RESEARCH SUMMARY

Small Embedded Data Center Program Pilot

BACKGROUND

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, Cadmus Group, and Lawrence Berkeley National Laboratory to learn from their experiences with this sector.

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

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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)

- 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. These include 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 would 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 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
	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, as well as 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 be done with inexpensive temperature monitors, allowing 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. At most sites in this study 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 suggested energy efficiency measures to reduce the IT power loads for SEDCs and the 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
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 set point
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 to implementation 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 with 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, the 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, and emphasis should be placed on identifying opportunities to retain them. 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.

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