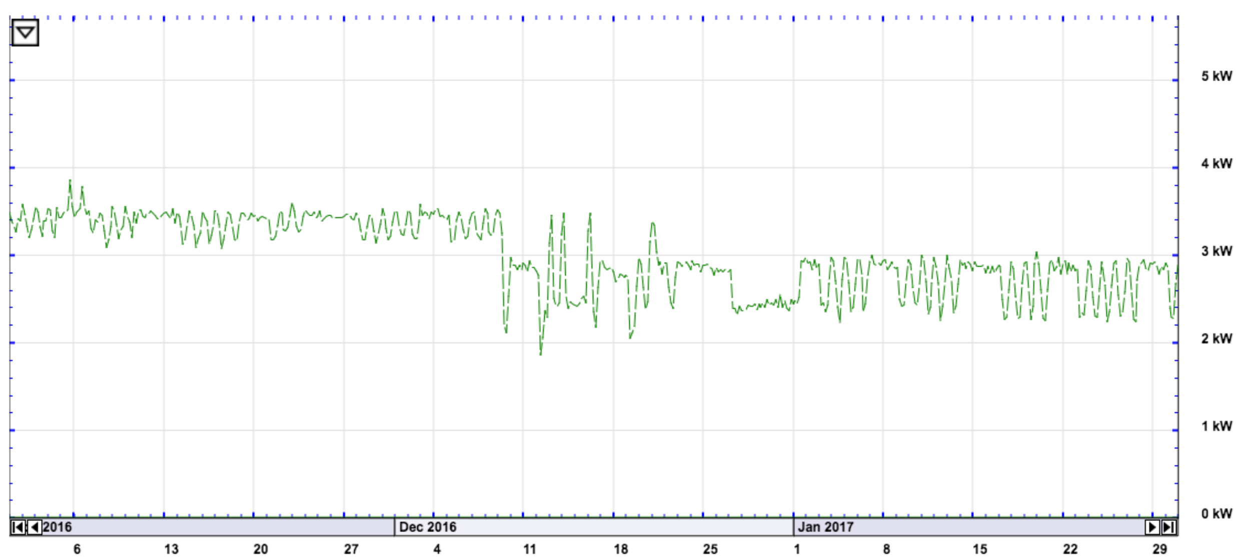
Site 5: Adjusting the SEDC Thermostat Set Point Temperature

The thermostat set point temperature at the Site 5 SEDC was 65°F. Inlet air temperatures ranged from 69°F to 72°F. In early December 2016 setpoint temperature was increased to 68°F so that the temperature monitored using the Site 5 WeatherGoose monitor located on the core switch rack would not exceed 77°F. Collected rack inlet temperatures from loggers located at three different racks ranged from 71°F to 75°F, increasing with greater distance from the split located on the wall. Figure 65 shows the location of the split cooling the main server racks.

Figure 65. Site 5 Server Racks and Cooling System

Figure 66 shows the change in cooling load after the set point temperature was increased from 65°F to 68°F on December 9, 2016. The average cooling power load in November 2016, before the thermostat set point was increased, was 3.38 ± 0.34 kW with a CV of 5%. After the set point was increased by 3°F, the cooling load was 2.70 ± 0.61 kW with a CV of 11%, a savings of 0.69 ± 0.70 kW. Assuming that this savings can be extrapolated to an annual savings, the 3°F set point adjustment would produce an annual savings of 6,044 kWh per year or about $604 per year (assuming a blended rate of 10¢ per kWh).

Figure 66. Cooling Power Load for Site 5 from Nov 1, 2016, to Jan 30, 2017



Site 6: Hot Aisle Containment

The SEDC at Site 6 did not have any dedicated cooling. Despite having an IT load of about 3.8 kW, the SEDC relied on a 750 cfm exhaust fan to remove heat from the server room and draw conditioned air from the rest of the office through a grate in the door. This approach was barely adequate since our temperature monitors showed that the server inlet temperature reached as high as 86°F. The participant planned to entertain bids for a dedicated CRAC unit. As part of this project, we decided to see if hot aisle containment might reduce the need for dedicated cooling. As an inexpensive test, plastic drapes were installed to create the hot aisle. Figure 67 and Figure 68 show the installation of the plastic drapes.

Figure 67. Plastic Drapes Partitioning a Hot Aisle in the Site 6 SEDC

Figure 68. Drapes at Site 6 Enclosing the Exhaust Fan in the Hot Aisle

With the installation of the plastic drapes, the inlet rack temperature was measured in the range of 75°F to 78°F. The combination of the exhaust fan and drapes was sufficient enough to pull conditioned office air into the server racks and maintain inlet rack temperatures within the recommended ASHRAE guidelines. The cost of the plastic was less than $100, averting the cost of installing a CRAC estimated in the tens of thousands. The power draw of the exhaust fan was rated at 312 W. The MLC of the Site 6 server room was estimated to be 1.1 based on the IT load and the exhaust fan rated power. Although the heated air is currently being exhausted to the outside, it could be put to use in the building to provide heat in the winter.

Site 6: Scheduling Network Switches

At Site 6, the installation of UPS network management cards allowed individual UPSs to be connected directly to the network, allowing remote monitoring and control of each UPS. As a result, IT staff could remotely schedule shut down and reboot of connected equipment and UPSs. In one IDF, a UPS was connected to a network switch with 48 ports that powered nine PoE phones and an access point (AP). A number of strategies were tested on this network switch.

Firstly, the IT SysAdmin manually turned off the PoE on the module that serviced the phones, and this resulted in a savings of about 24 W. When the data and PoE was turned off to the ports, the power load to the UPS decreased by about a 35 W load, and when just the data ports were powered, the draw to the ports was about 11W. When the UPS was used to turn off all power to the network switch, the measured power to the UPS showed a savings of 200 W.

For a level of redundancy, the switch has two power supply units (PSUs), each with their own power cord connected to the UPS. As a final test to measure the energy penalty for this redundancy, the power from the UPS through one of the power cords was shut off to the network switch. The drop in power during this time was about 26 W. The savings from the lack of redundancy during off hours is probably not worth the effort in smaller IDF or server rooms, but in economies of scale the savings might be worth it.

Site 6: Distributed Power Management (DPM)

At Site 6, VMware DPM was tested on a physical server that hosts a number of virtualized servers. Prior to migrating the virtual servers, the physical host was drawing 3,163 ± 37 W with a CV of 1.2%. After DPM was performed and the physical host was put on standby, the server was drawing 2,891 ± 18 W with a CV of 0.6%. Putting the host on standby resulted in a 272 ± 82 W decrease. If DPM is performed for 10 hours per day (overnight) during the weekdays and through the weekend, that total energy savings would be 1,388 kWh, or about $139 per year, for just that one server.

Site 7: Virtualization and Server Migration

During an initial visit at Site 7, our consultant from the Foundation recommended that the seven Apple Xserves used in their server room be replaced by virtual servers running on existing machines or on a new Mac Pro or Mini. Four Xserves, along with a number of Mac Minis, were used to perform iOS caching and Netboot. In July 2016 these were removed. A Mac Pro was purchased for the iOS caching and the Netboot functions were taken over by Linux VMs running on their existing VMWare hosts. The remaining three Xserves were employed to provide basic file sharing duties. These were removed in January 2017 and replaced with two network attached storage (NAS) systems.

To calculate the savings from removing the Xserves, we will use the power loads measured when the final three Xserves were removed. Two of the Xserves were removed on January 5, 2017, with a reduction in power load equaling 856 ± 90 W, and the third Xserve was removed the following day with a further reduction in load of 470 ± 65 W. The average power load based on these three Xserves is about 442 W. The power savings from removing the seven Xserves is approximately 3,000 W. The total annual savings for this server consolidation was about 9,035 kWh or $904 per year (assuming a 10¢ per kWh blended electricity rate).

Site 7: Adjusting Fan Settings on the RTU Air Handler

Similar to Site 4, our monitoring of the RTU at Site 7 showed that there was no cooling load to the SEDC and that the air handler was run continuously, resulting in an average power load to the RTU of 1.29 ± 0.05 kW with a CV of 2%. When the fan was set to AUTO, the average power load dropped to 0.06 ± 0.00 W with a CV of 2%. For a typical day, the energy savings from changing the fan from ON to AUTO was 29.5 kWh per day, about a 95% reduction in energy use. During the six months of the heating season when the air handler of the RTU would not operate, the energy savings would be 5,577 kWh or about $558 per year (assuming a blended rate of 10¢ per kWh). As with Site 4, additional savings would be obtained during the summer months based on the cycling of the mechanical system and the times when the air handler would be off.

Site 8: Scheduling Ports on Network Switches

As mentioned earlier, IT power load at all the sites were basically constant 24/7, even though little or no IT activity took place during evenings, weekends, or holidays. At Site 8, a test was set up to:

1. Measure the energy savings from powering down certain ports during off hours,
2. Determine the level of effort that would be required, and
3. Ascertain the amount of disruption that this might cause.

At Site 8, an elementary school, 33 access points (APs) were powered by PoE through cables connected to the network switches in the MDF. IT staff determined that 19 of these access points could be powered down from 11 pm to 5 am daily. The power load to the MDF was 1097.3 ± 1.6 W with a CV of 0.1% when the APs were powered on. When the APs were powered off at night, the power load to the MDF was 935.4 ± 0.4 W with a CV of 0.0%. Based on the difference in loads, the average draw of each of the 19 APs was about 8.5 W. Over a single day, the savings by powering down 19 APs for 6 hours was about 1 kWh total, which represents a 25% savings over a port fully powered constantly. Over a year this would equal about 354.5 kWh in electricity savings or about $35 per year (assuming a blended rate of 10¢ per kWh). The effort involved was simply programming the network management system to power on and power off the designated ports according to the specified schedule. To date, no issues have been encountered from powering down the Wi-Fi in certain portions of the school during off hours. Throughout the school district there are about 450 APs of which IT staff estimate about half might be able to be powered down for a possible annual savings of about $414. If it were possible to power down AP ports over the weekends, the savings would increase from 25% to about 46% per week, an annual savings of 7,769 kWh or $777 saved per year. Because of poor cellular penetration through the walls of the buildings, maintenance staff uses Wi-Fi calling after hours. If staff can avoid Wi-Fi calling, more APs could be shut down. This would require an administrative rule that required maintenance staff to subscribe to cell phone services that did not need to use Wi-Fi calling inside the buildings.

Phones are also currently powered by PoE, and Site 8 had 49 PoE phones. Unfortunately there are various models supporting different power states and it was decided not to attempt powering down phone ports at this time because of the effort involved.

Site 8: Distributed Power Management (DPM)

IT staff at Site 8 were willing to test DPM at their site since they had all the necessary software and resources to implement the procedure. One of the hosts was placed in “standby mode,” the low-power mode of VMware DPM. Storage for the host is on an external SAN. Putting the host into standby resulted in a 70 W decrease, likely from the CPU powering down and no internal hard drive to power down. The server is a 2S server so the estimated power draw for this type of server is about 365 W. Putting the server into standby mode represents about a 20% power savings, and the overall reduction in energy use by scheduling DPM during off hours would be about 13% for that one server. We did not consider putting storage on standby since the external SAN also serves as a backup repository and these are scheduled overnight and over weekends. If DPM is performed for 10 hours per day (overnight), during the weekdays, and through the weekend, that total energy savings would be 361 kWh or about $36 per year for that one server.

Site 9: Adjusting the SEDC Thermostat Set Point Temperature

Site 9 was an industrial site, and power measurements were not made at industrial sites so the estimated energy savings had to be calculated for the measures performed. Assuming a savings of 3% per 1°F increase in the set point temperature, Site 9 increased their SEDC thermostat set point temperature 8°F, from 69°F to 77°F. The annual savings from this is estimated to be about 5,670 kWh or $567 per year (assuming a blended electricity rate of 10¢ per kWh).

Site 9: IT Equipment Consolidation

We found two opportunities to consolidate IT equipment. Firstly, Site 9 had four extremely lightly loaded UPSs (<20%) and these were consolidated into two UPSs. The removal of the two UPSs (along with increased UPS utilization for the remaining two) resulted in annual energy savings of 438 kWh, about $44 per year in operational costs (assuming a 10¢ per kWh blended electricity rate). The UPS consolidation also avoids future unnecessary equipment purchases when UPS upgrades are necessary, resulting in roughly $2,700 in additional cost savings.

A number of dormant servers were identified and these idle servers were shut down. The annual savings from this action was 1,233 kWh or about $123 savings per year (using a blended rate of 10¢ per kWh).

Site 10: Adjusting the SEDC Thermostat Set Point Temperature

The set point temperature in the SEDC at Site 10 was found 68°F. IT staff was advised to raise the set point to 77°F and the followed through on this recommendation. The estimated annual savings for this measure is 1,134 kWh and, assuming a blended rate of 10¢ per kWh, the annual savings will be about $113.

Site 11: Airflow Management

At Site 11, the orientation of the servers resulted in poor delivery of conditioned air to the server inlets. Based on recommendations from MnTAP staff, ducting was installed to direct cool conditioned air towards the front of the servers. The heated air was also removed from the back of the servers. Monitoring was not performed after this measure was implemented.

Summary of Site Savings

Table 16 provides a summary of the savings obtained from the project participants.

Table 16. Summary Energy Savings from Data Center Measures

Category	Measure	Site	Energy Savings
IT	UPS consolidation	9	438 kWh/yr for consolidating 4 UPSs (<20% load) to 2 UPSs
	Shutting off dormant servers	9	1233 kWh/yr
	Virtualization	7	442 W per Xserve removed or about 9,000 kWh/yr for seven Xserves removed
	Scheduling network switches	6, 8	Site 6: 200 W for powering down a network switch or 1021 kWh/yr if turned off 10 hours each night during the workweek and all weekend Site 8: 355 kWh/yr for powering down 9 APs for 10 hours every night
	Distributed power management	6, 8	Site 6: 1,388 kWh/yr for 10 hours each night on weekdays and all day on weekends. Site 8: 361 kWh/yr for 10 hours each night on weekdays and all day on weekends.
Cooling	Adjusting the SEDC thermostat set point temperature	1, 2, 5, 9, 10	Site 1: 26,280 kWh/yr from 3°F increase Site 2: 9,636 kWh/yr from 4°F increase Site 5: 6,044 kWh/yr from 3°F increase Site 9: 5,670 kWh/yr from 8°F increase (estimate) Site 10: 1,134 kWh/yr from 9°F increase (estimate)

Category	Measure	Site	Energy Savings
	Airflow management	11	No post-retrofit data collected
	Cold or hot aisle containment	2, 6	Site 2: Increasing set point temperature 4°F plus cold aisle containment reduced power draw by 1.1 kW or 9,636 kWh/yr Site 6: Replacing a CRAC unit with a 312 W exhaust fan with hot aisle containment produced an estimated reduction of about 1.5 kW or a savings of 13,140 kWh/yr.
	Adjusting fan settings on the RTU air handler	4, 7	Site 4: 1,004 kWh over 6 month heating season, with economizing Site 7: 5,577 kWh over 6 month heating season, without economizing

Discussion of Results

The following discussion describes the results from the work done at the 11 participating sites. Sites 1 to 8 were commercial and institutional sites that were recruited and studied by CEE; Sites 9 to 11 were industrial sites recruited and studied by MnTAP. Appendix D: Small Embedded Data Center Program Pilot – Industrial Sites provides an in-depth discussion of MnTAP's work at the three industrial sites.

Server Virtualization

All but two of the SEDC server rooms employed some level of server virtualization. The exceptions were Sites 4 and 11. This is in contrast to the results of the electronic survey in which two thirds of the respondents had employed virtualization. In order to perform virtualization, a site must obtain the necessary server virtualization software and licensing. Hardware upgrades may be needed to ensure that the physical servers have adequate computer processing (CPU), memory and network I/O capacity, and that sufficient storage space is available to meet all virtualization storage needs. Site 8 was able to consolidate seven servers using both their existing server virtualization architecture and some additional new equipment. Based on discussions during this project, Site 4 intends to adopt server virtualization in an upcoming equipment refresh. ENERGY STAR has provided information on savings, costs, and other considerations for adopting server virtualization.[36]

Scheduling IT Equipment

At all the sites we observed a near constant IT power load with only a nominal variation resulting from actual user demand of IT services. When you consider that the work hours at the sites represent a fraction of the time that the data center is operating, an opportunity for savings exists by simply scheduling IT equipment to power off during off hours like evenings, weekends, and holidays. Powering down equipment 10 hours a day during the week and all day on weekends would reduce weekly on time by almost 60%, resulting in a similar relative reduction in energy use. This is an upper limit since some SEDC functions are necessary during non-work hours, such as for system backups, software updates, and remote access for employees working off-site and after hours. Even with these exceptions, scheduling IT equipment to power down during non-use times can be a low-cost, non-capital intensive measure.

The results from scheduling network switches show that this strategy could provide savings for both SEDC server rooms and IDFs using standard network switches as well as PoE switches. While the magnitude of savings is not huge, it can add up at institutional settings where the number of switches and PoE devices (like phones and access points) can be appreciable.

[36] ENERGY STAR. "Server Virtualization." energystar.gov. https://www.energystar.gov/products/low_carbon_it_campaign/12_ways_save_energy_data_center/server_virtualization (retrieved April 28, 2017)

Network and UPS management software can make the IT staff effort required to perform this measure fairly routine.

Network Switches

The best candidates for scheduling are the network switches. They are found in both server rooms and IDFs. Three options are possible:

1. Powering down ports,
2. Shutting off PoE, and
3. Shutting off power to the entire network switch from the UPS.

Results from the tests performed in this project found that power to the ports is on the order of a few watts depending on the data rate of the port. This can add up with the number of switches and ports in use in a building, on a campus, or in a district. The major network switch manufacturers like Cisco and Hewlett-Packard have energy management software that allows schedules to be programmed to place individual ports into different energy states, and IT SysAdmin can do this using a central application.

In addition to transferring data over the LAN, ports can also power devices through PoE switches. Currently there are two types of PoE switches: standard PoE, which can provide up to 15 W of power per port, and PoE+, which can provide up to 30 W. A third type of PoE switch called UPoE is just entering the market and can provide up to 60 W. Standard PoE provides sufficient power to VoIP (voice of Internet Protocol) phones and access points. Phones draw about the same power as data ports (2-4 W) while access points draw about 8-10 W. In this project, our efforts to use the energy management systems to control PoE encountered software bugs and we reported these bugs to the switch manufacturers. We await updates to the software packages to provide this functionality. For our tests, PoE had to be switched off manually for each port. PoE lighting systems are also coming onto the market; Philips, Cree, and Acuity all having PoE LED lighting systems available. These will require PoE+ and UPoE switches and will result in greater power demands over the network switches and from the SEDC.

The third scheduling approach could employ UPS management software to control the power from the UPS to connected equipment. In this case, the power to the network switches can be scheduled to be powered off at specific times. For this approach, IT staff would need to identify the network switches to be scheduled and designate the UPS outlets to be powered on and off.

Servers

A server is estimated to draw an average of about 330 W.[37] Assuming that some servers could be put into standby during off hours (at night and over weekends), the potential to reduce energy use for these servers could be as much as 60% or more. Scheduling server status using

[37] Armin Shehabi, S. Smith, D. Sartor, R. Brown, M. Herrlin, J. Koomey, E. Masanet, N. Horner, I. Azevedo, and W. Lintner. 2016. United States Data Center Energy Usage Report. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-1005775 http://eta.lbl.gov/publications/united-states-data-center-energy-usag (retrieved April 28, 2017)

live migration or DPM would seem like a good opportunity to reduce the server power draw during low utilization periods. A bare bones number of physical hosts could be kept awake during off hours while the remainder could be put on standby. When services are demanded, additional hosts would be brought online dynamically as needed, without any interruption of service to the users. The experience from Site 8 allows us to estimate a possible energy savings on the order of 10% for each server placed on standby during off hours (approximately 60% of the time). The magnitude of savings would depend on how many servers could be placed on standby through scheduling.

We encountered interest as well as hesitancy when we tried to test this measure with our participating sites. At one site that was well-virtualized, the SEDC ran only a few physical hosts. For redundancy, they wanted to make sure that they were always available and running. With the exception of two sites (Sites 6 and 8 both tested live migration/DPM, as described above), IT staff at the other sites showed interest but we could not get them to proceed beyond the discussion phase. Live migration/DPM does require additional software and hardware requirements beyond those used for virtualization. It seems that the level of effort, cost, and uncertainty of the approach was probably beyond the comfort level or interest at those sites.

Storage

Although storage is the third major power draw of SEDCs, placing storage on standby probably is a non-starter given the amount of scheduled backups that are performed during off hours. There are more necessary measures to pursue regarding storage than looking at equipment scheduling.

IT Equipment Refreshes

Equipment refresh rates for the SEDCs in this study were generally much longer than the two to three years typically stated for large enterprise data centers and often two to three times that. This is typically governed by budget and need. Equipment refreshes can bring greater energy efficiency as new models bring improved technologies that provide more capabilities per unit and as data center equipment certifications like ENERGY STAR allow for more informed energy choices.[38] With time equipment refreshes will naturally lead to higher energy efficiency. Within that context, there are a number of energy efficiency considerations for IT staff when planning equipment refreshes.

UPS Sizing

The size or capacity of the UPS can affect the overall efficiency of the data center. The efficiency of the UPS is dependent on the magnitude of the IT load relative to the capacity of the UPS. The greater the percent load of the battery capacity, the greater the efficiency of the UPS. Figure 69 shows a typical UPS efficiency curve.

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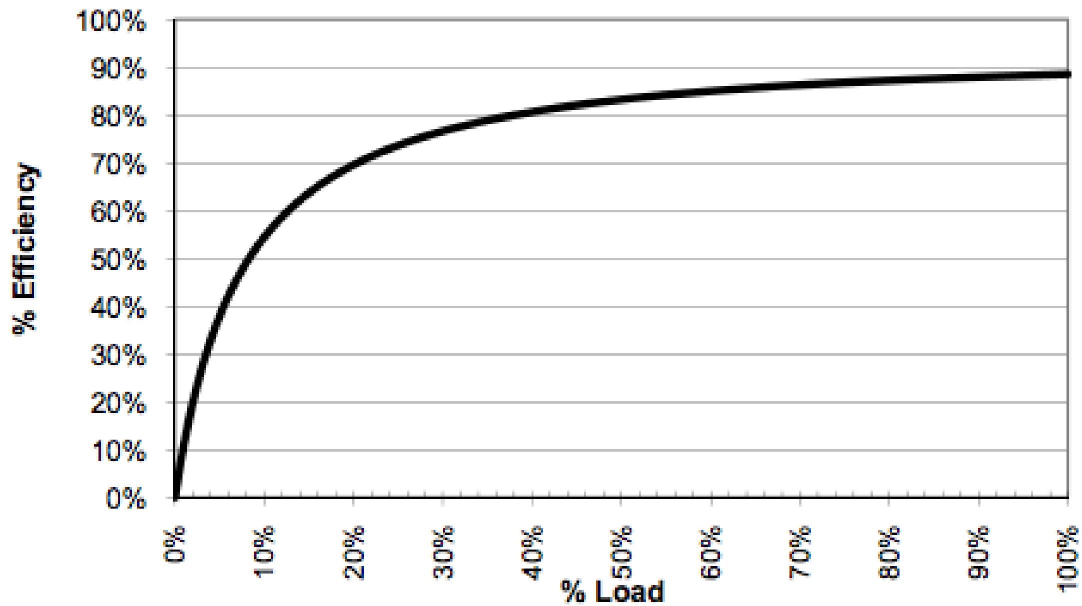
[38] ENERGY STAR. "Purchasing More Energy-Efficient Servers, UPSs, and PDUs." energystar.gov. https://www.energystar.gov/products/low_carbon_it_campaign/12_ways_save_energy_data_center/purchasing_more_energy_efficient_servers_upss_and_pdus (retrieved April 28, 2017)

Figure 69. Typical UPS Efficiency Curve[39]

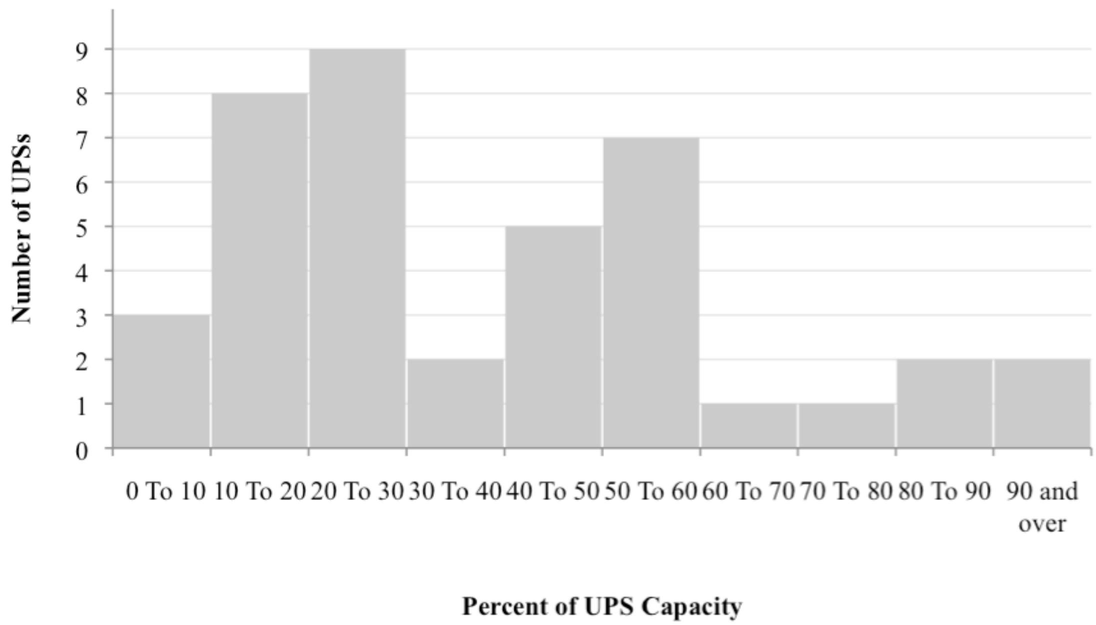


A choice must be made when sizing the UPS — IT staff must determine how much battery capacity is required to keep mission critical services running if a power outage does occur. In this study, the UPS capacities provided backup from minutes to an hour or more. The shorter time periods allowed for IT equipment to gracefully shut down, while the longer backup times allowed sufficient time for power to be restored via backup generation or resumption of service.

Figure 70 compares the measured load at each site to the UPS capacity to show the distribution of the percent of load for the UPSs in this study. The average UPS percent load was 38.1 ± 23.8% with a CV of 62.4%. Twenty-two UPSs (52% of the sample) had a percent load of 40% or less.

[39] Sawyer, R.L. 2012. Making Large UPS Systems More Efficient. White Paper 108, Revision 3. APC by Schneider Electric. http://www.apc.com/salestools/VAVR-6LJV7V/VAVR-6LJV7V_R3_EN.pdf (retrieved April 28, 2017)

Figure 70. Histogram of Percent Load of the UPSs



The rule of thumb for sizing a new UPS is to plan the capacity to be 20% to 25% greater than the load. Based on this recommendation, the majority of UPSs found in this study are oversized. When the time comes for a UPS refresh, proper sizing would be a cost-effective way to achieve greater energy efficiency. Sizing the UPSs for 60% to 80% loads would bring significant savings to a majority of the SEDCs in this study.

Require ENERGY STAR Certified Data Center Equipment through Purchasing Policies

Since September 2013, ENERGY STAR has been certifying energy-efficient IT equipment. These include servers, data storage, and large network equipment (LNE) such as switches, routers, and UPSs. The following are product specifications for the major SEDC IT equipment.

- Servers — efficiency and power factor requirements on PSUs and base idle power state allowances.[40]
- Storage Equipment — efficiency and power factor requirements on PSUs, the use of VFDs for equipment cooling, and capacity optimizing methods (COMs).[41]

[40] ENERGY STAR. "Enterprise Server Key Product Criteria." energystar.gov. https://www.energystar.gov/products/office_equipment/enterprise_servers/key_product_criteria (retrieved April 28, 2017)

[41] ENERGY STAR. "Data Center Storage Key Product Criteria." energystar.gov. https://www.energystar.gov/products/office_equipment/data_center_storage/key_product_criteria (retrieved April 28, 2017)

- LNE (i.e., switches and routers) — efficiency and power factor requirements on PSUs.[42]
- UPSs — minimum average efficiency requirements.[43]

All the major manufacturers of data center IT equipment now offer ENERGY STAR certified equipment. Institutional purchasing policies (e.g., for state government, schools, and higher education) should be adjusted to require ENERGY STAR certified data center equipment. Many of these institutions already require ENERGY STAR certified office equipment or computers so adjustments to purchasing policies would be minimal. The benefit of institutional policy is that IT staff would then have to specify ENERGY STAR certified equipment in the their next equipment refresh, despite their typical lack of concern with energy issues regarding their mission critical responsibilities.

Storage Management

Storage requirements for SEDCs typically increase each year. None of the participant sites took advantage of archival methods to remove seldom accessed files from their SANs. Opportunities were identified where files could be archived to tape drives rather than having them reside on constantly spinning disk drives. Total cost of ownership studies have found that disk storage consumes up to 105 times more energy than if stored on tape.[44] This would both free up storage space and reduce the storage needs of the SEDCs. ENERGY STAR describes a number of practices to better manage data storage.[45] These include:

- Automated Storage Provisioning,
- Data Compression,
- Deduplication,
- Snapshots,
- Thin Provisioning,
- RAID Level, and
- Tiering Storage.

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[42] ENERGY STAR. "Purchasing More Energy-Efficient Servers, UPSs, and PDUs." energystar.gov. https://www.energystar.gov/products/office_equipment/large_network_equipment/key_product_criteria (retrieved April 28, 2017)

[43] ENERGY STAR. "Uninterruptible Power Supplies Key Product Criteria." energystar.gov. https://www.energystar.gov/products/office_equipment/uninterruptible_power_supplies/key_product_criteria (retrieved April 28, 2017)

[44] Gadomski, R. 2014. "Reducing Energy Consumption and Cost in the Data Center." datacenterknowledge.com. http://www.datacenterknowledge.com/archives/2014/12/11/reducing-energy-consumption-cost-data-center/ (retrieved April 28, 2017)

[45] ENERGY STAR. "Better Management of Data Storage." energystar.gov. https://www.energystar.gov/products/low_carbon_it_campaign/12_ways_save_energy_data_center/better_management_data_storage (retrieved April 28, 2017)

Cloud Services

An Information Week poll of IT professionals looked at IT spending priorities for 2017. Over one third of the respondents (36%) cited the cloud as the technology that would receive the largest amount of their 2017 IT investment.[46] The following cloud services are typically available to SEDCs via Software as a Service (SaaS):

- Email/Contacts/Calendaring;
- Productivity/Accounting/Office Suites;
- Web/Database Hosting;
  Virtual Machines/Virtual Infrastructure/Cloud Storage; and
- Cloud Backup.

All of the participant sites employ some level of cloud services, either through a public cloud or their own private cloud (i.e., in the case of the health service provider, they employed their own enterprise scale data centers).

Cloud service providers have been reporting or estimating PUEs in the range of 1.12 to 1.2.[47,48,49] The server rooms with dedicated cooling in this study had an average MLC of 1.9 ± 0.4 with a CV of 21%. For the SEDCs to achieve the 1.2 MLC that cloud services might provide would require an average cooling load reduction of 74.5% ± 14.9% with a CV of 10%. To reduce energy costs, any services that can be migrated to cloud services and result in a reduction of IT equipment should be encouraged. Recall that the MLCs for these cases were calculated using the measured cooling load and do not include lighting or other overhead loads that would be included in an enterprise data center PUE calculation. If the MLC for an enterprise data center was calculated using just cooling load it would be less than the value calculated for the PUE. So this 75% reduction would actually be greater if the cloud services were provided by a data center with a 1.2 PUE (MLC < 1.2).

SEDC Cooling

ASHRAE recommends that the inlet temperature at server racks be in the range of 64.4°F to 80.6°F.[50] Measuring air temperatures within the server rooms with dedicated cooling systems showed two things:

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[46] Nunziata, S. 2016. "Where Your IT Dollars Are Headed in 2017." informationweek.com. http://www.informationweek.com/strategic-cio/it-strategy/where-your-it-dllars-are-headed-in-2017/a/d-id/1327454 (retrieved April 28, 2017)

[47] Google Data Centers. "Efficiency: How we do it." google.com. https://www.google.com/about/datacenters/efficiency/internal/ (retrieved April 28, 2017)

[48] Jeff Barr. 2015. "Cloud Computing, Server Utilization, & the Environment." aws.amazon.com. https://aws.amazon.com/blogs/aws/cloud-computing-server-utilization-the-environment/ (retrieved April 28, 2017)

[49] Microsoft Azure. "Azure Datacenter." azure.microsoft.com. https://azure.microsoft.com/en-us/overview/datacenters/ (retrieved April 28, 2017)

[50] ASHRAE TC 9.9, op cit.

2. There was a lot of mixing between the cold conditioned air that was supplied to the room and the heated air exiting the IT equipment and exhausted from the back of the server racks. Air temperatures on this side of the server rack (the hot aisle) were typically in the mid to high 80°s and above.

1. Thermostat set point temperatures were kept in the lower end of this range; and
2. There was a lot of mixing between the cold conditioned air that was supplied to the room and the heated air exiting the IT equipment and exhausted from the back of the server racks. Air temperatures on this side of the server rack (the hot aisle) were typically in the mid to high 80°s and above.

The absence of airflow management in these server rooms resulted in higher server rack inlet temperatures with a wide range of inlet temperatures from rack to rack. This variation restricted the ability to increase the thermostat set point temperatures into the upper range of the ASHRAE recommendations and therefore decreased the opportunity for savings from this measure.

A major conclusion from the ASHRAE recommendation is that we only need to be concerned with maintaining the rack inlet air temperature within the range specified, and the main obstacle in providing this is the mixing that occurs between the cold and hot aisles. Using airflow management to minimize this mixing will create more uniform temperatures along the inlet of the server racks and make it possible to deliver conditioned air in the upper range of the ASHRAE recommendations. Hot aisle and/or cold aisle containment is a practice that should be considered in SEDCs. This is not an expensive measure to undertake; it simply entails using blanking panels to block empty spaces in the server racks and plastic drapes to isolate the conditioned air from the hot server rack exhaust air.

The experience from Site 6 raises another interesting possibility. Instead of using a dedicated CRAC unit to provide conditioned air to the servers, Site 6 used the conditioned air from the rest of the office to supply the server rack. Conditioned office air was supplied through a grate in the server room door (Figure 71).

Figure 71. Supply Air Inlet to Site 6 SEDC

Using drapes to isolate the hot and cold aisles, an exhaust fan on the back side of the server racks creates greater negative pressure in the hot aisle and draws a greater flow of cool air across the IT equipment. The IT power load for Site 6 was about 3.8 kW. Sites 2, 4, and 11 had IT power loads less than 3.8 kW (3.2 kW, 3.2 kW, and 2.1 kW, respectively), and the average cooling load for these three sites was 1.8 kW. It might be possible that an exhaust fan with hot aisle isolation could have been used rather than a dedicated CRAC. Replacing the CRAC in these three sites with a 750 cfm exhaust fan drawing 312 W of power would provide on average an 82% reduction in cooling load. A fourth site, Site 10, had an IT load of 2.3 kW, but the cooling load for that site was not monitored. Four of the nine sites with dedicated cooling might be candidates for this exhaust fan approach. The benefit of the exhaust fan is that it helps to control airflow management, uses less energy (and costs less) than a dedicated CRAC unit, and can supply a stream of heated air that could serve other purposes within the building (i.e., space heating, domestic hot water preheat, CHP). However, this measure would not be feasible at a site where the building HVAC system was required to operate around the clock simply to provide cooling for the SEDC. If the building cooling setback is 78°F and that temperature is maintained at the server rack inlet, then this approach could be possible.

Finally, in a few cases the layout of the server racks made cold/hot aisle containment problematic because of how the racks are placed and/or how the ductwork is installed. This is similar to the issue of the number of SEDCs that are not designed with the intent of using them as SEDCs. Given the cooling loads of SEDCs, staff should take these factors into account when the SEDC is being designed and constructed.

Conclusions and Recommendations

Based on the results of our work with the 11 participating sites, we've identified and verified a number of measures that can increase the energy efficiency of SEDCs without introducing the need for large capital expenditures. Most of these measures deal with operational changes that can be performed by IT staff. In order to overcome the current inertia that impedes adoption, opportunities for utility programs are recommended to promote, achieve, and get credit for these savings. Finally, we may be facing a shift in how SEDCs and even commercial office spaces operate, which bring both challenges and opportunities to IT staff and building operations.

Operational Efficiency

Much like turning off lights when leaving a room or setting back the thermostat when going to sleep, energy savings opportunities in SEDCs are available through simple changes in operation based on activity or inactivity. These opportunities are typically overlooked because of the priority of maintaining mission critical services and the lack of awareness of IT staff, building facilities personnel, and the accounting staff who pay the energy bills. Simply put, energy savings can be obtained fairly quickly and at low cost with routine operational changes that have no impact on user needs for IT services. It is possible to achieve energy savings by powering down IT equipment during non-work hours or during times of non-utilization, and this can be about 60% of the work week (overnight and on weekends). IT staff are also more open to these operational efficiency measures since they avoid the capital expenditures involved with purchasing new equipment and any downtime in IT services, and they can be easily implemented and reversed if issues arise.

Similarly, for SEDCs with dedicated cooling systems, poor operations can result in energy inefficiencies. Ignorance is not bliss and relying on the thermostat set point to deliver cooling to the SEDC often results in overcooling. Monitoring air temperatures at the server inlets can now be done with inexpensive temperature monitors, and this allows for more precise and efficient cooling strategies to be performed.

This last point re-emphasizes the need to monitor important operational data to ensure that systems are working properly and operations are performed without an unnecessary and excessive use of energy. This study found that very little effort was made to monitor energy use and the necessary energy use data can now be easily and inexpensively obtained.

SEDC Monitoring Recommendations

A number of low-cost/no-cost monitoring approaches can help IT staff understand the operation of their SEDCs, estimate savings potential from possible measures, and improve their energy efficiency. Based on the data collected from the monitored sites, the following conclusions have been reached:

1. For all the sites we monitored, the power drawn by the UPS was found to be nearly constant 24/7 with a little variation due to server utilization or network activity. While we used smart power cables to monitor power loads at one minute increments, reading

the power load directly from the display on the UPS or using the UPS management software dashboard is sufficient to determine the baseline power draws of the SEDCs and estimate SEDC energy use. Refer to Figure 41 as indicative of the good agreement between the monitored power loads versus the observed UPS loads. This data can serve as a method to measure savings after energy efficiency measures have been implemented.

2. Monitoring air temperatures in the SEDC provides important information on the cooling of the server racks and the opportunities for reducing cooling loads in the SEDC. This project determined that air temperature monitors can be both convenient and inexpensive (under $50 per logger[51]), allowing access to data using a mobile device connected via Bluetooth. For SEDCs with dedicated cooling systems, these monitors should be placed at both the room thermostat and at the inlets of the server racks. The temperature data will help:
    a. Determine the correct room thermostat set point temperatures that result in 77°F server inlet air temperatures,
    b. Provide insights into airflow management strategies that need to be taken, and
    c. Monitor to ensure the mechanical system is operating properly by using temperature variations to discern mechanical system cycling.

Recommended SEDC Energy Efficiency Measures

Based on the findings of this pilot project, Table 17 and Table 18 list our suggested energy efficiency measures to reduce the IT and cooling power loads for SEDCs. These tables build on the measures created by Lawrence Berkeley National Laboratory that are listed in this report. The measures listed in Table 5 that were not tested in this study are included but italicized in Tables 14 and Table 15. Most of the operational measures can be performed immediately at very little cost. Equipment improvements can be performed as part of the normal budgeted IT equipment refresh. These equipment recommendations could be instituted as part of the purchasing policies in a similar fashion as defined in the ENERGY STAR discussion above and incentivized through deemed or measured savings as a part of utility programs.

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[51] Onset. "HOBO Temperature Data Logger: Part# MX100." onsetcomp.com. http://www.onsetcomp.com/products/data-loggers/mx100 (retrieved April 28, 2017)

Table 17. Measures to Reduce IT Power Loads in an SEDC

Category	Measure
Simple, No-Cost, or Very-Low-Cost Measures	1. Consolidation: Power down any unused (comatose) servers.
	2. Consolidation: Examine power backup requirements to determine if the UPSs are underutilized and consolidate if possible.
	3. Scheduling: Power down network switches, ports, and/or PoE during non-work hours such as nights, weekends, and holidays.
A Little More Work, But Still Fairly Simple	4. Power Reduction: Refresh IT equipment with high-efficiency ENERGY STAR models.
	5. Power Reduction: Upon UPS refresh, resize UPS to better match power loads of the SEDC to result in UPS utilizations in the range of 60-80%. Replace with ENERGY STAR UPS models.
	6. Power Reduction: Move IT services (applications, storage, etc.) to more energy-efficient external central data center space, co-location, or cloud solutions employing SaaS.
Higher Investment, But Can Be Cost Effective	7. Consolidation: Reduce the number of physical hosts by employing server virtualization.
	8. Consolidation: Archive unused storage onto tape drives and power down unneeded disk drives.
	9. Scheduling/Consolidation: Perform live migration or DPM on virtualized servers and place unused physical hosts on standby. This could require software upgrade, additional storage, or CPU replacement.
	10. *Power Reduction: Implement server power management.*
	11. *Monitoring: Implement rack power monitoring.*

Table 18. Measures to Reduce Cooling Loads in an SEDC

Category	Measure
Simple, No-Cost, or Very-Low-Cost Measures	1. Mechanical System: Increase temperature set points so that server rack inlet temperatures are at the high end of ASHRAE's recommended limit (~77°F).
	2. Airflow management: Install blanking panels and block holes between servers in racks.
	3. Mechanical System: Set air handler fan to AUTO instead of ON (i.e., running continuously), if allowed by code.
	4. Monitoring: Install low-cost Bluetooth temperature monitors to track rack inlet temperatures and SEDC thermostat setpoint.
A Little More Work, But Still Fairly Simple	5. Airflow management: Arrange or orient server racks so that distinct cold aisles and hot aisles are created.
	6. Airflow management: Perform cold aisle and/or hot aisle containment using drapes or other air barriers.
	7. Airflow management: Properly manage server cables by tying or clipping cords together.
Higher Investment, But Can Be Cost Effective	8. Mechanical System: Depending on power load of SEDC (<4 kW), consider installing an exhaust fan in hot aisle (to avoid need for dedicated cooling and provide CHP opportunities with the rest of the building).
	9. Mechanical System: Re-duct supply and return vents to promote rack- and row-level cooling (hot and cold aisles).
	10. *Monitoring: Implement infrastructure power monitoring.*
	11. *Mechanical System: Install variable frequency drives on cooling.*
	12. *Mechanical System: Install rack- and row-level cooling.*
	13. *Mechanical System: Use air-side economizers.*
	14. *Mechanical System: Install dedicated cooling for the room if cooling of SEDC requires building mechanical system to operate during non-work hours.*

Program Recommendations

There are a number of barriers that hinder the adoption of SEDC energy efficient practices. Foremost is IT staff lack of awareness and need. Education, incentives, and marketing from utility programs can help spur interest and increase motivation. A second issue is that, while the effort to implement operational efficiency measures can be relatively small, the absolute magnitude of the energy savings per SEDC may be correspondingly low. It is through economies of scale that these savings become truly appreciable. Programmatic efforts need to target leveraged opportunities where a number of sites are reached. This would also help justify programmatic transactional costs. Another possibility is to package these measures with other building measures to help increase the cost effectiveness of the entire suite of installed measures. The following discussion will address these and other possible programmatic issues in greater detail.

Incentives and Rebates

Equipment refresh rates for SEDCs are much longer than those reported for large enterprise data centers. We've seen equipment up to 10 years old still being used in SEDCs, while the typical refresh time for enterprise data centers is two to three years. Cost and maintaining IT services through proven practice are barriers that impede the adoption of more energy-efficient equipment and practices, possibly delaying improvements by 10 years or more. With energy efficiency being a low driving force in equipment selection and operational practice, rebates and other financial incentives can help to speed adoption. Purchasing ENERGY STAR IT equipment, performing server consolidation, migrating to cloud services, instituting IT equipment scheduling strategies, and increasing UPS utilization are all worthwhile measures that should be incentivized to help motivate SEDC market adoption. Our survey results showed that over 50% of the IT staff surveyed replied that their vendors were their trusted source of information for IT decisions. A midstream program to incentivize vendors to promote ENERGY STAR equipment or energy efficient IT practices would be beneficial.

Quantifying IT Savings

In order to predict savings to justify rebates and quantify incentives, an estimate or measure of the savings should be obtained. For IT measures, the IT equipment power loads published by Lawrence Berkeley National Laboratory (see the discussion on the predictive audit tool described above) can provide an estimate of savings for the proposed strategies. Monitoring the UPS load can also provide an inexpensive means to measure the savings that have been achieved. Table 19 summarizes suggested methods for quantifying savings for IT measures.

Table 19. Quantifying IT Measure Savings

Category	Measure	Savings
Server Consolidation	1. Power down any unused (comatose) servers.	2,891 kWh/yr per server (assuming average power of 330 W/server, as per Table 15)
	2. Reduce the number of physical hosts by employing server virtualization.	
	3. Reduce the servers by moving those IT services to the cloud (typically email, file, and database servers).	
UPS Utilization	4. Match power loads of the SEDC to increase UPS utilization to the 60-80% range.	kWh/yr = UPS_{load} *(($\eta_1 - \eta_0$)/$\eta_1\ \eta_0$) * 8760 hr/yr where UPS_{load} is the IT power load read off the UPS (in kVA) and η_0, η_1 are the UPS efficiencies at the initial and increased percent IT loads, respectively(obtained from Figure 69)
Storage Reduction	5. Move storage to cloud services	kWh/yr = ((# of HDDs * 9) + (# of SSDs * 6)) * 8760 hr/yr where # of HDDs are the number of hard disk drives taken off line and # of SSDs are the number of solid state drives taken off line
	6. Archive unused storage onto tape drives and power down unneeded disk drives.	
IT Equipment Scheduling	7. Perform Live Migration or DPM on virtualized servers and place unused physical hosts on standby.	kWh/yr = ($UPS_{load, on}$ - $UPS_{load, off}$) * $Hours_{off}$) where $UPS_{load,on}$ and $UPS_{load,off}$ are the IT power loads read from the UPS (in kVA) when the devices are scheduled on and scheduled off, respectively; and $Hours_{off}$ is the total number of hours in the year that the equipment is scheduled to be off. For the network switches, a deemed savings approach could also be used to calculate the expected savings. IT staff would need to keep track of the number and type of ports that would be powered on and off as well as any PoE devices (such as phone and access points) that are attached to those ports. Table 15 provides power draws for the different types of ports and 3 W per PoE phone and 9 W per AP can be used for their power loads.
	8. Power down network switches, ports, and/or PoE during non-work hours such as nights, weekends, and holidays.	

For more accurate IT power loads, devices like the Packet Power cables could be lent to SEDCs for a limited period to obtain more accurate measurements.

Retro-commissioning

For SEDCs that have dedicated mechanical systems, energy savings measures like airflow management, set point temperature adjustments, and mechanical system should be allowable under existing utility building retro-commissioning programs. These measures should be included as part of the packages of building measures that can and should be performed. Utilities should be able to claim these energy savings under those programs. Given the individualized nature of SEDCs, it is difficult to predict energy savings from specific cooling measures. We found that it was best to monitor the cooling power at the electrical panel, along with temperature data loggers monitoring inlet temperatures of the server racks. This monitoring should be included in any proposed plan. In addition to the equipment, a licensed electrician would need to install and remove the monitoring equipment in/from the electrical panel. Programmatic considerations would need to be made to account for the monitoring equipment and electrician costs.

Savings Aggregation

The low cost of many of these measures make them good candidates to be included with packages of other retrofits to increase the overall cost effectiveness of the total package. This would improve the attractiveness of more capital-intensive retrofits that would be worthwhile to complete. This approach would fit in well with a program delivered along the lines of Xcel Energy’s Fast-Track Rebate Program.[52]

Design Assistance

For the most part, at the sites in this study dedicated cooling systems were either added to rooms after the fact or the rooms already had a CRAC installed and server racks were added without considering airflows. With some planning and consideration of airflow management, cooling loads in these SEDCs could be greatly reduced with effective cooling supplied equally to all the racks. Considerations include the use of cold/hot aisle containment using partitions; proper placement of supplies and returns (or even relying solely on exhaust fans); better placement of SEDC room thermostats; and the ability to confidently increase thermostat set points. An opportunity exists for utilities to work with architects, engineers, and IT staff to properly design SEDC cooling systems that will provide energy savings and ensure a better running data center.

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[52] XcelEnergy. “Recommissioning”. xcelenergy.com. https://www.xcelenergy.com/programs_and_rebates/business_programs_and_rebates/energy_audits_and_studies/recommissioning (retrieved May 4, 2017)

Collocation

Tenant-office buildings are renting out more and more spaces with SEDCs that drive up the energy use of the building and raise operating costs. Another program opportunity would be to work with property managers and building owners to encourage creating a shared space for collocation opportunities within the office building. Design assistance could help building owners and property managers to efficiently design and construct these spaces, and commissioning services can help ensure that these spaces are efficiently operated and maintained. These collocation spaces would help building owners offer more affordable spaces to tenants.

Cloud Services

Finally, this project has shown that the energy efficiency of providing IT services could be increased by relying on cloud services rather than SEDCs. Large enterprise data centers are operated much more efficiently than SEDCs with PUEs reported as low as 1.1. Incentives should be provided based on carbon offsets to encourage customers to use cloud services either through enterprise services like Azure, Google, and Amazon or private cloud services through the use of their own more efficient centralized enterprise data centers.

Privacy and Data Security

Privacy and data security concerns are important barriers that would limit the adoption of collocation or cloud services. This is especially true in segments such as financial services or healthcare where data security is extremely important. Before collocation or cloud services are adopted, it is important to make sure that those efforts comply with any data security or privacy regulations that are in place.

Looking Forward

Over the coming years, IT workforce will see a shift in responsibilities. As IT services move into the cloud, on-site IT staff roles and responsibilities will be less about providing IT services and more about maintaining networks and networked equipment. IT staff are a very skilled workforce and losing this workforce from the commercial building sector represents a huge loss. Fortunately, there may be opportunities for retaining this skilled workforce with PoE and connected offices. As PoE lighting, connected office equipment, and other emerging IoT building systems are introduced into commercial buildings, on-site IT staff will be asked to perform increased energy management roles of these networked devices. These new network applications will also expand energy management roles and responsibilities to settings that do not typically employ energy management systems or strategies and are often not targeted by utility efficiency programs. This includes a proportion of buildings that make up the large government building and education sectors. These are also buildings that, because they don't have automation systems, have the largest savings potential without any negative impact on business operations.

Power over Ethernet (PoE)

At present, PoE ports provide 3 W to 10 W per port to power office devices like phones and access points. PoE+ and UPoE standards, providing 30 W to 60 W per port, respectively, are bringing new opportunities for more low voltage DC-powered office equipment to be introduced into workspaces. This includes PoE LED lighting, HVAC controls, and other office equipment. Cisco has developed their Digital Building System and has recruited partners such as Philips, Cree, Acuity, Delta Controls, Eaton, Johnson Controls, and others. Products are now available on the market and more and more systems will soon be in place. The data center power loads will also increase by an order of magnitude as these devices become powered and connected by network switches to the office LANs. Device control is being designed using network management software and accessed and controlled through dashboards. These will all be introduced into the IT realm and IT SysAdmins may soon need to be engaged as managers of lighting, office equipment energy use, and even HVAC.

The Internet of Things

Using Ethernet cables to deliver PoE and data allows the use of digital sensors and controls throughout the building. This technology system will be incorporated into new and existing commercial buildings that build on and enhance the existing infrastructure and experienced support/management staff. Data and information will be collected and used in a way that will begin to blur the boundaries between facilities, IT staff, and building operators. Building staff will need to be capable of reading dashboards, programming schedules, and interpreting and troubleshooting data.

IT Staff as Energy Managers

IT staff have the programming and implementation skills to install and maintain PoE devices in commercial and institutional settings. Currently they are responsible for PoE devices such as phones and access points. Their job duties also include maintaining commercial plug load devices such as computer workstations and office equipment with network connections such as printers and copiers (although they do not consider themselves to be "energy managers"). The equipment, management software, and end-use devices currently reside in today's offices (phones, access points, and PoE/PoE+ switches), are available on the market (PoE LED lighting, UPoE switches, and PoE-controlled HVAC controls), or soon will be available on the market (PoE-controlled advanced power strips and outlets). Expanding IT staff responsibilities to include the operational efficiency of existing PoE devices and adding the oversight of newer PoE devices such as lighting, plug load control, and possibly HVAC to their responsibilities will require education and training but are within the context of their current skill set. Experience with IT staff during this project suggests that they are not only open to these opportunities but very responsive to them. The fact that they are equipped with the necessary expertise and tools to take on sophisticated energy management activities should not be overlooked.

Concluding Remarks

This study has provided a snapshot of the current state of SEDC energy use in Minnesota, shown numerous opportunities for greater energy efficiency in this sector, and revealed that IT staff have the potential to effectively assist in energy management. Utility programs can play an important role in helping to increase energy efficiency in this sector and define good energy efficiency practice for IT staff, building engineers, architects, and designers. In some ways, promoting SEDC energy efficiency is similar to the early days of residential energy efficiency programs: 1.) The sector is fairly diverse and decentralized and 2.) Many of the effective measures are operational, relying on the behavior and actions of the energy users (such as turning off lights, setting back thermostats, and reducing phantom loads). Utility programs have a long history of effectively delivering programs to residential customers through marketing, rebates, incentives, and midstream efforts. SEDC energy efficiency programs could take similar efforts in helping increase energy efficiency. There is certainly opportunity given that as much as a third of the energy used by SEDCs is unnecessary and only about 2% of SEDC IT managers were found to be aware of utility program incentives for data centers.

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Appendix A: Literature Review

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This literature review was performed at the beginning of this project in 2015 to assess previous data center studies focused on SEDCs and to discern the applicability of those studies to the Minnesota market.

MnTAP White Paper: Energy Conservation Potential at Minnesota Data Centers

The white paper Energy Conservation Potential at Minnesota Data Centers: Identifying the Opportunity[53], produced by the Minnesota Technical Assistance Program (MnTAP) with Minnesota Department of Commerce, Division of Energy Resources, Conservation Applied Research & Development (CARD) funding, is an analysis of the data center energy efficiency opportunities and challenges in Minnesota. It covers the full range of data centers from server closets with a floor area less than 200 ft^2 to enterprise-class data centers with a floor area greater than 15,000 ft^2. Since this project is only concerned with small embedded data centers (SEDCs), we will review the findings of the white paper with respect to server rooms and server closets.

Classifications and Definitions

According to the U.S. EPA ENERGY STAR program,[54] server rooms are defined as data centers with a floor area of 200 - 500 ft^2 and an average of three servers and server closets are less than 200 ft^2 with an average of two servers. The MnTAP white paper also describes the IBM data center classification system, which has alternative definitions that are not based on floor area[55]:

> Server Room: A secondary computer location that usually is under IT control, usually less than 1000 sq ft and has some power & cooling as well as security capabilities.
>
> Server Closet: A very small room or "closet" often outside of IT control that has little to no security or cooling.

These definitions are preferable to the EPA ENERGY STAR classifications since they are not confined to floor area or number of servers and define a degree of infrastructure. As MnTAP points out, neither "scheme uses power consumption or power density as a basis for classifying data centers." However, the classifications do infer a correlation between size and power

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[53] J. Vanyo, R. Lundquist, and L. Babcock. Energy Conservation Potential at Minnesota Data Centers: Identifying the Opportunity, Minnesota Department of Commerce, Division of Energy Resources, COMM-03192012-53916, September 2014.

[54] U.S. EPA EnergyStar, Understanding and Designing Energy-Efficiency Programs for Data Centers, 2012.

[55] IBM, Data Center Operational Efficiency Self Assessment online tool, IBM Data Center Study webpage.

consumption. It should also be noted that the EPA ENERGY STAR Buildings Program does not consider server rooms or closets to be data centers.

The MnTAP report also describes two tier-based system classifications: one created by the Telecommunications Industry Association[56] and the other by the Uptime Institute.[57] Both classifications are defined by the level of system redundancy and server availability. SEDCs would most likely fall under Tier 1 (with no redundancy) and Tier 2 (with some redundancy) of the TIA-942 classification where:

Tier I – Basic: 99.671% Availability

- Susceptible to disruptions from both planned and unplanned activity
- Single path for power and cooling distribution, no redundant components (N)
- May or may not have a raised floor, UPS ,or generator
- Takes 3 months to implement
- Annual downtime of 28.8 hours
- Must be shut down completely to perform preventive maintenance

and

Tier 2 – Redundant Components: 99.741% Availability

- Less susceptible to disruption from both planned and unplanned activity
- Single path for power and cooling disruption, includes redundant components (N+1)
- Includes raised floor,UPS,and generator
- Takes 3 to 6 months to implement
- Annual downtime of 22.0 hours
- Maintenance of power path and other parts of the infrastructure require a processing shutdown

Similarly, SEDCs would likely be classed as Tier I (again, no redundancy) and Tier II (some redundancy) under the Uptime Institute classification where:

Tier I: Basic Site Infrastructure

The fundamental requirement(s):

- A Tier I basic data center has non-redundant capacity components and a single, non-redundant distribution path serving the computer equipment.

The performance confirmation test(s):

- Planned work will require most or all of the site infrastructure systems to be shut down affecting computer equipment, systems, and end users.
- An unplanned outage or failure of any capacity system, capacity component, or distribution element will impact the computer equipment.
- There is sufficient capacity to meet the needs of the site.

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[56] ADC Krone, TIA-942, Data Centre Standards Overview, ADC Communications, 2008.

[57] W. P. Turner IV, PE; J.H. Seader, PE; V. Renaud, PE; and K.G. Brill, Tier Classifications Define Site Infrastructure Performance, Uptime Institute, 2008.

The operational impact(s):

- The site is susceptible to disruption from both planned and unplanned activities. Operation errors or spontaneous failures of site infrastructure components will cause a data center disruption.
- The site infrastructure must be completely shut down on an annual basis to safely perform necessary preventive maintenance and repair work. Urgent situations may require more frequent shutdowns. Failure to regularly perform maintenance significantly increases the risk of unplanned disruption as well as the severity of the consequential failure.

Tier II: Redundant Capacity Components Site Infrastructure

The fundamental requirement(s):

- A Tier II data center has redundant capacity components and a single, non-redundant distribution path serving the computer equipment.

The performance confirmation test(s):

- Redundant capacity components can be removed from service on a planned basis without causing any of the computer equipment to be shut down.
- Removing distribution paths from service for maintenance or other activity requires the shutdown of computer equipment.
- An unplanned outage or failure of any capacity system or distribution element will impact the computer equipment. An unplanned capacity component failure may impact the computer equipment.

The operational impact(s):

- The site is susceptible to disruption from both planned activities and unplanned events. Operation errors or spontaneous failures of site infrastructure components may cause a data center disruption.
- The site infrastructure must be completely shut down on an annual basis to safely perform preventive maintenance and repair work. Urgent situations may require more frequent shutdowns. Failure to regularly perform maintenance significantly increases the risk of unplanned disruption as well as the severity of the consequential failure.

The capital costs required for the system redundancies defined by the higher tiers of both classification systems is likely beyond the resources or requirements of companies employing SEDCs. Given the mission critical nature of SEDCs, we expect some level of IT system redundancy. Ascertaining the level of redundancy will allow us to determine how disruptive our monitoring efforts may be on IT services at specific SEDC sites. However, defining specific tier classification for SEDCs is beyond the scope of what is needed for this project.

A few additional definitions provided in the white paper are relevant to SEDCs. These are:

Private – This is a use category where the data center services are not openly accessible by the general public. Services may be restricted to staff or securely allowed clients. Private data centers may manage some publicly available content.

Embedded – This is a physical category where a data center is contained or enclosed within a multipurpose building. The facility is not exclusively dedicated to support the data center. Power management, HVAC functions, physical security, and personnel amenities are shared with multiple building tenants or business functions.

Integrated Business Unit (IBU) – This is an organizational category where the data center is a support function of the primary business. This class of data center is wholly controlled and operated by the organization that owns it for the purpose of providing an internally maintained business service. These data centers are dedicated to serving the parent company exclusively.

For the purposes of this project, SEDCs will be defined as *private, embedded, integrated business server rooms and server closets with some level of redundancy for mission critical workloads.*

Findings

Barriers. MnTAP points out that the issue for data center energy efficiency is not that technical solutions aren't available; it is that the lacks of awareness, education, and management priorities hinder adoption of these practices and solutions. With regard to SEDCs, MnTAP found three major barriers to improving data center efficiency:

1. Without monitoring through submetering, decision makers and managers are unaware of the power demands of their data center and the SEDC's energy use (and the associated costs) with respect to the entire enterprise. Since some data centers may need to be taken offline in order to install monitoring equipment, and that involves risks and hassles that may impact the productivity and reliability of the data center.
2. Because of split incentives, IT managers and financial officers make business decisions independently of, and perhaps against, each other with regard to cost and energy use decisions for the company. The IT manager's priority is to deliver 24/7 reliability and high computational performance. The financial officer looks at the bottom line and high return on investment.
3. A general resistance to change or inertia within the organization is often at odds with the continuous improvement approach needed to achieve SEDC energy efficiency improvements. If business operations are moving smoothly the attitude is often, "why fix what's not broken?" Changes in the form of new approaches and technologies mean an increase in the level of complexity and the need for more training and education, and MnTAP observed that "fear of change, loss of control, and loss of reliability" are seen as major issues.

Energy Conservation Opportunities (ECOs). MnTAP has defined five categories of ECOs: Environmental, Electronic, Electrical, Educational, and Elimination, which they denote as the five "E's" and describe as:

- Environmental includes airflow, temperature, and humidity.
- Electrical is the infrastructure that provides power and lighting.
- Electronic includes consolidation, virtualization, and energy efficient equipment.
- Education is informing clients how they can contribute to a data center's efficiency.
- Elimination is migrating data center operations to an external service provider.

MnTAP notes that while environmental ECOs typically have the largest impact on improving data center energy efficiency, SEDCs generally do not have the heat density needed for dedicated cooling equipment. In these cases, cooling will come from the conditioned air of the entire space and from fans used to circulate air or exhaust heat from the server closet/room. In their report, MnTAP created a matrix of ECOs vs. data center types. Table 20 shows their findings on opportunities for server rooms and closets:

Table 20. Energy Conservation Opportunities (ECOs) for Server Rooms and Closets

ECO Type	ECO	Server Rooms/ Closets
Elimination	Out source	X
Electronic	Cabling	-
	Virtualize	-
	Consolidation	X
	High-Efficiency Servers	X
Environmental	High-Efficiency Cooling Equipment	-
	Hot/Cold aisles	-
	Space heating	-
Electrical	Efficient Power System	-
	High-Efficiency Lighting System	X
Education	Tenant Education	X

For a more specific list of ECOs, Lawrence Berkeley National Lab (LBNL) published a fact sheet that lists the top 14 measures for improving the energy efficiency for server rooms and closets.[58] We categorized these according to MnTAP's five "E's:"[59]

1. Environmental ECOs
    a. Increase temperature setpoints to the high end of ASHRAE's recommended limit.[a]

        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) and considerably reducing cooling energy usage.

    b. Install blanking panels and block holes between servers in racks for better air management.[a]

        Airflow management is conceptually simple and surprisingly easy to implement. The challenge is ensuring that the cool air from the cooling equipment gets to the inlet of the IT gear without getting mixed with the hot air coming from the back, and also ensuring that hot air going back to the cooling equipment does not mix with the cold air. This can be done by clearing clutter from the airflow path, blanking within and between the racks and the openings in the floor if the gear sits on a raised floor. Containment of cold or hot aisles is a more effective approach. When good airflow management is in place further savings can be realized through additional measures, such as raising temperature setpoints.

    c. Install variable frequency drives on cooling units.[c]

        If your server room is cooled with a Computer-Room Air Handler (CRAH) or Computer-Room Air Conditioner (CRAC) unit, it is highly likely that the unit has a single-speed fan, meaning that it is likely providing more airflow than your IT equipment needs. Units with variable frequency drives (VFDs) are capable of providing only the amount of air that is required by the IT equipment. To maximize potential energy savings, coordinate the implementation of airflow management measures and airflow isolation systems with the installation of a VFD on the cooling unit fan. See the fourth item on the list for air management suggestions. Ideally the fan speed should be dynamically controlled to maintain IT inlet temperature within the recommended range.

    d. Install rack- and row-level cooling.[c]

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[58] Mark Bramfitt, Rich Brown, Hoi Ying (Iris) Cheung, Pierre Delforge, Joyce Dickerson, Steve Greenberg, Rod Mahdavi, and William Tschudi. October 2012. "Improving Energy Efficiency for Server Rooms and Closets." Lawrence Berkeley National Laboratory.

[59] The LBNL fact sheet categorizes the measures as: a. Simplest, No-Cost, Or Very-Low-Cost Measures, b. A Little More Work But Still Fairly Simple, and c. High Investment, But Very Cost Effective. The category for each measure listed is denoted by the a, b, or c superscript appended after the measure title.

If you are installing a new server room or buying new racks consider local cooling. In-rack and in-row cooling refer 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. 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 provided by the internal server fans.

e. Use air-side economizers.[c]

An economizer simply draws in outside air for cooling when conditions are suitable. For a server closet with exterior walls or roof, there is a good possibility that an air-side economizer could be installed. It could be in the form of an exhaust fan removing heat in one portion of the room with an opening in another location allowing cool, outside air to enter. It could also 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 compressor cooling energy use.

f. Install dedicated cooling for the room, rather than depending on building cooling[c].

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.

2. Electrical ECOs

a. Examine power backup requirements and determine if *Uninterruptible Power Supply (UPS)* equipment is really needed and, if so, how much is enough.[a]

Many IT applications are not so critical that they cannot 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 UPS equipment. It can also help you save energy lost in power conversion as well as energy to cool these devices. Anything that needs high reliability should be a candidate for moving to a true data center or cloud solution.

3. Electronic ECOs

a. Determine computational functions/Turn off any unused servers.[a]

An Uptime Institute survey suggests that close to 30% of servers in data centers are consuming power and not actually doing any useful work. 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 run helps identify unused servers and opportunities for consolidation. Make sure to migrate any remaining data or workloads before shutting down.

b. Refresh the oldest equipment with high-efficiency models.[b]

Establish server refresh policies that account for increases in generation-on-generation computational ability, energy-efficiency, and power manageability improvements. Savings in energy and software costs will often justify a faster refresh than expected. Consider Energy Star, Climate Savers Computing Initiative Server Catalog (see urls on back page), high-temperature tolerant servers, and high-efficiency power supplies (80 PLUS). When purchasing new equipment, servers with solid-state drives (SSD), rather than hard disk drives, should be considered, as they feature faster speeds, consume less power, and are generally considered to be more reliable.

c. Implement server power management.[c]

Check for power management options that come with your server models and enable power management if possible. Power management saves energy, especially for applications that do not run continuously or are accessed infrequently. Power cycling can also be implemented to put servers that are unused for long periods of time in a light sleep mode. Lastly, consider built-in or add-in cards that enable servers to be powered on or off remotely when they are not in use.

d. Consolidate and virtualize applications.[c]

Typical servers in server rooms and closets run at very low utilization levels (5-15% on average), while drawing 60-90% of their peak power. Consolidating multiple applications on a smaller number of servers accomplishes the same amount of computational work with the same level of performance and 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. By increasing server utilization, this reduces both the number of servers required to run a given number of applications and overall energy use.

4. Education ECOs

a. Energy efficiency awareness training for IT custodial and facility staff.[b]

Have your IT and facilities staff attend server room energy efficiency awareness classes, offered by utility companies, ASHRAE, or other efficiency advocates, to take full advantage of best practices in that area.

b. Implement infrastructure power monitoring.[c]

Power monitoring identifies the energy use and efficiencies of the various components in an electrical distribution system. Power meters can be installed either at the panels serving the cooling units or directly on the IT and HVAC equipment. Another alternative is to read IT power from the UPS display and estimate cooling power from the nameplate, taking into account unit efficiency and operating hours. Often power distribution products will have built-in monitoring capability. A key metric is the Power Usage Effectiveness (PUE), which is the ratio of total power to IT input power (with the "overhead" being electrical distribution losses plus cooling power usage). Monitor and *strive to lower your PUE; a PUE over 2 shows significant room for improvement,1.5 is good, and 1.1 is excellent.*

5. Elimination ECOs
    a. Move to a more energy efficient internal or external data center space, or to cloud solutions.[b]

    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 to that location. When a data center is not available, many organizations are moving their equipment to co-location or cloud facilities (public or private cloud facilities both typically provide much better efficiencies than on-premise server rooms). Data centers, colocation, and cloud facilities typically also offer better security, redundancy, and efficiency than is usually available in server rooms.

Benchmarking. Tools and metrics exist to allow IT managers to compare the energy performance of their datacenters to accepted standards. For data center electrical use, the Green Grid's Power Usage Effectiveness (PUE) has become the industry standard metric for measuring infrastructure efficiency for data centers.[60] For a dedicated building, it is a dimensionless number defined as "the total facility energy divided by the IT equipment energy." The ideal theoretical limit is 1.0, which means that all the power going into the data center is used for IT. A typical PUE is about 2, with good values around 1.5.

The problem with SEDCs in mixed-use buildings is that the data center shares systems with other uses in the building, such as lighting, HVAC, security, and electrical distribution. Consequently, calculating the PUE for an SEDC can be problematic as the energy required to operate the data center cannot easily be determined. For cases like this, the Green Grid has defined another metric called the partial PUE (pPUE), where the pPUE is calculated for the equipment where power and energy use can be measured. The problem with using this metric is that the pPUE may be defined differently for each SEDC depending on what and where it can easily be measured. Without the ability to compare pPUEs between different sites the use of the PUE as a benchmarking metric for SEDCs is significantly hampered. Since ECOs for SEDCs will likely deal specifically with the IT equipment energy, an SEDC benchmarking metric based on IT equipment energy alone might be more useful in comparing SEDCs.

Of the benchmarking tools reviewed by MnTAP, ISO 50001[61] and vendor specific tools like the IBM Data Center Operational Efficiency Self-Assessment online tool[62] were identified as being useful for SEDCs. ISO 50001 is an energy management standard based on a process of

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[60] Victor Avelar, Dan Azevedo, and Alan French, editors, PUE™: A Comprehensive Examination of the Metric, The Green Grid, 2012.

[61] International Organization for Standardization. "ISO 50001 - Energy Management." iso.org. http://www.iso.org/iso/home/standards/management-standards/iso50001.htm (retrieved May 5, 2017)

[62] IBM, "Data Center Operational Efficiency Self-Assessment." ibm.com. http://www-935.ibm.com/services/us/igs/data-center/assessment.html (retrieved May 5, 2017)

continuous improvement. DOE has an online toolkit to assist an organization in the implementation process.[63] MnTAP suggests the ISO 50001 will be useful for SEDCs "as a starting point to indicate direction for energy efficiency effort." The IBM self-assessment is an online tool that leads the user through six pages of survey questions in order to rank the data center. It defines four stages that can be used to characterize a data center based on efficiency, availability, and flexibility. These are:

1. Basic: The environment is relatively stable and is maintained based on short-term objectives, with standalone infrastructure as the norm. Companies at this stage have the advantages of server consolidation, but have not implemented availability levels, which vary widely from application to application and site to site.
2. Consolidated: Server virtualization and site consolidation are used to take out sizable numbers of systems and facilities and thereby lower capital costs. At this level, server and storage technologies are well utilized and possibilities for improving availability through virtual machine (VM) mobility are beginning to be realized.
3. Available: IT infrastructure is treated as a general resource "pool" that can be allocated and scaled freely to meet the changing demands of workloads, and to ensure uptime and performance while providing high rates of utilization. The focus at this stage is on measuring and improving service levels while building out governance procedures that capture business requirements.
4. Strategic: Widespread adoption of policy-based information tools lowers the manual complexity of the data center and ensures availability requirements and dynamic movement of applications and data. At this stage instrumentation and metrics are constantly used to validate compliance with governance policies.

MnTAP believes that the IBM tool would be both relevant and useful to SEDCs as a benchmarking tool. There are also other benchmarking tools available that could be tested for SEDCs and could help in creating social norms to help convince IT managers and financial officers to take action towards reducing energy use of SEDCs. It is important to keep in mind that at a minimum, when utilizing benchmarking tools, baseline energy use and server utilization need to be monitored in order to determine the need and return on investment for possible energy efficiency measures.

Utility incentives. Utility programs in the form of rebates can incentivize organizations that employ SEDCs to implement ECOs. MnTAP has created a table showing data center efficiency incentives for select Minnesota utilities. Table 21 is reproduced below:

Table 21. Select Minnesota Utilities Data Center Efficiency Incentives

Utility	Service Territory	Data Center Incentives Offered
Austin Utilities	City of Austin	Prescriptive rebates on cooling equipment, servers, and clients.

[63] U.S. DOE. "Introduction to eGuide Level 2 for ISO 50001." energy.gov https://ecenter.ee.doe.gov/_layouts/ecenter/ppc.eguide/home.aspx (retrieved May 5, 2017)

Dakota Electric Association	Dakota county	Low interest energy efficiency loans, rebates on cooling equipment, audits, consulting and monitoring.
Minnesota Power	Northeastern Minnesota	Offer standard rebates, performance rebates, etc.
Otter Tail Power Co	Western Minnesota	Grants available for conservation and efficiency improvements based on demand and kwh saved.
Owatonna Public Utilities	Owatonna area	Prescriptive rebates on cooling equipment, servers, and clients.
Rochester Public Utilities	City of Rochester	Prescriptive rebates on cooling equipment, servers, and clients.
Xcel Energy	St. Paul/Minneapolis and suburbs	Specific Data Center Efficiency rebate program involving an energy study, cost estimates of energy saving measures, and rebate information. Study rebates up to 75% or $25,000, and rebates of up to 75% or $25,000, and rebates of $400 per kW saved in preapproved projects.

With regard to implementation, MnTAP found that utilities often rely on "vendors and consultants to work with the client to develop and implement energy efficient technologies and procedures. The utility only becomes involved at the beginning to approve proposed work and when it comes time to evaluate the project for rebate purposes."

White Paper Conclusions With respect to the objectives of the white paper, MnTAP found the following answers to the questions they posed:

- How aware are data center managers of the available energy efficiency opportunities? *Overall it was observed that data center staff members have an understanding of energy conservation opportunities at their facilities.*
- How much energy do data centers located in Minnesota consume? *Many data center managers do not measure their power consumption and do not know how efficient they are. Any ECOs available to a center may not be considered because there is no measured baseline energy use from which to calculate a rate of return to justify a specific investment. Based on site visits completed for this grant, the measurement of electrical consumption of data centers in general is lacking. Managers do not know the data center's PUEs at any level. In addition, data center managers view the installation of monitor control systems (MCSs) as a major inconvenience,*

since their operation may be off-line during the installation. Measuring efficiency and/or improving it takes a back seat to reliability. Therefore, managers must be convinced that the energy efficiency benefits associated with MCS installation outweighs the perceived risk or hassle of the installation itself.

- Do data center managers realize the impact improving the efficiency of their data center could have on their organization's budget? *At best, [IT managers] make broad statements about the percentage they think the data centers use compared to the entire building, but they do not know how much the entire building uses. Some have implemented specific energy efficient technologies and methods, but they do not know how much energy or money they saved, if any.*
- Are Minnesota utilities fully aware of data center operations and energy consumption across the state and in their territories? *For electric utilities, the data center sector is part of their overall commercial building CIPs.*
- Do CIP program managers have relevant information on options for improving the energy efficiency of data centers? *There is little focus on the unique energy conservation needs of data centers relative to a typical commercial building*
- Will a focus on improving the energy efficiency in Minnesota data centers contribute significantly to utilities meeting their State energy savings goals? *A more targeted focus may be justified to demonstrate the opportunity for state energy conservation available through data center energy management.*

And finally MnTAP drew these conclusions:

- Minnesota data center staff are aware of the energy efficiency options available; however, it is still unknown how much power Minnesota data centers demand or consume.
- Many Minnesota data center managers do not know the impact implementing ECOs will have on their organizations' bottom line.
- Minnesota electrical utilities may have limited awareness of the data center operations in their area even though data center ECOs can have an impact on facility energy efficiency.

NRDC Server Room Reports

In 2012 NRDC published two reports on server rooms. One reported the results of a survey of IT managers of server rooms with between 1 to 100 servers and the other reported on utility energy efficiency program design.

Small Server Rooms, Big Energy Savings by Drew Bennett and Pierre Delforge[64] – NRDC survey results are a good supplement to the MnTAP whitepaper as server rooms and closets were not well-represented in MnTAP's Minnesota Data Center Profile. Although, half of the 12 site visits

[64] Drew Bennett and Pierre Delforge, Small Server Rooms, Big Energy Savings: Opportunities and Barriers to Energy Efficiency on the Small Server Room Market, NRDC Issue Paper, February 2012, http://www.nrdc.org/energy/files/Saving-Energy-Server-Rooms-IssuePaper.pdf

that MnTAP performed for that profile were data closets or server rooms. The NRDC survey contained more information, including 30 survey responses from a wide range of businesses and organizations including "consulting, law, telecommunications, online advertising, public radio, biopharmaceutical, architecture, local government, religious organizations, non-profits, education, and many others." Of the respondents, the number of employees on site ranged from 3 to 750 and the number of servers ranged from 1 to 55. The survey focused on virtualization and cloud computing since those two strategies would likely provide server rooms with the greatest and most cost-effective energy savings. An EPA report to Congress in 2007[65] found that the average server in the U.S. operates at 5 to 15 percent utilization, suggesting an excellent opportunity for server consolidation and virtualization and/or cloud computing.

NRDC learned the following lessons:

1. There was a wide variation in ownership configurations with 13 percent of the respondents not owning servers and using cloud computing services, 20 percent having at least one server in the cloud, and 23 percent either renting servers off-site or hosted at a co-location.
2. Only 37% of small organizations surveyed by NRDC had virtualized at least one server and only 26% of all server stock of small and medium businesses (SMBs) had been virtualized. Only 23% of the small companies planned to increase their virtualization in the next 12 months.
3. Lack of information and misaligned incentives are the primary barrier to adoption of virtualization. The survey revealed that 54% of the organizations do not pay their utility bill based on kWh (e.g. the rent includes a fixed fee for utilities). For 58% of the organizations the IT managers did not have regular access to energy use data, and 93% of the organizations did not have ready access to the data center energy use.
4. Half of the small businesses surveyed said that they planned to upgrade their server room within the next year, indicating that opportunity for adopting ECOs exists in these small organizations.

These lessons mirror the findings and conclusions of the MnTAP whitepaper.

In addition to lack of information and misaligned incentives, NRDC noted the following barriers to adoption of cloud computing and virtualization:

- Energy savings was lower on the list of business priorities and the benefits were not great enough to overcome the corporate inertia;
- Privacy and data security was a barrier with company restrictions in place to prevent cloud computing or virtualization;

[65] U.S. EPA ENERGY STAR Program, Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431, August 2, 2007, http://www.energystar.gov/ia/partners/prod_development/downloads/EPA_Datacenter_Report_Congress_Final1.pdf

- Software and hardware costs are a greater priority to IT managers than energy costs; and
- Technology is not a barrier.

NRDC provided the following policy recommendations:

- Communication and education should be used to promote the use of cloud services, especially dealing with the issues of logistics, benefits, and data security.
- Increased marketing and outreach, along with training and education of IT managers and service providers, will abet the use of virtualization.
- Incentives such as rebates coupled with highlighting other benefits besides energy savings can overcome the issue of split incentives. Demand aggregation can also make small server rooms an attractive market for manufacturers and service providers.
- Timely marketing during the periods when new investments in technology occur will lead server room managers to greater adoption. Incentives to IT resellers and service providers can provide the leverage point to monitor those windows of opportunity.

Utility Energy Efficiency Program Design: Server Room Assessments and Retrofit by Mark Bramfitt and Pierre Delforge[66] – This NRDC study developed a set of recommendations for utility programs and services to target the server room market. The study lists the following as the ECOs that are most cost-effective:

- Server virtualization and consolidation (optimizing server utilization);
- ENERGY STAR servers (purchasing highly efficient equipment);
- Equipment refresh (replacing equipment that is over five years old with more efficient servers and refreshing with updated equipment every two years after);
- Server power management (varying power settings as needed);
- Use of centralized or cloud services (increasing server utilization and the use of more efficient equipment and infrastructure);
- Cooling (using more efficient HVAC equipment and airflow management, which may actually be less applicable for small server rooms and closets); and
- Power conditioning (using high efficiency UPSs and maximized loading, both of which are limited for server rooms)

This report suggests three components that should be included in a utility program targeted for server rooms:

- Education Materials and Evaluation Tools – Provide web-based marketing and outreach materials with an online energy savings calculation tool and enlist the vendor community to assist in outreach.
- On-Site Evaluations – Partner with IT service providers who can assess opportunities on site and help recruit for the program.

[66] Mark Bramfitt, P.E., and Pierre Delforge, Utility Energy Efficiency Program Design: Server Room Assessments and Retrofit, NRDC, April 11, 2012. http://docs.nrdc.org/energy/files/ene_12041101a.pdf

- Prescriptive Incentive Programs – Establish an incentive program targeted at server rooms that includes the participation of qualified IT service firms.

NRDC has developed a template for creating this program (Table 22):

Table 22. Program Design and Delivery Checklist

Activity	Planning	Launch	Delivery
Prepare work papers for server virtualization and consolidation and premium efficiency server rebate measures and submit to regulators for approval	❑		
Meet with program evaluators to review design and implementation plan	❑		
Identify potential vendor partners	❑		
Prepare education and marketing materials	❑		
Post marketing and education materials and evaluation tools to web site		❑	
Hold internal stakeholder (account representatives, program managers, etc.) training event		❑	
Hold vendor training event		❑	
Hold customer events (or integrate into other outreach activities)		❑	❑
Participate in vendor-sponsored outreach activities			❑
Monitor program results			❑

The elements of a prescriptive rebate program for virtualization and consolidation could follow these recommendations (Table 23):

Table 23. Essential Elements of a Prescriptive Rebate Program Design

Measure Name	Small-scale server virtualization and consolidation
Measure Description	Installation of software allowing consolidation of IT workloads on fewer physical servers, and removal of unneeded servers
Program Applicability	May be limited by project size or by customer class

Base Case Description	Servers dedicated to single IT workloads, typically at utilization rates below 10% become more energy efficient when servers are virtualized and consolidated.
Base Case Energy Consumption	On average, "volume" servers (single or dual-core machines manufactured three to six years ago) draw 225 Watts with little or no power management based on IT workload variability, resulting in annual consumption of about 1,970 kWh. If a new replacement server is purchased, both demand and energy use would be lower, as the latest generation servers draw only about 125 to 150 Watts on average, corresponding to annual consumption of 1,100 to 1,300 kWh.
Energy Savings	Demand: 0.125-0.225 kW per server removed (net) Energy: 1100-1970 kWh/yr per server removed (net)
Base Case Equipment Cost	Not Applicable
Measure Cost	Approximately $2000 per server removed, including software license and services, and assuming new servers
Measure Incremental Cost	Same as above
Effective Useful Life	5 years (could be higher)
Net To Gross Ratio	0.8

Cadmus Group: Pacific Gas and Electric Company Small Data Center Market Study

In 2013 the Cadmus Group performed a market study for Pacific Gas and Electric (PG&E) on small data centers (SDCs) in which they surveyed over 320 PG&E small and medium business (SMB) customers and performed in-depth interviews with select IT vendors and SDC managers.[67,68]

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[67] Allison Bard, Robert Huang, Mark Bramfitt, Kerstin Rock, and Michelle Lichtenfels, Pacific Gas and Electric Company Small Data Center Market Study, The Cadmus Group, Inc., December 27, 2013. http://www.calmac.org/publications/FINAL_REPORT_PGE_Small_Data_Center_Study.pdf

[68] Allison Bard, Robert Huang, Rafael Friedmann, "From Our Closet to Yours: Fashioning Energy Efficiency Programs for Small Data Centers," Proceedings, 2014 ACEEE Summer Study on Energy Efficiency in Buildings, paper 6-232, August 2014.

Classifications

Based on interviews, the Cadmus report classified server closets as SDCs of less than 200 square feet floor area with one server rack and classified server rooms as SDCs with floor area of 200 to 500 square feet with three server racks. A typical server had two processors and six cores. Most of the SDCs (over half surveyed) were found to be server closets.

Major segments with SDCs

From vendor interviews and the SDC manager survey, Cadmus found that SDCs were most often present in the following segments:

- government,
- schools,
- healthcare,
- financial services,
- professional services,
- manufacturing, and
- high tech and biotech.

Interestingly, the vendors saw little difference in the energy efficiency opportunities between SDCs in satellite offices of large organizations and stand-alone SMBs. Their interviews also revealed the major reasons that SDCs were kept on-site:

- inertia,
- security requirements (e.g., Sarbanes-Oxley, HIPPA),
- reliability (not dependent solely on connectivity), and
- better speed/performance.

Barriers

The primary barriers that Cadmus cited are:

- Energy efficiency is not a priority for SDC managers and is typically not part of the decision-making process. The top priorities are uptime, limiting costs, and data security.
- SDC managers and IT vendors are typically unable to even estimate their IT load, even though they knew the number of servers in their SDC (median = three).
- Resource constraints, upfront costs, and aversion to risk are other commonly cited barriers.

ECOs

The energy efficiency measures most often implemented in SDCs were IT measures. Most SDCs are not connected to HVAC controls, so HVAC ECOs happened less frequently. The most often implemented IT ECOs were reported to be: installation of energy efficient servers and UPSs, unused servers decommissioning, data storage management, and server utilization. More than half of the SDCs surveyed used some virtualization and nearly half were virtual servers.

Both IT vendors and SDC managers listed server virtualization, data storage management, and migration to the cloud as the best energy efficiency opportunities. Opportunity for cloud migration is limited as they lack some of the need that on-site SDCs provide in security, bandwidth, and control.

Decision-making

Cadmus found that vendors were an important part of the decision-making process as they provide a source of information, recommendations, and quotes. The final approval of the products and system lies with the internal IT manager, IT director, or the VP and the CFO or CEO approval of the final budget.

Recommendations to Utilities

Cadmus developed the following recommendations for utilities in dealing with SDCs:

- Programs should focus on IT systems rather than HVAC systems.
- Targeted incentive programs should be made available to alleviate high upfront costs and lack of funding for ECOs.
- Prescriptive incentives should be used to promote the implementation of ENERGY STAR UPSs, storage, and servers.
- A targeted server virtualization program to customer groups that are unlikely to implement server virtualization on their own should be provided through education, services, and incentives.
- Incentives should be provided for cloud migration or co-location.
- IT vendors, OEMs, and value-added resellers should be used to effectively reach SDC managers.
- Pilot projects should be considered that deal with the following:
    - different outreach approached to reach SDC managers
    - testing specific ECOs,
    - alternative program designs, and
    - SDC metering to quantify energy savings.

LBNL Report: Energy Efficiency in Small Server Rooms

Lawrence Berkeley National Laboratory performed a California Energy Commission (CEC) Public Interest Energy Research (PIER) Program-funded project looking at the energy efficiency issues of small server rooms, with the final report was published in the Spring of 2013.[69,70] This

[69] H.Y. Iris Cheung, Steve E. Greenberg, Roozbeh Mahdavi, Richard Brown, and William Tschudi. (Lawrence Berkeley National Laboratory, 2013. Energy Efficiency in Small Server Rooms. California Energy Commission. Publication number: CEC-XXX-2013-XXX.

[70] Iris (Hoi Ying) Cheung, Steve Greenberg, Roozbeh Mahdavi, Richard Brown, and William Tschudi, "Energy Efficiency in Small Server Rooms: Field Survey and Findings," Proceedings, 2014 ACEEE Summer Study on Energy Efficiency in Buildings, paper 9-109, August 2014.

project also produced the fact sheet cited above[71] and its longer version.[72] For this project, 30 small server rooms across eight different institutions were surveyed. A 30-minute walkthrough assessment was developed and conducted at each site. A walkthrough assessment protocol and tool was developed to document the server room, management, IT equipment, and HVAC equipment. A more detailed study of four of these sites was also performed.

Findings

The following observations were made based on the surveys and assessments:

- Most rooms that house SDCs were typically not intended for that purpose (particularly for cooling) and so are less than optimal for energy efficiency considerations.
- SDC energy costs are not paid by the larger organization and therefore the SDC is not be submetered, meaning that little to no feedback is provided to IT managers on SDC energy use or costs and there is little incentive for energy efficiency.
- Business operations, as opposed to energy efficiency, are the priority of IT managers.
- For IT ECOs,
  - Limited IT budgets and a lack of regular hardware updates means that IT equipment often is older and less energy efficient;
  - Server utilization is often low and is not often tracked, providing a good opportunity for server consolidation and virtualization; and
  - Colocation and cloud migration are obvious energy efficiency opportunities, but IT managers often prefer to keep servers in close proximity for possible power outages and data security considerations.
- For HVAC ECOs, when the SDC is separately zoned or has a dedicated computer room air conditioner (CRAC) or computer room air handler (CRAH),
  - Small server room set point temperatures are often lower than needed and this overcooling is a good opportunity for savings;
  - SDCs often do not have hot/cold air separation that can reduce cooling requirements; and
  - Scheduling and use of economizers can reduce SDC HVAC energy use.

In this study PUEs were calculated for the four sites studied in the detailed assessments. Because of site constraints, estimates were made when specific loads could not be measured. This reinforces the issue that PUE may not be a good benchmarking metric for SEDCs.

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[71] Mark Bramfitt, P.E., and Pierre Delforge, Utility Energy Efficiency Program Design: Server Room Assessments and Retrofit, NRDC, April 11, 2012. http://docs.nrdc.org/energy/files/ene_12041101a.pdf (retrieved April 28, 2017)

[72] Hoi Ying (Iris) Cheung, Rod Mahdavi, Steve Greenberg, Rich Brown, William Tschudi, Pierre Delforge, and Joyce Dickerson, "Fact Sheet: Improving Energy Efficiency for Server Rooms and Closets." Lawrence Berkeley National Laboratory, LBNL-5935E, September 2012.

Most of the barriers observed by the Lawrence Berkeley National Lab researchers were the result of organizational disincentives, rather that the result of technical reasons. Utility incentive and educational programs could be effective in overcoming these barriers. Furthermore, a lack of information prevented the adoption of some obvious ECOs. Measuring server power draw and utilization would help assess needs and opportunities.

Observations

Based on these papers, we come away with the following takeaways:

- The Cadmus and NRDC reports affirm our proposed segment approach using IT vendors to engage SEDC managers. The creative industry, small manufacturing, and small commercial segments we are targeting are among the major segments identified by the Cadmus Group as employing SEDCs. Comparing and contrasting with the other major segments in our region (such as healthcare, government, schools, and financial services) could help us determine the wider applicability of the approach we are demonstrating. A survey of these other segments might help identify other important leverage points that could facilitate wider participation in future programs. The vendor and IT manager survey instruments created by the Cadmus Group could serve as a good model for our instrument tool and allow us to collect data that would augment the Cadmus Group data, as well as allow us to compare our region to the population of their California-based study.
- Since IT managers have little awareness of their power draw/energy use and server utilization, we need to develop a protocol that allows us to measure and document these aspects of SEDCS while guaranteeing little to no impact on SEDC operations and reliability. The Packet Power jumper cable looks to be a good solution for the monitoring power draw and energy use both pre- and post-measure. Software tools for monitoring server utilization need to be identified and vetted for use in the project.
- It is likely that most of the measures implemented will be IT ECOs such as:
    - server consolidation,
    - server virtualization,
    - equipment replacement with ENERGY STAR UPSs and servers,
    - data storage management,
    - migration to the cloud, and
    - colocation.

  Data from the Packet Power jumper cables will allow us to assess energy savings. To do this effectively, the monitoring protocol will need to be established so that we will be able to assess the energy savings obtained from the various IT ECOs that are implemented.
- HVAC ECOs will be implemented as needed, with scheduling and setpoint temperature adjustment as the main low-cost items considered. Other opportunities will be implemented depending on cost and willingness of the business, and submetering of HVAC equipment will need to be performed for these cases.

- A benchmarking metric for SEDCs needs to be developed. PUE does not appear to be a good fit for SEDCs. The IBM self-assessment tool may provide an adequate qualitative measure and might be used for the interview process with IT managers. The Lawrence Berkeley National Lab assessment tool will be used for the SEDC on-site audit. We may need to augment it with additional information to help us characterize each site. The goal will be to develop a protocol to assess potential and opportunity and to account for actual savings.

- Because of the issue of split incentives, energy costs and savings likely are not determining factors for IT managers to take action. Some framing and messaging may be needed to persuade IT managers and financial officers to adopt ECOs (e.g. environmental messaging). The messaging will also develop as we monitor more sites and get data that we can use regarding SEDC energy use and costs. Working with the Foundation to give them the tools and information necessary to encourage participation will help us develop a program delivery plan. We will need to work with utilities to create rebates and incentives that will reduce both the initial costs and capital costs for SEDCs. A prescriptive incentive program appears to be a likely strategy for SEDC customers, and NRDC supplies a good template for this type of program.

Appendix B: Electronic Survey Questions

MINNESOTA DEPARTMENT OF COMMERCE

cee Center for Energy and Environment

MN Business Survey - Data Centers

With support from the Minnesota Department of Commerce through a Conservation Applied Research and Development (CARD) grant, the Center for Energy and Environment is conducting research to better understand Minnesota businesses use of data centers. We hope you are able to give us 5 minutes of your time to complete this survey, which will help support the promotion of a utility based data center efficiency program in Minnesota. Randomly selected survey participants will be offered a free on-site assessment.

All individual responses will be kept confidential with survey results reported in aggregated form only. Please respond by May 31st, 2015.

If you are not the appropriate contact, please forward this survey link to your Systems Administrator, IT Manager or Network Engineer.

Thank you in advance for providing this important information. If you have questions or comments about this survey, please contact Lester Shen, Center for Energy and Environment at lshen@mncee.org

Center for Energy and Environment Team

1. Business Name/Address

Business Name

Street Address (current location)

City

Zip Code

Phone Number

2. Is the business located in Minnesota

- Yes
- No

Completed: 5%

MINNESOTA DEPARTMENT OF COMMERCE

cee Center for Energy and Environment

MN Business Survey - Data Centers

This survey is for businesses with locations in Minnesota only.

3. Contact Information

Full Name

Title/Role

Email Address

4. Industry Classification of Primary Activity

- Advertising/Marketing
- Financial Services
- Government
- Healthcare
- Manufacturing
- Schools
- Other

5. Estimate the number of employees in the organization?

Please select one ...

6. Building Location/Type at the above address

- Office Complex
- Satellite office of a larger company
- Stand Alone Business/Building
- Manufacturing Facility
- Other

DATA CENTER BACKGROUND GATHERING

7. A team will be performing free on-site energy assessments of data centers for a sample of survey participants. Would you like to be added as an interested business that may benefit from this activity?

- Yes
- No

8. Is your company responsible for paying for electricity and natural gas use at your location?

- Yes
- No
- Don't know

9. Does your organization take steps to lower utility bills through efficiency efforts?

- Yes
- No
- Don't know

Completed: 30%

MINNESOTA DEPARTMENT OF COMMERCE

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MN Business Survey - Data Centers

10. If yes, does IT play a role in these efforts of trying to lower utilty bills?

- Yes
- No

11. Do you have a data center on site?

- Yes
- No

Completed: 36%

MINNESOTA DEPARTMENT OF COMMERCE

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MN Business Survey - Data Centers

Survey complete. The survey was intended to collect information on businesses with on-site data centers.

12. How would you describe the size of your data center?

- Server Closet <200 sq ft
- Server Room < 1000 sq ft
- Localized Data Center < 5000 sq ft
- Mid-tier Data Center 5000-15000 sq ft
- Enterprise Data Center > 15000 sq ft

Completed: 41%

MINNESOTA DEPARTMENT OF COMMERCE

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MN Business Survey - Data Centers

Survey complete. The survey is intended to collect information on small to mid-sized data centers.

13. Does your data center serve one location or multiple business locations?

- One location only
- Multiple business locations in Minnesota
- Multiple business locations (not all in Minnesota)

14. How many servers does your location host? (based on address provided)

- 1-3
- 4-9
- 10-20
- +20

15. How many server racks are in your server room?

- 1
- 2-4
- 5-9
- 10+

16. What is the average age of your servers?

- Less than 1 year old
- 1 year old
- 2-3 years old
- 3-5 years old
- 5+ years old

17. Do you monitor power usage of your data center?

- Yes
- No

18. Do you monitor server utilization?

- Yes
- No

19. Have you shifted to virtualization in any of your IT activities?

- Yes
- No
- Don't know

Completed: 63%

MINNESOTA DEPARTMENT OF COMMERCE

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MN Business Survey - Data Centers

20. What has been the barrier to shifting to virtualization? (select all that apply)

- Cost
- Downtime
- Maintenance/Staffing
- Policy
- Privacy
- Security
- Capacity
- Not sure what virtualization is
- Other

21. Do you use any cloud services or cloud computing?

- Yes
- No
- Don't know

Completed: 69%

MINNESOTA DEPARTMENT OF COMMERCE

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MN Business Survey - Data Centers

22. What are the barriers to using cloud services or cloud computing? (select all that apply)

- Cost
- Downtime
- Maintenance/staffing required
- Policy
- Privacy
- Security
- Other

23. Who are your trusted sources of information for making IT decisions? (select all that apply)

- Distributor
- Manufacturer
- Utility
- Vendor
- Other

24. How often does energy efficiency factor into your IT decisions?

- Always
- Sometimes
- Never

Completed: 77%

MINNESOTA DEPARTMENT OF COMMERCE

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MN Business Survey - Data Centers

25. What are the barriers to pursuing energy efficiency technologies for your company? (select all that apply)

- ☐ Energy efficiency not a priority
- ☐ Focused on up-front costs, not long-term payback
- ☐ No benefit to IT, a facility benefit
- ☐ Resource constraint
- ☐ Risk: Focused on up-time/performance
- ☐ Other

26. When do you plan to make upgrades to your servers?

- ○ Next 6 months
- ○ 6 - 12 months
- ○ 12 - 18 months
- ○ 18 - 36 months
- ○ 36 months +

27. What is your motivation to make server upgrades? (select all that apply)

- ☐ Cost
- ☐ Speed
- ☐ Dependability
- ☐ Part of regular updates
- ☐ Other

28. Who do you purchase data center equipment from? (controls/monitoring, racks/infrastructure, IT equipment)

- ☐ Manufacturers
- ☐ Value-added resellers (VARs)
- ☐ Distributors
- ☐ Vendors
- ☐ Other

29. Do you rely on specific vendors, distributors, value-added resellers (VARs) or manufacturers? Please provide their names.

30. Are you aware of any rebates or incentives from your utility to purchase energy efficient equipment for your data center?

- ○ Yes
- ○ No

31. What is the maximum you would be willing to invest up front for long-term energy savings on your utility bill? (assuming a payback of 3 yrs)

- ○ Not willing to invest more
- ○ Up to 10% more
- ○ Up to 20% more
- ○ Up to 30% more
- ○ Up to 50% more
- ○ Other

32. Have you upgraded your data centers and received a rebate or incentive in the last 24 months?

- ○ Yes
- ○ No

Completed: 100%

Appendix C: Electronic Survey Results

Shannon Montgomery and Liza Minor, WECC

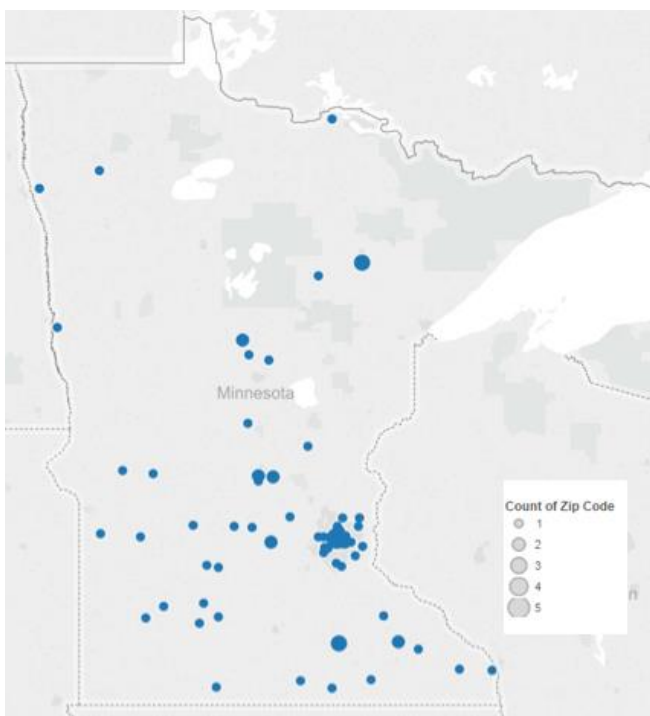
Lester Shen, CEE

Survey responses were solicited via email using lists from project partners (MnTAP, One Stop Efficiency Shop, and the Foundation) and help from organizations such as the B3 Benchmarking Program, Minnesota Council of Nonprofits, the Minnesota Department of Commerce Division of Energy Resources, the Minnesota Technical Reference Manual Advisory Committee, and the Minnesota Department of Employment and Economic Development.

A total of 134 responses were obtained representing a range of data center types from server closets with floor areas less than 200 ft^2 to enterprise data centers greater than 15,000 ft^2. For the SEDC project, we are only looking at data centers less than 1,000 ft^2. A total of 82 responses were obtained for this floor area category. 47of these were data closets less than 200 ft^2.

Responses came from all over the state. The map below shows the zip codes reported by each of the 82 SEDC respondents. Twenty nine responses came from the Twin Cities Metro area with the remaining 53 respondents located around the state.

Figure 72. Geographical Distribution of SEDC Survey Responses (By Zip Code)



Industry Classification

By industry classification, we got the following distribution:

Figure 73. Industry Classification

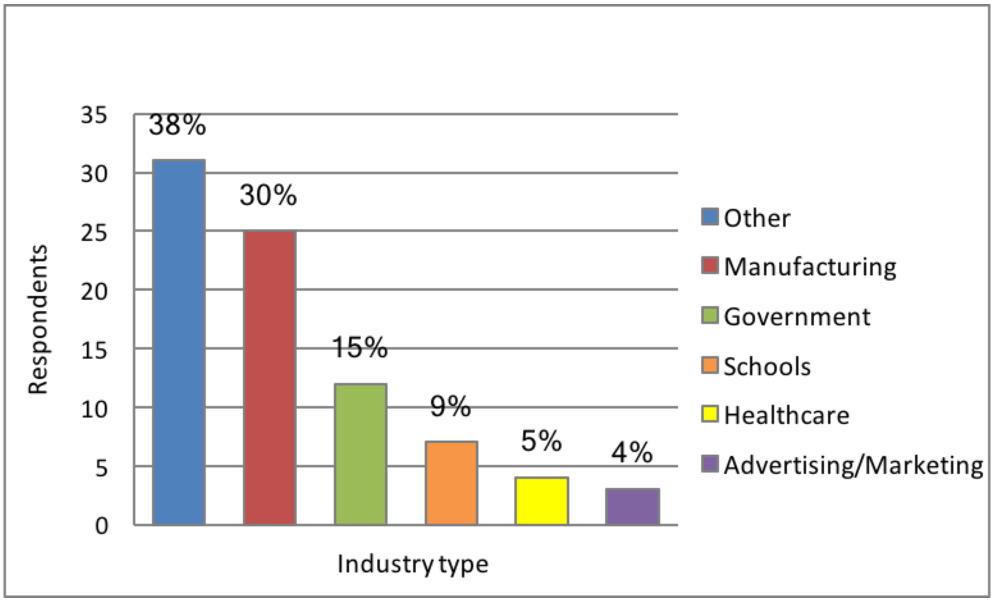


Figure 74. "Other" Industry Classification

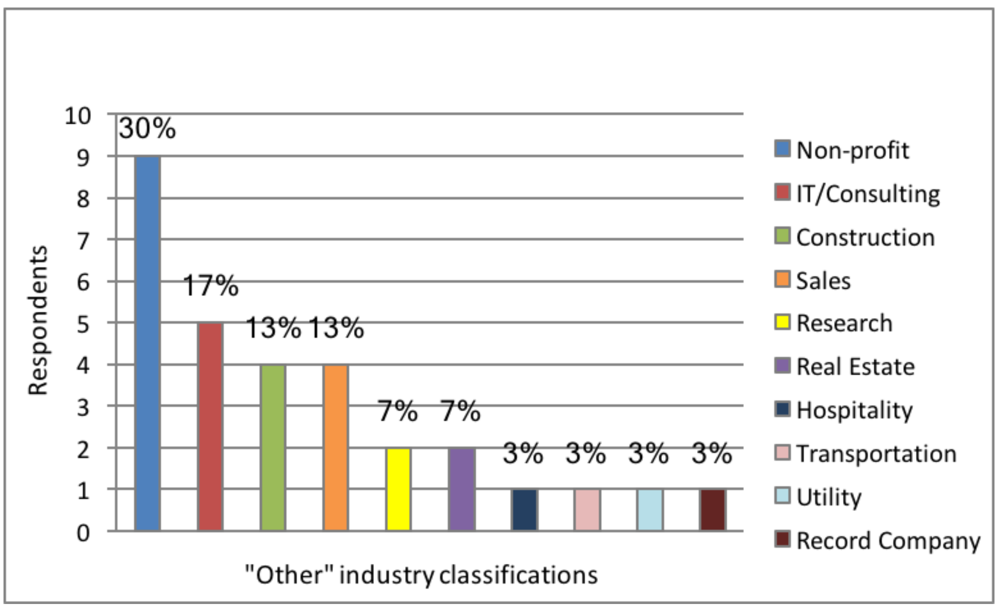


Table 24. Industry Classification

Industry Classification	Number of Respondents	Percent of Total
Other	31	38%
Manufacturing	25	30%
Government	12	15%
Schools	7	9%
Healthcare	4	5%
Advertising/Marketing	3	4%

Table 25. "Other" Industry Classification

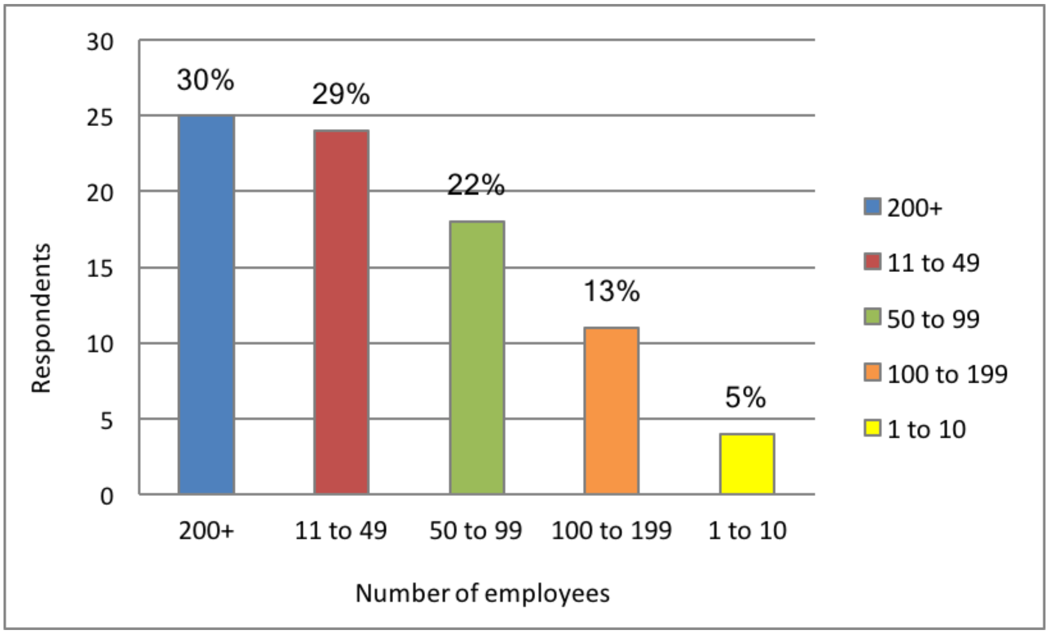
"Other" Industry Classification	Number of Respondents	Percent of Total
Non-profit	9	30%
IT/Consulting	5	17%
Construction	4	13%
Sales	4	13%
Research	2	7%
Real Estate	2	7%
Hospitality	1	3%
Transportation	1	3%
Utility	1	3%
Record Company	1	3%

- Almost a third of respondents are in Manufacturing, and nearly 40% are in a variety of other industries (listed below graphs).
- 15% of the respondents are government entities.
- The remaining 18% of respondents are in advertising/marketing, schools, and healthcare.

Number of Employees

To get an idea of the distribution of small and medium sized businesses (SMBs) surveyed, respondents were asked how many employees their businesses had on location. The following results were obtained:

Figure 75. Number of Employees



- It appears our electronic survey did reach a solid mix of small and medium size businesses that we hoped to target.

Table 26. Number of Employees

Number of Employees	Number of respondents	Percent of Total
200+	25	30%
11 to 49	24	29%
50 to 99	18	22%
100 to 199	11	13%
1 to 10	4	5%

Building Type

The SEDCs were found to occupy the following building types for our population of respondents:

Figure 76. Building Type

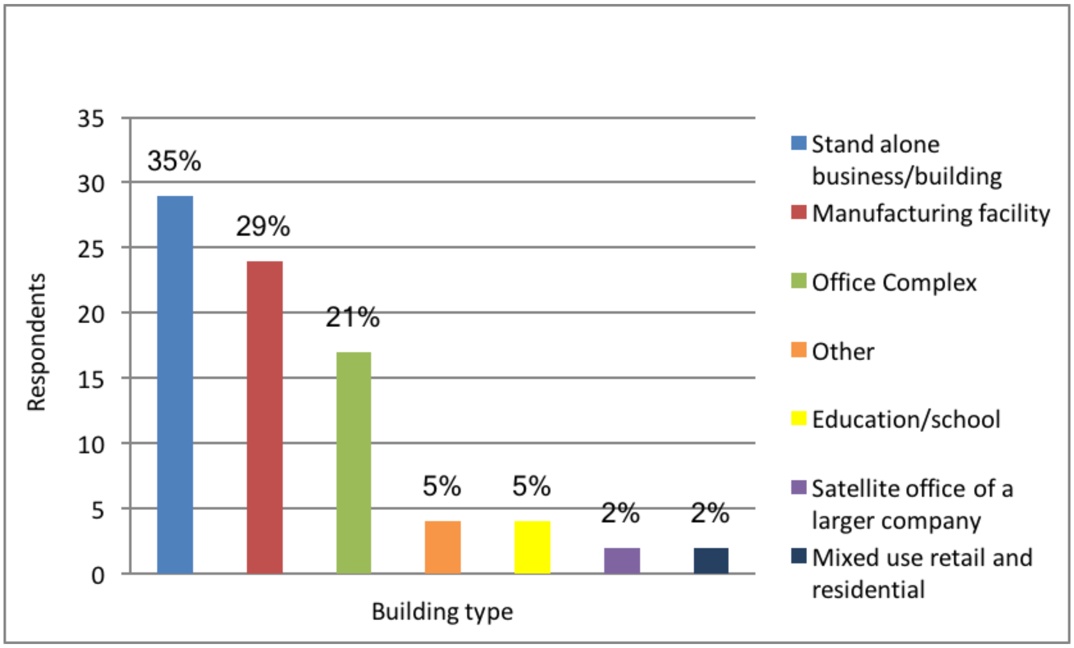


Table 27. "Other" Building Types

"Other" building types	Responses
Municipal wastewater facility with multiple processors	1
Main office and maintenance shop	1
Virtual	1
Nursing home/housing with service apartments	1

- The most frequent building type for respondents (38%) is a stand-alone/business building.
- Many are doing business from a manufacturing facility (29%) or an office complex (20%).

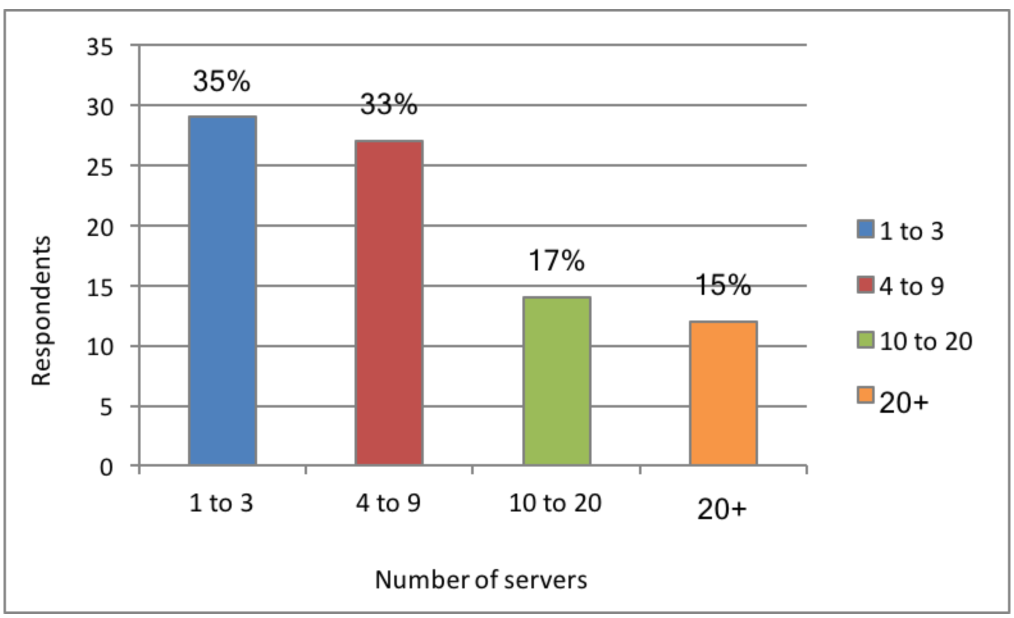
Table 28. Building Type

Building Type	Number of Respondents	Percent of Total
Stand-alone business/building	29	35%
Manufacturing facility	24	29%
Office Complex	17	21%
Other	4	5%
Education/school	4	5%
Satellite office of a larger company	2	2%
Mixed use retail and residential	2	2%

Number of servers hosted by business

With regard to characterizing the SEDCs at each business, a little more than a third of the business had 1-3 servers in their SEDC and about two thirds of the businesses used less than 10 servers.

Figure 77. Number of Servers Hosted by Business



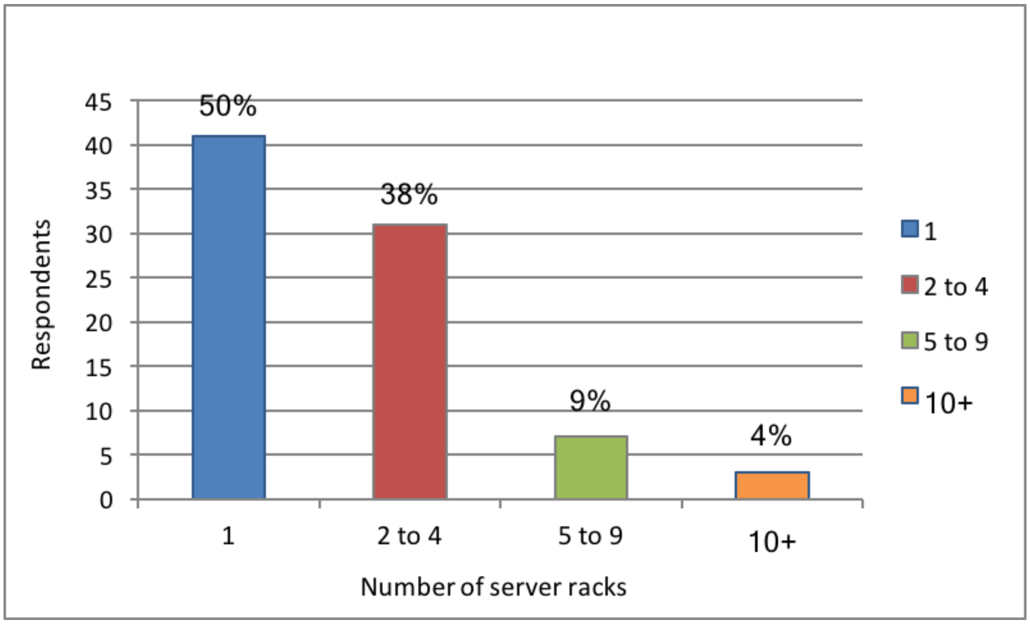
- A majority of responding businesses have 9 or fewer servers.

Table 29. Number of Servers Hosted by Business

Number of Servers	Number of Respondents	Percent of Total
1 to 3	29	35%
4 to 9	27	33%
10 to 20	14	17%
20+	12	15%

As would be expected, the number of server racks found in the SEDCs were limited to one in half of the businesses surveyed.

Figure 78. Number of Server Racks in Server Rooms



- The vast majority of businesses have 4 or fewer server racks, which align with the large number of businesses with Server Closets.

Table 30. Number of Server Racks in Server Rooms

Number of Server Racks	Number of Respondents	Percent of Total
1	41	50%
2 to 4	31	38%
5 to 9	7	9%
10+	3	4%

Monitors power usage of data centers

Figure 79. Monitors Power Usage of Data Centers

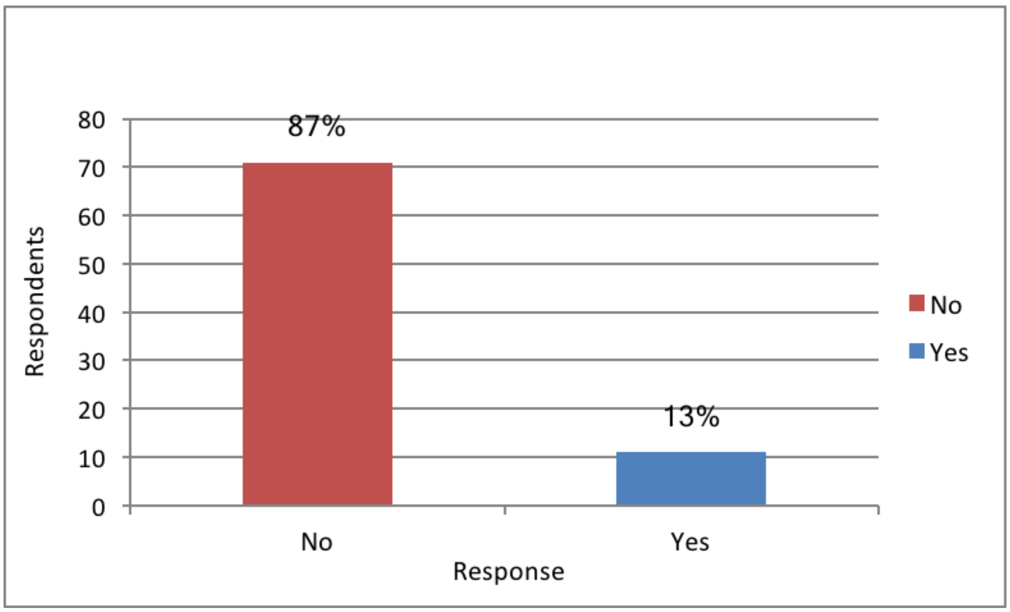


Table 31. Monitors Power Usage of Data Centers

Monitors Power Usage	Number of Respondents	Percent of Total
No	71	87%
Yes	11	13%

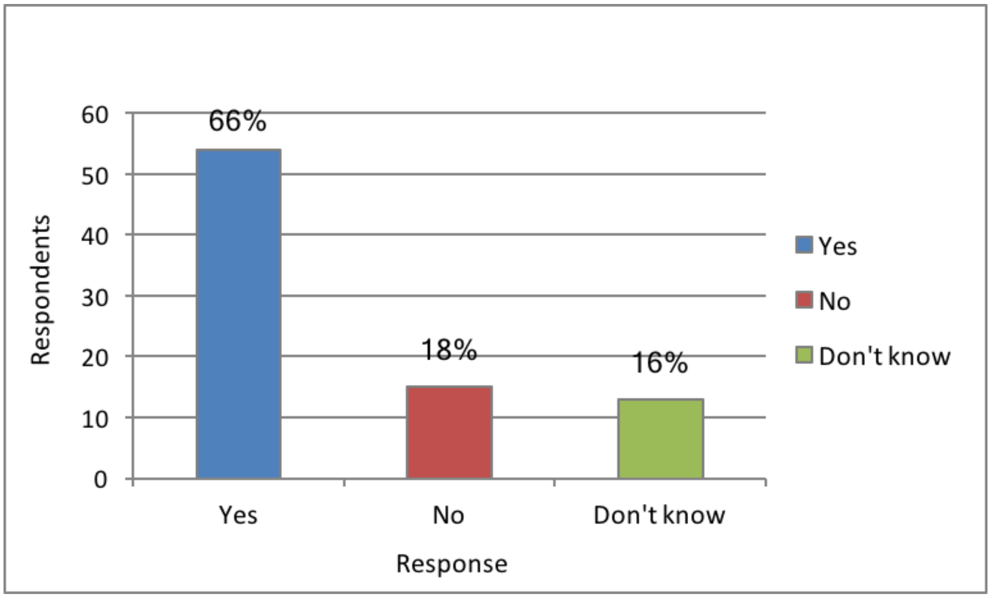
Responses from the 82 SEDCs found that only 13% monitor the power usage of their data centers while 60% monitor the server utilization. All eleven data centers that monitor power usage also monitor server utilization.

Virtualization and cloud services

66% per cent of the SEDCs have done some server virtualization (with the remaining 33% either responding “no” or “don’t know”) and 62% use cloud services.

Switched to virtualization in I.T. activities

Figure 80. Switched to Virtualization in IT Activities



- Most respondents (66%) have switched to virtualization in IT activities.
- There is a substantial group (34%) who would benefit from education around virtualization and its benefits.

Table 32. Switched to Virtualization in IT Activities

Switched to Virtualization	Number of Respondents	Percent of Total
Yes	54	66%
No	15	18%
Don't know	13	16%

Use Cloud services or cloud computing

Figure 81. Use Cloud Services or Cloud Computing

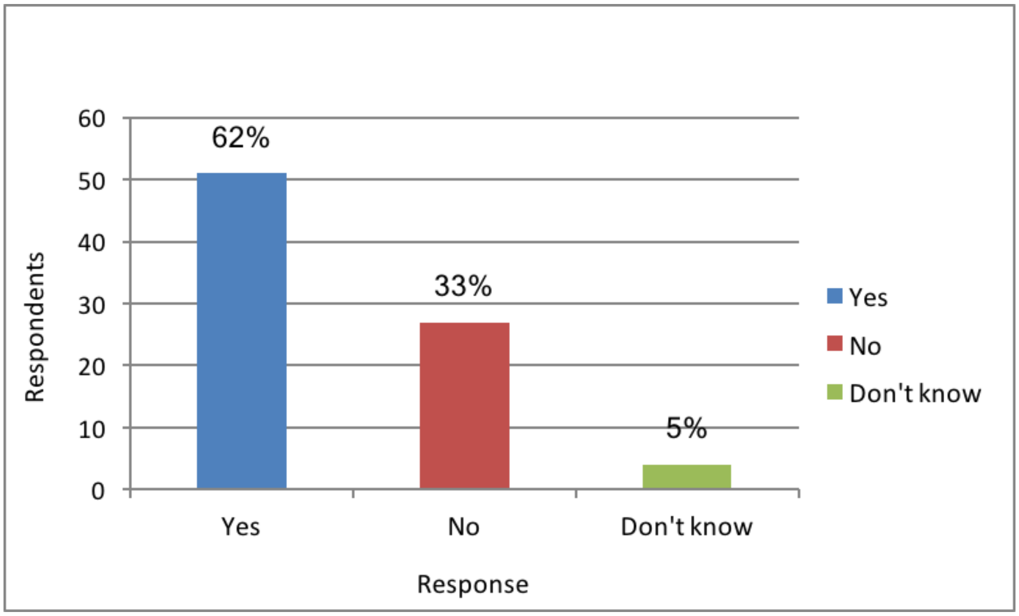


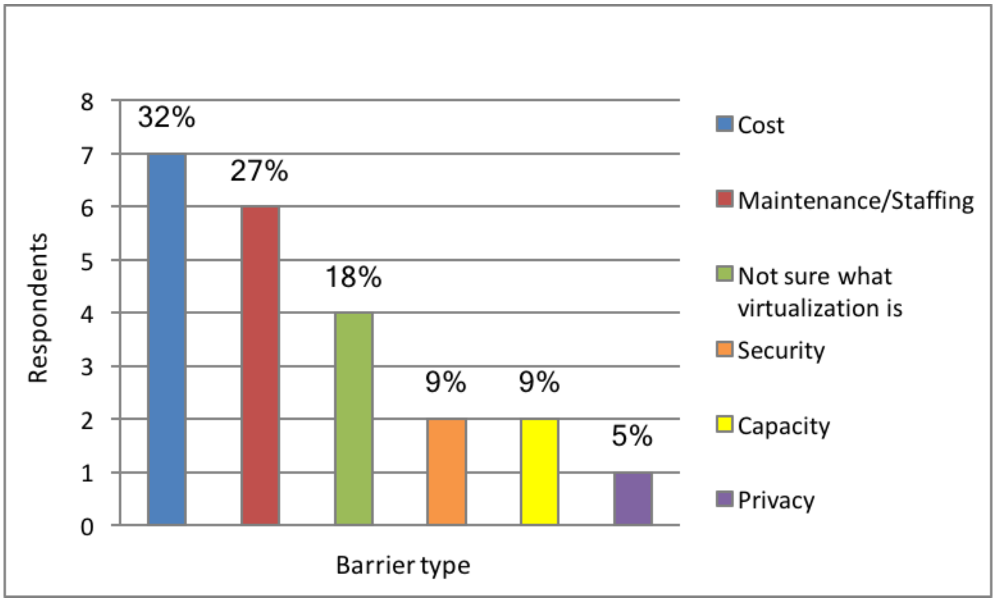
Table 33. Use Cloud Services or Cloud Computing

Use Cloud Services	Number of Respondents	Percent of Total
Yes	51	62%
No	27	33%
Don't know	4	5%

However, 48% of the respondents took advantage of both virtualization and cloud services. The main barriers to adopt virtualization were cost and maintenance/staffing.

Barriers to switching to virtualization

Figure 82. Barriers to Switching to Virtualization



- Cost is the largest barrier to switching to virtualization, according to 32% of respondents.
- Maintenance and staffing is the second largest barrier according to 27% of respondents.
- Nearly a fifth of respondents noted that they are not sure what virtualization is.
- No respondents noted downtime or policy as barriers to virtualization.

Table 34. Barriers to Switching to Virtualization

Barriers to Virtualization	Number of Respondents	Percent of Total
Cost	7	32%
Maintenance/Staffing	6	27%
Not sure what virtualization is	4	18%
Security	2	9%
Capacity	2	9%
Privacy	1	5%

Barriers to using cloud services or cloud computing

The main barriers to cloud services were security and cost.

Figure 83. Barriers to Using Cloud Services or Cloud Computing

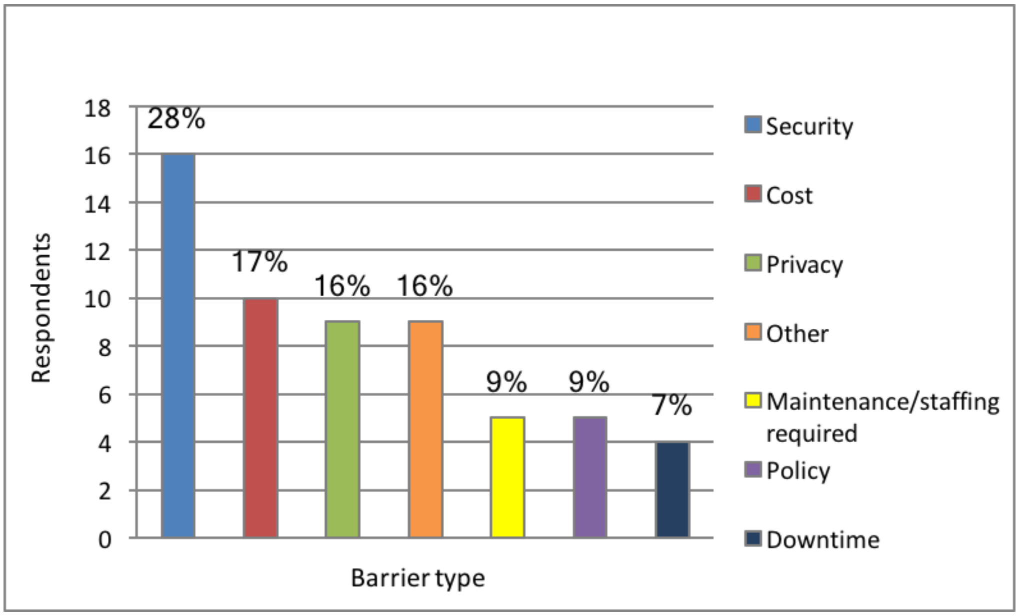


Table 35. "Other" Barriers to Using Cloud Services or Cloud Computing

"Other" barriers to using cloud services	Responses
Cloud services not needed	1
Proficiency	1
Servers are essential to business	1
Performance	1
Reliability	1
Don't Know	1
These are my tenants, not my servers	1
Like to have local control of information and software	1
Would be a corporate decision	1

Table 36. Barriers to Using Cloud Services or Cloud Computing

Barriers to Using Cloud Services	Number of Respondents	Percent of Total
Security	16	17%
Cost	10	7%
Privacy	9	9%
Other	9	9%
Maintenance/staffing required	5	16%
Policy	5	28%
Downtime	4	16%

Trusted sources of info for IT decisions

With regard to sources of information, IT managers gave the following response results:

Figure 84. Trusted Sources of Info for IT Decisions

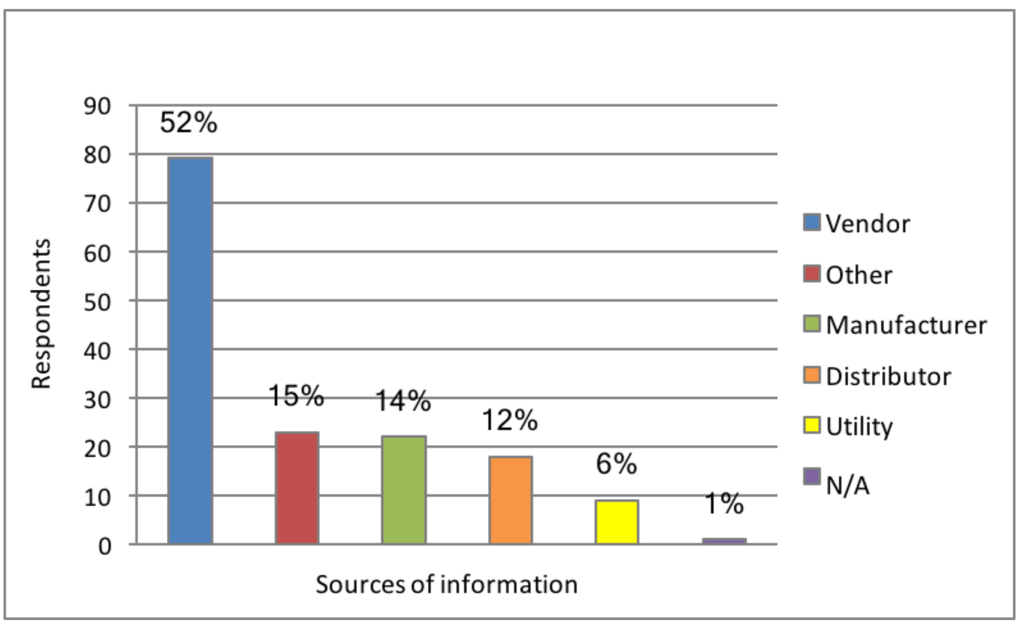


Figure 85. "Other" Trusted Sources of Info for IT Decisions

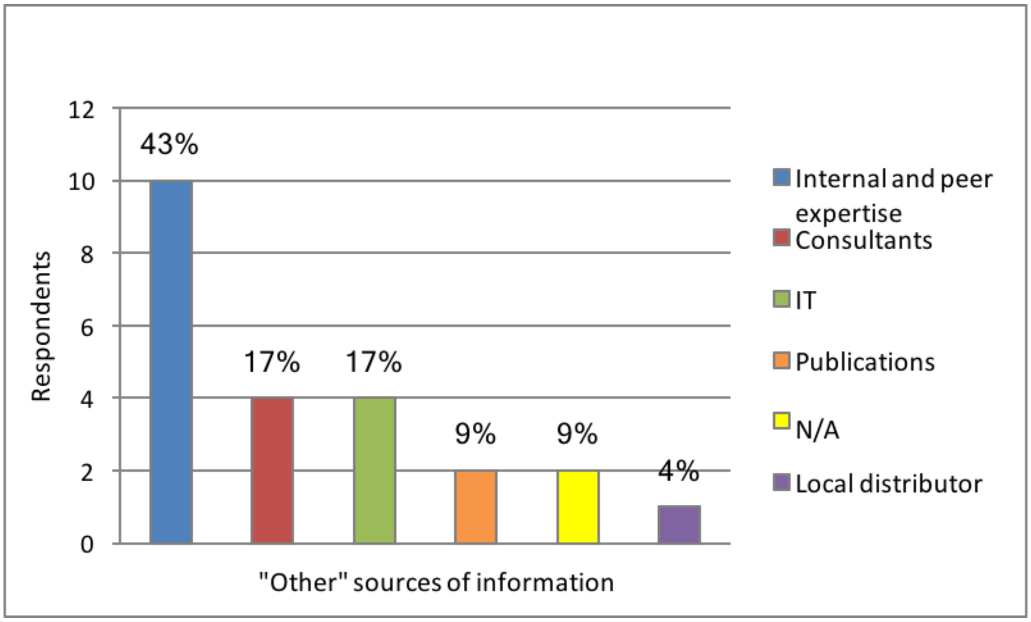


Table 37. Trusted Sources of Info for IT Decisions

Trusted Source of Info for IT Decisions	Number of Respondents	Percent of Total
Vendor	79	52%
Other	23	15%
Manufacturer	22	14%
Distributor	18	12%
Utility	9	6%
N/A	1	1%

Table 38. "Other" Trusted Sources of Info for IT Decisions

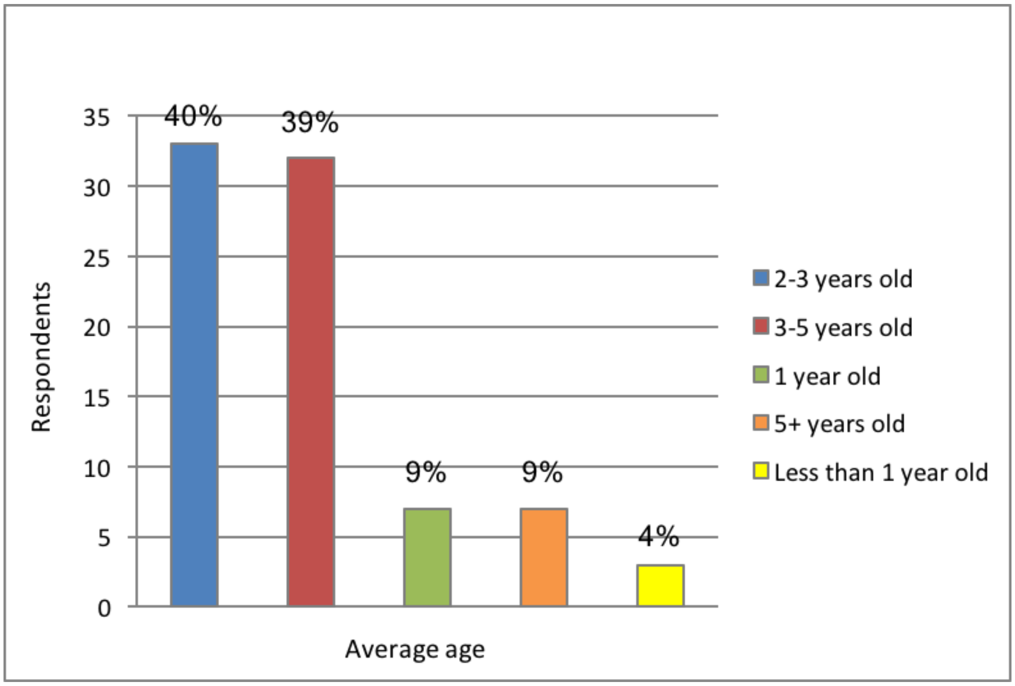
"Other" Trusted Source of Info for IT Decisions	Number of Respondents	Percent of Total
Internal and peer expertise	10	43%
Consultants	4	17%
IT	4	17%
Publications	2	9%
N/A	2	9%
Local distributor	1	4%

Responses could be made in more than one category. The Other category included replies such as consultant, peer, and brother. Vendors clearly are an important source of information and a channel to use to promote data center energy efficiency. This suggests that vendors could have a significant role in both outreach to SEDC IT managers and for advocating for energy efficiency measures. A midstream program targeted to vendors and distributors could also be effective. Similarly an upstream program with manufacturers might also be effective.

Average age of servers

The average age of servers yielded the following results:

Figure 86. Average Age of Servers



- The vast majority of servers (80%) are in the middle age range of 2-5 years old.
- 8% of respondents have servers older than 5 yrs. Identifying this group would provide some quick wins for energy savings and server performance

Table 39. Average Age of Servers

Age of Server	Number of Respondents	Percent of Total
2-3 years old	33	40%
3-5 years old	32	39%
1 year old	7	9%
5+ years old	7	9%
Less than 1 year old	3	4%

Typically the industry reports that the average IT refresh cycle is about three years. For SEDCs, 39 of 82 respondents (48%) have servers that are older than this average and 88% of the SEDCs have servers with an average age of two years or more.

When planning to upgrade servers

The responses for the timetable for server upgrades showed that 56% of the respondents were not planning upgrades for another year and 24% were not planning an upgrade for more than three years.

Figure 87. Timeline for Upgrading Servers

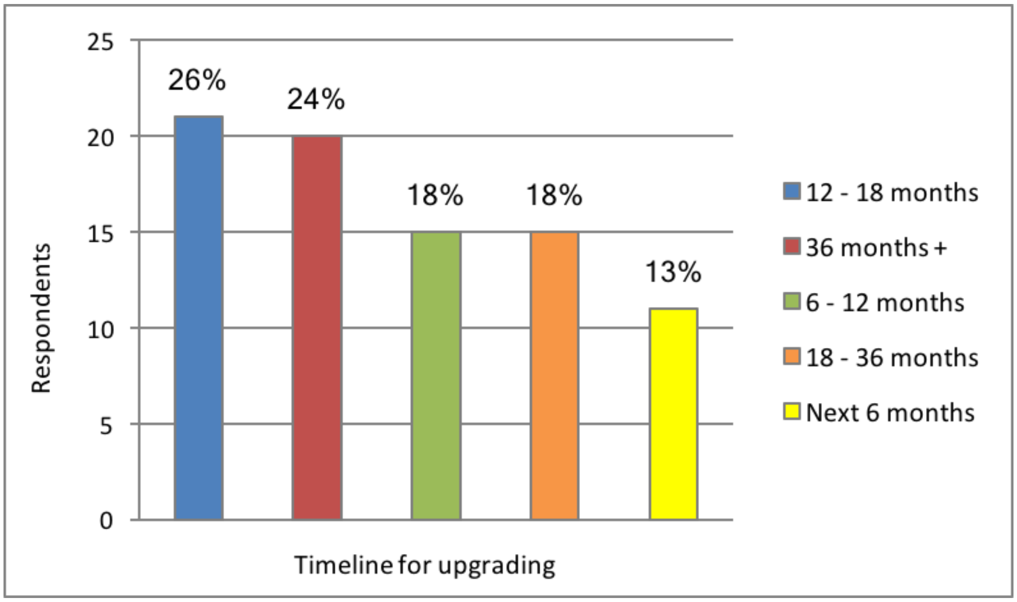


Table 40. Timeline for Upgrading Servers

Timeline for Server Upgrade	Number of Respondents	Percent of Total
12 - 18 months	21	26%
36 months +	20	24%
6 - 12 months	15	18%
18 - 36 months	15	18%
Next 6 months	11	13%

Motivation to make server upgrades

The main motivation for making server upgrades was dependability. Other responses are shown below:

Figure 88. Motivation to Make Server Upgrades

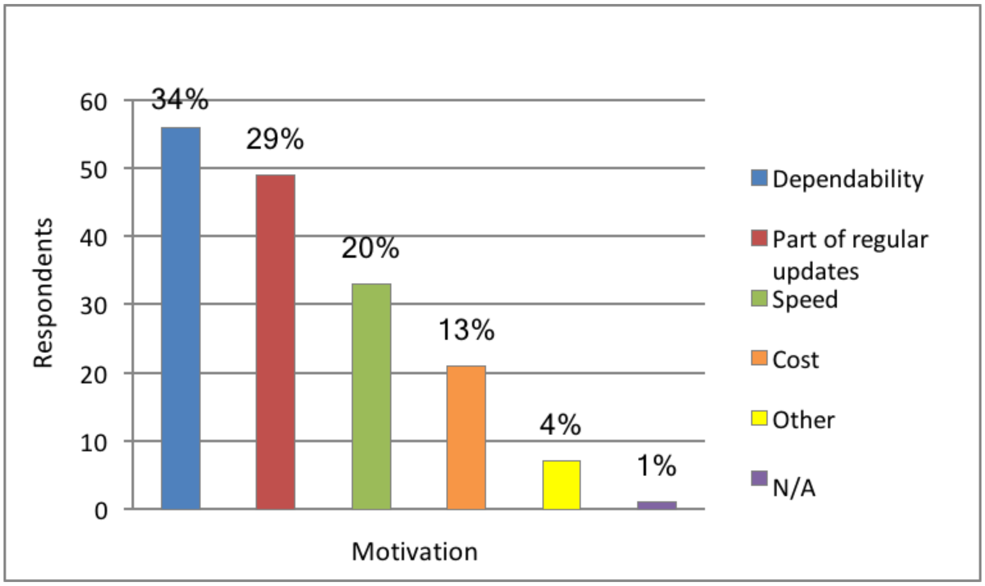


Table 41. "Other" Motivation to Make Server Upgrades

"Other" motivations	Responses
Stop working or can't keep up with load	1
We are moving a new facility	1
Age, requirements of ERP software upgrades	1
We just purchased a new server	1
Get tired of maintaining	1
Growth and compliance	1
Leaning to VM servers on clusters for stability and speed	1
N/A	1

- The primary motivation to make server upgrades is due to dependability, according to a third of respondents (34%).
- Another 31% of respondents note that upgrades are simply part of their regular updates.
- 19% of respondents are motivated by upgraded speed and 12% by cost savings.

Table 42. Motivation to Make Server Upgrades

Motivation for Server Upgrades	Number of Respondents	Percent of Total
Dependability	56	34%
Part of regular updates	49	29%
Speed	33	20%
Cost	21	13%
Other	7	4%
N/A	1	1%

If we look at the SEDC data in segments by floor area, then the results for server room responses (200 ft^2 < floor area > 1,000 ft^2) compared to data closets (floor area < 200 ft^2) found that:

- data closets were less like by half to monitor power usage than server rooms
- data closets were about a third less likely to monitor server utilization
- only half of the data closets took advantage of server virtualization while 86% of server rooms did
- about half of the data closets used cloud services compared to three quarters of the server rooms.

Impact of split incentives on taking energy efficiency actions

Both SEDC types paid utility bill, suggesting the split incentives was not a major issue for our respondents. The comparison of the two types of SEDCs is shown in the table below:

Table 43. Impact of Split Incentives

	Data closets (floor area < 200 ft^2)	Server Rooms (200 ft^2 < f.a. > 1,000 ft^2)	SEDCs (f.a. < 1,000 ft^2)
number of respondents	47	35	82
pay utility bills	91%	97%	94%
monitor power usage	9%	20%	13%
monitor server utilization	51%	71%	60%
uses some server virtualization	51%	86%	66%
uses cloud services	51%	77%	62%
average server age over 3 years	43%	54%	48%

The finding that split incentives is not a factor for these SMBs might explain the high number of responses that these businesses are taking energy efficiency steps to lower their utility bills.

Uses energy efficiency steps to lower utility bills

Figure 89. Use Energy Efficiency Steps to Lower Utility Bills

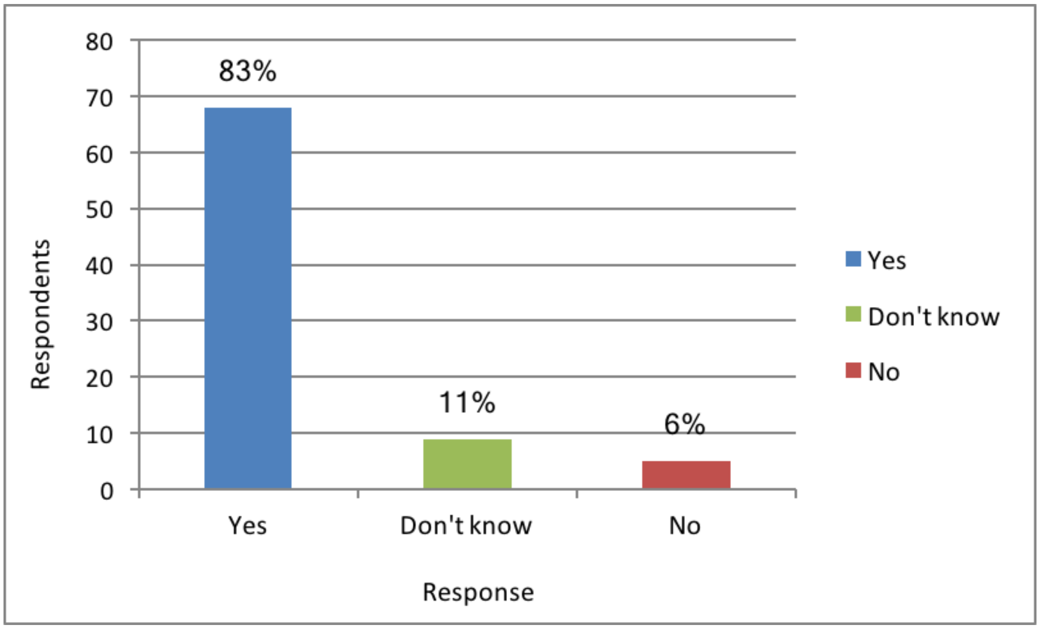
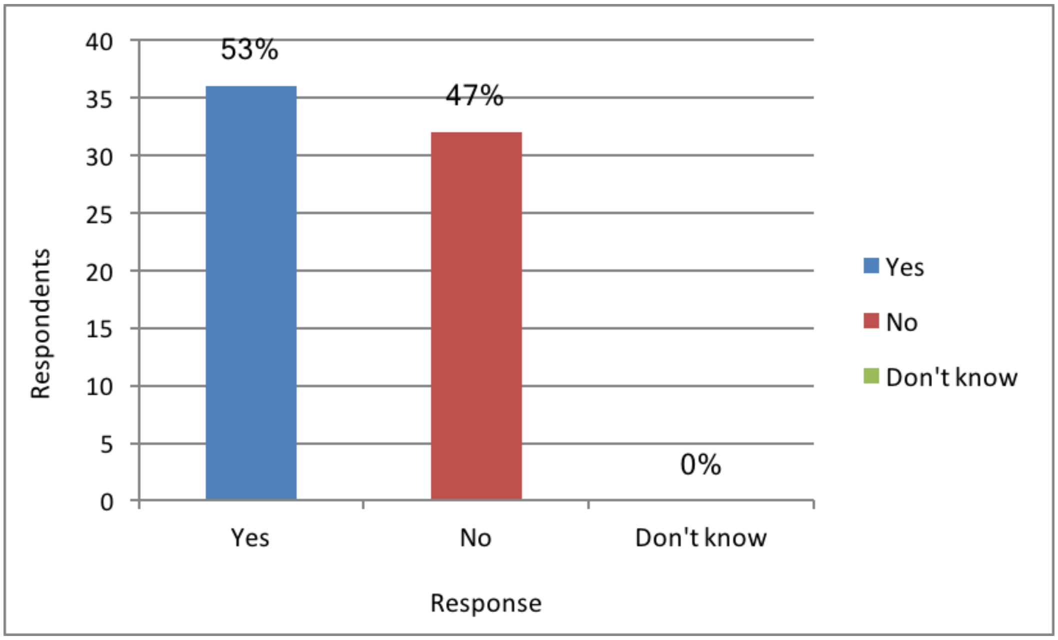


Table 44. Use Energy Efficiency Steps to Lower Utility Bills

Use EE to Lower Bills	Number of Respondents	Percent of Total
Yes	68	83%
Don't know	9	11%
No	5	6%

However, only about half of the respondents report that IT is involved in those energy efficiency efforts.

Figure 90. IT Is Involved in Energy Efficiency Efforts



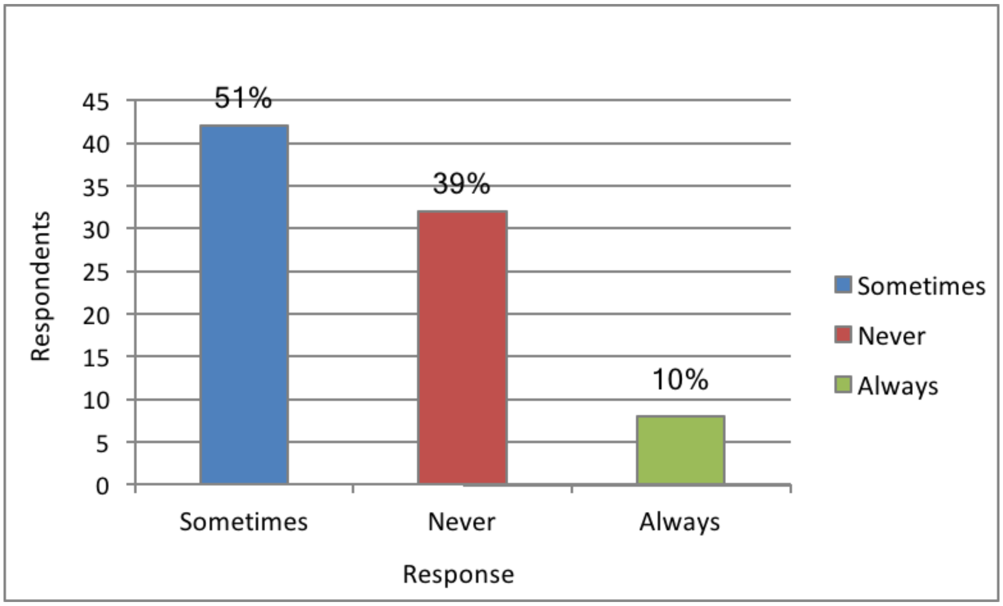
IT does appear to play a role beyond just a facilities manager

Table 45. Role of IT in Energy Efficiency Efforts

IT involved in EE efforts	Number of Respondents	Percent of Total
Yes	36	53%
No	32	47%

Energy efficiency is typically not a high priority for IT staff and the decisions they make.

Figure 91. How Often Energy Efficiency Factors into IT Decisions



Over a third (37%) of respondents never consider energy efficiency when making IT decisions.

Table 46. How Often Energy Efficiency Factors into IT Decisions

Factors EE into IT decisions	Number of Respondents	Percent of Total
Sometimes	42	10%
Never	32	51%
Always	8	39%

Barriers to pursuing energy efficiency technologies for your company

Figure 92. Barriers to Pursuing Energy Efficiency Technologies

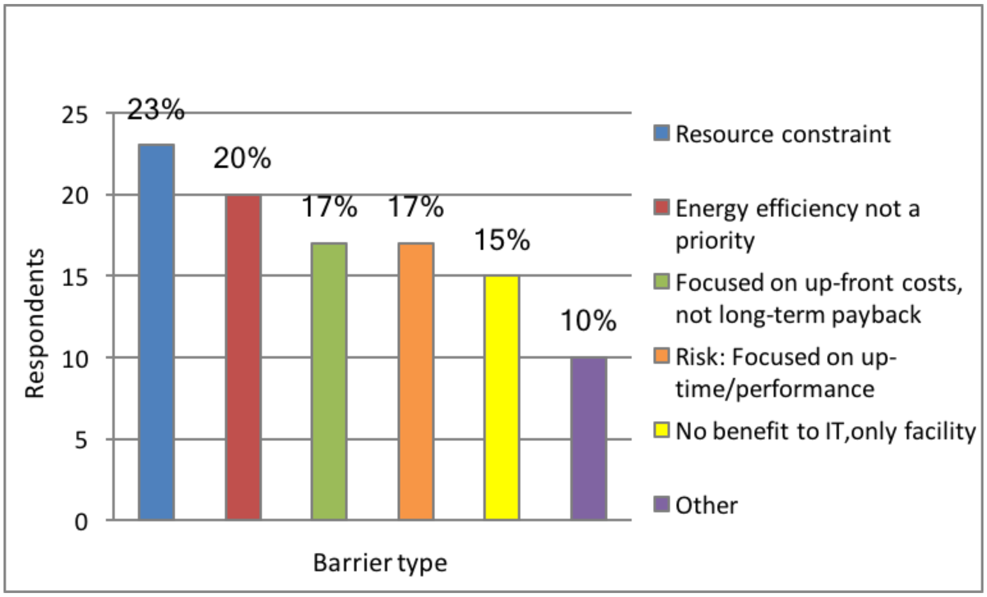


Table 47. "Others" Barriers to Pursuing Energy Efficiency Technologies

"Other" barriers	Responses
Depend on vendor for direction	2
Life cycle replacement of devices	1
Haven't looked into it	1
We're too small to have any impact	1
Time	1
Costs of updating are very high	1
Not a primary factor	1
Not sure	1
Lack of knowledge	1

- Respondents cited a variety of barriers to pursuing energy efficiency technologies for their companies. Resource constraints were the top barrier according to 23% of respondents.
- Energy efficiency was not cited as a priority for 18% of respondents.

- Another 18% cited risk as a top barrier.
- 17% of respondents are focused on upfront costs, not long term payback, and 15% do not see energy efficiency as a benefit to IT, just to the facility.

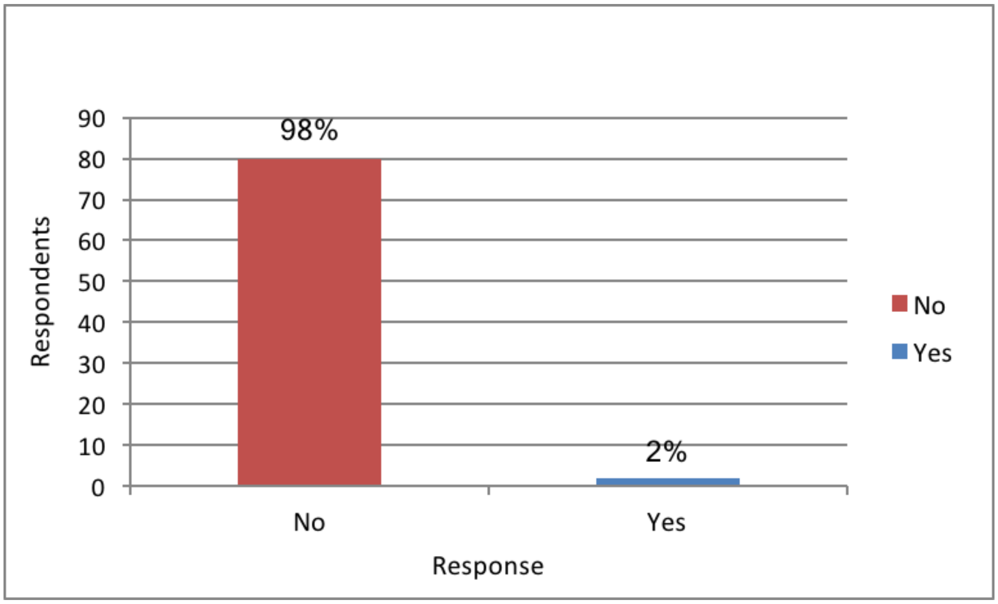
Table 48. Barriers to Pursuing Energy Efficiency Technologies

Barriers to Pursing EE Technology	Number of Respondents	Percent of Total
Resource constraint	23	23%
Energy efficiency not a priority	20	20%
Focused on up-front costs, not long-term payback	17	17%
Risk: Focused on up-time/performance	17	17%
No benefit to IT, only facility	15	15%
Other	10	10%

Aware of utility rebates or incentives for energy efficiency programs at data centers

SMBs surveyed also demonstrated an unawareness of utility rebates that might incentivize adoption of energy efficient IT alternatives.

Figure 93. Aware of Utility Rebates/Incentives for Energy Efficiency Programs



- This is a very big opportunity for utilities to create programs either direct to business or through the trade/distribution channel to education and create awareness of data center utility programs. It does appear energy efficiency is important to this business customer, but hasn't been a priority to seek out lower costs.

Table 49. Aware of Utility Rebates/Incentives for Energy Efficiency Programs

Aware of Utility Rebates/Incentives	Number of Respondents	Percent of Total
No	80	98%
Yes	2	2%

About half of the respondents expressed a willingness to invest in energy efficiency and over half were interested in our offer of a free on-site energy audit.

Figure 94. Maximum Business Is Willing to Invest Upfront for Long-Term Energy Savings on Utility Bill

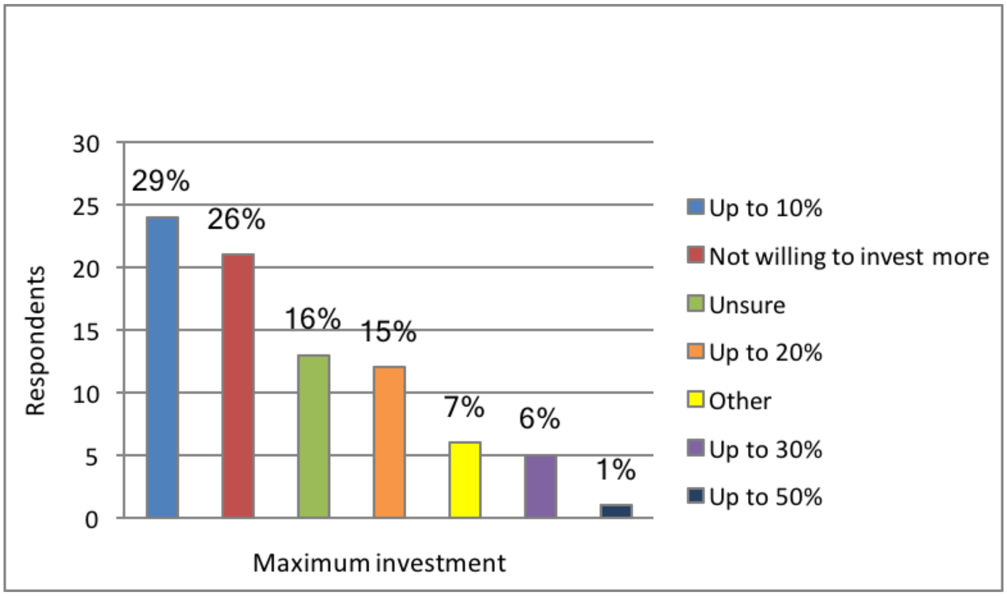


Table 50. "Other" Investment Options

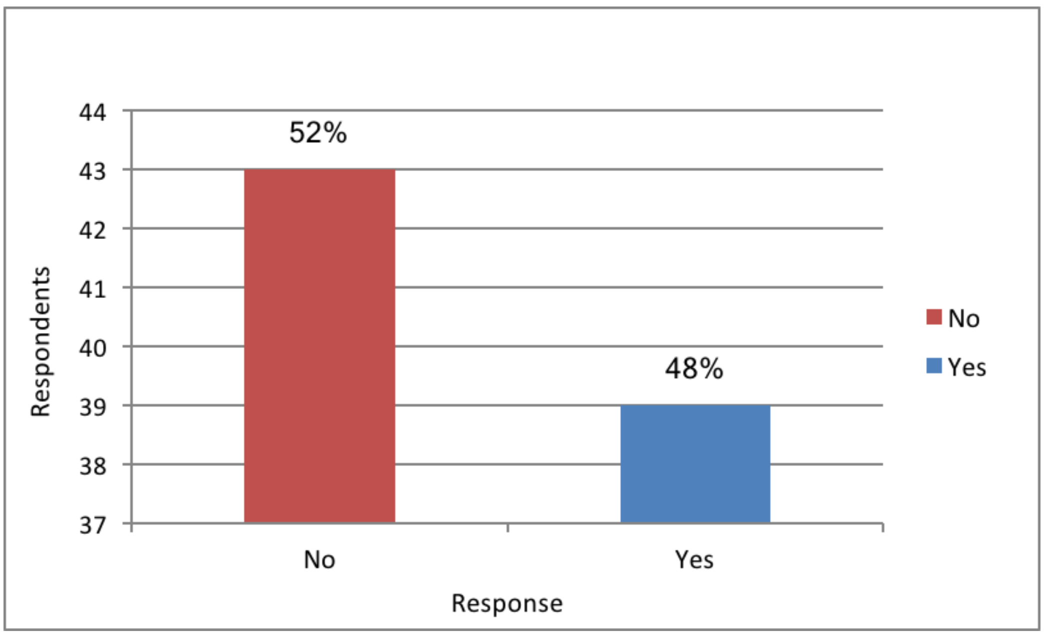
"Other" investment option	Respondents
N/A	2
It's a life cycle cost for us	1
Don't currently have the data to say, but open to discuss	1
We wish to virtualize and minimize IT not add more and complicate it	1
Server room is only a small part of the overall energy use by computing equipment	1
5%	1

Table 51. Maximum Business Is Willing to Invest Upfront for Long-Term Energy Savings on Utility Bill

Max Investment for Energy Savings	Number of Respondents	Percent of Total
Up to 10%	24	29%
Not willing to invest more	21	26%
Unsure	13	16%
Up to 20%	12	15%
Other	6	7%
Up to 30%	5	6%
Up to 50%	1	1%

Interested in free on –site energy assessment

Figure 95. Interested in Free On-Site Energy Assessment



- Separate list of interested parties will be provided as an excel file.

Table 52. Interested in Free On-Site Energy Assessment

Interested in Assessment	Number of Respondents	Percent of Total
No	43	48%
Yes	39	52%

Conclusions

1. We discovered a number of effective outreach channels to reach our target audience and these provided a wide distribution of responses from around the State.
2. Server virtualization and consolidation provides an opportunity for savings in SEDCs and especially data closets.
3. The use of cloud services is not yet widespread for SEDCs, especially with businesses that have data closets.
4. Servers in SEDCs have a longer deployment life than other data center types and an opportunity exists for a server replacement program.
5. IT managers' trusted sources of information point to opportunities with upstream and midstream programs, as well as serving as an important outreach channel.
6. The issue of split incentives was not found to be an issue with the SMBs surveyed, suggesting that reducing energy costs could be an important incentive in encouraging action.

Utility incentive programs that SEDCs can take advantage of is largely unknown to the SMBs that we surveyed. Creating targeted incentives for SEDCs could increase participation.

Appendix D: Small Embedded Data Center Program Pilot – Industrial Sites

Jon Vanyo, MnTAP

Introduction

The purpose of this project was to develop a strategy to engage small industrial sites in a server room energy efficiency project, measure energy consumption within these sites, and to identify cost-effective strategies to reduce energy usage in these small server rooms. MnTAP engaged three industrial sites, installing energy meters and identifying opportunities for energy savings

Engagement

Surveying

The engagement process was started by surveying industrial businesses with regard to their small server rooms. Businesses surveyed were identified through the intersecting set of contacts that receive the MnTAP electronic newsletter and whose company name appears in a Mergent Intellect NAICS code search between 31 and 33 for industrial manufacturing. Surveys were sent to 267 manufacturing businesses throughout the state of Minnesota. Table 53 contains some of the interesting survey results.

Table 53: Overall Survey Results

MnTAP Surveys Sent	267
Total Respondants (All groups)	135
Manufacturing Industry	24%
Sites with 1-4 racks of equipment	81%
Interest in no-cost energy assessment	48%
Sites using virtualization	66%
Sites that would spend 10 to 30 % more for energy efficient equipment assuming a 3 year payback period	49%

Outreach

Three sites were engaged through outreach by calling the site's survey contact. Sites were chosen based on survey results, with a preference for sites indicating an interest in a no-cost assessment. The call was completed to introduce and explain the project, learn whether there was still interest in an assessment, and to schedule scoping site visits. These sites were sent a project participation letter and project agreement to be signed by the owner. After receiving a signed project agreement, MnTAP proceeded with the initial site-visit to discuss server energy opportunities, complete additional surveys, create a log of IT equipment, and to plan meter installation.

Measurement

Metering

The primary method to collect energy data for server rooms was completed by monitoring the energy draw through each Uninterruptable Power Supply (UPS). UPSs serve as battery backups for servers and IT equipment, protecting them from sudden power loss or periods of distorted power flow. Because all data center IT equipment is typically powered through UPSs, monitoring UPS energy consumption provides the total IT energy consumption for small server rooms.

The other component used to calculate PUE in this study is the server room air conditioner energy consumption. Standard plug meters were not suitable for project sites as the AC units were hardwired to circuit panels. Because hardwiring current transformer (CT) meters were more complicated and required an electrician, only one of the three project sites completed this metering.

Individual server power draw was also measured in order to gain insight into energy consumption patterns within the servers themselves. While the total energy is already captured within the UPS measurement, measuring individual server energy consumption helped to identify under-utilized and idle servers in order to raise the potential for consolidation opportunities to IT staff. Most of the servers identified in this study have redundant plugs, allowing each server to connect to multiple Power Distribution Units (PDUs) to promote redundancy. In some cases both of these server plugs were monitored, but in many cases only one was monitored.

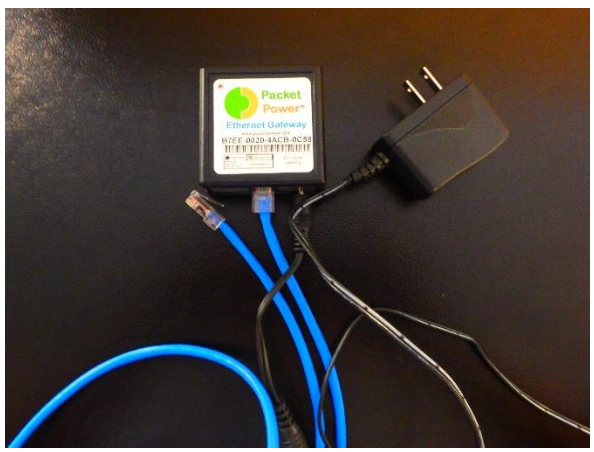
IT equipment measurement was completed with simple plug-load energy meters from Packet Power[73] (Figure 96). IT equipment is plugged directly into the meters. The meters then complete the circuit to the PDU.

[73] Packet Power. "About Packet Power." packetpower.com. http://www.packetpower.com/company (retrieved May 5, 2017)

Figure 96: Packet Power Meter

These meters send power information wirelessly to the Packet Power gateway, which connects to the internet via Ethernet port (Figure 97).

Figure 97: Packet Power Gateway



The data is then collected on a network where it can be monitored in real time, or downloaded to be analyzed later.

Meter installation was typically scheduled for times when the server equipment could be shutdown to avoid potential sudden power failures within equipment while disconnecting and reconnecting power cords. That being said, the purpose of the UPS is to continue providing power to equipment during power failures, so some UPS meters were installed while IT equipment was running. Most servers have redundant plugs, which allow meters to be installed on server plugs one at a time without depowering equipment. This was necessary for sites that preferred not to shut down their server equipment, but it carried an inherent risk of suddenly depowering equipment in the case that redundancy failed.

Results – Calculations and Estimations

After collecting the data, it was analyzed in order to identify opportunities. This involved calculating the total energy and dollar costs to run server equipment, calculating the UPS utilization and opportunities, and calculating the server utilization for each site and consolidation opportunity. Calculations with assumptions were completed to estimate the savings potential of modifying server room temperatures, automatically shutting off equipment, and outsourcing small server rooms to a large centralized data center. Finally, some additional best practices that were recommended to project sites do not have savings estimates, such as cabling and airflow management. The purpose of these calculations and estimations is to determine the order of magnitude for these savings opportunities within small server rooms.

Server Energy Consumption: (Total Energy Use: 47,700 kWh, $4770 per year)

The total server room energy consumption was estimated as the sum of energy flowing through the UPSs and HVAC to maintain server room operations and temperature. For two sites where HVAC energy was not measured, HVAC energy was estimated to be 50% of the IT energy, an estimate from Cisco in a previous study[74]. The site where HVAC energy was measured was running at a warmer than average room setpoint of 74°F (average was 70°F), and HVAC was measured at 67% of the IT energy. The average small server room in this study uses 47,700 kWh per year to maintain IT functions ($4,770 per year at a $.10 blended rate per kWh).

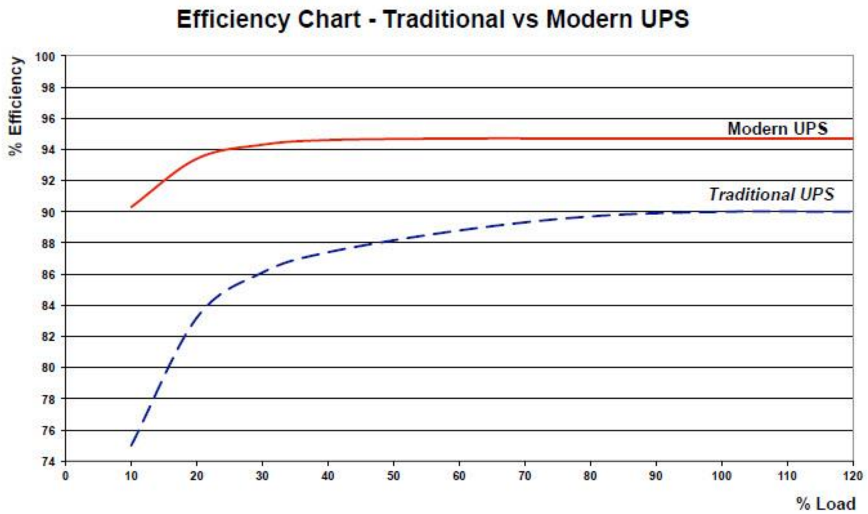
Improve UPS Utilization: (Savings: 370 kWh, $37 per year [Energy], $2300 Future UPS Equipment Savings)

UPS utilization was calculated by comparing the actual power drawn by the UPS to its rated power. Minor energy savings and substantial equipment savings are possible by more efficiently loading UPSs. Two of the three industrial assessment sites had very low UPS utilization rates, while the third site had nearly optimal UPS loading. The average UPS utilization between the three sites was 29%. The ideal UPS loading for systems using redundant UPSs is 50%. Maintaining 40% utilization was recommended in this study to leave an adequate safety factor. This allows a UPS to provide enough power to allow servers to gracefully shutdown in the event of a power outage, even if its mirror UPS fails. Using fewer UPSs at higher utilization results in slight energy gains due to better efficiency at higher load, but also benefits these sites by reducing the amount of equipment needed to be purchased by these server room operators. Figure 98, from UPS Systems, shows the efficiency of modern and traditional UPSs at various load percentages.[75] Only modern UPSs were identified in this project.

[74] Cisco. 2013. "Power Management in the Cisco Unified Computing System: An Integrated Approach." cisco.com. http://www.cisco.com/c/en/us/solutions/collateral/data-center-virtualization/unified-computing/white_paper_c11-627731.html (retrieved May 5, 2017)

[75] UPS Systems PLC. "ups efficiency search." upssystems.co.uk. http://www.upssystems.co.uk/?s=ups+efficiency (retrieved May 5, 2017)

Figure 98: UPS Efficiency vs. Load Percentage (from UPS Systems)



Sites in this study were recommended to reduce the number of UPSs being used on site by an average of 1.7 UPSs per site. The average energy savings opportunity due to UPS consolidation at industrial pilot sites was 370 kWh per year ($37 per year) based on increased UPS efficiency. The change will also reduce future UPS purchase costs by roughly $2,300.

Improve Server Utilization: (Savings: 1000 kWh, $100 per year)

Server utilization was calculated by comparing actual server power measurements to the "SPECpower_ssj2008" 100% active vs. idle power results for servers measured.[76] This study assumed that power draw for servers is linear between idle and active power draws, and that the measured point on this line corresponds to server utilization. For example, from "SPECpower_ssj2008", a Dell PowerEdge R620 server uses 50.2W at idle, and 227W at 100% load. An R620 server drawing 190W is estimated to be at (190W – 50.2W / 227W – 50.2W) or 79.1% utilization. The challenge in using this method is that there are often multiple types of the same model of server in the SPEC spreadsheet, or occasionally there are no servers of the metered model number within the SPEC spreadsheet. In either event, the approximation used in this study was to find and use a server with similar specifications by the same manufacturer that is in the spreadsheet to use as an approximation for the metered idle and active power draw. This method allowed for estimation of server utilization based on power measurements, allowing for estimates of energy savings associated with increasing server utilization.

The average server utilization for the two sites where this comparison was completed was 29.5%. The comparison was not completed for the third site because it was using more obscure servers that were not benchmarked within "SPECpower_ssj2008." The target utilization from Green Grid states that 50% processor utilization is considered "good", while 75% is considered

[76] The SPECpower_ssj® 2008 benchmark is the first industry-standard benchmark that evaluates the power and performance characteristics of single server and multi-node servers.

"very good."[77] If these two sites were to increase their server utilization to 50%, they would see an average energy reduction of 1000 kWh per year ($100 per year).

Servers accounted for approximately 27% of the energy draw in the server room on average in this study, or 13,000 kWh per year ($1,300 per year). If the results from this study are representative of industry as a whole, increasing server utilization to 50% will save 1000 kWh per year ($100 per year) per site in energy.

Server utilization is commonly increased through virtualization. One virtualization vendor provided an estimate of $3,249 per physical machine per year for virtualization software. At this price, small server rooms will have difficulty in justifying virtualization via energy savings alone, and will need to consider other factors, such as reduced equipment purchases, to justify this type of change. Sites that are already using virtualization should be readily able to increasing server utilization to 50%.

Increase Temperature Set Points: (Savings: 2500 kWh, $250 per year)

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) has set a recommended operating temperature range for server rooms between 64.4°F and 80.6°F.[78] They have also set a recommended humidity range with dew point between 41.9°F and 59°F, and relative humidity not to exceed 60%. Former studies have found that every 1°F increase in server room temperature reduces cooling energy by 2-5%.[79] In order to maintain a factor of safety, project partners in this study agreed to recommend a temperature set point of 77°F to project participants. This study found that server room temperatures in small server rooms are typically low, with an average temperature of 70°F. Assuming a savings of 3% per 1°F, sites that raise room temperatures to 77°F will save an average of 21% of their cooling energy simply by raising temperature set points. An average small industrial site from this study will save 2,500 kWh per year ($250 per year) by raising their server room temperature set point to 77°F.

Implement Automatic Equipment Shutdown and Scheduling: (Savings: 578 kWh, $58 per year)

Collected power data from each industrial site shows slightly greater power draw from equipment during the day, and a relatively constant, smaller draw from IT equipment at night and on weekends. Analyzing this data resulted in a hypothesis that IT equipment can be

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[77] Richard Talaber, Ed., Tom Brey, and Larry Lamers. 2009. Using Virtualization to Improve Data Center Efficiency. White Paper 19. The Green Grid.

[78] ASHRAE TC 9.9. 2011. 2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance. Whitepaper. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

[79] N. El-Sayed, I. Stefanovici, G. Amvrosiadis, A.A. Wang, and B. Schroeder. 2012. "Temperature Management in Data Centers: Why Some (Might) Like It Hot." SIGMETRICS'12, June 11-15, 2012. http://www.cs.toronto.edu/~bianca/papers/temperature_cam.pdf (retrieved May 5, 2017)

shutdown at nights and on weekends resulting in substantial energy savings. An initial order of magnitude estimate was completed by assuming that 50% of equipment can be powered down for 50% of the time by using automatic scheduling. If this is possible, the average server room energy consumption can be reduced by 11,900 kWh per year ($1,190). This strategy was not able to be tested in this project, but would be an extremely valuable opportunity if it proves technically viable. Implemented results for network access point shutdown and server standby were found at Sites 6 and 8 in the main report.

To test equipment shutdown, Site 8 powered down 19 network access points for 6 hours each night, reducing power draw when they were powered down by 161.9 W, or 8.5 W per access point. This is an annual savings of 18.6 kWh per year ($1.86) per access point.

Site 6 used Distributed Power Management software through VMware to put a server on standby during off hours. This one server was able to reduce power draw by 8.6% when powered down. The typical industrial server room uses 13,000 kWh per year on server energy. If DPM can be used for 50% of the time, this is a 559 kWh ($55.90) annual savings for a typical server room.

Therefore, the average savings potential per site using the shutdown and standby strategies tested in this project is 577.6 kWh per year ($57.76).

Implement Cabling: (Best Practice)

Cabling involves properly managing server cables by tying or clipping cords together. Not only does this help to make server rooms look more visually organized, it also helps to promote airflow by leaving open space behind the server. As shown in Figure 99, a tangle of cords can block airflow through servers.

Figure 100 demonstrates well-organized cables that will allow airflow through servers and promote efficient air transfer. Improving cabling was recommended to one project site. Its impact on energy was not measured; improved airflow is expected to slightly reduce server temperatures, which could then result in a slightly higher HVAC temperature set point to attain energy savings.

Figure 99. Messy Cables Block Airflow

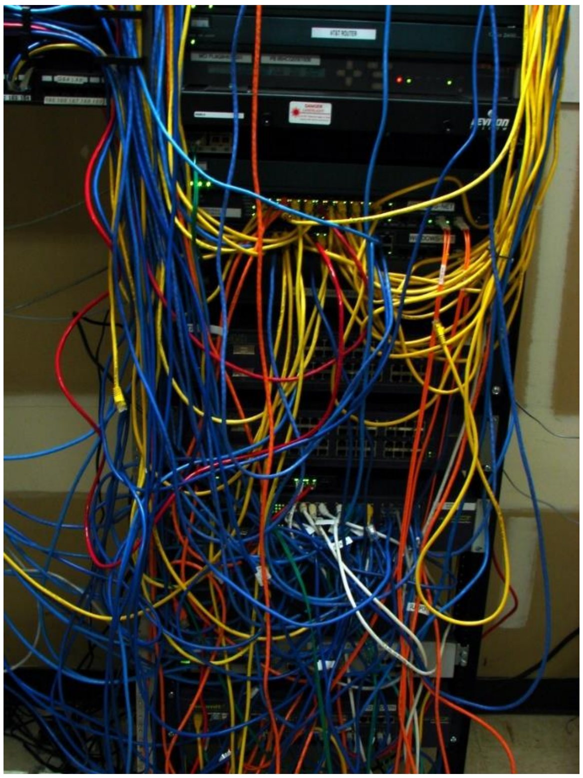

Figure 100. Proper Cabling Promotes Airflow

Improve Airflow Management: (Best Practice)

Servers are designed to intake cool air through the front and to eject warm air out the back. Ensuring that cool air from the AC unit is being provided to the front of the servers and that warm air is being drawn from behind the servers is a simple way to ensure that energy is not being wasted through undesirable heat transfer. Site 11 had this backwards and is planning to solve the problem by installing ducting to run cool air to the front of their servers. Larger data centers typically create hot/cold aisles by using a type of barrier or curtain to keep hot and cold air from mixing, reducing cooling energy requirements. Hot-cold aisles were implemented at site 6, resulting in server inlet air temperatures being reduced from 86°F to 78°F. At that site, this change allowed the business continue cooling with just fans rather than installing an HVAC unit.

Consider Outsourcing: (17,650 kWh, $1,765 per year)

When a small server room transfers information to a large data center to host, there is opportunity for energy savings. This is because large data centers can be more efficient due to economies of scale, and potential energy savings for large data centers have a large and considerable effect on operating costs. For example, it is more cost effective for large data centers to purchase and implement virtualization software and maintain high levels of server utilization than it is for a small-embedded data center.

The average PUE measured throughout this project (calculated as (IT+HVAC)/IT) is 1.88 for small server rooms. The PUE was estimated by Amazon Web Services as 1.2 for cloud data centers.[80] Using this estimate, moving small server room capabilities to the cloud reduces cooling and auxiliary energy consumption by 37%, or roughly 17,650 kWh per year ($1,765) per small server room. Additional energy savings are likely to manifest in the form of more efficient equipment, additional consolidation, etc., which will save additional energy invisible to the PUE score.

Outsourcing was not tested in this study. This is primarily because small server rooms from this study have IT staff responsible for maintaining equipment, and this staff would rather work towards making their server room run more efficiently than towards exporting their responsibilities offsite. Some sites are concerned with security or with losing direct control of server operations, and are therefore not interested in sending data to the cloud. While outsourcing servers will likely work as an energy savings opportunity for some businesses, others will prefer keeping their data on-site and in saving energy through other opportunities.

[80] Amazon Web Services. 2015. "Cloud Computing, Server Utilization, & the Environment." aws.amazon.com. https://aws.amazon.com/blogs/aws/cloud-computing-server-utilization-the-environment/ (retrieved May 5, 2017)

Implementation

Energy savings opportunities were identified at each of the three industrial sites that took part in this project. The results are shown in Table 54. Each site had reasonably similar recommendations. Increasing server room temperature is an easy to implement method to reduce energy consumption. Automatic equipment shutdown at nights and on weekends has been recommended at each site with savings estimates provided. Further discussion of this opportunity is discussed above. Consolidating UPS loading was another common opportunity that will save sites some energy and much more in avoided future equipment purchases. Consolidating and removing under-utilized servers will also result in small energy savings.

Table 54: Energy Savings Recommendations

	Recommendation	Annual Savings	Cost Savings	Implementation Cost Estimate	Status
9	Increase room temperature from 69°F to 77°F	5,670 kWh	$670 per year	0	Implemented
9	Balance and consolidate UPS load	438 kWh, 2 Fewer UPS purchases (future)	$40 per year $2400 (future equipment)	0	Implemented
9	Consolidate and remove idle servers	1,233 kWh	$120 per year	0	Implemented
9	Automatically turn off equipment at nights and on weekends	19,700 kWh	$1,575 per year	Unknown	Recommended
10	Increase room temperature from 68°F to 77°F	2,670 kWh	$335 per year	0	Implemented
10	Automatically turn off equipment at nights and on weekends	8,200 kWh	$650 per year	Unknown	Recommended
10	Consolidate UPS load	473 kWh, 3 Fewer UPS purchases (future)	$60 per year $3600 (future equipment)	0	Recommended
11	Increase room temperature from 74°F to 77°F	1,134 kWh	$90 per year	0	Recommended
11	Automatically turn off equipment at nights and on weekends	7,850 kWh	$625 per year	Unknown	Recommended
11	Re-orient servers such that cool air is directed towards the front and warm air is removed from the back.	Unknown	Unknown	0	Implemented

Conclusion

The typical server room from this study used an estimated 47,700 kWh per year in energy for IT and HVAC. The opportunities for energy savings have been consolidated into Table 55 to show the potential savings from each opportunity for the typical small server room in this study.

Table 55: Typical Small Server Room Energy Efficiency Opportunities

Opportunity	Annual Energy Savings (kWh)	Annual Energy Cost Savings ($)	Other Cost Savings ($)
Optimize Temperature Set Points	2,500	$200	$0
Optimize Server Utilization	1,000	$80	Unknown
Server and AP Automatic Scheduling	578	$46	$0
Optimize UPS Utilization	370	$30	$2,300
Cabling	Unknown	Unknown	$0
Airflow Management	Unknown	Unknown	$0
Total	4,448	$356	$2,300

Optimizing room temperature and server utilization have the largest potential for energy savings of the listed opportunities. The greatest cost savings for these small server rooms comes from UPS consolidation, where sites can eliminate extra UPSs and the corresponding equipment purchase cost.

The estimated overall (utility) energy savings potential for consolidating small server rooms into larger, more efficient data centers is shown in Table 56.

Table 56: Estimated Energy Savings by Consolidating Small Server Rooms into Large Data Centers

Opportunity	Annual Energy Savings (kWh)	Annual Energy Cost Savings ($)	Other Cost Savings ($)
Outsource Small Server Room to Cloud	17,650	$1,400	Unknown

Comparing the two tables shows that the greatest energy savings is expected when small server rooms are consolidated into large data centers. However, many sites prefer hosting their own server rooms, and there are simple opportunities for these sites to save energy as well.

There are 27,000 industrial manufacturing sites in Minnesota. The potential impact of applying the largest identified solutions at half of these sites is presented in Table 57.

Table 57: Minnesota Overall Energy Savings Potential

Opportunity	Annual Energy Savings per Site (kWh)	Annual Minnesota Energy Savings Potential (kWh)	Cost Savings at $.08/kWh
Increase Room Temperature to 77°F	2,500	33,750,000	$2,700,000
Increase Server Utilization to 50%	1,000	161,000,000	$12,880,000
Outsource Small Server Rooms to Large Data Centers	17,650	238,275,000	$19,000,000

This researcher recommends that utility account reps promote the opportunity to increase server room temperatures to 77°F with their clients. It is an extremely simple way for businesses with small server rooms to save approximately 2,500 kWh per site per year.

Additionally, a utility program to incentivize businesses with small server rooms to move their data to large, centralized server rooms is estimated to save a large amount of energy overall. This solution is somewhat more complex, however, as the larger data center may be in another utility's service area, which may make tracking savings difficult. Additionally, some small businesses have dedicated IT staff to run their server rooms whose positions may be jeopardized if their server room is outsourced. However, for sites who prefer to focus on their core business function and who consider data management a hassle, this type of change could conceivably provide a large benefit.

Appendix E: Device Inventory Form

Device Inventory Form

Room:

Server Rack:

	#	Make	Model	Type	Role
Example	7	HP	Procurve Switch 2610-48 (J9088A)	Switch	File Server
	42				
	41				
	40				
	39				
	38				
	37				
	36				
	35				
	34				
	33				
	32				
	31				
	30				
	29				
	28				
	27				
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	9				
	8				
	7				
	6				
	5				
	4				
	3				
	2				
	1				

Appendix F: SEDC Estimated Power Audit Sheet

SEDC Estimated Power Audit Sheet

Site: **Date:**

		Total no#
Servers	1S	
	2S+	
External Storage	HDD	
	SDD	
Switches	100 MB Ports	
	1000 MB Ports	
	10 GB Ports	
	40 GB Ports	
	100 GB Ports	
Routers		
Modems		
Appliances		

UPS	**Load (%)**	**Total Capacity (kVA)**