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New York State Data Center Market Characterization

Final Report

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New York State Data Center Market Characterization

Final Report

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Notice

Abstract

New York State Energy Research and Development Authority (NYSERDA) collaborated with the Cadmus Team to examine the data center market in New York State. The Cadmus Team conducted two surveys, the first was targeted at data center managers of commercial customers and the second was an in-depth survey of data center managers who are involved in New York State data center management. From the first survey the Cadmus Team estimated that there are approximately 200,000 data center spaces in New York State, the majority of which are server closets. The in-depth survey explored 32 different Energy Efficient Technologies and Best Practices (EETBPs) in IT, power infrastructure, air flow management, HVAC, and humidification. The in-depth survey sought to determine if data center managers had implemented or planned to implement EETBPs and to assess the manager's level of interest in EETBPs. It was found that IT EETBPs were most often implemented and data center managers and industry players also showed the most interest in IT EETBPs. Finally, the in-depth survey showed higher available savings if implementation barriers could be overcome.

The Cadmus Team, through a model, estimated that New York State is responsible for 8.3 percent of data center energy use in the United States with enterprise data centers and server closets and rooms dominating the energy use. The Business as Usual (BAU) Model showed that data center energy use will continue to increase if efficiency improvements are not implemented from approximately 7.6 million MWh in 2014 to 11.2 million MWh in 2020. The Cadmus Team also found that following a Best Practice Operation (BPO) scenario would result in a 44 percent reduction in energy use compared to a BAU scenario, a Best Practice Technology (BPT) scenario would result in a 68 percent energy reduction, and a Cutting-edge Technology (CET) scenario would result in a 71 percent energy reduction. The team concluded that the majority of the potential energy savings are economically viable because most of the EETBPs have a two-year or less payback period.

A review of the market trends showed that aside from the colocation sector, where the majority of data center managers and industry players house their IT equipment, New York State is not the most desirable location for the energy intensive data center. Nevertheless, New York State maintains a robust existing base of data center facilities, and market interventions may drive higher uptake of EETBPs.

Finally, the in-depth survey also determined that IT EETBPs were most frequently implemented by the finance, higher education, and healthcare centers. These sectors also expressed the most interest in IT EETBPs if they had not yet implemented them. The data center managers of these three sectors “always” or “often” considered energy efficiency and energy costs in their decision making process approximately 40 percent of the time.

Keywords

Data Center, Energy Efficiency, Energy Efficient Technology and Best Practices, Consumption and Load Growth Model, Data Center Infrastructure Management, Cloud Services, Virtualization, Utility-scale Data Center, Emerging Technologies, Co-location, Market Potential, Technical Potential, Overall Potential, Direct Liquid Cooling, Massive Array of Idle Disks, Passive Optical Network, Hot Aisle-Cold Aisle Configuration, Containment, Power Utilization Rate, Power Usage Effectiveness (PUE), Solid State Storage, Uninterruptible Power Supply, Variable Speed Drives, Adjusting Server Inlet Temperatures, Air-side Economizer, Containerized Data Center, In-row Cooling, Waste-heat Recovery, Latency

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Acronyms and Abbreviations List

AC	Alternating Current
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
AWS	Amazon Web Services
BAU	Business as Usual Model
BPO	Best Practice Operation (Scenario)
BPT	Best Practice Technology (Scenario)
BMS	Building Management System
CAGR	Compound Annual Growth Rate
CET	Cutting Edge Technology (Scenario)
CFD	Computational Fluid Dynamics
CHP	Combined Heat and Power
CPU	Central Processing Unit
CST	Customer-Sited Tier
DC	Direct Current
DCIM	Data Center Infrastructure Management
DOE	Department of Energy
EETBPs	Energy-efficient Technology and Best Practices
EPA	Environmental Protection Agency
ETAC	Emerging Technologies and Accelerated Commercialization (Program)
GB	Gigabytes
GDP	Gross Domestic Product
HDD	Hard Disc Drive
HVAC	Heating, Ventilation, and Air Conditioning
IaaS	Infrastructure as a Process
IDC	International Data Corporation
IoT	Internet of Things
IP	Internet Protocol
IPE	Industrial Process and Efficiency (Program)
IT	Information Technology
LEDs	Light Emitting Diodes
MAID	Massive Array of Idle Disks
MW	Megawatts
MWh	Megawatt-hours
NGO	Nongovernmental Organization
NYSERDA	New York State Energy Research and Development Authority
PaaS	Platform as a Service

PPA	Power Purchase Agreement
PUE	Power Usage Effectiveness
PV	Photovoltaic
ROI	Return on Investment
SaaS	Software as a Service
SSD	Solid State Drive
SVP	Silicon Valley Power
TB	Terabytes
TC	Technical Committee
UPS	Uninterruptible Power Supplies
VSDs	Variable Speed Drives
VoIP	Voice over Internet Protocol

Summary

The New York State Energy Research and Development Authority (NYSERDA) contracted with Cadmus to assess the energy efficiency opportunity and potential of data centers in the commercial and industrial market in New York State. The Cadmus team—Cadmus (primary contractor), Willdan Energy Solutions, Northwestern University, Bramfitt Consulting, Terra Novum, and AlterAction Consulting (collectively the Team)—conducted a comprehensive study that examined the data center market in New York State and included:

- Quantification of current data center energy use and energy savings potential through a model that forecasts estimated energy use from 2014 until 2020 through different energy-efficient technology and best practice (EETBPs) implementation scenarios.[1]
- Examination of the major market and industry trends affecting and driving data center demand.
- Assessment of implemented EETBPs and EETBPs' potential.

To augment the Team's technical research and understanding and gather primary data, the Cadmus team conducted two surveys. The first survey (first survey) targeted data center managers of commercial customers located in New York State. The second survey (in-depth interview) engaged, at length, data center managers and industry players [e.g. information technology (IT) vendors, value-added resellers, IT and facility consultants, service providers, and systems integrators] who are involved with and integral to New York State data center management.

The first survey was administered to 233 businesses in New York State. The Cadmus team used the results to estimate the number of data centers in New York State. As shown in Table S-1, the Cadmus team estimated roughly 200,000 data center spaces in New York State, the overwhelming majority of which are server closets.

[1] The inclusion of alternative power sources, such as fuel cells, solar power, and wind power as EETBPs are analyzed in Section 7:Market Trends, and are not modeled for their potential impact on data center energy use or consumption under any of the scenarios in this report.

Table S-1. Estimated Number of Data Center Types in New York State

Data Center Type	Number
Enterprise (white space[2] greater than 20,000 sq. ft.; at least 500 servers)	398
Mid-Tier (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1,109
Localized (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2,620
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	22,625
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	178,664
Total	205,416

The Cadmus team compared the research findings in Table S-1 to other calculated estimates of data center spaces nationally. The Team multiplied national estimates of the number of data center spaces by New York State's portion of gross domestic product (GDP), population, and commercial office space. The resulting estimates of the total number of data centers in Table S-1 (from the first survey) are within a 90% confidence interval of the calculated estimates resulting from the three alternate methodologies (as shown later in the report in Table 6.

The in-depth survey was an online survey that asked 90 questions covering a wide range of data center efficiency and other issues. Data center managers and industry players took the in-depth survey. The in-depth survey asked respondents to define the single data center they "know best" (familiar data center) and then answer specific questions about that familiar data center. Through this line of questioning, the Cadmus team was able to link all responses to its respective data center space type. The results of the in-depth survey informed the analysis of trends, EETBP implementation, and energy use at data centers in New York State.

S.1 Energy Efficient Technologies and Best Practices Opportunities

The in-depth survey covered 32 different EETBPs across five different categories: IT, power infrastructure, air flow management, HVAC, and humidification. The survey asked data center managers and industry players if they had implemented EETBPs or if they were planning to implement EETBPs. If they had not implemented or planned to implement EETBPs, the survey asked if they were interested in EETBPs.

[2] White space is generally defined as the total square footage inside the cooling envelope and includes server and storage racks, power supplies, and space between racks.

With this data, the Cadmus team determined the following about each EETBP:

- **Market potential** by examining the percentage of data center managers and industry players that were planning to implement or were interested in the EETBP.
- **Technical potential** (how much energy the EETBP could save) by examining the average EETBP energy savings as a percentage at the measure level, the portion of the data center load impacted by the EETBP, and the indirect savings from cooling benefits.[3]
- **Overall potential** by averaging the market and technical potential.
- **Opportunity portfolio grades,** escalating with higher overall potential and lower implementation rates, which reflected the ability of an EETBP to reduce load.

Using the in-depth survey results and subsequent EETBP analysis, the Cadmus team provides the following findings regarding EETBP implementation, interest, and opportunity, which are also shown in Table S-2 and Table S-3:

- **Implementation**: Data center managers and industry players implemented IT EETBPs more often than other types of EETBPs.[4] Led by high server virtualization implementation, IT demonstrated the largest EETBP uptake by data centers of all sizes. Not surprisingly, airflow management, HVAC, and humidification EETBPs have better implementation rates in larger data centers. Power infrastructure measures, with the exception of energy-efficient uninterruptible power supplies (UPSs), only show minor uptake by larger data centers. Survey participants reported implementing humidification measures the least frequently of the five EETBP categories.
- **Interest**: Data center managers and industry players showed the most interest in the IT EETBPs as well. Respondents expressed moderate interest in the majority of the other EETBPs. Mid-tier data centers expressed the most interest across all EETBP types. Enterprise, mid-tier, and localized respondents expressed interest in solar power for their data center.
- **Opportunity**: In the EETBP opportunity portfolio analysis, grades "A" through "E" were assigned denoting overall opportunity based on overall potential and the percentage of respondents that did not implement the EETBP. A higher grade was given to EETBPs with lower implementation rates and higher overall potential, as shown in Table 2 and (blanks in the table represent EETBPs that are not applicable to that particular data center type). In this EETBP portfolio analysis, EETBPs with the highest overall potential and lowest implementation rates, which suggests higher available savings if implementation barriers could be overcome, were highlighted.

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3 Cooling benefits refer to the energy savings associated with a decreased need for cooling.

4 IT EETBPs consist of IT equipment upgrades or IT solutions including for example decommissioning of unused servers, direct liquid cooling of chips, server power management, server virtualization, solid state storage, etc. For a complete list of EETBPs including IT EETBPs see table S-3.

- In larger data centers: Combined heat and power, solar power, direct current to the rack,[5] and air-side and water-side economization appear ripe for market assistance. The Cadmus team recognizes, however, that these EETBPs have technical and cost limitations.
- In server rooms and/or closets: Eight of the 12 EETBPs received an "A" or "B" letter grade, demonstrating that a host of energy savings opportunities are available even for these smaller facilities.

Table S-2. Grading Scheme of EETBPs

		Percentage of Survey Respondents That Did Not Implement EETBP in Their Data Center			
		0 to 24	25 to 49	50 to 74	75 to 100
Overall Potential	High	D	C	B	A
	Medium	E	D	C	B
	Low	E	E	D	C

5 This measure was misspelled in the survey and referred to as "Data Center current (as opposed to AC) to the racks." For consistency purposes, the information is reported as observed in the survey.

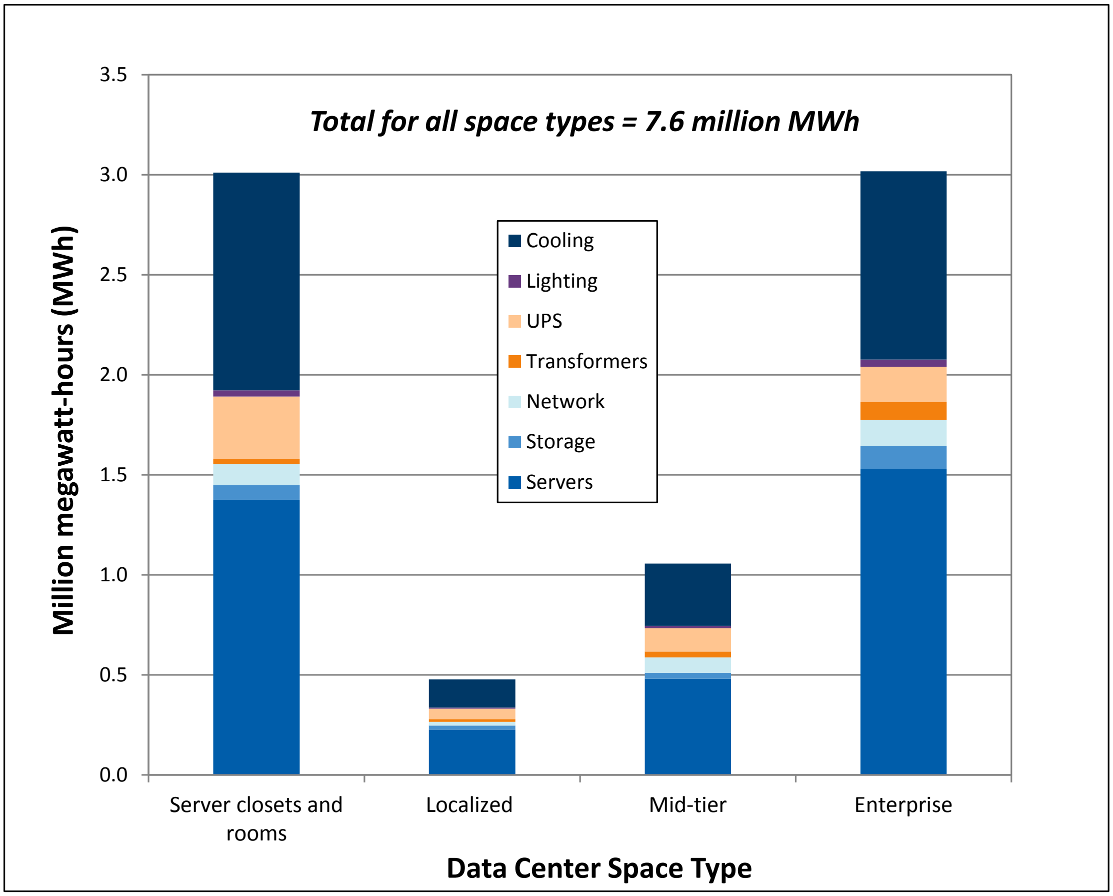
Table S-3. Evaluation of Data Center EETBP Opportunity by Space Type

	EETBP	Enterprise	Mid-Tier	Localized	Server Rooms & Closets
IT Equipment	Decommissioning of unused servers	C	C	C	C
	Direct liquid cooling of chips	C	C	C	
	Energy efficient data storage management	B	C	C	B
	Energy efficient servers	C	B	B	B
	Massive array of idle disks (MAID)	C	C	C	
	Passive optical network	B	B	B	
	Server power management	B	B	B	B
	Server virtualization/consolidation	D	C	C	C
	Solid state storage	B	C	C	B
Power Infrastructure	Combined heat and power	A	A		
	Direct current to the racks	A	B	A	
	Energy efficient power supplies (UPS)	C	C	B	B
	Polymer electrolyte membrane fuel cells	B	B		
	Solar power	A	A		
	Solid oxide fuel cells	B	B	B	
	Wind power	B	B		
Air Flow Management	Computational fluid dynamics optimization	C	C	C	
	Containment	B	C	A	B
	Hot or cold aisle configuration	E	E	D	
	Hot or cold aisle configuration plus containment	B	B		
HVAC	Adjusting server inlet temperatures	C	B	B	B
	Air-side economizer	A	B	A	
	Containerized data center	B	B	B	B
	Data Center Infrastructure Management (DCIM)	C	C	A	
	In-row cooling	E	D	D	
	Premium efficiency motors	D	D	C	D
	Variable speed drives on pumps/fans	E	D	C	D
	Waste heat recovery	B	B	B	
	Water-side economizer	A	A	A	
Humidity	Broaden humidity range	C	D	C	
	Install misters, foggers, or ultrasonic humidifiers	C	D		
	Turn off humidifiers	D	D	D	

S.2 Load Growth

The Cadmus team built a model to estimate the energy use of data centers in New York State during the years 2014 to 2020. The model examined the energy consumption of the four different data center types under a business as usual (BAU) scenario as well as different future EETBP adoption scenarios. As shown in Figure S-1, a total of 7.6 million megawatt-hours (MWh) per year is estimated to be consumed by data centers in New York State in 2014. This estimated total represents 8.3% of U.S. data center energy use according to recently published national estimates. As a percent of total NYS commercial load, this represents approximately 10% of net NYS commercial consumption.[6] The model estimated that enterprise data centers (due to the estimated number of servers per enterprise data center) and server closets and rooms (due to the estimated number of these smaller data center types) dominate the energy use. When developing this model, the Cadmus team hoped that specific energy use and efficiency data (e.g., Power Usage Effectiveness (PUE), IT load) could be used. However, most of the time, data center managers, were unaware of these values for their data centers.

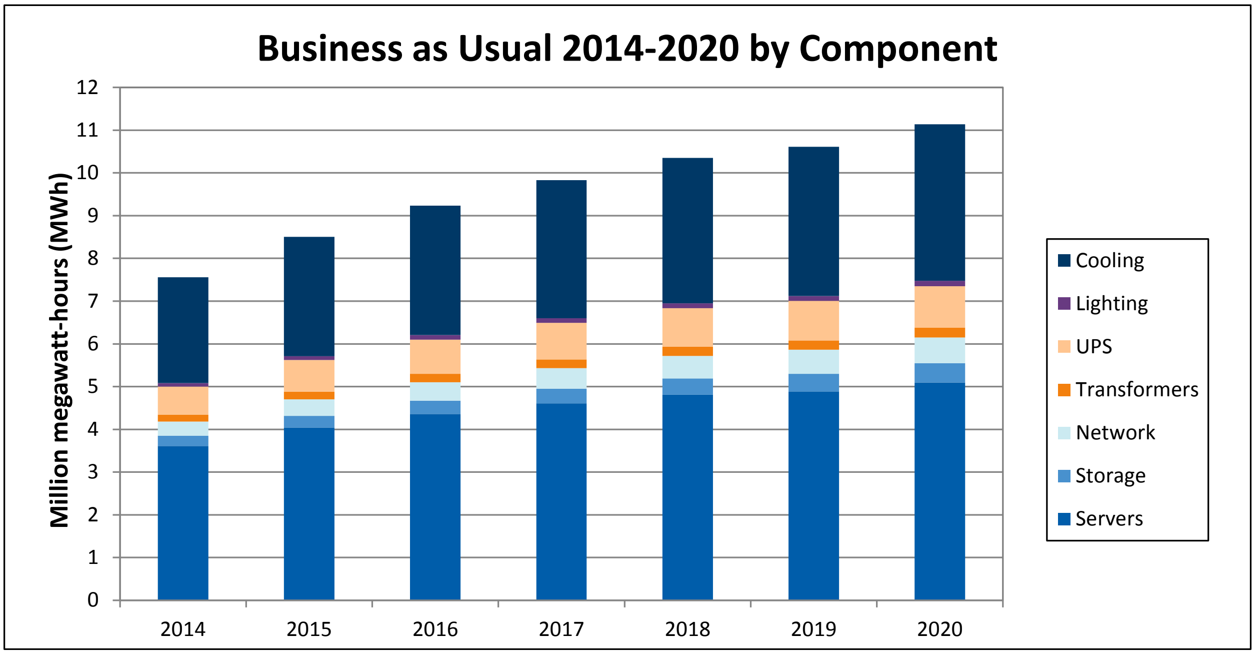
Figure S-1. Estimated 2014 New York State Data Center Energy Use



6 Patterns and Trends, New York State Energy Profiles: 1998-2012, p34. Table 3-10a, describing New York State Net Commercial Consumption of energy by fuel type, 1998-2012.

The Cadmus team modeled a BAU scenario, which assumed limited disruption in current market behaviors and included approximations of data center demand growth, performance, and energy use of future IT devices and IT device refresh rates. As shown in Figure S-2, the modeled trends in the BAU show that data center energy use will continue to rise in the absence of further efficiency improvements, from around 7.6 million MWh in 2014 to around 11.2 million MWh in 2020.

Figure S-2. BAU Projections for New York State Data Center Energy Use by Component



In addition to the BAU scenario, the Cadmus team examined three technology-based scenarios:

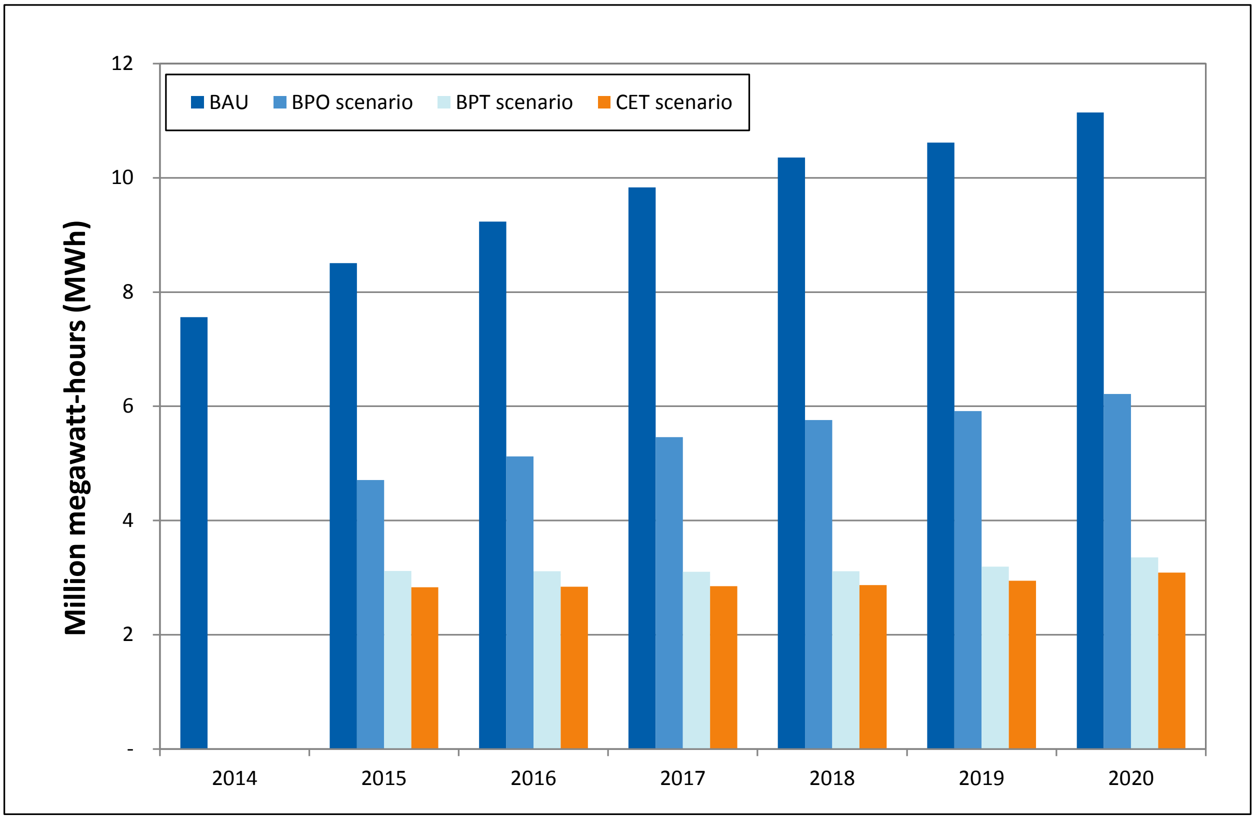
- Best practice operation (BPO) scenario: reducing energy use by changing existing equipment operation.
- Best practice technology (BPT) scenario: BPO plus the adoption of energy-efficient commercially available technology.
- Cutting-edge technology (CET) scenario: BPO and BPT plus the adoption of pilot or early commercial technology.

Figure S-3 shows New York State data center energy use in all four scenarios, assuming the facilities adopt specified EETBP measures regardless of their cost.

- The BPO scenario forecasts a 44% reduction in energy use across the entire projection period compared to the BAU scenario. This reduction is due to more efficient market average technology adoption through IT device refresh cycles in the BAU scenario.

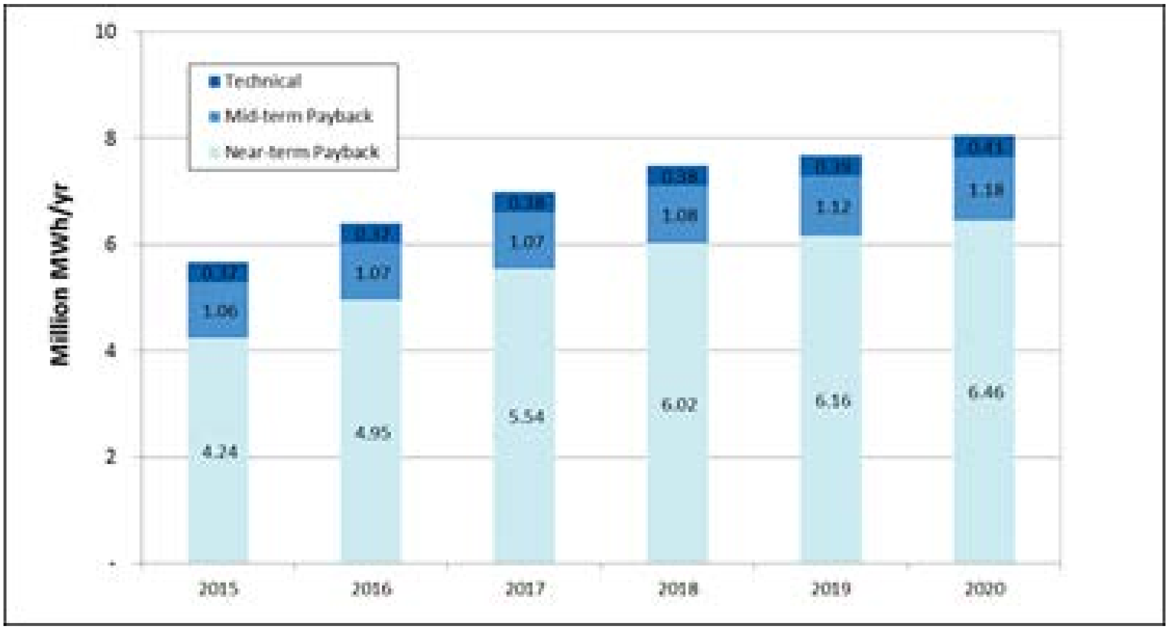
- The BPT scenario forecasts a 68% energy reduction in energy use across the entire projection period compared to the BAU scenario. This reduction is due to greater adoption of the most energy-efficient IT devices and infrastructure systems components.
- The CET scenario forecasts the reduction in total energy use by another 3% compared to the BPT scenario.

Figure S-3. Technical Potential Energy Use Projections (2014 to 2020)



Finally, as shown in Figure S-4, total technical potential savings was broken out by near-term payback potential (EETBPs with a payback period less than or equal to two years) and mid-term payback potential (EETBPs with a payback period greater than two years but less than or equal to five years). The remaining potential was considered a part of the overall technical potential. These results suggest that the vast majority of potential energy savings should be economically achievable in the near term because most of the EETBPs were estimated to have payback periods of less than two years.

Figure S-4. Technical, Mid-term Payback, and Near-term Payback Potentials for Energy Savings (Million MWh)



S.3 Market Trends

The Cadmus team focused its review of the major market trends by identifying which trends would inform policy decisions, promote energy efficiency, and attract and retain data center development. The review included the following eight major market trends:

- Data center market growth.
- Cloud services capturing an increasing portion of the IT market.
- Colocation sector growth.
- Utility-scale data center development.
- Data center site selection considerations.
- Emerging energy efficiency measures and technologies.
- Self-generation and wholesale market access.
- Nongovernmental organization (NGO), media, and regulatory attention regarding data center environmental impacts.

Some of these issues were explored through the in-depth survey. For example:

- Eighty-three percent (83%) of industry players and 74% of data center managers in New York State indicated the use of cloud services—mainly for data storage, web application management, and e-mail.
- Ninety-three percent (93%) of industry players and 55% of data center managers have their IT equipment in a colocation facility.

- Most data center managers believe they are keeping their locations in New York State. However, industry players were not as sure that their clients' operations would remain in New York State.

The review of market trends concluded that, New York State is a target for the colocation sector and the financial services industry. Opportunities exist for New York State customers to expand or migrate into colocation facilities or improve existing data center facilities and encounter similar cost and performance found in other geographic areas.

New York State has a robust existing base of data center facilities and the existing facilities are proximal to the businesses located in the region, which supports their continued operation. Market interventions may drive higher uptake of EETBPs in these facilities. These interventions, many used in other states and utilities, could include the following actions:

- Offering a sales tax exemption for purchases of servers, communications equipment, and in some cases power delivery and conditioning equipment, like a host of other states (e.g., Arizona, North Carolina Alabama, Virginia, and Texas).
- Extending access to wholesale electric markets for smaller data center facilities less than 1 MW of load.
- Providing publically-funded energy efficiency programs, that include:
    - Offering education, training, and certification programs, and trade ally partnerships. Many utilities (e.g., Seattle City Light, Sacramento Utility District, and Duke Energy) report that education and training programs drive rebate program participation.
    - Focusing on programs that address market niches such as embedded data centers (server rooms and closets). Utilities on the west coast are developing programs for small data centers based on a market evaluation completed in 2014.
- Conducting emerging technology evaluation and demonstration efforts that can lead to new incentive program offerings and proof to customers that new technologies can work in the data center environment. NYSERDA has supported emerging technology projects, as have California investor-owned utilities, Duke Energy, and the Energy Trust of Oregon.
- Allowing sub-metering and pass-through energy charges for multi-tenant data centers (retail colocation facilities). California utilities allow sub-metering for a very limited class of customers and may extend the tariff to data center operators.

S.4 Finance, Higher Education, and Healthcare Sectors

The Cadmus team examined the in-depth survey responses of data center managers in the finance, higher education, and healthcare commercial sectors about their understanding of the NYSERDA program, implementation and interest in EETBPs, decision making factors and barriers, and attitudes toward market trends (e.g., cloud, colocation, and plans for staying in New York State). The in-depth survey provided results for 24 financial services firms, 20 colleges and universities (colleges/universities), and 10 hospitals. The Cadmus team's findings include:

- IT EETBPs were, by far, the most frequently implemented type of EETBP, with server virtualization/consolidation and decommissioning of unused servers as the most frequently implemented.
- Data center managers from the three commercial sectors that had not yet implemented an EETBP expressed the most interest in IT EETBPs—particularly server virtualization/consolidation, server decommissioning, energy-efficient servers, data storage management, solid state storage, and server power management.
- Data center managers in all three sectors consider energy efficiency and energy costs in their decision making process "always" or "often" at least 40% of the time.
- Data center managers from all three sectors were not knowledgeable of their IT loads or their data centers' PUEs.
- Hospitals appeared to use cloud services more frequently than college/universities and financial services. Financial services had a particularly high use of the colocation services due to space and power constraints. Latency was more of a concern for the financial sector.
- All hospital and virtually all colleges/universities data center managers indicated they were keeping their data centers in New York State. However, 25% of financial services indicated they were moving data center operations out of New York State.

1 Introduction

Data center energy consumption is no longer a concern of just people in the energy efficiency community. In 2012, this issue earned widespread recognition on the front page of *The New York Times* in an article titled, “Pollution, Power, and the Internet: Industry Wastes Vast Amounts of Electricity, Belying Image.” A 2011 study by Professor Jonathan Koomey, prepared at the request of *The New York Times*,[7] estimated data center energy to be 2% of United States (U.S.) energy use, a percentage that has continued to grow.

However, data centers have tremendous opportunities to save energy. For example, CoreSite and Digital Realty Trust, two of the largest colocation providers in the country, announced that they are the only data centers that have joined the White House’s Better Buildings Challenge and have committed to reducing energy consumption by 20% between 2011 and 2020.[8] New York State, with a large number of commercial buildings and a thriving financial sector, one of the largest concentrations of data centers in the U.S. [9]

NYSERDA, through its Industrial Process and Efficiency Program, has allocated over $100 million to help improve the energy efficiency of the industrial sector (which includes data centers) through incentive programs targeted at that market sector. NYSERDA contracted with Cadmus to assess New York State’s current and predicted (through the next five years) data center energy use, trends driving data center load growth, and data center energy savings opportunities. In addition to Cadmus, the team included Willdan Energy Solutions, Professor Eric Masanet of Northwestern University, Mark Bramfitt of Bramfitt Consulting, Terra Novum, and AlterAction Consulting.

To assess the energy efficiency opportunity and potential of data centers, the Cadmus team needed to clearly define the market as there are numerous definitions of a data center space. Data centers can range from a storage room with a single server cooled by a common household box fan to an entire building that houses a “utility-scale“ data center with 10 megawatts (MW) of IT load, industrial-sized chillers, and cooling towers that keep the space temperature-controlled. These two examples illustrate the extreme

7 Koomey, JG. 2011 Growth in Data center electricity use 2005 to 2010. Oakland, California; Press A (Series Editor).

8 Colocation facilities allow customers to leases space (everything from a space within a rack to an entire floor) for their IT equipment. Cooling and power is provided by the colocation facility.

9 A recent study indicated that Northern Virginia was going to overtake New York in 2015: http://www.datacenterknowledge.com/archives/2014/09/25/n-virginia-set-to-become-biggest-data-center-market-by-2015

variability within the data center space. A storage room with a single server and a utility-scale data center differ in several important ways: the number of customers in New York State (tens versus hundreds of thousands), the potential efficiency opportunities (hundreds of watts per site versus MWs per site), and the market trends that will affect their future growth.

To address the variability of data center spaces, the Cadmus team defined specific data center space types and studied them individually. In addition, the Cadmus team surveyed NYSERDA's customers (notably data center managers and consultants used to run data centers in New York State) and used the results to augment the team's existing technical research and understanding.

This report describes the following activities that the Cadmus team performed to conduct this study:

- An estimate of data center IT load.
- An assessment of EETBPs used in data center space.
- The development of a model that projects energy consumption and load growth.
- An examination of data center market trends.
- A closer look at three specific commercial sectors – higher education, finance, and health care.
- An annotated bibliography that identifies high-level data center market studies.

2 Methodology

The scope and scale of this study were broad. This section reviews the methodologies that the Cadmus team used to establish data center load, the scale of EETBP use, load projection models, market trends, and the annotated bibliography in Appendix A.

Survey of New York State Organizations

To establish the number of data centers in New York State, the Cadmus team conducted a random survey of New York State businesses. Table 1 summarizes a list of business contacts representing five different organization sizes based on employee size that purchased from Dun and Bradstreet.

Table 1. Contact Lists by Organization Size

Business Type	Number of Employees	Number of Contacts
Micro	1-4	1,000
Small	5-49	500
Medium	50-499	500
Large	50-999	500
Enterprise	1,000+	500

For each organization-type list, Cadmus team made random calls to connect with the proper IT contact and ask the following questions:

- Do you have a data center space in New York State?
    - If so, how many of the following data center space types do you have in New York State?
        - Enterprise (white space greater than 20,000 sq. ft.; at least 500 servers)
        - Mid-Tier (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)
        - Localized (white space 500 to 1,999 sq. ft.; 25 to 99 servers)
        - Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)
        - Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)
- Do you know how many servers your data center space has?
- Do you have space in a colocation facility?
- Do you have an IT manager and, if so, could you please provide his or her contact information?

As shown in Table 2, compared to their relative frequency in New York State, the enterprise, large, and medium organization sizes were oversampled because the larger organizations were more likely to have data center spaces than organizations with fewer than 50 employees (small and micro organizations). The team met all of the targets for completed surveys with the exception of medium-sized organizations, where completes were short by four organizations.

Table 2. Organization Sizes Surveyed in New York State

Organization Type (Number of Employees)	Number of Organizations in New York State	Number of Organizations Randomly Drawn for Sample	Number of Surveys Completed	Targeted Sample Size
Micro (4 or fewer)	776,031	1,000	51	41
Small (5-49)	161,812	500	48	34
Medium (50-499)	15,761	500	61	65
Large (500-999)	909	500	37	35
Enterprise (1,000+)	984	500	36	35
Total	955,497	3,000	233	210

After completing the telephone surveys, the contacts were also asked if they would be willing to take an additional 30-minute survey online to answer more detailed questions about energy efficiency and their data centers.

2.1 In-Depth Survey of Data Center Managers and Industry Players

The Cadmus team conducted a 30-minute survey (in-depth survey) using an online survey application called Qualtrics. Respondents could complete the survey on a computer, tablet, or smart phone. A $50 Visa gift card was offered as an incentive to participate in the online survey.

The Cadmus team designed the online survey to gather more details and to gain a better understanding of the data center market in New York State and the potential energy efficiency opportunities. In addition to the contacts from the random telephone survey of New York State organizations, the Cadmus team targeted people who were responsible for either IT operations, facilities operations, or both (data center managers) as well as IT vendors, value-added resellers, IT consultants, service providers, and systems integrators (industry players). The Cadmus team worked to achieve target sample sizes by data center size, industry segment, and industry player group.

From past experience issuing surveys in the IT field, the Cadmus team recognized the value of leveraging IT conferences as a productive venue to encourage participation in the in-depth survey. Face-to-face interaction with data center managers and industry players proved to be an effective method for administering a more detailed survey. The Cadmus team administered the in-depth survey at the following conferences:

- Data Center Dynamics on March 12, 2014
- Bloomberg Enterprise Technology Summit on April 24, 2014
- Telx on June 5, 2014
- Agrion Disrupt Event on June 11, 2014
- Telecom Exchange on June 25, 2014
- Schools, Colleges, and Universities: A Construction Report Card on September 11, 2014
- iHT2 Health IT Summit on September 16-17, 2014

In addition to these conferences, the Cadmus team also worked with the following organizations to distribute the in-depth survey:

- New York 7x24 Exchange
- State University of New York Binghamton Center for Energy-Smart Electronic Systems
- Cushman & Wakefield

Table 3 and Table 4 show the number of targeted and completed in-depth surveys for data center managers. The in-depth survey was targeted equally across the respective data center space sizes (with server rooms and closets considered a single size type). In addition, per NYSERDA's request, the Cadmus team targeted a minimum number of financial services, higher education, and hospital data center managers to complete the in-depth survey (Table 4).

Table 3. Size Targets for In-Depth Survey of Data Center Managers

Data Center Space Type	Number Completed	Number Targeted
Enterprise (white space greater than 20,000 sq. ft.; at least 500 servers)	20	17
Mid-Tier (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	25	18
Localized (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	21	18
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	24	18
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	4	
Total	94	71

Table 4. Commercial Sector Targets for In-Depth Survey of Data Center Managers

Data Center Industry Type	Number Completed	Number Targeted
Financial Services	24	18
Higher Education	20	18
Hospitals	10	18
Total	54	54

Table 5 shows the targeted number of in-depth surveys for industry players. Interested in understanding the difference between industry players and data center managers, the Cadmus team targeted industry players (focused on IT equipment and/or power and cooling infrastructure) who specialize in particular data center space types. For these industry player surveys, the survey targets for localized data centers were not met. However, the survey targets for smaller data centers (server rooms and closets) and especially larger data centers (enterprise and mid-tier) were met. Many of the surveyed industry players provided IT and facility-focused data center services.

Table 5. Targets for In-Depth Survey of Industry Players

Data Center Space Type Serviced by Industry Players	Number Completed (IT-Focused)	Number Targeted (IT-Focused)	Number Completed (Facility-Focused)	Number Targeted (Facility-Focused)
Enterprise (white space greater than 20,000 sq. ft.; at least 500 servers) Mid-Tier (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	16	7	23	7
Localized (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4	7	5	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers) Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	8	7	10	7
Total	28	21	38	21

The in-depth survey helped to characterize the market by providing the following:

- Insight into the NYSERDA's existing data center energy efficiency incentive program.
- Reasons for using and not using cloud and co-location services.
- Factors limiting and helping to expand IT operations in New York State.
- The number of data center spaces operated by companies of different sizes and types and some general information about these spaces.
- In-depth information about a single data center space with which respondents were most familiar, including:
    - Total IT load.
    - Challenges with implementing energy efficiency measures.
    - Implementation status and interest in a series of data center efficiency measures.
    - Specific power draws and status of efficient practices with servers, network switches, data storage, power infrastructure, and cooling.

2.2 Energy Efficient Technology and Best Practices

Section 5 provides a high-level overview of the major trends, technologies, and technology opportunities within the data center market—particularly those relevant to the market in New York State. In addition to information gathered from the in-depth surveys of data center managers and industry players, Section 5 includes insight gathered from supplemental primary and secondary research, data center program implementation experience, and conversations with technical subject matter experts.

2.3 Consumption and Load Growth Model

The Cadmus team developed a model to estimate the energy use of data centers in New York State from 2014 to 2020. The model estimates energy use for different data center types, under different future scenarios that include the adoption of EETBP. The model is based on an existing mathematical model of data center energy use in the U.S. and technical potentials for efficiency improvements; the model was originally developed for the U.S. Environmental Protection Agency's 2007 *Report to Congress on Server and Data Center Energy Efficiency*. A limitation of the existing model was that it estimated technical potentials in static fashion. More specifically, it enabled analysis of "before" and "after" cases for efficiency improvements, but did not explicitly consider the timescales or costs of efficient technology adoption. The Cadmus team expanded the model to accommodate timescale and cost of efficient technology. To accommodate this functionality, the model was expanded to include IT device stock turnover, temporal projections based on demand growth, and typical payback periods for EETBP. More detail on the model can be found in Section 6.

2.4 Major Market Trends Assessment

Section 7 provides a high level overview of the major trends affecting the data center market—particularly those relevant to the market in New York State. In addition to secondary research and information gathered from the in-depth survey of data center managers and industry players, the market trends section included insight gathered from high-level management personnel at high-tech companies.

2.5 Identify Data Center Market Studies

To provide NYSERDA with an overview of the available research on data center energy efficiency, the Cadmus team identified reports, studies, and white papers from experts in the industry, higher education, and government; the information included in the annotated bibliography, located in Appendix A, contains thorough information on data center trends and efficiency measure implementation through March. For each entry, the bibliography contains a summary and key takeaways from the study. For all entries, the Cadmus team determined that:

- **The information is still relevant.** The data center industry moves much more quickly than other industries (e.g., servers have product life cycles of one to two years). If a report was written more than three years ago, special care was taken to ensure that the information remains relevant.
- **The information is unbiased.** Data center energy efficiency is a relatively new field. As such, there are information gaps where certain areas need further study. The annotated bibliography includes industry white papers and technical bulletins, but it does not include material that appeared to be "content marketing"—that is, where industry players issue detailed "white papers" or "technical bulletins" that served to inform readers, but also promote specific products.

3 Current NYSERDA Data Center Program

During the in-depth survey of data center managers and industry players (see Section 2.2), the survey asked, generally, about respondents' awareness of NYSERDA's Industrial Process and Efficiency Program (IPE Program) offering. The results presented in Figure 1, Figure 2, and Figure 3, although far from a comprehensive evaluation of the program, offer insight into the data center community's awareness of the program, how it heard about the program, and how to best promote the program.

As shown in Figure 1, many more industry players (over 70%) were aware of the data center incentives than the data center managers (less than 50%).

Figure 1. Familiarity with NYSERDA Data Center Program

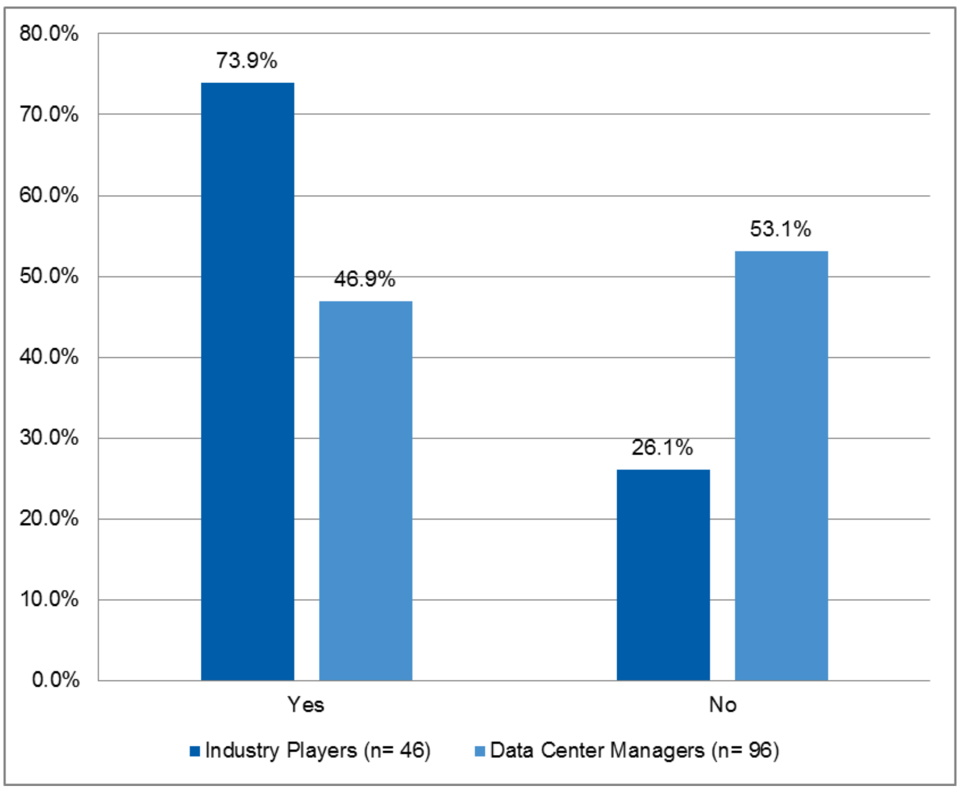


Figure 2 shows the manner in which industry players and data center managers heard about NYSERDA's IPE Program (more than one response was allowed). Industry players and data center managers most frequently responded that they learned about the program through in-person meetings, webinars, and presentations. In addition, respondents listed e-mail/newsletters, word of mouth, and the website as a popular means of hearing about the program.

Figure 2. Means of Hearing about NYSERDA Data Center Program

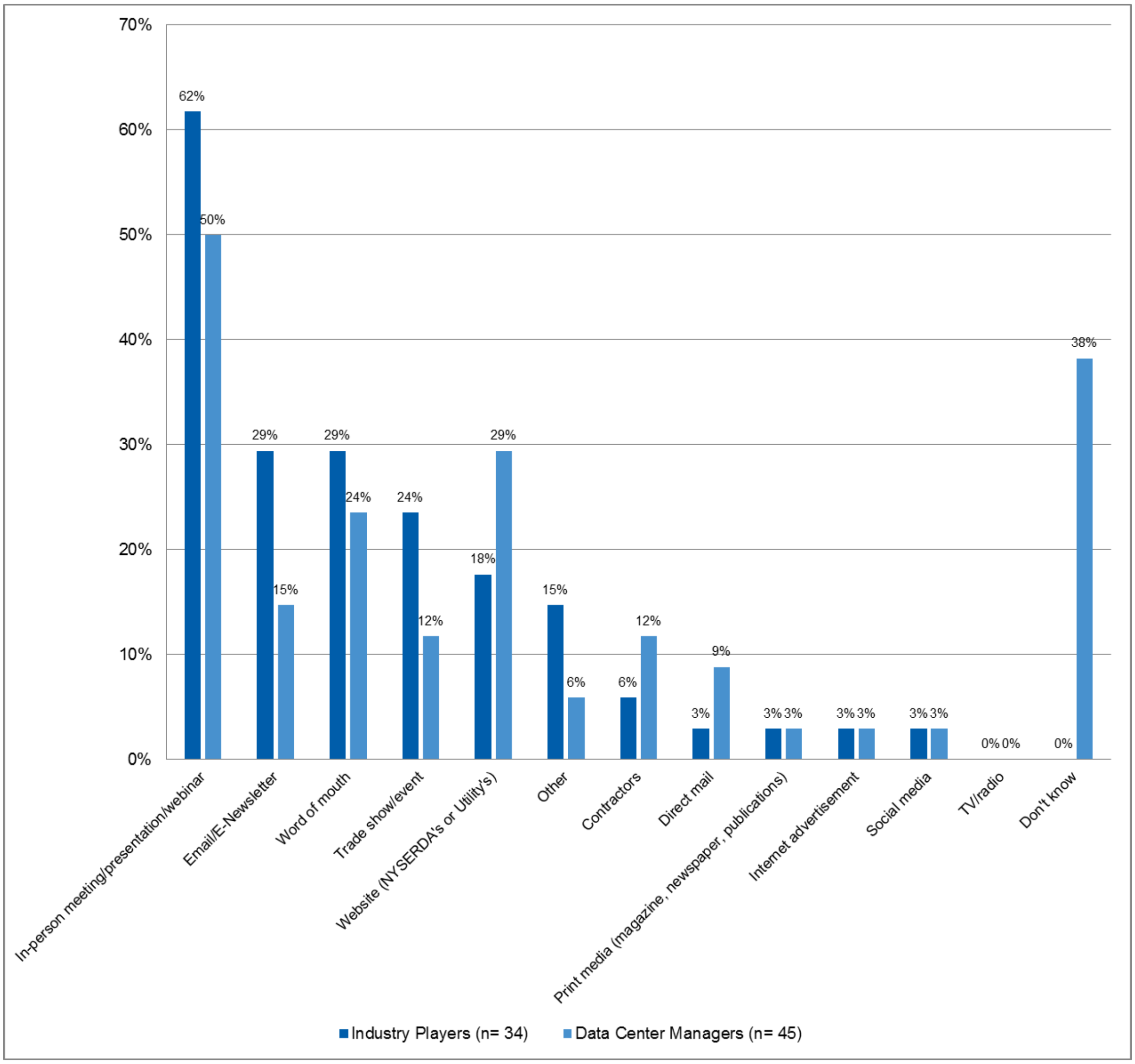
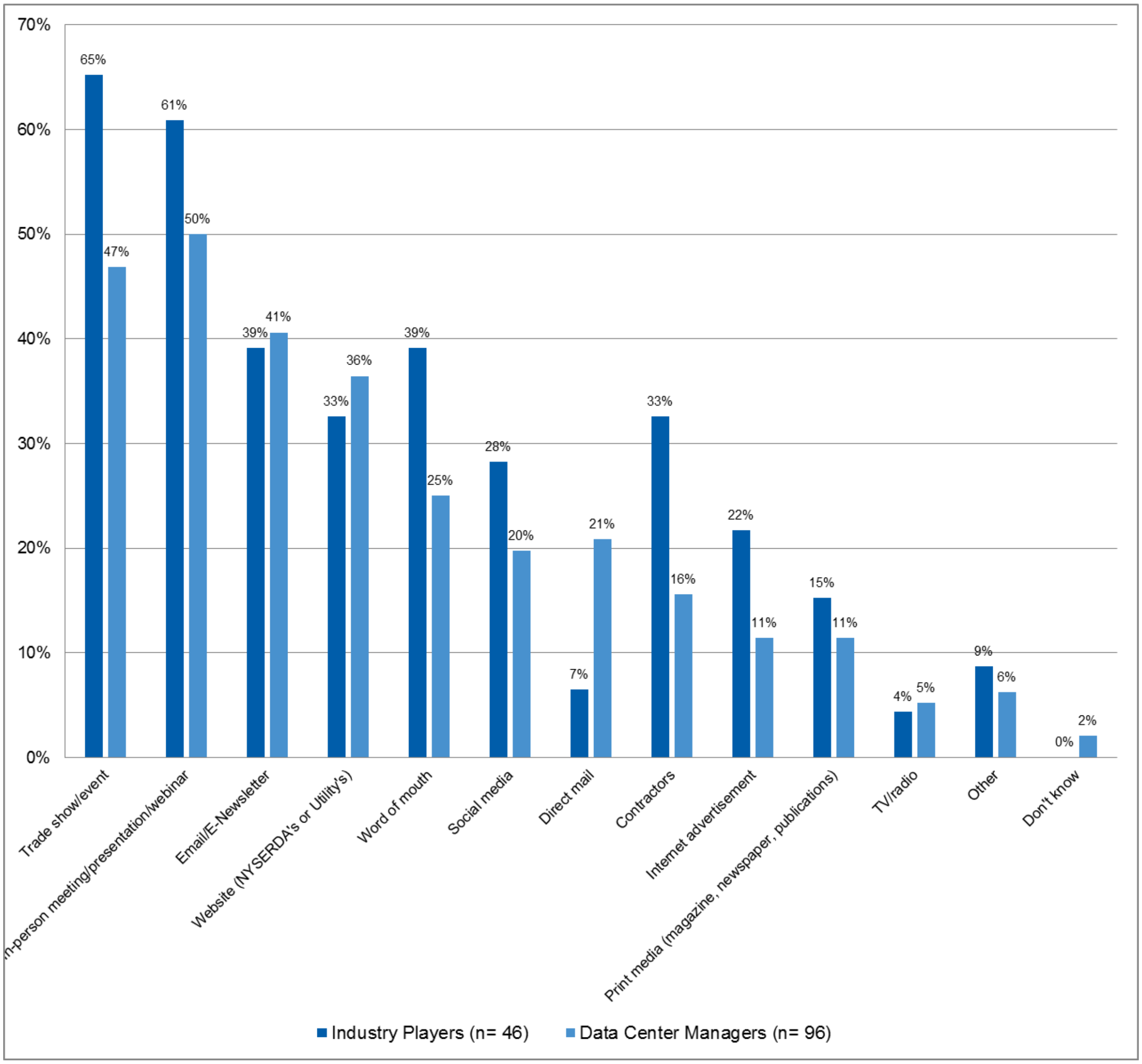


Figure 3 shows the methods that data center managers and industry players chose for promoting NYSERDA IPE Program. Respondents from both groups most frequently chose the following methods for promoting the program:

- In-person meetings, webinars, and presentations.
- Trade show/event.
- E-mail/newsletter.

Figure 3. Recommended Means to Promote NYSERDA Data Center Program



4 Number of Data Centers in New York State

The Cadmus team used the results of the first (random) survey of New York State businesses (described in Section 3.1) to estimate the number of data center spaces in New York State. For each of the five organization sizes surveyed, the Cadmus team learned the percentage of organizations that had a data center space in New York State. In addition, the team were able to determine the average number of data center spaces (of a particular size) for each organization size. With this data, the number of data centers was estimated in the following manner:

$$\#\mathrm{DC}_{\mathrm{st}} = \sum_{t,i} \%t_{\,t\,,i} * \left(\frac{DC}{Org}\right)_{t,i} * \#Org_i$$

Where:

#DCs$_t$	=	the number of New York State data center spaces of size *t*
%$t_{t,\,i}$	=	percentage of organizations in New York State of size *i* that have data center spaces of size *t*
(*DC/Org*)$_{t,\,i}$	=	the number of New York State data center spaces of size *t* per organization of size *i* that have data center spaces
#Org$_i$	=	the number of organizations of size *i* in New York State
t	=	size categories which were equal to:

- Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers).
- Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers).
- Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers).
- Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers).
- Server Closets (white space less than 100 sq. ft.; fewer than 5 servers).

i = size categories of organizations which were equal to:

- Micro (4 or fewer employees).
- Small (5-49).
- Medium (50-499).
- Large (500-999).
- Enterprise (1,000 or more).

Table 6 shows the result of the model estimate. Based on the survey of New York State businesses, the Cadmus team estimates that roughly 205,416 data center spaces exist in New York State (with a 90% confidence interval between 117,969 and 292,863 data center spaces). By far, the server closet is the most prevalent type of data center space type.

The Cadmus team compared these estimates for each data center type to national estimates of the number of data center spaces in the U.S.,[10] multiplied by the (1) portion of the U.S. gross domestic product (GDP), (2) population, and (3) commercial office space located in New York State.

These comparisons in Table 6 show that at least one of the national data center estimates adjusted for New York State are within the 90% confidence interval for all data center space types except for localized data centers and server rooms (where the survey-based number is low). In general, the data seem to show that there are more server closets than to be expected when compared to the national data. Given the premium for real estate in New York City, perhaps data center managers distribute their servers to many smaller spaces rather than a single larger space.

Table 6. Number of New York State Data Centers by Type (Includes Three Additional Methodologies)

	NYSERDA Survey Results				National Data Used as Basis for NY State		
Data Center Type	**Estimate Based on Survey**	**Precision [11]**	**90% confidence interval - Low**	**90% confidence interval - High**	**Estimate Based on % GDP**	**Estimate Based on % Office Space**	**Estimate Based on % Population**
Enterprise	398	39%	242	555	694	696	540
Mid-Tier	1,109	38%	687	1,530	795	797	619
Localized	2,620	15%	2,237	3,002	5,619	5,637	4,374
Server Rooms	22,625	17%	18,789	26,462	105,900	106,230	82,427
Server Closets	178,664	46%	96,014	261,314	120,111	120,486	93,489
Total	205,416	42%	117,969	292,863	233,119	233,846	181,448

[10] Villars, Richard, International Data Corporation (IDC), "U.S. Datacenter Census and Construction 2013 -1017 Forecast", October 2013, Table 1.

[11] In general, precision defines the absolute or relative range within which the true value is expected to occur within a specified level of confidence. We are 90% confident that the total number of data centers is between 117,969 and 292,863. 90% confidence interval equals estimate ± precision*estimate or 205,416 ± 0.42*205,416

5 Analysis of Energy-Efficient Technologies and Best Practices

This section and analysis is based on the in-depth surveys of data center managers and industry players (see Section 2.2). The survey asked participants to identify a data center with which they are familiar in New York State (familiar data center) and define the space type for their familiar data center based on the criteria in Table 7. Respondents answered a series of questions about their familiar data centers regarding implementation of and interest in 32 EETBPs. The survey also asked participants questions regarding decision-making factors and barriers related to energy consumption and energy efficiency in their familiar data centers.

Table 7. Data Center Space Type Definitions[12]

Space Type	Typical White Space Floor Area (ft^2)	Typical IT Devices
Server closet	less than 100	Fewer than 5 servers; minimal external storage
Server room	100 to 999	5 to 24 servers; minimal external storage
Localized data center	500 to 1,999	25 to 99 servers; moderate external storage
Mid-tier data center	2,000 to 19,999	100 to 499 servers; extensive external storage
Enterprise data center	greater than 20,000	At least 500 servers; extensive external storage

The section describes potential impacts to data center load, usage of technology and practices in the market, and implementation barriers. This section also includes a general description of information from the in-depth survey that is applicable to this task, the categories by which the analysis was conducted, desired outcomes, and an overview of each subsection. For this analysis, the Cadmus team aimed to achieve the following goals:

- Define the EETBPs included in the survey and analyzed in the study.
- Understand the current market penetration of and interest in a variety of data center EETBPs within the four[13] different data center space types.
- Enhance the understanding of what enables or prevents the installation of energy-efficient technologies in the data center.
- Assess the energy savings potential of the 32 EETBPs.
- Create EETBP opportunity portfolios for each of the four data center space types.

12 Data center size categories defined in "U.S. Data Center Census and Construction 2013-2017 Forecast," October 2013, International Data Corporation (IDC).

13 For this analysis, server room and server closets were collapsed into a single category.

The following subsections describe the analyses that the Cadmus team performed as a part of this task:

- **EETBP Definitions.** A description of the 32 EETBPs discussed throughout this report is provided.
- **Analysis of EETBP Implementation and Interest Levels.** The Cadmus team analyzed the survey results regarding implementation of and interest in EETBPs for the respondent's familiar data center. The results from both the data center managers' and industry players' surveys were broken into the four data center types (enterprise, mid-tier, localized, and server rooms and closets) based on how the respondents categorized their familiar data center.
- **EETBP Energy Savings Potential and Opportunity.** The Cadmus team assessed the overall potential for each EETBP to save energy and impact data center load in New York State. EETBP opportunity was estimated by examining market potential, technical potential, and degree of implementation.
- **EETBP Decision-Making Factors and Barriers.** The Cadmus team analyzed the survey results for six questions related to energy efficiency decision-making factors and barriers. Where applicable, Cadmus presented and broke down the results from the data center manager and industry player surveys into the four data center types to show how size and perspective impacted concerns and attitudes.
- **EETBP Conclusions.** The Cadmus team drew on the findings from all of the previous subsections to provide conclusions and recommendations.

5.1 Energy-Efficient Technologies and Best Practices Definitions

The in-depth survey asked questions about a number of EETBPs to data center managers and industry players. To combine EETBPs with similar purposes, the Cadmus team grouped the 32 EETBPs into the following five technology or system type categories:

- IT.
- Power Infrastructure.
- Airflow Management.
- HVAC.
- Humidification.

The following subsections define all of the EETBPs within these five categories.

5.1.1 IT Energy-Efficient Technologies and Best Practices

IT EETBPs reduce the energy consumed by servers, storage, and network equipment in the data center.

Decommissioning unused servers removes servers not being used for productive work from the data center. Eliminating unproductive servers directly lowers energy consumption from IT equipment and indirectly lowers energy consumption from cooling equipment.[14]

Direct liquid cooling of chips cools IT equipment components—such as the central processing unit (CPU)—with a precision cooling system that continually circulates a cool or warm liquid to heat transfer plates or coils located on or within racks or servers.[15] Much of the cooling required in data centers is used to cool CPUs and other computing components, which fail when they overheat. The copper-based heat transfer plates are bolted to the CPUs and attached to two tubes. One tube brings cool or warm liquid in to the heat absorber, while the other tube sucks the hot liquid away from the CPU. The liquid keeps the copper element cool, which in turn keeps the CPU cool. Liquid cooling systems drastically reduce the amount of energy required for cooling.

Energy-efficient data storage management allows data to be stored more efficiently by using technology such as:[16]

- Data de-duplication, which removes unnecessary files, reduces the storage footprint, and reduces the need to buy more storage disks that would consume energy.
- Thin provisioning, which allocates storage only when it is used (instead of overprovisioning to avoid running out of space); this requires fewer servers and less power.
- Tiered storage, which automatically places information rarely-accessed in higher latency equipment that uses less energy.
- Automated storage provisioning, which improves storage efficiency by automatically right-sizing and reallocating unused storage.

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14 Uptime Institute. *Important to Recognize the Dramatic Improvement in Data Center Efficiency*. September 25, 2012. blog.uptimeinstitute.com/2012/09/important-to-recognize-the-dramatic-improvement-in-data-center-efficiency/

15 Coles, Henry and Greenberg, Steve. "Direct Cooling for Electronic Equipment." Ernest Orlando Lawrence Berkeley National Laboratory. Environmental Technologies Division. March 2014. http://eetd.lbl.gov/sites/all/files/direct_liquid_cooling.pdf

16 U.S. Environmental Protection Agency. "Better Management of Data Storage." https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_storage_mgmt

Energy-efficient servers (new load or refresh) implies the process of decommissioning older, inefficient servers and replacing them with new, energy-efficient servers. Commonly, new servers can also process more information using the same amount or energy or less, resulting in process efficiency improvements. Installing energy-efficient servers directly lowers energy consumption from IT equipment and indirectly lowers energy consumption from cooling equipment. New, energy-efficient servers consume less energy than older servers through the use of more energy-efficient technology such as:[17]

- Energy-efficient components like power supplies, CPUs, voltage regulators, and internal cooling fans.
- Power-saving technology that allows CPUs to dial-up and dial-down depending on workload and reduces voltage when idle.
- New operating systems that optimize power usage of separate computational workloads.

Massive array of idle disks (MAID) is a storage technology that only spins storage disks when they are in active use, rather than traditional storage disks that continually spin drives even when data is not being accessed. MAIDs only require power to spin disks when actively in use, therefore reducing energy consumption.[18]

Passive optical network uses optical fiber cabling to bring data directly to the end user, rather than active networking, which uses switch gear to route data to end users. Passive optical networking eliminates the need for electric-powered switch gear and reduces overall data center energy consumption.[19]

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17 U.S. Environmental Protection Agency. "Purchasing More Energy-Efficient Servers, UPSs, and PDUs." https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_purchasing

18 Rouse, Margaret." Massive Array of Idle Disks (MAID)." TechTarget. January 2009. http://searchstorage.techtarget.com/definition/MAID

19 Zhang, Yi et al. "Energy Efficiency in Telecom Optical Networks." IEEE Communications Surveys and Tutorials, Vol. 21, No. 4, Fourth Quarter, 2010. http://learn.tsinghua.edu.cn:8080/2007310303/Energy_Efficiency_in_Telecom_Optical_Networks.pdf

Server consolidation combines workloads such as applications running on multiple servers and consolidates them to run on a smaller number of applications and servers. Through server consolidation, heterogeneous and multiple workloads can be consolidated onto fewer servers and multiple applications (such as email systems) can be combined into one system.[20] Similar to virtualization, consolidation allows fewer servers to do the same amount of work, thus saving energy used by IT and cooling systems.

Server power management is an integrated platform that allows data center operators to manage system-level processor and memory subsystem power consumption data. IT managers are able to define policies to power down idle servers and/or automatically limit power usage at the system, processor, and memory levels, thus reducing overall energy consumption.[21]

Server virtualization decouples computational workload (such as applications) from the physical platform on which it is hosted (such as a server).[22] This approach allows multiple instances of the applications to run on the same server, increasing the server's ability to handle multiple workloads at the same time. Virtualization saves energy by allowing fewer servers to perform the same amount of work and indirectly lowers energy consumption from cooling equipment (by reducing waste heat).

Solid state storage stores data on interconnected flash memory chips that retain data without the use of conventional magnetic spinning disks.[23] Much of the energy consumed by traditional storage is consumed by the spinning disks, making solid-state storage far more energy efficient than traditional storage technologies.[24]

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20 Torres J, Carrera D, Hogan K, Gavalda R, Beltran V, Poggi N. 2008. Reducing wasted resources to help achieve green data centers. In: Proc 4th workshop on high-performance, power-aware computing (HPPAC).

21 Mittal, Sparsh. "Power Management Techniques for Data Centers: A Survey." Oak Ridge National Laboratory. Technical Report. 2014. https://ft.ornl.gov/sites/default/files/Survey_DataCenter.pdf

22 Torres J, Carrera D, Hogan K, Gavalda R, Beltran V, Poggi N (2008) Reducing wasted resources to help achieve green data centers. In: Proc 4th workshop on high-performance, power-aware computing (HPPAC '08), 2008

23 Santo Domingo, Joel. "SSD vs. HDD: What's the Difference?" PC Magazine. Feb 20, 2014. http://www.pcmag.com/article2/0,2817,2404258,00.asp

24 U.S. Environmental Protection Agency. "Better Management of Data Storage." https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_storage_mgmt

5.1.2 Power Infrastructure Energy-Efficient Technologies and Best Practices

Power infrastructure EETBPs tend to reduce the energy data centers consume generally, but also from conventional energy sources (e.g., nonrenewable sources such as oil and gas).

Combined heat and power (CHP; with an absorption chiller) generates electricity at the site, thus avoiding transmission losses associated with the grid and capturing the waste heat for usage. The absorption chillers use the waste heat to drive the refrigeration cycle, thereby reducing electricity consumption.[25]

Converting racks to direct current (DC; as opposed to AC) reduces the power lost by converting between AC and DC power. Traditionally, data centers draw AC power delivered from the grid and convert it to DC power to store energy storage through the UPS. The DC power is then converted back to AC voltage for the power distribution units, which is distributed to the racks and then converted back into the DC voltage required to power digital electronics.[26] A power delivery system that distributes DC power directly to the racks reduces energy consumed by the AC-DC-AC-DC conversion process and indirectly saves energy by reducing data center cooling requirements.

Energy-efficient uninterruptible power supplies replace inefficient uninterruptable power supplies with energy-efficient power supplies that reduce electricity lost by the inverter and transformer. UPSs are commonly used to supply power to data centers and protect IT equipment from power interruptions or disturbances in the electrical grid.[27] Due to the high load of data centers, replacing legacy UPSs with newer, energy-efficient UPSs can result in significant energy savings.

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25 Brown, Richard; Alliance to Save Energy; ICF Incorporated; ERG Incorporated; & U.S. Environmental Protection Agency. (2008). Report to Congress on Server and Data Center Energy Efficiency: Public Law 109-431. *Lawrence Berkeley National Laboratory*. Lawrence Berkeley National Laboratory: Lawrence Berkeley National Laboratory. Available online at: https://escholarship.org/uc/item/74g2r0vg

26 Tschudi, Bill. “DC Power for Improved Data Center Efficiency.” Lawrence Berkeley National Laboratory. March 2008. Available online at: http://hightech.lbl.gov/documents/data_centers/DCDemoFinalReport.pdf

27 U.S. Environmental Protection Agency. "Purchasing More Energy-Efficient Servers, UPSs, and PDUs." *ENERGY STAR*. Available online at: https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_purchasing.

Polymer electrolyte membrane fuel cells produce electricity by oxidizing hydrogen fuel and oxygen from the air using an electrochemical conversion device.[28] The electricity produced by polymer electrolyte membrane fuel cells can be used reduce the amount of energy consumed from the grid, thus avoiding transmission losses.

Solar power is created when sunlight is converted to electricity through the use of solar photovoltaic (PV) cells.[29] Sunlight is a renewable energy source.

Solid oxide fuel cells produce electricity by oxidizing fuel through the use of a solid oxide material or ceramic. Benefits to solid oxide fuel cells include high electric efficiencies, fuel flexibility, and long-term stability compared to other fuel cells.[30] Using solid oxide fuel cells to power all or part of a data center's electric load increases energy efficiency by avoiding transmission losses associated with the grid.

Wind power converts wind energy into electricity by harnessing wind power from turbines.[31] Wind energy is a renewable source.

5.1.3 Airflow Management Energy-Efficient Technologies and Best Practices

Inefficient data center designs and configurations can create hot and cold spots where IT equipment is either over- or under-cooled. Airflow management EETBPs address issues related to ineffective airflow.

Blanking panels, grommets, and structured cabling help optimize data center airflow by forcing cooling air to go through equipment instead of around it, sealing areas where cable enter and exit plenums, and eliminating disorderly and excess cables constrain exhaust airflow from rack-mounted equipment, respectively.[32] Preventing the mixing of hot and cold air reduces the recirculation of hot air within the rack, thus reducing the energy consumed by cooling equipment.

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[28] U.S. Department of Energy and U.S. Environmental Protection Agency. "How Fuel Cells Work." http://www.fueleconomy.gov/feg/fcv_PEM.shtml

[29] U.S. Department of Energy. "Solar Photovoltaic Technology Basics." National Renewable Energy Laboratory. http://www.nrel.gov/learning/re_photovoltaics.html

[30] U.S. Department of Energy. "Why SOFC Technology?" http://energy.gov/fe/why-sofc-technology

[31] U.S. Department of Energy. "Wind Energy Basics." National Renewable Energy Laboratory. http://www.nrel.gov/learning/re_wind.html

[32] U.S. EPA ENERGY STAR, "Properly Deployed Airflow Management Devices," http://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_airflow_mgmt

Computational fluid dynamics is used to model data center airflow and helps data center managers identify and optimize cooling distribution, reducing overall energy consumption. Computational fluid dynamics analysis couples rack-level temperature sensors with a complex software that models the temperature and pressure distributions in the data center. The software helps data center managers identify inefficiencies in the HVAC equipment's ability to cool IT equipment by simulating alternative configurations to evaluate different solutions.[33]

Hot or cold-aisle configuration prevents the mixing of hot and cool air, which helps reduce energy consumed by cooling equipment. IT equipment generally takes cold air in through the front and exhausts hot air out the back.[34] If racks are configured where the back of one rack is facing the front of another, hot air exhausted from the first rack is drawn in to the front of the second, increasing data center cooling requirements. Configuring data center racks where the fronts of the IT equipment are facing each other in a cold aisle and the backs are facing each other in a hot aisle promotes desirable air circulation patterns and cooling efficiencies, thereby reducing overall energy consumption.

Hot or cold-aisle configuration and containment combines hot or cold-aisle configuration with containment solutions (e.g., strip curtains or rigid enclosures).[35] This solution maximizes data center airflow optimization and further reduces cooling requirements.

5.1.4 HVAC Energy-Efficient Technologies and Best Practices

HVAC EETBPs reduce the energy consumed by equipment associated with cooling the IT equipment within the data center.

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33 Clark, Jeff. "Computational Fluid Dynamics (CFD) for Data Centers." The Data Center Journal. March 20, 2012. http://www.datacenterjournal.com/facilities/computational-fluid-dynamics-cfd-for-data-centers/

34 Bouley, Dennis and Brey, Tom. "Fundamentals of Data Center Power and Cooling Efficiency Zones." The Green Grid. White Paper #21. 4 March 2009. http://www.thegreengrid.org/~/media/WhitePapers/Fundamentals%20of%20Power%20and%20Cooling%20Zones%20White%20Paper.ashx?lang=e

35 Lin, Paul; Avelar, Victor; and Niemann, John. "Implementing Hot and Cold Air Containment in Existing Data Centers." Schneider Electric and APC. White Paper 153. 2013. http://www.apcmedia.com/salestools/VAVR-8K6P9G/VAVR-8K6P9G_R0_EN.pdf

Air-side economizers are mechanical devices that use outside air to cool data centers. In colder months, data centers can leverage free cooling so compressors can be ramped down or turned off, significantly reducing data center energy consumption.[36]

Containerized data centers, or modular data centers, are portable data centers whose equipment is housed in a shipping container that can be transported and installed for data center capacity. In addition to being scalable and easily deployed, containerized data centers are also highly efficient.[37] Modular data centers are tightly-packed, integrated systems that gain efficiencies from the close proximity of the cooling and IT equipment. Using this technology gives data center operators flexibility for expanding their facility in the future, allowing for a more efficient building structure.

Data center infrastructure management (DCIM) is a software-based data center integration and monitoring tool that allows data center managers to see a complete picture of their data center's energy performance and identify energy consumption inefficiency patterns. These integrated platforms monitor IT, power, and cooling equipment in real time through sensors integrated with specialized software and hardware.[38] DCIM allows data center managers to identify and address energy inefficiencies in their data centers.

In-row cooling technology places smaller cooling units between server cabinet rows to target cool air at the server equipment and cool the data center more effectively. These smaller, more efficient units can reduce overall cooling tonnage by either reducing the work of or replacing standard room-cooling equipment (e.g., computer room air conditioning or computer room air handling units). [39]

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36 U.S. Environmental Protection Agency. "Air-Side Economizer." ENERGY STAR. https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_economizer_air-side.

37 Rath, John. "DCK Guide To Modular Data Centers: Why Modular?" Data Center Knowledge. 20 Oct. 2011. http://www.datacenterknowledge.com/archives/2011/10/20/dck-guide-to-modular-data-centers-why-modular/

38 Harris, Mark. "Data Center Infrastructure Management Tools Monitor Everything and Ease Capacity Planning and Operational Support." CIO.com. 18 Sept. 2013. http://www.cio.com/article/2382408/data-center/data-center-infrastructure-management-tools-monitor-everything-and-ease-capacity-plannin.html

39 U.S. Department of Energy. "Improving Data Center Efficiency with Rack or Row Cooling Devices: Results of "Chill-Off 2" Comparative Testing. http://datacenters.lbl.gov/sites/all/files/dc_chilloff2.pdf

Premium efficiency motors use best practices in electrical motors which can significantly reduce energy consumed by data center pumps and fans. Replacing motors at the end of their service life with premium efficiency motors can increase efficiency by around three to five percentage points over standard efficiency motors.[40] Savings from premium efficiency motors add up in data centers which operate 24/7, especially for larger motors.

Raising server inlet temperatures closer to the high end of temperatures recommended by ASHRAE's 2011 *Thermal Guidelines for Data Processing Environments*[41] reduces the energy needed to cool the data center. Server inlet temperature refers to the temperature of the air that is flowing into the server to cool the internal components. Many data center operators run their data centers at very low temperatures despite the ability for servers and IT equipment to run at high end of temperatures recommended by ASHRAE (64.4 °F to 80.6 °F). Increasing the temperature of the data center reduces the energy needed by HVAC equipment to cool the data center. For every 1 °F increase in server inlet temperature, data centers can reduce cooling system energy usage by an estimated 1.5%.[42]

Variable speed drives (VSDs) allow pumps and fans to be modulated based on actual load, as opposed to traditional pumps and fans that operate at a single speed.[43] By allowing this equipment to ramp-up or ramp-down on need, VSDs reduce inefficiencies and save energy consumed by data center HVAC equipment.

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40 U.S. Department of Energy. "When to Purchase Premium Efficiency Motors." at:http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/whentopurchase_nema_motor_systemts1.pdf

41 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc (2011). ASHRAE TC 9.9. "Thermal Guidelines for Data Processing Environments." www.tc99.ashraetcs.org.

42 Desai, Tejas, Ankita Gupta, Sameer Bahere, and Nathan Winkler. "Data Center Temperature Set Point Impact on Cooling Efficiency." AEE WEEC 2013 Washington, DC. 2013. http://hightech.lbl.gov/documents/data_centers/DCDemoFinalReport.pdf

43 American Council for an Energy-Efficient Economy (ACEEE). "Glossary: Adjustable Speed Drive." http://www.aceee.org/glossary

Water-side economizers are mechanical devices that allow the compressor to be bypassed and rely on the evaporative cooling in the condenser phase of the refrigeration cycle to cool the water or refrigerants used by computer room air conditioners or handlers (computer room air conditioning or computer room air handling units). [44] These economizers can operate during cooler months, creating energy savings by reducing compressor operating hours. Because data centers operate 24/7, free cooling can yield particularly high energy savings in many climates.[45]

Waste heat recovery systems reuse lost or wasted heat generated by computing equipment. Heat generated by IT equipment is pumped out of the data center and reused in the buildings heating system or other heat recovery systems.[46] Waste heat recovery systems save energy on two fronts—they reduce energy needed to cool the data center and reduce the energy needed to operate the building's heating system.

5.1.5 Humidification Energy-Efficient Technologies and Best Practices

Humidification EETBPs reduce energy used by humidification and/or dehumidification equipment.

Broadening humidity ranges in data centers reduces humidifier runtime, thus reducing energy required to power humidification equipment. Historically, data center managers have actively controlled relative humidity at around 50% for fear that too much humidity in data centers can corrode equipment, and too little can increase electrostatic charge buildup that can short IT equipment.[47] Due to new humidity-resistant IT equipment and less strict temperature requirements, data center managers can widen the allowable range to 30% to 70% relative humidity, as recommended by ASHRAE.[48]

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44 Evans, Tony. "The Different Technologies for Cooling Data Centers." Schneider Electric and APC. White Paper 59. 2012. http://www.apcmedia.com/salestools/VAVR-5UDTU5/VAVR-5UDTU5_R2_EN.pdf

45 Pacific Gas and Electric Company. "Data Center Best Practices Guide: Energy efficiency solutions for high-performance data centers." 2012. http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/DataCenters_BestPractices.pdf

46 Data Center Knowledge. "Data Centers That Recycle Waste Heat." http://www.datacenterknowledge.com/data-centers-that-recycle-waste-heat/

47 Clark, Jeff. "Humidity in the Data Center: Do We Still Need to Sweat It?" The Data Center Journal. N.p., 27 Mar. 2012. 06 Oct. 2014. http://www.datacenterjournal.com/facilities/humidity-in-the-data-center-do-we-still-need-to-sweat-it/>

48 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 2011. ASHRAE TC 9.9. "Thermal Guidelines for Data Processing Environments." www.tc99.ashraetcs.org

Energy-efficient humidifiers including misters, foggers, or ultrasonic humidifiers use mechanical energy to generate a fog or mist of water particles into the air. Heat in the air is absorbed by the water droplets, which causes them to evaporate, thus increasing the humidity. Ultrasonic humidifiers are an especially efficient option as they do not raise the data center temperature with humidity.[49] Installing energy-efficient humidification equipment reduces energy required by the data center humidification process.

Turn-off humidifiers including external humidification equipment and humidifier controls in data center cooling equipment reduces the energy required to power humidification equipment. New humidity-resistant IT equipment and ASHRAE temperature guidelines reduce the need for humidity controls, especially in data centers without free cooling capacity.[50]

5.2 Analysis of Energy-Efficient Technologies and Best Practices Implementation and Interest

The Cadmus team used the in-depth survey results to analyze the implementation rates of the five EETBP categories and assess market interest in each category. Cadmus asked all survey participants to consider each of the 32 EETBPs and indicate its status at the familiar data center using the following responses:

1. Implemented
2. Planned to implement
3. Not yet implemented
4. Did not know if they had implemented

If respondents answered with a 1 or a 2, they did not receive a follow-up question regarding interest in that specific EETBP. The survey asked participants a follow-up question if they responded with answers 3 or 4. This follow-up question gauged their interest in that same EETBP for the familiar data center using the following responses:

5. Interested
6. Not interested
7. Did not know if they were interested

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49 Pacific Gas & Electric. "High Performance Data Centers: A Design Guidelines Source Book." January 2008. http://hightech.lbl.gov/documents/data_centers/06_DataCenters-PGE.pdf

50 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc (2011). ASHRAE TC 9.9. "Thermal Guidelines for Data Processing Environments." www.tc99.ashraetcs.org

In the tables to follow, the team broke out affirmative implementation and interest results for each technology by respondent type and data center type for the five EETBP categories. (Please see Appendix B for the responses to EETBP implementation and interest questions.)

The **implementation tables** in this section display the percentage of the 139 respondents (94 data center managers and 45 industry players) who indicated that they have implemented the EETBPs in their familiar data center. Purple cell shading indicates this percentage in the following manner:

- White = 0
- Light purple ≥ 0 to 33%
- Medium purple ≥ 33% to 66%
- Dark purple ≥ 66% to <100%
- Very dark purple = 100%

The **interest tables** in this section display the percentage of data center managers and industry players who indicated at they are interested in the EETBPs. The *n* columns indicate how many respondents answered the interest question, because respondents who said they had implemented or planned to implement an EETBP were not asked an interest question for that EETBP. Blue cell shading indicates this percentage in the following manner:

- White = 0
- Light blue = >0 to 33%
- Medium blue ≥ 33% to 66%
- Dark blue ≥ 66% to <100%
- Very dark blue = 100%

5.2.1 IT EETBP Implementation

As shown in Table 8, IT EETBP implementation rates were higher than expected when compared with previous studies that have documented the rate of server virtualization[51] and decommissioning of unused servers (which is a housekeeping issue versus an implementation issue). The higher implementation rates for storage and server management practices (energy-efficient data storage management and server power

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[51] Due to these benefits, virtualization has become commonplace in large data centers. A 2011 survey of over 500 large enterprise data centers found that 92% use virtualization to some degree. *Veeam Launches V-Index To Measure Virtualization Penetration Rate*, VEEAM, 2011. www.veeam.com/news/veeam-launches-v-index-to-measure-virtualization-penetration-rate.html Exit ENERGY STAR.

management) and equipment (solid state drives, energy efficient servers) were not expected. In general, it appears, New York State data centers, even smaller-sized ones, are implementing IT efficiency measures. The server virtualization implementation rate in smaller data centers—more than 50%—was surprising when previous studies had indicated lower rates.[52]

To determine if data center managers and industry players reported similar implementation information, the Cadmus team ranked each technology based on the implemented percentage from highest to lowest for managers and industry players. As shown in Table 9, data center managers and industry players did not show major comparative differences in the degree to which they indicated each EETBP was implemented. For both parties, server virtualization/consolidation was the most commonly implemented IT measure, followed by decommissioning of unused servers, energy-efficient servers, server power management, and energy-efficient storage management. Direct liquid cooling of chips, passive optical networks, and MAID were the least frequently implemented technologies.

Table 8. Implemented IT EETBPs – All Respondents

EETBP	All	Enterprise	Mid-Tier	Localized	Server Rooms & Closets
	n=139	n=33	n=38	n=27	n=41
Decommissioning of unused servers	**58%**	61%	61%	52%	59%
Direct liquid cooling of chips	**3%**	3%	5%	4%	0%
Energy efficient data storage management	**32%**	24%	42%	44%	22%
Energy-efficient servers	**42%**	55%	45%	44%	29%
Massive array of idle disks (MAID)	**8%**	9%	11%	7%	5%
Passive optical network	**12%**	15%	18%	11%	2%
Server power management	**37%**	42%	45%	33%	29%
Server virtualization/consolidation	**72%**	88%	74%	67%	61%
Solid state storage	**24%**	24%	34%	33%	10%

52 A 2012 NRDC paper entitled *Small Server Rooms, Big Energy Savings* included an informal survey of 30 small businesses (ranging from three to 750 employees) and found that only 37% used virtualization.

Table 9. Comparison of IT EETBP Implementation Survey Results

Manager	Rank	Industry Player
Server virtualization/consolidation	**1**	Server virtualization/consolidation
Decommissioning of unused servers	**2**	Decommissioning of unused servers
Energy-efficient servers	**3**	Energy-efficient servers
Server power management	**4**	Server power management
Energy-efficient data storage management	**5**	Energy-efficient data storage management
Solid state storage	**6**	Solid state storage
Passive optical network	**7**	Massive array of idle disks (MAID)
Massive array of idle disks (MAID)	**8**	Passive optical network
Direct liquid cooling of chips	**9**	Direct liquid cooling of chips

5.2.2 Power Infrastructure EETBP Implementation

Table 10 shows the alternative power source measures—wind, solar, and fuel cells—were not often implemented at data centers. Due to risk aversion in data centers and perceived risks associated with new and/or alternative technologies, these low implementation rates are not surprising. The use of combined heat and power (14% overall) was in line with national estimates of 12%.[53] Energy-efficient UPSs, a conventional efficiency technology, were used at over half the data centers in New York State; particularly at enterprise and mid-tier facilities.

However, the high implementation rate of direct current—19% overall and even implemented in the small data center space—was most surprising. The reported implementation rates of direct current may have been altered by a typo within the question.[54] Industry experts indicate that 98% of available IT equipment only can run on AC power and that the use of DC power has declined significantly over the past decade. However, some telecom providers and cloud computing providers (such as Facebook's open computer project, which details their direct current power supplies) have customized their equipment to run on direct current.[55]

53 More information is available at: http://www.epa.gov/chp/documents/faq.pdf

54 Due to an oversight, instead of being asked about implementation of and interest in direct current instead of AC current to the racks, respondents were asked about "data center current (as opposed to AC) to the racks."

55 More information is available at: http://searchdatacenter.techtarget.com/feature/DC-power-in-the-data-center-A-viable-option

As shown in Table 11, data center managers and industry players did not show many comparative differences in the degree to which they indicated each power infrastructure EETBP was implemented. For both participant groups, the installation of an energy-efficient UPS was the most frequently implemented technology, followed by direct current to the racks, combined heat and power, and then the alternative fuel sources.

Table 10. Implemented Power Infrastructure EETBPs – All Respondents

EETBP	All	Enterprise	Mid-Tier	Localized	Server Rooms & Closets
	n=139	n=33	n=38	n=27	n=41
Combined Heat and Power	**14%**	12%	18%	19%	7%
Direct Current	**19%**	15%	34%	15%	10%
Energy Efficient UPS	**53%**	61%	66%	37%	44%
PEM Fuel Cells	**2%**	3%	3%	4%	0%
Solar Power	**7%**	6%	13%	4%	5%
Solid Oxide Fuel Cells	**3%**	6%	3%	4%	0%
Wind Power	**4%**	3%	3%	4%	5%

Table 11. Comparison of Power Infrastructure EETBP Implementation Survey Results

Manager	Rank	Industry Player
Energy-Efficient UPS	1	Energy-Efficient UPS
Direct Current	2	Direct Current
Combined Heat and Power	3	Combined Heat and Power
Solar Power	4	Solar Power
Wind Power	5	Solid Oxide Fuel Cells
Solid Oxide Fuel Cells	6	PEM Fuel Cells
PEM Fuel Cells	7	Wind Power

5.2.3 Airflow Management EETBP Implementation

The Cadmus team expected that airflow management practices would be implemented more often as the data center space became larger and opportunities to improve the circulation of hot and cold air were available. As shown in Table 12, the Cadmus team observed a drop-off in implementation during the transition from larger to smaller facilities. As expected, hot aisle/cold aisle configuration was the most frequently implemented airflow management strategy, followed by the inexpensive and easily-implemented blanking panels, grommets, and structured cabling. Overall, more than half of data centers using hot aisle/cold aisle configuration also added an additional efficiency measure of containment. Not surprisingly, expensive computational fluid dynamics optimization, the least implemented airflow management EETBP, was most frequently implemented in larger data centers. As shown in Table 13, there was no difference in the ranking of these EETBPs between data center managers and industry players.

Table 12. Implemented Airflow Management EETBPs – All Respondents

EETBP	All	Enterprise	Mid-Tier	Localized	Server Rooms & Closets
	n=139	n=33	n=38	n=27	n=41
Blanking Panels, Grommets, Stuctured Cabling	**35%**	33%	53%	22%	27%
Computational Fluid Dynamics Optimization	**12%**	21%	16%	11%	2%
Hot or Cold Aisle Configuration	**52%**	67%	66%	48%	29%
Hot or Cold Aisle Plus Containment	**25%**	33%	37%	19%	12%

Table 13. Comparison of Airflow Management EETBP Implementation Survey Results

Manager	Rank	Industry Player
Hot or Cold Aisle Configuration	1	Hot or Cold Aisle Configuration
Blanking Panels, Grommets, Structured Cabling	2	Blanking Panels, Grommets, Structured Cabling
Hot or Cold Aisle Plus Containment	3	Hot or Cold Aisle Plus Containment
Computational Fluid Dynamics Optimization	4	Computational Fluid Dynamics Optimization

5.2.4 HVAC EETBP Implementation

As shown in Table 14, the most implemented HVAC EETBPs overall were variable speed drives, DCIM, and in-row cooling, which were implemented in roughly 40% of New York State data centers. Premium efficiency motors and raising the server inlet temperature to the higher end of the recommended ASHRAE range were implemented in over 20% of data centers. Containerized data centers, air-side and water-side economizers, and waste heat recovery were below 20% implementation. As with airflow management EETBPS, for the most part, a dramatic decrease was observed in the adoption of these technologies as the data centers got smaller. Some of the results are puzzling, and could have resulted from an incorrect understanding of the technology. For example, DCIM and in-row cooling would not be expected in a server room or closet. Also, the high implementation of in-row cooling is somewhat counter to other reports in the marketplace.[56] Another odd result of the survey is that so few enterprise data centers—only 18%—have raised their temperatures to the higher end of the ASHRAE recommended range (80.6˚F). As shown in Table 15, the ranking of HVAC EETBP implementations did not vary substantially, as both participant groups rated variable speed drives, in-row cooling, DCIM and premium efficiency motors as the top four implemented measures, although in different order.

Table 14. Implemented HVAC EETBPs – All Respondents

EETBP	All	Enterprise	Mid-Tier	Localized	Server Rooms & Closets
	n=139	n=33	n=38	n=27	n=41
Air-side Economizer	**17%**	27%	16%	11%	15%
ASHRAE Recommended Temperature	**21%**	18%	34%	15%	15%
Containerized Data Center	**14%**	21%	13%	19%	7%
DCIM	**38%**	58%	53%	22%	15%
In-row Cooling	**37%**	55%	45%	30%	17%
Premium Efficiency Motors	**24%**	33%	34%	22%	10%
Variable Speed Drives on Pumps/Fans	**40%**	64%	42%	22%	27%
Waste Heat Recovery	**9%**	9%	11%	7%	7%
Water-side Economizer	**14%**	24%	13%	11%	7%

Table 15. Comparison of HVAC EETBP Implementation Survey Results

Manager	Rank	Industry Player
Variable Speed Drives on Pumps/Fans	1	Variable Speed Drives on Pumps/Fans
DCIM	2	In-Row Cooling
In-Row Cooling	3	DCIM
Premium Efficiency Motors	4	Premium Efficiency Motors
ASHRAE Recommended Temperature	5	ASHRAE Recommended Temperature
Air-side Economizer	6	Air-Side Economizer
Containerized Data Center	7	Water-Side Economizer
Water-side Economizer	8	Containerized Data Center
Waste Heat Recovery	9	Waste Heat Recovery

56 http://www.datacenterknowledge.com/archives/2014/06/06/report-rack-row-cooling-growing-anticipated/

5.2.5 Humidification EETBP Implementation

As shown in Table 16, the implementation of humidification EETBPs is relatively low, with only around 20% of New York State data centers implementing no-cost measures—turning off humidifiers or broadening the humidity range. Respondents embraced humidification EETBPs at a higher rate for mid-tier data centers than larger enterprise data centers. As shown in Table 17, both industry players and data center managers were least likely to install adiabatic humidification (misters and ultrasonic humidifiers). Opposite of industry players, data center managers favored turning off humidifiers more than broadening the humidity range.

Table 16. Implemented Humidification EETBPs – All Respondents

EETBP	All	Enterprise	Mid-Tier	Localized	Server Rooms & Closets
	n=139	n=33	n=38	n=27	n=41
Broaden Humidity Range	**19%**	18%	29%	22%	10%
Install Misters/Ultrasonic Humidifiers	**12%**	12%	26%	7%	0%
Turn off Humidifiers	**23%**	27%	26%	26%	12%

Table 17. Comparison of Humidification EETBP Implementation Survey Results

Manager	Rank	Industry Player
Turn Off Humidifiers	**1**	Broaden Humidity Range
Broaden Humidity Range	**2**	Turn Off Humidifiers
Install Misters/Ultrasonic Humidifiers	**3**	Install Misters/Ultrasonic Humidifiers

5.2.6 IT EETBP Interest

As shown in Table 18, interest in IT EETBPs is high, similar to implementation rates. Overall, respondents were most interested in server power management and energy-efficient servers and data storage management. Half or more of the respondents who had not already implemented these EETBPs were interested in doing so at the enterprise level. Also, direct liquid cooling had the highest interest level (30%) at the enterprise level, and roughly 40% of respondents were interested in decommissioning unused servers and solid state storage. Respondents at the mid-tier data center level appear to be particularly enthusiastic about IT EETBPs. All categories, except for MAID and direct liquid cooling received over 50% interest. In the smaller spaces, localized and server rooms and closets, respondents showed moderate to strong interest in all of the EETBPs, except for MAID, passive optical networks, and direct liquid cooling of chips (which are EETBPs that are less applicable to these space types).

To determine if data center managers and industry players reported similar interest information, the Cadmus team ranked each technology based on the interest percentage from highest to lowest for managers and industry players. As shown in Table 19, data center managers and industry players showed some differences in interest levels for IT EETBPs. Energy efficient servers and data storage management, server power management, and decommissioning unused servers were both group's top four technologies, but they were ranked differently.

Table 18. IT EETBP Interest – All Respondents

EETBP	All	*n*	Enterprise	*n*	Mid-Tier	*n*	Localized	*n*	Server Rooms & Closets	*n*
Decommissioning of unused servers	**50%**	**24**	40%	5	60%	5	75%	4	40%	10
Direct liquid cooling of chips	**22%**	**117**	30%	23	27%	33	22%	23	13%	38
Energy efficient data storage management	**63%**	**54**	60%	10	60%	10	67%	9	64%	25
Energy-efficient servers	**62%**	**42**	50%	4	75%	8	57%	7	61%	23
Massive array of idle disks (MAID)	**24%**	**112**	13%	23	39%	31	13%	23	26%	35
Passive optical network	**28%**	**101**	24%	21	52%	27	28%	18	11%	35
Server power management	**61%**	**46**	67%	9	83%	6	50%	10	57%	21
Server virtualization/consolidation	**41%**	**34**	0%	1	60%	5	50%	4	38%	24
Solid state storage	**43%**	**72**	41%	17	60%	15	46%	13	33%	27

Table 19. Comparison of IT EETBP Interest Survey Results

Manager	Rank	Industry Player
Energy-efficient servers	**1**	Server power management
Energy efficient data storage management	**2**	Energy efficient data storage management
Server power management	**3**	Decommissioning of unused servers
Decommissioning of unused servers	**4**	Energy-efficient servers
Solid state storage	**5**	Server virtualization/consolidation
Server virtualization/consolidation	**6**	Solid state storage
Passive optical network	**7**	Passive optical network
Massive array of idle disks (MAID)	**8**	Massive array of idle disks (MAID)
Direct liquid cooling of chips	**9**	Direct liquid cooling of chips

5.2.7 Power Infrastructure EETBP Interest

Table 20 shows data the center managers and industry players' interest in each power infrastructure EETBP, per survey responses. Overall, direct current, solar power, and energy efficient UPS were the most popular EETBPs. As mentioned in the previous section, energy efficient UPS is a conventional energy efficiency measure and more than half of the respondents who have not yet implemented this measure are interested in it. Direct current has been receiving media coverage for the past few years, which could explain the high interest in this technology. [57, 58] While the interest level in solar power was higher than expected, other recent surveys also indicate that data center managers are considering renewable power sources.[59] Generally, respondents were moderately interested in direct current and solar power. All space types showed the strongest interest in energy efficient UPSs. There was also a moderate interest in fuel cell technology at the mid-tier level, which could be due to recent media coverage on the use of fuel cells in data centers.[60] At the server room and closet level, respondents indicated low interest in all technologies, except for energy efficient UPS. Due to their small size, many power infrastructure EETBPs are not applicable to these spaces, so this was expected. As shown in Table 21, the ranking of the power infrastructure EETBPs was similar for data center managers and industry players.

Table 20. Power Infrastructure EETBP Interest – All Respondents

EETBP	All	*n*	Enterprise	*n*	Mid-Tier	*n*	Localized	*n*	Server Rooms & Closets	*n*
Combined Heat and Power	28%	99	33%	18	32%	25	42%	19	16%	37
Direct Current	40%	90	48%	21	57%	21	50%	16	19%	32
Energy Efficient UPS	61%	46	57%	7	80%	10	77%	13	38%	16
PEM Fuel Cells	24%	130	26%	31	42%	36	26%	23	5%	40
Solar Power	37%	111	35%	26	46%	28	36%	22	31%	35
Solid Oxide Fuel Cells	21%	126	23%	31	41%	34	17%	23	5%	38
Wind Power	17%	129	23%	31	26%	35	17%	24	5%	39

57 https://gigaom.com/2012/01/13/the-next-big-thing-for-data-centers-dc-power/

58 http://www.wired.com/2011/12/ac-dc-power-data-center/

59 http://www.energymanagertoday.com/power-cooling-drive-decisions-locate-data-centers-0106972/

60 http://www.datacenterdynamics.com/focus/archive/2014/02/microsoft-our-rack-data-center-fuel-cell-concept-works

Table 21. Comparison of Power Infrastructure EETBP Interest Survey Results

Manager	Rank	Industry Player
Energy-Efficient UPS	**1**	Energy-Efficient UPS
Direct Current	**2**	Direct Current
Solar Power	**3**	Solar Power
Combined Heat and Power	**4**	Combined Heat and Power
PEM Fuel Cells	**5**	PEM Fuel Cells
Solid Oxide Fuel Cells	**6**	Wind Power
Wind Power	**7**	Solid Oxide Fuel Cells

5.2.8 Airflow Management EETBP Interest

Table 22 shows data center managers and industry players' interest in each airflow management EETBP, per survey responses. Generally, interest in airflow management EETBPs was low to moderate for all four EETBPs, with hot aisle/cold aisle configuration plus containment and CFD optimization being the most and least popular EETBPs, respectively. Mid-tier respondents expressed a much higher interest in all four airflow EETBPs. As evidenced in the other EETBP categories, the mid-tier respondents seem to be particularly enthusiastic about EETBPs overall. Server rooms and closet respondents expressed low interest the airflow management EETBPs, which makes sense. Due to their smaller size, improving the circulation of hot and cold air is less critical. As seen in Table 23, managers and industry players generally ranked these technologies in the same order, except for blanking panels, grommets, and structured cabling and hot aisle/cold aisle configuration. Industry players preferred blanking panels, grommets, and structured cabling over hot aisle/cold aisle configuration, possibly due to the fact that industry players may sell these low-cost air flow solutions.

Table 22. Airflow Management EETBP Interest – All Respondents

EETBP	All	*n*	Enterprise	*n*	Mid-Tier	*n*	Localized	*n*	Server Rooms & Closets	*n*
Blanking Panels, Grommets, Stuct. Cabling	**31%**	**70**	35%	17	67%	12	43%	14	7%	27
Computational Fluid Dynamics Optimization	**24%**	**105**	30%	23	50%	26	16%	19	5%	37
Hot or Cold Aisle Configuration	**33%**	**45**	29%	7	67%	9	22%	9	25%	20
Hot or Cold Aisle Plus Containment	**40%**	**84**	41%	17	84%	19	33%	15	18%	33

Table 23. Comparison of Airflow Management EETBP Interest Survey Results

Manager	**Rank**	**Industry Player**
Hot or Cold Aisle Plus Containment	**1**	Hot or Cold Aisle Plus Containment
Hot or Cold Aisle Configuration	**2**	Blanking Panels, Grommets, and Structured Cabling
Blanking Panels, Grommets, and Structured Cabling	**3**	Hot or Cold Aisle Configuration
Computational Fluid Dynamics Optimization	**4**	Computational Fluid Dynamics Optimization

5.2.9 HVAC EETBP Interest

Table 24 shows data center managers and industry players' interest in each HVAC EETBP, per survey responses. Interestingly, the HVAC EETBPs received the most varied responses. Overall, DCIM, in-row cooling, air-side and water-side economizers, and raising server inlet temperatures were the EETBPs in which respondents were most interested. An explanation for this may be that DCIM has received a lot of attention in data center publications,[61] and economization and high server inlet temperatures are commonly cited as data center energy efficiency best practices.[62] As discussed in the HVAC EETBP implementation section, there were low rates of HVAC EETBP implementation in localized and server room & closet data centers. The lack of implementation in localized data centers may explain why localized respondents expressed moderate interest in all HVAC EETBPs, except for containerized data center. Similar to the implementation results, interest in in-row cooling and DCIM was higher than expected for server rooms & closets.

61 http://www.datacenterknowledge.com/archives/2014/09/24/gartner-tackles-data-center-management-with-dcim-magic-quadrant/

62 https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency

As shown in Table 25, data center managers and industry players do not appear to be interested in similar EETBPs. This disinterest could be due to the focus areas of the industry players who were surveyed. Both managers and industry players ranked DCIM and economization as HVAC EETBPs in which they were more interested and containerized data center and VSDs as EETBPs in which they were less interested, but those were the only similarities. Another explanation for the range of responses seen in both tables is that location and space configuration can dictate which HVAC EETBPs are viable. Therefore, an individual's interest in an EETBP may be influenced by data center size, location, and space configuration (for example, economization can be difficult in New York City, due to limited rooftop space and access to outside air).

Table 24. HVAC EETBP Interest – All Respondents

EETBP	All	*n*	Enterprise	*n*	Mid-Tier	*n*	Localized	*n*	Server Rooms & Closets	*n*
Air-side Economizer	**37%**	**99**	29%	21	52%	29	44%	18	26%	31
ASHRAE Recommended Temperature	**36%**	**92**	37%	19	57%	21	39%	18	21%	34
Containerized Data Center	**20%**	**94**	19%	16	30%	27	29%	17	9%	34
DCIM	**45%**	**66**	45%	11	64%	11	57%	14	33%	30
In-row Cooling	**41%**	**73**	20%	10	44%	16	56%	16	39%	31
Premium Efficiency Motors	**30%**	**89**	38%	13	32%	22	56%	18	14%	36
Variable Speed Drives on Pumps/Fans	**26%**	**66**	44%	9	31%	16	43%	14	7%	27
Waste Heat Recovery	**31%**	**101**	24%	17	33%	30	42%	19	26%	35
Water-side Economizer	**36%**	**132**	38%	29	54%	37	44%	25	12%	41

Table 25. Comparison of HVAC EETBP Interest Survey Results

Manager	Rank	Industry Player
In-row Cooling	**1**	DCIM
DCIM	**2**	ASHRAE Recommended Temperature
Air-side Economizer	**3**	Water-side Economizer
Water-side Economizer	**4**	Air-side Economizer
Waste Heat Recovery	**5**	In-row Cooling
ASHRAE Recommended Temperature	**6**	Premium Efficiency Motors
Premium Efficiency Motors	**7**	Waste Heat Recovery
Variable Speed Drives on Pumps/Fans	**8**	Containerized Data Center
Containerized Data Center	**9**	Variable Speed Drives on Pumps/Fans

5.2.10 Humidification EETBP Interest

Table 26 shows the data center managers and industry players' interest in each humidification EETBP, per survey responses. With the exception of mid-tier data center respondents, which as discussed previously appear to be particularly enthusiastic about all EETBPs, respondents from the other data center types had a low level of interest in all three humidification EETBPs. This low level of interest could be due to the lower energy savings potential for humidification EETBPs. As shown in Table 27, both industry players and data center managers were least interested in turning off humidifiers. Opposite of industry players, data center managers were more interested in broadening the humidity range than installing misters/ultrasonic humidifiers, possibly due to the fact that broadening the humidity range is a no-cost measure.

Table 26. Humidification EETBP Interest – All Respondents

EETBP	All	*n*	Enterprise	*n*	Mid-Tier	*n*	Localized	*n*	Server Rooms & Closets	*n*
Broaden Humidity Range	**28%**	**96**	17%	18	48%	25	22%	18	23%	35
Install Misters/Ultrasonic Humidifiers	**29%**	**111**	29%	24	44%	27	25%	20	20%	40
Turn off Humidifiers	**25%**	**93**	16%	19	46%	26	19%	16	16%	32

Table 27. Comparison of Humidification EETBP Interest Survey

Manager	Rank	Industry Player
Broaden Humidity Range	**1**	Install Misters/Ultrasonic Humidifiers
Install Misters/Ultrasonic Humidifiers	**2**	Broaden Humidity Range
Turn off Humidifiers	**3**	Turn off Humidifiers

5.3 EETBP Energy Savings Potential

The Cadmus team analyzed the 32 EETBPs included in the survey and previously discussed for their potential to save energy and impact data center load. The team first established factors that determine an EETBP's technical potential to save energy, and then chose factors that may indicate willingness by the marketplace to implement an EETBP in the future, which was defined as market potential. Both technical and market potential were analyzed and then combined to establish the overall potential of each EETBP to save energy through adoption by the marketplace.

The technical potential was determined using the following factors, which were researched by the Cadmus team and are defined in Section 5.3.1:

- Average EETBP energy savings as a percentage at the measure level.
- Portion of the data center load impacted by the EETBP.
- Indirect savings potential.

The Cadmus team determined market potential using the following survey data responses from data center managers and industry players.

- Plans to implement the EETBP.
- Interest in the EETBP.

5.3.1 Technical Potential

The Cadmus team estimated technical potential by multiplying the average EETBP energy savings at the measure level by the portion(s) of the data center load impacted by the EETBP and an indirect energy savings factor (where applicable) to create a generalized total energy savings percentage for each EETBP at the data center level. Based on that total savings percentage, the team assigned each EETBP a high, medium, or low score to quantify its technical potential.[63] The following subsections describe the factors used to determine technical potential and Appendix C provides additional documentation.

Average EETBP energy savings at the measure level quantifies how much energy could be saved if an EETBP is implemented instead of a conventional alternative (e.g., difference between energy used by motors without VSDs and energy used by motors with VSDs). EETBP savings for any given project can vary widely based on the data center size, configuration, and the energy efficiency sophistication of staff. When assigning the average EETBP energy savings, the Cadmus team assumed that the EETBP had not previously been implemented (which would result in reduced savings). The average EETBP energy savings at the measure level was estimated by using either the midpoint of a published energy savings range or a “standard practice scenario” using assumptions based on industry information and experience in the field. See Appendix C for the sources and assumptions used to create the generalized savings percentages for each EETBP. Note that measures-level savings cannot be added together to estimate multi-measure project savings due to interactive effects, nor should they be not be used to estimate energy efficiency project savings due to their generalized nature.

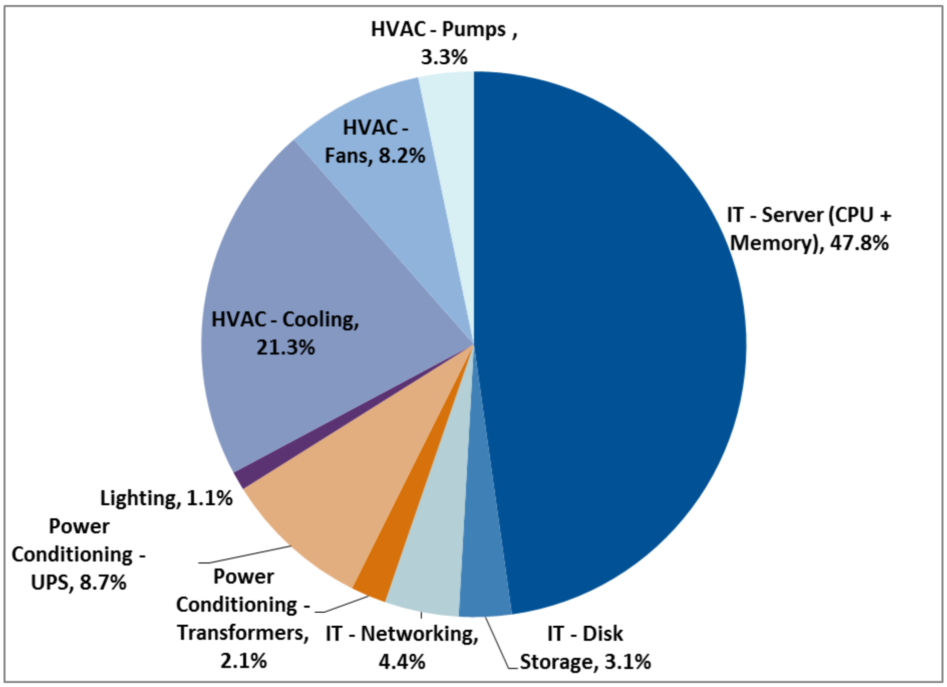
63 EETBPs with a total energy savings percentage of less than 2% were given a low score, between 2% and 10% was a medium score, and over 10% earned a high score.

The portion of the data center load impacted by the EETBP was estimated from the following sources to create a generalized breakdown of energy usage in the data center (Figure 4).

- Academic research.[64]
- Results from the survey conducted by the Cadmus team.
- Technical experience from working within data centers.

For reference, the data center loads equate to power usage effectiveness (PUE) of 1.81, which is in line with the Uptime Institute's reported average PUE of 1.8 to 1.89.[65] Load percentages were used to assess the impact of the EETBPs on overall data center load.

Figure 4. Load Attributable to Data Center Component



64 PUE source: Cheung et al. (2013), Masanet et al. (2011)
Server energy usage source: Masanet et al. (2011)
Storage energy usage sources: Cadmus survey and Dell (2010) and IDC (2010) for HDD and SSD; Spectra (2103) and ComputerWeekly.com (2013) for MAID and tape
Network energy usage source: Mahadevan et al.(2010)

65 http://uptimeinstitute.com/images/stories/Uptime_Institute_2012_Data_Industry_Survey.pdf

Indirect energy savings are reductions in power conditioning losses and waste heat production due to IT load reductions (e.g., from server consolidation). For example, if the energy load from IT equipment is reduced from 100 kW to 50 kW, then power conversions losses are reduced because 50% less energy needs to be conditioned. Additionally, because a reduced IT load will result in less heat being created in the data center, the tonnage of cooling required will also be reduced. See Appendix C for information on which EETBPs are considered to have indirect savings benefits.

5.3.2 Market Potential

The Cadmus team estimated market potential by examining EETBPs that data center managers and industry players indicated they were either "planning to implement" or "interested" in implementing in their survey responses. The Cadmus team determined the percentage of overall respondents who had responded that they were "planning to implement" each EETBP, and then assigned a high or low score to each EETBP based on whether the percentage was above or below the median. The same method was used to score the "interested" responses. The "plan to implement" and "interested" scores were then averaged to create high, medium, or low market potential scores. Appendix C provides additional documentation.

5.3.3 Overall Potential

The Cadmus team assessed the overall potential of each EETBP to save energy by averaging each EETBP's technical potential and market potential scores. Then the EETBPs were sorted based on this averaged score and categorized as having high, medium, or low potential based on the score.[66] It is important to note that due to constant runtime, data center EETBPs categorized as having low potential can still result in valuable energy savings and are worthy of consideration. However, they may not have as significant of an energy savings impact and/or face serious market adoption issues. Table 28 shows the technical potential, market potential and overall potential results for each EETBP. Not surprisingly, many of the power infrastructure EETBPs scored well for technical potential (and therefore overall potential as well), as the use of on-site alternative power sources would reduce data centers' reliance on the electrical grid.

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[66] See Appendix C to see how the numerical technical and market scores were converted into high, medium, and low scores.

Table 28. EETBP Energy Saving Potential

	EET	Technical Potential Score	Market Potential Score	Overall Potential
IT	Decommissioning of unused servers	Medium	High	High
	Direct liquid cooling of chips	Medium	Low	Low
	Energy efficient data storage management	Low	High	Medium
	Energy efficient servers	High	High	High
	Massive array of idle disks (MAID)	Low	Low	Low
	Passive optical network	Medium	Medium	Medium
	Server power management	Medium	High	High
	Server virtualization/consolidation	High	High	High
	Solid state storage	Low	High	Medium
Power Infrastructure	Combined heat and power	High	Medium	High
	Direct current to the racks	Medium	High	High
	Energy efficient power supplies (UPS)	High	High	High
	Polymer electrolyte membrane fuel cells	High	Low	Medium
	Solar power	High	Medium	High
	Solid oxide fuel cells	High	Low	Medium
	Wind power	High	Low	Medium
Air Flow Mgmt	Computational fluid dynamics optimization	Low	Low	Low
	Containment	Medium	High	High
	Hot or cold aisle configuration	Low	Low	Low
	Hot or cold aisle configuration plus containment	Medium	High	High
HVAC	Adjusting server inlet temperatures to the high end of ASHRAE recommended range	Medium	Medium	Medium
	Air-side economizer	High	Medium	High
	Containerized data center	Medium	Medium	Medium
	Data Center Infrastructure Management (DCIM) System	Medium	High	High
	In-row cooling	Low	Medium	Low
	Variable speed drives on pumps/fans	Medium	Low	Low
	Premium efficiency motors	Low	Low	Low
	Waste heat recovery	Medium	Medium	Medium
	Water-side economizer	High	Medium	High
Humidity	Broaden humidity range	Low	Low	Low
	Install misters, foggers, or ultrasonic humidifiers	Low	Low	Low
	Turn off humidifiers	Low	Low	Low

5.3.4 EETBP Portfolios for Data Center Types

The Cadmus team used the analysis of EETBP implementation, interest, and potential described in the preceding sections to create EETBP opportunity portfolios for each data center space type. The purpose of the portfolios is to identify where energy saving opportunities exists for each data center space type and which EETBPs may warrant targeted efforts due to currently low implementation rates, in spite of high energy savings potential.

To create the EETBP portfolios, the Cadmus team first determined the applicability of each technology to each data center space type. Cadmus determined applicability by reviewing the survey data regarding implementation of EETBPs (discussed in Section 5.2) and the team's collective experience working in data centers. Note that alternative power sources were considered in terms of being developed exclusively for the data center and not the building. In other words, alternative power sources were applicable to the larger data center sizes. Applicability is reflected in Table 30 by the presence of a letter grade.[67] If an EETBP does not have a letter grade (blank cell) for a certain data center space type, then that EETBP was not deemed to be applicable.

The data center load reduction opportunity for each EETBP based on the data center space type is denoted by the letter grade. As shown Table 29, the letter grades are based on overall potential (Table 28) and the percentage of respondents that did not implement the EETBP (Section 5.2).[68] Higher overall potential and higher percentage that did not implement leads to higher opportunities. Table 30 shows EETBP opportunity portfolios for each data center space type. Interpretations of these letter grades follow.

Table 29. EETBP Grading

		% of EETBP Survey Respondents That Did Not Implement			
		0 to 24	25 to 49	50 to 74	75 to 100
Overall Potential	High	D	C	B	A
	Medium	E	D	C	B
	Low	E	E	D	C

67 Because server rooms and server closets are analyzed together, the reader should note that some HVAC and air flow management measures may be applicable to server rooms, but not server closets,

68 The reader should note that, where necessary, the Cadmus team smoothed the portfolio grades. Realistically, market intervention and transformation efforts will not be specifically targeted to each space type. Therefore, smoothing the portfolios creates more logical conclusions to direct future energy efficiency program decisions. An unsmoothed version of the chart is available in Appendix C.

5.3.4.1 Grades A and B

EETBPs assigned grades A and B have the highest overall potential to save energy and the lowest installation rates. Thus, they represent the biggest opportunity for increased market penetration and energy savings. However, despite the high potential of these EETBPs, the low rates of implementation indicate that significant barriers must exist, especially in the case of A grades. These barriers may relate to the Return on Investment (ROI), perceived risk, comfort with/understanding of the technology, space limitations, and/or senior management support. This analysis suggests that efforts to break down these barriers would likely have a significant impact on statewide data center energy consumption. These efforts may include incentives, marketplace collaboration, pilots, education, and targeted cost-share energy studies. Appropriate efforts to increase market penetration may depend on the size of the data center, the data center manager's level of technical sophistication, the cost of implementing the EETBP, and the perceived risks.

5.3.4.2 Grade C

EETBPs assigned a C grade represent moderate opportunity for increased market penetration and energy savings, as the EETBP either has high potential and is already being adopted by the marketplace, or the potential is lower, but many data centers still have not adopted this EETBP. Increased market penetration of these EETBPs is desirable, but some assistance may be required to increase implementation rates and fully realize the energy saving potential of these EETBPs. Appropriate efforts to increase implementation may include market enablement through education on best practices, market partnerships, case studies, and prescriptive utility incentives.

5.3.4.3 Grades D and E

EETBPs assigned grades D and E represent the lowest opportunity to reduce data center energy usage in the future. In the case of E grades, the EETBPs have relatively high installation rates for their energy savings potential. Analysis suggests that these measures have the lowest potential to save energy and/or may see sufficient market adoption. To maintain implementation rates and encourage installation of these EETBPs, the market may benefit from case studies, general best practices documents, and other low-level efforts.

Table 30. EETBP Opportunity Portfolios by Data Center Space Type

	EETBP	Enterprise	Mid-Tier	Localized	Server Rooms & Closets
IT Equipment	Decommissioning of unused servers	C	C	C	C
	Direct liquid cooling of chips	C	C	C	
	Energy efficient data storage management	B	C	C	B
	Energy efficient servers	C	B	B	B
	Massive array of idle disks (MAID)	C	C	C	
	Passive optical network	B	B	B	
	Server power management	B	B	B	B
	Server virtualization/consolidation	D	C	C	C
	Solid state storage	B	C	C	B
Power Infrastructure	Combined heat and power	A	A		
	Direct current to the racks	A	B	A	
	Energy efficient power supplies (UPS)	C	C	B	B
	Polymer electrolyte membrane fuel cells	B	B		
	Solar power	A	A		
	Solid oxide fuel cells	B	B	B	
	Wind power	B	B		
Air Flow Management	Computational fluid dynamics optimization	C	C	C	
	Containment	B	C	A	B
	Hot or cold aisle configuration	E	E	D	
	Hot or cold aisle configuration plus containment	B	B		
HVAC	Adjusting server inlet temperatures	C	B	B	B
	Air-side economizer	A	B	A	
	Containerized data center	B	B	B	B
	Data Center Infrastructure Management (DCIM)	C	C	A	
	In-row cooling	E	D	D	
	Premium efficiency motors	D	D	C	D
	Variable speed drives on pumps/fans	E	D	C	D
	Waste heat recovery	B	B	B	
	Water-side economizer	A	A	A	
Humidity	Broaden humidity range	C	D	C	
	Install misters, foggers, or ultrasonic humidifiers	C	D		
	Turn off humidifiers	D	D	D	

5.4 EETBP Decision-Making Factors and Barriers

Understanding the decision-making process and motivations of data center operators, along with the barriers they face, is critical to developing more effective energy efficiency programs for data centers. Survey questions asked respondents to specify, identify, or rank various factors related to energy usage and energy efficiency in the data center, project, and budgetary approval.

Data center managers and industry players' results within each of the four data center space types were evaluated and compared to the overall responses to identify if there were factors that specifically affected certain data center sizes. In some instances, the responses for the different data center space types did not differ dramatically from the overall trends. If this was the case, the analysis focused on the overall results.

5.4.1 Energy Efficiency and Energy Cost Considerations

Energy efficiency and energy cost considerations are increasingly considered in data center capital budget decisions due to rising energy costs. This question aimed to understand how relevant these concerns are when making decisions. The survey asked respondents how often energy efficiency and energy costs are considered at their familiar data center and gave them the option of selecting from "always," "often," "sometimes," "never," and "don't know."

As shown in Figure 5, most data center managers appear to factor energy efficiency and energy costs into their decision-making process to some degree. In survey results for both respondent groups, energy efficiency and energy costs are "always" or "often" considered roughly 70% of the time for enterprise and mid-tier data centers. In localized data centers and server rooms and closets, energy efficiency and energy costs are considered "always" or "often" roughly half as frequently as the larger data center types. The micro-level analysis of the results indicates that energy efficiency concerns frequently impact decision-making at larger data centers, while smaller data centers are less concerned with energy efficiency and energy costs and/or are still working towards assimilating this practice into their decision-making process. As shown in Figure 6, for industry players this drop off in considering energy efficiency and energy costs into their decision making does not occur until the smallest data center type – server closets and server rooms and closets. In fact, all six industry players that work with localized data centers stated they consider energy efficiency and energy costs in their decisions.

Figure 5. Frequency of Energy Efficiency and Energy Cost Considerations (Data Center Managers)

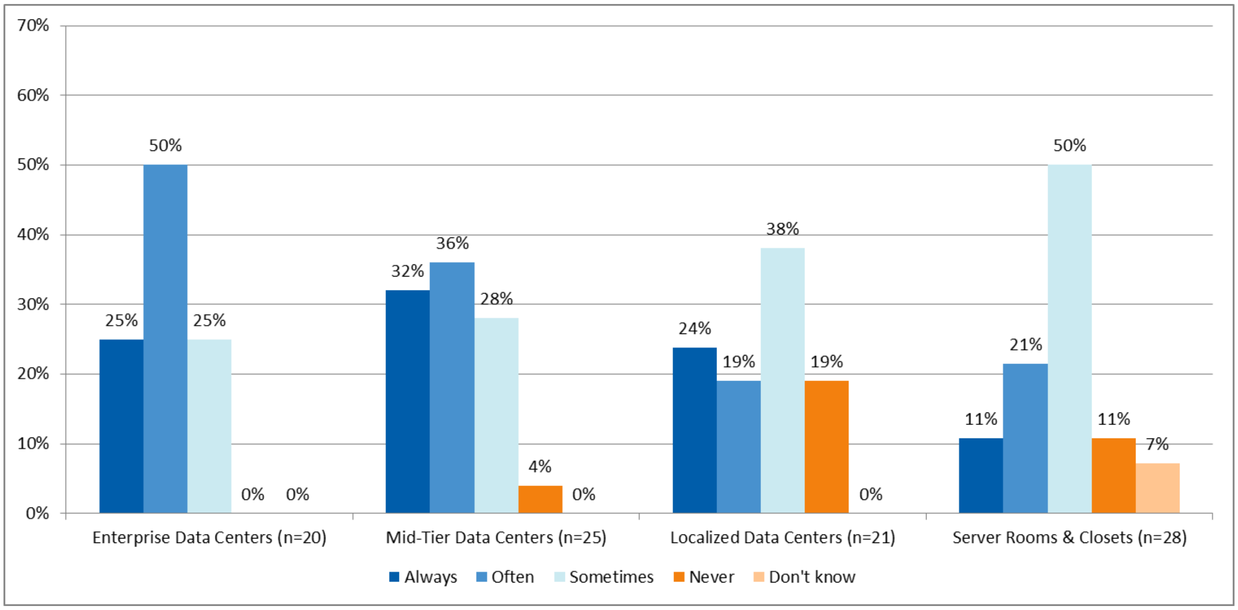
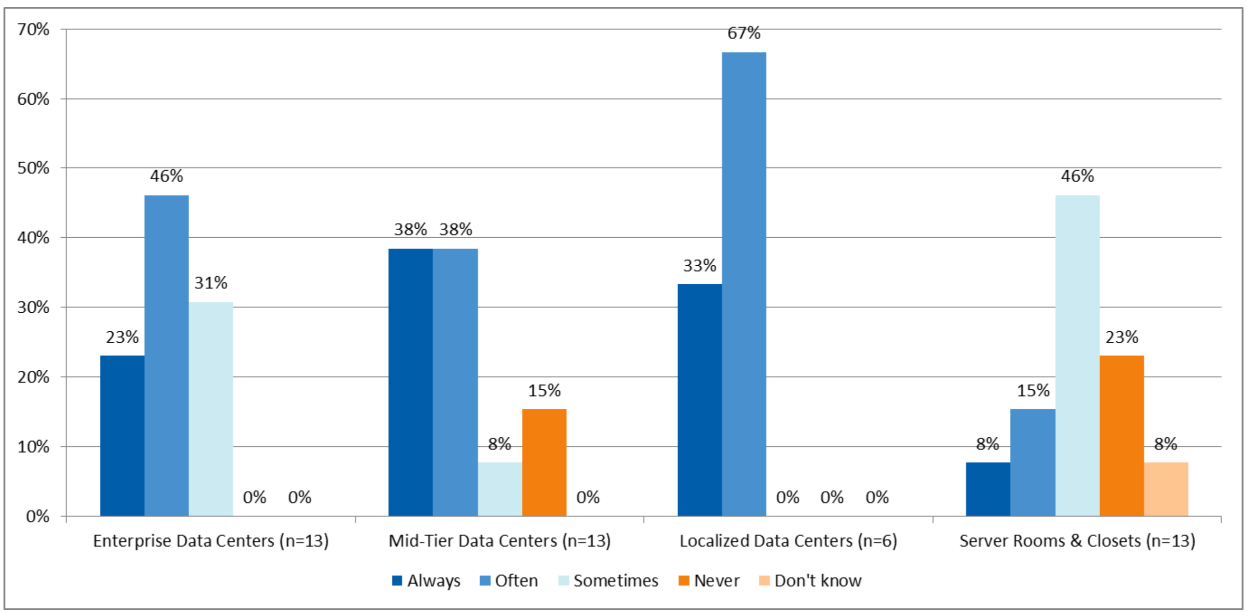


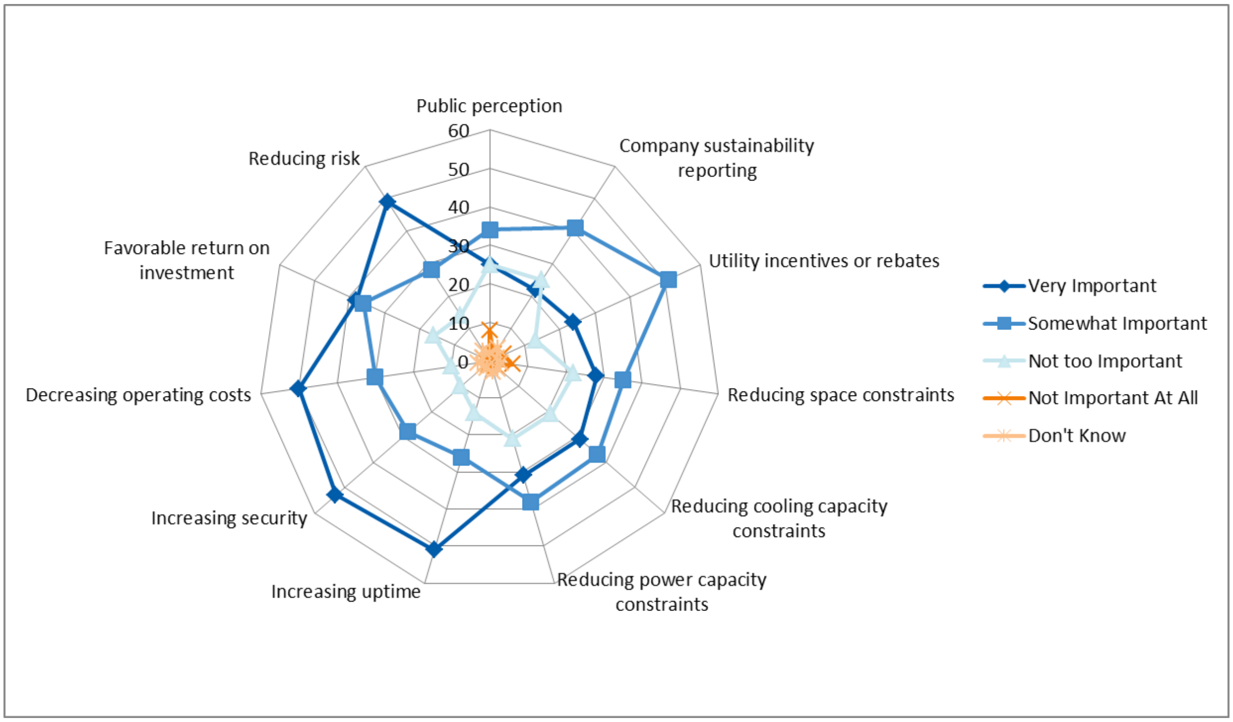
Figure 6. Frequency of Energy Efficiency and Energy Cost Considerations (Industry Players)



5.4.2 Energy Efficiency Project Approval

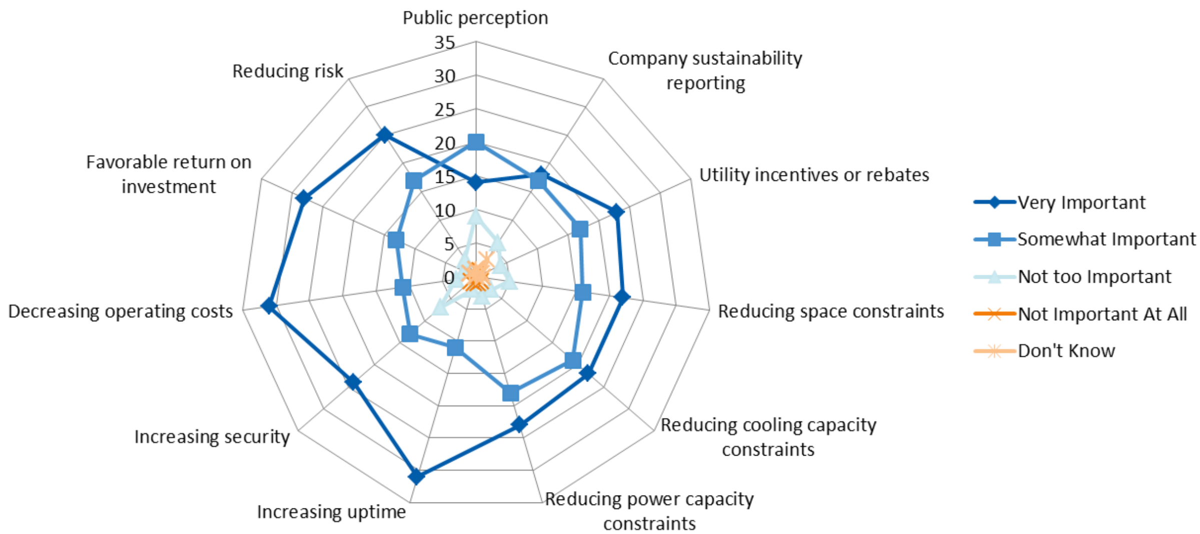
To increase the understanding of the primary factors that drive approval of energy efficiency projects, the survey asked respondents to rank various factors as either “very important,” “somewhat important,” “not too important,” “not important at all.” or “don’t know.” [69] Figure 7 and Figure 8 show how many respondents placed each factor in the provided response categories. The figures show increasing uptime and decreasing operating costs were top concerns for both participant groups. Data center managers appear to place a higher value on reducing risk and increasing security, while more industry players cited favorable return on investment (ROI) as “very important.” About one-fourth of industry players and data center managers listed utility incentives or rebates as very important. While data center managers often said that corporate sustainability reporting was somewhat important, far fewer industry players listed that as important. No single decision factor was deemed “very important” by more than 55% of data center managers and by more than 35% of industry players.

Figure 7. Decision Factors in Approving Energy Efficiency Projects (Data Center Managers, n = 94)



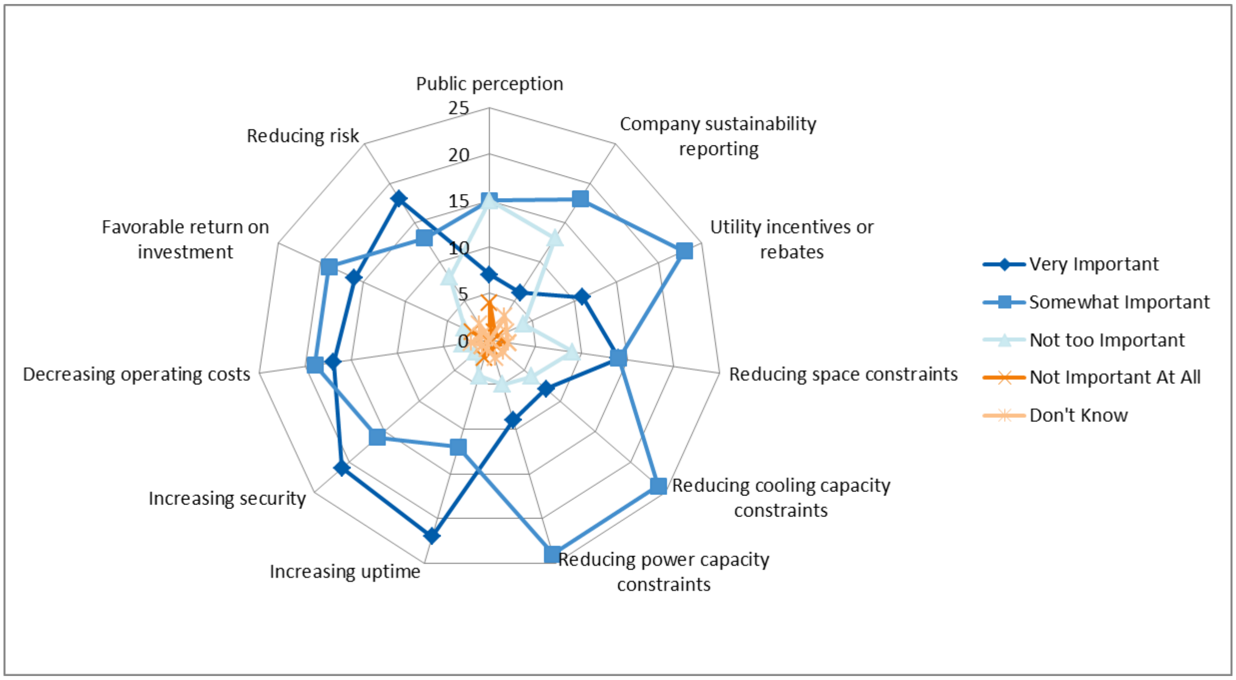
69 The survey question was “Please indicate the level of importance for each of the following factors in receiving approval for an energy efficiency project at your familiar data center.”

Figure 8. Decision Factors in Approving Energy Efficiency Projects (Industry Players, n = 45)



Evaluation of responses for the different data center space types shows some of the more distinct concerns each participant group faces. At the enterprise level, the top two concerns for all respondents were increasing security and increasing uptime. At the mid-tier level the top two concerns were increasing uptime and decreasing operating costs, while those at localized data centers were largely focused on decreasing operating costs. As shown in Figure 9, while similar factors as those described at the macro level remain important for server rooms and closets, reducing cooling and power constraints also featured prominently, along with utility incentives and rebates. In summary, as expected, uptime, security, and cost are top concerns in the data center industry, however, how each factor is weighed is somewhat dependent on the size of the data center, and factors of secondary (somewhat) importance vary more widely.

Figure 9. Decision Factors in Approving Energy Efficiency Projects (All Respondents, Server Rooms and Closets, n = 41)



5.4.3 Budgetary Funding Standards

Within any business sector, budgets and costs are always important decision-making factors. The Cadmus team asked respondents to select which supporting information or standards need to be met to receive budgetary funding for energy efficiency projects within their data centers. They could choose one or more of the following six options:

- Energy study on data center space.
- Preliminary calculations of energy and costs savings.
- Examples or case studies of projects at similar facilities.
- Return on investment calculations.
- Other.
- Don't know.

As shown in Figure 10 and Figure 11, at the enterprise level, both groups of respondents indicated that preliminary calculations of energy and costs savings were most important for receiving budgetary funding. For the other data center sizes, both groups listed ROI calculations as the top decision-making factor. Generally, it appears that energy studies, preliminary savings calculations, case studies, and ROI all may be used to some degree in budgetary decision-making. While decision-makers at larger data centers are more likely to rely on energy and cost savings calculations, overall ROI is utilized the most to support budgetary decisions.

Figure 10. Budgetary Funding Standards (Data Center Managers)

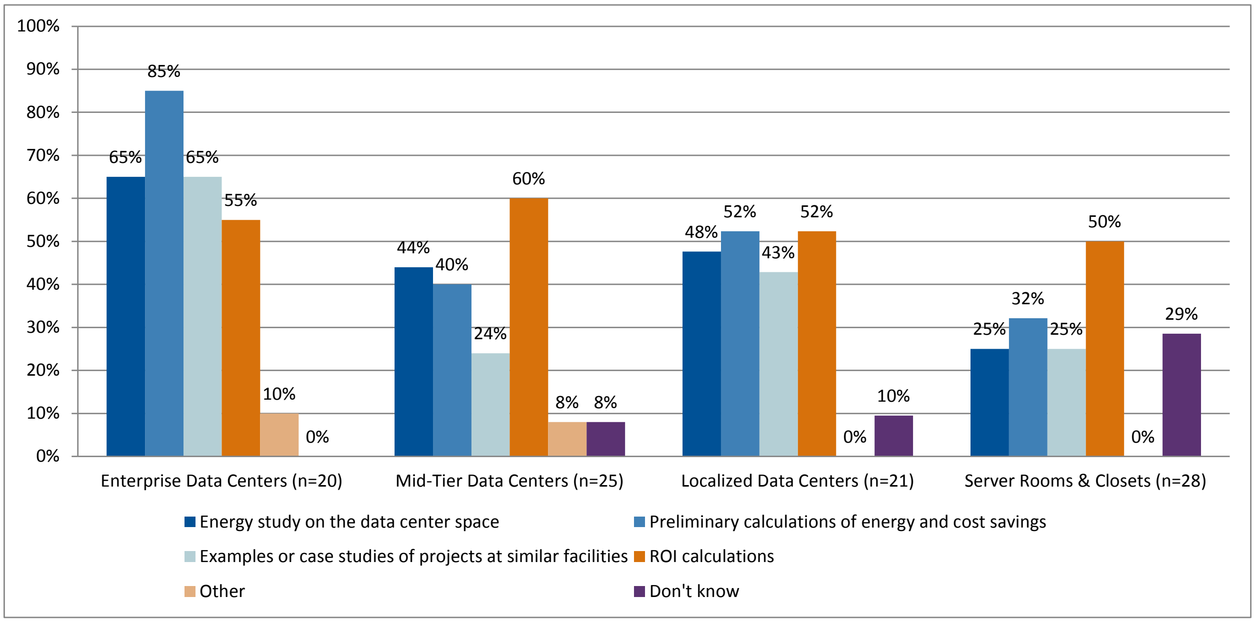
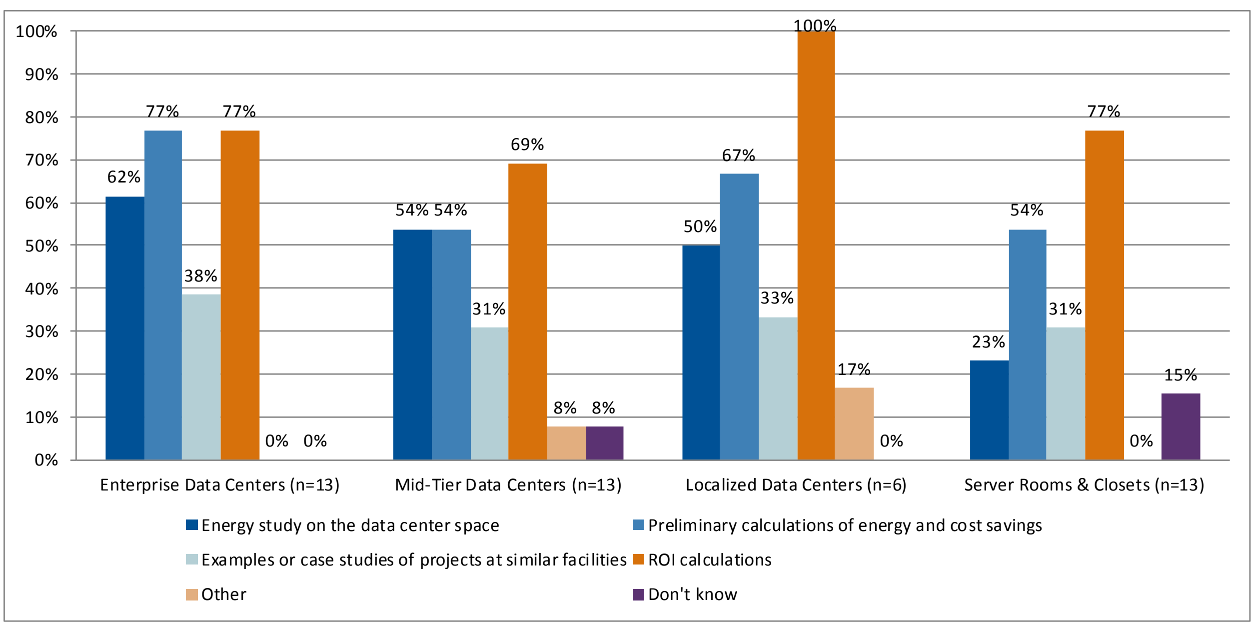


Figure 11. Budgetary Funding Standards (Industry Players)



5.4.4 IT Load

Knowing the current IT load in a data center is necessary to determine the amount of cooling required, appropriate UPS sizing, and approximate energy consumption. For this reason, the survey asked how data center managers and industry players estimate IT load in their respective data center.

Figure 12 and Figure 13 show the responses from data center manager and industry player groups and compare the responses across the different data center types. The most notable difference between the two participant groups is the higher percentage of data center managers who don't know how they estimate their IT load, especially in smaller data centers. Data center managers and industry players most commonly used management software (e.g. BMS, DCIM) and reading from the UPS to determine IT load.

Figure 12. Estimating IT Load (Data Center Managers)

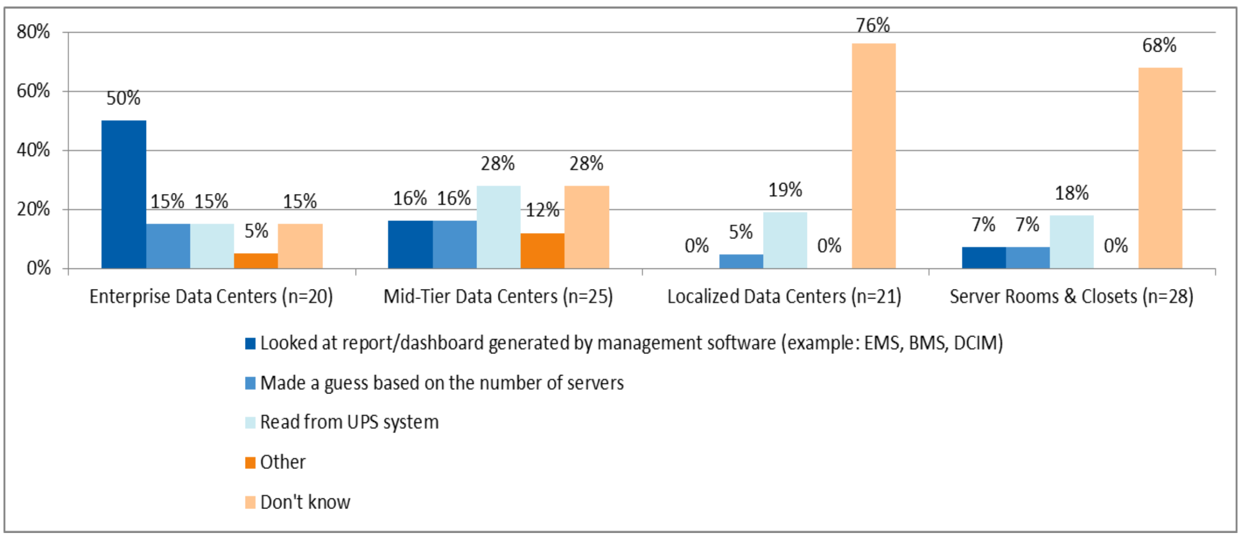
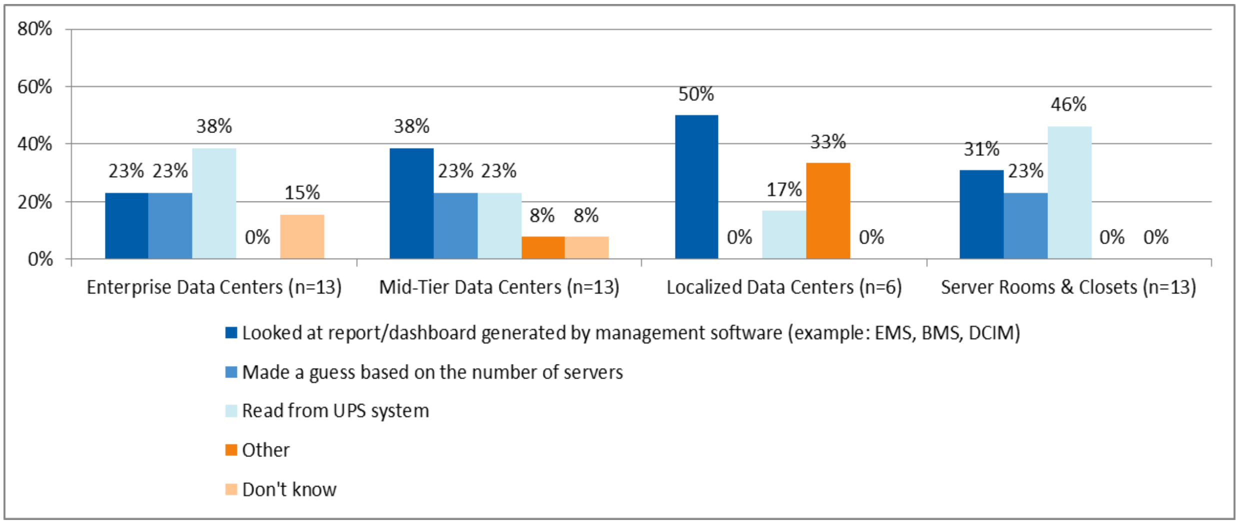


Figure 13. Estimating IT Load (Industry Players)

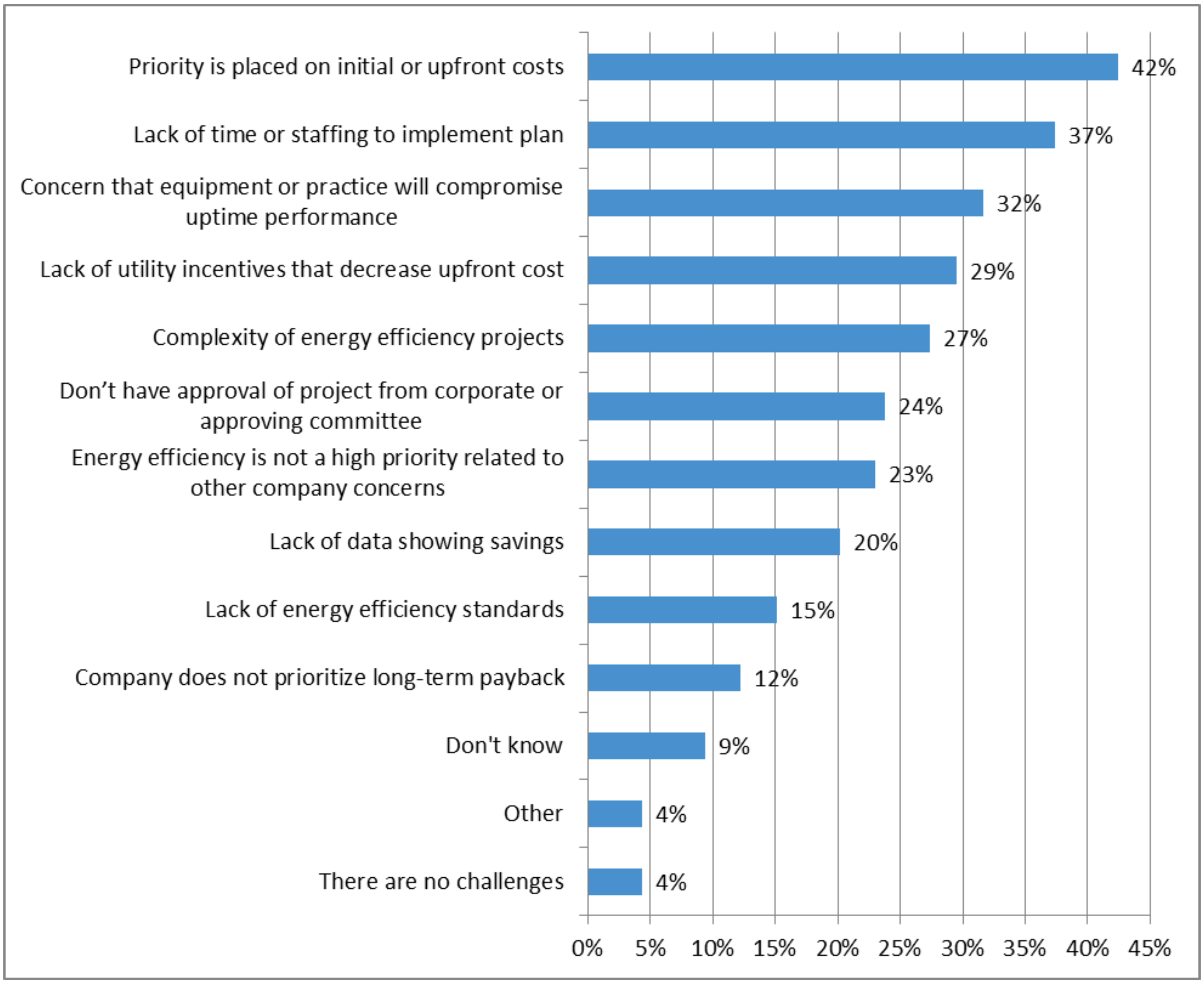


Findings from this question illustrate that while data centers of different sizes face different challenges, a general lack of understanding by managers regarding data center energy usage exists, particularly in smaller data centers. Reflecting on the adage of "what gets measured gets managed," managers' inability to measure IT load will inevitably impact their ability to manage energy consumption in their data centers. This knowledge gap potentially represents a major barrier for making data centers more energy efficient.

5.4.5 Energy Challenges

The survey asked data center managers and industry players to select challenges they face in saving energy at their familiar data center from a list of 13 options. They were allowed to select multiple challenges. As shown in Figure 14, many data center managers and industry players are working in an environment where priority is placed on initial or upfront costs and/or there is a lack of time or staff to implement an energy saving plan or project. Respondents were also concerned that the equipment or a practice will compromise uptime performance and cited a lack of utility incentives that decrease upfront costs as a challenge. The results are presented here at the macro-level, as the major themes remained the same for the two groups and four different data center space types.

Figure 14. Energy Efficiency Project Barriers (All Respondents, n=139)



5.4.6 Addressing Energy Challenges in Data Centers

The survey asked data center managers only to identify the best way to address energy challenges in data centers. They were given the following nine choices and were allowed to choose multiple options.

- Change how operational costs are allocated.
- Conduct a study to confirm energy savings.
- Demonstrate other benefits (increased redundancy or uptime).
- Hire a consulting firm or contractor.
- Hire new staff.
- Seek programs with financial assistance/incentives.
- Shift focus to long-term savings.
- Other.
- Don’t know.

As shown in Figure 15 and Figure 16, the responses were broken out by data center space type. Enterprise data center managers most frequently chose conducting an energy study and demonstrating other benefits, while mid-tier and localized data center managers seem to value financial incentives the most. Approximately a quarter of managers for server rooms and closets did not know how to address energy challenges. Others server room and closet managers identified conducting study to confirm energy savings as a potential solution (20%), followed by seek programs with financial assistance/incentives (17%). Overall, incentives and energy studies appear to be data center managers preferred approach for addressing energy challenges.

Figure 15. How Best to Address Energy Challenges in Data Centers (Enterprise and Mid-Tier)

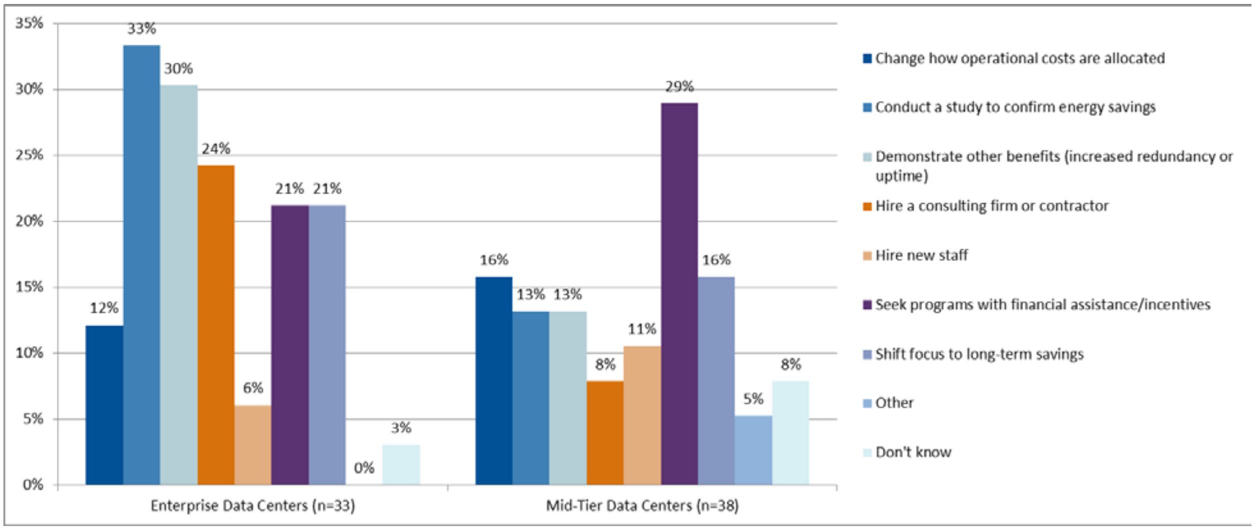
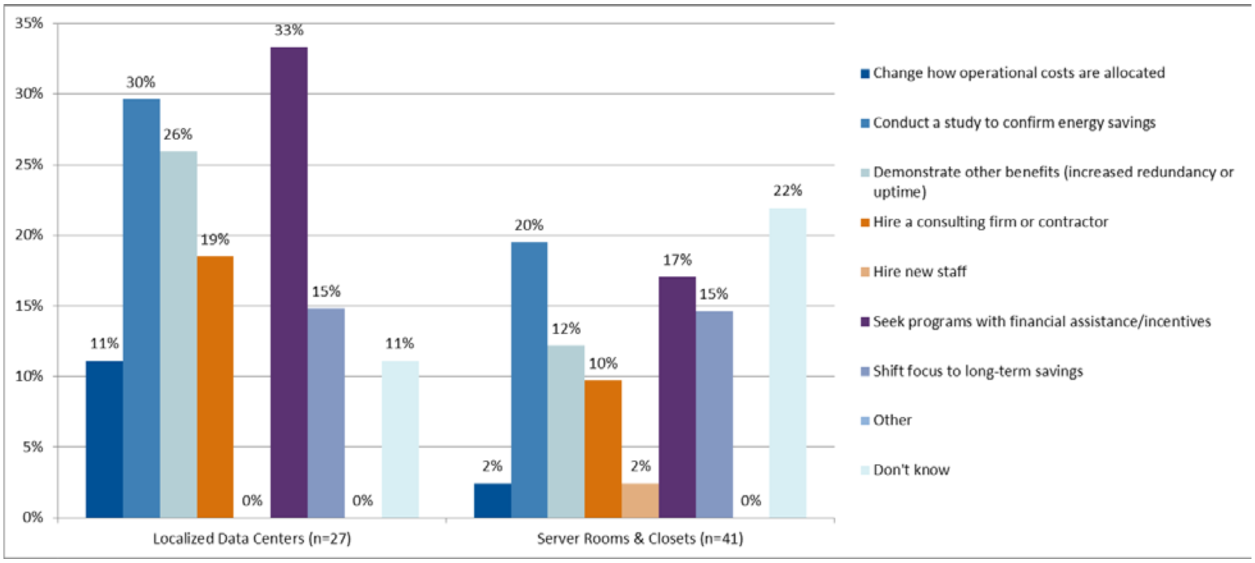


Figure 16. How Best to Address Energy Challenges in Data Centers (Localized and Server Rooms and Closets)



5.5 EETBP Findings

This section provides a cross-cut analysis of the survey respondents' implementation of, and interest in, 32 energy efficiency technologies across four different data center space types. The section also includes the decision-making factors and barriers associated with data centers of different sizes.

With regard to implementation, IT EETBPs led with high server virtualization implementation, even in smaller data centers, and demonstrated the largest uptake by data centers of all sizes. Facility-side measures, including airflow management, HVAC, and humidification, have better implementation rates in larger facilities, which, in many cases, is likely due to these measures being applicable to large facilities, but not small ones. Power infrastructure measures, with the exception of energy efficient UPS, are mostly untapped and only show some minor uptake by larger data centers. Humidification measures, two of them no-cost measures, showed the lowest implementation rates of the five major types of efficiency measures. No major differences existed between the perspectives of data center managers and industry players when it came to measure implementation.

When the team looked at EETBPs in which respondents were interested, but not implementing (possibly due to market barriers), the team found more interest in IT EETBPs than the four other categories. While this has to be countered with an acknowledgement of lower sample sizes, it appears that a high number of data center managers who have not yet implemented IT EETBPs are interested in doing so. Respondents expressed moderate interest in the majority of the other EETBPs. The "interested" responses by data center managers and industry players varied the most with HVAC EETBPs. An interesting finding from examining the data is that mid-tier data centers consistently showed the most interest across all EETBP types. This could be due to the fact that mid-tier data center staff understand the benefits of energy efficient measures, but perhaps do not have the resources to execute. Perhaps the most surprising result was the large percentage of data center managers at the enterprise, mid-tier, and localized levels who expressed interest in solar power for their data center.

Factoring in their overall potential (i.e., technical and market) and the rate of implementation, opportunity portfolios, the ability to reduce data center load, were estimated for each EETBP (Section 5.3.4). Findings included:

- Combined heat and power, solar power, direct current to the rack,[70] and air-side and water-side economization appear ripe for market assistance in larger data centers. These EETBPs earned "A" grades in the opportunity portfolio analysis at larger data centers. Despite their high grades, Cadmus recognizes the technical and cost limitations of these technologies.
- Eight of the 12 EETBPs considered applicable to server rooms and/or closets received an "A" or "B" grade, demonstrating that a host of energy savings opportunities are available even for these smaller facilities. However, the currently low market penetration of these applicable EETBPs indicates that data center operators need assistance to overcome barriers. In many cases, key barriers may be a lack of financial resources, staff resources, and/or technical sophistication with regard to energy management.
- Hot or cold aisle configuration, in-row cooling, and VSDs, because of their high implementation rates and low overall potential, earned "E" grades in the opportunity portfolio analysis in enterprise data centers.

[70] This measure was flawed in that is was misspelled in the survey and referred to as "Data Center current (as opposed to AC) to the racks." However, the Cadmus group is reporting the information as observed in the survey.

Encouragingly, respondents from data centers of all sizes indicated that energy plays some role in their organization's decision-making process. This role is especially true in larger facilities, though the reason for lower levels of concern in smaller facilities may be due to a lack of understanding regarding energy consumption. To receive project energy efficiency project approval, respondents indicated that increasing uptime and decreasing operating costs were top concerns. In addition, data center managers appear to place a higher value on reducing risk and increasing security, while more industry players cited favorable return on investment (ROI) as "very important." ROI analysis was also deemed as the piece of information most important to receive budgetary approval. For smaller data centers, energy efficiency will look more attractive to data center operators when it is linked to its ability to reduce power, and cooling constraints.

Finally, when considering barriers to implementing EETBPs, many respondents indicated that upfront costs and/or a lack of time or staff are the largest barriers to energy savings projects. In addition, it is clear that data center managers, but not industry players, for smaller spaces struggle to estimate the IT load in their data centers. As this is a first step to calculating support equipment requirements and evaluating energy saving opportunities, this lack of understanding is preventing informed decisions about energy management from occurring in some data centers. Also, the surveyed data center managers valued incentives, but in many cases, they equally valued other assistance such as consultants, energy studies, and the demonstration of other benefits.

6 Model Data Center Energy Consumption and Load Growth

For this task, the Cadmus team focused on developing and applying an analysis framework for estimating the energy use of data centers in New York State from 2014 to 2020, for different data center types, and under different future scenarios for the adoption of EETBPs. The analysis framework was based largely on an existing mathematical model of U.S. data center energy use and technical potentials for efficiency improvements, which was originally developed for the United States Environmental Protection Agency's 2007 *Report to Congress on Server and Data Center Energy Efficiency*[71] and later expanded and published for public use.[72]

A limitation of the existing model is that it was designed for estimating technical potentials in static fashion. More specifically, the existing model enables analysis of "before" and "after" cases for efficiency improvements, but does not explicitly consider the timescales or costs of efficient technology adoption. To enable the scenario projections required in this task, the Cadmus team expanded the existing model in three ways:

1. Added IT device stock turnover and vintage modeling capabilities to analyze the influence of hardware refresh cycles on the ability of New York State data centers to adopt new IT device technologies over the projection period.
2. Added temporal projection capabilities, which enable the estimation of New York State data center energy use on the basis of growth in demand for data center services, and in consideration of historical technological improvements in the capacity (e.g., computations of servers and terabytes (TB) of storage per hard disc drive (HDD) and energy efficiency (e.g., watts per computation for servers and watts per TB for storage) of IT devices over time.
3. Associated typical payback periods with the EETBPs that are included in the existing model to enable assessment of near-term payback and mid-term payback potentials alongside technical potentials.

The following subsections describe the data sources, assumptions, modeling approaches, and results associated with each subtask. The sections also summarize input values for model parameters in each

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71 Brown R, Masanet, E., Nordman, B., Tschudi, W., Shehabi, A., Stanley, J., Koomey, J., Sartor, D., Chan, P., Loper, J., Capana, S., Hedman, B., Duff, R., Haines, E., Sass, D., and A. Fanara: Report to Congress on Server and Data Center Energy Efficiency: Public Law 109-431. Edited by Berkeley, California: Lawrence Berkeley National Laboratory. 2007.

72 Masanet ER, Brown RE, Shehabi A, Koomey JG, Nordman B. 2011. "Estimating the Energy Use and Efficiency Potential of U.S. Data Centers," Proceedings of the IEEE 99:1440-1453.

scenario. Further details on the background, parameters, and equations associated with the existing model are provided in a 2011 IEEE paper on the model.[73]

6.1 Current Data Center Energy Use in New York State

This subtask focused on estimating the current (i.e., 2014) annual energy use of the New York State data center market in the aggregate and across five data center space types: (1) server closets; (2) server rooms; (3) localized data centers; (4) mid-tier data centers; and (5) enterprise data centers. These space types are specified explicitly in the existing model and based on the characteristics summarized in Table 31. (During the rest of the analysis server closets and server rooms are collapsed into a single category.)

Table 31. Data Center Space Type Definitions[74]

Space Type	Typical White Space Floor Area (ft^2)	Typical IT Devices
Server closet	less than 100	Fewer than 5 servers; minimal external storage
Server room	100 to 999	5 to 24 servers; minimal external storage
Localized data center	500 to 1,999	25 to 99 servers; moderate external storage
Mid-tier data center	2,000 to 19,999	100 to 499 servers; extensive external storage
Enterprise data center	greater than 20,000	At least 500 servers; extensive external storage

The Cadmus team estimated the current New York State data center energy use with the existing model and a combination of data obtained from the in-depth survey (see Section 3.2) and the literature to specify the model's input parameters. Table 32 summarizes the input parameter values for estimating the energy use of New York State data centers by space type in 2014. In general, the input parameter values that the team based on study survey data were those that the team considered to be robust in terms of their sample size and feasibility compared to national-level data from other studies in the literature. For study survey data input parameters deemed unreliable, or for parameters not covered by the study survey questions, the team used national-average data from the literature as a proxy. The sources of the input parameters summarized in Table 32 are described as follows.

73 Masanet ER, Richard E. Brown, Arman Shehabi, Jonathan G. Koomey, and Bruce Nordman: Estimating the Energy Use and Efficiency Potential of U.S. Data Centers. Edited by Lawrence Berkeley National Laboratory; 2011.

74 Data center size categories defined in "U.S. Data Center Census and Construction 2013-2017 Forecast," October 2013, International Data Corporation (IDC).

For each space type, the existing model estimates the total power use of IT devices (i.e., servers, storage devices, and network gear) in bottom-up fashion. For servers and network switches, bottom-up estimates are based on the number of installed devices and the average power use of each device; for storage devices, estimates are based on the installed storage capacity and average power use intensity (W/TB) of each type of storage device. The power use associated with electricity and cooling infrastructure system components (i.e., transformers, UPSs, lighting, and cooling) is expressed in the model as watts of power consumed by each component per watt of power delivered to the IT devices. The model converts power use to energy use by assuming continuous operation of the data center (8,760 hours per year).

The Cadmus team obtained the estimated number of data centers within each space type in New York State based on a dedicated survey of New York State organizations described in Section 2.1. The team obtained the numbers of installed servers and network switches for each space type, as well as the installed capacity of different storage types, from the study survey data, using combined responses from data center managers and industry players as shown in Appendix D: Table D-3 (servers), Table D-119 (switches), and Tables D-158, D-161, and D-163 (storage devices).

To estimate the average power use of each IT device, the team used recent national average data from the literature due to low reliability in the in-depth survey response data. While the survey asked respondents to provide the number of installed servers and the total power draw of servers in their data centers, fewer than 30% of respondents provided these data (Appendix D, Table D-3). Furthermore, dividing total power draw by total installed servers from each respondent yielded widely varying results. Therefore, the team used the latest measured data for average server power use as a more credible proxy. The Cadmus team estimated average power use per server at 235 W based on measured power use data for typical volume servers.[75] Similarly, the team used national average data for the average power use of external storage devices[76] and network rack switches[77] due to insufficient survey data, as well as typical data on the power use intensity of tape storage, solid states drives (SSD), and different speeds of hard disk drives (HDDs). [78]

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[75] Koomey, J. 2011. *Growth in Data center electricity use 2005 to 2010*. Oakland, CA: Analytics Press.

[76] Reinsel D. 2011. A Plateau in Sight for the Rising Costs to Power and Cool the World's External Storage? Edited by International Data Corporation (IDC).

[77] Mahadevan P, Shah A, Bash C. 2010. Reducing lifecycle energy use of network switches. In Sustainable Systems and Technology (ISSST), 2010 IEEE International Symposium on 17-19 May 2010: 1-6.

[78] Pflueger J. 2010 Understanding Data Center Energy Intensity: A Dell Technical White Paper. Round Rock, TX. Dell Incorporated.

The low response rates and lack of reliable data regarding IT device power draw underscores the need for greater monitoring of—and accessibility to—device-level power draws in many typical data centers.

Table 32. 2014 NYS Data Center Energy Use Modeling Parameters

Description	Model parameter*	Server closets and rooms	Localized	Mid-tier	Enterprise
Servers					
Number of NYS data centers		201,289	2,620	1,109	398
Avg. number of servers per data center		3.3	42	211	1,866
Total installed servers	$\check{N}^{S}$	668,151	110,040	233,999	742,668
Power use per server (kW)		0.235	0.235	0.235	0.235
Energy use per server (kWh/yr)	$\check{e}^{S}$	2,059	2,059	2,059	2,059
Total server energy use (million MWh/yr)		1.38	0.23	0.48	1.53
Storage					
External storage capacity per data center (TB)	$\check{N}^{ST}$	21	54	186	1,928
% capacity stored on solid state drives (SSD)		1%	7%	3%	3%
% capacity stored on tape drives		20%	0%	19%	16%
% capacity stored on 15k rpm HDD		19.8%	33.5%	14.0%	17.8%
% capacity stored on 10k rpm HDD		26.9%	27.0%	18.7%	37.3%
% capacity stored on 7.2k rpm HDD		30.8%	26.0%	42.1%	21.9%
% capacity stored on variable speed HDD		1.6%	6.5%	3.1%	4.1%
Power use of SSD (W/TB)		3.5	3.5	3.5	3.5
Power use of tape (W/TB)		27.2	27.2	27.2	27.2
Power use of 15k HDD (W/TB)		26.7	26.7	26.7	26.7
Power use of 10k HDD (W/TB)		15.5	15.5	15.5	15.5
Power use of 7.2k HDD (W/TB)		8.4	8.4	8.4	8.4
Power use of variable HDD (W/TB)		6.5	6.5	6.5	6.5
Weighted average energy use (W/TB)	$\check{e}^{ST}$	17.7	16.1	15.7	17.0
Total external storage energy use (million MWh/yr)		0.07	0.02	0.03	0.11
Network equipment					
Avg. number of network devices per installed server		0.1	0.1	0.1	0.1
Total installed devices	$\check{N}^{N}$	68,646	11,305	24,041	74,267
Power use per device (kW)		0.175	0.191	0.365	0.203
Energy use per device (kWh/yr)	$\check{e}^{N}$	1,533	1,674	3,197	1,774
Total network device energy use (million MWh/yr)		0.11	0.02	0.08	0.13
Infrastructure systems					
Transformers (W/W)	ε^{IS}_{1}	0.05	0.05	0.05	0.05
UPS (W/W)	ε^{IS}_{2}	0.20	0.20	0.20	0.10
Lighting (W/W)	ε^{IS}_{3}	0.02	0.02	0.02	0.02
Cooling systems (W/W)	ε^{IS}_{4}	0.70	0.53	0.53	0.53
PUE	$1 + \mathrm{sum}(\varepsilon^{IS}_{i})$	1.94	1.80	1.80	1.70
Total infrastructure system energy use (million MWh/yr)		1.67	0.21	0.47	1.24
Total data center energy use (million MWh/yr)		**3.01**	**0.48**	**1.06**	**3.02**

* refers to the corresponding variable name in the existing model [2]

The existing model estimates the energy use of electricity and cooling infrastructure systems in terms of four major components: (1) power transformers; (2) UPSs; (3) lighting; and (4) cooling systems (which includes the combined energy use of compressors, fans, pumps, and other cooling system components). Despite the broad use of power utilization effectiveness (PUE) as a measure of infrastructure system energy efficiency, the vast majority of survey respondents indicated that they did not know the PUE of their most familiar data center. (This finding reflects that many data center managers do not emphasize energy efficiency in their evaluation of data center operation). As such, the Cadmus team estimated the PUE of New York State data centers using average data from the literature, based on typical component-level values for data centers with similar equipment configurations as specified in the in-depth survey data (see Appendix D, Tables D-132 through D-140). Specifically, the team estimated the PUEs of server closets and rooms based on recent data from Lawrence Berkeley National Laboratory[79] and the PUEs of the remaining space types on national average data.[80,81,82] As such, the PUE estimates in the study should be reasonable proxies for each space type in the absence of comprehensive empirical data or infrastructure energy use simulations for regional climate and equipment configurations in New York State, both of which are absent from the public domain.

Figure 17 depicts the resulting estimates of 2014 New York State data center energy use, in which the total estimated energy use of New York State data centers is 7.6 billion kWh. The energy use of enterprise data centers and server closets and rooms dominates New York State data center energy use (80% of the total), primarily due to the large number of installed servers per enterprise data center and large number of these smaller data center types estimated by the in-depth survey data. These general findings are consistent with previous studies, which attribute the majority of U.S. data center energy use to the nation’s largest and smallest data centers.[83,84]

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79 H. Y. Iris Cheung SEG, Roozbeh Mahdavi, Richard Brown, William Tschudi. 2013. “Energy Efficiency in Small Server Rooms.” Edited by Berkeley, California: Lawrence Berkeley National Laboratory.

80 Masanet ER, Brown RE, Shehabi A, Koomey JG, Nordman B. 2011. “Estimating the Energy Use and Efficiency Potential of U.S. Data Centers.” Proceedings of the IEEE, 99:1440-1453.

81 Masanet E, Shehabi A, Koomey J. 2013. “Characteristics of low-carbon data centres.” Nature Climate Change, 3:627-630.

82 Shehabi A, Masanet E, Price H, Horvath A, Nazaroff WW. 2011. “Data center design and location: Consequences for electricity use and greenhouse-gas emissions. Building and Environment,” 46:990-998.

83 Masanet ER, Brown RE, Shehabi A, Koomey JG, Nordman B. 2011. “Estimating the Energy Use and Efficiency Potential of U.S. Data Centers. Proceedings of the IEEE, 99:1440-1453.

84 Council NRDC. 2014. Data Center Efficiency Assessment: Scaling Up Energy Efficiency Across the Data Center Industry: Evaluating Key Drivers and Barriers. Edited by New York, New York.

For comparison, the most recent published estimate of national-level energy use suggests that U.S. data centers consumed a total of 91 million MWh in 2013.[85] The estimated energy use of New York State data centers in 2014 is 8.3% of this amount, which is similar to the New York State share of U.S. national economic output (8% of U.S. GDP in 2013).[86] While all regional data center energy use estimates are inherently uncertain, the rough alignment between the New York State share of national data center energy use and national GDP is encouraging as a coarse reality check. However, this study's estimates of the total installed servers in NYS in 2014 (1.75 million) accounts for around 14% of the most recent published estimate of the total installed servers in the United States (12.2 million in 2011),[87] which is substantially higher than New York State's share of national GDP. Reconciling the differences between New York State's estimated shares of national data center energy use and installed servers is not possible given lack of better data. However, these differences underscore the uncertainties associated with regional bottom-up estimates of data center energy use. Future studies should conduct surveys and site visits with larger sample sizes to estimate the New York State installed IT device base and power usage with greater confidence. Therefore, for the purposes of this study, the team considered the total New York State data center energy use estimates in Figure 17 a reasonable best guess in light of data constraints.

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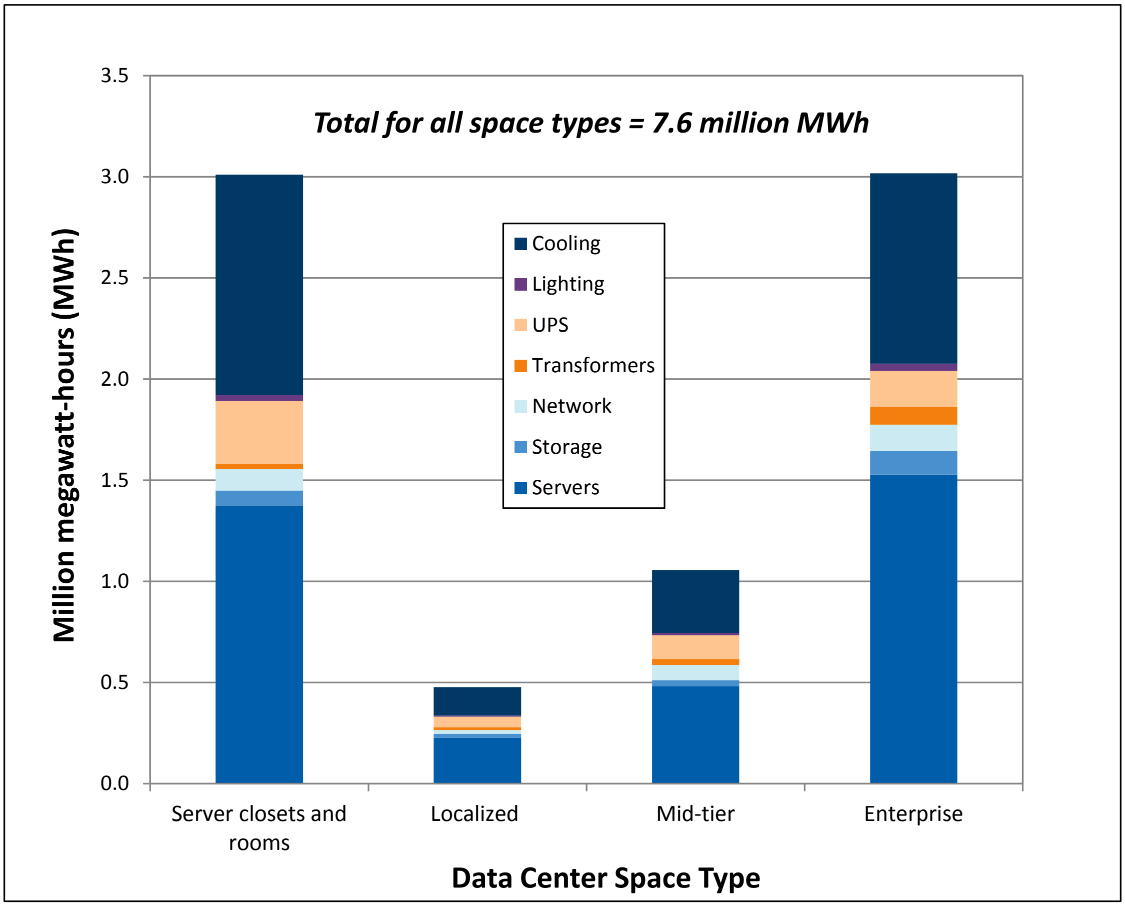
85 Council NRDC. 2014. Data Center Efficiency Assessment: Scaling Up Energy Efficiency Across the Data Center Industry: Evaluating Key Drivers and Barriers. Edited by. New York, New York.

86 U.S. Bureau of Economic Analysis, ["Widespread But Slower Growth in 2013,"] news release (June 11, 2014), http://bea.gov/newsreleases/regional/gdp_state/2014/pdf/gsp0614.pdf.

87 NRDC. 2014..Data Center Efficiency Assessment: Scaling Up Energy Efficiency Across the Data Center Industry: Evaluating Key Drivers and Barriers. New York, New York.

Figure 17. Estimated 2014 NYS Data Center Energy Use



6.2 Business as Usual Data Center Energy Use in New York State (2014 to 2020)

The Cadmus team used the estimated 2014 New York State data center energy use to project a BAU scenario over the time period 2014 to 2020. The purpose of the BAU scenario was to assess New York State data center energy use in the near future in the absence of any efficiency improvements, with the exception of efficiency gains realized through IT device replacements that will occur due to periodic IT hardware refresh cycles. The consideration of refresh cycles and technological improvements in new IT devices allows for a more realistic BAU scenario, given that each new generation of IT devices brings with it significant improvements in performance and energy use. However, all other data center characteristics (i.e., PUE) remained frozen in the BAU scenario. The periodic refresh cycles in this study consider both standard refresh cycles set by data center managers and periodic replacements of servers in more ad hoc fashion, using an overall average replacement time for the entire server stock in each space type.

There were three steps in the construction of the BAU scenario. First, the Cadmus team identified data to approximate the demand in growth for New York State data center services in the near term. This study employed data from Cisco's Visual Networking Index Initiative, which developed projections of Internet protocol (IP) data demands in a number of different categories (e.g., email and streaming video) and world regions.[88] Ideally, future demand for data center services in New York State would be projected based on specific services demanded by different economic sectors (e.g., medical record storage growth for the health care sector), as these services will influence the IT device and operations configurations at New York State data centers. However, in the absence of any information on the current services being provided by New York State data centers, Cisco's projections of overall IP traffic were used for all purposes in North America as a reasonable proxy for data center service demand growth in NYS. Cisco projects a compound annual growth rate (CAGR) of 20% for all IP traffic over the period 2013 to 2018, which the Cadmus team extended to 2020 to construct the BAU scenario. This approach differs from previous studies, which have based future energy use estimates solely on projected installed server counts from vendors and market research firms, which are uncertain and heavily influenced by market demands.[89,90,91]

Second, the Cadmus team developed relationships between the performance and energy use of future IT devices to project the relative change in energy efficiency that could be expected for servers, external storage, and network switches over the projection period. They characterized server performance by the number of computations per server, which have been increasing at a compound annual growth rate (CAGR) of 41% based on Moore's Law. Storage performance was characterized by using the areal density per disk of HDD storage as a proxy for improvements in all storage types, which has also been increasing steadily and rapidly for many years. For this study, a CAGR for areal density of 19% was assumed for the projection period, based on recent industry analysis data.[92] Lastly, a CAGR of 10% was assumed for network gear capacity as a conservative proxy.

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88 Systems C. 2014. "Visual Networking Index (VNI): The Zettabyte Era—Trends and Analysis.".

89 Council NRDC. 2014. Data Center Efficiency Assessment: Scaling Up Energy Efficiency Across the Data Center Industry: Evaluating Key Drivers and Barriers. Edited by New York, New York.

90 Brown R, Masanet, E., Nordman, B., Tschudi, W., Shehabi, A., Stanley, J., Koomey, J., Sartor, D., Chan, P., Loper, J., Capana, S., Hedman, B., Duff, R., Haines, E., Sass, D., and A. Fanara: Report to Congress on Server and Data Center Energy Efficiency: Public Law 109-431. Edited by Berkeley, California: Lawrence Berkeley National Laboratory. 2007.

91 Koomey, J. 2011. *Growth in Data center electricity use 2005 to 2010*. Oakland, CA: Analytics Press.

92 Zhang F. 2012. Storage Space Market Brief - Issue 12. IHS Technology.

At the same time, the average power use of IT devices per unit of performance is decreasing. As a result, future IT devices that are purchased due to standard refresh cycles will offer higher performance at greater energy efficiency. However, their future power use in total depends on the relationship between performance and efficiency increases. Server power use was characterized by computations per watt, which have been increasing at a CAGR of 56% according to Koomey's Law.[93] Similarly, the power use of external storage devices and network switches was characterized by TB of storage per watt (CAGR of 10%) and GB of data transfer per watt (CAGR of 11%), respectively, based on analysis of manufacturer data.[94, 95] Using these data, the relative power use of an IT device in year *i* (indexed to 2014 values) was expressed as in Equation 2, using servers to illustrate the general relation:

$$\text{Power use of typical server in year } i \text{ (W/server)} = [1 + \text{CAGR (computations/server)}]^{(i-2014)} / [1 + \text{CAGR (computations/W)}]^{(i-2014)} \qquad (2)$$

Table 33 summarizes the resulting estimates in the power use of new IT devices purchased over the projection period. Table 33 expresses the estimated energy use of IT devices manufactured each year as a fraction of the energy use of IT devices manufactured in 2014. Substantial power use reductions per server are expected, given steep increases in both computational performance and energy efficiency. Interestingly, the power use of an external HDD was expected to grow, given that increases in areal density are occurring faster than decreases in power use per disk TB.

Table 33. Projected Fraction of Power Use of New IT Devices (Relative to 2014)

Year of Manufacture	W/Server	W/TB	W/Switch
2014	1	1	1
2015	0.91	0.91	0.99
2016	0.83	0.83	0.98
2017	0.75	0.75	0.97
2018	0.68	0.68	0.96
2019	0.62	0.62	0.95
2020	0.57	0.57	0.94

93 Koomey JB, Stephen; Sanchez, Marla; Wong, Henry. 2011. Implications of Historical Trends in the Electrical Efficiency of Computing. IEEE Annals of the History of Computing, 33.

94 Hardware Ts. 2014. Performance Charts Hard Drives. 2014.

95 Alcatel-Lucent. 2014. Measuring Network Energy Consumption: Global 'What if' Analyzer of Network Energy Consumption.

Third, the Cadmus team developed a stock growth and turnover model to project the number of new IT devices entering New York State data centers each year due to standard hardware refresh rates and demand growth for data center services. For this study, the team assumed average refresh cycles of four years for servers, external storage, and network switches, respectively, based on combined responses from data center managers and industry players in the in-depth survey (Appendix D, Tables D-89, D-179, and D-116). Results of the stock growth and turnover model are expressed in terms of workload met by IT devices of each vintage within New York State data centers over the projection period, with workload indexed to 2014 values. Table 34, Table 35, and Table 36 summarize the results for servers, external storage, and network switches. Total workload growth for New York State data centers in New York State is expected to increase by threefold in 2020, based on Cisco's IP traffic projections.

Table 34. Workload Met by Server Vintage

Year of Manufacture	2015	2016	2017	2018	2019	2020
2014	0.75	0.50	0.25	-	-	-
2015	0.45	0.45	0.45	0.45	-	-
2016		0.49	0.49	0.49	0.49	-
2017			0.54	0.54	0.54	0.54
2018				0.60	0.60	0.60
2019					0.86	0.86
2020						0.99
Total	**1.20**	**1.44**	**1.73**	**2.07**	**2.49**	**2.99**

Table 35. Workload Met By External Storage Vintage

Year of Manufacture	2015	2016	2017	2018	2019	2020
2014	0.75	0.50	0.25	-	-	-
2015	0.45	0.45	0.45	0.45	-	-
2016		0.49	0.49	0.49	0.49	-
2017			0.54	0.54	0.54	0.54
2018				0.60	0.60	0.60
2019					0.86	0.86
2020						0.99
Total	**1.20**	**1.44**	**1.73**	**2.07**	**2.49**	**2.99**

Table 36. Workload Met by Network Switch Vintage

Year of Manufacture	2015	2016	2017	2018	2019	2020
2014	0.75	0.50	0.25	-	-	-
2015	0.45	0.45	0.45	0.45	-	-
2016		0.49	0.49	0.49	0.49	-
2017			0.54	0.54	0.54	0.54
2018				0.60	0.60	0.60
2019					0.86	0.86
2020						0.99
Total	**1.20**	**1.44**	**1.73**	**2.07**	**2.49**	**2.99**

Based on the data in Table 34, Table 35, and Table 36, the Cadmus team calculated the future power use of servers, external storage, and network switches by dividing the relative workload of each vintage by its relative capacity (computations per server) and then multiplying by its relative power use (watts per server). Next, two types of server replacements were assumed for each space type. For nonvirtualized servers (i.e., those that are not hosting virtual servers), the Cadmus team assumed that one new server would replace one old server. For virtualized servers (i.e., physical servers hosting one or more virtual servers), the team assumed that the number of new servers purchased will be based on the workload requirements each year. Based on survey data in Appendix D, Tables D-90 through D-92, this study estimated that 27%, 39%, 46%, and 34% of physical servers in server rooms and closets, localized data centers, mid-tier data centers, and enterprise data centers, respectively, are presently hosting virtual servers. These results were used in the existing modeling approach described in Subtask 6.1 to generate estimates of the total energy use of data centers in New York State each year between 2014 and 2020, as summarized in Figure 18 and Figure 19.

Figure 18. BAU Projections for NYS Data Center Energy Use by Component

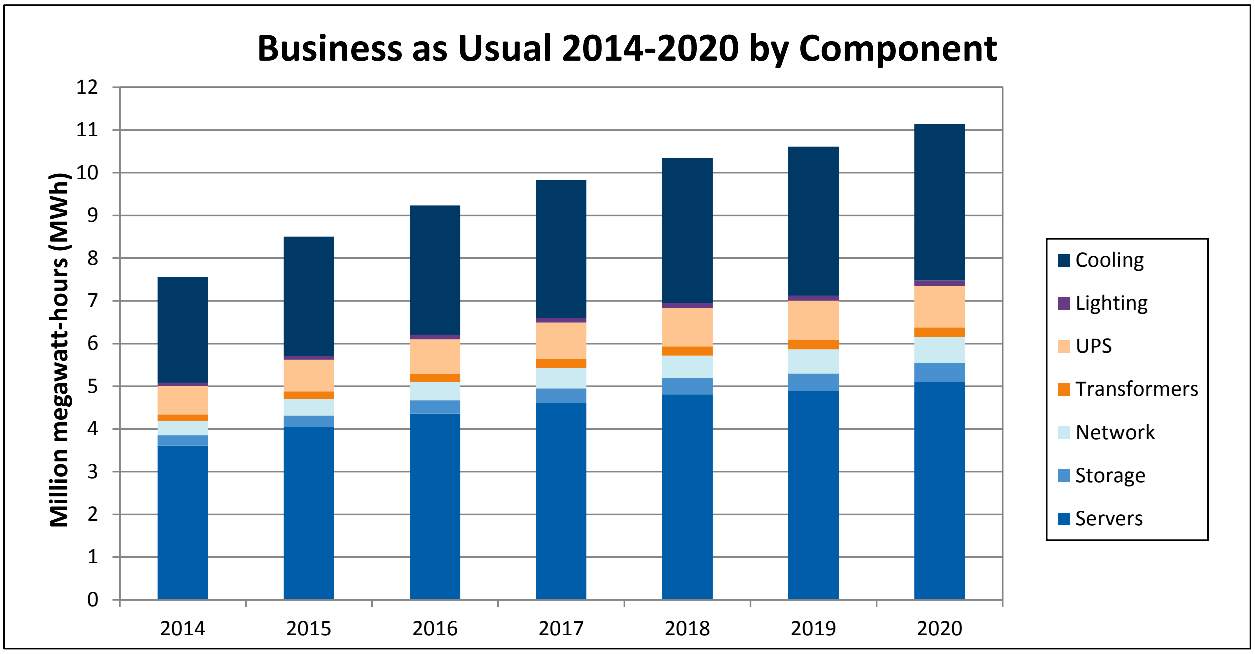
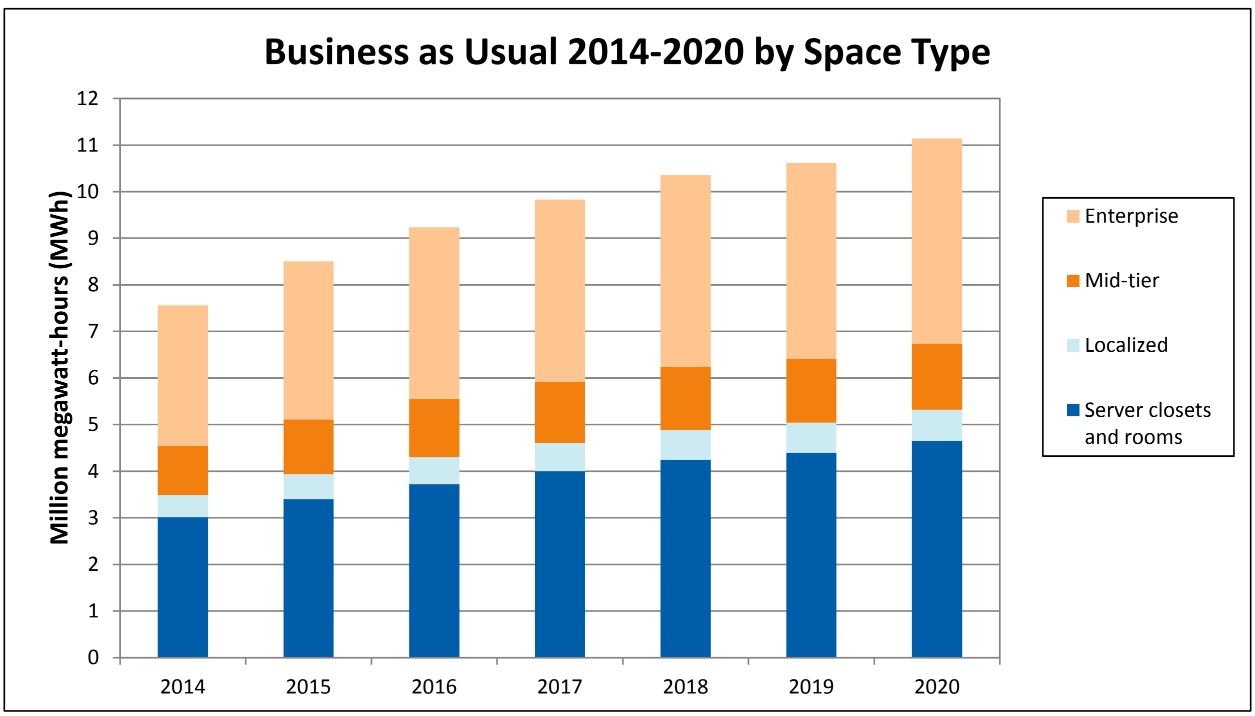


Figure 19. BAU Projections for NYS Data Center Energy Use by Space Type



The trends in the BAU scenario underscore the importance of considering technological change for IT devices when analyzing the energy use associated with demand growth. While demand for New York State data center services is expected to triple by 2020, under standard refresh cycles New York State data centers are also likely to substantially improve their energy efficiency simply by purchasing more powerful and energy efficient IT devices on the market. The most significant improvements are expected for servers, whose computational capacity and energy efficiency are increasing rapidly. As a result, data center energy use is projected to grow by 47% by 2020 to 11.2 million MWh. Conversely, if one estimated future energy use on the basis of "frozen efficiency," which does not consider hardware replacement, the BAU scenario would suggest a nearly threefold increase in the energy use of New York State data centers by 2020.

6.3 Technology Scenario-Based Data Center Energy Use in New York State (2014 to 2020)

This section assesses the potential of different technologies and operational practices for reducing New York State data center energy use compared to the BAU scenario. The Cadmus team considered three different scenarios:

1. **A best practice operations scenario (BPO)**, in which New York State data centers adopt best practice strategies for reducing the energy use of existing IT devices and infrastructure equipment, such as the use of server virtualization and increasing temperature set points.
2. **A best practice technologies scenario (BPT),** which includes all improvements made in the BPO scenario, but in which New York State data centers also adopt the most energy efficient, commercially-available technologies that are in widespread use for IT devices and infrastructure systems.
3. **A cutting-edge technologies scenario (CET),** which includes all improvements made in the BPT scenario, but also includes novel technologies that are currently at the pilot or early commercial stages of availability.

The Cadmus Group also considered the demand-side EETBPs discussed in Section 5 within these three scenarios. Furthermore, the team considered technical, economic, and achievable energy savings potential within each scenario, based on typical payback periods for each EETBP obtained from the literature. Technical potential is defined as the energy savings that can be realized through the adoption of EETBPs without regard to their cost, and, therefore, represents maximal energy savings. Near-term paybacl potential is defined in this study as the energy savings that can be realized through the adoption of EETBPs with simple payback periods of less than two years. Finally, mid-term payback potential is defined as the energy savings that can be realized through the adoption of EETBPs with simple payback periods of greater than two years but less than five years.

Table **37** summarizes the demand-side EETBPs considered in each scenario, the data center space types to which they are considered applicable, and their average payback periods based on literature data. Due to lack of publicly available data on cost variations between space types, the team assumed that the average payback periods listed in Table 37 would be valid across all data center space types in New York State. Future studies should consider cost variations as better data become available.

The existing model quantifies the net energy savings associated with operations and technology improvements at an aggregated level. For example, improvements to cooling system efficiency such as using variable speed drives and efficient motors are expressed as net aggregate changes to the cooling system power use per unit of IT power (W/W) in the model. Therefore, it was necessary to map EETBPs to the appropriate aggregate parameters in the model and, where necessary, to bundle their net energy savings together to facilitate scenario evaluations.

Table 37 lists the parameters in the existing model that the team used to model the effects of EETBPs in this study, with typical simple paybacks period ranges obtained from published case studies and estimates shown in Table 38.

Table 37. Summary of EETBPs, Scenarios, and Payback Periods

EETBP	Model parameters*	Server closet and rooms	Local-ized	Mid-tier	Enter-prise	Payback period (years)**
Decommissioning of unused servers	Θ	BPO	BPO	BPO	BPO	-
Energy efficient servers	α^S, γ^S	BPT	BPT	BPT	BPT	1-1.5
Server virtualization/consolidation	ρ^S	BPO	BPO	BPO	BPO	0.1-1.5
Server power management	β^S	BPO	BPO	BPO	BPO	-
Energy efficient data storage management	ρ^{ST}	BPO	BPO	BPO	BPO	0.5 - 0.9
Solid state storage	α^{ST}, γ^{ST}	CET	CET	CET	CET	2-3
Massive array of idle disks (MAID)			BPT	BPT	BPT	1-1.5
Efficient network topology	α^N, γ^N		BPT	BPT	BPT	
Energy efficient transformers	$\varepsilon^{IS}{}_1$	BPT	BPT	BPT	BPT	2-4
Direct current (as opposed to AC) to the racks			CET	CET	CET	5.3
Energy efficient power supplies (UPS)	$\varepsilon^{IS}{}_2$	BPT	BPT	BPT	BPT	1-6.7
Energy efficient lighting	$\varepsilon^{IS}{}_3$	BPT	BPT	BPT	BPT	2.2-3
Computational fluid dynamics optimization	$\varepsilon^{IS}{}_4$		BPO	BPO	BPO	<1
Blanking panels, grommets, or structured cabling		BPO	BPO	BPO	BPO	1
Adjusting server inlet temperatures		BPO	BPO	BPO	BPO	-
Broaden humidity range			BPO	BPO	BPO	-
Turn off humidifiers			BPO	BPO	BPO	-
Hot or cold aisle configuration			BPT	BPT	BPT	1-2.2
Hot or cold aisle configuration plus containment (e.g., strip curtains or rigid enclosures)				BPT	BPT	0.7-3.3
Variable speed drives on pumps/fans		BPT	BPT	BPT	BPT	0.5-2.4
Premium efficiency motors		BPT	BPT	BPT	BPT	2.6
Air-side economizer		BPT	BPT	BPT	BPT	0.8-6.9
In-row cooling			BPT	BPT	BPT	2-3
Water-side economizer			BPT	BPT	BPT	2.3-6.9
Install misters, foggers, or ultrasonic humidifiers				BPT	BPT	1.9-5.1
Direct liquid cooling of chips			CET	CET	CET	1-2

* Refers to the corresponding variable name in the existing model[96]

** Blank indicates immediate payback.

[96] Masanet ER, Brown RE, Shehabi A, Koomey JG, Nordman B. 2011. Estimating the Energy Use and Efficiency Potential of U.S. Data Centers. Proceedings of the IEEE, 99:1440-1453.

Table 38. List of Sources for Payback Periods of EETBPs

Sources for Payback Periods of EETBPs (Listed in Table 37)
Appliances N: **NetApp Introduces Unified Scale-Out Storage Systems and Virtualization Software for the Unbound Cloud Era**. 2014.
Asetek: **Internal Loop Liquid Cooling**. 2014.
Associates JGa: **Enterprise Class SSD: A Business Benefit Analysis**. 2014.
Bushell, Michael J: **Top 10 Energy Conservation Measures for Data Centers**. Willdan Energy Solutions. Presentation to Energy Center of Wisconsin, December 11, 2014.
Consulting F: **The Total Economic Impact of VMware vCenter Configuration Manager**. 2009.
Corporation ID: **IT Management and Virtualization Software Reduce Cost and Energy Consumption at BMC Datacenter: An ROI Case Study**. Framingham, MA; 2008.
Corporation ID: **Storage Economics: Assessing the Real Cost of Storage**. London, UK; 2008.
Corporation ID: **The Business Value of Dell EqualLogic and Compellent Primary Storage Solutions**. London, UK.
Courtot P: **Energy Savings Potential of CSL-3 Transformers and PDU's in Data Centers**. 2009.
Ellis DL: **DATA CENTER DESIGN CONSIDERATIONS AND TRENDS**. Edited by IEEE Central Tennessee Section; 2009.
Energy USDo: **Database Technology Company Saves $262,000 Annually**. Washington, DC; 2009.
Geet IMaOV: **Data Center Energy Efficiency and Renewable Energy Site Assessment: Anderson Readiness Center**. Edited by Golden, CO: National Renewable Energy Laboratory; 2014.
Google: **Google's Green Data Centers: Network POP Case Study**. Mountain View, CA: 2011.
Grid G: **CASE STUDY: THE ROI OF COOLING SYSTEM ENERGY EFFICIENCY UPGRADES**. 2011.
Group SVL: **Cisco Lab Setpoint Increase: Energy Efficient Data Center Demonstration Project**. San Jose, CA; 2008.
Group SVL: **Control of Computer Room Air Handlers Using Wireless Sensors: Energy Efficient Data Center Demonstration Project**. San Jose, CA; 2009.
IBM: **2009**. Somers, NY; Cloud Computing: An Explanation of Where ROI Comes From.
Kanellos M: **The World's Best Green Technology?** 2010.
Kelly M: **365 Main Energy Efficiency Initiatives**.
Mahdavi R: **Energy Efficiency Opportunities in Federal High Performance Computing Data Centers: Prepared for the U.S. Department of Energy Federal Energy Management Program**. Berkeley, CA: Lawrence Berkeley National Laboratory; 2013.
Mahdavi R: **Opportunities to Improve Energy Efficiency in Three Federal Data Centers: Prepared for the U.S. Department of Energy's Federal Energy Management Program**. Berkeley, CA: Lawrence Berkeley National Laboratory; 2014.
Power EN: **Energy Efficiency Solutions for Your Data Center**. 2014.
Research F: **The Total Economic Impact of HP 3PAR Storage**. Cambridge, MA; 2012.
Resources WDoN: **Godfrey & Kahn – Server Virtualization**. 2012.
Systems HD: **Tiered Storage and Virtualization in the Real World: Calculating the ROI and Cost Savings of a Move to Tiered Storage by Fidelity National Information Services**. 2009. vol October 2009.]
Target T: **Data Center Energy Efficiency Guide**. 2011.
Technologies P: **Initial investment payback analysis report: Dell PowerEdge R710 solution with Hyper-V vs. Dell PowerEdge 2850 solution**. Durham, North Carolina; 2009.
Vellante D: **JCPenney tiers away energy costs**. 2010.
Wire B: **Asetek Wins Frost & Sullivan Award for Their Revolutionary Data Center Cooling Solution**. 2014.

Before assessing the energy savings potentials of different EETBPs in each scenario, it was first necessary to calibrate the existing model to current New York State data center IT device characteristics and to incorporate the current penetrations of EETBPs for IT devices in New York State in the 2014 baseline results. Table 39 summarizes the assumed parameter values in the model for the 2014 baseline, which includes current operations practices (e.g., current use of power management settings for servers) and adoption of demand-side EETBPs (e.g., current penetration of ENERGY STAR® servers). Input parameter values were based on in-depth survey data that the Cadmus team considered robust in terms of their sample size and feasibility compared to national-level data from other studies in the literature. For the in-depth survey data input parameters deemed unreliable, or for parameters not covered by the study survey questions, national-average data from the literature was used as a proxy.

Table 39. 2014 Baseline Conditions and EETBP Penetrations

Parameter description	Model parameters*	Server closets and rooms	Localized	Mid-tier	Enterprise
Average processor utilization across installed servers	$\hat{u}$	23%	29%	33%	27%
Device reduction ratio for servers	ρ^S	1	1	1	1
Percent legacy (inactive) servers	Θ	5%	5%	5%	5%
Virtualization software utilization	ű	5%	5%	5%	5%
Percent ENERGY STAR® servers	α^S	8%	8%	8%	8%
Ratio ENERGY STAR: typical server power use	γ^S	70%	70%	70%	70%
Percent power management enabled	β^S	37%	40%	46%	54%
Device reduction ratio for storage	ρ^{ST}	1	1	1	1
Percent energy efficient storage	α^{ST}	17%	14%	22%	23%
Ratio efficient: typical storage power use	γ^{ST}	37%	45%	42%	49%
Percent energy efficient network	α^N	0%	10%	10%	10%
Ratio efficient: typical network power use	γ^N	-	50%	50%	50%

* Refers to the corresponding variable name in the existing model.

The baseline average processor utilization by space type was based on combined responses from the surveyed data center managers and industry players (Appendix D. Table D-101). By default, the device reduction ratio (which is used in the model to evaluate further opportunities for server consolidation and virtualization) is set to 1 in the baseline year. The survey did not explicitly ask respondents to estimate the percentage of servers that are no longer active—but still plugged in and drawing power—or the average processor utilization overhead associated with running virtualization software on host servers. Therefore, the most recent national average values for these parameters were used as a reasonable proxy. The Cadmus team estimated the percentage of servers that are ENERGY STAR certified based on recent market penetration data from the ENERGY STAR program.[97] Similarly, the Cadmus team found that the ratio of power use by ENERGY STAR servers compared to typical server of similar performance characteristics was 70% based on recent ENERGY STAR program test data.[98] The percentage of servers was estimated with device-level power management features using combined manager and vendor survey responses from Appendix D (Table D-101).

The device reduction ratio for storage was set at 1, based on the average capacity utilization of around 40% for tape, SSD, and HDD storage reported by survey respondents (Appendix D, Tables D-167 through D-173). The 1 value arose from the fact that the default capacity utilization for HDDs in the existing model is 40%. The percentage of storage devices was estimated with best practice energy efficiency based on combined responses from surveyed data center managers and industry players (Appendix D, Tables D-144 through D-147). The ratio of efficient storage power use to typical power use for in each space type reflects the power draw of 7.2K HDDs compared to 10K and 15K HDDs, the power draw of SSDs compared to 7.2K HDDs, and the power draw of variable (MAID) storage compared to tape storage based on data from Dell, and weighted to each space type by the present day capacity of each installed storage type reported in the survey data in Appendix D, Tables D-156-D-172.[99]

For this study, the Cadmus team limited the efficient network modeling to the effects of more efficient network topologies in localized, mid-tier, and enterprise data centers. This limitation is due to lack of publicly available data on the relative energy efficiencies of different switch technologies and the complexities of directly comparing those technologies at the device level. Rather, this study explored the potential of more efficient configurations of network switches, which can reduce the overall energy use of the network systems inside the data center as a whole. The team assumed that the ratio of efficient network device power use to typical network device power use would be 50%, based on published data for an efficient "fat tree" topology compared to a traditional hierarchical network topology.[100]

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97 ENERGY STAR Unit Shipment and Market Penetration Report Calendar Year 2013 Summary. https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2013_USD_Summary_Report.pdf?9223-d0f5

98 The ENERGY STAR program estimates savings from certified servers to be 30%.http://www.energystar.gov/products/certified-products/detail/enterprise-servers

99 Pflueger J. 2010 Understanding Data Center Energy Intensity: A Dell Technical White Paper. Round Rock, TX. Dell Incorporated..

100 Mahadevan P, Shah A, Bash C. 2010. "Reducing lifecycle energy use of network switches. In Sustainable Systems and Technology (ISSST)." 2010 IEEE International Symposium on 17-19 May 2010: 2010:1-6.

The Cadmus team then adjusted the model input parameter values listed in Table 39, as well as the model input parameter values for infrastructure systems listed in Table 32, over the projection periods within each scenario to assess the energy savings associated with improvements to operational energy efficiency and adoption of EETBPs. The following sections describe the input parameter assumptions for each scenario.

6.3.1 Best Practice Operation Scenario

The Cadmus team designed the BPO scenario to capture near-immediate savings that could be realized through the adoption of best practices for existing IT devices and equipment or with investments in software (e.g., server virtualization) and systems strategies (e.g., data deduplication for storage) that can lead to energy savings through consolidation of existing IT devices. As such, this scenario considered maximal adoption of server and storage virtualization to minimize device counts, server-level power management features to save energy at low levels of processor utilization, and multiple cooling management measures to reduce cooling power use with minor changes to space layouts and configurations.

The adoption of relevant EETBPs for the BPO scenario (Table 37) was approximated in the model by changing the input parameter values from the 2014 baseline (Table 32 and Table 39) to a state representative of maximal remaining adoption in New York State data centers. The model assumed all changes to be feasible within the first year (i.e., 2015) of the projection period and to continue throughout the projection period, given they are not constrained by IT device refresh cycles. Table 40 summarizes the input parameter assumptions associated with the BPO scenario, in which all changes compared to the 2014 baseline have been highlighted in light gray for ease of reference.

Table 40. Best Practice Operations Scenario Conditions and EETBP Penetrations

Parameter description	Model parameters*	Server closets and rooms	Localized	Mid-tier	Enterprise
Average post-consolidation processor utilization across installed servers	υ	60%	60%	60%	60%
Device reduction ratio for servers	ρ^S	2.34	1.87	1.67	2.04
Percent legacy (inactive) servers	Θ	0%	0%	0%	0%
Virtualization software utilization	ű	5%	5%	5%	5%
Percent ENERGY STAR servers	α^S	8%	8%	8%	8%
Ratio ENERGY STAR: typical server power use	γ^S	70%	70%	70%	70%
Percent power management enabled	β^S	100%	100%	100%	100%
Device reduction ratio for storage	ρ^{ST}	2	2	2	2
Percent energy efficient storage	α^{ST}	17%	14%	22%	23%
Ratio efficient: typical storage power use	γ^{ST}	45%	50%	50%	46%
Percent energy efficient network	α^N	0%	10%	10%	10%
Ratio efficient: typical network power use	γ^N	-	50%	50%	50%
Transformers (W/W)	ε^{IS}_1	0.05	0.05	0.05	0.05
UPS (W/W)	ε^{IS}_2	0.20	0.20	0.20	0.10
Lighting (W/W)	ε^{IS}_3	0.02	0.02	0.02	0.02
Cooling systems (W/W)	ε^{IS}_4	0.63	0.48	0.48	0.48

* Refers to the corresponding variable name in the existing model.[101]

To model maximal adoption of server virtualization, the device reduction ratio was increased for servers until the average post-consolidation processor utilization across all remaining servers reached a level of about 60% in each space type. This change resulted in increased server reduction ratios in each space type (i.e., reduced server counts). The target of 60% maximum average utilization was based on an industry rule of thumb to allow a utilization buffer for peak demand; however, the maximum allowable average processor utilization may vary greatly by data center based on their business needs and risk strategies.

To model the removal of legacy servers from the population, the percentage of inactive servers was reduced to zero for all space types. The percentage of servers utilizing power management was increased to 100% in all space types to assess the maximum technical potential of this EETBP. Importantly, the model only considers power management enabled at the server hardware level; it does not account for power management of server clusters within the data center, which would lead to even greater power management savings than estimated in this study. To model the effects of storage virtualization and consolidation strategies such as thin provisioning, the device reduction ratio for storage devices, to 2, which represents an average storage capacity utilization of 80%. Lastly, to approximate the combined

[101] Masanet ER, Brown RE, Shehabi A, Koomey JG, Nordman B. 2011. "Estimating the Energy Use and Efficiency Potential of U.S. Data Centers." Proceedings of the IEEE 99:1440-1453.

effects of raising temperature set points, improved airflow management, installation of baffles, and adjusting humidity controls, the team conservatively adopted a 10% reduction in cooling load based on data.[102, 103, 104]

6.3.2 Best Practice Technologies Scenario

The Cadmus team designed the BTO scenario to capture energy savings that could be realized through the adoption of more efficient IT devices and infrastructure systems components, with a focus on commercially-available technologies in widespread use. As such, this scenario considered maximal adoption of efficient servers, storage devices, network topographies, and equipment related to data center power provision, lighting, and cooling. The adoption of more energy-efficient technologies for servers and storage devices was limited by stock turnover of the existing IT devices over the projection period, as discussed in Subtask 6.2. However, the team assumed equipment upgrades related to power, lighting, and cooling systems to occur in the first year of the projection period, given that these technologies are typically not subjected to standard refresh cycles. As such, this study assumed that all such equipment could be upgraded for the purpose of quantifying the full technical potential of such replacements. Table 41 summarizes the input parameter assumptions associated with the BTO scenario, in which all changes compared to the 2014 baseline have been highlighted in dark gray for ease of reference.

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[102] Brown R, Masanet, E., Nordman, B., Tschudi, W., Shehabi, A., Stanley, J., Koomey, J., Sartor, D., Chan, P., Loper, J., Capana, S., Hedman, B., Duff, R., Haines, E., Sass, D., and A. Fanara. 2007. Report to Congress on Server and Data Center Energy Efficiency: Public Law 109-431. Edited by. Berkeley, California: Lawrence Berkeley National Laboratory.

[103] Masanet ER, Brown RE, Shehabi A, Koomey JG, Nordman B. 2011. Estimating the Energy Use and Efficiency Potential of U.S. Data Centers. Proceedings of the IEEE, 99: 1440-1453.

[104] Shehabi A, Masanet E, Price H, Horvath A, Nazaroff WW. 2011. Data center design and location: Consequences for electricity use and greenhouse-gas emissions. Building and Environment. 46: 990-998.

Table 41. Best Practice Technology Scenario Conditions and EETBP Penetrations

Parameter description	Model parameters*	Server room	Localized	Mid-tier	Enterprise
Average post-consolidation processor utilization across installed servers	υ	60%	60%	60%	60%
Device reduction ratio for servers	ρ^S	2.34	1.87	1.67	2.04
Percent legacy (inactive) servers	ϴ	0%	0%	0%	0%
Virtualization software utilization	ű	5%	5%	5%	5%
Percent ENERGY STAR servers (2014)	α^S	8%	8%	8%	8%
2015		43%	43%	43%	43%
2016		68%	68%	68%	68%
2017		87%	87%	87%	87%
2018		100%	100%	100%	100%
2019		100%	100%	100%	100%
2020		100%	100%	100%	100%
Ratio ENERGY STAR: typical server power use	γ^S	70%	70%	70%	70%
Percent power management enabled	β^S	100%	100%	100%	100%
Device reduction ratio for storage	ρ^{ST}	2	2	2	2
Percent energy efficient storage (2014)	α^{ST}	17%	14%	22%	23%
2015		48%	46%	51%	52%
2016		71%	70%	73%	73%
2017		88%	88%	89%	89%
2018		100%	100%	100%	100%
2019		100%	100%	100%	100%
2020		100%	100%	100%	100%
Ratio efficient: typical storage power use	γ^{ST}	45%	50%	50%	46%
Percent energy efficient network	α^N	0%	100%	100%	100%
Ratio efficient: typical network power use	γ^N	-	50%	50%	50%
Transformers (W/W)	ε^{IS}_1	0.03	0.03	0.03	0.03
UPS (W/W)	ε^{IS}_2	0.05	0.05	0.05	0.05
Lighting (W/W)	ε^{IS}_3	0.01	0.01	0.01	0.01
Cooling systems (W/W)	ε^{IS}_4	0.37	0.16	0.16	0.16

To assess the effects of best-practice efficient server adoption, the Cadmus team assumed that all new servers purchased each year (as calculated by the stock turnover model) would be ENERGY STAR certified. Table 41 shows the estimated penetration of ENERGY STAR servers each year in the projection period, given a four-year server refresh cycle (discussed in Subtask 6.2). These assumptions lead to a 100% penetration by 2018 in all space types. Similarly, it was assumed that all new storage devices purchased each year would be best-practice efficient devices appropriate to the data center space type (discussed in Subtask 6.2). The estimated penetrations over the projection period are based on a refresh cycle of four years, as discussed previously. Unlike efficiency upgrades to servers and storage, the team assumed that network upgrades would not be subject to network device refresh cycles. Specifically, only changes to network topologies were considered, which could involve both consolidation and elimination of existing network devices and the purchase of new devices to enable more efficient topologies. Therefore, the team assumed the percentage of networks with best-practice efficient hardware to be 100% starting in the first year of the projection period for localized, mid-tier, and enterprise data centers given the importance and practicality of efficient topologies in these space types. Furthermore, the BPT scenario assumed that the ratio of efficient network device power use to typical network device power use would be 50%, based on published data for an efficient "fat tree" topology compared to a traditional hierarchical network topology.[105]

Equipment upgrades for power, lighting, and cooling system components were modeled as follows. For lighting, an energy use reduction of 50% was assumed in aggregate to approximate the savings achievable through upgrades to LEDs and lighting controls.[106] For transformers, it was assumed that all space types could achieve 97% efficiency through upgrades to high-efficiency power distribution units. Similarly, the team assumed that all UPSs could be upgraded to 95% efficiency. [107] Lastly, cooling efficiency improvements for each space type were based on achievable cooling load data from published best-practice cooling system technologies for each space type,[108, 109]which include the combined effects of adopting variable speed pumps and fans, cooling system controls, efficient layout configurations, economizers, and high-efficiency chillers, depending on the space type.

6.3.3 Cutting Edge Technology Scenario

The purpose of the CET scenario was to evaluate the potential of promising cutting-edge technologies for reducing the energy use of data centers in New York State. This study considered three such technologies, which are currently commercialized but have low market penetration: (1) solid state storage; (2) the use of direct current; and (3) direct-to-chip liquid cooling. The Cadmus team selected these three technologies on the basis of credible data in the literature for assessment of energy savings. Solid state drives (SSDs) offer an energy-efficient option for many different types of data access applications, including file servers, e-mail, database applications, and streaming video.[110]

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105 Mahadevan P, Shah A, Bash C. 2010. "Reducing lifecycle energy use of network switches. In Sustainable Systems and Technology (ISSST)." IEEE International Symposium on 17-19 May 2010: 2010:1-6.

106 Worrell E, Angelini, T., and E. Masanet." 2011. "Managing Your Energy: An ENERGY STAR® Guide for Identifying Energy Savings in Manufacturing Plants" Berkeley, CA: Lawrence Berkeley National Laboratory.

107 Masanet ER, Brown RE, Shehabi A, Koomey JG, Nordman B. 2011. Estimating the Energy Use and Efficiency Potential of U.S. Data Centers. Proceedings of the IEEE 99:1440-1453.

108 Masanet E, Shehabi A, Koomey J. 2013. "Characteristics of low-carbon data centres." Nature Climate Change 3:627-630.

109 Shehabi A, Masanet E, Price H, Horvath A, Nazaroff WW. 2011. "Data center design and location: Consequences for electricity use and greenhouse-gas emissions. Building and Environment 46:990-998.

110 Kasavajhala V. 2011. Solid State Drive vs. Hard Disk Drive Price and Performance Study: A Dell Technical White Paper. Edited by. Round Rock, TX.: Dell Incorporated.

For this study, SSDs were assumed to require 3.5 W/TB—as opposed to 26.7 W/TB for 15K HDDs, 15.5 W/TB for 10K HDDs, 8.4 W/TB for 7.2K HDDs, and 6.5 W/TB for variable HDDs—based on industry data.[111] As a conservative assumption, this study assumes that SSDs and 7.2K HDDs would comprise 25% and 75% of capacity presently stored on all HDD types, and that MAID storage would replace all present day tape storage, leading to a best practice to typical efficiency ratios of 45-45% in the cutting edge scenario.

The Cadmus team approximated energy savings associated with the use of direct current by assuming transformer losses are eliminated across all space types. Direct-to-chip liquid cooling is assumed to reduce cooling energy use by 30% based on recent test data from Lawrence Berkeley National Laboratory on a commercialized system.[112]

Table 42 summarizes the input parameter assumptions associated with the CET scenario, in which all changes compared to the BPT scenario have been highlighted in very dark grey for ease of reference. This study assumes that all cutting edge technology adoption will occur in the first year of the projection period.

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[111] Pflueger J. 2010. Understanding Data Center Energy Intensity: A Dell Technical White Paper. Round Rock, TX.: Dell Incorporated.

[112] Greenberg H. 2014. CaS: Direct Liquid Cooling for Electronic Equipment. Berkeley, California: Lawrence Berkeley National Laboratory.

Table 42. Cutting-Edge Technology Scenario Conditions and EETBP Penetrations

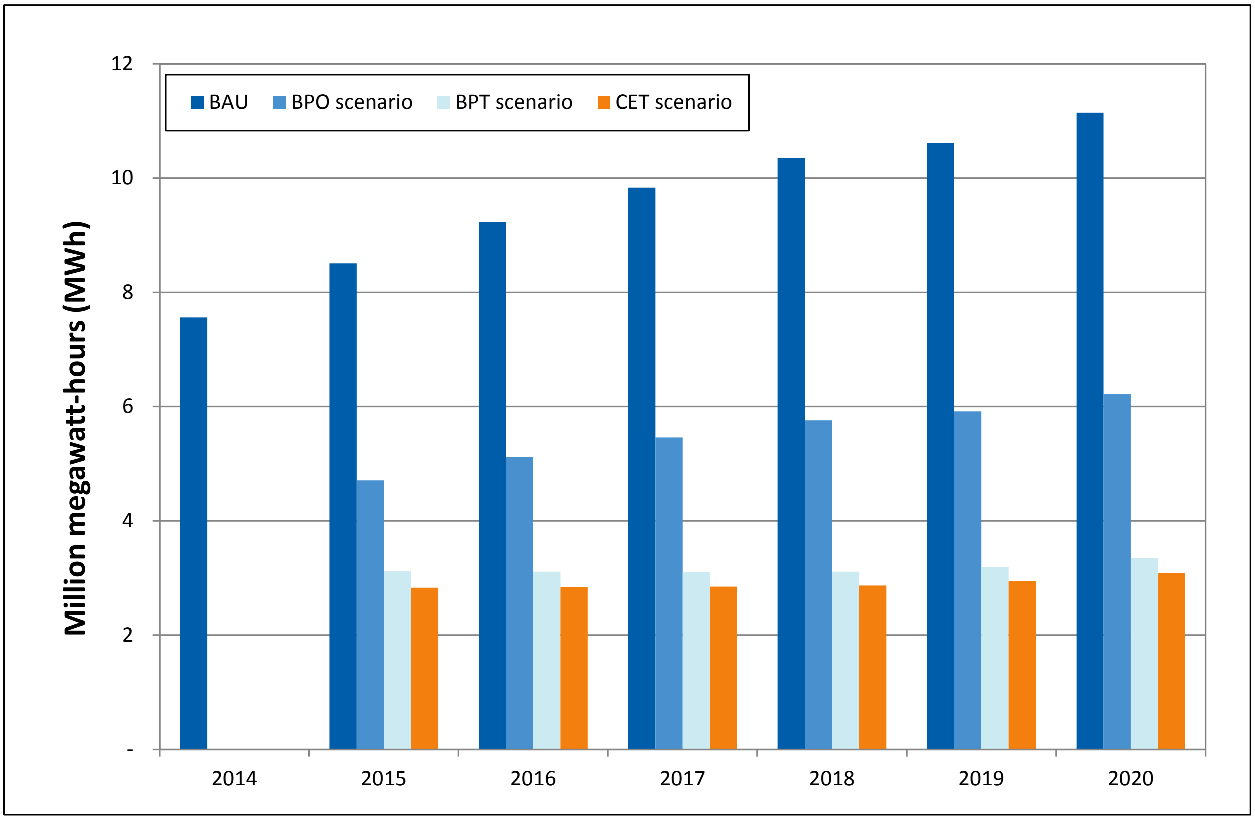
Parameter description	Model parameters*	Server room	Localized	Mid-tier	Enterprise
Average post-consolidation processor utilization across installed servers	υ	60%	60%	60%	60%
Device reduction ratio for servers	ρ^S	2.34	1.87	1.67	2.04
Percent legacy (inactive) servers	Θ	0%	0%	0%	0%
Virtualization software utilization	ű	5%	5%	5%	5%
Percent ENERGY STAR servers (2014)	α^S	8%	8%	8%	8%
2015		43%	43%	43%	43%
2016		68%	68%	68%	68%
2017		87%	87%	87%	87%
2018		100%	100%	100%	100%
2019		100%	100%	100%	100%
2020		100%	100%	100%	100%
Ratio ENERGY STAR: typical server power use	γ^S	70%	70%	70%	70%
Percent power management enabled	β^S	100%	100%	100%	100%
Device reduction ratio for storage	ρ^{ST}	2	2	2	2
Percent energy efficient storage (2014)	α^{ST}	17%	14%	22%	23%
2015		48%	46%	51%	52%
2016		71%	70%	73%	73%
2017		88%	88%	89%	89%
2018		100%	100%	100%	100%
2019		100%	100%	100%	100%
2020		100%	100%	100%	100%
Ratio efficient: typical storage power use	γ^{ST}	37%	45%	42%	49%
Percent energy efficient network	α^N	0%	100%	100%	100%
Ratio efficient: typical network power use	γ^N	-	50%	50%	50%
Transformers (W/W)	ε^{IS}_1	0	0	0	0
UPS (W/W)	ε^{IS}_2	0.05	0.05	0.05	0.05
Lighting (W/W)	ε^{IS}_3	0.01	0.01	0.01	0.01
Cooling systems (W/W)	ε^{IS}_4	0.26	0.11	0.11	0.11

6.4 Results: Technical Potentials

Figure 20 depicts the technical potentials for energy savings in each scenario, which plots the modeling results for total New York State data center energy use in all scenarios assuming all specified EETBP measures would be adopted regardless of their cost. Table 43 lists the estimated energy savings of each scenario compared to the BAU scenario in each year. The results suggest that substantial energy savings might be realized in NYS data centers in the near term through the adoption of straightforward best practice operations strategies, ranging from around 26 million MWh in savings through 2020 (for the BPO scenario) to around 42 million MWh in savings (for the CET scenario). Specifically, the BPO scenario leads to reductions in energy use of around 44% Adopting best practice technologies adds even more energy savings.

The BPT scenario results suggest that total New York State data center energy use might be reduced by around 68% across the entire projection period, due to greater adoption of the most energy-efficient IT devices and infrastructure systems components than is expected in the BAU scenario. In other words, the BPT scenario results suggest that energy use might be drastically reduced through the adoption of proven, commercially-available best practice technologies and operations strategies. The CET scenario, which added the adoption of SSDs, direct current, and direct-to-chip liquid cooling, reduces total energy use by another 3% compared to the BPT scenario. These results suggest that even greater energy savings might be realized through the adoption of emerging technologies that have not yet seen widespread adoption in U.S. data centers. The availability of such significant potentials for energy efficiency improvements is consistent with past studies of data centers at the U.S. national level[113], especially considering the remaining potential for adoption of server virtualization, power management, and energy-efficient servers as indicated by the survey data.

Figure 20. Technical Potential Energy Use Projections (2014 to 2020)



113 Brown R, Masanet, E., Nordman, B., Tschudi, W., Shehabi, A., Stanley, J., Koomey, J., Sartor, D., Chan, P., Loper, J., Capana, S., Hedman, B., Duff, R., Haines, E., Sass, D., and A. Fanara: Report to Congress on Server and Data Center Energy Efficiency: Public Law 109-431. Edited by Berkeley, California: Lawrence Berkeley National Laboratory. 2007.

Table 43. Technical Potentials for Energy Savings by Scenario (Million MWh)

Values in the table expressed as energy savings compared to BAU energy use each year.

Scenario	2015	2016	2017	2018	2019	2020	Total
Business as usual (BAU)	-	-	-	-	-	-	-
Best practice operations (BPO)	3.80	4.11	4.37	4.59	4.70	4.93	26.50
Best practice technologies (BPT)	5.39	6.12	6.73	7.24	7.42	7.79	40.69
Cutting edge technologies (CET)	5.67	6.39	6.98	7.48	7.67	8.05	42.26

Table 44 summarizes the results for each scenario by data center component in New York State, while Table 45 through Table 47 summarize the estimated technical potentials for energy savings by component in the BPO, BPT, and CET scenarios, respectively, compared to the BAU energy use. These tables reveal that in all three energy efficient scenarios, the potential for energy savings is dominated by servers and cooling systems. For servers, most energy savings are realized through changes to operational strategies in the BPO scenario, with more limited savings added due to the adoption of ENERGY STAR servers in the BPT scenario. This outcome is consistent with past studies, which suggest that server virtualization is the single largest opportunity for improving server efficiency due to substantial reductions in server counts.[114]

The energy savings for all infrastructure system components is due to two factors: (1) reductions in power and cooling demand due to efficiency improvements to IT devices, and (2) reductions in energy use due to efficiency improvements to the infrastructure system components themselves. In the BPO scenario, most of the energy savings for cooling, and all of the energy savings for transformers, UPS, and lighting in Table 45, are due to reductions in power and cooling demand from more efficient IT devices. Additional cooling savings in the BPO scenario result from the assumed improvements related to airflow, temperature, and humidity management. However, the results in Table 44 through Table 47 suggest that significant energy savings might also be available through efficiency improvements to external storage (in the BPO and BPT scenarios) and network devices (in the BPT scenario) and through upgrades to transformers, lighting, UPS, and cooling system equipment (in the BPT and CET scenarios).

[114] Masanet ER, Brown RE, Shehabi A, Koomey JG, Nordman B. 2011. Estimating the Energy Use and Efficiency Potential of U.S. Data Centers. Proceedings of the IEEE 99:1440-1453.

Table 44. BAU Projections for NYS Data Center Energy Use by Component (Million MWh)

Component	2014	2015	2016	2017	2018	2019	2020	Total
Servers	3.61	4.04	4.36	4.61	4.81	4.88	5.10	31.41
Storage	0.24	0.27	0.31	0.35	0.38	0.41	0.45	2.41
Network	0.33	0.38	0.43	0.48	0.53	0.56	0.61	3.33
Transformers	0.16	0.18	0.19	0.20	0.21	0.22	0.23	1.39
UPS	0.66	0.74	0.80	0.86	0.90	0.92	0.97	5.86
Lighting	0.08	0.09	0.10	0.11	0.11	0.12	0.12	0.74
Cooling	2.48	2.79	3.03	3.23	3.40	3.49	3.67	22.10
Total	7.56	8.50	9.24	9.83	10.35	10.61	11.14	67.24

Table 45. BPO Scenario Technical Potential Energy Savings by Component (Million MWh)

Component	2014	2015	2016	2017	2018	2019	2020	Total
Servers	-	1.86	2.01	2.13	2.23	2.27	2.37	**12.87**
Storage	-	0.14	0.16	0.17	0.19	0.21	0.22	**1.09**
Network	-	-	-	-	-	-	-	**-**
Transformers	-	0.07	0.08	0.08	0.09	0.09	0.09	**0.50**
UPS	-	0.32	0.34	0.37	0.38	0.39	0.41	**2.22**
Lighting	-	0.04	0.04	0.05	0.05	0.05	0.05	**0.28**
Cooling	-	1.36	1.48	1.57	1.66	1.70	1.78	**9.55**
Total	**-**	**3.80**	**4.11**	**4.37**	**4.59**	**4.70**	**4.93**	**26.50**

Table 46. BPT Scenario Technical Potential Energy Savings by Component (Million MWh)

Component	2014	2015	2016	2017	2018	2019	2020	Total
Servers	-	2.10	2.45	2.73	2.96	3.01	3.14	**16.37**
Storage	-	0.16	0.20	0.24	0.28	0.30	0.33	**1.52**
Network	-	0.12	0.14	0.16	0.17	0.18	0.20	**0.97**
Transformers	-	0.12	0.14	0.15	0.16	0.17	0.17	**0.91**
UPS	-	0.62	0.69	0.74	0.79	0.81	0.85	**4.49**
Lighting	-	0.07	0.08	0.09	0.09	0.09	0.10	**0.52**
Cooling	-	2.19	2.43	2.62	2.79	2.86	3.00	**15.90**
Total	**-**	**5.39**	**6.12**	**6.73**	**7.24**	**7.42**	**7.79**	**40.69**

Table 47. CET Scenario Technical Potential Energy Savings by Component (Million MWh)

Component	2014	2015	2016	2017	2018	2019	2020	Total
Servers	-	2.10	2.45	2.73	2.96	3.01	3.14	**16.37**
Storage	-	0.21	0.24	0.27	0.30	0.32	0.35	**1.69**
Network	-	0.12	0.14	0.16	0.17	0.18	0.20	**0.97**
Transformers	-	0.16	0.18	0.19	0.20	0.21	0.22	**1.16**
UPS	-	0.63	0.69	0.74	0.79	0.81	0.85	**4.50**
Lighting	-	0.07	0.08	0.09	0.09	0.09	0.10	**0.52**
Cooling	-	2.38	2.61	2.81	2.98	3.05	3.21	**17.04**
Total	**-**	**5.67**	**6.39**	**6.98**	**7.48**	**7.67**	**8.05**	**42.26**

Table 48 summarizes the results for each scenario by data center space type in New York State. Table 49 through Table 51 summarize the estimated technical potentials for energy savings by space type in the BPO, BPT, and CET scenarios, respectively, compared to the BAU energy use. Viewing the results in this fashion reveals that the energy savings in Table 49 through Table 51 are predominantly achievable in New York State enterprise data centers and server closets and rooms.

Table 48. BAU Projections for NYS Data Center Energy Use by Space Type (Million MWh)

Space type	2014	2015	2016	2017	2018	2019	2020	Total
Server closets and rooms	3.01	3.40	3.72	4.00	4.25	4.40	4.65	27.44
Localized	0.48	0.53	0.58	0.61	0.63	0.64	0.67	4.14
Mid-tier	1.06	1.18	1.26	1.32	1.36	1.36	1.41	8.93
Enterprise	3.02	3.39	3.68	3.91	4.11	4.21	4.41	26.73
Total	**7.56**	**8.50**	**9.24**	**9.83**	**10.35**	**10.61**	**11.14**	**67.24**

Table 49. BPO Scenario Technical Potential Energy Savings by Space Type (Million MWh)

Space type	2014	2015	2016	2017	2018	2019	2020	Total
Server closets and rooms		1.71	1.87	2.00	2.12	2.19	2.32	**12.22**
Localized	-	0.22	0.24	0.25	0.26	0.26	0.27	**1.49**
Mid-tier	-	0.39	0.42	0.43	0.44	0.44	0.45	**2.57**
Enterprise	-	1.47	1.59	1.69	1.77	1.81	1.89	**10.22**
Total	**-**	**3.80**	**4.11**	**4.37**	**4.59**	**4.70**	**4.93**	**26.50**

Table 50. BPT Scenario Technical Potential Energy Savings by Space Type (Million MWh)

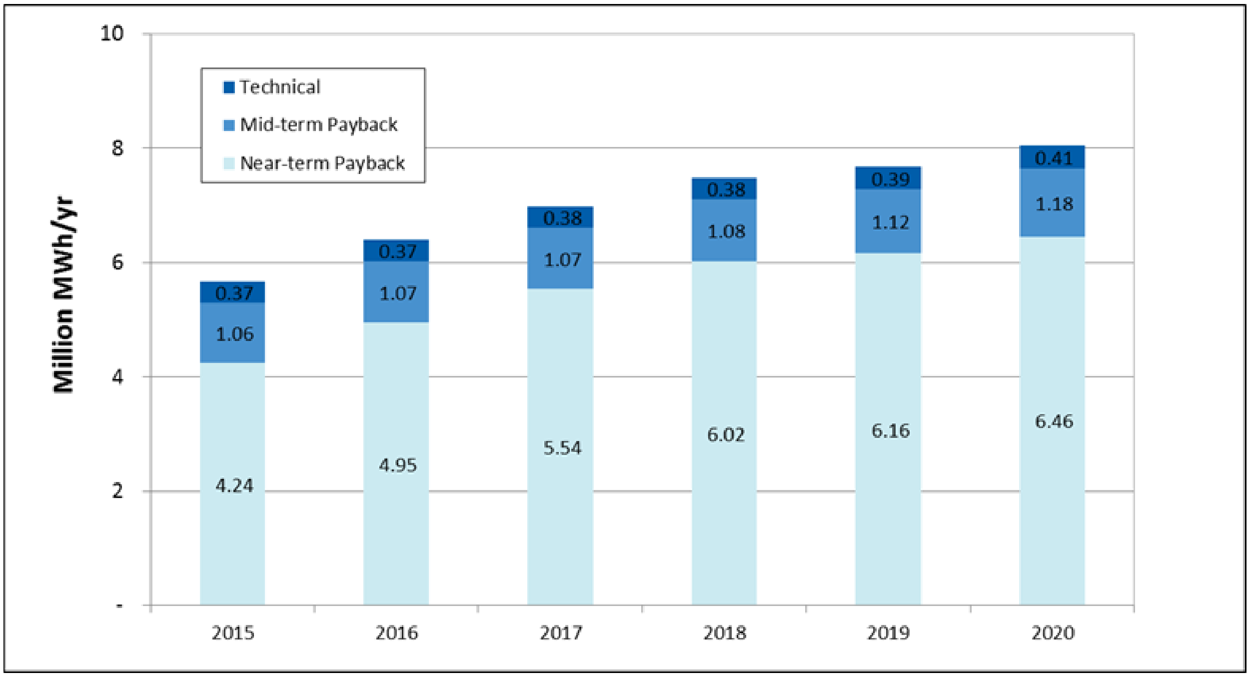
Space type	2014	2015	2016	2017	2018	2019	2020	Total
Server closets and rooms	-	2.16	2.47	2.73	2.96	3.06	3.23	**16.62**
Localized	-	0.34	0.39	0.42	0.45	0.46	0.48	**2.54**
Mid-tier	-	0.72	0.81	0.87	0.92	0.92	0.95	**5.19**
Enterprise	-	2.16	2.46	2.70	2.91	2.98	3.12	**16.33**
Total	**-**	**5.39**	**6.12**	**6.73**	**7.24**	**7.42**	**7.79**	**40.69**

Table 51. CET Scenario Technical Potential Energy Savings by Space Type (Million MWh)

Space type	2014	2015	2016	2017	2018	2019	2020	Total
Server closets and rooms	-	2.30	2.60	2.85	3.08	3.19	3.37	**17.38**
Localized	-	0.36	0.40	0.43	0.46	0.47	0.49	**2.60**
Mid-tier	-	0.75	0.84	0.90	0.95	0.95	0.99	**5.38**
Enterprise	-	2.27	2.56	2.79	2.99	3.06	3.21	**16.89**
Total	**-**	**5.67**	**6.39**	**6.98**	**7.48**	**7.67**	**8.05**	**42.26**

Figure 21 shows the total estimated potential energy savings each year categorized by EETBP implementation cost. As previously discussed, near-term payback potential is defined in this study as the energy savings that can be realized through the adoption of EETBPs with simple payback periods of less than two years, while mid-term payback potential is defined as the energy savings that can be realized through the adoption of EETBPs with simple payback periods of greater than two years but less than five years. The remaining potential is considered part of the overall technical potential. To generate the results in Figure 25, the team used the estimated payback period ranges in Table 37 to assign EETBPs to a specific potentials category. Importantly, given the variations in payback periods found in the literature for many EETBPs, the team used the highest value of payback period when assigning EETBPs to each category.

Figure 21. Technical, Mid-term Payback, and Near-term Payback Potentials for Energy Savings (Million MWh)



These results suggest that the majority of potential energy savings should be economically achievable, a finding that is quickly understood through observation of the short payback periods associated with many EETBPs in Table 37. Future studies should incorporate more robust cost estimates for these and all other EETBPs to improve the utility of the near-term payback and mid-term payback potentials analysis. Table 52 through Table 55 list the near-term payback and mid-term payback potentials estimate by data center component and space type in New York State, which allow for identification of estimated energy savings by cost category.

Table 52. Near-term Payback Potential for Energy Savings by Component (Million MWh)

Component	2014	2015	2016	2017	2018	2019	2020	Total
Servers	-	2.10	2.45	2.73	2.96	3.01	3.14	**16.37**
Storage	-	0.16	0.20	0.24	0.28	0.30	0.33	**1.52**
Network	-	-	-	-	-	-	-	**-**
Transformers	-	0.08	0.10	0.11	0.12	0.12	0.13	**0.65**
UPS	-	0.36	0.42	0.47	0.51	0.52	0.55	**2.83**
Lighting	-	0.05	0.05	0.06	0.06	0.07	0.07	**0.36**
Cooling	-	1.50	1.73	1.93	2.09	2.14	2.25	**11.64**
Total	**-**	**4.24**	**4.95**	**5.54**	**6.02**	**6.16**	**6.46**	**33.37**

Table 53. Near-term Payback Potential for Energy Savings by Space Type (Million MWh)

Space type	2014	2015	2016	2017	2018	2019	2020	Total
Server closets and rooms	-	1.87	2.18	2.44	2.66	2.75	2.90	**14.80**
Localized	-	0.25	0.29	0.33	0.35	0.36	0.37	**1.95**
Mid-tier	-	0.46	0.54	0.60	0.65	0.64	0.66	**3.55**
Enterprise	-	1.65	1.94	2.17	2.36	2.41	2.52	**13.06**
Total	**-**	**4.24**	**4.95**	**5.54**	**6.02**	**6.16**	**6.46**	**33.37**

Table 54. Mid-term Payback Potential for Energy Savings by Component (Million MWh)

Component	2014	2015	2016	2017	2018	2019	2020	Total
Servers	-	2.10	2.45	2.73	2.96	3.01	3.14	**16.37**
Storage	-	0.21	0.24	0.27	0.30	0.32	0.35	**1.69**
Network	-	0.12	0.14	0.16	0.17	0.18	0.20	**0.97**
Transformers	-	0.13	0.14	0.15	0.16	0.17	0.17	**0.92**
UPS	-	0.38	0.44	0.50	0.54	0.55	0.58	**2.99**
Lighting	-	0.07	0.08	0.09	0.09	0.09	0.10	**0.52**
Cooling	-	2.29	2.53	2.72	2.89	2.96	3.11	**16.49**
Total	**-**	**5.30**	**6.02**	**6.61**	**7.11**	**7.28**	**7.64**	**39.96**

Table 55. Mid-Term Payback Potential for Energy Savings by Space Type (Million MWh)

Space type	2014	2015	2016	2017	2018	2019	2020	Total
Server closets and rooms	-	2.12	2.42	2.68	2.90	3.00	3.17	**16.28**
Localized	-	0.33	0.37	0.41	0.43	0.44	0.46	**2.44**
Mid-tier	-	0.68	0.77	0.83	0.88	0.88	0.91	**4.95**
Enterprise	-	2.17	2.46	2.69	2.89	2.96	3.11	**16.28**
Total	**-**	**5.30**	**6.02**	**6.61**	**7.11**	**7.28**	**7.64**	**39.96**

7 Market Trends

7.1 Overview

The following nine industry trends are shaping how information technology services will be provided to customers in New York State:

- Data center market growth.
- Cloud services captures an increasing portion of it market.
- Co-location sector growth.
- Utility-scale data center development.
- Data center site selection considerations.
- Energy efficiency measures and technologies adoption (described in Section 5).
- Emerging energy efficiency measures and technologies.
- Self-generation and wholesale market access.
- Nongovernmental organization (NGO), media, and regulatory attention regarding data center environmental impacts.

These trends can help inform policy decisions about promoting energy efficiency and attracting and retaining data center development.

For the purpose of characterizing the data center market in New York State, this report identifies trends that are influencing the growth and composition of the local market. While these trends exist nationally and globally, they have particular significance for New York with regard to retaining and attracting data center development. The primary market trend for the industry has been tremendous growth, at rates not matched by any other market segment. The remaining eight trends are largely dependent on the market growth picture, either directly or indirectly. For each trend, the report contains:

- A high-level description.
- Subsections that describe key aspects of the trend.
- Quotes from key industry players that support the description of the trend (if available).[115]

This section of the report concludes with an outline for future considerations related to policy development opportunities for New York State.

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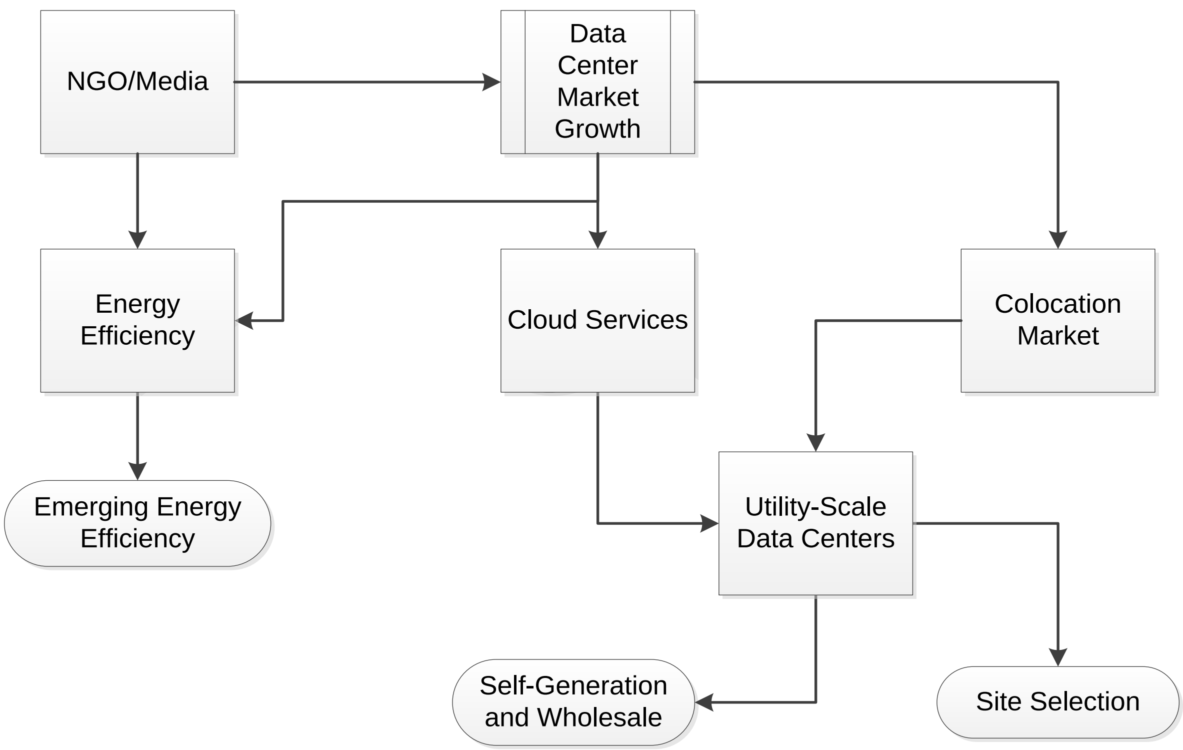
[115] Many of the industry players interviewed were reticent to be quoted unless their comments were approved by their companies. Rather than limit comments to those that were approved by companies, the Cadmus team opted to instead only sometimes indicate the role of the industry player and the type of company represented.

7.2 Dependency Model

Figure 22 shows the interactions and dependencies of the trends. The model suggests that the data center market growth in the segment is the central trend. Specifically, data center growth can affect other market trends in the following ways:

- Data center managers have to address power, space, and cooling capacity issues with either cloud services, co-location, or energy efficiency measures (both conventional and emerging).
- Huge growth in cloud and co-location market can lead to massive utility-scale data centers, which can lead to self-generation and siting issues. [116]
- Media, nongovernmental organizations, and regulatory agencies become concerned with the massive growth of the data center market and energy efficiency issues.

Figure 22. Market Trend Interdependency



[116] Utility-scale data centers are generally measured by the size of the facility's total load (in MW) and commonly built with 40-MW load.

7.3 Trend 1: Data Center Market Growth

Although the growth rate in the national data center sector has slowed somewhat, it still remains high for this market and is projected to increase by 9.6% year-over-year during the next decade and is driven by increases in raw computation, networking, and data storage – particularly for some industries like content delivery, health care, and social networking.[117] In 2007, the U.S. Environmental Protection Agency (EPA) published an assessment of national energy use and the growth of data centers in the United States. This assessment generated market and regulatory scrutiny leading to an intense focus on the need for energy efficiency.[118] Although IT growth rates remain high, a variety of factors have slowed energy consumption in the sector, as well as the adoption of energy-efficient technologies (particularly virtualization) and migration to cloud-based services housed in utility-scale data centers, which have inherent efficiency advantages.

7.3.1 The 2000s: Challenging the Anecdotal Growth Rate

As the IT industry experienced rapid growth due to the rise of social media and the boom of dotcoms at the turn of the century, there were widespread reports that the energy use of the sector would outstrip the ability of utilities to provide service. Even IT industry insiders voiced concerns that the projected growth rates for IT and data centers would challenge their ability to source power in the United States.[119]

The collapse of the dotcom bubble moderated the discussion of energy availability and the 2007 Report to Congress reset the energy discussion entirely by grounding existing and projected energy use by the sector with empirical analysis. The 2007 Report to Congress projected the sector's energy use by relying on shipment data for IT equipment—notably servers. The analysis indicated that energy use by the sector had indeed been growing at a significant rate (it had doubled over the previous five years), but remained a fairly small portion of energy use in the United States and around the globe. The report also projected future energy use growth rates based on scenarios related to the adoption of energy efficient technologies and best practices (Figure 23). Without adoption of energy efficiency by the industry, the growth rate

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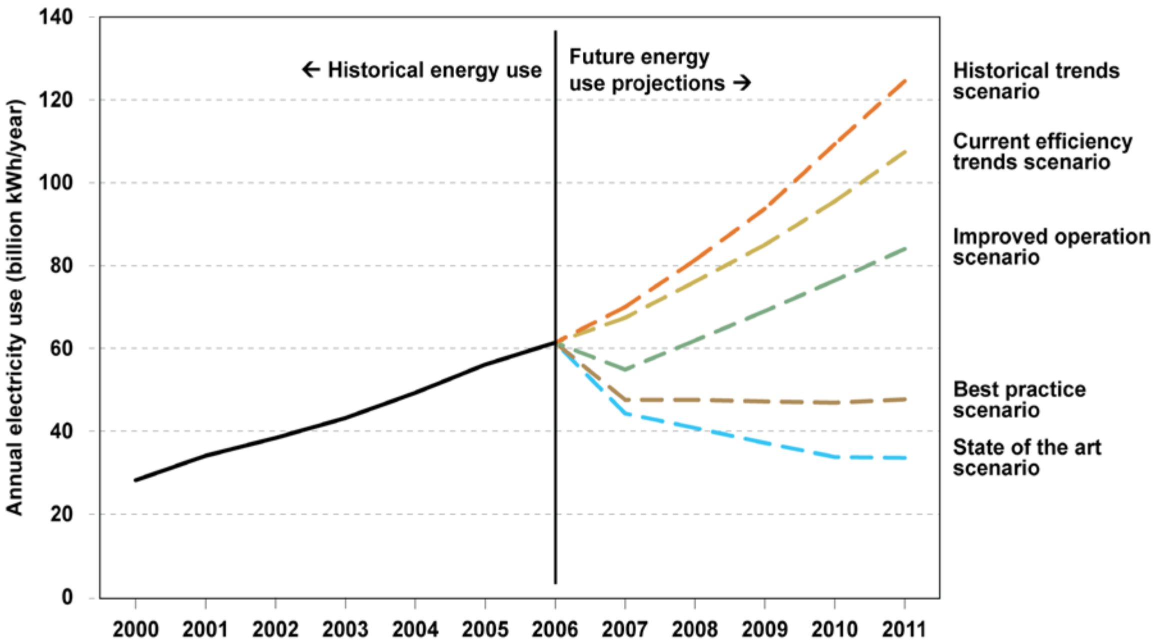
117 Choi Granade, Hannah, J. Creyts, A. Derkach, P. Farese, S. Nyquist, and K. Ostrowski. 2009. McKinsey Global Energy and Materials. Unlocking Energy Efficiency in the U.S. Economy, p. 68.

118 U.S. Environmental Protection Agency ENERGY STAR Program, "Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431." August 2, 2007.

119 Jennifer Mitchell-Jackson, Opinion Dynamics, Jonathan G. Koomey, LBNL, Michele Blazek, AT&T, and Bruce Nordman, LBNL, 2002. "National And Regional Implications Of Internet Data Center Growth In The US."

would likely continue (historical trends scenario). With widespread adoption of the most energy-efficient measures, growth would essentially flat-line or even lead to a modest decline in energy use by the sector (best practice and state–of- the-art scenarios). These potential market growth projections were widely accepted and propagated throughout the industry for several years.

Figure 23. Historical and Predicted Energy Use for Data Centers (2007)



The 2007 Report to Congress generated industry and regulatory attention. The data center and IT industries responded by forming two associations focused solely on energy efficiency: The Green Grid and Climate Savers Computing Initiative. These associations along with other trade groups and industry conference organizers devoted increasing attention to efficiency. For example:

- Industry analysts, such as the Green Grid, IDC, and the 451 Group, began noting that enterprise data center operators were reporting widespread capacity shortfalls (i.e., they were running out of space, power, and/or cooling capacity in their existing facilities).
- Both the Department of Energy (DOE) and Environmental Protection Agency (EPA) turned their attention to data center energy efficiency, partnering to deliver a suite of programs and services to assist the industry in evaluating performance.
- The IT industry shifted focus to energy efficiency, with existing players reorienting their products and service offerings with a new energy efficiency focus and new entrants offering technologies and products to address the same opportunities. Several new classes of technologies and products can be attributed to the new focus on energy efficiency, including DCIM tools, airflow management products and services, and modular or containerized data centers.

7.3.2 2011: Resetting the Growth Rate

In 2011, at the request of *The New York Times*, which was examining the utility- scale data center industry, Jonathon Koomey updated the information in the 2007 Report to Congress to determine what growth rate had actually occurred in the preceding five years. Using the same fundamental research techniques, the report indicated that the annual growth rate of energy use for the data center sector had been 36% between 2005 and 2010 in the United States. This growth resulted in an estimate that total energy use of the sector was between 1.7% and 2.2% of total electric use in the United States.[120] The moderation in growth was primarily due to a reduction in the growth rate of the installed server base, in part due to server virtualization. Although the report acknowledged that operators of utility-scale data centers (particularly those operated by cloud service providers) had likely implemented significant energy efficiency measures, it suggested that for the remainder of the market energy efficiency gains were probably minimal.

7.3.3 Predicting Future Growth

Predicting the growth of data center sector energy use presents a fundamental challenge; proposed methodologies rely on estimates that are one step removed from an actual prediction regarding energy, and they often overlook key factors that may dramatically alter growth rates. The projected growth patterns for the industry described in the 2007 Report to Congress simply speculated that existing growth rates would continue, possibly attenuated by increased adoption of energy efficiency measures and practices. It did not consider, for example, what increases in content delivery services might mean for the industry or a dramatic increase in processor efficiency.

7.3.4 Growth Rate Drivers

Drivers and ameliorators of data center energy use growth follow:

- **User Growth.** By 2018, there will be nearly four billion global Internet users (more than 51% of the world's population), up from 2.5 billion in 2013.[121] This growth will not significantly affect the United States, as Internet access in North America is at 85%.[122]

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120 Koomey, Jonathan. 2011. "Growth in Data Center Electricity Use 2005 to 2010." Analytics Press. www.analyticspress.com/datacenters.html

121 http://www.cisco.com/c/en/us/solutions/service-provider/visual-networking-index-vni/index.html

122 http://www.internetworldstats.com/stats.htm

- **New IT Services.** Although IT services have very high penetration rates for some functions and for some sectors of the economy, many more uses are expected to be developed. Descriptions of some of these potential uses are:
    - ***Digital Records:*** Increased migration of business recordkeeping from paper to digital systems means records are being maintained in active data storage systems far longer. Examples of this trend include legislation like Sarbanes-Oxley, which requires business records be maintained longer and the digitization of health records. According to the International Data Corporation (IDC), annual sales of storage capacity will grow by more than 30% every year between 2013 and 2017, but that growth will be slower than the steep pace recorded a few years ago because organizations have adopted ways of using storage more efficiently.[123]
    - ***Content Delivery:*** Services that allow access to media “on demand” are quickly gaining market share. For example, content delivery networks were projected to increase three-fold from 2012 to 2017, with video representing 81% of that growth. [124]
    - ***Internet of Things (IoT):*** Gartner indicated that IoT will grow 30 fold between 2009 and 2020 in terms of installed units.[125] One major driver is that infrastructure systems will increasingly be monitored and managed through the Internet, using centralized processing. Building automation, security, and transportation automation are examples of new uses that will drive an increased need for data center infrastructure.
- **Communications Services Migration.** Technologies such as Voice over Internet Protocol (VoIP), telecomm systems, and teleconferencing rely, to some extent, on data center infrastructure.[126] VoIP is of particular interest due to its growth. It has gone from a hobby to widely used platform in the past decade, and is in the process of replacing standard analog telephone service. [127] It has become so pervasive that people no longer realize they are using VoIP when they make a call. According to *IBISWorld's VoIP in the U.S.* report, the market has increased 16.7% annually over the last five years.[128] As these systems draw new users, and existing telecomm workloads migrate to these new platforms, data center infrastructure demands will increase.

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123 http://www.computerworld.com/article/2497852/data-center/efficiency-will-hold-down-storage-growth--idc-says.html

124 Large distributed system of servers deployed in multiple data centers across the Internet. The goal of a CDN is to serve content to end-users with high availability and high performance. http://www.informatandm.com/wp-content/uploads/2012/10/CDN-whitepaper.pdf

125 IoT refers to making the Internet accessible beyond desktops, laptops, tablets and smartphones. It includes consumer electronics, household appliances, jet engines, oil rig drills, and entire factories. http://www.gartner.com/newsroom/id/2636073

126 Voice over Internet Protocol phone is a telephone or component of a telephone system that converts sound into Internet Protocol data packets for transmission through an Ethernet connection.

127 Analog Telephone converts sound into analog waveforms for transmission through the Public Switched Telephone Network (PSTN).

128 www.shoretel.com/about/newsroom/industry_news/VoIP_market_growing_at_more_than_16_percent_annually.html#sthash.qIBZhe5z.dpuf

- **Energy Efficiency Adoption.** As the best practices, technologies, and measures that provide superior energy efficiency performance in data centers permeate throughout the market, energy use in the sector will be mitigated.
- **New Technologies.** As described in a following section, new data center technologies could drive additional gains in energy efficiency, ameliorating sector energy use growth.

7.3.5 Growth Prediction Methodologies

Several methodologies predict energy use by the data center sector, with caveats regarding their inherent weaknesses. Understanding the underlying assumptions, translating the purported growth rate to predicted energy use in the sector, and identifying the confounding factors that are not addressed are all challenges associated with these estimates. Examples of growth prediction methodologies include:

- **IT Supplier-Side Estimates**. Many sources predict the future financial performance of the IT industry as a whole, as well as for more selective segments of the industry. Investment and financial firms that cover the industry, along with market analysts, produce short- and long-term market forecasts that might in some way serve as proxy measures for the prediction of data center growth. For example, predictions of growth for the major IT equipment suppliers (i.e., the largest server, storage, and networking companies) would provide a forward-looking estimate of the installed IT equipment base. IT supplier-sides estimates were used in the 2007 Report to Congress. Absent misgivings of how the growth rates for the selected companies were derived, this methodology needs to make sure that it accounts for technology advances (e.g., more efficient processors or a move to solid state data storage technology) and adoption of energy efficiency measures in existing and new data center facilities.

- **User-side Growth Forecasts.** Rather than relying on estimates of market growth from suppliers, this methodology bases analysis on the demand for IT services and the infrastructure needed to support it, and appears to be a better proxy for eventual energy use growth. For example, an Internet search service growth rate could nominally predict the IT infrastructure needs for a portion of the operations at Google and Microsoft. It is likely that analysis of this kind drives the estimates for equipment supplier growth noted in the IT supplier-side estimates methodology, but demand estimates could potentially yield more fine-tuned results. Estimates of the increase in digitized medical record keeping would link to higher data storage growth rates, but lower processing and communication growth rates. For the growth analysis detailed in Section 6, the Cadmus team used user-side growth estimates from Cisco on internet traffic as a proxy for demand growth and to account for adoption of energy efficiency measures in existing and new data center facilities.

- **Broad Industry Metrics.** Attempts have been made to synthesize a variety of estimates into broad industry metrics that focus on predicting overall growth rates. Again, these estimates from firms (e.g., IDC, Forrester Research, and Gartner) primarily attempt to gauge the financial vitality of the IT industry rather than the specific growth rates for data center facilities and in turn energy use. For example, Cisco has projected overall Internet communications growth rates based on estimates for the number of people globally who will be accessing the Web, the increasing use of the Internet for voice and video communications (VoIP, teleconferencing), and the Internet of Things (the connection of building automation and infrastructure monitoring and control systems to the Web).

7.3.6 Growth Prediction Parameters Specific to New York State

The prediction methodologies and the growth factors do not speak to specific requirements in New York State, where power costs and availability and general costs of doing business may deter data center infrastructure growth rates. These factors do not preclude data center sector growth across the board, but may attenuate growth for many or even most subcategories. One of the growth prediction methodologies (user-side analysis) may be particularly useful for projecting growth in New York State. Given the preponderance of the financial services industry in the New York City metro region, it would be pertinent to analyze projected growth rates for this sector to inform an overall assessment for New York State. In particular, securities and commodities trading operations are essentially wholly dependent on data center infrastructure, and though this infrastructure is increasingly being sited in New Jersey, it could be expected to drive growth in New York State as well. In addition, it might also be worth considering the growth of content delivery and communications services, which will require infrastructure commensurate with population; thus, these services will grow regardless of factors (like costs) that would otherwise discourage investment in New York State.

7.4 Trend 2: Cloud Services Capture is an Increasing Portion of IT Market

The IT sector is undergoing a large shift from end-user owned and operated data centers to the acquisition of IT capabilities from cloud service providers. A recent study indicated that the worldwide cloud computing market will grow at a 36% annual growth rate through 2016.[129] This migration allows end users to effectively outsource portions of their IT workloads, avoiding capacity shortfall issues in their own facilities, and eliminating the need to move to colocation providers.

129 http://www.forbes.com/sites/louiscolumbus/2013/09/04/predicting-enterprise-cloud-computing-growth/

7.4.1 Cloud Services Defined

The cloud and cloud services are not well defined within the industry. The original definition of cloud services included any IT function that was supported by systems that were not directly proximate to the end user. This definition is truly too broad because any IT service that relied on a data center (or even server closet) would meet the criterion. Now, most industry experts characterize cloud services as IT services that are delivered to an end user using centralized, shared computing resources, and are typically delivered through the Internet.[130] An additional key component of the definition is that another company provides the cloud services. However, this criterion has become blurred as businesses deploy "internal clouds" to solely support solely their own IT needs. The Cadmus team has defined the following terms to facilitate the discussion of the trend for this study:

- **Cloud Services:** IT services delivered by a provider using IT equipment and software owned and managed by that provider, and delivered to clients using the Internet.
- **The Cloud:** The physical infrastructure that cloud service providers use to deliver their services, including data center facilities, IT equipment, and software.
- **Cloud Providers:** Companies who offer cloud services of varying types. The market leaders are Google, Amazon Web Services (AWS), and Microsoft. They offer the following three types of services:
    - **Software as a Service (SaaS) Providers:** Companies that offer software services that are delivered using the cloud model. Many software companies are moving to SaaS business models, such as Adobe and Microsoft (the Microsoft Office suite of programs).
    - **Infrastructure as a Service (IaaS) Providers:** Companies (such as AWS, Google's Compute Engine) that provide an organization with the equipment used to support operations, including storage, hardware, servers and networking components. The company owns the equipment and is responsible for housing, running, and maintaining it and charges clients on a pay-per-use basis.
    - **Platform as a Service (PaaS) Providers:** Companies (such as Windows Azure, AWS, Google App engine) that provide service aimed at developers that helps them develop and test applications without having to worry about the underlying infrastructure.

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[130] Mims, Christopher. "Amazon and Google are in an epic battle to dominate the cloud-and Amazon may already have won." April 16, 2014. http://qz.com/196819/how-amazon-beat-google-attempt-to-dominate-the-cloud-before-it-even-got-started/

The concept of delivering IT services through a utility-like business model became possible with the build-out of the Internet, allowing users to access services from providers that operate IT infrastructure at massive scale. Now, users can source IT capacity, managed services, and a wide variety of applications and services from cloud providers. End users across all business types now have the ability to access cloud services, including applications as utilitarian as email or applications as complex as intensive workloads supported by high performance computing systems. Cloud providers run the gamut—from firms that provide raw computing capacity to firms that offer broad suites of services and applications to firms that have transitioned their software and applications to cloud delivery models.

7.4.2 Efficiency of Cloud Services

According to one report, accessing IT services through the cloud can have positive environmental impacts if cloud provider data centers are designed and operated for energy efficiency and high utilization.[131] For IT managers, accessing cloud services can help them to avoid developing or expanding their own data centers or sourcing co-location capacity; this may result in a lower impetus for improving energy efficiency in enterprise data centers, because energy efficiency upgrades are often pursued in part to relieve capacity shortfalls in existing facilities.

7.4.3 Cloud Services In-Depth Survey Results

The in-depth survey results reflect the popularity of the cloud. As shown in Figure 24 through Figure 26, 83% of industry players and 74% of data center managers in New York State indicated they used cloud services. Of the limited number of surveyed data center managers and industry players who said they were not using the cloud were asked why, most indicated they were still evaluating cloud services, followed by security concerns. As expected, surveyed respondents reported they most frequently use cloud services for data storage, Web application management, and email.

131 Pierre, Delforge. “Is Cloud Computing Always Greener? Finding the Most Energy and Carbon Efficient Information Technology Solutions for Small- and Medium-Sized Organizations.” October 2012. NRDC Issue Brief

Figure 24. Respondents Use of Cloud Services in New York State

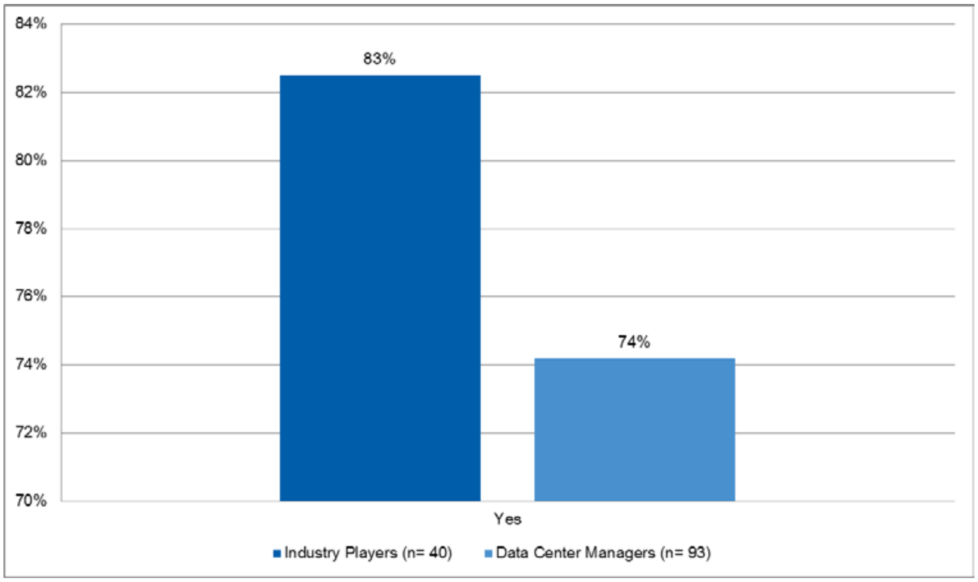


Figure 25. Cloud Service Applications Used in New York State

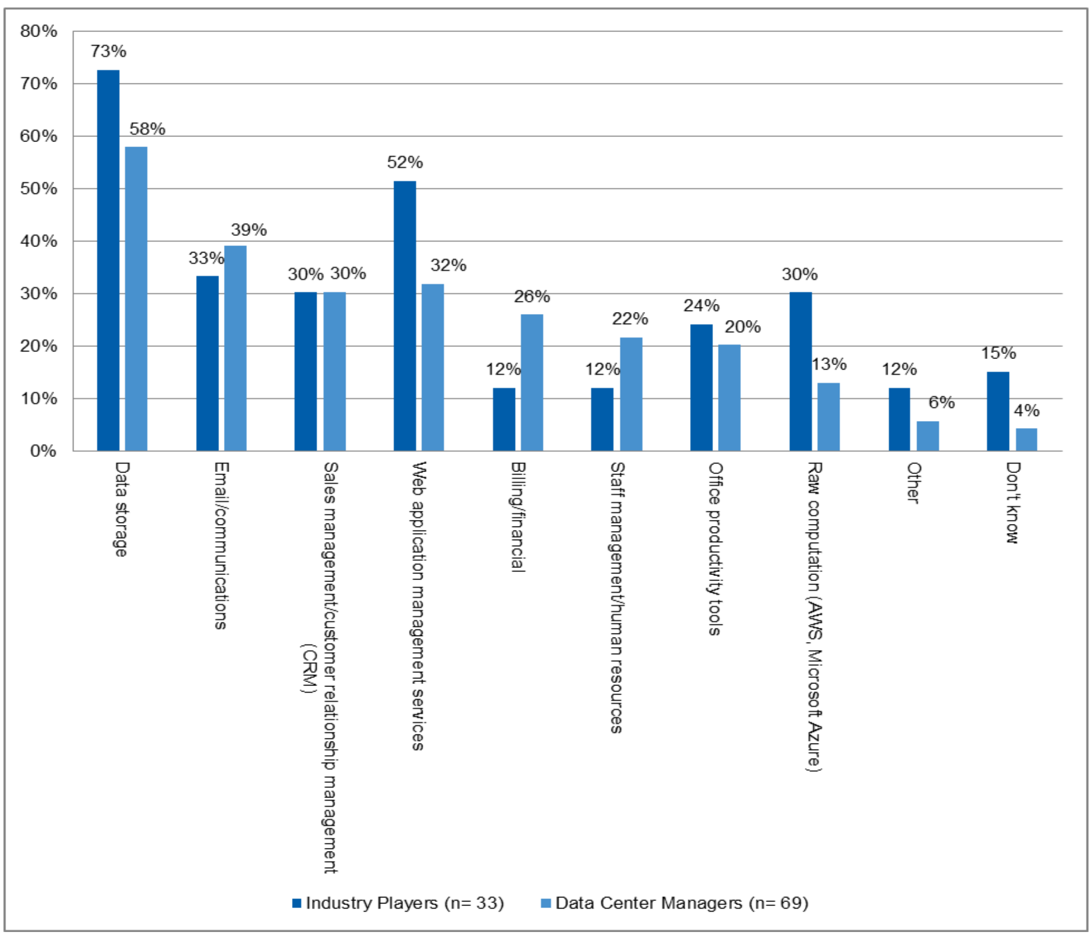
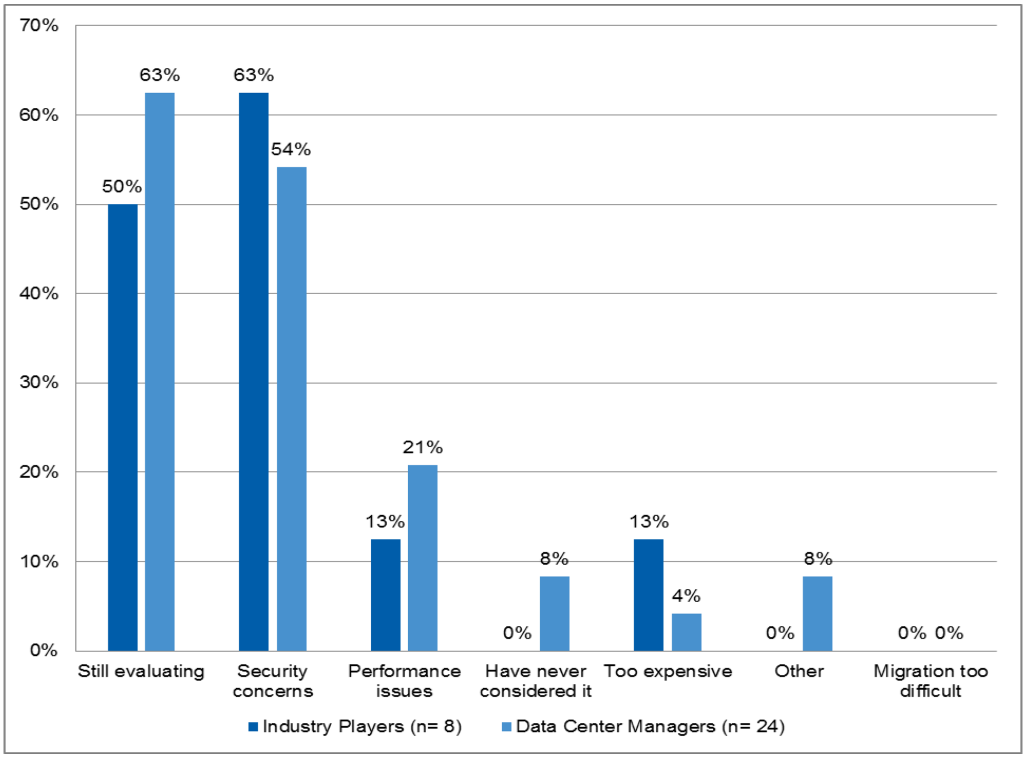


Figure 26. Reasons for Not Using Cloud Services



7.5 Trend 3: Colocation Sector Growth

Colocation providers offer their customers power, cooling, and network conductivity to support their servers and software. Colocation space ranges in scale from entire data centers to a single slot in a server rack. This service's obvious appeal is that a company can control its IT but does not have to worry about the cost of building its own data center. With regard to latency requirements (i.e., the need to place IT resources near users so that they do not suffer from data communication delays), these issues can be accommodated by having multiple locations to provide services more locally to customers spread over large regions. It is certainly beneficial in New York City, where constructing a data center would be prohibitively expensive. A recent report predicted 15% growth in the colocation market in 2014. [132]

132 http://www.datacenterdynamics.com/focus/archive/2014/01/15-growth-forecast-north-america-colocation-market-2014-0

7.5.1 Colocation Survey Results

Based on the in-depth survey results (shown in Figure 27, Figure 28, and Figure 29), the Cadmus team found that more than 93% of industry players and 55% of data center managers have their IT equipment in a colocation facility, reflecting the popularity of colocation. Data center managers and industry players cited the following reasons for leasing colocation space:

- More affordable than securing/using our own data center space.
- Ran out of physical space.
- Don't have our own data center.
- Ran out of cooling/power capacity.

In terms of why they did not use a colocation facility, data center managers cited being able to use their own facilities, expense, and security concerns as their three top reasons.

Figure 27. Percentage of Respondents Using Colocation Facilities in New York State

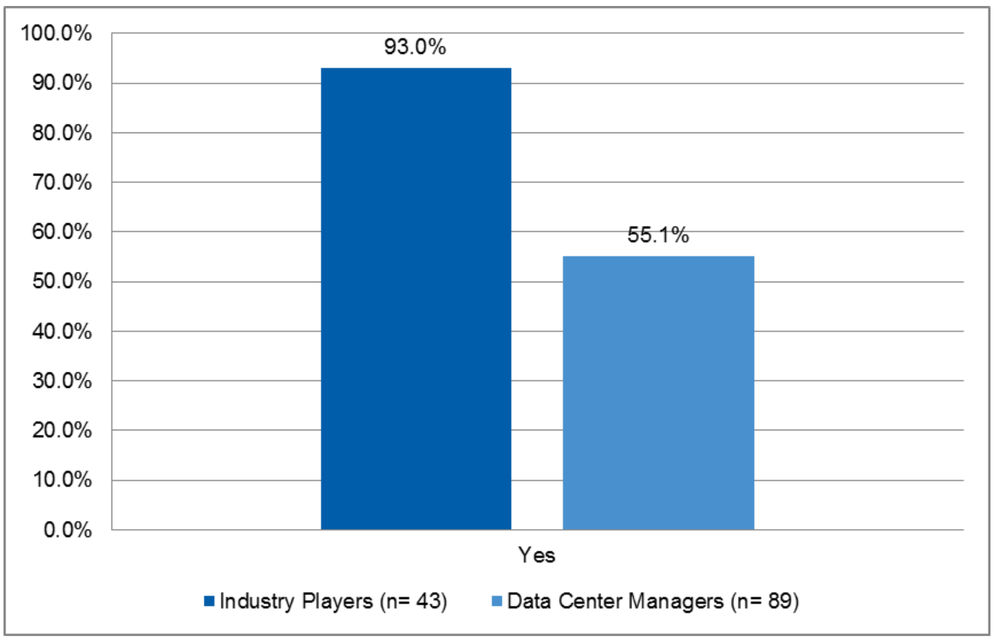


Figure 28. Reasons for Using Colocation Facilities in New York State

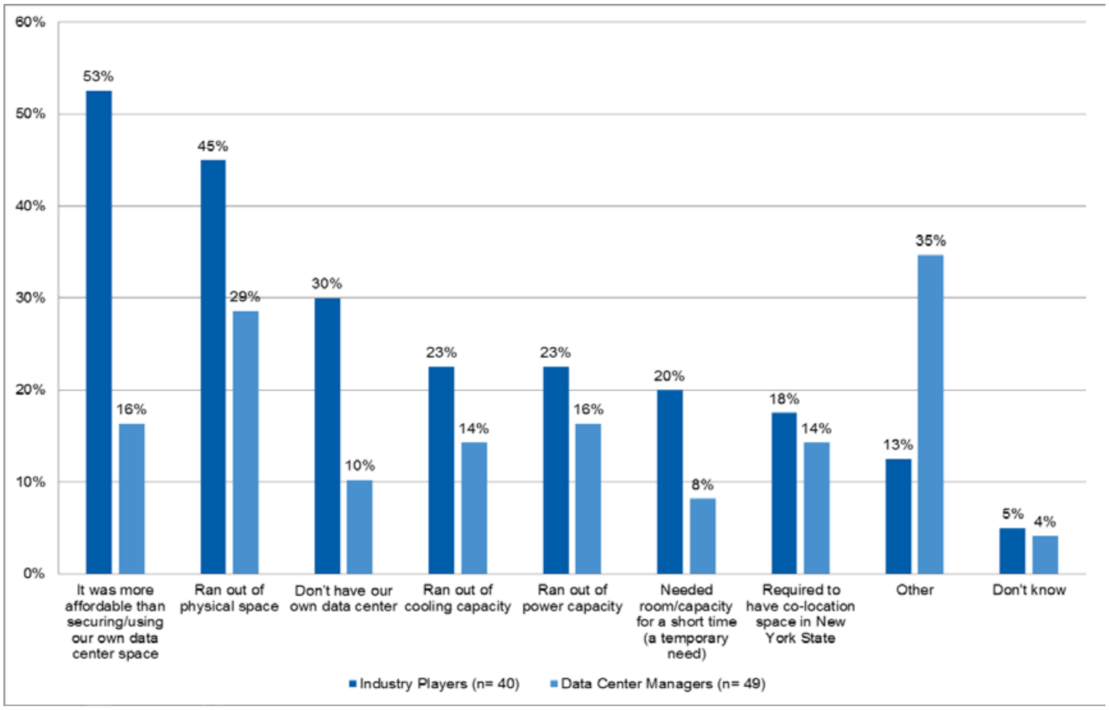
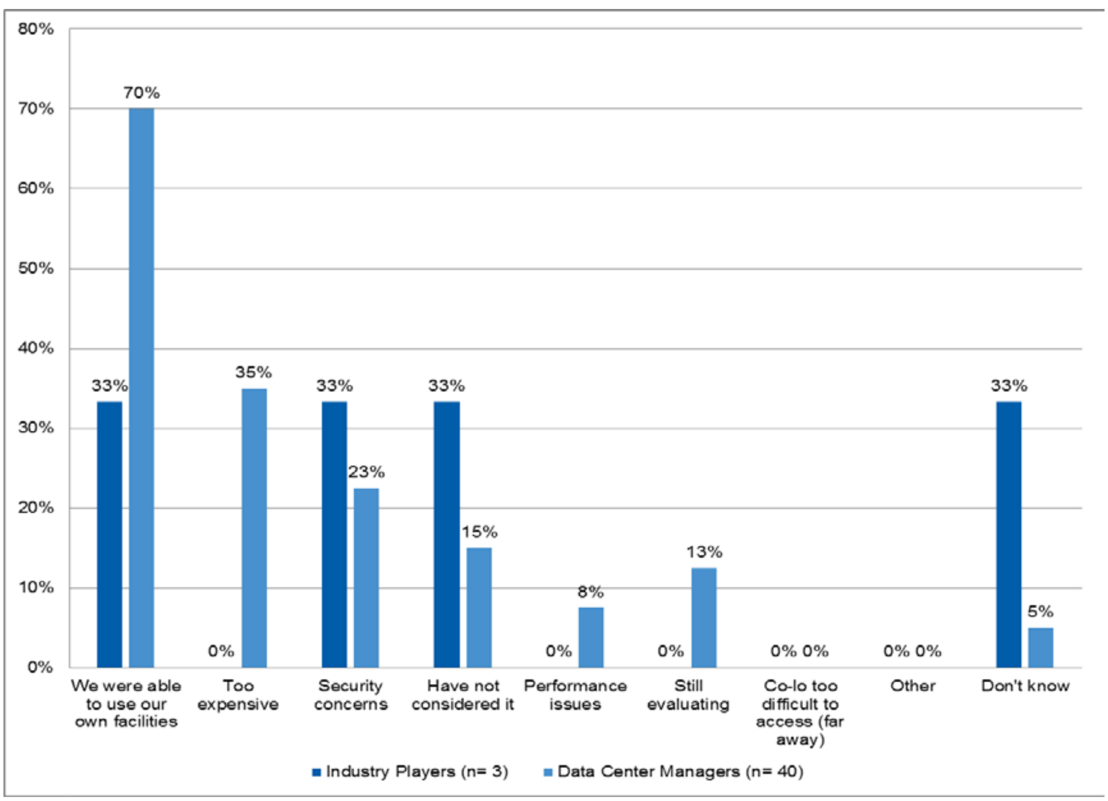


Figure 29. Reasons for Not Using Colocation Facilities in New York State



7.5.2 Understanding the Colocation Market

The colocation data center market has two models of operation:

- **Wholesale:** In the wholesale model, a tenant leases a fully-built data center space or very large portions of them, such as an entire floor of a building. Oftentimes the tenant is then responsible for handling all IT operations in that space (but not always).
- **Retail:** In the retail model, a customer leases space within the colocation facility; this is usually a rack, space within a rack, or a caged-off area.

The following sections describe the differences and implications of these two models with regard to energy efficiency.

7.5.2.1 Wholesale Colocation

Wholesale colocation companies act essentially as speculative real estate developers, building data centers that they put on the market as ready to occupy. Wholesale colocation centers are most often leased in total to single tenants—the owner “hands over the keys” to the tenant, who has responsibility for managing the entire facility. In some cases the wholesale colocation owner retains responsibility for some building management functions. DuPont Fabros and Digital Realty Trust dominate the wholesale colocation data center market, though many companies have developed similar properties. Some wholesale providers have begun to offer subunits in their facilities, but the units are generally standardized and quite large (Digital Realty Trust offers modular units in some facilities that support standard units of IT equipment load).[133]

A number of wholesale colocation developers have specialized in identifying vacant or underutilized commercial or industrial properties with existing utility power supply that can be converted into data centers. (On the West Coast, Fortune Data Centers has converted two former manufacturing facilities with stranded power capacity—unused capacity—into wholesale colocation centers.) Utilities seeking to attract data center development might consider identifying these types of sites and promoting them to both wholesale and retail colocation data center developers.

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133 http://www.digitalrealty.com/us/turn-key-flex-us/

Wholesale colocation data center providers tout the energy efficiency of their new facilities, though improvements are limited primarily to cooling systems and power delivery and conditioning, as tenants are responsible for provisioning the actual data center floor with IT equipment and airflow management features. Because wholesale colocation facilities have single tenants, the design and operation of the data center can be far more tightly integrated and managed compared to retail facilities. For example, a tenant can specify the power reliability for the whole facility, avoiding power conditioning power losses for systems that exceed their needs. Similarly, airflow management measures can be impacted far more easily in a wholesale facility because there is solely one tenant.

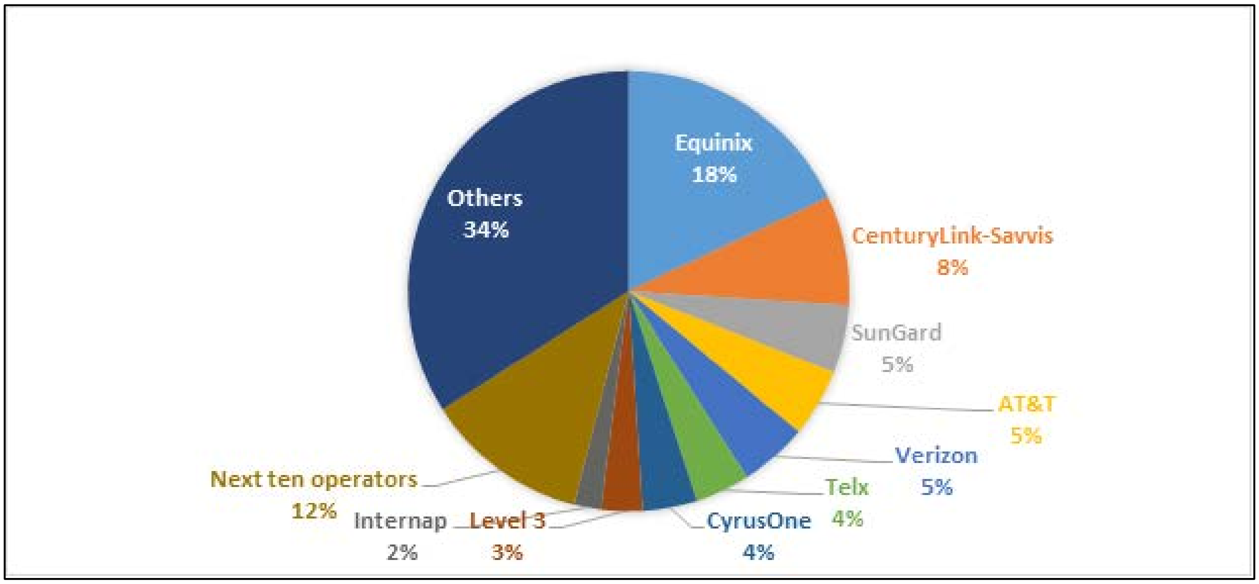
7.5.2.2 Retail Colocation

Retail colocation customers include enterprises that need a temporary or long-term increment of facility capacity, and startup firms that are reluctant to devote financial resources to building their own facilities. Retail colocation data centers face a similar challenge to wholesale developers in that they have little control (other than a cap on power demand) over how IT equipment is deployed and operated by their tenants. Retail colocation centers rely on customers who require incremental data center space to meet capacity needs as well as small customers (notably, tech startups) who prefer to manage their own IT systems but do not want or cannot afford to build and operate their own data center facilities. Retail colocation facilities, therefore, have multiple tenants.

Retail colocation data centers are often referred to as data center hotels where tenants rent space for their IT infrastructure, receiving cooling, communications, and high-reliability power from the building owner. The provision of those services are governed by service level agreements outlined in leases, indicating for example how much redundancy is incorporated in the power delivery and conditioning system, or simply how reliable the power supply must be. Retail co-los (colocation facilities in the industry vernacular) might be better characterized as condominiums rather than hotels, as tenant leases have longer durations, and tenants are largely responsible for what happens inside their unit. That unit could be a slot in a rack, a rack or number of racks on a shared floor, or a dedicated area of a floor partitioned from other customers. (The partitions are often just metal fencing, so these spaces are often called cages.) Unlike a wholesale colocation customer that can control airflow management, retail colocation customers often do not have that efficiency option and are limited to using more efficient IT equipment.

Leases for colocation space are typically denominated not just with regard to space, but also by the power capacity available to the tenant, typically rated in circuits and amps (or power drops). Colocation operators sometimes meter power use by their tenants and charge for that use (often with an adder to account for cooling costs), often contrary to utility regulations that prohibit power resale. (As an example, Pacific Gas and Electric Company's Electric Tariff 18 prohibits resale of electricity except under strictly prescribed circumstances.)[134] The retail colocation industry is highly fractured, with the largest operators only making up about half of the market (Figure 34).

Figure 30. Retail Colocation Market Leaders in United States Q3 2013[135]



7.5.3 Colocation Sector Growth

It is difficult to assess the often conflicting trends that may affect the growth of the colocation market. Colocation data centers rely, in large part, on customers who have outgrown their own data center facilities. With the intense growth rates that the sector continues to experience, that pipeline of tenants remains a major driver of growth. However, industry analysts believe that colocation companies may see

134 http://www.pge.com/tariffs/tm2/pdf/ELEC_RULES_18.pdf

135 http://www.datacenterdynamics.com/focus/archive/2014/01/us-retail-colo-market-broken-down

a decline in that customer base as customers decline the option of securing colocation space by choosing to outsource applications to cloud service providers. In fact, many colocation companies have long offered managed services options to customers, essentially renting data center space and IT equipment to enterprise and other customers and acting as raw computing cloud service providers.

In summary, the factors impacting colocation sector growth include:

- The adoption of energy-efficient technologies by enterprise data center operators that mitigate the impacts of IT growth on existing facilities, which would otherwise require sourcing additional data center capacity, including colocation space.
- The outsourcing of IT workloads to cloud service providers that obviates the need for securing additional data center capacity, including colocation space.
- The trend for small firms (notably tech industry startups) to source only colocation capacity and/or cloud services.
- The need for some workloads to be located in a particular geographic area (e.g., near financial markets), or proximate to users (e.g., content delivery close to consumers)

Several alternatives may be considered valid for the vitality of the colocation industry:

- **New colocation facility development.** Tracking the establishment of new colocation facilities through industry reports could be accomplished. This option might best be considered a metric of where the colocation industry thinks the market is going, as the industry has gone through under- and over-building phases.[136] At the last Data Center Dynamics conference, the New York metro data center market was described as a tight market.[137]
- **Lease rates.** Tracking lease rates is perhaps a good leading measure of colocation space demand, though there may be no ready source of market-aggregated lease rate data. Another sign of a tight market, multitenant lease rates in New Jersey have stabilized after years of decline. [138]

Colocation industry revenue statistics. Revenue growth for the major colocation providers (Table 56) can be considered a proxy for market growth. However, other contributing factors could include building new or purchasing existing facilities, acquiring other companies, lease rate increases, and higher tenant occupancy rates.

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136 It is important to remember that even though a colocation facility is built, it may not be fully or even partially leased so there is no correlation between building and occupancy and energy use.

137 http://www.datacenterdynamics.com/focus/archive/2014/03/dcd-converged-new-york-2014-filling-spaces

138 http://www.datacenterdynamics.com/focus/archive/2014/03/dcd-converged-new-york-2014-filling-spaces

Table 56. Colocation Data Center Company Revenue Growth[139]

Colocation Providers	2012-2013 Growth	2013 Revenue (millions)	2011-2012 Growth	2012 Revenue (millions)
Digital Realty Trust	15.9%	$1,482	20.4%	$1,279
DuPont Fabros	13.0%	$375	15.7%	$332
Equinox	14.0%	$2,152	20.6%	$1,887
Coresite	13.6%	$234	19.1%	$206
CyrusOne	19.6%	$263	20.9%	$220
QTS	21.9%	$178	21.7%	$146
Total	15.1%	$4,684	20.1%	$4,070

Based on available information about the sector, and the acknowledged confounding factors that make assessment imprecise, it is reasonably clear that both the wholesale and retail colocation markets are currently experiencing strong growth. This growth is occurring despite diminished capacity shortfall conditions for enterprise customers and competition from cloud-based service providers.

7.5.4 Energy Efficiency in the Colocation Market

The colocation data center market has been slow to adopt leading energy efficiency designs in new facilities and faces particular challenges in retrofitting existing facilities. This challenge represents a significant market opportunity. The New York City metropolitan region is one of the largest colocation data center market in the country,[140] and any efforts to address energy efficiency opportunities and customer attraction and retention should certainly address this large and important sector.

[139] Data from http://wiredre.com/data-center-earnings-season-update-q1-2014/

[140] However, a recent study indicated that Northern Virginia was going to overtake New York in 2015. http://www.datacenterknowledge.com/archives/2014/09/25/n-virginia-set-to-become-biggest-data-center-market-by-2015

7.5.4.1 Differences Between Wholesale and Retail

The adoption of energy efficiency in colocation facilities has been led by wholesale developers, who can position the lower cost of operation for their facilities directly to potential tenants. For example, Digital Realty Trust, the leading wholesale colocation developer, promotes the efficiency of their cooling and power delivery systems to potential clients, who in many cases take on full operational responsibility for the data centers they lease. The reason that wholesale providers can market energy efficiency is that their tenants become responsible for power costs more directly than those that use retail services.

Retail colocation providers can also promote the energy efficiency of the cooling and power delivery in their facilities, but it is much harder to partner with tenants to install additional measures like airflow management/containment in a multi-tenant environment. A classic example is the difficulty in encouraging tenants to rigorously install blanking panels in their equipment racks to prevent bypass airflow. Further, in retail colocation facilities, tenants are typically charged for units of power delivery capacity (power blocks) but not directly for use. For example, if a customer is paying for 20 amps of power delivery capacity that is not metered and charged by usage, they have no financial incentive to reduce a 15-amp load.

7.5.4.2 A Green Contracting Template

A recent study conducted by the Natural Resources Defense Council emphasized the need to align contract incentives in colocation facilities between providers and customers. [141] For example, instead of charging for power blocks, colocation provider should always charge directly for power and cooling on a per kilowatt-hour basis. The Green Grid is moving forward with developing a green multi-tenant data center contract template that would ask for commitments to environmental performance from both the colocation provider and customer.

7.5.4.3 Sub-metering May Be Best Market Intervention

An energy efficiency market intervention strategy for the retail colocation market may be regulatory policy that allows for sub-metering and direct charges for energy use. However, most utility regulatory environments expressly prohibit sub-metering of electric use for the purposes of reselling power, though there are markets where this practice occurs (i.e., marinas). Retail colocation data center operators have been known to charge tenants directly for power (often with an overhead charge to account for cooling

[141] NRDC, “Data Center Efficiency Assessment.” August 2014.

and power delivery energy use) even though the practice runs counter to regulation. In California, the Public Utilities Commission has made an exception for sub-metering and charging for actual energy use for multi-floor, multi-tenant commercial buildings, expressly to encourage energy efficiency. However, the policy requires landlords to meter and bill tenants on the same basis as the utility (requiring energy, demand, time-of-use, and even real-time metering, and with no markups), and has not been widely adopted.

7.6 Trend 4: The Advent of Utility-Scale Data Centers

Leading cloud service providers, high tech firms, financial companies, and colocation providers now develop data centers that are denominated by the tens of megawatts of power load they require rather than their physical size. Some of these developments are being “scaled out” into facilities with total loads exceeding 100 MW. Given that power costs are the single largest operational expense for these utility-scale data centers, industry leaders such as Google, Microsoft, Facebook, and eBay have dramatically changed the way data centers are designed and operated, with an intense focus on energy efficiency. Until recently, many of the design features of these data centers were closely guarded for strategic advantage, but they are now increasingly shared and even promoted within the industry as a whole.

These companies not only report the PUE of their facilities (often reported as an average across all their data center spaces), but they promote leading-edge features as well. For example, Yahoo has promoted the air-side convective cooling of their chicken coop data center design in Lockport, NY,[142] Microsoft promotes their use of modular/container data center designs,[143] and Google shares that they use cooling water from the sea in a data center development in Finland that reused a former pulp mill.[144]

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[142] http://www.datacenterknowledge.com/archives/2013/03/25/yahoo-building-a-bigger-computing-coop/

[143] http://www.globalfoundationservices.com/posts/2013/march/26/microsoft-cloud-scale-data-center-designs.aspx

[144] http://www.wired.com/2012/10/google-finland-data-center-2/

Although some of the design features of utility-scale data centers are unique, and many cannot be cost-effectively adopted as retrofit measures in existing facilities, some measures and technologies are being adopted in the enterprise/legacy data center market. For example, these data centers do not always feature backup power systems like generators or even UPS equipment, because in the event of a power failure the IT workloads are simply migrated to another location. Air-side economizers have become a de facto standard for centers built in the last few years as it is often difficult to retrofit air-side economization in an existing data center.

7.6.1 Operators of Utility-Scale Data Centers

Utility-scale data centers are facilities described by the power load (in megawatts or in electric utility terms) rather than physical size. Although enterprise data centers supporting large companies may have loads as high as a few megawatts, utility-scale facilities are typically served with a dedicated substation and have loads exceeding five megawatts. The largest facilities are commonly scaled at tens of megawatts, with some centers exceeding 100 megawatts of total facility electric load. Apple's data center in Maiden, NC, is expected to have a load exceeding 100 megawatts when completed. It also features one of the largest solar photovoltaic generation installations in the industry, coupled with natural gas fuel cells and wholesale market purchases of renewable energy.[145] lists examples of the four classes of utility-scale data center operators: colocation centers, Internet-focused companies, financial companies, and government agencies.

Table 57. Utility-Scale Data Center Operators

Class	Examples
Colocation	Digital Realty Trust, Equinix, Century Link
Financial Sector	Bank of America, Wells Fargo, Stock Exchanges
Internet-Focus	Google, Facebook, eBay, Microsoft
Government Agencies	Federal Agencies (IRS, NSA)

145 Available online at: http://www.datacenterknowledge.com/archives/2014/07/17/apple-data-center-energy-use-grows-remains-100-percent-renewable/

7.6.2 Technologies Only at Scale

Some of the leading-edge technologies used in utility-scale data centers are not transferable to traditional data centers, largely because of scale issues. Utility-scale data center operators (other than colocation facilities) often manage IT loads in a manner that smaller-scale facilities cannot easily mimic, including:

- Homogeneity leads to more efficient cooling. Simply due to scale, racks of equipment at utility-scale facilities are typically very homogeneous, resulting in even power loading per rack throughout the facility. This design allows for operation of cooling systems that are very tightly matched with actual heat loads—the systems deliver just the right amount of cooling to meet loads. In a heterogeneous environment, such as colocation facilities, it is more difficult to match cooling supply and loads without resultant equipment overheating.
- **Homogeneity leads to higher server utilization.** Utility-scale operators typically provide a small number of IT services (i.e., Google may devote a whole data center or a portion of one to providing Internet search or email service) compared to an enterprise data center that may support hundreds of types of workloads. With specific, homogeneous workloads, IT equipment, notably servers, can be specifically designed for a given task, often resulting in higher efficiency and utilization rates, improving efficiency and productivity. With vast pools of IT equipment devoted to singular workloads, operators can rely on load management schemes rather than virtualization to boost utilization rates. For example, eBay can bring computing capacity units online during peak demand periods, and shut them down when demand is slower. Using load management schemes offers an energy efficiency advantage compared to virtualization, as the energy use overhead to support virtualization software (which can be quite significant) is removed. According to a 2014 Natural Resources Defense Council report, average server utilization has been static, between 12 and 18%, from 2006 through 2012. Hyper-scale cloud providers can realize higher utilization rates ranging from 40 to 70 percent.[146]
- **Custom designed equipment**. Industry reports indicate that utility-scale operators are increasingly designing and sourcing their IT equipment directly from custom suppliers rather than buying equipment from traditional suppliers like Dell or HP.[147] Facebook, through its Open Compute initiative, has shared their custom designs of their hardware. [148]
- **Shorter refresh rates.** Operators report that their equipment refresh rates (the period between replacements of IT assets) are much shorter than industry averages, in part to capture the improved efficiencies of new equipment designs. For example, eBay reports a refresh cycle of two years; the industry average is on the order of four to five years.[149]

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146 http://www.nrdc.org/energy/files/data-center-efficiency-assessment-IP.pdf

147 http://www.gartner.com/newsroom/id/2751519

148 http://www.opencompute.org/

149 http://www.zdnet.com/blog/btl/ebay-datacenter-chief-dean-nelson-we-are-living-moores-law/38127

- **Use of pods.** The smallest units of modular/container data centers (sometimes called pods) are in the form of 20-foot shipping containers, capable of hosting IT loads of 100 kW or more. Though units of this size could be sited with traditional brick and mortar data centers, they are more generally deployed in groups at utility-scale sites, or as temporary or mobile units.
- **No power system redundancy.** Several leading data center operators now operate their data centers without back-up power systems (e.g., generators and uninterruptible power supplies). Because they are able to fail over IT loads from one facility to another in their portfolio, they can withstand lower reliability at each individual data center. The result of removing backup power systems and mechanical cooling can lead to reported PUEs that are lower than 1.1, with only lighting and fan energy accounting for energy overheads.
- **Free cooling only.** Many utility-scale data center operators are now building facilities without any mechanical cooling (other than fans) for similar reasons: if the environmental conditions at a given site are too extreme for outside-air use, the IT workloads can simply be rerouted to other centers. Google was one of the first data centers to use the free cooling only concept in 2009 with their Belgian data center.[150]
- **Self-generation.** The operators of the largest data center facilities are also beginning to seek self-generation solutions, as well as sourcing electricity on the wholesale market. Enterprise and smaller data centers are simply less likely to consider these options due to opportunity costs; it is not worth seeking these options for the relatively small electric loads of their facilities.

7.6.3 Transferable Technologies and Measures

Other energy efficiency technologies, measures, and practices are broadly applicable throughout the market, either as best practices for the design of new facilities, or as retrofit measures for existing operations, or in some cases both. For example, utility-scale data center operators have been leaders in incorporating airflow management strategies in their facilities, often with designs that completely isolate supply and return cooling air. Many of these measures can be retrofitted to existing facilities. Similarly, the ranges of products falling under the classification of DCIM have migrated from use in the largest data centers down into the enterprise market. These tools have some blend of features, including energy metering and monitoring, environmental condition monitoring, asset management, cooling system controls, and IT equipment controls.

150 http://www.greenbiz.com/news/2009/07/22/google-embraces-free-cooling-belgian-data-center

To some extent, the demand for energy efficient IT equipment by the largest operators has a trickle-down effect for the balance of the market. Although many of the largest firms are now specifying and sourcing their own IT equipment, the major equipment manufacturers have been focusing on efficiency and performance (rather than solely on performance), including features like standby modes and building equipment to ENERGY STAR standards.

7.7 Trend 5: Data Center Site Selection Considerations

A unique set of requirements must be met to attract data center development, including current and future power costs, power availability, site size, access to renewable and low carbon power, and policies regarding on-site generation. Developers of new data centers, particularly those who are building utility-scale facilities, seek a unique set of site attributes, with the most important related to aspects of electric utility service.

Although current and future power costs and power capacity availability remain primary criteria for site selection, secondary factors related to environmental considerations are becoming increasingly important for a subset of developers. For example, developers of wholesale and retail colocation facilities still seek to develop new facilities “where their customers are” making regions like the New York City metro area viable for development. In addition, other submarkets remain attracted to the New York State/City region due to latency requirements (i.e., the need to place IT resources near users so that they do not suffer from data communication delays), including financial trading operations and content delivery providers.

7.7.1 Power Costs Remain a Prime Site Selection Criterion

For developers of utility-scale data centers, with loads in the tens of megawatts, the cost of power is a key siting consideration as power represents the single largest operational expense for the facility. For enterprise data centers, the opportunity to expand existing facilities in lower-power cost areas, or to migrate to cloud service providers, are the usual paths taken to avoid power cost premiums. Generally speaking, absent other factors that might induce a developer to consider a higher cost region, developers are seeking power rates in the three to four cents per kilowatt-hour range, leading the current trend of site development in the Midwest and parts of the Pacific Northwest.

Parties seeking to attract utility-scale and enterprise data center development should be aware that quoting an average industrial customer rate is insufficiently precise for these developments. The facilities, due to their load, will take service at transmission voltage, and due to load factors that approach unity, as well as typically high power factors, the power rates will be exceptionally low. A consultant who helps clients to select potential data center development sites, noted: "Don't just hand me your rate sheet. I can tell you our demand, usage, and profile; you tell me how much it will cost."

7.7.2 Future Rates Are Also a Consideration

Data center developers are aware that utilities are unable to predict future power rates with any specificity or certainty due to the vagaries of the power generation market, fuel prices, and regulatory procedures. However, the general power generation market in a given geographical market can be characterized, as well as regulatory initiatives that are likely to affect future power rates. For example, if a given region has a large proportion of power generation from coal-and natural gas-fired plants, future power prices will be very sensitive to changes in these commodities. If new natural gas transmission pipelines are being installed in the region, improving access and likely leading to higher use by power generators, that is a worthwhile development to share with a prospective data center developer. Similarly, regulatory initiatives to phase out fossil-fueled plants to reduce power generation emissions, or to phase out nuclear facilities, can have broad impacts on future power prices. In essence, while developers do not expect a chart listing power prices for the next decade, they do expect to have an understanding of local market conditions and regulatory environments that give them a sense of where power costs might go in the long term.

7.7.3 Power Capacity Availability and Time to Serve

Developers of relatively small data centers—anywhere from a few hundred kilowatts of load to maybe a megawatt or two—expect to arrange for power service through the regular new service process at utilities. Their site is already chosen, and they expect to pay an engineering charge and new service construction fees, leaving only scheduling as a negotiation point.

In contrast, for developers of large, multi-megawatt facilities, there is recognition that they must seek utility guidance prior to site selection to determine if reasonable power capacity can be extended to a given site. In fact, these developers often seek guidance from utilities in advance to determine where their facilities can be served. For these developers, power service availability is truly a “go/no go” criterion, perhaps at a level that utilities are unfamiliar with considering. Utilities often take the position that they must perform a “regional ability to serve” study to commit to serving such large loads, expecting funding for the work from the developer as well as fairly long lead times to complete the analysis. Developers understandably do not consider paying for a study that might indicate that their load cannot be served within reasonable parameters a worthwhile investment and will seek out utilities that are more accommodating of their requests.

In addition, developers of large, multi-megawatt facilities are seeking this power service within a specific time frame. Ideally, developers want power to be available within six months from the decision to secure a site, though they may have some flexibility in accepting increments of power capacity over time. For example, a utility-scale facility may have a projected load of 40 MW, but the load may ramp up over a three-year period. Therefore, the utility could build the substation yard and add transformer capacity as loads increase. (In practice, this approach is most applicable to colocation data center developers who have less ability to predict load growth. As tenants lease space, the utility can add capacity.) It should be noted that in some instances customers seek power service on an even shorter schedule. For example, Microsoft has installed modular data centers with loads of about 1 MW on greenfield sites in three months.

7.7.4 Utility Site Selection Support: Best Practices

Several utilities, including Dominion Power (Virginia), the Tennessee Valley Authority, and Silicon Valley Power (Santa Clara, CA) have developed business groups that are charged with making site selection for large load facilities more accommodating for developers.

Dominion Power has formed a cross-functional, matrixed organization that seeks to provide superior response times to large-load development requests. The group includes economic development representatives, account service representatives, electric planning engineers, and construction managers, offering a one-stop shop to respond to development requests. Dominion has also pre-identified regions and sites where large loads can be serviced.

Tennessee Valley Authority, a wholesale utility, has undertaken an effort to identify 50 or so specific sites where large-load customers can be served. Detailed information about each site is available to economic development groups and directly to developers.

Silicon Valley Power (SVP) is a relatively small municipal utility in the heart of Silicon Valley, with data centers constituting as much as half of their customer base. Prospective large-load facility developers are able to meet with SVP's planning, engineering and construction groups, as well as the city's planning department responsible for granting development permits, at one time. SVP prides itself on superior coordination between the various work groups, power prices somewhat lower than the surrounding investor-owned utility, and short project lead and construction times.

An independent developer of wholesale colocation centers in the San Francisco Bay Area notes: "The most maddening thing is to get a wishy-washy answer from the utility like 'well we could serve you this much around here but we'd have to do a study first and we don't know anything about timing.'"

7.7.5 Trending: Expansion of Existing Facilities Rather Than Greenfield Development

High profile utility-scale data center operators like Google, Apple, and Microsoft are increasingly turning to expansion of existing facilities in their data center portfolio rather than seeking new sites. From a management perspective, limiting the number of data center sites makes sense, and diversification of sites from a reliability and redundancy standpoint reaches diminishing returns at some point, so these companies appear to be limiting their overall fleet size. Additionally, the companies have bought very large sites (often over a hundred acres) to accommodate growth (and in some cases to accommodate on-site solar electric plants).[151] Accordingly, utilities serving these sites are receiving load capacity increase requests, and these operators are reducing their presence in the site selection market.

A vice president for data center operations for a leading high tech company and cloud service provider notes: "We're about done with new sites in North America if we can keep expanding our existing ones. We're still looking in emerging markets, but figure we're set here."

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151 http://www.wired.com/2014/04/green-apple/

7.7.6 Low Carbon and Renewable Power Gains Favor

As some data operators come under increasing scrutiny for the environmental impacts of their power use, the composition of the generation profiles of utilities has become of interest. That interest takes two forms: (1) the relative cleanliness of the power supplied by a utility can become a criterion in making site selection decisions for new or expanding data centers, and (2) some operators are seeking access to wholesale power markets so that they can manage their own power supply portfolio on the basis of cost and carbon profile. As such, utilities should consider the following:

- Be prepared to respond to data center developers by revealing the carbon impacts of their power generation portfolio, preferably in sufficient detail such that data center operators can accurately report their carbon impacts based on their load pattern.
- Report on initiatives to lower the carbon content of their power generation portfolio based on regulatory or business initiatives, such as renewable energy generation requirements or replacement of existing power generation facilities with lower carbon alternatives.

In addition, regulatory policy related to allowing customers to access wholesale generation markets, with utilities retaining distribution responsibility, will be important to some customers, and may be important criteria in site selection decisions.

7.7.7 Geographical Sensitivity: Climate

There has been speculation in the data center trade press that data center developers will increasingly consider climatic conditions as a criterion for site selection, and though there have been reports of data center developments where climate conditions are ideal for efficient cooling system designs, it is not apparent that this criterion is heavily weighed by leading developers of large-scale facilities, either nationally or globally. Utility-scale data center designs today are wholly dependent on outside air (sometimes supplemented with evaporative cooling) for cooling, so moderate (or cold) climatic conditions are ideal, as is availability of water supply.

However, information technology equipment is increasingly rated for operation in high temperature environments, so climatic conditions are not crucial for site selection. For example, Dell has certified their entire server line for operation at high temperatures, essentially indicating that the equipment can be cooled solely by outside air, anywhere in the United States.[152]

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[152] http://www.dell.com/learn/us/en/555/power-and-cooling-technologies-best-practices

In fact, where climate conditions have remained a concern in site selection is for the prevalence of catastrophic weather events such as hurricanes and flooding, which are evaluated alongside other risks by data center operators and developers. The data center siting consultant noted: “I’ve never had a client choose a site based on climate from an energy efficiency perspective; the concern is about weather and risk.”

7.7.7.1 Geographical Sensitivity: Urban Centers

Data centers are generally built in urban environments rather than rural areas, but that is becoming less true for operators of utility-scale facilities. The conventional thinking is that urban environments simply feature better access to support infrastructure (power, transportation) and proximity to staff, other business functions, and to users of IT services. However, for utility-scale data centers, all of these factors except access to power infrastructure are becoming unimportant, and in fact developers of these facilities are increasingly seeking large sites that are unavailable in urban areas (see Section 7.7.5). Operators of enterprise data centers will continue to seek sites in urban environments as the proximity issues noted above remain important to their operations. Similarly, colocation providers need to have close physical proximity to their clients and therefore build their facilities almost solely in urban areas (discussed as follows). When asked about building in the Midwest, a small colocation developer (two sites on the West Coast) said: “The colocation market, especially the retail side, is still about being geographically close to your customers. You can’t build in the middle of nowhere and expect to attract tenants.”

7.7.8 Key Trend for New York State: Colocation Facilities Are Geographically and Latency Sensitive

Colocation data centers have long been sited “where the customers are”—in urban centers near where their tenants are headquartered. It makes intuitive sense, as the IT assets housed in colocation centers are almost always still maintained by tenant IT staffs, so physical proximity to those employees is essential. Even for start-ups, another key market for colocation companies, the same physical proximity requirement applies. Lastly, a subset of tenants have latency requirements—notably financial firms that operate on public and private exchanges—that again largely determine their choice of a colocation facility.

These three sets of typical colocation tenants drive the site selection of these facilities, leading to a very vibrant market in the New York metro area. A principal at a colocation real estate brokerage and consulting firm opined: "The New York metro region, along with Silicon Valley, will always have a very strong co-lo market. There is simply a built-in market for clients that are stronger than anywhere else in the United States or even globally."

As shown in Figure 31 and Figure 32, survey data on the latency issue revealed that it was more apparent in colocation facilities. For those respondents that did understand the issue, more than two-thirds of industry players and more than a half of data center managers said latency requirements required their colocation facility be located in New York State. For cloud services, for those who did understand the issue, more than a half of industry player and less than half of data center managers have latency requirements that required cloud services to be located in New York State. Many of the respondents indicated they did not know if latency was an issue.

Figure 31. Latency Issues Colocation in New York State

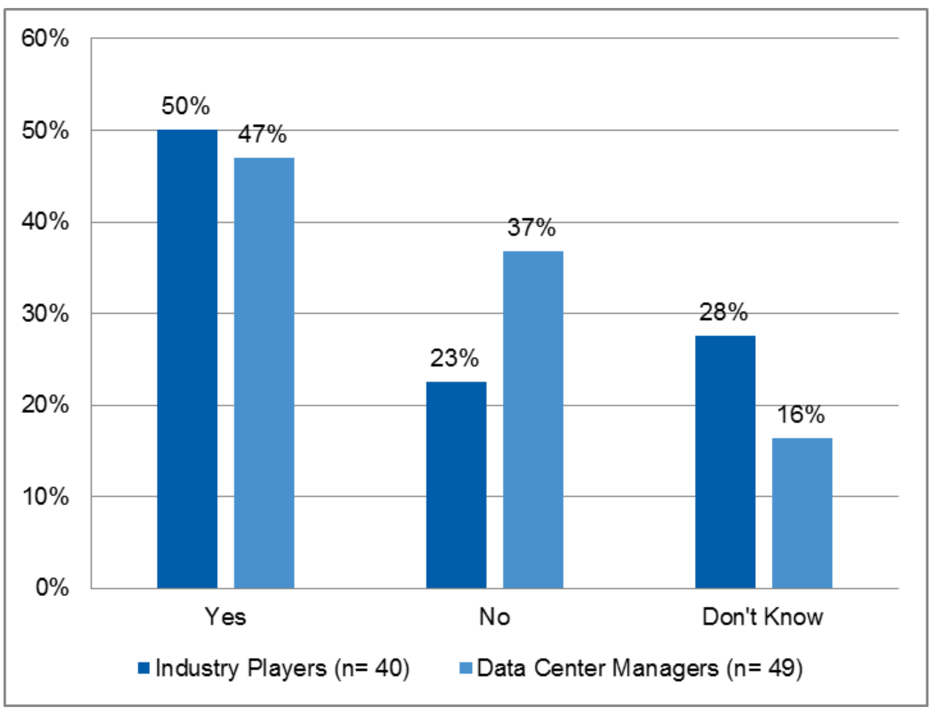
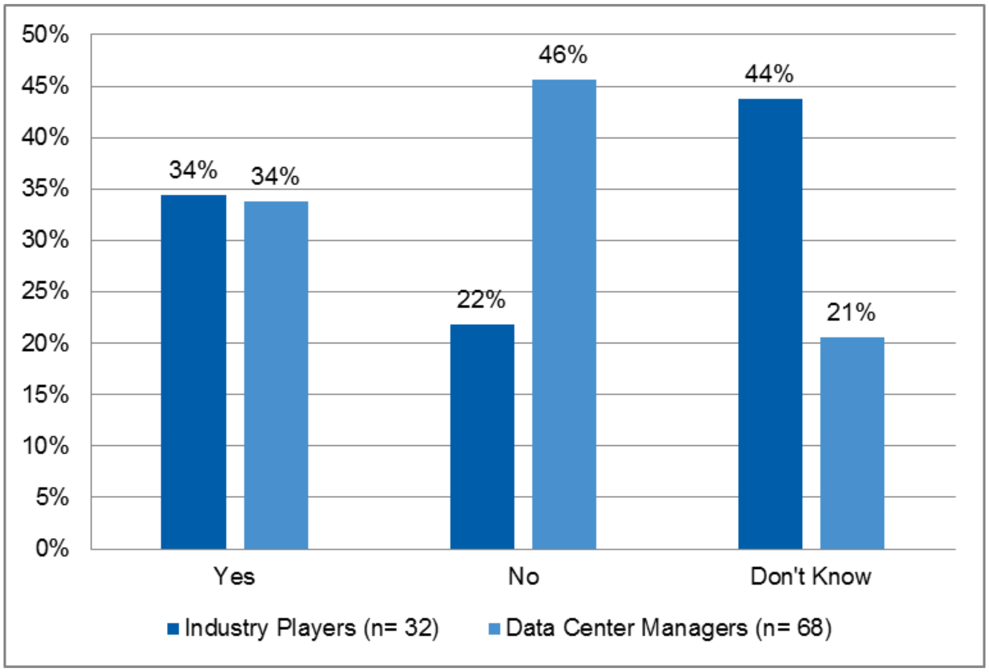


Figure 32. Latency Issues Cloud Services in New York State



7.7.9 Tax Incentives

To foster economic development, many states have enacted legislation to reduce taxation of new data centers. Additionally, some cities and counties have adopted property tax forgiveness. Interestingly, property tax forgiveness or other local incentives are rarely of much import to data center developers given the capital costs of development (which typically range from $7 million to $15 million per megawatt of facility electric load) and other site selection criteria (notably power costs).

However, sales tax forgiveness can be very lucrative to a utility-scale data center operator who plans to deploy tens of thousands of servers and supporting IT equipment, with regular equipment replacement occurring every few years. States have typically enacted legislation that forgives sales taxes on IT equipment for new, large data centers, with requirements for employment levels. These measures have typical durations of 20 years, and a minimum investment level for the new facilities.

Although the Cadmus team knows of no tax forgiveness measure that links energy efficiency requirements to the tax incentives, that may be an option to explore. In other words, a new data center development would receive tax incentives if a minimum energy efficiency performance level was maintained.

7.8 Trend 6. Emerging Energy Efficiency Measures and Technologies

A number of emerging technologies will provide new opportunities for lowering data center energy use and costs. The majority of market attention in the industry has been on facility efficiency: addressing opportunities in power conditioning and delivery and in cooling systems. Future opportunities continue to address those areas of power consumption, but also focus on the information technology equipment itself, as well as overall, holistic management of the data center.

Emerging technologies and measures include:

- Arm-based servers.
- Cold data storage tiering.
- Optical data storage.
- Immersion cooling.
- Internally modular UPS.

These measures may be suitable for inclusion in energy efficiency incentive programs, or may first require evaluation and demonstration as emerging technologies through programs such as NYSERDA's Emerging Technologies and Accelerated Commercialization (ETAC) program. The following sections describe a set of emerging energy efficiency technologies and measures for data centers. After each description, an indication of market applicability is included, and an indication of whether the measure is suitable for retrofits, new construction/installation, or both. New construction refers either to new facility construction or new equipment purchases, including replacement of existing equipment at end of life.

7.8.1 ARM-Based Servers

There is increasing interest in developing servers that use processors with ARM architectures (a family of instruction set designs for computer processors developed by ARM Holdings) to deliver computing power at higher energy efficiencies than traditional equipment using x86 chips. ARM architecture processors that have almost all of the market share in mobile electronic devices such as cell phones and tablets, where energy efficiency is a paramount design criterion to extend operating time between battery charging. Despite significant improvements in energy efficiency for x86 processors, along with other efficiency features, ARM-based servers could represent a significant technology shift. These types of servers would be best suited for hyperscale workloads—lightweight tasks carried on a very large scale—such as serving content for widely-used Web sites and apps. Web giants like Facebook and Google have the largest demands for hyperscale workloads.[153] HP recently became the first major vendor to offer 64-bit ARM architecture on its Moonshot server. [154]

Applicability: all markets.

7.8.2 Cold Data Storage Tiering

Demonstrated by Facebook and shared through the Open Compute Project, cold storage tiering essentially extends the MAID storage scheme on a data-center scale.[155] Cold storage is used for data that is accessed infrequently, but cannot be relegated to the traditional third tier of data storage (archived tape). Facebook saves data of this type on traditional disc storage arrays, which are then turned off. If data is needed from these archives, the appropriate disk is simply powered up (access time is obviously compromised). Data stored in this tier requires almost no energy other than modest climate control and power used for initial disk writing and occasional data retrieval. Facebook has built separate facilities for the cold storage equipment because climate conditions are acceptable over a much broader range than for primary data center equipment.

Applicability: Enterprise and utility-scale; new construction.

7.8.3 Optical Data Storage

Optical data storage systems are beginning to lose market share in personal computers and laptops as new systems rely on Web-based and solid state storage, but they may take hold in data center operations as another avenue for high efficiency cold storage of data. Again, Facebook has demonstrated this technology and shared it through the Open Compute Project.[156] The storage system uses writable DVDs to store rarely accessed data, using a mechanical magazine to house hundreds of DVDs (similar in

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153 http://www.zdnet.com/moonshot-can-hps-shot-at-microserver-domination-succeed-7000013749/

154 http://www.pcworld.com/article/2688912/hps-moonshot-server-now-packs-64bit-arm-chips.html

155 http://www.opencompute.org/projects/storage/

156 http://www.pcworld.com/article/2092420/facebook-puts-10000-bluray-discs-in-lowpower-storage-system.html

concept to magnetic tape library machines). The advantage of using optical storage over magnetic disks is cost, physical density (more data storage in less space). Although an energy use comparison of optical and magnetic disk systems has not been offered, it is expected that the systems are nominally comparable in terms of efficiency.

Applicability: Enterprise and utility-scale; new construction.

7.8.4 Immersion Cooling

As high performance computing systems reach energy densities exceeding 10 and even 20 kW per rack of equipment, a variety of liquid cooling strategies are increasingly being considered, including systems that fully immerse servers in a liquid bath.[157] Several companies are refining these systems, and there are installations where test results are being collected (Intel recently performed a demonstration program). In simple terms, servers are modified (fans are removed and disk drives sealed), and then placed in a bath of nonconducting cooling solution (mineral oil or proprietary material). The cooling bath can be cooled in a variety of ways, most often with an air-cooled coil. The energy savings from the systems result from completely obviating the fan energy required in typical data center designs, as well as the fan energy of the servers themselves.

Applicability: High performance computing; new construction.

7.8.5 Internally Modular UPS

A recommended practice to improve the energy efficiency of UPS is to match the capacity of the equipment as closely as possible with the load. UPS equipment can reach efficiency levels of 95% and higher when loaded; efficiency can drop dramatically under light loading. Data center managers have rarely been able to boost loading for central, large-scale UPS systems, as they are often sized for projected load when the data center is fully utilized. Further, when operated in 2N configuration (fully redundant), loading can only reach 50%, where high operating efficiency is rarely achieved. Another option for data center managers has been to use rack-mounted UPS systems that can be matched closely to the load in the rack. This scheme is best applied to server rooms and localized data centers, but is not often utilized in enterprise or utility-scale facilities.

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157 http://www.datacenterknowledge.com/archives/2013/07/01/the-immersion-data-center/

New UPS systems are now being offered that are "internally modular," with power management capabilities that load modules within the UPS at differing levels. [158] In effect, the central, large-scale system looks like a series of smaller modules. In operation, one or a set of the internal modules can be run at high loading and high efficiency, with remaining modules available on standby with very low energy use.

Applicability: Enterprise and utility-scale data centers; retrofit and new construction.

7.9 Trend 7: Self-Generation and Wholesale Market Access

Particularly for utility-scale data center operators, options for generating power onsite or having access to the wholesale power market are becoming very important. Several leading utility-scale data center operators are pursuing self-generation programs (solar electric and fuel cells), although most colocation and enterprise centers are not pursuing self-generation options. A few operators (notably Google) seek access to the wholesale power market so that they can purchase renewable or low carbon energy.

In New York State, it appears that customers with loads of 1 MW or more, served at transmission voltage, are eligible to access the wholesale power market.[159] Given that most utility-scale data centers have loads in the tens of megawatts, which would certainly be served at transmission voltage, this potential barrier to customer attraction is obviated.

7.9.1 Data Center Load Profiles Perfect for Self-Generation?

Running 24 hours a day, data centers as a stand-alone commercial end use have very high load factors—approaching 1. This high load factor is attractive for the deployment of self-generation systems, because they can be specified to meet facility loads only, without the complications of selling power back to the utility during times of overproduction. Perhaps more importantly, the capital cost of a generation system can be recouped over a greater number of operating hours per year compared to other commercial end uses, like office buildings. Despite the inherent attractiveness of data center loads, very few operators are pursuing self-generation. Of those that are, fuel cells and solar photovoltaic systems appear most popular, with combined heat and power systems a distant third. With very high load factors,

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158 http://www.datacenterdynamics.com/focus/archive/2013/03/efficiency-versus-resilience-data-center-ups-systems

159 http://www.nyiso.com/public/about_nyiso/understanding_the_markets/wholesale_retail/index.jsp

utility-scale and enterprise facilities with large loads, power cost sensitivity, and an increasing focus on the environmental impacts of power use—why are self-generation technologies not gaining more traction in this market? A number of reasons are described in this section.

7.9.1.1 Power Cost Not Compelling for Large Loads

One notable factor that yields limited interest in all self-generation technologies for large-scale data centers is that power rates for these facilities are generally the lowest that utilities charge. Because of their large size, utilities charge data centers in this class industrial rates, which have the lowest charges of any customer class. These rates often feature demand and energy charges on a time-of-use or even real-time basis, but because data centers have such high load factors, the average rate remains very low. These facilities are often served at a transmission voltage level, with the customer owning and maintaining switching and substation facilities, resulting in still lower energy rates.

For example, in Pacific Gas and Electric service territory in Northern California (including most of Silicon Valley), commercial rates average 16 cents/kWh, depending on load profile (real-time rates are mandatory for almost all commercial customers). Large data centers, however, are served under industrial rates when peak loads exceed 500 kW. With high load factors, data centers are charged power rates that average just below 9 cents/kWh. Self-generation technologies can be difficult to justify when power rates are at this level—there may indeed be projected cost savings, but with other concerns (outlined as follows) operators may not find the financial benefits compelling. Remember too that in many areas of the country rates are much lower than in California (and New York State), making the financial picture more daunting for self-generation. In some areas of the country, new utility-scale data centers are buying retail utility power below 4 cents/kWh, making it very difficult to justify self-generation solely on financial terms.

Of the three self-generation technologies, solar electric systems may be the most financially viable. Depending on how a power purchase agreement (PPA) is structured, solar electric systems can be competitive with utility power, especially if only supplanting power at peak-period rates. Because solar electric system prices have dropped dramatically in recent years, solar power can be secured for about 4 cents/kWh. CHP, also referred to as cogeneration, is highly dependent on natural gas prices to determine competitiveness with utility-provided power, and has other disadvantages (described as follows). However, CHP systems can be structured with a PPA, yielding power costs in the 6 cents/kWh range. Natural gas fuel cells have gained some traction in the data center market, in part because they may yield capital cost saving in the development of new facilities. Again, the technology is of course dependent on natural gas, and though prices for natural gas are very low, fuel cells generate power in the nine cents per kilowatt-hour range.

7.9.2 CHP Considerations

Cogeneration technology is often discounted for application in data centers for two reasons other than financial viability: use of the waste heat and reliability. Regulatory rules often prescribe that CHP plants receive natural gas at generation rates only when they match or exceed the heat rate of thermal power plants in the region. In essence, this means that the plants truly have to operate as cogenerators, using all or most of the waste heat from the plant for beneficial purposes. CHP projects can meet this requirement by feeding waste heat into a campus heating loop system, or heating water for other useful purposes. The waste heat can also be used to feed absorption chillers to produce chilled water.

For data centers, where there is no use for heat in any direct fashion, absorption chilling becomes the sole option. Although absorption chilling is a long-standing proven technology, it has lost favor due to technical complexity. The difficulty of integrating a CHP plant with absorption chilling into a data center power configuration that is focused primarily on reliability is perhaps the fatal flaw. It could be said that data center operators are not wholly confident in their power conditioning and supply systems as they are without adding the complexity of integrating a CHP plant into the mix.

In summary, while CHP systems could be cost competitive with utility-provided power, they have not seen broad adoption in data centers due to technical complexity related both to the use of waste heat and integration into an electric distribution system focused on high reliability. Utility and/or public sector incentives for CHP systems in data centers are unlikely to significantly improve the prospects for cogeneration system development in the data center market.

7.9.3 Solar Electric Considerations

Of the three self-generation technologies, solar electric (photovoltaic, or PV) has the best financial returns, particularly if it is only used to meet peak- and partial-peak power use. (Systems that attempt to reach a net-zero energy use profile will have much poorer financial returns given the very low off-peak rates that large data centers are charged.) Technically, solar electric power is fairly easy to integrate into a data center; the direct current generation of the system could even be introduced directly into the power delivery and conditioning systems without rectification, though it is not known if that has ever been accomplished. Some utility-scale data center operators, notably Apple, have secured very large sites for their facilities such that they can develop multi-megawatt solar electric plants. [160]

The main disadvantage of solar electric for data centers is energy generation density – to serve the energy-dense loads of a data center, solar electric requires orders of magnitude more space than the data center rooftop to have a meaningful impact. Nevertheless, some data center operators, including colocation operators, have installed rooftop systems with the acknowledgement that they serve only a very small portion of the total load of the facility.

7.9.4 Natural Gas Fuel Cell Considerations

Fuel cells have gained attention in the data center market as technology has improved. (Although the underlying technology is old, new catalysts and system designs have reintroduced the technology to the marketplace). Fuel cells have the advantage of essentially zero emissions, relatively high energy density, and no need to reclaim and reuse waste heat. Coupled with very low natural gas prices and high claimed reliability, they would appear ideal for the high load factor regime of data centers. In fact, the leading fuel cell company in this market, Bloom Energy, is positioning fuel cells as having a fundamental advantage over traditional data center power delivery and conditioning designs. With duplicate fuel cells (in a “2n” configuration) the need for backup generators and UPS systems would be unnecessary, dramatically reducing the capital cost of a data center.

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160 http://www.wired.com/2014/04/green-apple/

Unfortunately, despite these advantages and potential advantages, fuel cells suffer from a very high capital cost and subsequent generation costs. Though closely guarded, one utility-scale data center operator noted that generation costs were on the order of 9 cents/kWh, even with natural gas secured directly from a transmission line at very low prices.

Fuel cells may prove to be applicable for meeting loads at data centers that exceed existing utility service capability—it may be cheaper to install fuel cells than to upgrade utility supply, particularly if backup generation capacity is also removed.

7.9.5 Incentives for Self-Generation

Historically, NYSERDA's Customer-Sited Tier (CST) program,[161] which provides financial incentives for qualifying self-generation projects, can certainly support adoption of solar electric and fuel cell projects for data centers, though it should be noted that the project size limitations are quite low compared to the energy loads of enterprise and certainly utility-scale data centers. The CST program will likely become part of the Clean Energy Fund. A pilot program to extend incentives for larger load projects might be warranted. Further, a program to encourage rooftop solar voltaic systems on data centers, acknowledging that the projects will likely address only a small portion of the facility load, might nevertheless attract attention from the industry.

7.9.6 Wholesale Market Access

In many states some utility customers are allowed access to wholesale energy markets, buying power or natural gas directly from generators or suppliers and paying the utility solely for distribution services. For operators of utility-scale data centers, the ability to access wholesale markets is almost a prerequisite for site selection decisions, as a means of allowing these companies to make short and long term purchase contracts to minimize costs and arbitrage against potential rising prices.

161 https://www.nyserda.ny.gov/About/Renewable-Portfolio-Standard/Customer-Sited-Tier

The utility-scale data center operators who have multiple sites (or a fleet of facilities) generally have a utility management group in their organization charged with arranging with utilities for power capacity at new and existing sites, analyzing rates, engaging with utility energy efficiency programs, and purchasing power on the wholesale market. These operators may choose power supply options solely on the basis of costs and cost escalation provisions, but at least one operator, Google, demands access to wholesale markets so that they can purchase wind generation. Google entered into a power purchase agreement with a local utility in Oklahoma to procure wind energy, a first for the utility.[162]

Regulatory policies regarding customer access to wholesale power supply markets are becoming increasingly important to utility-scale data center operators. These policies will be an important component of a data center development attraction program. New York State is well-positioned in this regard, given the current wholesale market access rules of the New York Independent System Operator.

7.10 Trend 8: NGO, Media, and Regulatory Attention

Two leading nongovernmental environmental organizations, national media outlets, and trade publications, along with federal and state regulatory agencies are scrutinizing the environmental impacts of the data center industry, which has led to changes in site selection considerations and other market responses. Some of the activities performed by these organizations are:

- The Natural Resources Defense Council and Greenpeace have engaged the data center industry, criticizing leading companies for poor environmental stewardship, and promoting energy efficiency, transparency, and procurement of clean power.
- National media outlets including *The New York Times* have described the emergence of utility-scale data centers and the environmental impacts that accrue to the industry through growing power use.
- Data center trade publications, industry analyst groups, conferences, and trade organizations have devoted significant coverage to energy-related issues, including energy efficiency and power procurement, but remain largely ignorant of energy utility policies in general.
- The U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) have developed energy efficiency benchmarking tools for data centers and efficiency standards for some types of IT equipment, but have not established significant regulations regarding the design and operation of data centers.
- ASHRAE amended standards for data center environments, largely in an effort to promote more efficient operation.

162 http://www.grda.com/google-and-grda-announce-renewable-energy-agreement-in-oklahoma/

7.10.1 Environmental Groups Focus on Industry

Two leading environmental organizations, Greenpeace and the Natural Resources Defense Council, have assigned analysts to cover the data center industry. Although both organizations have focused on the environmental impacts of data center energy use and have targeted a similar set of market players, their approaches are quite different.

7.10.1.1 Greenpeace

Greenpeace has been critical of the data center industry, producing an annual report that evaluates major operators against a set of criteria, and advocating for industry improvements. [163] Those criteria include: deployment of energy efficient technologies, designs, and operating practices; infrastructure siting decisions; the use and advocacy for renewable power generation sources; and transparency with regard to reporting. Greenpeace's reports stirred strong opposition within the industry, with extensive discussions held at industry conferences and online discussion groups. Nevertheless, several companies that have been rated in the succession of reports have pointed to improvements in their rankings against the criteria.

7.10.1.2 Natural Resources Defense Council

The NRDC has taken a somewhat more conciliatory approach to the data center industry, focusing on preparing reports and white papers that advocate improved energy efficiency technology adoption and evaluate the relative merits of the market move to the cloud service model. For example, their report,[164] *Data Center Efficiency Assessment, Scaling Up Energy Efficiency Across the Data Center Industry: Evaluating Key Drivers and Barriers*, recommended addressing common issues with these actions:

- Adopt a simplified CPU utilization metric to address underutilization of IT assets.
- Increase disclosure of data center energy and carbon performance.
- Align incentives between decision makers on data center efficiency.

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163 http://www.greenpeace.org/international/en/press/releases/Google-leads-latest-Greenpeace-climate-ranking-of-IT-industry--/

164 http://www.nrdc.org/energy/files/data-center-efficiency-assessment-IP.pdf

7.10.2 National Media Coverage

National media outlets, including *Newsweek, The Wall Street Journal,* and *The New York Times* have devoted some attention to the energy use impacts of the data center industry, particularly since the advent of utility-scale facilities. For example, a series of articles by James Glanz that appeared in *The New York Times* in 2012 and 2013 precipitated a great deal of industry discussion. [165] The articles highlighted the immense scale of new data center facilities, as well as the impacts of their energy use. One article was headlined: *Power, Pollution and the Internet* where it was stated that data centers "were using only 6%to 12% of the electricity powering their servers to perform computations. The rest was essentially used to keep servers idling and ready in case of a surge in activity that could slow or crash their operations." Another article by Glanz, *Data Barns in a Farm Town, Gobbling Power and Flexing Muscle,* focused on Microsoft's data center in central Washington and their confrontations with citizens groups over backup diesel generator pollution. The data center industry was critical of the coverage because it appeared not to credit the strides the industry had achieved in incorporating energy efficiency into new designs. [166]

7.10.3 Trade Press, Analysts, and Conferences Focus on Energy Efficiency

For about the past six years, the data center industry has had a very vigorous focus on energy efficiency, with the topic dominating trade press reporting, analyst coverage, and industry conference agendas. For example, trade press outlets such as Data Center Dynamics Focus and Data Center Knowledge, devote significant resources and publication space to energy efficiency-related articles. Analyst coverage from companies such as the 401 Group and IDC has regularly surveyed the industry regarding energy issues, and conference agendas often feature energy-related presentations (particularly from the vendor community). The industry-led trade group, The Green Grid, has a utility subcommittee that has produced reports on utility efficiency program development and delivery for several years, and has called for program standardization to promote better industry engagement.

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165 http://www.nytimes.com/2012/09/23/technology/data-centers-waste-vast-amounts-of-energy-belying-industry-image.html?pagewanted=all&module=Search&mabReward=relbias%3Ar%2C%7B%221%22%3A%22RI%3A5%22%7D

166 http://www.datacenterknowledge.com/archives/2012/09/24/roundup-early-reaction-to-the-ny-times/

Despite this focus however, industry participants remain ignorant of the energy utility industry, and in particular, the intricacies of energy efficiency program development and delivery. Similarly, the industry is prone to mischaracterizations of other utility issues such as service reliability, utility transmission and distribution system losses, rate structures, predicted rate increases, and power availability.

7.10.4 Federal Government Activities

Both DOE and EPA have turned their attention to data center energy efficiency. Their efforts have focused on training, education, and outreach, setting efficiency standards for equipment, and recognizing efficient data centers. Some of the actions the DOE has taken include: [167]

- Developed a Data Center Energy Practitioner Program, which trained industry on assessment data center efficiency through their Data Center Pro software tool.
- Drafted numerous technical guidance documents and case studies on data center efficiency.
- Drafted guidance through its Uniform Methods Project on monitoring and verification of data center IT equipment savings.

Some of the actions the EPA has taken through the ENERGY STAR program include: [168]

- Developed an assessment tool for data centers that rewarded efficient facilities with an ENERGY STAR certification. Data centers in the top quartile of efficiency performance earn ENERGY STAR certification. Some data centers earning ENERGY STAR certification have been part of a national public service announcement campaign.
- Provided monthly webinar trainings on the basics of data center efficiency.
- Developed a utility energy efficiency program development and delivery guide for utilities, the first time it has developed a document of this type.
- Certified as energy efficient a series of key data center pieces: servers, data storage, and uninterruptible power supplies. There are also plans in place for certifying networking equipment as well.

The DOE has also sought to develop energy efficiency standards for facilities and equipment, although the data center industry remains wary of the effect that established standards might have on the industry.

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[167] http://energy.gov/eere/femp/resources-data-center-energy-efficiency

[168] www.energystar.gov/lowcarbonit

7.10.5 ASHRAE Begins to Address New Construction Standards

ASHRAE is a building technology society that is very influential in developing codes and standards for new buildings. The organization focuses on building systems, energy efficiency, indoor air quality, and sustainability. Through technical committee (TC) 9.9,[169] ASHRAE has issued thermal guidelines for data centers for many years. Last updated in 2011, the thermal guidelines include a set of allowable environmental conditions as well as the recommended temperature and humidity ranges.

The new allowable ranges were developed with IT and data center industry participant involvement, and to a large degree reflect relaxed environmental condition control by leading data center operators. These relaxed conditions allow operators to use air- and water-side economizers systems for most and sometimes all of the year, dramatically reducing data center energy use. The new provisions of TC 9.9 related to data centers also specifies that new facilities must incorporate economizers in cooling systems, as well as airflow isolation measures. Some states adopt ASHRAE standards as their building energy code.

The changes to the ASHRAE standards offer an opportunity for energy efficiency program managers to update new construction incentive programs and to educate the operators of existing facilities regarding potential energy savings from adopting allowable environmental condition levels rather than adhering to the recommended ranges.

7.10.6 Opportunities to Leverage NGO, Media, and Regulatory Involvement

NYSERDA and New York State utilities have opportunities to leverage NGO, media, and regulatory involvement in the data center industry as follows:

- Environmental organizations, analysts, and trade associations can act as allies in promoting energy efficiency program engagement.
- Active participation in industry conferences is a viable tactic for promoting energy efficiency programs to both customers and potential trade allies. Respondents to the surveys for this report named conferences as one of the two best avenues for customer outreach.
- NYSERDA has an opportunity to take a leading role in interacting with the data center industry on a holistic basis, potentially through participation on the Green Grid's Utility Committee. Alternately, NYSERDA could partner with one or more New York utilities to act as liaisons to the industry, prepared to educate and inform data center operators regarding energy and utility policy issues.

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169 http://ecoinfo.cnrs.fr/IMG/pdf/ashrae_2011_thermal_guidelines_data_center.pdf

- There is an opportunity to coordinate activities with the DOE and EPA to further an energy efficiency focus for the data center industry in New York State.
- NYSERDA could consider evaluating energy efficiency standards for new data centers, determining when to adopt new provisions developed by organizations such as ASHRAE.

7.10.7 Survey Attitudes About Staying in New York State

Figure 33, Figure 34, and Figure 35 explore the attitudes toward keeping a data center in New York State as expressed by data center managers and industry players during the Cadmus team's in-depth survey. The survey results support the following findings:

- Most data center managers believe they will remain in New York. However, industry players were not as sure that their client's operations were staying in New York State.
- Data center managers ranked organizational consideration and approval as the largest barrier to IT operations growth in New York State. Real estate, facility, and energy costs were then ranked as some of the top limitations for industry players and data center managers. More than one response was allowed in response to the barriers question.
- Both participant groups said that the best means to help data center growth would be tax credits for energy efficiency upgrades, utility incentives for energy efficiency upgrades, and energy rate discounts for new data centers.

Figure 33. Are Data Centers Staying in New York State?

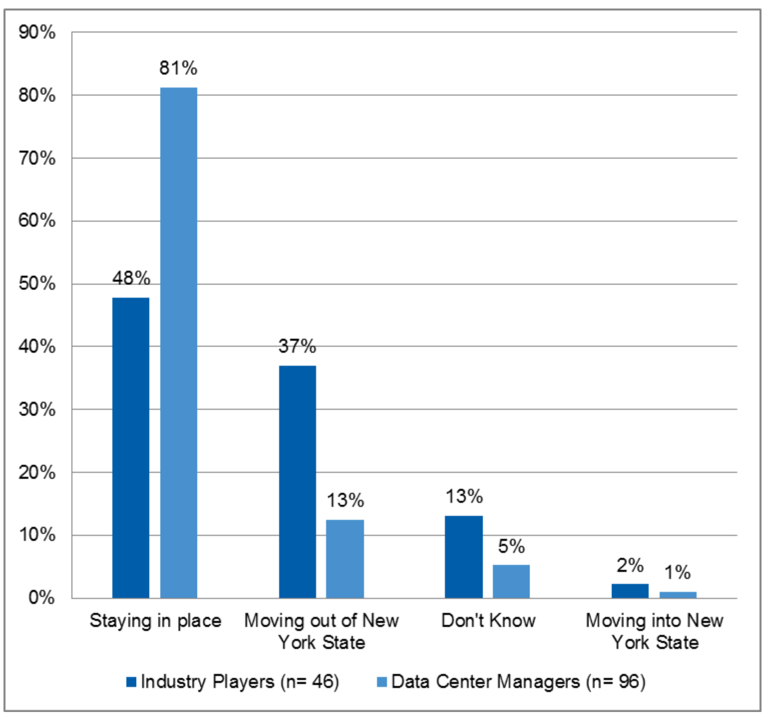


Figure 34. What Limits Data Center Growth in New York State?

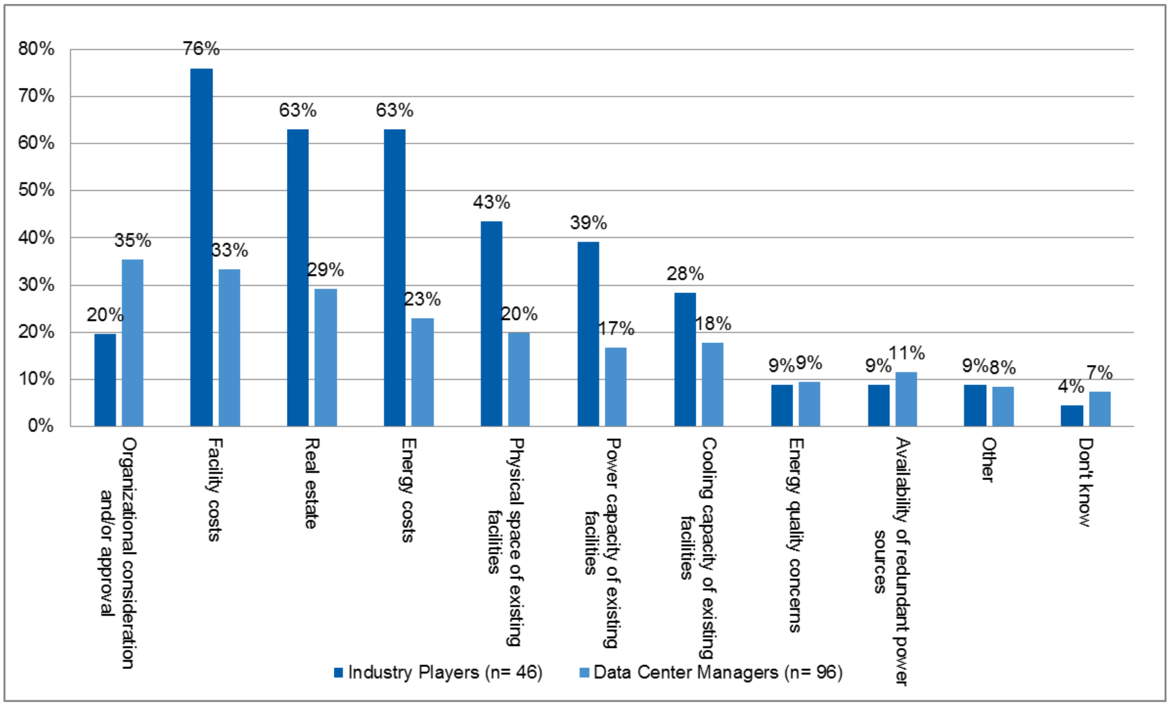
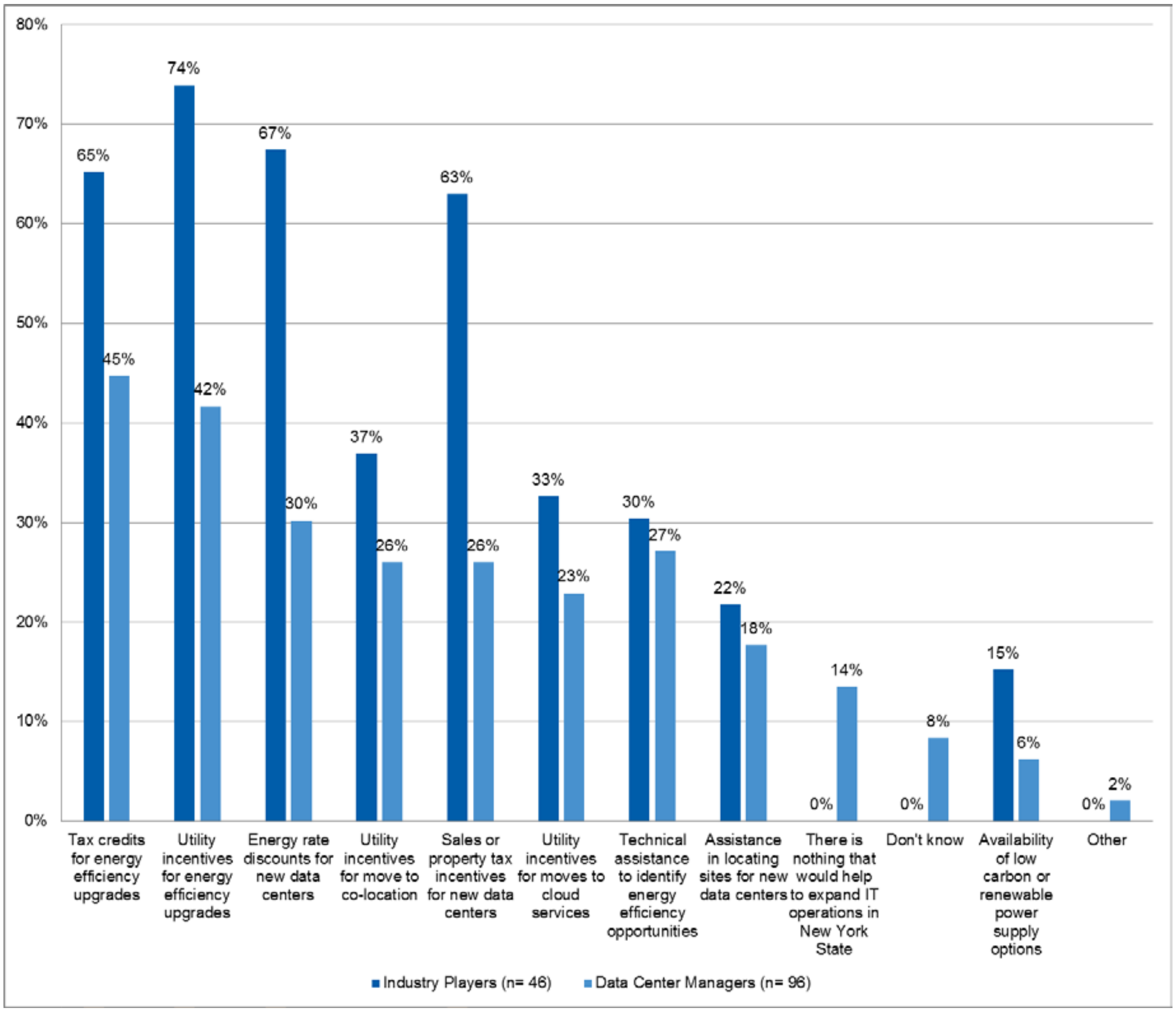


Figure 35. What Would Help Data Center Growth in New York State?



7.11 Future Considerations for Program Development and Delivery in New York State

7.11.1 Overview

The eight market trends discussed in this section have implications for the vitality of the data center sector in New York State. Based on those implications, several areas of regulatory and utility program development and delivery are recommended to support energy efficiency adoption, and retention of data center facilities.

New York State has a robust existing base of data center facilities. These facilities have a high value and are unlikely to be retired at a high rate, and their proximity to the businesses located in the region also supports their continued use. These regional market conditions predicate several potential market interventions that may drive high adoption rates for energy efficiency measures and technologies and a more attractive climate for development of new facilities and retention of existing ones. A number of initiatives implemented in other states, might improve attractiveness, and perhaps more importantly, support sector retention. These initiatives could include:

- Offering a sales tax exemption for purchases of IT equipment.
- Extending access to wholesale electric markets for smaller data center facilities.
- Provide publically-funded energy efficiency programs, that include:
  - Focus on offerings that increase energy savings awareness, which could include education, training, and certification programs, and trade ally partnerships;
  - Focus on programs targeting the smaller data center market (server rooms and closets), new construction incentive and design assistance programs;
- Conduct emerging technology evaluation and demonstration efforts based on market demand.
- Allowing sub-metering and pass-through energy charges for multi-tenant data centers (retail colocation facilities).

These initiatives are more fully described in the following subsections.

7.11.2 Sales Tax Exemption

Developers of utility-scale data centers often seek sites in states that grant tax exemptions for new projects. A host of states, including Washington, Arizona, North Carolina Alabama, Virginia, and Texas offer qualifying data centers exemption from sales taxes for servers, communications equipment, and in some cases power delivery and conditioning equipment, usually for a limited time period. These tax exemptions have been critical to retention and attraction of large-scale data centers and collocation data center operators in these areas. The exemption is usually predicated on a commitment to hire a certain number of workers, and usually has a fixed term (often 20 years). A measure that covers smaller-scale developments might have similar effects.

7.11.3 Wholesale Power Market Access

Some large-scale data center developers are keen to directly access wholesale power markets to secure power that meets their environmental requirements. For example, Google has successfully lobbied states to allow it access to wholesale markets as a precondition of building new data centers. In many states, only large electric use customers (typically with loads exceeding one megawatt) are allowed access to the wholesale power supply markets, allowing them to purchase renewable power, low-carbon power, or to otherwise structure their own power purchases. Allowing smaller loads to participate in wholesale access may be useful in retaining and attracting enterprise data center operators. Certain large industrial customers in New York State, with demands exceeding one MW and served at transmission voltage are eligible to purchase wholesale power. A program extending wholesale market access to customers who meet the load and/or service voltage requirements may make New York State a more attractive location for new data center development.

7.11.4 Energy Efficiency Program Offerings

Through several program mechanisms, New York State offers energy efficiency programs that are both generally and in some cases specifically applicable to the data center market. Though it is probably not advisable or warranted to offer these programs to the sophisticated developers and operators of utility-scale data centers, a comprehensive, coherent portfolio of program offerings throughout the state would support the retention of the existing industry base. Specifically, a program portfolio that addresses small-scale and enterprise data centers, whether for retrofits, expansions, or new development, are recommended. The broad program elements include:

- Customer outreach, education, and training programs.
- Provision of technical support to evaluate efficiency opportunities.
- Incentives for specific types of retrofit projects.
- Incentives for select types of new construction and expansion of existing facilities.
- A channel partner program.

A comprehensive, coherent (the same or as close to it across all utilities and agencies) program portfolio should also enhance the cost-effective delivery of energy savings results for the various entities.

The EPA has published "Understanding and Designing Energy Efficiency Programs for Data Centers"[170], which indicates that program offerings for smaller data centers (server rooms and closets), new construction programs, and technology demonstration programs are often considered "advanced" program elements for utility portfolios. The Cadmus team offers the following future considerations for these markets:

- For the **small-scale data center market**, support for airflow management retro-commissioning that relies on a combination of short-duration on-site pre- and post-project monitoring and calculation methodology to determine energy savings from a variety of low-cost airflow management improvements could be advanced. Careful monitoring of the outcome of a small-scale data center program design assessment effort currently underway on the west coast (a partnership between the Northwest Energy Efficiency Alliance and California utilities) will likely inform any program approach that would be valuable in New York. This effort seeks to understand the market and devise suitable market interventions which could drive energy efficiency adoption in this hard-to-reach segment. Lastly, at least one utility, Commonwealth Edison, is offering incentives to customers who migrate IT equipment from server closets to colocation facilities.[171] Although a program of this nature has both technical and regulatory challenges, it is worthy of consideration given New York's preponderance of office facilities.
- **New Construction/Expansion Program** could be designed to support the design and build of new facilities or expand existing facilities with superior energy efficiency features may not only generate cost-effective energy savings but serve as a customer attraction and retention tool. A program might include design assistance and/or project incentives for the specification and deployment of measures and technologies such as high-efficiency UPS and power delivery equipment, air- and/or water-side economizers, airflow isolation, and other premium-efficiency cooling measures. It should be noted that there are challenges in designing and delivering new construction programs for this market due to a lack of codes and standards that can be referenced as baselines. Although PG&E's new construction program established an energy efficiency baseline for data centers.[172] Further, providing incentives for utility-scale projects presents risks to the utility because incentive payments may be exceedingly large and because these customers are generally following best design practices without utility program encouragement (and so could be considered free riders).

Other recommendations for new and expanded program offerings include:

- Expanding training and education programs offered to vendors, design professionals, facility managers, and IT professionals. Many utilities, including Seattle City Light, Sacramento Utility District, and Duke Energy, report that such programs drive rebate program participation.

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170 http://www.energystar.gov/index.cfm?c=power_mgt.datacenter_utility_guide

171 https://www.comed.com/Documents/business-savings/DataColocation_flyer.pdf

172 http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/hightech/data_center_baseline.pdf

- Supporting data center energy efficiency professional certification programs, such as support for existing certification programs such as the Department of Energy's Data Center Engineering Professional program for New York applicants.
- Developing a channel partner or trade ally program, working with system integrators and other IT service firms to promote efficient technology adoption and participation in incentive and other programs.

7.11.5 Emerging Technology Evaluation and Demonstration

NYSERDA and utility efforts to evaluate and demonstrate emerging technologies for data center efficiency are valuable in providing the basis for new program offerings and a continued focus on these efforts might enhance the general climate for the data center industry in New York State. Alongside a few other areas (e.g., California investor-owned utilities, Duke Energy, and the Energy Trust of Oregon.), New York State technology programs, such as NYSERDA's ETAC program have significant cachet within the industry, which and that esteem could be leveraged to support the vitality of the data center industry in the State.

7.11.6 Power Sub-metering

Allowance for sub-metering and pass-through cost collection could be a key to unlocking energy efficiency potential in both the commercial multi-tenant market and the retail colocation data center market. Both of these markets suffer from an even more acute split incentive barrier than the facility manager/IT manager divide that exists throughout the data center market as a whole. Further investigation to determine if removing this barrier by allowing sub-metering and direct charge pass-through is warranted for this market segment. California utilities allow sub-metering for a very limited class of customers, and may extend the tariff to data center operators, allowing tenants of collocation centers to directly benefit from energy efficiency upgrades.

8 Finance, Higher Education, and Healthcare Sectors

8.1 Introduction

The Cadmus team provided additional in-depth survey results analysis for three particular commercial sectors:

- Financial Services.
- Higher Education.
- Hospitals.

This section describes these three particular commercial sectors' understanding of the NYSERDA program, implementation and interest in EETBPs, decision making factors and barriers, and attitudes toward market trends (e.g., cloud, colocation, and plans for staying in New York State). The information is based on the in-depth survey results of data center managers at 24 financial services firms, 20 colleges and universities, and 10 hospitals. Table 58 shows the breakdown by data center types. Financial services respondents managed larger data centers—a high percentage of which were enterprise price data centers. None of the 10 hospital respondents managed an enterprise data center. Only one familiar data center was a server closet in the financial services sector.

Table 58. Breakdown of Financial, Higher Education, and Healthcare Sectors

Data Center Type	Financial Services	Colleges/ Universities	Hospitals
Enterprise (white space greater than 20,000 sq. ft.; at least 500 servers)	9	5	0
Mid-Tier (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5	3	4
Localized (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	6	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1	5	3
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	0	0
Total	24	20	10

8.2 Current NYSERDA Program

For the three commercial sectors, this section examines the level of understanding of the existing NYSERDA Industrial and Process Efficiency (IPE) Program, how they heard about the IPE Program, and their recommendations for the best way to promote the IPE Program.

As shown in Figure 36, many more data center managers of colleges/universities were aware of the NYSERDA incentives than those of financial services and hospitals.

Figure 36. Specific Commercial Sector's Familiarity with NYSERDA Data Center Program

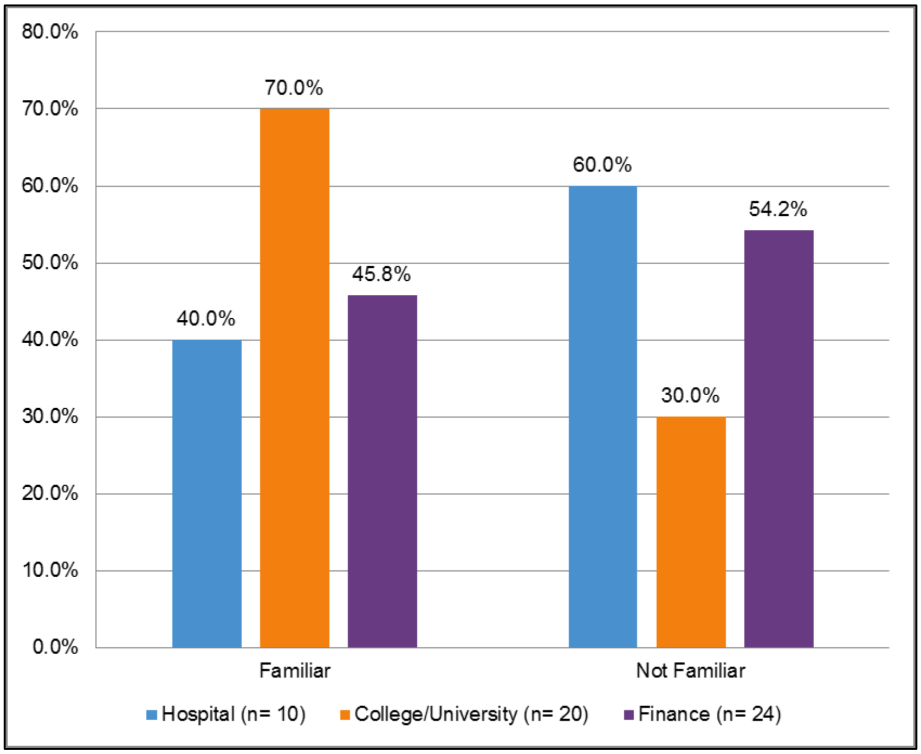


Figure 37 shows how data center managers from different commercial sectors learned about NYSERDA's IPE Program (more than one response was allowed). The most frequently selected option was through in-person meetings, webinars, and presentations. In addition, respondents listed: website, through their contractors, and word of mouth as a popular means of hearing about the program.

Figure 37. Specific Commercial Sector's Means of Hearing about NYSERDA Data Center Program

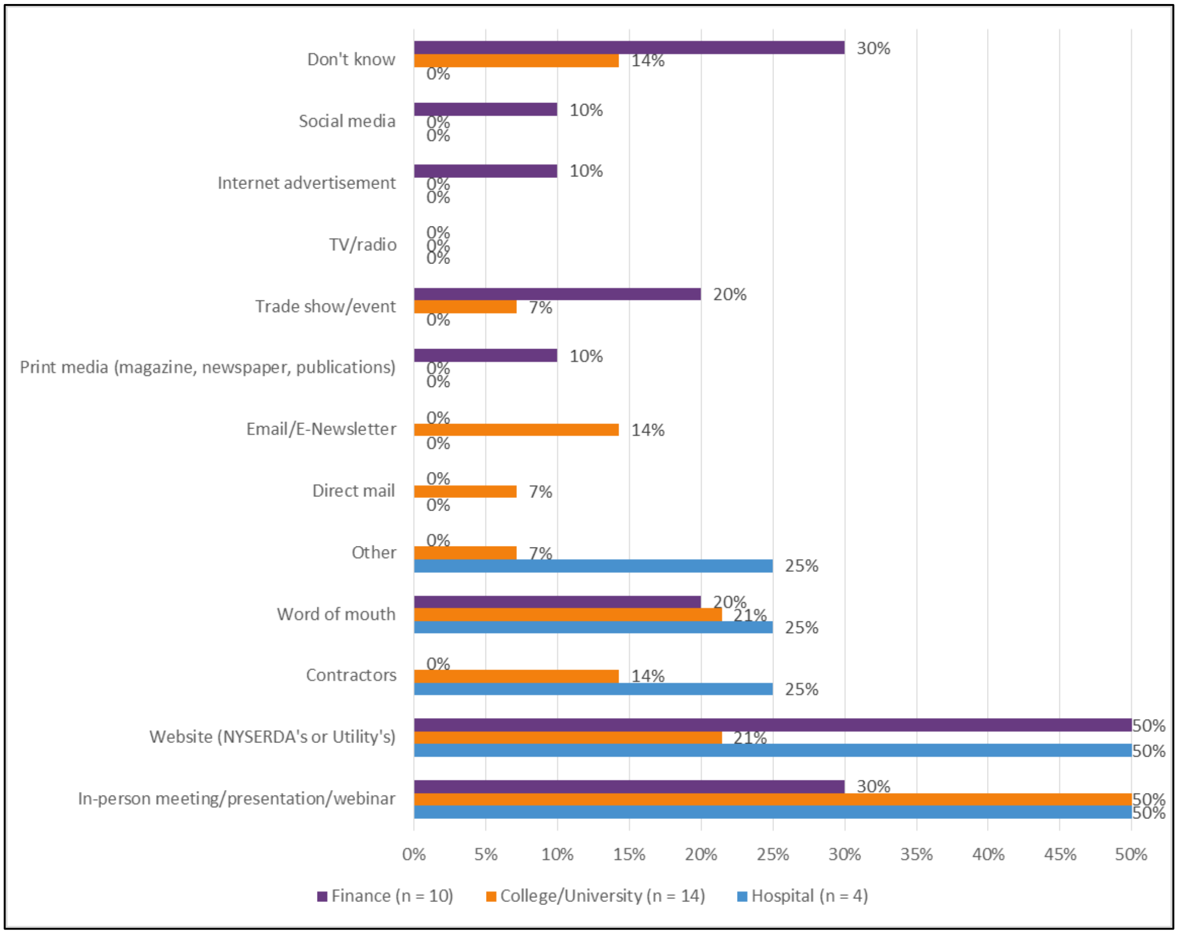
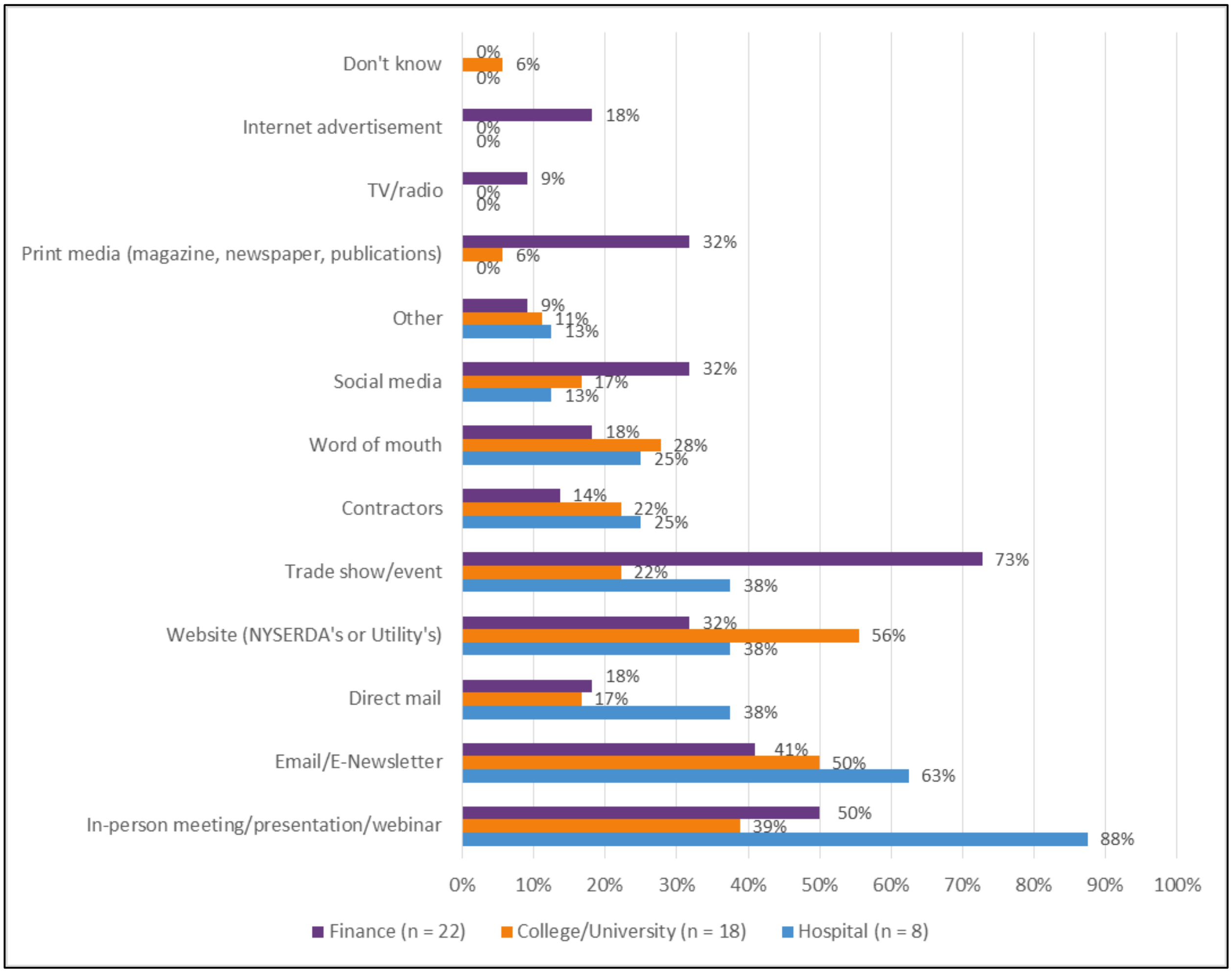


Figure 38 shows that in-person meetings, webinars, and presentations were the most highly recommended means to promote the NYSERDA IPE Program.

Figure 38. Specific Commercial Sector's Recommended Means to Promote NYSERDA Data Center Program



8.3 Energy Efficient Technologies and Best Practices

This section examines how implementation and interest levels vary across 32 different EETBPs by the three commercial sectors (See Section 5 for a full description of EETBPs). As detailed in Section 5, affirmative implementation and interest results of each EETBP were broken out by commercial sector type for each of the five EETBP categories (IT, power infrastructure, air flow management, HVAC, and humidification). The tables in this section display the percentage of the data center managers from each commercial sector that have:

1. Implemented the EETBP.
2. Not implemented, but are interested in the EETBP.
3. Planned to implement and are interested in the EETBP.

8.3.1 EETBP Implementation

The following tables examine the percentage within the three commercials sectors that have implemented five different classes of EETBPs. As shown in Table 59 through Table 63, IT EETBPs were, by far, the most frequently implemented type of EETBP. Table shading indicates the percentage of implementation by participants in the following manner:

- White = 0.
- Light purple = >0 to 33%.
- Medium purple = >33% to 66%.
- Dark purple = >66% to <100%.
- Very dark purple = 100%.

As shown in Table 60, server virtualization/consolidation and decommissioning of unused servers were the most frequently implemented, followed by energy-efficient servers and data storage management. Hospitals and colleges/universities, in general, had higher implementation rates of IT EETBP than financial services.

Table 59. Specific Commercial Sectors' Implemented IT EETBPs

EETBPs	Hospital	College/Univ.	Finance
	n = 10	n = 20	n = 24
Decommissioning of unused servers	80%	70%	46%
Direct liquid cooling of chips	0%	5%	0%
Energy efficient data storage management	50%	45%	13%
Energy-efficient servers	60%	40%	25%
Massive array of idle disks (MAID)	0%	5%	8%
Passive optical network	20%	10%	8%
Server power management	50%	25%	25%
Server virtualization/consolidation	80%	75%	75%
Solid state storage	30%	10%	29%

As shown in Table 60, energy-efficient UPSs were the most frequently implemented (with especially high implementation levels in hospitals).[173] Alternative power sources were discovered—one fuel cell was in place at a financial services data center and renewable power sources (i.e., wind and solar) were used at a few data centers. Combined heat and power had been adopted at a few data centers. This adoption is in line with national estimates of 12%.[174]

Table 60. Specific Commercial Sector's Implemented Power Infrastructure EETBPs

EETBP	Hospital	College/Univ.	Finance
	n = 10	n = 20	n = 24
Combined heat and power (absorption chiller)	10%	15%	8%
Direct Current	20%	15%	8%
Energy efficient power supplies (UPS)	80%	30%	42%
Polymer electrolyte membrane fuel cells	0%	0%	4%
Solar power	0%	10%	8%
Solid oxide fuel cells	0%	0%	0%
Wind power	10%	0%	4%

As shown in Table 61, air flow management practices were deployed some of the time in these three sectors. The most common practices—blanking panels, grommets, structured cabling, and hot/cold aisle containment—were being used in all three sectors. Computational fluid dynamics was being used at four college/university data centers. Surprisingly, containment was not being adopted along with the hot/aisle cold aisle configuration. College/university data centers appear to be adopting more air flow management EETBPs than financial services or hospitals.

Table 61. Specific Commercial Sector's Implemented Air Flow Management EETBPs

EETBP	Hospital	College/Univ.	Finance
	n = 10	n = 20	n = 24
Blanking panels, grommets, or structured cabling	40%	40%	13%
Computational fluid dynamics optimization	0%	20%	0%
Hot or cold aisle configuration	20%	65%	38%
Hot or cold aisle configuration plus containment	0%	15%	8%

173 The high implementation rate of direct current, compared to what is expected, may have been due to a typo discovered in the survey question. Instead of being asked about implementation of and interest in "direct current (as opposed to AC) to the racks", respondents were asked about "data center current (as opposed to AC) to the racks."

174 More information is available at http://www.epa.gov/chp/documents/faq.pdf

As shown in Table 62, the most implemented HVAC EETBPs were variable speed drives, DCIM, and in-row cooling. Containerized data centers appear to be more prevalent in financial services data centers. Economizers and waste heat recovery were found at a few data centers.

Table 62. Specific Commercial Sector's Implemented HVAC EETBPs

EETBP	Hospital	College/Univ.	Finance
	n = 10	n = 20	n = 24
Air-side economizer	10%	10%	8%
ASHRAE Recommended Temperature	10%	10%	13%
Containerized data center	0%	10%	21%
DCIM	20%	30%	42%
In-row cooling	20%	35%	25%
Premium efficiency motors	20%	25%	4%
Variable speed drives on pumps/fans	40%	50%	25%
Waste heat recovery	10%	10%	4%
Water-side economizer	10%	15%	8%

As shown in Table 63, a small portion of data center managers have addressed humidity with the exception of the finance sector data center managers that are turning off humidification units.

Table 63. Specific Commercial Sector's Implemented Humidification EETBPs

EETBP	Hospital	College/Univ.	Finance
	n = 10	n = 20	n = 24
Broaden humidity range	20%	25%	17%
Install misters, foggers, or ultrasonic humidifiers	0%	5%	17%
Turn off humidifiers	10%	20%	38%

8.3.2 EETBP Interest

Table 64 through Table 68 provides an examination of the percentage of commercial sector data centers that expressed interest in the five different classes of EETBPs. Table shading indicates the percentage of participants expressing interest in the following manner:

- White = 0.
- Light blue = >0 to 33%.
- Medium blue = >33% to 66%.
- Dark blue = >66% to <100%.
- Very dark blue = 100%.

The *n* columns indicate how many respondents answered the question. These numbers are provided because when respondents indicated that they had implemented or planned to implement an EETBP, they were not asked an interest question for that EETBP. As a result, sample sizes, indicated for each table cell, can be quite small for EETBPs where respondents frequently indicated they had implemented or planned to implement certain EETBPs.

In general, similar to the implementation findings, IT EETBPs received the highest interest from data center managers in the three commercial sectors. As shown in Table 64, many data center managers expressed high interest (as indicated by the dark blue shading) in server virtualization, decommissioning of servers, energy-efficient servers, data storage management, and server power management. Both college/university and financial services data center managers expressed high interest in four out of nine IT EETBPs.

Table 64. Specific Commercial Sector's Interest in IT EETBPs

EETBP	Hospital	*n*	College/Univ.	*n*	Finance	*n*
Decommissioning of unused servers	**0%**	0	**75%**	4	**67%**	6
Direct liquid cooling of chips	**20%**	10	**25%**	16	**39%**	18
Energy efficient data storage management	**50%**	2	**88%**	8	**75%**	8
Energy-efficient servers	**67%**	3	**75%**	8	**57%**	7
Massive array of idle disks (MAID)	**40%**	10	**21%**	19	**44%**	16
Passive optical network	**0%**	6	**19%**	16	**47%**	15
Server power management	**50%**	4	**60%**	10	**67%**	9
Server virtualization/consolidation	**0%**	1	**100%**	2	**67%**	3
Solid state storage	**75%**	4	**53%**	15	**56%**	9

As shown in Table 65, college/university and financial services data center managers showed high interest in efficient power supplies. A moderate amount of interest (as indicated by the medium blue shading) was shown in DC to the racks. Financial services data center managers showed at least moderate interest in all of the power infrastructure EETBPs.

Table 65. Specific Commercial Sector's Interest in Power Infrastructure EETBPs

EETBP	Hospital	*n*	College/Univ.	*n*	Finance	*n*
Combined heat and power (absorption chiller)	**33%**	9	**31%**	16	**62%**	13
Direct Current	**33%**	6	**47%**	15	**60%**	15
Energy efficient power supplies (UPS)	**0%**	0	**77%**	13	**78%**	9
Polymer electrolyte membrane fuel cells	**20%**	10	**25%**	20	**41%**	22
Solar power	**22%**	9	**56%**	18	**50%**	18
Solid oxide fuel cells	**11%**	9	**20%**	20	**41%**	22
Wind power	**11%**	9	**25%**	20	**38%**	21

As shown in Table 66, none of the sectors showed high interest in the air flow management EETBPs, although all three sectors showed moderate interest in hot/cold aisle containment. Financial services data center managers showed the most interest in air flow management EETBPs with medium interest in three of four types.

Table 66. Specific Commercial Sector's Interest in Air Flow Management EETBPs

EETBP	Hospital	*n*	College/Univ.	*n*	Finance	*n*
Blanking panels, grommets, or structured cabling	**25%**	4	**36%**	11	**47%**	15
Computational fluid dynamics optimization	**30%**	10	**31%**	16	**44%**	18
Hot or cold aisle configuration	**43%**	7	**29%**	7	**30%**	10
Hot or cold aisle configuration plus containment	**57%**	7	**38%**	16	**53%**	17

As shown in Table 67, only DCIM received high interest from financial services data center managers. In row-cooling received moderate interest from all three sectors. Financial services and college/university data center managers showed stronger interest compared to hospitals, in air flow management EETBPs, showing at least moderate interest in seven of nine EETBPs.

Table 67. Specific Commercial Sector's Interest in HVAC EETBPs

EETBP	Hospital	*n*	College/Univ.	*n*	Finance	*n*
Air-side economizer	**13%**	8	**47%**	17	**44%**	18
ASHRAE Recommended Temperature	**13%**	8	**56%**	16	**44%**	16
Containerized data center	**29%**	7	**6%**	18	**25%**	12
DCIM	**60%**	5	**31%**	13	**67%**	9
In-row cooling	**43%**	7	**58%**	12	**55%**	11
Premium efficiency motors	**29%**	7	**38%**	13	**33%**	15
Variable speed drives on pumps/fans	**0%**	5	**50%**	10	**46%**	13
Waste heat recovery	**25%**	8	**50%**	16	**31%**	13
Water-side economizer	**20%**	10	**45%**	20	**40%**	20

As shown in Table 68, no humidification EETBPs received high interest. Installing adiabatic humidification received moderate interest from the hospital and financial services sectors. Financial services showed the most interest in air flow management EETBPs, showing at least moderate interest in all three EETBPs.

Table 68. Specific Commercial Sector's Interest in Humidification EETBPs

EETBP	Hospital	*n*	College/Univ.	*n*	Finance	*n*
Broaden humidity range	**14%**	7	**27%**	15	**50%**	14
Install misters, foggers, or ultrasonic humidifiers	**33%**	9	**22%**	18	**47%**	15
Turn off humidifiers	**25%**	8	**31%**	16	**55%**	11

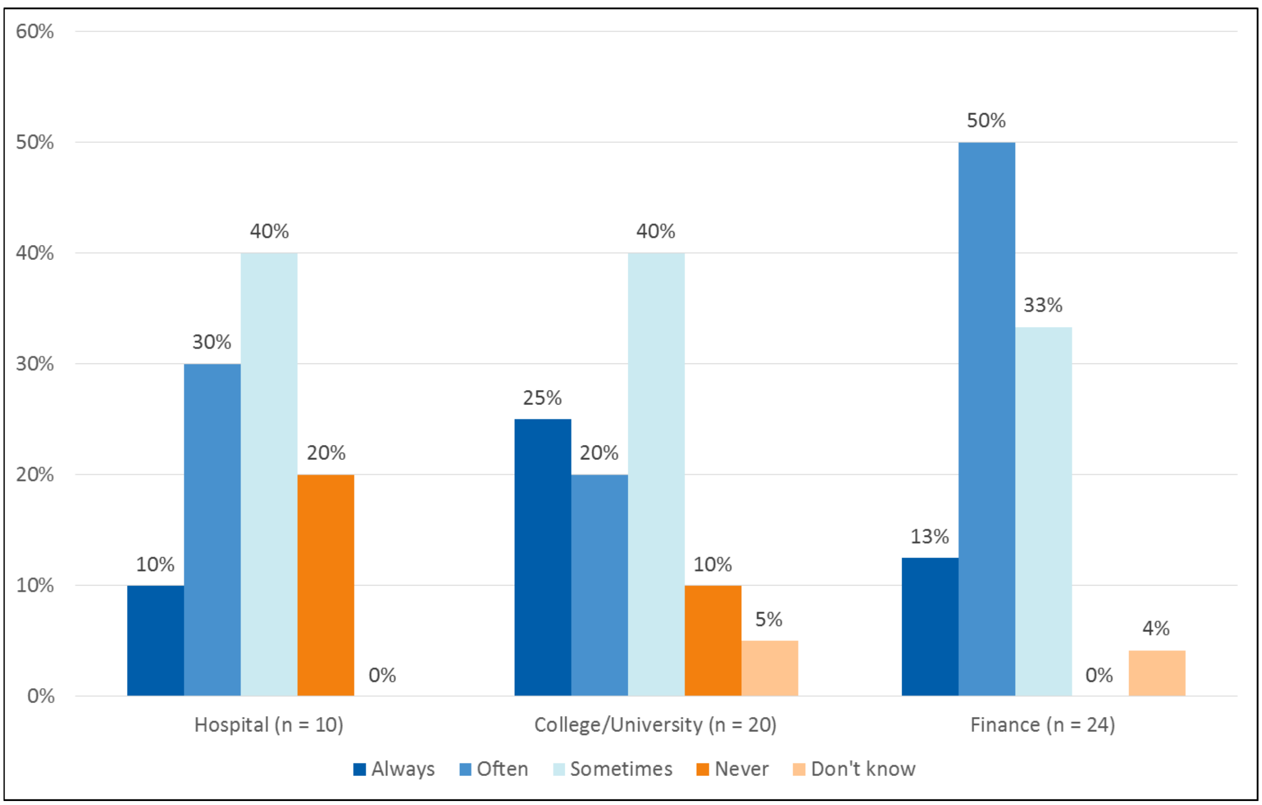
8.4 EETBP Decision-Making Factors and Barriers

This section examines the decision-making process and motivations of data center operators, along with the barriers they face, for the three commercial sectors. Survey questions asked respondents to specify, identify, or rank various factors related to energy usage and energy efficiency in the data center. Please see Section 5 for more details.

8.4.1 Energy Efficiency and Energy Cost Considerations

Figure 39 shows that data center managers in all three sectors appeared to factor energy efficiency and energy costs into their decision-making process to some degree. In survey results for all three sectors, energy efficiency and energy costs are "always" or "often" considered at least 40% of the time. Interestingly, a few college/university and hospital data center managers mentioned that they "never" consider energy efficiency and costs. None of the financial services data center managers replied "never" to this question.

Figure 39. Specific Commercial Sector's Frequency of Energy Efficiency and Energy Cost Considerations



8.4.2 Energy Efficiency Project Approval

To increase the understanding of the primary factors that drive approval of energy efficiency projects, the survey asked respondents to rank various factors as either “very important,” “somewhat important,” “not too important,” “not important at all,” or “don’t know.” Figure 40, Figure 41, and Figure 42 show the decision factors for approving energy efficiency projects for the healthcare, higher education, and financial service sectors respectively. For hospitals and financial services, reducing risk, increasing uptime, decreasing operating costs, and increasing security were the factors that are “very important” when obtaining energy efficiency project approval. Surprisingly, college/university data center managers deemed the same factors as very important, except they did not as frequently rank reducing risk as very important.

Figure 40. Hospital (n = 10) Decision Factors in Approving Energy Efficiency Projects

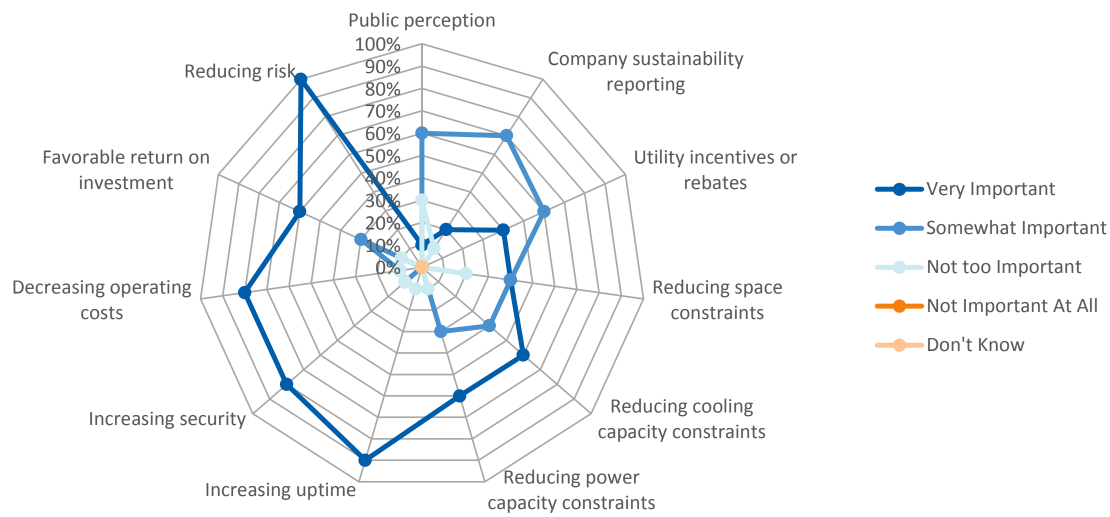


Figure 41. College/University (n = 20) Decision Factors in Approving Energy Efficiency Projects

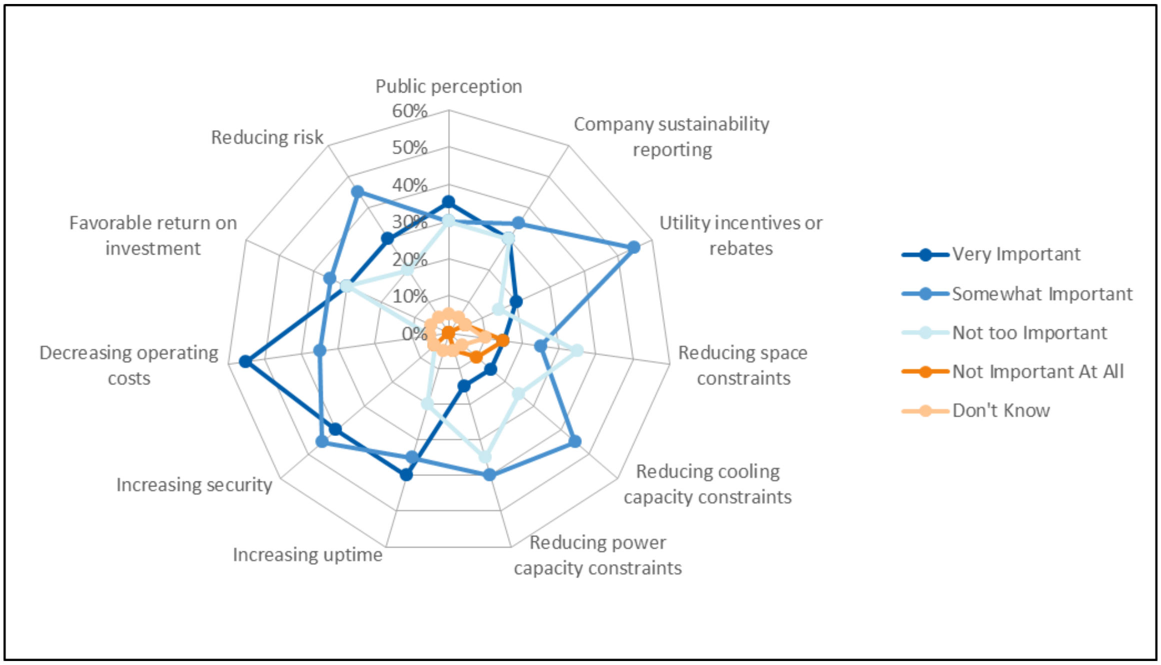
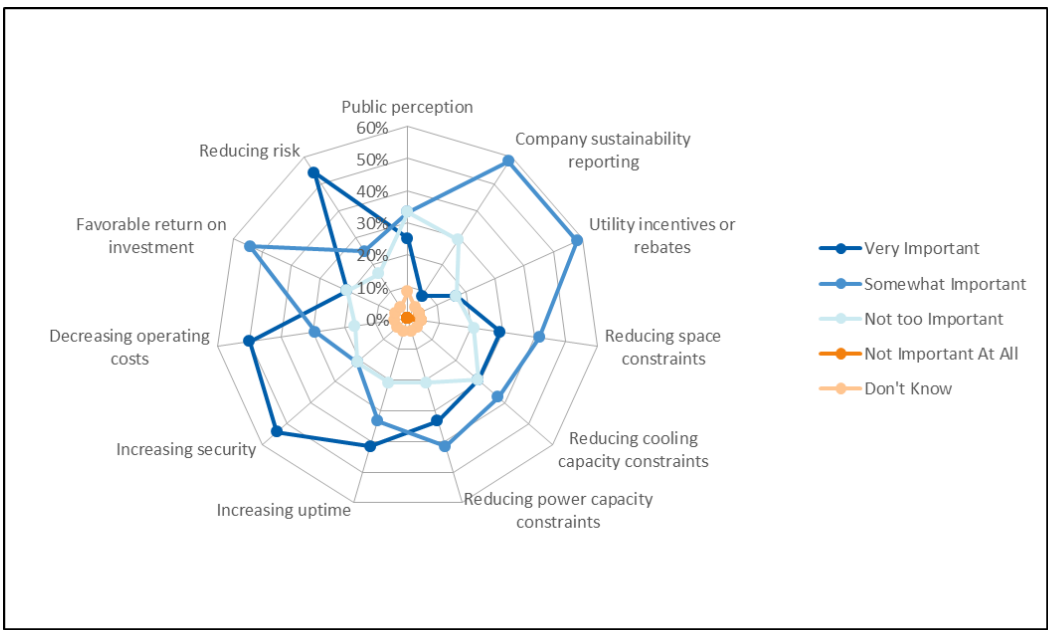


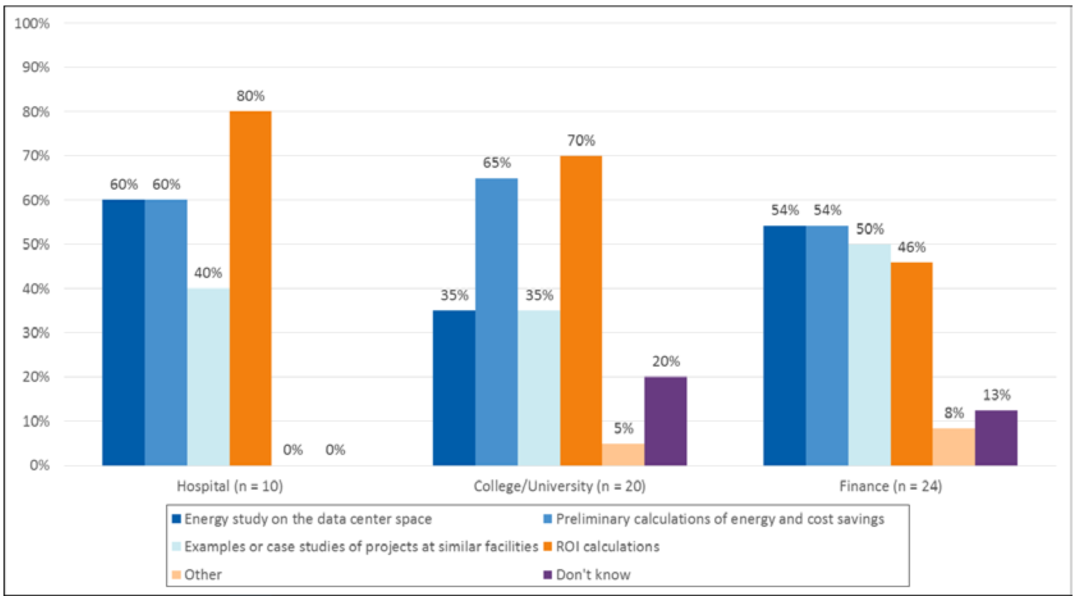
Figure 42. Financial Services (n = 24) Decision Factors in Approving Energy Efficiency Projects



8.4.3 Budgetary Funding Standards

Figure 43 shows the results of asking data center managers to select which supporting information or standards need to be met to receive budgetary funding for energy efficiency projects. Hospitals appear to favor return on investment (ROI) calculations while colleges/universities rely on ROI calculations and energy and cost savings. ROI does not appear to be as important to financial services compared to the other two commercial sectors.

Figure 43. Specific Commercial Sector's Budgetary Funding Standards

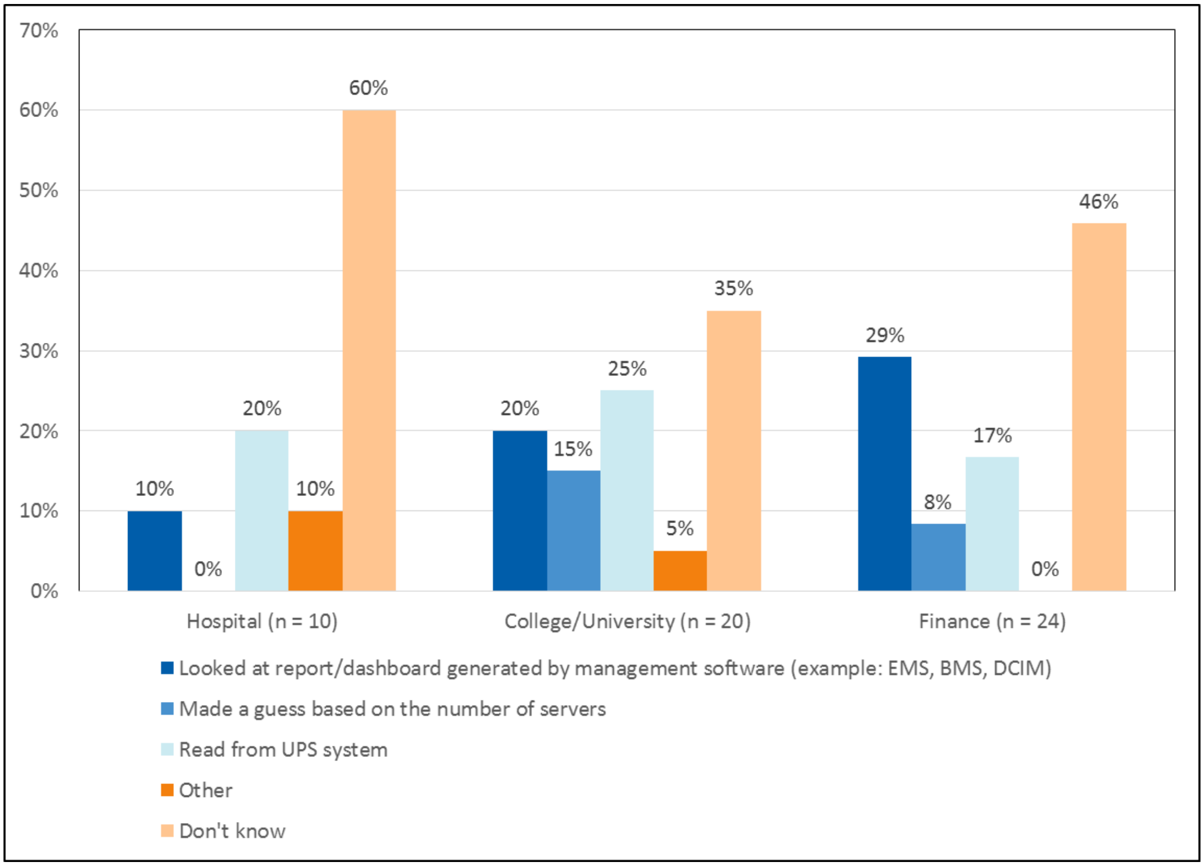


8.4.4 IT Load

Figure 44 shows how data center managers in the three commercial sectors estimate their IT load. Knowing the current IT load in a data center is necessary to determine the amount of cooling required, appropriate UPS sizing, and approximate energy consumption. Although it is interesting to note how IT load is mostly estimated via the UPS or management software, the most interesting result is that most data center managers do not know how their IT load is estimated. In addition, other facts pointed toward the lack of understanding of some of the fundamental concepts regarding data center efficiency:

- Sixty to 70% of data center managers in these three sectors did not know their server load (the main component of IT load) at their data centers.
- None of the hospital and college/university data center managers and only two financial services data center managers knew their PUE, which measures how efficiently a data center is cooled and is the most widely recognized and adopted measurement of data center efficiency.

Figure 44. Specific Commercial Sector's Estimating IT Loads



8.4.5 Energy Challenges

Figure 45, Figure 46 and Figure 47 show the results of asking data center managers to select challenges they face in saving energy at their familiar data center. They were allowed to select multiple challenges from a list of 13 options. Upfront costs and lack of time/staffing were the most frequently cited barriers for data center managers at hospitals and colleges/universities. Concerns about compromising uptime performance and lack of time/staffing were the most frequently cited barriers for financial services. Interestingly, no single barrier was cited more than half of the time.

Figure 45. Hospitals Energy Efficiency Project Barriers

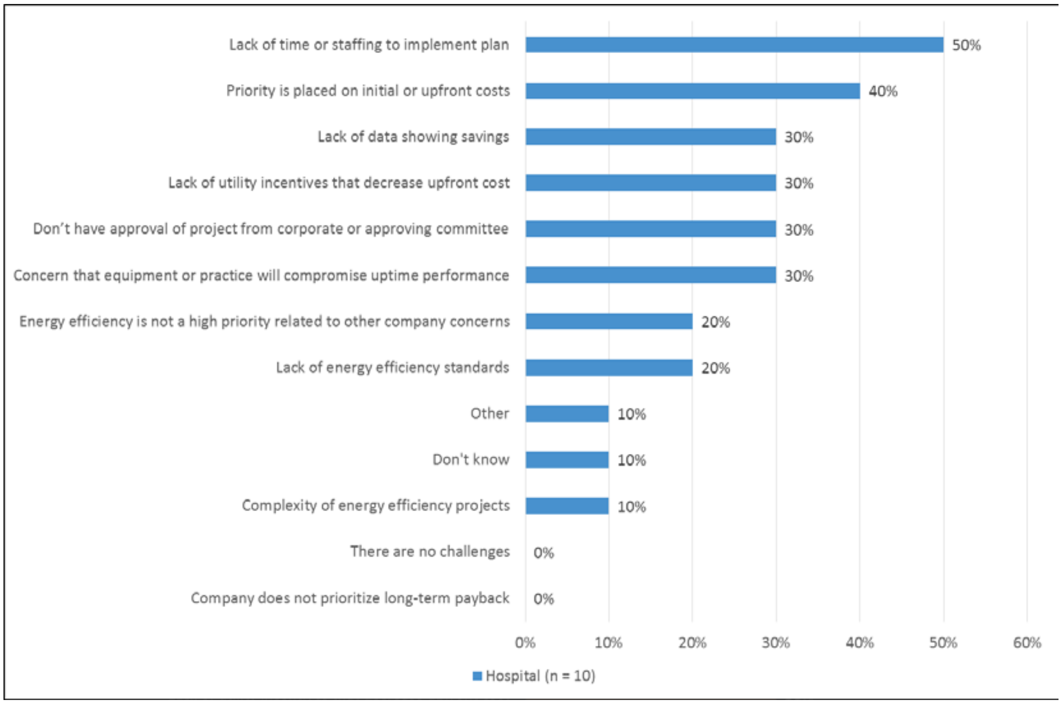


Figure 46. Colleges/Universities Energy Efficiency Project Barriers

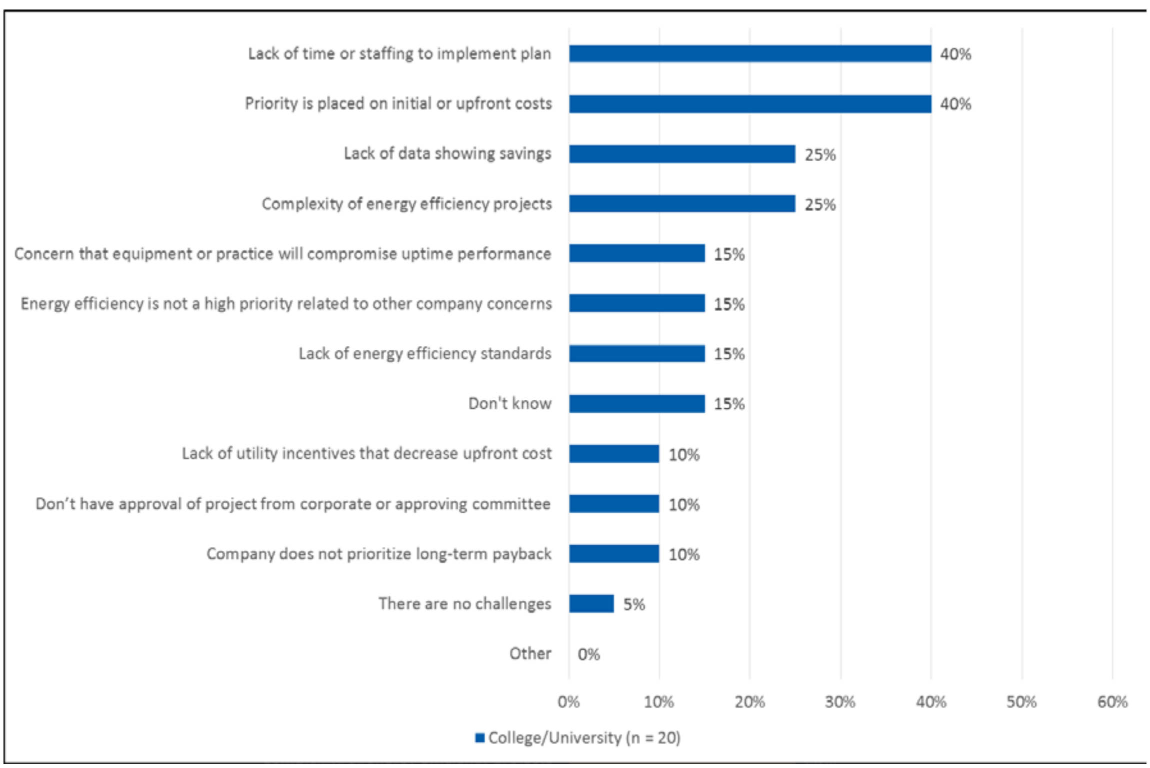
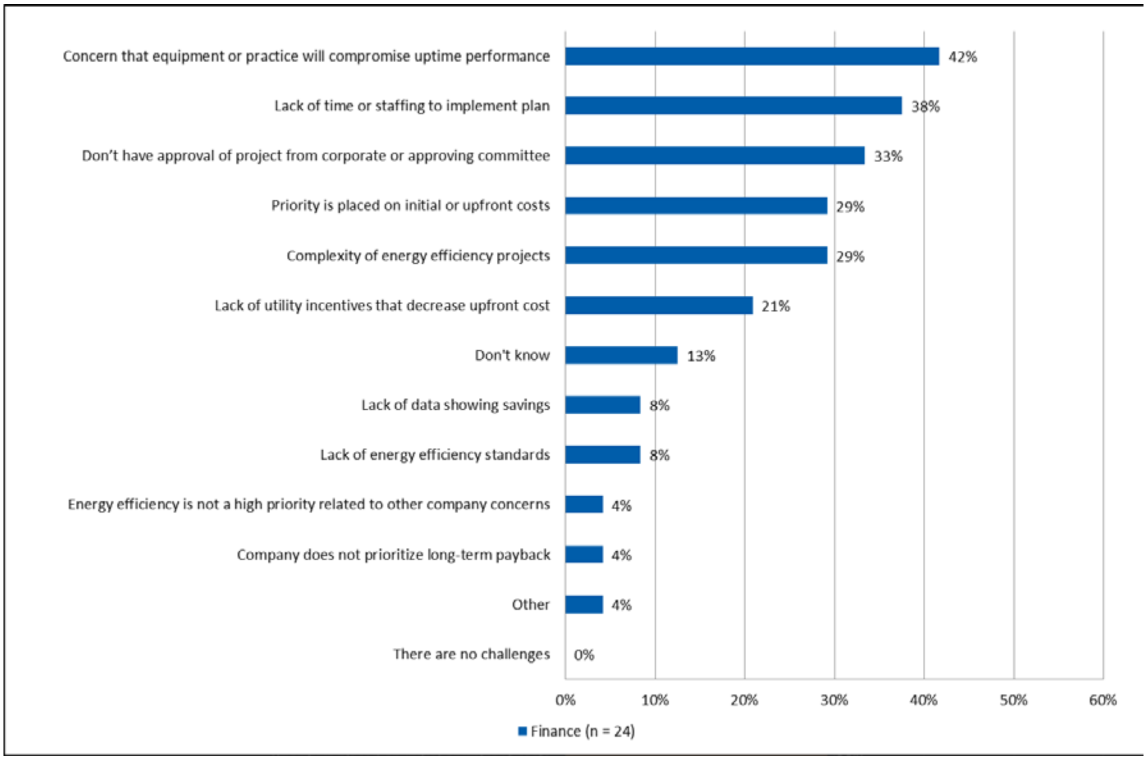


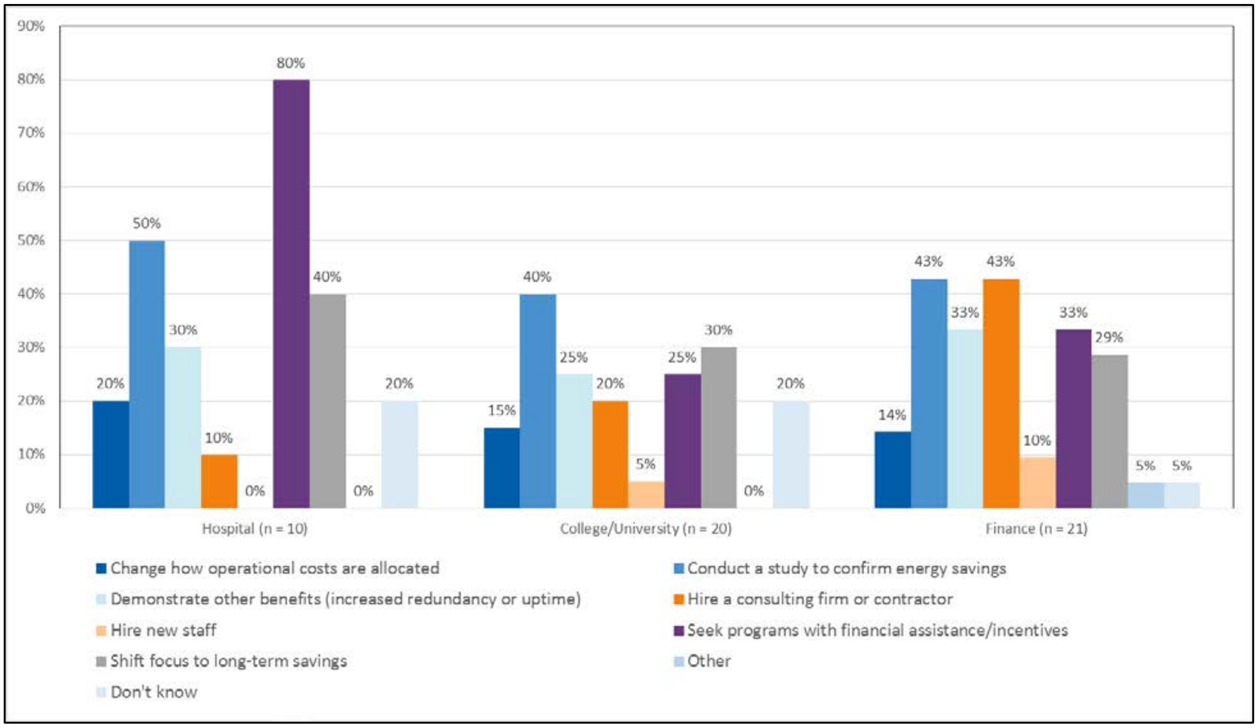
Figure 47. Financial Services Energy Efficiency Project Barriers



8.4.6 Addressing Energy Challenges in Data Centers

Figure 48 shows the results of asking data center managers from the three commercial sectors to identify the best way(s) to address energy challenges in data centers. They were given nine choices and were allowed to choose multiple options. Only in one instance did a way to address energy challenges garner more than half of the responses—"seeking financial assistance or incentives" was cited by 80% of the hospital data center managers. Data center managers from all three sectors also selected "conducting study to confirm savings" at a relatively high frequency as well.

Figure 48. Specific Commercial Sector’s How Best to Address Energy Challenges in Data Centers



8.5 Market Trends

This section examines the how the three specific commercial sectors deal with cloud services, colocation facilities, and latency issues. Their attitudes about keeping their data centers in New York State are also described.

8.5.1 Cloud Services

Cloud services are IT services that are delivered to an end-user using centralized, shared computing resources, and are typically delivered through the Internet by a different company (see Section 7.4.1). As shown in Figure 49, hospitals indicated a higher use of the cloud services compared to colleges/universities and financial services. As shown in Figure 50, hospitals used the cloud mostly for email/communications, as well as billing/financial, and staff management. Most of the time, financial services used the cloud for data storage management and sales management/customer relationship management. College/universities used the cloud for Web application management services, data storage, and office productivity tools. As shown in Figure 51, the one hospital not using cloud services pointed toward performance and security issues as the reason for not using cloud services. Although still evaluating cloud services, some colleges/universities also cited security concerns as the main barrier to cloud services and financial services cited security concerns and performance issues as the main barrier to cloud services.

Figure 49. Specific Commercial Sector's Use of Cloud Services in New York State

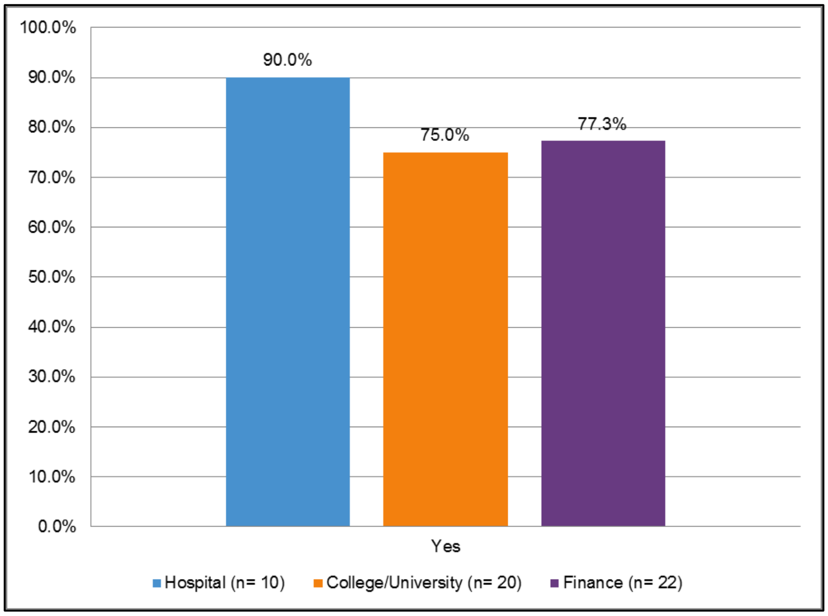


Figure 50. Specific Commercial Sector's Cloud Service Applications Used in New York State

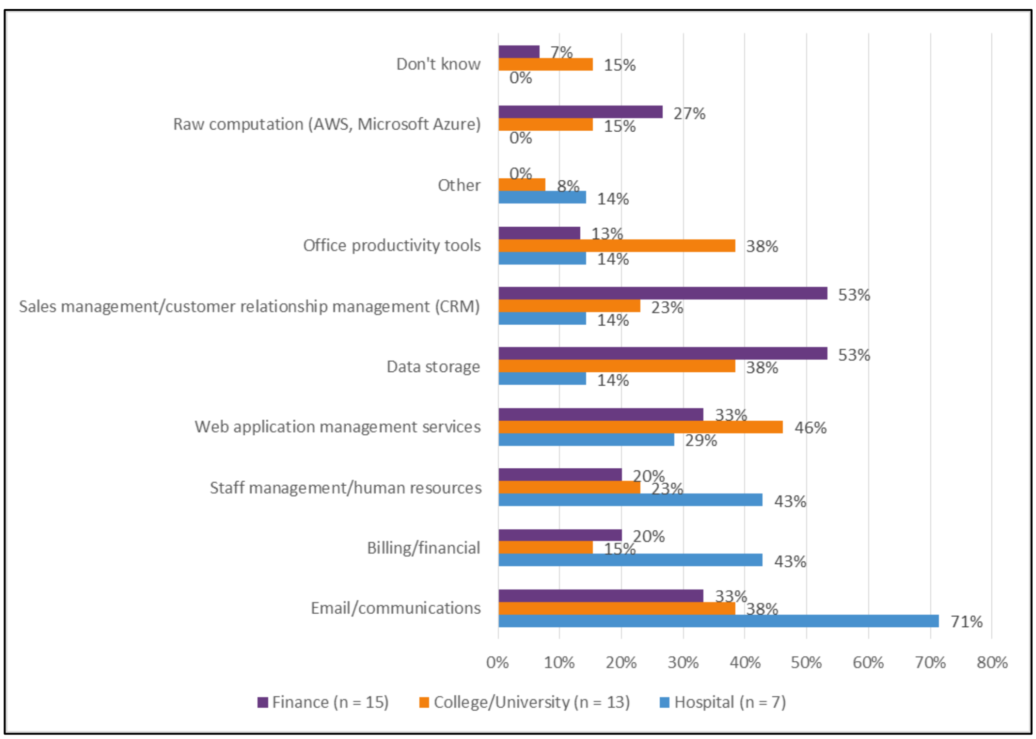
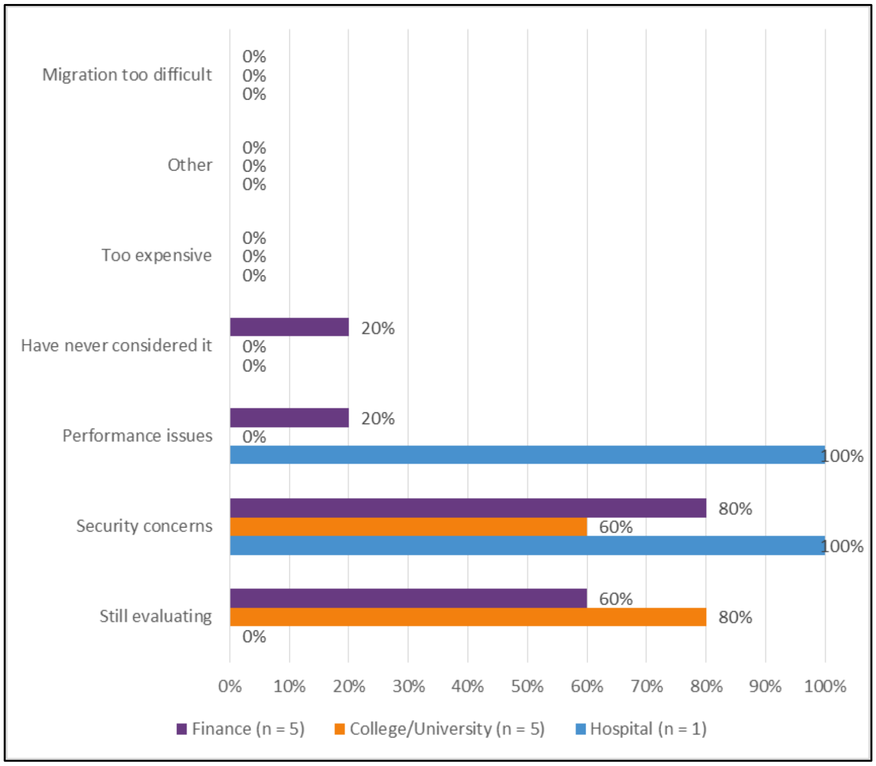


Figure 51. Specific Commercial Sector's Reasons for Not Using Cloud Services



8.5.2 Colocation Services

Colocation providers offer their customers power, cooling, and network conductivity to support their servers and software. Colocation space ranges in scale from entire data centers to a single slot in a server rack (see Section 7.5.2). As shown in Figure 52, colleges/universities had a much smaller adoption of colocation facilities. As shown in Figure 53, financial services mentioned running out of space and power as the reasons for using the co-location services. All five hospitals and four out of five colleges/ universities did not select from the team's list of reasons in the survey but rather selected "Other" and specifically mentioned data backup/disaster recovery as the reason for using colocation. As shown in Figure 54, two out of the three financial services firms mentioned cost as the reason for not using colocation. Two of the three hospitals cited "security concerns" and "being able to use their own facilities" as reasons for not using colocation. Over half of the 12 colleges/universities stated they were able to use their own facilities instead of colocation.

Figure 52. Percentage of Specific Industries Using Colocation Facilities in New York State

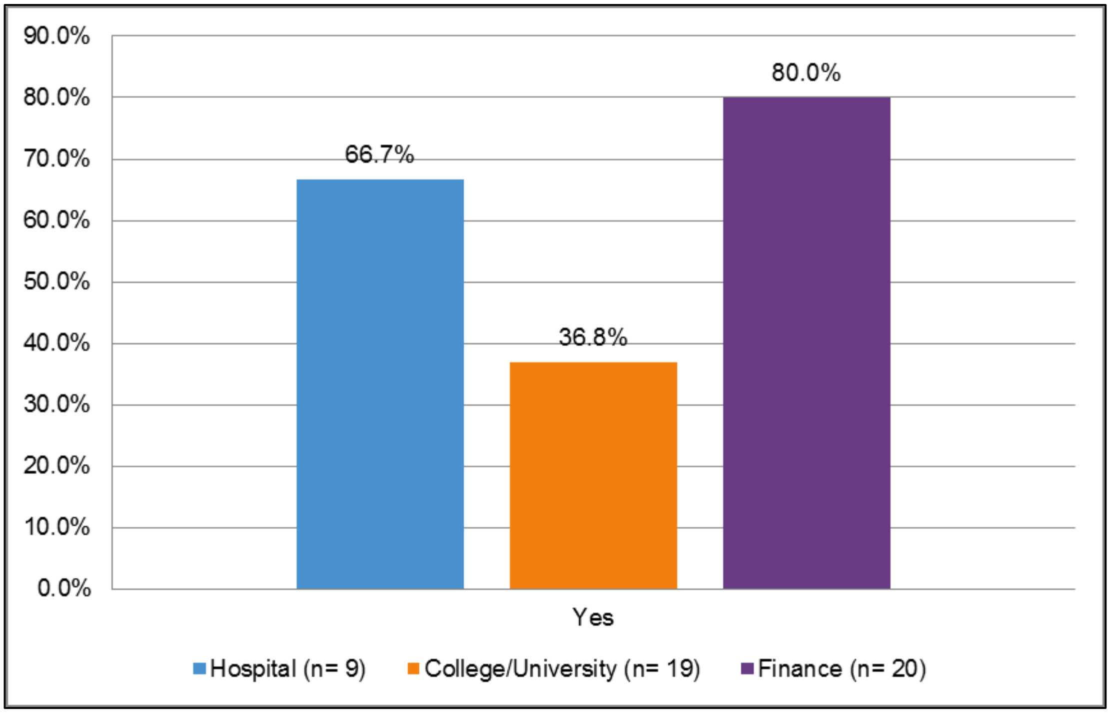


Figure 53. Specific Commercial Sector's Reasons for Using Colocation Facilities in New York State

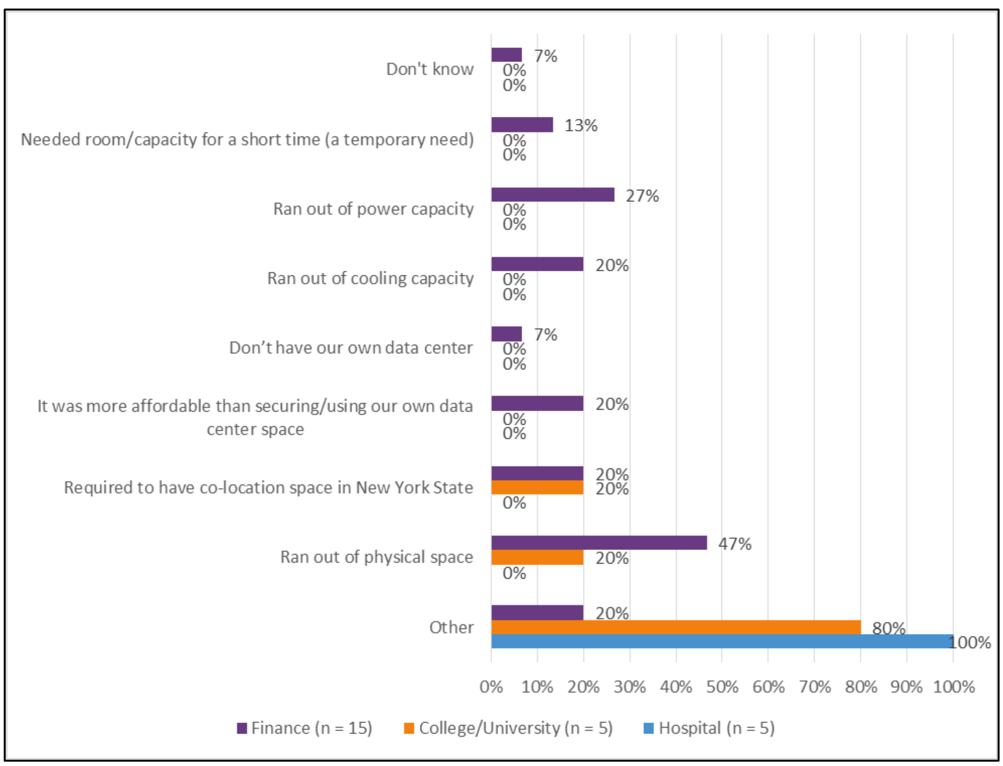
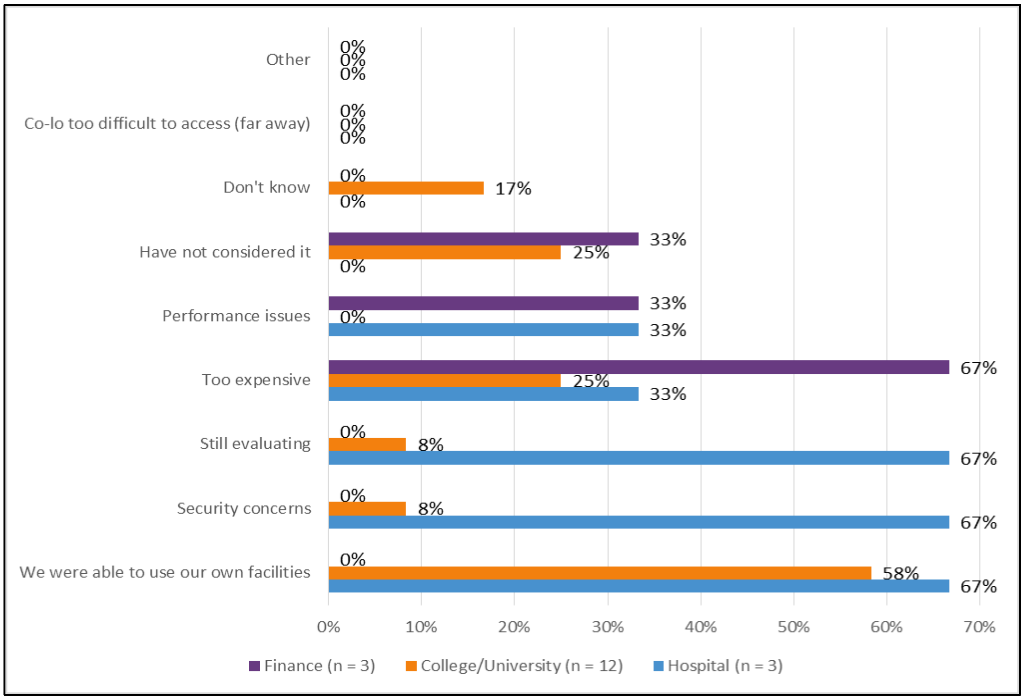


Figure 54. Specific Commercial Sector's Reasons for Not Using Colocation Facilities in New York State



8.5.3 Latency

As shown in Figure 55 and Figure 56, financial services were more concerned with latency requirements (i.e., the need to place IT resources near users so they do not suffer from data communication delays) than colleges/universities for both colocation and cloud services. Given the urgency of data access in the financial sector compared to higher education and healthcare, this result is not surprising.

Figure 55. Specific Commercial Sector's Latency Issues Require Colocation in New York State

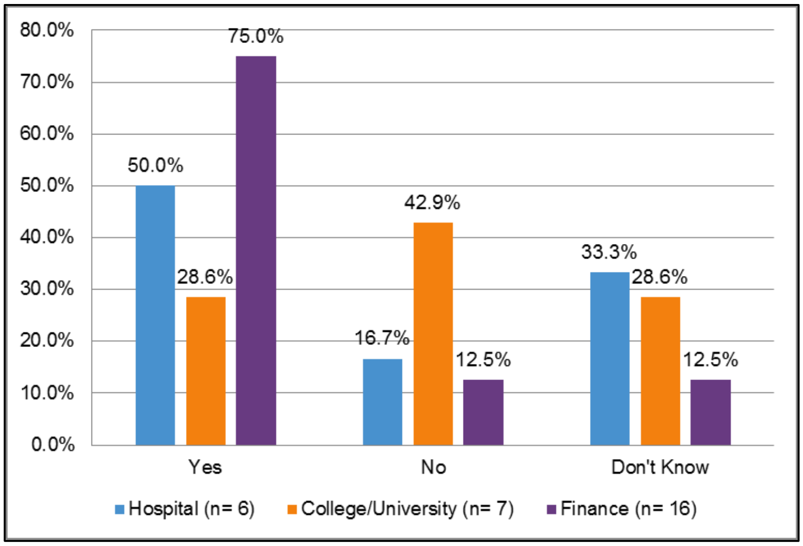
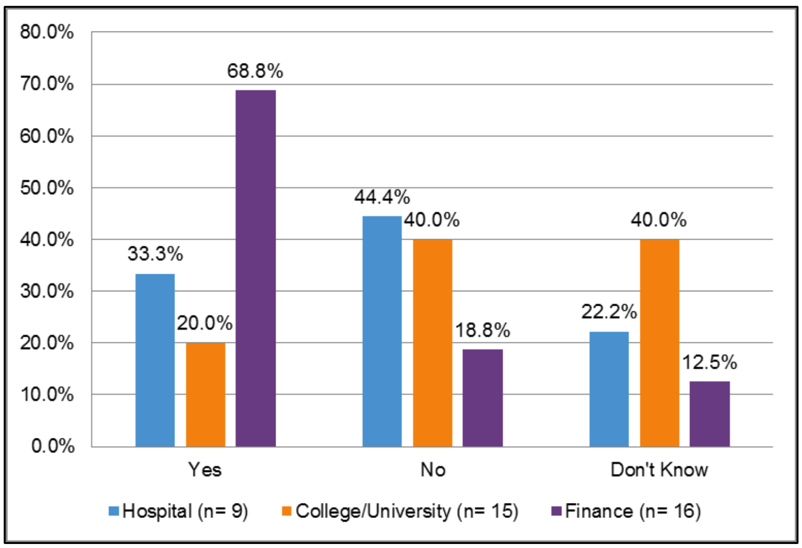


Figure 56. Specific Commercial Sector's Latency Issues Require Cloud Services in New York State



8.5.4 Attitudes About Staying in New York State

As shown in Figure 57, all hospital and virtually all colleges/universities data center managers were keeping their data centers in New York State. However, financial services were much more likely to be moving data center operations out of New York State. As shown in Figure 58, different answers were given regarding the barriers to data center growth in New York State. College/university data center managers cited organizational considerations and approvals as the top barrier limiting data center growth. Hospitals cited organizational considerations and approvals, facility costs, space and power capacity of existing facilities as limiting data center growth. However, financial services data center managers ranked cost of real estate first, followed by space and power capacity of existing facilities, as limiting data center growth. In general the three commercial sectors selected technical assistance to identify energy efficiency upgrades, utility incentives and tax credits for upgrades, and energy rate discounts for new data centers as ways to help data center growth in New York State.

Figure 57. Are Specific Commercial Sector's Data Centers Staying in New York State?

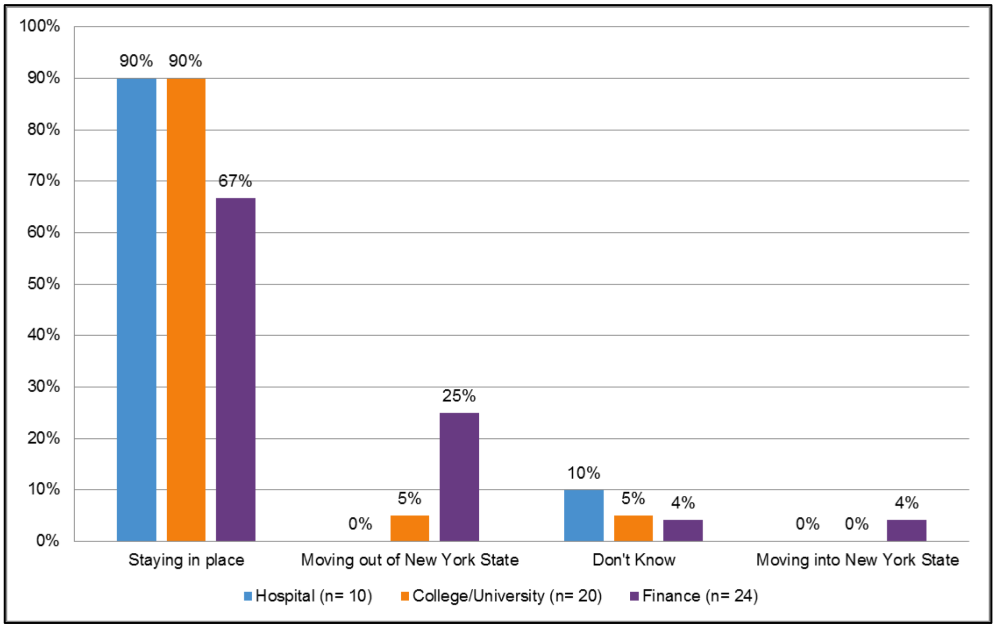
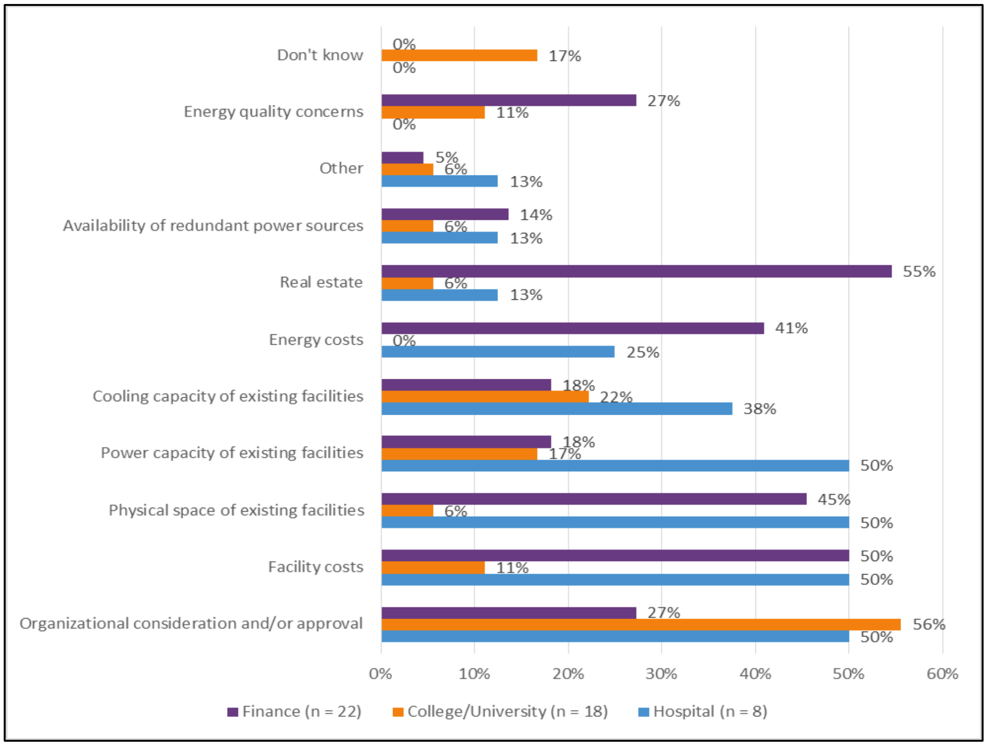


Figure 58. What Limits Data Center Growth in New York State for Specific Industries?



8.5.5 Findings

Based on the examination of these three commercial sectors, the Cadmus team's findings specific to hospitals, colleges/universities, and financial services include:

- More data center managers of colleges/universities were aware of the NYSERDA incentives than those in financial services and hospitals.
- IT EETBPs were, by far, the most frequently implemented type of EETBP, with server virtualization/consolidation and decommissioning of unused servers as the most frequently implemented. Other frequently implemented EETBPs included energy-efficient UPSs, blanking panels, grommets, structured cabling, and hot/cold aisle containment, variable speed drives and DCIM, and turning off humidifiers.
- Data center managers that had not implemented any EETBPs expressed the most interest IT EETBPs—particularly server virtualization/consolidation, server decommissioning, energy efficiency servers, data storage management, solid state storage, and server power management. Other EETBPs of high interest (two-thirds or greater of data center managers expressed interest) included efficient power supplies, and DCIM. High interest was not expressed for air flow management EETBPs and humidification EETBPs.
- All data center managers consider energy efficiency and energy costs in their decision making process "always" or "often" at least 40% of the time.
- Increasing uptime, decreasing operating costs, and increasing security appear to be the factors that are "very important" to energy efficiency project approval.

- ROI appears to be the most frequently-cited piece of supporting information needed for approval of energy efficiency projects. The barrier cited as most often holding back efficiency projects was lack of time and staffing.
- Confirmation of energy savings was cited as the best way to address energy channels in the data center.
- Data center managers were not knowledgeable about their IT load or PUE.
- Hospitals appeared to use cloud services more frequently than college/universities and financial services.
- Performance issues and security were the most frequently cited reasons for not adopting cloud services.
- Financial services data center managers cited a particularly high use of colocation services due to space and power constraints. Colleges/universities data center managers did not use colocation facilities as often as those from financial services and hospitals. Hospitals and colleges/universities cited backup/recovery as the reason for using colocation space.
- Latency was more of a concern for those in the financial sector.
- All hospital and virtually all college/university data center managers indicated they were keeping their data centers in New York State. However, 25% of financial services indicated they were moving data center operations out of New York State.
- These commercial sectors selected technical assistance to identify energy efficiency upgrades, utility incentives and tax credits for upgrades, and energy rate discounts for new data centers as ways to help data center growth in New York State.

Appendix A: NYSERDA Data Center Market Characterization Study Annotated Bibliography

Appendix A. NYSERDA Data Center Market Characterization Study Annotated Bibliography

Provided below is an annotated bibliography of key data center market studies. In addition to the study's citation, the executive summary is provided, when available, to summarize the document. The bibliography is divided into the following types of documents:

High Level Market Studies Examining Larger Data Center Trends

"Data Center Efficiency Assessment: Scaling Up Energy Efficiency Across the Data Center Industry: Evaluating Key Drivers and Barriers". August 2014. NRDC and Anthesis.

The authors provided the following executive summary components for this paper:

> If just half of the technical savings potential for data center efficiency that we identify in this report were realized (to take into account the market barriers discussed in this report), electricity consumption in U.S. data centers could be cut by as much as 40 percent. In 2014, this represents a savings of 39 billion kilowatt-hours annually, equivalent to the annual electricity consumption of all the households in the state of Michigan. Such improvement would save U.S. businesses $3.8 billion a year.
>
> In light of the continued, rapid growth of the data center industry, including the emergence of new business models broadly defined as cloud computing, NRDC retained Anthesis to conduct a study to assess progress on energy efficiency in the data center industry. The study focused on three key data center issues: the level of utilization of IT equipment, the impact of and potential for efficiency opportunities in multitenant data centers, and the degree to which the evolution of the industry's technology and delivery model is aligning incentives to further drive energy efficiency.

"GeSI SMARTer 2020: The Role of ICT in Driving a Sustainable Future." December 2012. The Climate Group on behalf of the Global eSustainability Initiative (GeSI). [37]

The authors provided the following executive summary for this paper:

> As was explored in the SMART 2020 report, the rise of information and communications technology (ICT) has been one of the most transformative developments of the last several decades. But the world has changed since the publication of that report, and SMARTer 2020 seeks to take a fresh look at the role ICT can play in GHG abatement by considering recent trends, incorporating updated data, and looking a broader use of ICT in other industries. From tablets and increased use of broadband networks to cloud computing and smartphones, ICT has become an increasingly integral part of the global economy. It has continuously contributed to economic growth, resulting in an improved quality of life for people around the world. ICT has the possibility to address many of the problems in our society, including the threat of climate change. For instance, consider the use of ICT-enabled GHG abatement solutions in transportation. Through the use of eco-driving, real-time traffic alerts, and the proliferation of ICT-enabled logistics systems, ICT stands to reduce total mileage and the amount of fuel required to transport people and goods. Online maps are excellent examples: by synthesizing maps with real-time traffic data and making this available on mobile devices these tools enable users to optimize routing decisions, reduce fuel consumption, and lower emissions. Furthermore, with the adoption of telecommuting and video conferencing, in certain circumstances ICT can eliminate transportation needs altogether. All of these contribute to reductions in energy use and, accordingly, reductions in GHG emissions.
>
> These reductions in emissions are not limited to the transportation sector, but can be applied across the economy. In addition to transportation, this report considers five other end-use sectors: agriculture and land use, buildings, manufacturing, power, and consumer and service. ICT-enabled solutions offer the potential to reduce annual emissions by an estimated 9.1 $GtCO_2e$ by 2020, representing 16.5 percent of the projected total in that year, an abatement potential more than 16% higher than previously calculated in the SMART 2020 report.

Masanet, E., Brown, R.E., Shehabi, A., Koomey, J.G., and B. Nordman. "Estimating the Energy Use and Efficiency Potential of U.S. Data Centers. 2011. Proceedings of the IEEE, Volume 99, Number 8. [96]

The authors provided the following abstract for this article:

Data centers are a significant and growing component of electricity demand in the United States. This paper presents a bottom-up model that can be used to estimate total data center electricity demand within a region as well as the potential electricity savings associated with energy efficiency improvements. The model is applied to estimate 2008 U.S. data center electricity demand and the technical potential for electricity savings associated with major measures for IT devices and infrastructure equipment. Results suggest that 2008 demand was approximately 69 billion kilowatt hours (1.8% of 2008 total U.S. electricity sales) and that it may be technically feasible to reduce this demand by up to 80% (to 13 billion kilowatt hours) through aggressive pursuit of energy efficiency measures. Measure-level savings estimates are provided, which shed light on the relative importance of different measures at the national level. Measures applied to servers are found to have the greatest contribution to potential savings.

Koomey, Jonathan. "Growth in Data Center Electricity Use 2005 to 2010." 2011. Analytics Press. www.analyticspress.com/datacenters.html. [59]

The authors provided the following executive summary for this article:

This study assesses growth in data center electricity use from 2005 to 2010 for the US and the world. It uses data and methods similar to earlier analyses to create a consistent time series of data center electricity use. The key results for the analysis are as follows:

- Growth in the installed base of servers in data centers had already begun to slow by early 2007 because of virtualization and other factors.
- The 2008 financial crisis, the associated economic slowdown, and further improvements in virtualization led to a significant reduction in actual server installed base by 2010 compared to the IDC installed base forecast published in 2007.
- Growth in electricity used per server probably accounted for a larger share of demand growth from 2005 to 2010 than it did in 2000 to 2005.
- Assuming that the midpoint between the Upper and Lower bound cases accurately reflects the history, electricity used by data centers worldwide increased by about 56% from 2005 to 2010 instead of doubling (as it did from 2000 to 2005), while in the US it increased by about 36% instead of doubling.
- Electricity used in global data centers in 2010 likely accounted for between 1.1% and 1.5% of total electricity use, respectively. For the US that number was between 1.7 and 2.2%.
- Electricity used in US data centers in 2010 was significantly lower than predicted by the EPA's 2007 report to Congress on data centers. That result reflected this study's reduced electricity growth rates compared to earlier estimates (see FigureES-1), which were driven mainly by a lower server installed base than was earlier predicted rather than the efficiency improvements anticipated in the report to Congress.
- While Google is a high profile user of computer servers, less than 1% of electricity used by data centers worldwide was attributable to that company's datacenter operations.

In summary, the rapid rates of growth in data center electricity use that prevailed from to 2005 slowed significantly from 2005 to 2010, yielding total electricity use by data centers in 2010 of about 1.3% of all electricity use for the world, and 2% of all electricity use for the US.

Koomey, Jonathan; Berard, Stephen; Sanchez, Marla; Wong, Henry. "Implications of Historical Trends in the Electrical Efficiency of Computing." 2011. IEEE Annals of the History of Computing. [57]

The authors provided the following summary for this article:

The electrical efficiency of computation has doubled roughly every year and a half for more than six decades, a pace of change comparable to that for computer performance and electrical efficiency in the microprocessor era. These efficiency improvements enabled the creation of laptops, smart phones, wireless sensors, and other mobile computing devices, with many more such innovations yet to come.

Malmodin, Jens, Moberg, Asa, Lunden, Dag, Finnveden, Goran, and Lovehagen, Nina. "Greenhouse Gas Emissions and Operational Electricity Use in the ICT and Entertainment and Media Sectors." 2010. Journal of Industrial Ecology, 14:5. [31]

The authors provided the following abstract for this paper:

> The positive and negative environmental impacts of information and communication technology (ICT) are widely debated. This study assesses the electricity use and greenhouse gas (GHG) emissions related to the ICT and entertainment & media (E&M) sectors at sector level, including end users, and thus complements information on the product level. GHGs are studied in a life cycle perspective, but for electricity use, only the operational use is considered. The study also considers which product groups or processes are major contributors. Using available data and extrapolating existing figures to the global scale for 2007 reveals that the ICT sector produced 1.3% of global GHG emissions in 2007 and the E&M sector 1.7%. The corresponding figures for global electricity use were 3.9% and 3.2%, respectively. The results indicate that for the ICT sector, operation leads to more GHG emissions than manufacture, although impacts from the manufacture of some products are significant. For the E&M sector, operation of TVs and production of printed media are the main reasons for overall GHG emissions. TVs as well as printed media, with the estimations made here, led to more GHG emissions on a global level in 2007 than PCs (manufacture and operation). A sector study of this type provides information on a macro scale, a perspective easily lost when considering, for example, the product-related results of life cycle assessments. The macro scale is essential to capture changes in total consumption and use. However, the potential of the ICT sector to help decrease environmental impacts from other sectors was not included in the assessment.

Grove, Deborah. "Data Center Whitepaper." July 31, 2009. Northeast Energy Efficiency Partnerships. [51]

The authors provided the following executive summary for this paper:

> In interviews, NEEP stakeholders express a certain hesitation about tackling this issue. The hesitation to date seems to hinge on a divergence of opinions about whether infrastructure or IT is the major culprit, and what should be tackled first.
>
> The process of Data Center Energy Efficiency incentives and take-up is an iterative one: low hanging fruit beckons in air management, followed by improved consolidation and virtualization, with additional power efficiency strategies to follow, combined with operating system and semiconductor chip density improvements with energy-aware capabilities (2-6 years down the line), etc.
>
> If this process is undertaken, the size of the potential savings in NEEP sponsors' service territories is estimated to be 1500 - 3000 MW. The authors of this report believe that an overall savings of 30% of energy used (across all data center sizes in the Northeast region) can be achieved without IT improvements. Leveraging IT improvements, that target can be as high as 50%. Clearly, there is no reason to wait longer to begin offering awareness and education programs followed by incentives, where possible.

Kaplan, James, Forrest, William, Kindler, Noah. "Revolutionizing Data Center Energy Efficiency." July 2008. McKinsey and Company. [35]

The authors provided the following abstract for this paper:

> With their enormous appetite for energy, today's data centers emit as much carbon dioxide as all of Argentina. Left on their current path, data center output will quadruple by the year 2020. This report, part of McKinsey's ongoing body of research on data center management, outlines ways for organizations and the broader community to improve data center energy efficiency and address the twin challenges of rising data center spend and Greenhouse Gas (GHG) emissions. It introduces CADE (Corporate Average Datacenter Efficiency), a new industry standard efficiency measure developed by McKinsey, in conjunction with the Uptime Institute.

Malmodin, Jens. “Carbon Footprint of Mobile Communications and ICT.” 2008. Ericsson Research. [30]

The author provided the following abstract for this paper:

> There is an ongoing discussion regarding energy consumption and carbon dioxide (CO2) emissions associated with the information and communications technology (ICT) sector and its potential to reduce the CO2 emissions in society. In this study performed by Ericsson Research the CO2 emissions of the ICT sector have been estimated by combining the results from external reports with results from internal life cycle assessments of telecommunication systems. The results show that the ICT sector was responsible for about 2 % of global direct CO2 emissions in 2007 while at the same time contributing to 7 % of the global gross domestic product (GDP). For mobile communications, the corresponding figures are about 0.2 % and 2%, respectively. Moreover, it is shown that ICT has the potential to reduce society’s CO2 emissions by 5% - 20% in the short to medium term.

Koomey, Jonathan. “Worldwide Electricity Used in Data Centers.” 2008. Environmental Research Letters. [58]

The authors provided the following abstract for this article:

> The direct electricity used by data centers has become an important issue in recent years as demands for new Internet services (such as search, music downloads, video-on-demand, social networking, and telephony) have become more widespread. This study estimates historical electricity used by data centers worldwide and regionally on the basis of more detailed data than were available for previous assessments, including electricity used by servers, data center communications, and storage equipment.
>
> Aggregate electricity use for data centers doubled worldwide from 2000 to 2005. Three quarters of this growth was the result of growth in the number of the least expensive (volume) servers. Data center communications and storage equipment each contributed about 10% of the growth. Total electricity use grew at an average annual rate of 16.7% per year, with the Asia Pacific region (without Japan) being the only major world region with growth significantly exceeding that average.
>
> Direct electricity used by information technology equipment in data centers represented about 0.5% of total world electricity consumption in 2005. When electricity for cooling and power distribution is included, that figure is about 1%. Worldwide data center power demand in 2005 was equivalent (in capacity terms) to about seventeen 1000 MW power plants.

U.S. Environmental Protection Agency ENERGY STAR Program, “Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431.” August 2, 2007. [20]

The authors provided the following executive summary for this paper:

> The United States (U.S.) Environmental Protection Agency (EPA) developed this report in response to the request from Congress stated in Public Law 109-431. This report assesses current trends in energy use and energy costs of data centers and servers in the U.S. and outlines existing and emerging opportunities for improved energy efficiency. It provides particular information on the costs of data centers and servers to the federal government and opportunities for reducing those costs through improved efficiency. It also makes recommendations for pursuing these energy-efficiency opportunities broadly across the country through the use of information and incentive-based programs.

Surveys Exploring Operation and Technology

“2013 Uptime Institute Annual Data Center Industry Survey Report and Full Results.” 2013. Uptime Institute Professional Services, LLC. [67]

The authors provided the following summary for this article:

> The third annual Uptime Institute Data Center Industry Survey is an in-depth study collecting responses via email from 1,000 data center facilities operators in 2013. People interviewed included IT managers, and senior executives from around the world. Third party describes companies that provide computing capacity as a service in any form: Software as a Service, cloud computing, multi-tenant colocation, or wholesale data center providers. Industries include banking, manufacturing, healthcare, retail, education, government, and other industries. The data suggest third-party data center service providers are growing at the expense of in-house IT operations. This is reflective of a growing shift we've noted in these surveys and anecdotally for the last few years. Approximately 85% of large enterprise data center operators surveyed employed some form of third-party compute capacity to supplement their existing internal digital infrastructure portfolio. Many enterprise data center operators are not effectively collecting or presenting cost and performance data to their executives, which could lead to misinformed outsourcing decisions. Over 70% of third-party data center service providers are focused on efficiency, cost and performance, providing monthly or more frequent report on data center cost. Nearly 40% of enterprise data center owners have no scheduled reporting on the other hand. Only 14% of third party operators report data center cost and performance.

Kaiser, Jessica. "Survey Results: Data Center Economizer Use." 2011. White Paper 41: The Green Grid. [49]

Kaiser defines economizers as "cooling technologies that take advantage of favorable outdoor conditions to provide partial or full cooling without using the energy of a refrigeration cycle." She provides the following executive summary for her white paper:

> In early 2011, The Green Grid (TGG)—an international, non-profit consortium working to enhance data center resource efficiency—conducted a survey to learn more about current economizer awareness, perceptions, and use in the data center industry. The survey's results indicate that economizers are well-known throughout the data center industry and that adoption is becoming fairly widespread. Economizers represent an effective means of increasing energy efficiency and reducing costs in data centers, and TGG expects this survey's findings to spur further economizer research, education, and adoption efforts. The following paper highlights some of the most interesting results from TGG's survey.

Information Week issues a continuing series of reports that are based upon in-depth surveys of hundreds of large data center operators. The reports provide insight into the status of technology implementation for a wide-ranging number of topics – servers, storage, and networking – as well as general surveys regarding the data center industry as whole. Because surveys are done annually, the surveys can show you how these data change over time. For example, one can learn how the implementation rate of Massive Array of Idle Discs storage has changed over time. The surveys include the following:

- Marko, Kurt. "State of Servers: Full, Fast and Diverse." November 2012. Information Week Reports. Reports.informationweek.com. [61]
- Marko, Kurt. "State of Server Technology." October 2011. Information Week Reports. Reports.informationweek.com. [62]
- Marko, Kurt. "2012 State of the Data Center." June 2012. Information Week Reports. Reports.informationweek.com. [63]
- Marko, Kurt. "State of Storage 2012." February 2012. Information Week Reports. Reports.informationweek.com. [64]
- Marko, Kurt. "2014 State of Enterprise Storage." Information Week Reports. 2014. Reports.informationweek.com. [75]
- Marko, Kurt. "2014 State of Server Technology." November 2013. Information Week Reports. Reports.informationweek.com. [76]

- Marko, Kurt. “Data Center Decision Time.” June 10, 2013. Information Week Reports. Reports.informationweek.com. [77]

- Wittmann, Art. “Private Clouds Set Up.” December 2013. Information Week Reports. Reports.informationweek.com. [78]

- Marks, Howard. “2013 Backup Technologies Survey.” April 2013. Information Week Reports. Reports.informationweek.com. [79]

- Feldman, Johnathan. “2013 IT Spending Priorities Survey.” May 2013. Reports.informationweek.com. [80]

- Masters Emison, Joe. “2013 State of Cloud Computing.” May 2013. Reports.informationweek.com. [81]

- Biddick, Michael. “2014 Application Consolidation Survey.” December 2013. Reports.informationweek.com. [82]

- Wittmann, Art. “2014 Private Cloud Survey.” January 2014. Information Week Reports. Reports.informationweek.com. [83]

- Marko, Kurt. “2014 State of Storage.” February 2014. Information Week Reports. Reports.informationweek.com. [84]

- Marko, Kurt. “Back up Mobile Devices May Be A Nonissue.” August 2013. Information Week Reports. Reports.informationweek.com. [85]

- Masters Emison, Joe. “Cloud Security And Risk Survey.” September 2013. Information Week Reports. Reports.informationweek.com. [86]

- Masters Emison, Joe, and Feldman, Johnathon. “Data Center Debate: Standardization Vs. Specialization.” March 2013. Information Week Reports. Reports.informationweek.com. [87]

- Marko, Kurt. “SDN Buyer’s Guide.” May 2013. Information Week Reports. Reports.informationweek.com. [88]

- Whittmann, Art. “Server Innovation.” November 2013. Information Week Reports. Reports.informationweek.com [89]

- Marko, Kurt. “State of Servers.” October 28, 2013. Information Week Reports. Reports.informationweek.com. [90]

- Marko, Kurt. “Storage Disruption.” February 25, 2013. Information Week Reports. Reports.informationweek.com. [91]

- Marks, Howard. “Storage Virtualization Gets Real.” December 2013. Information Week Reports. Reports.informationweek.com. [92]

- Daconta, Michael. “Cloud Adoption: Time to Run.” January 2014. Information Week Reports. Reports.informationweek.com. [93]

- Cobb, Michael. “Monitoring Security In Cloud Environments.” October 2013. Information Week Reports. Reports.informationweek.com. [94]

Evaluations of Utility Data Center Programs

U.S. Environmental Protection Agency ENERGY STAR Program. "Understanding and Designing Energy-Efficiency Programs for Data Centers." November, 2012. [69]

The authors provided the following summary for this guide:

> The U.S. Environmental Protection Agency (EPA) is providing this guide to help inform energy efficiency program administrators about opportunities to save energy in data centers, and to share emerging practices for program design and implementation based on the experiences of recent data center programs. Data centers consume up to 50 times the electricity of standard office space. In 2010, between 1.7% and 2.2% of the total electricity use in the United States was consumed by data centers. United States data center electricity use nearly doubled between 2000 and 2005, and increased by approximately 36% between 2005 and 2010. Despite some recent efficiency gains, data centers remain a significant and growing energy end use.2 Industry analysts expect data center energy consumption to continue to grow at a rate of more than 9% per year through 2020 (from a base of 200 trillion end-use BTUs in 2008 to 600 trillion end-use BTUs in 2020).3 Utilities and other energy-efficiency program administrators can play a significant role in helping customers reduce data center operating costs, while also reducing energy demand.
>
> This guide will:
> - Characterize the data center market;
> - Highlight energy-efficiency program opportunities in data centers;
> - Provide an overview of data center programs throughout the country;
> - Discuss the market structure and resulting challenges, and suggest solutions to overcome those challenges;
> - Summarize appropriate program models and measures;
> - Explain program planning strategies and evaluation, measurement, and verification (EM&V) best practices that can mitigate program implementation barriers; and
> - Suggest implementation strategies for data center programs.

"Energy Efficiency Baselines for Data Centers: Statewide Customized New Construction and Customized Retrofit Incentive". November 30, 2011. Prepared by Integral Group Programs for the California Public Utility Commission. [13]

The authors provided the following background for this paper:

> The California Customized incentive programs are designed to help California utility customers save energy by implementing energy efficiency measures. Many market sectors, such as residential and commercial, are served by well-established calculation methods. The industrial sector –in particular, high tech industrial facilities such as laboratories, cleanrooms and data centers – are large consumers of energy, yet are poorly targeted by standard incentive calculations. Customized incentive programs for high tech customers are designed to help the customer go beyond selection of incrementally more efficient components, and push designers and owners to consider new design strategies not normally offered in lowest first- cost situations. Historically, data centers have not received the same level of attention as commercial projects. This leaves ample opportunity to significantly reduce the energy budget for data center facilities by incorporating non-standard but well proven design strategies.

"Process Evaluation of Pacific Gas & Electric Company's 2006-2008 High-Tech Program." May 20, 2009. Prepared by Energy Market Innovation for Pacific Gas and Electric. [55]

The authors provided four of the overarching key findings of the evaluation:

1) Overall, the current program model and delivery appears to be successful.
2) The current program is not scalable to meet increased goals of the 2009 – 2011 program cycle.

3) The Integrated Audits were not used strategically to identify customers with high-tech facilities in need of efficiency improvement.
4) The Program only partially implemented various training and education services specified in the PIP.

"Evaluation, Verification, and Measurement Study FY 2008/2009 Program." December 31, 2009. Prepared by Summit Blue for Silicon Valley Power. [66]

The authors provided the following executive summary for this study:

> Silicon Valley Power (SVP) serves about 51,000 customers and has annual sales approaching 3,000 GWh and a summer peak demand of nearly 500 MW. The largest portion of its electrical sales is to its large commercial and industrial customers (88%) while about 9% of sales are to residential customers. The utility has a high load factor of about 74.6%. SVP owns power generation facilities. More than 30% of its power comes from geothermal, wind, and other eligible renewable sources.
>
> SVP has a number of energy efficiency and renewable energy programs in both the residential and nonresidential sectors. However, 95% of the savings achieved through its energy efficiency programs comes from the non-residential sector. Therefore, the impact evaluation efforts for SVP's FY 08-09 are centered on SVP's non-residential custom projects.
>
> In addition to impact evaluation, the Summit Blue team also performed a process evaluation that focused on colocation data centers. Energy Market Innovations, Inc. (EMI), under sub-contract with Summit Blue, conducted this research to provide targeted information on the colocation data center market in SVP service territory.

Industry and Government White Papers and Technical Bulletins on Energy Efficiency

Bruschi, John. Rumsey, Peter, Anliker, Robin, Chu, Larry, and Gregson, Stuart. "Best Practices Guide for Energy-Efficient Data Center Design." March 2011. [17]

The authors provided the following abstract for this paper:

> This guide provides an overview of best practices for energy-efficient data center design which spans the categories of Information Technology (IT) systems and their environmental conditions, data center air management, cooling and electrical systems, on-site generation, and heat recovery. IT system energy efficiency and environmental conditions are presented first because measures taken in these areas have a cascading effect of secondary energy savings for the mechanical and electrical systems. This guide concludes with a section on metrics and benchmarking values by which a data center and its systems energy efficiency can be evaluated. No design guide can offer 'the most energy-efficient' data center design but the guidelines that follow offer suggestions that provide efficiency benefits for a wide variety of data center scenarios.

"Data Center Site Infrastructure Tier Standard: Operational Sustainability." 2010. Uptime Institute Professional Services, LLC. [40]

The authors provided the following abstract for this paper:

> The Uptime Institute Tier Standard: Operational Sustainability is an objective methodology for data center owners to align the facility management program with the specific tier of installed site infrastructure in order to achieve the organization's business objectives or mission imperatives. Tier Standard: Operational Sustainability establishes the behaviors and risks beyond the Tier Classification System (I, II, III, and IV) that impact long-term data center performance. Tier Standard: Operational Sustainability unifies site management behaviors with the Tier functionality of the site infrastructure.

DRAFT – For Consortium for Energy Efficiency Committee Use Only. "Data Center Energy Efficiency Program Guidance." DRAFT July 13, 2010. [16]

The authors provided the following background for this draft paper:

> This information is intended to serve as guidance for administrators of voluntary energy efficiency programs in the United States and Canada. The intent of the document is to be a resource for efficiency program administrators who are considering developing new data center programs, integrating data center program offerings into existing efficiency programs, or enhancing current data center programs. The content is based on the experiences of participants on the CEE Data Centers and Servers Committee.
>
> The objectives of this guidance document include:
>
> 1. To support greater awareness among energy efficiency program administrators of major data center energy savings opportunities
> 2. To enable energy efficiency program administrators to identify data center efficiency program opportunities, provide examples of program approaches from the CEE membership and identify key program design considerations
> 3. To identify different methods available to baseline and demonstrate energy savings in data centers and key assumptions used in these methods.
>
> There are other potential objectives that this document might serve over time. It will be updated by the CEE Data Center and Servers Committee, as appropriate.

"Energy Logic: Reducing Data Center Energy Consumption by Creating Savings that Cascade Across Systems." 2008. Emerson Network Power. [19]

The authors provided the following executive summary for this paper:

> A number of associations, consultants and vendors have promoted best practices for enhancing data center energy efficiency. These practices cover everything from facility lighting to cooling system design, and have proven useful in helping some companies slow or reverse the trend of rising data center energy consumption. However, most organizations still lack a cohesive, holistic approach for reducing data center energy use. Emerson Network Power analyzed the available energy-saving opportunities and identified the top 10. Each of these 10 opportunities were then applied to a 5,000-square-foot data center model based on real-world technologies and operating parameters. Through the model, Emerson Network Power was able to quantify the savings of each action at the system level, as well as identify how energy reduction in some systems affects consumption in supporting systems.
>
> The model demonstrates that reductions in energy consumption at the IT equipment level have the greatest impact on overall consumption because they cascade across all supporting systems. This led to the development of Energy Logic, a vendor-neutral roadmap for optimizing data center energy efficiency that starts with the IT equipment and progresses to the support infrastructure. This paper shows how Energy Logic can deliver a 50 percent or greater reduction in data center energy consumption without compromising performance or availability.
>
> This approach has the added benefit of removing the three most critical constraints faced by data center managers today: power, cooling and space. In the model, the 10 Energy Logic strategies freed up two-thirds of floor space, one-third of UPS capacity and 40 percent of precision cooling capacity.
>
> All of the technologies used in the Energy Logic approach are available today and many can be phased into the data center as part of regular technology upgrades/refreshes, minimizing capital expenditures.
>
> The model also identified some gaps in existing technologies that could enable greater energy reductions and help organizations make better decisions regarding the most efficient technologies for a particular data center.

Industry and Government White Papers and Technical Bulletins on Efficiency Metrics

"Harmonizing Global Metrics for Data Center Energy Efficiency: Global Taskforce Reaches Agreement Regarding Data Center Productivity". March 13, 2014. The Green Grid. [101]

The author provided the following executive summary for this white paper:

> The data center has become an increasingly important part of most business operations in the twenty-first century. With escalating demand and rising energy prices, it is essential for the owners and operators of these mission-critical facilities to assess and improve data center performance using energy efficiency and greenhouse gas (GHG) emission metrics. However, even with the global presence of many companies, these metrics often are not applied consistently at a global level.
>
> To address these inconsistencies, a group of global leaders has been meeting regularly to agree on standard approaches and reporting conventions for key energy efficiency and GHG emission metrics. These organizations are: the U.S. Department of Energy's Save Energy Now and Federal Energy Management Programs (March 2009 – October 2012); the U.S. Environmental Protection Agency's ENERGY STAR Program; the European Commission Joint Research Centre Data Centres Code of Conduct; Japan's Ministry of Economy, Trade and Industry; Japan's Green IT Promotion Council; and The Green Grid Association.
>
> This current document, the last joint statement from the Taskforce, reflects agreements reached as of March 13, 2014. It provides recommendations for quantifying data center energy productivity and an update regarding data center productivity proxies, thus fulfilling this Taskforce's current objectives.

Avelar, Victor; Azevedo, Dan; French, Alan. "PUE™: A Comprehensive Examination Of The Metric." 2012. The Green Grid. [47]

The author provided the following executive summary for this white paper:

> Power usage effectiveness (PUE™) has become the industry-preferred metric for measuring infrastructure energy efficiency for data centers. The PUE metric is an end-user tool that helps boost energy efficiency in data center operations. It was developed by The Green Grid Association, a non-profit, open industry consortium of end users, policy makers, technology providers, facility architects, and utility companies working to improve the resource efficiency of information technology and data centers throughout the world. Since its original publication in 2007, PUE has been globally adopted by the industry. Over the past years, The Green Grid has continued to refine the metric measurement methodology with collaborative industry feedback. This collective work has been brought together here to simplify the absorption and use of the PUE metric. To produce this document, The Green Grid consolidated all its previously published material related to PUE and included new material as well. This document supersedes prior white papers and consolidates all things that The Green Grid has developed and published relating to PUE. As such, this document is recommended by The Green Grid to those implementing, using, and reporting PUE. Quick access to various levels of information is provided via the links embedded throughout the document. This document allows executives to gain a high level of understanding of the concepts surrounding PUE, while providing in-depth application knowledge and resources to those implementing and reporting data center metrics.

"Future of Data Centre Efficiency Metrics." 2010. The Chartered Institute for IT. [95]

The authors provided the following abstract for this paper:

> This paper reviews the current state of data center energy efficiency metrics, both those proposed and those already in use. The analysis of these metrics concludes that there are underlying, potentially insoluble problems in measuring the IT work or service output of a data center in order to report efficiency. Despite a number of years of work by many skilled parties none of the current or proposed metrics is able to address this issue in a general form. Further, even if these metrics were to be developed, many data centers are operated by more than one party and the areas of responsibility of these parties do not map well onto the parts

of the data center measured by each group of metrics. This mismatch would make it hard to obtain measurements in many data centers and even harder to assign responsibility or target the performance of each party when key components of the targeting metrics are not within their control.

Haas, Jon, Monroe, Mark, Pflueger, John, Pouchet, Jack, Snelling, peter, Rawson, Andy, Rawson, Freeman. "Proxy Proposals for Measuring Data Center Productivity." January, 2009. [99]

The authors provided the following background for this white paper:

> The Green Grid produced a metric to measure productivity of a data center and suggested Data Center Productivity (DCP) be a measure of useful work, divided by total facility power. The Green Grid is proposing that a simple indicator such as DCP can be useful because it will be easier to implement than a metric. The goal of this is to find an easy indicator to substitute for a difficult measurement but provides a substantial indication of useful work completed at data centers. This paper proposes several proxies and is engaging the industry by presenting them and asking for feedback.

"A Framework for Data Center Energy Productivity." 2008. A Green Grid White Paper. [98]

The authors provided the following executive summary for this white paper:

> This paper presents:
>
> - A technical analysis of the problem of assessing the energy efficiency of a data center and the IT equipment that composes the data center,
> - An examination of various power and energy efficiency metrics that have been proposed, and a discussion of their attributes and applicability, and
> - An analysis of ways in which those attributes fall short of providing the comprehensive tools necessary to optimize data center energy utilization.
>
> This paper introduces a new family of data center resource optimization metrics designated collectively as Data Center Productivity (DCP) metrics and presents the first derivative metric within this family called Data Center energy Productivity (DCeP). The DCeP metric provides a unique analytical tool that may be used to track the overall work product of a data center per unit of energy expended to produce this work. While DCeP in its current form is only applicable to improvements in a single data center, it is hoped that this work will provide a framework to develop similar metrics for comparing across different data centers.

Industry and Government White Papers and Technical Bulletins on Cloud Computing

Mims, Christopher. "Amazon And Google Are In An Epic Battle To Dominate The Cloud-And Amazon May Already Have Won." April 16, 2014. [100]

The author provided the following background for this article:

> In technology, it's sometimes good to let a pioneer figure out the pitfalls of a new market. Apple's iPod transformed music listening after countless lesser MP3 players failed to make a real dent. Google is now trying to do something similar in cloud computing. The company last month announced price cuts that made its cloud services cheaper than Amazon's, the leader in cloud services for businesses. At almost the same time, Google orchestrated a flurry of coverage of its cloud services. But whereas music players were a fragmented industry when the iPod appeared, in cloud computing Google is playing catch-up with a single market leader, Amazon, which has a track record of destroying incumbents in every industry it gets into. What Google has in its favor, besides a sheer technical expertise, is that it already runs the biggest cloud-computing operation in the world—just that it puts most of it to a different use. The resulting battle is likely to be epic, and its outcome determines nothing less than who will control the internet.

Cook, Gary. "How Green Is Your Cloud". Greenpeace. 2012. [73]

Greenpeace analyses the environmental impacts of data centers run by the cloud services industry, including scoring of energy efficiency, reporting, procurement of renewable power, and general power sourcing. The author provided the following executive summary for this article:

> Facebook, Amazon, Apple, Microsoft, Google, and Yahoo – these global brands and a host of other IT companies are rapidly and fundamentally transforming the way in which we work, communicate, watch movies or TV, listen to music, and share pictures through "the cloud." The growth and scale of investment in the cloud is truly mind-blowing, with estimates of a 50-fold increase in the amount of digital information by 2020 and nearly half a trillion in investment in the coming year, all to create and feed our desire for ubiquitous access to infinite information from our computers, phones and other mobile devices, instantly.

Pierre, Delforge. "Is Cloud Computing Always Greener? Finding the Most Energy and Carbon Efficient Information Technology Solutions for Small- and Medium-Sized Organizations." October, 2012. NRDC Issue Brief. [71]

The NRDC compares the relative environmental impacts of IT equipment use for customer-operated data centers and for "cloud" IT services. The conclusion is that well-managed data centers can match the energy efficiency performance of cloud services, though cloud providers can further reduce their environmental impact based on their power sourcing. The author provided the following summary for this article:

> As a growing number of small- and medium-sized organizations (SMOs), such as private companies, hospitals, government agencies and educational institutions, seek to improve the energy efficiency of their Information Technology (IT) operations by moving computing applications to an Internet-based "cloud" platform, it is becoming increasingly important to understand the associated energy and climate impacts. Until now there was no independent analysis to establish whether this system of Internet-based shared servers for multiple customers is indeed the most eco-friendly choice. To uncover the major factors determining how on-premise server rooms and cloud computing stack up in carbon emissions and energy savings, the Natural Resources Defense Council and WSP Environment & Energy have partnered on groundbreaking research, examining five different scenarios with the goal of making it easier for companies to compare options and consider sustainability in their decision-making.

Masero, Sonny. "Powering the Cloud: Maintaining Service Availability and Reducing Data Center Costs with Effective Power Management." November 2011. White Paper by CA Technologies. [33]

The author provided the following abstract for this white paper:

> Challenge
> As data center technologies evolve and energy prices soar, power consumption has become a driving force behind operational and investment decisions. For cloud and IT service providers, continuity of supply to the data center can also have a major financial impact on their operations and reputation in the marketplace. To mitigate such problems, organizations need to take a more proactive approach to operational power management and service assurance.
>
> Opportunity
> Although many organizations have started to measure key energy efficiency metrics, such as PUE, this is not sufficient for day-to-day power management. By deploying a data center power management solution, IT and facilities departments can gain a holistic view of demand and consumption at a device, circuit and even phase level.
>
> Benefits
> A single pane view of power consumption means that costs, demand and carbon emissions can be measured and managed in real-time on an ongoing basis. As a result, organizations will be able to maximize the utilization of their data center assets, decrease the consumption of kWh/m2 (and CO_2/m2) and associated

operating cost per m2 and develop more accurate billing models for internal and external cloud-based services.

Industry and Government White Papers and Technical Bulletins on Small Data Centers

"Small Data Center Market Study." December 27, 2013. Prepared for PG&E by Cadmus, Bramfitt Consulting and PECI. [100]

> This study examined the untapped small data center (SDC) market, including: localized data centers (rooms with less than 1,000 square feet of white space); server rooms (less than 500 square feet); and server closets (less than 200 square feet). The study included 34 in-depth informational interviews with SDC managers of small medium business (SMB) customers; 18 in-depth informational interviews with information technology (IT) vendors (equipment manufacturers, value-added resellers [VARs], IT service providers, and system integrators); and surveys of over 320 SMB customers to establish which types of SMBs had SDCs. The study concluded that: about half of SMBs have SDCs; SDC managers, typically IT staff, were very difficult to reach for in-depth interviews (over 1,000 organizations were contacted to complete 34 interviews); decision-making is complex as IT vendors; and energy efficiency was not a priority at the SDCs.

Bennett, Drew; Delforge, Pierre. "Small Server Rooms, Big Energy Savings". February, 2012. NRDC Issue Paper. [72]

This NRDC white paper describes the energy efficiency opportunities applicable to server rooms, closets, and small localized data centers. The author provided the following summary for this article:

> Small server rooms house over half of all computer servers in the United States, accounting for approximately 1 percent of all electricity use in the country. Administrators of server rooms have been slow to adopt best practices in energy efficient operations, despite the fact that server rooms represent a large share of data centers' electricity use. A new survey by the Natural Resources Defense Council (NRDC) suggests this gap is poised to increase over the coming years without policy intervention.

Delforge, Pierre. "Are There Ghosts in Your Closet? Saving Wasted Energy in Computer Server Rooms." February, 2012. NRDC white paper. [70]

NRDC provides a general account of energy savings opportunities in the small server room market, both from a national perspective, and for the individual facilities themselves. The author provided the following summary for this article:

> Computer servers and the facilities that house them, from the server closet in your office to the warehouse scale data center in a business park, are the hidden side of your digital life. When you talk on your cell phone, tweet or chat on social networking sites, shop and bank online, email at work or at home, you are using a web of servers located all over the internet. This fast growing army of servers is powering the digital economy, enriching people's lives, creating jobs, and supporting economic growth. It is also responsible for wasting massive amounts of energy. All U.S. data centers together are estimated to consume over 75 billion kWh annually, equivalent to the output of 26 medium sized coal-fired power plants. NRDC estimates that half of this energy—equivalent to the output of 13 power plants—is going to waste. By taking steps to lower and optimize energy use in server rooms, companies can reduce carbon pollution while saving money.

"Google's Green Data Centers: Network POP Case Study." 2011. Google Inc. [15]

> Google facilities claim to use approximately half of the energy of a typical energy center. This paper is intended to describe retrofit measures Google employed in their numerous propriety data centers and smaller networking rooms called POPS or "Points of Presence". Google spent $25,000 to optimize data center room's

airflow and reduce air conditioner use, in plastic curtains, air return extensions, and a new air conditioner controller that returned a savings of $67,000/year.

Industry and Government Papers on IT Equipment Efficiency

Niles, Suzanne, and Donovan, Patrick. "Virtualization and Cloud Computing: Optimized Power, Cooling, and Management Maximizes Benefits." 2011. White Paper 118: Revision 3 by Schneider Electric. [43]

The authors provided the following executive summary for this white paper:

> IT virtualization, the engine behind cloud computing, can have significant consequences on the data center physical infrastructure (DCPI). Higher power densities that often result can challenge the cooling capabilities of an existing system. Reduced overall energy consumption that typically results from physical server consolidation may actually worsen the data center's power usage effectiveness (PUE). Dynamic loads that vary in time and location may heighten the risk of downtime if rack-level power and cooling health are not understood and considered. Finally, the fault-tolerant nature of a highly virtualized environment could raise questions about the level of redundancy required in the physical infrastructure. These particular effects of virtualization are discussed and possible solutions or methods for dealing with them are offered.

"How VMware Virtualization Right-sizes IT Infrastructure to Reduce Power Consumption." 2011. Whitepaper: VMware. [48]

The authors provided the following background for this article:

> Rising energy costs and consumption in datacenters is a hot topic, whether you care about saving money, deploying new IT services, keeping the datacenter running or sparing the environment. As energy climbs the list of corporate priorities, "Green IT" solutions are proliferating. Prioritizing potential fixes is not easy amidst this flood of information. There is no silver bullet, but virtualization often tops the list because it right-sizes the largest culprits of energy over-consumption – underutilized x86 desktops and servers. In typical environments these machines sit idle almost all of the time, consuming significant amounts of power. VMware solutions help customers safely consolidate these machines onto much less hardware, both through initial consolidation efforts and dynamically as computing requirements change. This white paper explains how innovations in virtualization technology from VMware provide a foundation for a dramatically more efficient and greener IT environment.

"V-Index: Virtualization Penetration Rate in the Enterprise." 2011. Veeam Software. [68]

The authors provided the following summary for this report:

> The V-index tracks the penetration of virtualization across the server estates of at least 500 large-scale enterprises across the United States, United Kingdom, France and Germany (in the Q3 V-index, 578 enterprises were surveyed. In the Q2 V-index, 544 enterprises were surveyed). The aim is to take an ongoing snapshot of the penetration rate of virtualization and thereby highlight potential trends and issues that affect its progress towards becoming the de facto IT platform. This quarter the V-index has been updated to include enterprise use of virtual desktop infrastructures and factors influencing changes in hypervisor purchasing. A study was conducted in Q3 2011 and Q2 2011 by Vanson Bourne, an independent market research company.

Reinsel, David. "Industry Developments and Models: A Plateau in Sight for the Rising Costs to Power and Cool the World's External Storage?" 2010. IDC Opinion. [25]

The author provided the following summary for this paper:

> This study evaluates enterprise storage power and cooling costs in light of the economic crisis that began in 2008, the increasing adoption of storage efficiency technologies, and the change in assumptions around the

adoption of more efficient hardware technology (e.g., small form factor HDDs and SSDs). Within this study, IDC updates the total number of spinning disks in enterprise external storage today and estimates the real costs associated with powering and cooling these disks through 2014. It also puts this cost in perspective to the overall annual costs of acquiring and managing storage hardware.

"Datacenter Efficiency: Executive Strategy Brief." 2010. Microsoft Corporation. [38]

The authors provided the following summary for this executive strategy brief:

Operating highly-efficient datacenters is imperative as more consumers and companies move to a cloud computing environment. With high energy costs and pressure to reduce carbon emissions, datacenter operators need to accurately measure and continually innovate in order to optimize power usage and environmental sustainability. This strategy brief discusses the factors that affect efficiency at the component, server, and system level; a holistic approach to right-sizing servers and datacenter infrastructure; and Microsoft's strategy for improving datacenter efficiency in future designs.

Talaber, Richard, Brey, Tom, and Lamers, Larry. "Using Virtualization to Improve Data Center Efficiency." 2009. White Paper 19: The Green Grid. [44]

The authors provided the following abstract for this white paper:

This paper outlines some of the advantages, considerations, processes, and implementation strategies needed to reduce server power consumption in a data center using virtualization techniques. Virtualization has long held the promise of energy savings due to its server consolidation capabilities. This paper provides those responsible for reducing energy consumption with a description of the advantages and processes that should be considered when virtualizing servers in the data center.

Industry and Government Papers on Cooling and Power Equipment Efficiency

Strutt, Steve. "Data Center Efficiency and IT Equipment Reliability at Wider Operating Temperature and Humidity Ranges." 2012. White Paper 50: The Green Grid. [46]

The author provided the following executive summary for this white paper:

The paper concludes that many data centers can realize overall operational cost savings by leveraging looser environmental controls within the wider range of supported temperature and humidity limits as established by equipment manufacturers. Given current historical data available, data centers can achieve these reductions without substantively affecting IT reliability or service availability by adopting a suitable environmental control regime that mitigates the effects of short-duration operation at higher temperatures. Further, given recent industry improvements in IT equipment efficiency, operating at higher supported temperatures may have little or no overall impact on system reliability. Additionally, some of the emerging IT solutions are designed to operate at these higher temperatures with little or no increase in server fan energy consumption. How organizations deploy wider operating ranges may be influenced by procurement lifecycles and equipment selection decisions.

Navarro, George, and Thrash, Brad. "Evaluation of Eco Mode in Uninterruptible Power Supply Systems." 2012. White Paper 48: The Green Grid. [45]

The authors provided the following executive summary for this white paper:

The Green Grid Association, a non-profit, open industry consortium working to improve the resource efficiency of information technology (IT) and data centers throughout the world, developed this white paper to provide data center owners, operators, and designers with an evaluation of uninterruptible power supply (UPS) EcoMode operation. The Eco Mode feature can improve data center efficiency and power usage effectiveness (PUE™) when appropriately designed and deployed. In fact, The Green Grid Data Center Maturity Model (DCMM) identifies UPS Eco Mode deployment as one of its energy savings recommendations. This white paper explores in detail the application considerations for UPS Eco Mode performance and makes recommendations regarding other power distribution equipment (e.g., static switches) needed to ensure a reliable power system.

The deployment of UPS Eco Mode also requires an understanding of the power quality and ride-through requirements of modern IT power supplies in server, network and storage equipment. This white paper gives a perspective on the latest voltage and ride-through capabilities for modern IT power supplies. Because knowledge of the utility grid power quality is important to optimize UPS Eco Mode operation, The Green Grid also provides suggestions for evaluating utility grid power quality. In addition, the white paper discusses the energy efficiency gains and economic benefits of UPS Eco Mode, illustrated by examples of improvements for various types of data centers.

EPA ENERGY STAR. “EBay Data Center Retrofits: The Costs and Benefits of Ultrasonic Humidification and Variable Speed Drives.” March 2, 2012. Sponsored by U.S. EPA and DOE. [54]

The authors provided the following parts of the introduction for this report:

The design and construction of eBay’s new flagship $287 million data center facility1 has incorporated a myriad of energy-efficiency measures. In addition, eBay considers retrofitting existing data center facilities a top priority. eBay’s 139,000 square foot data center (65,000 square feet of white space) in Phoenix houses2 all of eBay’s business units. This facility, built in 2004, has been the target of numerous energy-efficiency upgrades. This case study describes the costs and benefits deriving from two retrofit measures eBay employed in its Phoenix facility: ultrasonic humidification; and variable speed drives (VSDs). If implemented effectively, both measures can yield cost-effective energy savings. Table 1 presents these measures’ simple paybacks (costs divided by annual energy savings), with and without incentives from Arizona Public Service (APS) Company. Ultrasonic humidification pays for itself in half a year with incentives, and in less than 2.0 years without incentives. VSDs pay for themselves in 1.6 years with incentives and 2.6 years without incentives.

Robbins, David, and Skiff, Mark. “Breaking Down the Glass House: NetApp Global Dynamic Lab Delivers Higher Power Density, Greater Efficiency, and Lower Capital and Operating Costs.” May 2010. NetApp. [52]

The authors provided the following abstract for this paper:

Designing, building, and operating a modern data center is an expensive proposition. Faced with the need for a facility capable of simulating the loads of large-scale data centers in order to fully test our storage products, NetApp used every innovation possible in its Global Dynamic Laboratory (GDL). By tailoring the facility to meet our specific needs and using cooling with ambient air, an innovative building design, and careful project planning, NetApp was able to reduce construction costs by more than two-thirds and annual operating costs by approximately 60%, while at the same time delivering 7 times more power and cooling to meet the needs created by densely packed equipment racks filled with the most up-to-date equipment. This white paper describes the GDL design and implementation.

Hydeman, Mark, Swenson, David. “Controls for Data Centers Are They Necessary?” March, 2010. American Society of Heating, Refrigerating and Air-Conditioning Engineers. [50]

ASHRAE journal article found that high humidity is rarely an issue in most data centers and concluded that "it is difficult to make a case for actively controlling humidity in data centers." Typically, the temperature of IT equipment is significantly higher than that of the cooling coils' operating dew-point. Furthermore, most IT equipment is rated for operation up to 80% RH. The study states that humidification appears to be unnecessary if you follow best practices for electrostatic discharge: use IT equipment rated and tested for

ESD conformance with IEC61000-4-2, and, where personnel handle electronic circuit boards and components, use personnel grounding procedures.

Rasmussen, Neil and Spitaels, James. “A Quantitative Comparison of High Efficiency AC vs. DC Power Distribution for Data Centers.” 2010. Schneider Electric White Paper 127. [9]

The authors provided the following executive summary for this white paper:

> This paper presents a detailed quantitative efficiency comparison between the most efficient DC and AC power distribution methods, including an analysis of the effects of power distribution efficiency on the cooling power requirement and on total electrical consumption. The latest high efficiency AC and DC power distribution architectures are shown to have virtually the same efficiency, suggesting that a move to a DC-based architecture is unwarranted on the basis of efficiency.

Bouley, Dennis. “Fundamentals of Data Center Power and Cooling Efficiency Zones.” 2009. From the 2nd Annual Green Grid Technical Forum. Schneider Electric. [22]

> This study provides information about how to calculate free cooling hours. It provides step by step instructions on what to measure and how, referencing other Green Grid studies.

Bouley, Dennis and Brey, Tom. “Fundamentals of Data Center Power and Cooling Efficiency Zones.” March 4, 2009. White Paper: The Green Grid. [23]

The authors provided the following short executive summary for this white paper:

> Data center efficiency is impacted by physical infrastructure equipment residing both inside and outsideof the physical data center. This paper provides a comprehensive overview of where the power and cooling efficiency losses are likely to occur, and offers suggestions regarding how to correct the inefficiencies.

“Five Strategies for Cutting Data Center Energy Costs Through Enhanced Cooling Efficiency.” 2007. Emerson Network Power. [21]

The authors provided the following executive summary for this paper:

> As electricity prices and IT power consumption continue to rise, IT-related energy costs are getting increased scrutiny. Cooling accounts for approximately 37 percent of electricity usage within a well-designed data center and, in many cases, represents a significant opportunity to reduce IT energy costs.
>
> This paper presents five strategies for increasing data center cooling efficiency:
> 1. Proper sealing of the data center environment
> A vapor seal plays a critical role in controlling relative humidity, reducing unnecessary humidification and dehumidification.
> 2. Optimizing air flow
> Rack arrangement, computer room air conditioner placement and cable management all impact the amount of energy expended to move air within the critical facility.
> 3. Using economizers where appropriate
> Economizers allow outside air to be used to support data center cooling during colder months, creating opportunities for energy-free cooling.
> 4. Increasing cooling system efficiency
> New technologies, such as variable capacity systems and improved controls, are driving increased efficiency of room air conditioning systems.
> 5. Bringing cooling closer to the source of heat
> Supplemental cooling systems bring cooling closer to the source of heat, reducing the amount of energy required for air movement.

> Together, these methods can reduce cooling system energy costs by 30 to 45 percent and generate significant, recurring savings. Coupled with emerging technologies such as higher-efficiency processors and new chip-based cooling technologies, these measures can keep energy costs in line as server densities and the price of energy continue to rise.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has issued a series of books and white papers regarding the HVAC considerations in data centers. These documents range from general guidance to cooling a data center to specific issues such as liquid cooling, high density data center, and temperatures and humidity levels. The documents are listed below.

- ASHRAE Technical Committee (TC) 9.9 Mission Critical Facilities, Technology Spaces, and Electronic Equipment. "2011 Thermal Guidelines for Data Processing Environments." 2011. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. [11]
- Suttile, Zachary. "Particulate and Gaseous Contamination in Datacom Environments." 2009. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. [5]
- Suttile, Zachery. "Design Considerations for Datacom Equipment Centers, Second Edition." 2009. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. [2]
- Suttile, Zachary. "Real-Time Energy Consumption Measurements in Data Centers." 2009. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. [8]
- Suttile, Zachary. "Best Practices for Datacom Facility Energy Efficiency, Second Edition." 2009. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. [7]
- Suttile, Zachary. "High Density Data Centers: Case Studies and Best Practices." 2008. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. [4]
- Suttile, Zachary. "Structural and Vibration Guidelines for Datacom Equipment Centers." 2007. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. [6]
- Suttile, Zachary. "Liquid Cooling Guidelines for Datacom Equipment Centers." 2006. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. [3]
- Suttile, Zachary. "Datacom Equipment Power Trends and Cooling Applications." 2005. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. [1]

Industry and Government Papers on Air Flow Management

EPA ENERGY STAR. "EBay Data Center Retrofits: The Costs and Benefits of Ultrasonic Humidification and Variable Speed Drives." March 2, 2012. Sponsored by U.S. EPA and DOE. [54]

The authors provided the following parts of the introduction for this report:

> The design and construction of eBay's new flagship $287 million data center facility1 has incorporated a myriad of energy-efficiency measures. In addition, eBay considers retrofitting existing data center facilities a top priority. eBay's 139,000 square foot data center (65,000 square feet of white space) in Phoenix houses2 all of eBay's business units. This facility, built in 2004, has been the target of numerous energy-efficiency upgrades. This case study describes the costs and benefits deriving from two retrofit measures eBay employed in its Phoenix facility: ultrasonic humidification; and variable speed drives (VSDs). If implemented effectively, both measures can yield cost-effective energy savings. Table 1 presents these measures' simple paybacks (costs divided by annual energy savings), with and without incentives from Arizona Public Service (APS) Company. Ultrasonic humidification pays for itself in half a year with incentives, and in less than 2.0 years without incentives. VSDs pay for themselves in 1.6 years with incentives and 2.6 years without incentives.

Mathew, Paul; Tschudi, William; Edgar, David. "Data Center Airflow Management Retrofit." U.S. Department of Energy DOE/Technical Case Study Bulletin. September 2010. [10]

The authors provided the following summary for this report:

> As data center energy densities, measured in power-use per square foot, increase, energy savings for cooling can be realized by optimizing airflow pathways within the data center. Due to constraints from under-floor dimensions, obstructions, and leakage, this is especially important in existing data centers with typical under-floor air distribution. Fortunately, airflow-capacity can be improved significantly in most data centers, as described below in the airflow management overview. In addition, a generalized air management approach is provided listing measures to improve data center airflow. This case study bulletin presents air management improvements that were retrofitted in an older legacy data center at Lawrence Berkeley National Laboratory (LBNL). Particular airflow improvements, performance results, and benefits are reviewed. Finally, a series of lessons learned gained during the retrofit project at LBNL is presented.

Christian Belady. "Technical Note: Using EC Plug Fans to Improve Energy Efficiency of Chilled Water Cooling Systems in Large Data Centers." 2008. Emerson Network Power. [34]

The authors provided the following conclusion to this technical note:

> Based on the performance tests discussed in this application note, it is clear that operating the fan motor at lower speeds using EC plug fans or VFD provides substantial energy savings in the large data centers with chilled water cooling systems. It is easy to upgrade an installed Liebert Deluxe System/3 to VFD for the energy savings that solution offers. With new installations, the VFD offers lower capital costs compared to the EC plug fan, so it is a good option when budget constraints rule out installation of EC plug fans. In raised floor data centers in which it can be used to best advantage, however, the EC plug fan offers the lowest annual operating cost and is the best solution for the life of the product.

Appendix B1: Data Center Manager Implementation and Interest Results

Appendix B1 – Data Center Manager Implementation and Interest Results

Manager Implementation

Enterprise IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	0	18	0	2	20
Decommissioning of unused servers	0	12	3	5	20
Energy-efficient servers	0	9	2	9	20
Energy efficient data storage management*	2	3	3	12	20
Passive optical network**	1	3	9	7	20
Solid state storage	2	7	5	6	20
Massive array of idle disks (MAID)	2	3	10	5	20
Direct liquid cooling of chips	2	1	8	9	20
Server power management***	0	8	3	9	20

Mid-Tier IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	1	18	3	3	25
Decommissioning of unused servers	0	15	4	6	25
Energy-efficient servers	1	11	6	7	25
Energy efficient data storage management*	0	9	6	10	25
Passive optical network**	1	5	18	1	25
Solid state storage	1	7	11	6	25
Massive array of idle disks (MAID)	5	0	17	3	25
Direct liquid cooling of chips	6	1	16	2	25
Server power management***	1	8	11	5	25

Localized IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	2	15	1	3	21
Decommissioning of unused servers	0	14	2	5	21
Energy-efficient servers	1	10	4	6	21
Energy efficient data storage management*	3	11	3	4	21
Passive optical network**	4	2	9	6	21
Solid state storage	3	8	7	3	21
Massive array of idle disks (MAID)	7	2	10	2	21
Direct liquid cooling of chips	1	1	17	2	21
Server power management***	0	9	6	6	21

Server Room IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	1	15	4	4	24
Decommissioning of unused servers	1	16	3	4	24
Energy-efficient servers	5	9	8	2	24
Energy efficient data storage management*	5	6	7	6	24
Passive optical network**	10	1	10	3	24
Solid state storage	3	4	12	5	24
Massive array of idle disks (MAID)	7	0	16	1	24
Direct liquid cooling of chips	5	0	19	0	24
Server power management***	1	9	10	4	24

Server Closet IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	1	3	0	0	4
Decommissioning of unused servers	1	3	0	0	4
Energy-efficient servers	2	0	1	1	4
Energy efficient data storage management*	2	0	1	1	4

Passive optical network**	3	0	1	0	4
Solid state storage	3	0	1	0	4
Massive array of idle disks (MAID)	3	0	1	0	4
Direct liquid cooling of chips	2	0	2	0	4
Server power management***	3	0	1	0	4

Enterprise Power Infrastructure

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Wind Power	1	1	18	0	20
Solar Power	1	1	15	3	20
Combined Heat and Power	3	3	6	8	20
Polymer Membranes	2	0	18	0	20
Solid Oxide Fuel Cells	3	0	17	0	20
Energy Efficient UPS	0	12	3	5	20
Data Center Current	1	2	12	5	20

Mid-Tier Power Infrastructure

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Wind Power	2	1	20	2	25
Solar Power	0	2	21	2	25
Combined Heat and Power	2	4	14	5	25
Polymer Membranes	1	1	22	1	25
Solid Oxide Fuel Cells	3	0	20	2	25
Energy Efficient UPS	0	13	10	2	25
Data Center Current	1	8	13	3	25

Localized Power Infrastructure

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Wind Power	1	1	17	2	21
Solar Power	1	1	16	3	21

Combined Heat and Power	6	4	9	2	21
Polymer Membranes	4	1	13	3	21
Solid Oxide Fuel Cells	5	1	13	2	21
Energy Efficient UPS	4	8	6	3	21
Data Center Current	2	4	10	5	21

Server Rooms Power Infrastructure

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Wind Power	2	2	20	0	24
Solar Power	2	1	19	2	24
Combined Heat and Power	3	1	20	0	24
Polymer Membranes	3	0	21	0	24
Solid Oxide Fuel Cells	4	0	19	1	24
Energy Efficient UPS	3	11	6	4	24
Data Center Current	5	2	15	2	24

Server Closet Power Infrastructure

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Wind Power	1	0	3	0	4
Solar Power	1	0	2	1	4
Combined Heat and Power	1	0	2	1	4
Polymer Membranes	1	0	2	1	4
Solid Oxide Fuel Cells	1	0	2	1	4
Energy Efficient UPS	0	1	2	1	4
Data Center Current	0	0	3	1	4

Enterprise Airflow Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Computational Fluid Dynamics (CFD) Optimization	2	4	11	3	20
Blanking Panels	2	6	8	4	20
Hot or Cold Aisle Configuration	0	13	3	4	20

Hot or Cold Aisle Configuration plus Containment	1	6	10	3	20

Mid-Tier Airflow Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Computational Fluid Dynamics (CFD) Optimization	0	2	19	4	25
Blanking Panels	2	10	9	4	25
Hot or Cold Aisle Configuration	0	14	9	2	25
Hot or Cold Aisle Configuration plus Containment	0	5	17	3	25

Localized Airflow Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Computational Fluid Dynamics (CFD) Optimization	5	2	10	4	21
Blanking Panels	4	4	8	5	21
Hot or Cold Aisle Configuration	2	9	6	4	21
Hot or Cold Aisle Configuration plus Containment	3	2	10	6	21

Server Room Airflow Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Computational Fluid Dynamics (CFD) Optimization	4	0	20	0	24
Blanking Panels	4	7	12	1	24
Hot or Cold Aisle Configuration	4	7	13	0	24
Hot or Cold Aisle Configuration plus Containment	5	2	16	1	24

Server Closet Airflow Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Computational Fluid Dynamics (CFD) Optimization	1	0	3	0	4
Blanking Panels	1	0	3	0	4
Hot or Cold Aisle Configuration	0	1	3	0	4
Hot or Cold Aisle Configuration plus Containment	0	0	4	0	4

Enterprise HVAC Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
DCIM	2	12	3	3	20
Containerized Data Center	2	3	7	8	20
Variable Speed Drives on Pumps/Fans	0	11	6	3	20
Premium Efficiency Motors	2	3	6	9	20
ASHRAE Recommended Temperature	2	2	10	6	20
Air-side Economizer	1	6	10	3	20
In-row Cooling	1	12	2	5	20
Waste Heat Recovery	1	1	8	10	20
Water-side Economizer	2	5	9	4	20

Mid-Tier HVAC Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
DCIM	2	12	7	4	25
Containerized Data Center	3	2	16	4	25
Variable Speed Drives on Pumps/Fans	4	8	8	5	25
Premium Efficiency Motors	7	6	9	3	25
ASHRAE Recommended Temperature	3	7	14	1	25
Air-side Economizer	6	3	15	1	25
In-row Cooling	2	8	11	4	25
Waste Heat Recovery	5	3	14	3	25
Water-side Economizer	6	2	15	2	25

Localized HVAC Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
DCIM	5	4	7	5	21
Containerized Data Center	4	5	11	1	21
Variable Speed Drives on Pumps/Fans	5	4	8	4	21
Premium Efficiency Motors	4	3	11	3	21

ASHRAE Recommended Temperature	3	4	12	2	21
Air-side Economizer	3	1	12	5	21
In-row Cooling	3	5	11	2	21
Waste Heat Recovery	4	2	11	4	21
Water-side Economizer	3	1	15	2	21

Server Room HVAC Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
DCIM	4	4	15	1	24
Containerized Data Center	6	3	14	1	24
Variable Speed Drives on Pumps/Fans	5	8	10	1	24
Premium Efficiency Motors	6	3	15	0	24
ASHRAE Recommended Temperature	8	2	13	1	24
Air-side Economizer	4	3	17	0	24
In-row Cooling	6	5	12	1	24
Waste Heat Recovery	4	2	17	1	24
Water-side Economizer	4	2	18	0	24

Server Closet HVAC Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
DCIM	1	1	2	0	4
Containerized Data Center	2	0	2	0	4
Variable Speed Drives on Pumps/Fans	2	1	1	0	4
Premium Efficiency Motors	1	0	3	0	4
ASHRAE Recommended Temperature	1	0	3	0	4
Air-side Economizer	0	0	3	1	4
In-row Cooling	0	0	4	0	4
Waste Heat Recovery	0	0	4	0	4
Water-side Economizer	0	0	4	0	4

Enterprise Humidity Implementation					
Turn off Humidifiers	1	7	8	4	20
Broaden Humidity Range	1	4	8	7	20
Install Misters/Ultrasonic Humidifiers	1	2	12	5	20
Mid-Tier Humidity Implementation					
Turn off Humidifiers	2	6	17	0	25
Broaden Humidity Range	3	7	14	1	25
Install Misters/Ultrasonic Humidifiers	3	5	16	1	25
Localized Humidity Implementation					
Turn off Humidifiers	1	7	10	3	21
Broaden Humidity Range	1	5	12	3	21
Install Misters/Ultrasonic Humidifiers	4	2	11	4	21
Server Room Humidity Implementation					
Turn off Humidifiers	3	4	15	2	24
Broaden Humidity Range	2	3	18	1	24
Install Misters/Ultrasonic Humidifiers	2	0	22	0	24
Server Closet Humidity Implementation					
Turn off Humidifiers	0	1	3	0	4
Broaden Humidity Range	0	0	3	1	4
Install Misters/Ultrasonic Humidifiers	0	0	4	0	4

Manager Interest

Enterprise IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	0	0	0	0
Decommissioning of unused servers	0	1	2	3
Energy-efficient servers	0	2	0	2
Energy efficient data storage management*	1	4	0	5
Passive optical network**	4	2	4	10
Solid state storage	1	3	3	7
Massive array of idle disks (MAID)	4	1	7	12
Direct liquid cooling of chips	3	4	3	10
Server power management***	0	3	0	3

Mid-Tier IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	1	3	0	4
Decommissioning of unused servers	0	3	1	4
Energy-efficient servers	1	5	1	7
Energy efficient data storage management*	1	4	1	6
Passive optical network**	1	14	4	19
Solid state storage	1	9	2	12
Massive array of idle disks (MAID)	5	12	5	22
Direct liquid cooling of chips	7	9	6	22
Server power management***	1	3	0	4

Localized IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	0	2	1	3
Decommissioning of unused servers	0	2	0	2

Energy-efficient servers	1	4	0	5
Energy efficient data storage management*	1	5	0	6
Passive optical network**	7	3	3	13
Solid state storage	3	6	1	10
Massive array of idle disks (MAID)	11	2	4	17
Direct liquid cooling of chips	7	5	6	18
Server power management***	0	3	3	6

Server Room IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	5	6	3	14
Decommissioning of unused servers	1	2	1	4
Energy-efficient servers	1	9	3	13
Energy efficient data storage management*	3	6	3	12
Passive optical network**	7	1	12	20
Solid state storage	3	7	5	15
Massive array of idle disks (MAID)	8	8	7	23
Direct liquid cooling of chips	6	3	15	24
Server power management***	1	5	5	11

Server Closet IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	1	0	0	1
Decommissioning of unused servers	0	0	1	1
Energy-efficient servers	0	2	1	3
Energy efficient data storage management*	0	2	1	3
Passive optical network**	1	2	1	4
Solid state storage	1	1	2	4
Massive array of idle disks (MAID)	1	1	2	4
Direct liquid cooling of chips	0	2	2	4
Server power management***	0	3	1	4

Enterprise Renewables

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	1	5	13	19
Solar Power	1	7	8	16
Combined Heat and Power	2	4	3	9
Polymer Membranes	5	6	9	20
Solid Oxide Fuel Cells	7	5	8	20
Energy Efficient UPS	0	2	1	3
Data Center Current	0	7	6	13

Mid-Tier Renewables

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	3	7	12	22
Solar Power	3	11	7	21
Combined Heat and Power	4	6	6	16
Polymer Membranes	3	11	9	23
Solid Oxide Fuel Cells	4	12	7	23
Energy Efficient UPS	0	8	2	10
Data Center Current	1	9	4	14

Localized Renewables

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	3	4	11	18
Solar Power	3	6	8	17
Combined Heat and Power	5	7	3	15
Polymer Membranes	5	5	7	17
Solid Oxide Fuel Cells	7	4	7	18
Energy Efficient UPS	2	8	0	10
Data Center Current	3	7	2	12

Server Room Renewables

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	5	1	16	22
Solar Power	5	8	8	21
Combined Heat and Power	9	5	9	23
Polymer Membranes	8	2	14	24
Solid Oxide Fuel Cells	10	2	11	23
Energy Efficient UPS	2	5	2	9
Data Center Current	9	3	8	20

Server Closet Renewables

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	0	0	4	4
Solar Power	0	1	2	3
Combined Heat and Power	0	0	3	3
Polymer Membranes	0	0	3	3
Solid Oxide Fuel Cells	0	0	3	3
Energy Efficient UPS	0	0	2	2
Data Center Current	0	1	2	3

Enterprise Airflow Interest

Technology	Don't Know	Interested	Not Interested	Total
Computational Fluid Dynamics (CFD) Optimization	2	5	6	13
Blanking Panels	1	5	4	10
Hot or Cold Aisle Configuration	1	1	1	3
Hot or Cold Aisle Configuration plus Containment	1	6	4	11

Mid-Tier Airflow Interest

Technology	Don't Know	Interested	Not Interested	Total
Computational Fluid Dynamics (CFD) Optimization	1	11	7	19

Blanking Panels	3	7	1	11
Hot or Cold Aisle Configuration	0	6	3	9
Hot or Cold Aisle Configuration plus Containment	0	15	2	17

Localized Airflow Interest

Technology	Don't Know	Interested	Not Interested	Total
Computational Fluid Dynamics (CFD) Optimization	6	3	6	15
Blanking Panels	3	4	5	12
Hot or Cold Aisle Configuration	3	2	3	8
Hot or Cold Aisle Configuration plus Containment	4	4	5	13

Server Room Interest

Technology	Don't Know	Interested	Not Interested	Total
Computational Fluid Dynamics (CFD) Optimization	7	2	15	24
Blanking Panels	6	2	8	16
Hot or Cold Aisle Configuration	4	5	8	17
Hot or Cold Aisle Configuration plus Containment	6	4	11	21

Server Closest Interest

Technology	Don't Know	Interested	Not Interested	Total
Computational Fluid Dynamics (CFD) Optimization	0	0	4	4
Blanking Panels	0	0	4	4
Hot or Cold Aisle Configuration	0	0	3	3
Hot or Cold Aisle Configuration plus Containment	0	0	4	4

Enterprise HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	1	2	2	5
Containerized Data Center	2	2	5	9
Variable Speed Drives on Pumps/Fans	0	4	2	6

Premium Efficiency Motors	2	5	1	8
ASHRAE Recommended Temperature	1	6	5	12
Air-side Economizer	1	5	5	11
In-row Cooling	1	1	1	3
Waste Heat Recovery	1	4	4	9
Water-side Economizer	2	9	6	17

Mid-Tier HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	3	6	0	9
Containerized Data Center	3	5	11	19
Variable Speed Drives on Pumps/Fans	5	4	3	12
Premium Efficiency Motors	7	6	3	16
ASHRAE Recommended Temperature	3	11	3	17
Air-side Economizer	6	12	3	21
In-row Cooling	4	7	2	13
Waste Heat Recovery	7	8	4	19
Water-side Economizer	6	14	4	24

Localized HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	4	6	2	12
Containerized Data Center	3	5	7	15
Variable Speed Drives on Pumps/Fans	5	6	2	13
Premium Efficiency Motors	5	8	2	15
ASHRAE Recommended Temperature	6	5	4	15
Air-side Economizer	5	6	4	15
In-row Cooling	3	7	4	14
Waste Heat Recovery	5	7	3	15
Water-side Economizer	6	8	5	19

Server Room HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	5	6	8	19
Containerized Data Center	4	3	13	20
Variable Speed Drives on Pumps/Fans	6	1	8	15
Premium Efficiency Motors	6	2	13	21
ASHRAE Recommended Temperature	6	4	11	21
Air-side Economizer	6	6	9	21
In-row Cooling	3	9	6	18
Waste Heat Recovery	8	6	7	21
Water-side Economizer	9	3	12	24

Server Closet HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	0	1	2	3
Containerized Data Center	1	0	3	4
Variable Speed Drives on Pumps/Fans	1	0	2	3
Premium Efficiency Motors	1	0	3	4
ASHRAE Recommended Temperature	1	0	3	4
Air-side Economizer	1	0	2	3
In-row Cooling	1	0	3	4
Waste Heat Recovery	1	1	2	4
Water-side Economizer	1	0	3	4

Enterprise Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	1	2	6	9
Broaden Humidity Range	1	2	6	9
Install Misters/Ultrasonic Humidifiers	1	5	7	13

Mid-Tier Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	2	11	6	19
Broaden Humidity Range	3	10	4	17
Install Misters/Ultrasonic Humidifiers	3	10	6	19

Localized Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	5	2	4	11
Broaden Humidity Range	5	3	5	13
Install Misters/Ultrasonic Humidifiers	6	3	6	15

Server Room Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	6	3	9	18
Broaden Humidity Range	5	6	9	20
Install Misters/Ultrasonic Humidifiers	6	6	12	24

Server Closet Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	0	0	3	3
Broaden Humidity Range	0	0	3	3
Install Misters/Ultrasonic Humidifiers	1	0	3	4

Appendix B2: Industry Player Implementation and Interest Results

Appendix B2 - Industry Player Implementation and Interest Results

Industry Player Implementation

Enterprise IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	1	11	0	1	13
Decommissioning of unused servers	1	8	1	3	13
Energy-efficient servers	2	9	0	2	13
Energy efficient data storage management*	5	5	0	3	13
Passive optical network**	7	2	4	0	13
Solid state storage	9	1	1	2	13
Massive array of idle disks (MAID)	10	0	1	2	13
Direct liquid cooling of chips	9	0	4	0	13
Server power management***	2	6	4	1	13

Mid-Tier IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	1	10	0	2	13
Decommissioning of unused servers	0	8	1	4	13
Energy-efficient servers	1	6	0	6	13
Energy efficient data storage management*	3	7	1	2	13
Passive optical network**	5	2	3	3	13
Solid state storage	3	6	0	4	13
Massive array of idle disks (MAID)	6	4	3	0	13
Direct liquid cooling of chips	2	1	9	1	13
Server power management***	1	9	1	2	13

Localized IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	1	3	0	2	6
Decommissioning of unused servers	1	0	1	4	6
Energy-efficient servers	2	2	0	2	6
Energy efficient data storage management*	3	1	0	2	6
Passive optical network**	3	1	2	0	6
Solid state storage	3	1	0	2	6
Massive array of idle disks (MAID)	2	0	4	0	6
Direct liquid cooling of chips	2	0	3	1	6
Server power management***	3	0	1	2	6

Server Room IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	2	6	0	2	10
Decommissioning of unused servers	1	4	2	3	10
Energy-efficient servers	2	2	3	3	10
Energy efficient data storage management*	5	2	3	0	10
Passive optical network**	4	0	4	2	10
Solid state storage	3	0	3	4	10
Massive array of idle disks (MAID)	4	2	2	2	10
Direct liquid cooling of chips	2	0	5	3	10
Server power management***	2	2	2	4	10

Server Closet IT Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Server virtualization/consolidation	2	1	0	0	3
Decommissioning of unused servers	1	1	1	0	3
Energy-efficient servers	1	1	1	0	3

Energy efficient data storage management*	1	1	1	0	3
Passive optical network**	2	0	1	0	3
Solid state storage	1	0	1	1	3
Massive array of idle disks (MAID)	1	0	1	1	3
Direct liquid cooling of chips	2	0	1	0	3
Server power management***	2	1	0	0	3

Enterprise Power Infrastructure

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Wind Power	4	0	8	1	13
Solar Power	2	1	8	2	13
Combined Heat and Power	4	1	5	3	13
Polymer Membranes	5	1	6	1	13
Solid Oxide Fuel Cells	6	2	5	0	13
Energy Efficient UPS	2	8	2	1	13
Data Center Current	6	3	2	2	13

Mid-Tier Power Infrastructure

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Wind Power	2	0	11	0	13
Solar Power	0	3	7	3	13
Combined Heat and Power	3	3	6	1	13
Polymer Membranes	8	0	5	0	13
Solid Oxide Fuel Cells	7	1	4	1	13
Energy Efficient UPS	0	12	0	1	13
Data Center Current	0	5	7	1	13

Localized Power Infrastructure

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Wind Power	2	0	4	0	6
Solar Power	2	0	3	1	6

Combined Heat and Power	2	1	2	1	6
Polymer Membranes	4	0	2	0	6
Solid Oxide Fuel Cells	3	0	2	1	6
Energy Efficient UPS	3	2	0	1	6
Data Center Current	1	0	3	2	6

Server Rooms Power Infrastructure

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Wind Power	4	0	6	0	10
Solar Power	3	1	5	1	10
Combined Heat and Power	3	2	5	0	10
Polymer Membranes	3	0	7	0	10
Solid Oxide Fuel Cells	5	0	5	0	10
Energy Efficient UPS	1	4	4	1	10
Data Center Current	1	1	6	2	10

Server Closet Power Infrastructure

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Wind Power	1	0	2	0	3
Solar Power	0	0	3	0	3
Combined Heat and Power	2	0	1	0	3
Polymer Membranes	2	0	1	0	3
Solid Oxide Fuel Cells	1	0	1	1	3
Energy Efficient UPS	0	2	0	1	3
Data Center Current	1	1	1	0	3

Enterprise Airflow Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Computational Fluid Dynamics (CFD) Optimization	9	3	1	0	13
Blanking Panels	7	5	0	1	13
Hot or Cold Aisle Configuration	3	9	1	0	13

Hot or Cold Aisle Configuration plus Containment	5	5	1	2	13

Mid-Tier Airflow Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Computational Fluid Dynamics (CFD) Optimization	5	4	2	2	13
Blanking Panels	1	10	0	2	13
Hot or Cold Aisle Configuration	0	11	0	2	13
Hot or Cold Aisle Configuration plus Containment	0	9	2	2	13

Localized Airflow Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Computational Fluid Dynamics (CFD) Optimization	1	1	3	1	6
Blanking Panels	1	2	1	2	6
Hot or Cold Aisle Configuration	1	4	0	1	6
Hot or Cold Aisle Configuration plus Containment	2	3	0	1	6

Server Room Airflow Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Computational Fluid Dynamics (CFD) Optimization	2	1	5	2	10
Blanking Panels	2	3	4	1	10
Hot or Cold Aisle Configuration	3	2	5	0	10
Hot or Cold Aisle Configuration plus Containment	3	2	4	1	10

Server Closet Airflow Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
Computational Fluid Dynamics (CFD) Optimization	2	0	0	1	3
Blanking Panels	1	1	0	1	3
Hot or Cold Aisle Configuration	0	2	0	1	3
Hot or Cold Aisle Configuration plus Containment	1	1	0	1	3

Enterprise HVAC Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
DCIM	4	7	2	0	13
Containerized Data Center	2	4	5	2	13
Variable Speed Drives on Pumps/Fans	3	10	0	0	13
Premium Efficiency Motors	5	8	0	0	13
ASHRAE Recommended Temperature	5	4	2	2	13
Air-side Economizer	9	3	1	0	13
In-row Cooling	3	6	4	0	13
Waste Heat Recovery	5	2	3	3	13
Water-side Economizer	6	3	2	2	13

Mid-Tier HVAC Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
DCIM	2	8	0	3	13
Containerized Data Center	1	3	7	2	13
Variable Speed Drives on Pumps/Fans	1	8	3	1	13
Premium Efficiency Motors	2	7	4	0	13
ASHRAE Recommended Temperature	1	6	3	3	13
Air-side Economizer	3	3	5	2	13
In-row Cooling	1	9	2	1	13
Waste Heat Recovery	6	1	5	1	13
Water-side Economizer	4	3	5	1	13

Localized HVAC Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
DCIM	0	2	2	2	6
Containerized Data Center	1	0	1	4	6
Variable Speed Drives on Pumps/Fans	1	2	0	3	6

Premium Efficiency Motors	1	3	2	0	6
ASHRAE Recommended Temperature	2	0	1	3	6
Air-side Economizer	2	2	1	1	6
In-row Cooling	2	3	0	1	6
Waste Heat Recovery	2	0	2	2	6
Water-side Economizer	2	2	2	0	6

Server Room HVAC Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
DCIM	3	2	4	1	10
Containerized Data Center	3	0	5	2	10
Variable Speed Drives on Pumps/Fans	2	3	4	1	10
Premium Efficiency Motors	5	1	3	1	10
ASHRAE Recommended Temperature	2	4	4	0	10
Air-side Economizer	1	3	4	2	10
In-row Cooling	3	2	5	0	10
Waste Heat Recovery	3	1	4	2	10
Water-side Economizer	3	1	4	2	10

Server Closet HVAC Implementation

Technology	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Total**
DCIM	1	1	0	1	3
Containerized Data Center	2	0	0	1	3
Variable Speed Drives on Pumps/Fans	2	0	1	0	3
Premium Efficiency Motors	2	0	1	0	3
ASHRAE Recommended Temperature	2	0	1	0	3
Air-side Economizer	1	0	1	1	3
In-row Cooling	1	1	0	1	3
Waste Heat Recovery	2	0	1	0	3
Water-side Economizer	2	0	1	0	3

Enterprise Humidity Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Turn off Humidifiers	5	2	5	1	13
Broaden Humidity Range	5	2	4	2	13
Install Misters/Ultrasonic Humidifiers	6	2	5	0	13

Mid-Tier Humidity Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Turn off Humidifiers	5	4	2	2	13
Broaden Humidity Range	5	4	3	1	13
Install Misters/Ultrasonic Humidifiers	5	5	3	0	13

Localized Humidity Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Turn off Humidifiers	5	0	0	1	6
Broaden Humidity Range	3	1	2	0	6
Install Misters/Ultrasonic Humidifiers	3	0	2	1	6

Server Room Humidity Implementation	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Technology					
Turn off Humidifiers	6	1	2	1	10
Broaden Humidity Range	5	1	4	0	10
Install Misters/Ultrasonic Humidifiers	6	0	3	1	10

Server Closet Humidity Implementation

Technology	Don't Know	Implemented	Not Implemented	Plan to Implement	Total
Turn off Humidifiers	0	0	3	0	3
Broaden Humidity Range	1	0	2	0	3
Install Misters/Ultrasonic Humidifiers	1	0	2	0	3

Industry Player Interest

Enterprise IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	1	0	0	1
Decommissioning of unused servers	1	1	0	2
Energy-efficient servers	2	0	0	2
Energy efficient data storage management*	3	2	0	5
Passive optical network**	7	3	1	11
Solid state storage	5	4	1	10
Massive array of idle disks (MAID)	8	2	1	11
Direct liquid cooling of chips	7	3	3	13
Server power management***	3	3	0	6

Mid-Tier IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	1	0	0	1
Decommissioning of unused servers	0	0	1	1
Energy-efficient servers	0	1	0	1
Energy efficient data storage management*	2	2		4
Passive optical network**	5	0	3	8
Solid state storage	3	0	0	3
Massive array of idle disks (MAID)	8	0	1	9
Direct liquid cooling of chips	4	0	7	11
Server power management***	0	2	0	2

Localized IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	1	0	0	1

Decommissioning of unused servers	1	1	0	2
Energy-efficient servers	2	0	0	2
Energy efficient data storage management*	2	1	0	3
Passive optical network**	2	2	1	5
Solid state storage	3	0	0	3
Massive array of idle disks (MAID)	4	1	1	6
Direct liquid cooling of chips	4	0	1	5
Server power management***	2	2	0	4

Server Room IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	4	2	1	7
Decommissioning of unused servers	0	1	2	3
Energy-efficient servers	2	2	1	5
Energy efficient data storage management*	1	7	0	8
Passive optical network**	6	1	1	8
Solid state storage	5	1	0	6
Massive array of idle disks (MAID)	6	0	0	6
Direct liquid cooling of chips	4	0	3	7
Server power management***	1	3	0	4

Server Closet IT Interest

Technology	Don't Know	Interested	Not Interested	Total
Server virtualization/consolidation	1	1	0	2
Decommissioning of unused servers	1	1	0	2
Energy-efficient servers	1	1	0	2
Energy efficient data storage management*	1	1	0	2
Passive optical network**	3	0	0	3
Solid state storage	1	0	1	2
Massive array of idle disks (MAID)	1	0	1	2
Direct liquid cooling of chips	2	0	1	3

Server power management***	1	1	0	2

Enterprise Power Infrastructure

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	4	2	6	12
Solar Power	3	2	5	10
Combined Heat and Power	3	2	4	9
Polymer Membranes	4	2	5	11
Solid Oxide Fuel Cells	7	2	2	11
Energy Efficient UPS	2	2	0	4
Data Center Current	3	3	2	8

Mid-Tier Power Infrastructure

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	3	2	8	13
Solar Power	2	2	3	7
Combined Heat and Power	5	2	2	9
Polymer Membranes	7	4	2	13
Solid Oxide Fuel Cells	8	2	1	11
Energy Efficient UPS	0	0	0	0
Data Center Current	1	3	3	7

Localized Power Infrastructure

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	2	0	4	6
Solar Power	1	2	2	5
Combined Heat and Power	1	1	2	4
Polymer Membranes	3	1	2	6
Solid Oxide Fuel Cells	2	0	3	5
Energy Efficient UPS	1	2	0	3
Data Center Current	1	1	2	4

Server Room Power Infrastructure

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	2	1	7	10
Solar Power	2	2	4	8
Combined Heat and Power	4	1	3	8
Polymer Membranes	5	0	5	10
Solid Oxide Fuel Cells	5	0	5	10
Energy Efficient UPS	2	1	2	5
Data Center Current	1	1	5	7

Server Closet Power Infrastructure

Technology	Don't Know	Interested	Not Interested	Total
Wind Power	2	0	1	3
Solar Power	1	0	2	3
Combined Heat and Power	3	0	0	3
Polymer Membranes	2	0	1	3
Solid Oxide Fuel Cells	1	0	1	2
Energy Efficient UPS	0	0	0	0
Data Center Current	1	1	0	2

Enterprise Airflow Interest

Technology	Don't Know	Interested	Not Interested	Total
Computational Fluid Dynamics (CFD) Optimization	6	2	2	10
Blanking Panels	4	1	2	7
Hot or Cold Aisle Configuration	2	1	1	4
Hot or Cold Aisle Configuration plus Containment	4	1	1	6

Mid-Tier Airflow Interest

Technology	Don't Know	Interested	Not Interested	Total

Computational Fluid Dynamics (CFD) Optimization	3	2	2	7
Blanking Panels	0	1	0	1
Hot or Cold Aisle Configuration	0	0	0	0
Hot or Cold Aisle Configuration plus Containment	0	1	1	2

Localized Airflow Interest

Technology	Don't Know	Interested	Not Interested	Total
Computational Fluid Dynamics (CFD) Optimization	3	0	1	4
Blanking Panels	0	2	0	2
Hot or Cold Aisle Configuration	0	0	1	1
Hot or Cold Aisle Configuration plus Containment	1	1	0	2

Server Room Interest

Technology	Don't Know	Interested	Not Interested	Total
Computational Fluid Dynamics (CFD) Optimization	5	0	2	7
Blanking Panels	2	0	4	6
Hot or Cold Aisle Configuration	0	0	0	0
Hot or Cold Aisle Configuration plus Containment	4	1	2	7

Server Closet (Vendor)

Technology	Don't Know	Interested	Not Interested	Total
Computational Fluid Dynamics (CFD) Optimization	2	0	0	2
Blanking Panels	1	0	0	1
Hot or Cold Aisle Configuration	0	0	0	0
Hot or Cold Aisle Configuration plus Containment	0	1	0	1

Enterprise HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	3	3	0	6
Containerized Data Center	2	1	4	7
Variable Speed Drives on Pumps/Fans	2	0	1	3

Premium Efficiency Motors	4	0	1	5
ASHRAE Recommended Temperature	5	1	1	7
Air-side Economizer	7	1	2	10
In-row Cooling	4	1	2	7
Waste Heat Recovery	6	0	2	8
Water-side Economizer	8	2	2	12

Mid-Tier HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	1	1	0	2
Containerized Data Center	1	3	4	8
Variable Speed Drives on Pumps/Fans	3	1	0	4
Premium Efficiency Motors	4	1	1	6
ASHRAE Recommended Temperature	2	1	1	4
Air-side Economizer	2	3	3	8
In-row Cooling	2	0	1	3
Waste Heat Recovery	6	2	3	11
Water-side Economizer	4	6	3	13

Localized HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	0	2	0	2
Containerized Data Center	2	0	0	2
Variable Speed Drives on Pumps/Fans	0	0	1	1
Premium Efficiency Motors	1	2	0	3
ASHRAE Recommended Temperature	1	2	0	3
Air-side Economizer	1	2	0	3
In-row Cooling	0	2	0	2
Waste Heat Recovery	2	1	1	4
Water-side Economizer	2	3	1	6

Server Room HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	3	3	1	7
Containerized Data Center	4	0	4	8
Variable Speed Drives on Pumps/Fans	3	1	2	6
Premium Efficiency Motors	4	3	1	8
ASHRAE Recommended Temperature	3	2	1	6
Air-side Economizer	2	2	1	5
In-row Cooling	4	2	2	8
Waste Heat Recovery	4	2	1	7
Water-side Economizer	4	2	4	10

Server Closet HVAC Interest

Technology	Don't Know	Interested	Not Interested	Total
DCIM	0	0	1	1
Containerized Data Center	1	0	1	2
Variable Speed Drives on Pumps/Fans	1	0	2	3
Premium Efficiency Motors	1	0	2	3
ASHRAE Recommended Temperature	1	1	1	3
Air-side Economizer	2	0	0	2
In-row Cooling	0	1	0	1
Waste Heat Recovery	2	0	1	3
Water-side Economizer	1	0	2	3

Enterprise Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	5	1	4	10
Broaden Humidity Range	7	1	1	9
Install Misters/Ultrasonic Humidifiers	7	2	2	11

Mid-Tier Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	5	1	1	7
Broaden Humidity Range	5	2	1	8
Install Misters/Ultrasonic Humidifiers	5	2	1	8

Localized Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	4	1	0	5
Broaden Humidity Range	3	1	1	5
Install Misters/Ultrasonic Humidifiers	3	2	0	5

Server Room Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	4	2	2	8
Broaden Humidity Range	4	2	3	9
Install Misters/Ultrasonic Humidifiers	4	2	3	9

Server Closet Humidifier Interest

Technology	Don't Know	Interested	Not Interested	Total
Turn off Humidifiers	1	0	2	3
Broaden Humidity Range	2	0	1	3
Install Misters/Ultrasonic Humidifiers	2	0	1	3

Appendix C: Details on Overall Potential Analysis

Appendix C – Details on Overall Potential Analysis

Measure Level Savings

EET:	**Decommissioning of unused servers**	
Measure Level Savings %:		5%
Assumptions:	5% zombie servers	
Source:	Source: Masanet et al. (2011) national analysis	

EET:	**Energy efficient servers**	
Measure Level Savings %:		30%
Assumptions:	Average ratio of ENERGY STAR server power to typical server power is 70%	
Source:	Source: Masanet et al. (2011) national analysis and EPA ENERGY STAR data	

EET:	**Server virtualization/consolidation**	
Measure Level Savings %:		56%
Assumptions:	3:1 virtualization ratio; 240 W physical server; 320 W blade server	
Source:	Eric's Model; Masanet et al. (2011) national analysis; http://www.thegreengrid.org/~/media/Member%20Added/Calculating%20TCO%20for%20Energy.pdf?lang=en	

EET:	**Server power management**	
Measure Level Savings %:		14%
Assumptions:		
Source:	Source: Masanet et al. (2011) national analysis; assuming 20% average processor utilization	

EET:	**Direct liquid cooling of chips**	
Measure Level Savings %:		25%
Assumptions:	Baseline would be chiller with CRAHs	

Source:	M&V conducted by Willdan for a supercomputer installation with liquid cooling
EET:	**Energy efficient data storage management**
Measure Level Savings %:	30%
Assumptions:	high end of data compression savings range
Source:	https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_storage_mgmt
EET:	**Solid state storage**
Measure Level Savings %:	94%
Assumptions:	HDD = 16.1 W/TB; SSD = 0.9 W/TB
Source:	Source: Dell (2010)
EET:	**Massive array of idle disks (MAID)**
Measure Level Savings %:	88%
Assumptions:	HDD = 16.1 W/TB; MAID = 1.9 W/TB
Source:	Source: Dell (2010)
EET:	**Passive optical network**
Measure Level Savings %:	50%
Assumptions:	Average ratio of efficient network power (W/GB) to traditional network power (W/GB) is 50%
Source:	Source: Mahaveden et al. (2010) - topology improvements; PON case study
EET:	**Wind power**
Measure Level Savings %:	27%
Assumptions:	Using Rackspace's clean power index as a middle of the road sourcing example
Source:	http://www.greenpeace.org/usa/Global/usa/planet3/PDFs/clickingclean.pdf

EET: **Solar power**
Measure Level Savings %: 27%
Assumptions: Using Rackspace's clean power index as a middle of the road sourcing example
Source: http://www.greenpeace.org/usa/Global/usa/planet3/PDFs/clickingclean.pdf

EET: **Combined heat and power (absorption chiller)**
Measure Level Savings %: 35%
Assumptions: Grid efficiency is 49%; CHP efficiency is 75% (reduced cited efficiency from 80% to 75% to be conservative)
Source: http://www.arb.ca.gov/cc/ccei/presentations/chpefficiencymetrics_epa.pdf

EET: **Polymer electrolyte membrane fuel cells**
Measure Level Savings %: 18%
Assumptions: Grid efficiency is 49%; PEMFC efficiency is 60%
Source: http://energy.gov/eere/fuelcells/comparison-fuel-cell-technologies

EET: **Solid oxide fuel cells**
Measure Level Savings %: 18%
Assumptions: Grid efficiency is 49%; SOFC efficiency is 60% w/o recovery
Source: http://energy.gov/eere/fuelcells/types-fuel-cells

EET: **Energy efficient power supplies (UPS)**
Measure Level Savings %: 16%
Assumptions: Baseline Efficiency = 80%; Emerging Tech Efficiency = 95%
Source: Eric's Model

EET: **Direct current (as opposed to AC) to the racks**
Measure Level Savings %: 11%

Assumptions:	AC Efficiency = 68%; DC Efficiency = 76%
Source:	Luiz André Barroso and Urs Hölzle. "The Datacenter as a Computer: An Introduction to the Design of Warehouse-Scale Machines" 2009

EET:	**Computational fluid dynamics optimization**
Measure Level Savings %:	12.0%
Assumptions:	CFD results are incorporated in the data center, resulting in setpoint being raised 8 F
Source:	Desai, Tejas, Ankita Gupta, Sameer Bahere, and Nathan Winkler. "Data Center Temperature Set Point Impact on Cooling Efficiency." AEE WEEC 2013 Washington, DC. Web. 2013.

EET:	**Blanking panels, grommets, or structured cabling**
Measure Level Savings %:	1.5%
Assumptions:	Setpoint can be raised 1 F
Source:	Desai, Tejas, Ankita Gupta, Sameer Bahere, and Nathan Winkler. "Data Center Temperature Set Point Impact on Cooling Efficiency." AEE WEEC 2013 Washington, DC. Web. 2013.

EET:	**Hot or cold aisle configuration**
Measure Level Savings %:	4.5%
Assumptions:	Setpoint can be raised 3 F
Source:	Desai, Tejas, Ankita Gupta, Sameer Bahere, and Nathan Winkler. "Data Center Temperature Set Point Impact on Cooling Efficiency." AEE WEEC 2013 Washington, DC. Web. 2013.

EET:	**Hot or cold aisle configuration plus containment (e.g., strip curtains or rigid enclosures)**
Measure Level Savings %:	12%
Assumptions:	Setpoint can be raised 8 F (Based on sample ComEd project)
Source:	Desai, Tejas, Ankita Gupta, Sameer Bahere, and Nathan Winkler. "Data Center Temperature Set Point Impact on Cooling Efficiency." AEE WEEC 2013 Washington, DC. Web. 2013.

EET:	**Data Center Infrastructure Management (DCIM) System**

Measure Level Savings %:		7%
Assumptions:	Used savings from Liebert iCom system to estimate savings from DCIM controls	
Source:	http://shared.liebert.com/SharedDocuments/LiebertFiles/Cutting%20Costs%20from%20the%20Data%20Center%20vFinal%2003%2019%2009.pdf	

EET:	**Containerized data center**	
Measure Level Savings %:		12.5%
Assumptions:	considering midpoint of 10-15% savings estimate due to right sizing	
Source:	http://www.ellipticalmedia.com/pdf/whitepapers/EMSUPTIME.pdf	

EET:	**Variable speed drives on pumps/fans**	
Measure Level Savings %:		45%
Assumptions:	20% reduction in speed	
Source:	https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_vsds	

EET:	**Premium efficiency motors**	
Measure Level Savings %:		3.2%
Assumptions:	Conservative efficiency improvement of ~3%	
Source:	http://www.copper.org/environment/sustainable-energy/electric-motors/education/motor_text.html	

EET:	**Adjusting server inlet temperatures closer to the high end of ASHRAE recommended temperature range of 80F**	
Measure Level Savings %:		12%
Assumptions:	Setpoint is raised 8 F	
Source:	Desai, Tejas, Ankita Gupta, Sameer Bahere, and Nathan Winkler. “Data Center Temperature Set Point Impact on Cooling Efficiency.” AEE WEEC 2013 Washington, DC. Web. 2013.	

EET:	**Air-side economizer**	
Measure Level Savings %:		74%

Assumptions:	6525 hours of free cooling/year (Average for NYC, Albany, Buffalo for Temp below 65F DB)	
Source:	https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_economizer_airside	
EET:	**In-row cooling**	
Measure Level Savings %:		11%
Assumptions:	Using midpoint of the 7-15% range	
Source:	APC WP #130	
EET:	**Waste heat recovery**	
Measure Level Savings %:		20%
Assumptions:	Data center with delta T of 20 F; about 10 F delta T could be recovered with HX effectiveness of 50% and efficiency of 95%	
Source:	Tejas Desai	
EET:	**Water-side economizer**	
Measure Level Savings %:		47%
Assumptions:	4134 hours of free cooling/year (Average for NYC, Albany, Buffalo for Temp below 45 WB)	
Source:	https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_economizer_waterside	
EET:	**Turn off humidifiers**	
Measure Level Savings %:		50%
Assumptions:		
Source:	https://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_inlet_temp	
EET:	**Broaden humidity range**	
Measure Level Savings %:		38%
Assumptions:	Decreasing runtime from 80% to 20%; 50% energy savings from turning off humidifiers	
Source:	https://www.energystar.gov/ia/products/power_mgt/downloads/BNY_Mellon_Data_Center_case_study.pdf?b81e-4eb7	

EET:	**Install misters, foggers, or ultrasonic humidifiers**
Measure Level Savings %:	90%
Assumptions:	
Source:	https://www.energystar.gov/ia/products/power_mgt/downloads/Energy_Star_fact_sheet.pdf?0b55-1475

Technical Potential

EET	Measure Level Savings	Data Center Level Savings	Indirect savings	Total Data Center Savings	Technical Potential Score
Decommissioning of unused servers	5.0%	2.4%	yes	3.1%	0.5
Direct liquid cooling of chips	25.0%	7.4%	no	7.4%	0.5
Energy efficient data storage management	30.0%	0.9%	yes	1.2%	0.0
Energy efficient servers	30.0%	14.3%	yes	18.6%	1.0
Massive array of idle disks (MAID)	88.2%	1.4%	yes	1.8%	0.0
Passive optical network	50.0%	2.2%	yes	2.9%	0.5
Server power management	14.0%	6.7%	yes	8.7%	0.5
Server virtualization/consolidation	55.6%	26.5%	yes	34.5%	1.0
Solid state storage	94.4%	1.5%	yes	1.9%	0.0
Combined heat and power	34.7%	34.7%	no	34.7%	1.0
Direct current to the racks	10.5%	5.8%	yes	7.6%	0.5
Energy efficient power supplies (UPS)	15.8%	8.7%	yes	11.4%	1.0
Polymer electrolyte membrane fuel cells	18.3%	18.3%	no	18.3%	1.0
Solar power	27.0%	27.0%	no	27.0%	1.0
Solid oxide fuel cells	18.3%	18.3%	no	18.3%	1.0
Wind power	27.0%	27.0%	no	27.0%	1.0
Computational fluid dynamics optimization	1.5%	0.5%	no	0.5%	0.0
Containment	12.0%	3.9%	no	3.9%	0.5
Hot or cold aisle configuration	4.5%	1.5%	no	1.5%	0.0
Hot or cold aisle configuration plus containment	12.0%	3.9%	no	3.9%	0.5
Adjusting server inlet temperatures to the high end of ASHRAE recommended range	12.0%	3.9%	no	3.9%	0.5
Air-side economizer	74.5%	15.9%	no	15.9%	1.0
Containerized data center	12.5%	5.3%	no	5.3%	0.5
Data Center Infrastructure Management (DCIM) System	7.0%	2.3%	no	2.3%	0.5
In-row cooling	11.0%	0.9%	yes	1.2%	0.0
Variable speed drives on pumps/fans	45.0%	5.2%	no	5.2%	0.5
Premium efficiency motors	3.2%	0.4%	no	0.4%	0.0
Waste heat recovery	20.0%	4.3%	no	4.3%	0.5
Water-side economizer	47.2%	10.1%	no	10.1%	1.0
Broaden humidity range	37.5%	0.8%	no	0.8%	0.0
Install misters, foggers, or ultrasonic humidifiers	90.0%	1.9%	no	1.9%	0.0
Turn off humidifiers	50.0%	1.1%	no	1.1%	0.0

Market Potential

EET	Overall Plan to Implement %	Plan to Implement Score	Overall Interest %	Interest Score	Market Potential Score
Decommissioning of unused servers	25.0%	1	50.0%	1	1.0
Direct liquid cooling of chips	12.9%	0	22.0%	0	0.0
Energy efficient data storage management	28.6%	1	61.8%	1	1.0
Energy efficient servers	27.1%	1	60.5%	1	1.0
Massive array of idle disks (MAID)	11.4%	0	23.9%	0	0.0
Passive optical network	15.7%	1	27.5%	0	0.5
Server power management	23.6%	1	59.6%	1	1.0
Server virtualization/consolidation	13.6%	1	44.8%	1	1.0
Solid state storage	23.6%	1	42.5%	1	1.0
Combined heat and power	15.0%	1	28.0%	0	0.5
Direct current to the racks	16.4%	1	39.6%	1	1.0
Energy efficient power supplies (UPS)	14.3%	1	60.9%	1	1.0
Polymer electrolyte membrane fuel cells	4.3%	0	23.7%	0	0.0
Solar power	12.9%	0	36.6%	1	0.5
Solid oxide fuel cells	6.4%	0	21.3%	0	0.0
Wind power	3.6%	0	16.9%	0	0.0
Computational fluid dynamics optimization	12.1%	0	23.6%	0	0.0
Containment	15.0%	1	31.0%	1	1.0
Hot or cold aisle configuration	10.0%	0	29.6%	0	0.0
Hot or cold aisle configuration plus containment	14.3%	1	40.0%	1	1.0
Adjusting server inlet temperatures to the high end of ASHRAE recommended range	12.9%	0	35.5%	1	0.5
Air-side economizer	11.4%	0	37.0%	1	0.5
Containerized data center	17.9%	1	20.0%	0	0.5
Data Center Infrastructure Management (DCIM) System	14.3%	1	44.8%	1	1.0
In-row cooling	10.7%	0	40.5%	1	0.5
Variable speed drives on pumps/fans	11.4%	0	30.0%	0	0.0
Premium efficiency motors	12.9%	0	25.4%	0	0.0
Waste heat recovery	18.6%	1	30.4%	0	0.5
Water-side economizer	9.3%	0	35.3%	1	0.5
Broaden humidity range	11.4%	0	27.8%	0	0.0
Install misters, foggers, or ultrasonic humidifiers	8.6%	0	28.6%	0	0.0
Turn off humidifiers	10.0%	0	24.5%	0	0.0

Overall Potential

EET	Technical Potential Score	Market Potential Score	Overall Potential
Decommissioning of unused servers	0.5	1.0	0.8
Direct liquid cooling of chips	0.5	0.0	0.3
Energy efficient data storage management	0.0	1.0	0.5
Energy efficient servers	1.0	1.0	1.0
Massive array of idle disks (MAID)	0.0	0.0	0.0
Passive optical network	0.5	0.5	0.5
Server power management	0.5	1.0	0.8
Server virtualization/consolidation	1.0	1.0	1.0
Solid state storage	0.0	1.0	0.5
Combined heat and power	1.0	0.5	0.8
Direct current to the racks	0.5	1.0	0.8
Energy efficient power supplies (UPS)	1.0	1.0	1.0
Polymer electrolyte membrane fuel cells	1.0	0.0	0.5
Solar power	1.0	0.5	0.8
Solid oxide fuel cells	1.0	0.0	0.5
Wind power	1.0	0.0	0.5
Computational fluid dynamics optimization	0.0	0.0	0.0
Containment	0.5	1.0	0.8
Hot or cold aisle configuration	0.0	0.0	0.0
Hot or cold aisle configuration plus containment	0.5	1.0	0.8
Adjusting server inlet temperatures to the high end of ASHRAE recommended range	0.5	0.5	0.5
Air-side economizer	1.0	0.5	0.8
Containerized data center	0.5	0.5	0.5
Data Center Infrastructure Management (DCIM) System	0.5	1.0	0.8
In-row cooling	0.0	0.5	0.3
Variable speed drives on pumps/fans	0.5	0.0	0.3
Premium efficiency motors	0.0	0.0	0.0
Waste heat recovery	0.5	0.5	0.5
Water-side economizer	1.0	0.5	0.8
Broaden humidity range	0.0	0.0	0.0
Install misters, foggers, or ultrasonic humidifiers	0.0	0.0	0.0
Turn off humidifiers	0.0	0.0	0.0

Unsmoothed EETBP Opportunity Portfolios by Space Type

		Enterprise	Mid-Tier	Localized	Server Rooms & Closets
IT Equipment	Decommissioning of unused servers	C	C	C	C
	Direct liquid cooling of chips	C	C	C	
	Energy efficient data storage management	B	C	C	B
	Energy efficient servers	C	B	B	B
	Massive array of idle disks (MAID)	C	C	C	
	Passive optical network	B	B	B	
	Server power management	B	B	B	B
	Server virtualization/consolidation	D	C	C	C
	Solid state storage	B	C	C	B
Power Infrastructure	Combined heat and power	A	A		
	Direct current to the racks	A	B	A	
	Energy efficient power supplies (UPS)	C	C	B	B
	Polymer electrolyte membrane fuel cells	B	B		
	Solar power	A	A		
	Solid oxide fuel cells	B	B	B	
	Wind power	B	B		
Air Flow Management	Computational fluid dynamics optimization	C	C	C	
	Containment	B	C	A	B
	Hot or cold aisle configuration	E	E	D	
	Hot or cold aisle configuration plus containment	B	B		
HVAC	Adjusting server inlet temperatures	C	B	B	B
	Air-side economizer	A	B	A	
	Containerized data center	B	B	B	B
	Data Center Infrastructure Management (DCIM)	C	C	A	
	In-row cooling	E	D	D	
	Premium efficiency motors	D	D	C	D
	Variable speed drives on pumps/fans	E	D	C	D
	Waste heat recovery	B	B	B	
	Water-side economizer	A	A	A	
Humidity	Broaden humidity range	C	D	C	
	Install misters, foggers, or ultrasonic humidifiers	C	D		
	Turn off humidifiers	D	D	D	

Appendix D: Backing Tables for Model

Appendix D-Backing Tables for Model

Table 1: For each type of data center space listed, please indicate / how many you have in New York State

Role	Manager
Values	
Sum of For each type of data center space listed, please indicate / how many you have in New York State.-Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	145
Count of For each type of data center space listed, please indicate / how many you have in New York State.-Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)2	96
Max of For each type of data center space listed, please indicate / how many you have in New York State.-Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)2	100
Min of For each type of data center space listed, please indicate / how many you have in New York State.-Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)2	0
Sum of For each type of data center space listed, please indicate / how many you have in New York State.-Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	249
Count of For each type of data center space listed, please indicate / how many you have in New York State.-Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)2	96
Max of For each type of data center space listed, please indicate / how many you have in New York State.-Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)2	100
Min of For each type of data center space listed, please indicate / how many you have in New York State.-Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)2	0
Sum of For each type of data center space listed, please indicate / how many you have in New York State.-Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	127
Count of For each type of data center space listed, please indicate / how many you have in New York State.-Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)2	96
Max of For each type of data center space listed, please indicate / how many you have in New York State.-Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)2	50
Min of For each type of data center space listed, please indicate / how many you have in New York State.-Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)2	0
Sum of For each type of data center space listed, please indicate / how many you have in New York State.-Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	459
Count of For each type of data center space listed, please indicate / how many you have in New York State.-Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)2	96
Max of For each type of data center space listed, please indicate / how many you have in New York State.-Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)2	332
Min of For each type of data center space listed, please indicate / how many you have in New York State.-Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)2	0
Sum of For each type of data center space listed, please indicate / how many you have in New York State.-Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	95
Count of For each type of data center space listed, please indicate / how many you have in New York State.-Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)2	96
Max of For each type of data center space listed, please indicate / how many you have in New York State.-Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)2	44
Min of For each type of data center space listed, please indicate / how many you have in New York State.-Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)3	0

Table 2: What is the average square footage / of your Enterprise Data Center(s) in New York State?

Role	Manager
Values	
Sum of What is the average square footage / of your Enterprise Data Center(s) in New York / State?-TEXT	776030
Count of What is the average square footage / of your Enterprise Data Center(s) in New York / State?-TEXT	17
Max of What is the average square footage / of your Enterprise Data Center(s) in New York / State?-TEXT2	300000
Min of What is the average square footage / of your Enterprise Data Center(s) in New York / State?-TEXT2	1030
Sum of What is the average square footage / of your Mid-Tier Data Center(s) in New York / State?-TEXT	219867
Count of What is the average square footage / of your Mid-Tier Data Center(s) in New York / State?-TEXT	25
Max of What is the average square footage / of your Mid-Tier Data Center(s) in New York / State?-TEXT2	50000
Min of What is the average square footage / of your Mid-Tier Data Center(s) in New York / State?-TEXT2	1500
Sum of What is the average square footage / of your Localized Data Center(s) in New York / State?-TEXT	27388
Count of What is the average square footage / of your Localized Data Center(s) in New York / State?-TEXT	23
Max of What is the average square footage / of your Localized Data Center(s) in New York / State?-TEXT2	8000
Min of What is the average square footage / of your Localized Data Center(s) in New York / State?-TEXT2	100
Sum of What is the average square footage / of your Server Room(s) in New York State?-TEXT	7156
Count of What is the average square footage / of your Server Room(s) in New York State?-TEXT	27
Max of What is the average square footage / of your Server Room(s) in New York State?-TEXT2	999
Min of What is the average square footage / of your Server Room(s) in New York State?-TEXT2	40
Sum of What is the average square footage / of your Server Closet(s) in New York / State?-TEXT	5702
Count of What is the average square footage / of your Server Closet(s) in New York / State?-TEXT	9
Max of What is the average square footage / of your Server Closet(s) in New York / State?-TEXT2	5157
Min of What is the average square footage / of your Server Closet(s) in New York / State?-TEXT2	3

Table 3: On average, how many physical servers are installed at your / Enterprise Data Center(s) in New York State?

Role	Manager
Values	
Sum of On average, how many physical servers are installed at your / Enterprise Data Center(s) in New York State?-TEXT	49667
Count of On average, how many physical servers are installed at your / Enterprise Data Center(s) in New York State?-TEXT	19
Max of On average, how many physical servers are installed at your / Enterprise Data Center(s) in New York State?-TEXT2	17333
Min of On average, how many physical servers are installed at your / Enterprise Data Center(s) in New York State?-TEXT2	600
Sum of On average, how many physical servers are installed at / your Mid-Tier Data Center(s) in New York / State?-TEXT	5830
Count of On average, how many physical servers are installed at / your Mid-Tier Data Center(s) in New York / State?-TEXT	27
Max of On average, how many physical servers are installed at / your Mid-Tier Data Center(s) in New York / State?-TEXT2	450
Min of On average, how many physical servers are installed at / your Mid-Tier Data Center(s) in New York / State?-TEXT2	100
Sum of On average, how many physical servers are installed at / your Localized Data Center(s) in New York / State?-TEXT	1136
Count of On average, how many physical servers are installed at / your Localized Data Center(s) in New York / State?-TEXT	26
Max of On average, how many physical servers are installed at / your Localized Data Center(s) in New York / State?-TEXT2	99
Min of On average, how many physical servers are installed at / your Localized Data Center(s) in New York / State?-TEXT2	25
Sum of On average, how many physical servers are installed at / your Server Room(s) in New York State?-TEXT	349
Count of On average, how many physical servers are installed at / your Server Room(s) in New York State?-TEXT	38
Max of On average, how many physical servers are installed at / your Server Room(s) in New York State?-TEXT2	20
Min of On average, how many physical servers are installed at / your Server Room(s) in New York State?-TEXT2	5
Sum of On average, how many physical servers are installed at / your Server Closet(s) in New York State?-TEXT	36
Count of On average, how many physical servers are installed at / your Server Closet(s) in New York State?-TEXT	14
Max of On average, how many physical servers are installed at / your Server Closet(s) in New York State?-TEXT2	4
Min of On average, how many physical servers are installed at / your Server Closet(s) in New York State?-TEXT2	1

Table 4: How many of your data centers in New York State have undertaken virtualization?

	Useful response summary				Response count		
Manager responses	**All**	**Most**	**Some**	**None**	**Useful**	**Don't know**	**Total**
Enterprise	40%	36%	20%	4%	25	2	27
Mid-tier	59%	21%	21%	0%	29	2	31
Localized	52%	29%	19%	0%	1	0	1
Server room	23%	28%	18%	33%	40	5	45
Server closet	11%	19%	30%	41%	27	3	30

Table 5: How many of your Enterprise Data Centers / in New York State are located in a co-location facility?

	Useful response summary				Response count		
Manager responses	**All**	**Most**	**Some**	**None**	**Useful**	**Don't know**	**Total**
Enterprise	28%	24%	16%	32%	25	2	27
Mid-tier	7%	10%	30%	53%	30	1	31
Localized	10%	10%	26%	55%	31	1	32
Server room	0%	2%	17%	80%	41	4	45
Server closet	0%	3%	14%	83%	29	1	30

Table 6: What is the total square footage of your familiar data center? Manager responses.

Role	Manager					
	Column Lab					
Values	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**
Sum of What is the total square footage of your / familiar data / center?-TEXT		741750	18730	186000	6103	4159
Count of What is the total square footage of your / familiar data / center?-TEXT2		16	18	21	3	15
Max of What is the total square footage of your / familiar data / center?-TEXT3		200000	3380	50000	6000	999
Min of What is the total square footage of your / familiar data / center?-TEXT4		4000	200	300	3	40
Sum of What is the total number of physical servers / installed at your familiar data center?-TEXT		55300	887	5030	10	231
Count of What is the total number of physical servers / installed at your familiar data center?-TEXT4		17	20	23	4	23
Max of What is the total number of physical servers / installed at your familiar data center?-TEXT3		20000	99	450	3	20
Min of What is the total number of physical servers / installed at your familiar data center?-TEXT2		500	25	100	1	5

Table 7: What is the total square footage of your familiar data center? Vendor responses.

Role	Vendor					
	Column Lab					
Values	Don't know	Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)
Sum of What is the total square footage of your / familiar data / center?-TEXT		267000	2060	104800	76	14040
Count of What is the total square footage of your / familiar data / center?-TEXT2		10	3	10	2	7
Max of What is the total square footage of your / familiar data / center?-TEXT3		100000	1000	25000	60	10000
Min of What is the total square footage of your / familiar data / center?-TEXT4		3000	60	300	16	200
Sum of What is the total number of physical servers / installed at your familiar data center?-TEXT		11100	110	1550	6	65
Count of What is the total number of physical servers / installed at your familiar data center?-TEXT4		5	3	9	2	5
Max of What is the total number of physical servers / installed at your familiar data center?-TEXT3		5000	50	400	3	20
Min of What is the total number of physical servers / installed at your familiar data center?-TEXT2		1000	30	100	3	5

Table 8: What is the total square footage of your familiar data center? Combined manager and vendor responses.

Role	(All)					
	Column Lab					
Values	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**
Sum of What is the total square footage of your / familiar data / center?-TEXT		1008750	20790	290800	6179	18199
Count of What is the total square footage of your / familiar data / center?-TEXT2		26	21	31	5	22
Max of What is the total square footage of your / familiar data / center?-TEXT3		200000	3380	50000	6000	10000
Min of What is the total square footage of your / familiar data / center?-TEXT4		3000	60	300	3	40
Sum of What is the total number of physical servers / installed at your familiar data center?-TEXT		66400	997	6580	16	296
Count of What is the total number of physical servers / installed at your familiar data center?-TEXT4		22	23	32	6	28
Max of What is the total number of physical servers / installed at your familiar data center?-TEXT3		20000	99	450	3	20
Min of What is the total number of physical servers / installed at your familiar data center?-TEXT2		500	25	100	1	5

Table 9: What is the total IT load (kW) of your familiar data center? Manager responses.

Role	Manager				
How did you estimate the total IT load for your / familiar data center? / [Select all that apply]	(Multiple Items)				
	Column Labels				
Values	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**
Sum of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT		5476230	71.7	28061	3543.1
Count of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT2		11	3	16	5
Max of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT3		5400000	45	8700	3000
Min of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT4		110	6.7	55	3.1

Table 10: What is the total IT load (kW) of your familiar data center? Vendor responses.

Role	Vendor				
How did you estimate the total IT load for your / familiar data center? / [Select all that apply]	(Multiple Items)				
	Column Labels				
Values	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**
Sum of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT	14700	100258	4300		1895
Count of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT2	7	3	6		3
Max of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT3	5000	100000	2000		1800
Min of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT4	200	8	200		15

Table 11: What is the total IT load (kW) of your familiar data center? Combined manager and vendor responses.

Role	(All)					
How did you estimate the total IT load for your / familiar data center? / [Select all that apply]	(Multiple Items)					
	Column Labels					
Values	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**
Sum of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT		5490930	100329.7	32361		5438.1
Count of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT2		18	6	22		8
Max of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT3		5400000	100000	8700		3000
Min of What is the total IT load (in kilowatts) of / your familiar data / center? This includes servers, storage, and / networking.-TEXT4		110	6.7	55		3.1

Table 12: Please indicate if you have implemented, plan to implement, or have not implemented server virtualization/consolidation at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Server virtualization/consolidation	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	1			2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)		18		2	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2	15	1	3	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	18	3	3	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	3			4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1	15	4	4	24
Grand Total	**6**	**70**	**8**	**12**	**96**

Table 13: Please indicate if you have implemented, plan to implement, or have not implemented server virtualization/consolidation at your familiar data center. Vendor responses.

Role	Vendor			
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Server virtualization/consolidation	**Column Labels**			
Row Labels	**Don't Know**	**Implemented**	**Plan to Implemen**	**Grand Total**
Don't know		1		1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	1	11	1	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	3	2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	10	2	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2	1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	6	2	10
Grand Total	**7**	**32**	**7**	**46**

Table 14: Please indicate if you have implemented, plan to implement, or have not implemented server virtualization/consolidation at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Server virtualization/consolidation	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	2			3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	29		3	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	18	1	5	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	28	3	5	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3	4			7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	21	4	6	34
Grand Total	**13**	**102**	**8**	**19**	**142**

Table 15: Please indicate if you have implemented, plan to implement, or have not implemented decommissioning of unused servers at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Decommissioning of unused servers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)		12	3	5	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)		14	2	5	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		15	4	6	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	3			4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1	16	3	4	24
Grand Total	**4**	**60**	**12**	**20**	**96**

Table 16: Please indicate if you have implemented, plan to implement, or have not implemented decommissioning of unused servers at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Decommissioning of unused servers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know				1	1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	8	1	3	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1		1	4	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		8	1	4	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1	1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1	4	2	3	10
Grand Total	**4**	**21**	**6**	**15**	**46**

Table 17: Please indicate if you have implemented, plan to implement, or have not implemented decommissioning of unused servers at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Decommissioning of unused servers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2			1	3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	20	4	8	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	14	3	9	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		23	5	10	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2	4	1		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	20	5	7	34
Grand Total	**8**	**81**	**18**	**35**	**142**

Table 18: Please indicate if you have implemented, plan to implement, or have not implemented energy-efficient servers at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Energy-efficient servers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1			1	2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)		9	2	9	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	10	4	6	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	11	6	7	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		1	1	4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	5	9	8	2	24
Grand Total	**10**	**39**	**21**	**26**	**96**

Table 19: Please indicate if you have implemented, plan to implement, or have not implemented energy-efficient servers at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Energy-efficient servers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	2	9		2	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2	2		2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	6		6	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1	1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	2	3	3	10
Grand Total	**9**	**20**	**4**	**13**	**46**

Table 20: Please indicate if you have implemented, plan to implement, or have not implemented energy-efficient servers at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Energy-efficient servers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2			1	3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	2	18	2	11	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	12	4	8	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	17	6	13	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3	1	2	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	7	11	11	5	34
Grand Total	**19**	**59**	**25**	**39**	**142**

Table 21: Please indicate if you have implemented, plan to implement, or have not implemented energy efficient data storage management at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Energy efficient data storage management*	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1			1	2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	2	3	3	12	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	11	3	4	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		9	6	10	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		1	1	4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	5	6	7	6	24
Grand Total	**13**	**29**	**20**	**34**	**96**

Table 22: Please indicate if you have implemented, plan to implement, or have not implemented energy efficient data storage management at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Energy efficient data storage management*	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servei	5	5		3	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	1		2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3	7	1	2	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1	1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	5	2	3		10
Grand Total	**18**	**16**	**5**	**7**	**46**

Table 23: Please indicate if you have implemented, plan to implement, or have not implemented energy efficient data storage management at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Energy efficient data storage management*	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2			1	3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servei	7	8	3	15	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	6	12	3	6	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3	16	7	12	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3	1	2	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	10	8	10	6	34
Grand Total	**31**	**45**	**25**	**41**	**142**

Table 24: Please indicate if you have implemented, plan to implement, or have not implemented passive optical network at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Passive optical network**	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	3	9	7	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4	2	9	6	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	5	18	1	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3		1		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	10	1	10	3	24
Grand Total	**21**	**11**	**47**	**17**	**96**

Table 25: Please indicate if you have implemented, plan to implement, or have not implemented passive optical network at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Passive optical network**	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	7	2	4		13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	1	2		6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5	2	3	3	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4		4	2	10
Grand Total	**22**	**5**	**14**	**5**	**46**

Table 26: Please indicate if you have implemented, plan to implement, or have not implemented passive optical network at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Passive optical network**	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	8	5	13	7	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	7	3	11	6	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	6	7	21	4	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	5		2		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	14	1	14	5	34
Grand Total	**43**	**16**	**61**	**22**	**142**

Table 27: Please indicate if you have implemented, plan to implement, or have not implemented solid state storage at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Solid state storage	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	2	7	5	6	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	8	7	3	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	7	11	6	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3		1		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	4	12	5	24
Grand Total	**14**	**26**	**36**	**20**	**96**

Table 28: Please indicate if you have implemented, plan to implement, or have not implemented solid state storage at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Solid state storage	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	9	1	1	2	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	1		2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3	6		4	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		1	1	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3		3	4	10
Grand Total	**20**	**8**	**5**	**13**	**46**

Table 29: Please indicate if you have implemented, plan to implement, or have not implemented solid state storage at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Solid state storage	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	11	8	6	8	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	6	9	7	5	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	4	13	11	10	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	4		2	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6	4	15	9	34
Grand Total	**34**	**34**	**41**	**33**	**142**

Table 30: Please indicate if you have implemented, plan to implement, or have not implemented massive array of idle disks (MAID) at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Massive array of idle disks (MAID)	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	2	3	10	5	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	7	2	10	2	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5		17	3	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3		1		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	7		16	1	24
Grand Total	**26**	**5**	**54**	**11**	**96**

Table 31: Please indicate if you have implemented, plan to implement, or have not implemented massive array of idle disks (MAID) at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Massive array of idle disks (MAID)	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	10		1	2	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2		4		6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	6	4	3		13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		1	1	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4	2	2	2	10
Grand Total	**24**	**6**	**11**	**5**	**46**

Table 32: Please indicate if you have implemented, plan to implement, or have not implemented massive array of idle disks (MAID) at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Massive array of idle disks (MAID)	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	12	3	11	7	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	9	2	14	2	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	11	4	20	3	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	4		2	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	11	2	18	3	34
Grand Total	**50**	**11**	**65**	**16**	**142**

Table 33: Please indicate if you have implemented, plan to implement, or have not implemented direct liquid cooling of chips at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Direct liquid cooling of chips	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	2	1	8	9	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	1	17	2	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	6	1	16	2	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		2		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	5		19		24
Grand Total	**18**	**3**	**62**	**13**	**96**

Table 34: Please indicate if you have implemented, plan to implement, or have not implemented direct liquid cooling of chips at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Direct liquid cooling of chips	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servei	9		4		13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2		3	1	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	1	9	1	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2		5	3	10
Grand Total	**18**	**1**	**22**	**5**	**46**

Table 35: Please indicate if you have implemented, plan to implement, or have not implemented direct liquid cooling of chips at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Direct liquid cooling of chips	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servei	11	1	12	9	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	1	20	3	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	8	2	25	3	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	4		3		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	7		24	3	34
Grand Total	**36**	**4**	**84**	**18**	**142**

Table 36: Please indicate if you have implemented, plan to implement, or have not implemented server power management at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Server power management* **	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)		8	3	9	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)		9	6	6	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	8	11	5	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3		1		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1	9	10	4	24
Grand Total	**7**	**34**	**31**	**24**	**96**

Table 37: Please indicate if you have implemented, plan to implement, or have not implemented server power management at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Server power management* **	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	2	6	4	1	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3		1	2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	9	1	2	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2	1			3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	2	2	4	10
Grand Total	**11**	**18**	**8**	**9**	**46**

Table 38: Please indicate if you have implemented, plan to implement, or have not implemented server power management at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following IT energy efficiency practices at your familiar data center.-Server power management* **	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	2	14	7	10	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	9	7	8	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	17	12	7	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	5	1	1		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	11	12	8	34
Grand Total	**18**	**52**	**39**	**33**	**142**

Table 39: Please indicate if you have implemented, plan to implement, or have not implemented efficient UPS at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following power infrastructure energy efficiency practices at / your familiar data / center.-Energy efficient power supplies (UPS)	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	1			2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)		12	3	5	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4	8	6	3	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		13	10	2	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		1	2	1	4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	11	6	4	24
Grand Total	**8**	**46**	**27**	**15**	**96**

Table 40: Please indicate if you have implemented, plan to implement, or have not implemented efficient UPS at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following power infrastructure energy efficiency practices at / your familiar data / center.-Energy efficient power supplies (UPS)	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know		1			1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	2	8	2	1	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	2		1	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		12		1	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		2		1	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1	4	4	1	10
Grand Total	**6**	**29**	**6**	**5**	**46**

Table 41: Please indicate if you have implemented, plan to implement, or have not implemented efficient UPS at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following power infrastructure energy efficiency practices at / your familiar data / center.-Energy efficient power supplies (UPS)	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	2			3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	2	20	5	6	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	7	10	6	4	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		25	10	3	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		3	2	2	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4	15	10	5	34
Grand Total	**14**	**75**	**33**	**20**	**142**

Table 42: Please indicate if you have implemented, plan to implement, or have not implemented direct current to racks at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following power infrastructure energy efficiency practices at / your familiar data / center.-Data center current (as opposed to AC) to the racks	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	1			2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	2	12	5	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2	4	10	5	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	8	13	3	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)			3	1	4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	5	2	15	2	24
Grand Total	**10**	**17**	**53**	**16**	**96**

Table 43: Please indicate if you have implemented, plan to implement, or have not implemented direct current to racks at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following power infrastructure energy efficiency practices at / your familiar data / center.-Data center current (as opposed to AC) to the racks	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	6	3	2	2	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1		3	2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		5	7	1	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1	1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1	1	6	2	10
Grand Total	**10**	**10**	**19**	**7**	**46**

Table 44: Please indicate if you have implemented, plan to implement, or have not implemented direct current to racks at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following power infrastructure energy efficiency practices at / your familiar data / center.-Data center current (as opposed to AC) to the racks	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2	1			3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	7	5	14	7	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	4	13	7	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	13	20	4	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1	4	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6	3	21	4	34
Grand Total	**20**	**27**	**72**	**23**	**142**

Table 45: Please indicate if you have implemented, plan to implement, or have not implemented CFD optimization at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Computational fluid dynamics optimization	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers	2	4	11	3	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	2	10	4	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		2	19	4	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		3		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4		20		24
Grand Total	**14**	**8**	**63**	**11**	**96**

Table 46: Please indicate if you have implemented, plan to implement, or have not implemented CFD optimization at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Computational fluid dynamics optimization	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers	9	3	1		13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	1	3	1	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5	4	2	2	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2			1	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	1	5	2	10
Grand Total	**20**	**9**	**11**	**6**	**46**

Table 47: Please indicate if you have implemented, plan to implement, or have not implemented CFD optimization at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Computational fluid dynamics optimization	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers	11	7	12	3	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	6	3	13	5	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5	6	21	6	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3		3	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6	1	25	2	34
Grand Total	**34**	**17**	**74**	**17**	**142**

Table 48: Please indicate if you have implemented, plan to implement, or have not implemented Blanking panels, grommets, or structured cabling at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Blanking panels, grommets, or structured cabling	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	2	6	8	4	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4	4	8	5	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	10	9	4	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		3		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4	7	12	1	24
Grand Total	**15**	**27**	**40**	**14**	**96**

Table 49: Please indicate if you have implemented, plan to implement, or have not implemented Blanking panels, grommets, or structured cabling at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Blanking panels, grommets, or structured cabling	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	7	5		1	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	2	1	2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	10		2	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1		1	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	3	4	1	10
Grand Total	**13**	**21**	**5**	**7**	**46**

Table 50: Please indicate if you have implemented, plan to implement, or have not implemented Blanking panels, grommets, or structured cabling at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Blanking panels, grommets, or structured cabling	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	9	11	8	5	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	6	9	7	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3	20	9	6	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2	1	3	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6	10	16	2	34
Grand Total	**28**	**48**	**45**	**21**	**142**

Table 51: Please indicate if you have implemented, plan to implement, or have not implemented Hot or cold aisle configuration at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Hot or cold aisle configuration	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)		13	3	4	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2	9	6	4	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		14	9	2	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		1	3		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4	7	13		24
Grand Total	**8**	**44**	**34**	**10**	**96**

Table 52: Please indicate if you have implemented, plan to implement, or have not implemented Hot or cold aisle configuration at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Hot or cold aisle configuration	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	3	9	1		13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	4		1	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		11		2	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		2		1	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	2	5		10
Grand Total	**8**	**28**	**6**	**4**	**46**

Table 53: Please indicate if you have implemented, plan to implement, or have not implemented Hot or cold aisle configuration at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Hot or cold aisle configuration	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	3	22	4	4	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	13	6	5	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		25	9	4	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		3	3	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	7	9	18		34
Grand Total	**16**	**72**	**40**	**14**	**142**

Table 54: Please indicate if you have implemented, plan to implement, or have not implemented Hot or cold aisle configuration plus containment (e.g., strip curtains or rigid enclosures) at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Hot or cold aisle configuration plus containment (e.g., strip	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	6	10	3	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	2	10	6	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		5	17	3	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)			4		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	5	2	16	1	24
Grand Total	**11**	**15**	**57**	**13**	**96**

Table 55: Please indicate if you have implemented, plan to implement, or have not implemented Hot or cold aisle configuration plus containment (e.g., strip curtains or rigid enclosures) at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Hot or cold aisle configuration plus containment (e.g., strip	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	5	5	1	2	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2	3		1	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		9	2	2	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1		1	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	2	4	1	10
Grand Total	**12**	**20**	**7**	**7**	**46**

Table 56: Please indicate if you have implemented, plan to implement, or have not implemented Hot or cold aisle configuration plus containment (e.g., strip curtains or rigid enclosures) at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following air flow management energy efficiency practices / at your familiar data / center.-Hot or cold aisle configuration plus containment (e.g., strip	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	6	11	11	5	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	5	10	7	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)		14	19	5	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1	4	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	8	4	20	2	34
Grand Total	**23**	**35**	**64**	**20**	**142**

Table 57: Please indicate if you have implemented, plan to implement, or have not implemented DCIM system at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Data Center Infrastructure Management (DCIM) System	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	1			2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	2	12	3	3	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	4	7	5	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	12	7	4	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1	2		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4	4	15	1	24
Grand Total	**15**	**34**	**34**	**13**	**96**

Table 58: Please indicate if you have implemented, plan to implement, or have not implemented DCIM system at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Data Center Infrastructure Management (DCIM) System	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	4	7	2		13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)		2	2	2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	8		3	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1		1	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	2	4	1	10
Grand Total	**11**	**20**	**8**	**7**	**46**

Table 59: Please indicate if you have implemented, plan to implement, or have not implemented DCIM system at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Data Center Infrastructure Management (DCIM) System	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2	1			3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	6	19	5	3	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	6	9	7	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	4	20	7	7	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2	2	2	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	7	6	19	2	34
Grand Total	**26**	**54**	**42**	**20**	**142**

Table 60: Please indicate if you have implemented, plan to implement, or have not implemented Variable speed drives on pumps/fans at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Variable speed drives on pumps/fans	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)		11	6	3	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	4	8	4	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	4	8	8	5	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2	1	1		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	5	8	10	1	24
Grand Total	**18**	**32**	**33**	**13**	**96**

Table 61: Please indicate if you have implemented, plan to implement, or have not implemented Variable speed drives on pumps/fans at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Variable speed drives on pumps/fans	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	3	10			13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	2		3	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	8	3	1	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	3	4	1	10
Grand Total	**10**	**23**	**8**	**5**	**46**

Table 62: Please indicate if you have implemented, plan to implement, or have not implemented Variable speed drives on pumps/fans at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Variable speed drives on pumps/fans	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	3	21	6	3	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	6	6	8	7	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5	16	11	6	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	4	1	2		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	7	11	14	2	34
Grand Total	**28**	**55**	**41**	**18**	**142**

Table 63: Please indicate if you have implemented, plan to implement, or have not implemented Premium efficiency motors at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Premium efficiency motors	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	2	3	6	9	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4	3	11	3	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	7	6	9	3	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		3		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6	3	15		24
Grand Total	**22**	**15**	**44**	**15**	**96**

Table 64: Please indicate if you have implemented, plan to implement, or have not implemented Premium efficiency motors at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Premium efficiency motors	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	5	8			13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	3	2		6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	7	4		13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	5	1	3	1	10
Grand Total	**16**	**19**	**10**	**1**	**46**

Table 65: Please indicate if you have implemented, plan to implement, or have not implemented Premium efficiency motors at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Premium efficiency motors	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	3				3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	7	11	6	9	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	6	13	3	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	9	13	13	3	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3		4		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	11	4	18	1	34
Grand Total	**38**	**34**	**54**	**16**	**142**

Table 66: Please indicate if you have implemented, plan to implement, or have not implemented Raising server inlet temperature at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Adjusting server inlet temperatures closer to the high end of ASHRAE recommended temperature range of 80F	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1		1		2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	2	2	10	6	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	4	12	2	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3	7	14	1	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		3		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	8	2	13	1	24
Grand Total	**18**	**15**	**53**	**10**	**96**

Table 67: Please indicate if you have implemented, plan to implement, or have not implemented Raising server inlet temperature at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Adjusting server inlet temperatures closer to the high end of ASHRAE recommended temperature range of 80F	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	5	4	2	2	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2		1	3	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	6	3	3	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	4	4		10
Grand Total	**13**	**14**	**11**	**8**	**46**

Table 68: Please indicate if you have implemented, plan to implement, or have not implemented Raising server inlet temperature at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Adjusting server inlet temperatures closer to the high end of ASHRAE recommended temperature range of 80F	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2		1		3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	7	6	12	8	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	4	13	5	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	4	13	17	4	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3		4		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	10	6	17	1	34
Grand Total	**31**	**29**	**64**	**18**	**142**

Table 69: Please indicate if you have implemented, plan to implement, or have not implemented Air side economizer at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate whether or not you are / interested in implementing the / following HVAC energy efficiency practices at your / familiar data / center.-Air-side economizer	**Column Labels**				
Row Labels	**Don't Know**	**Interested**	**Not Interested**	**(blank)**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	5	5		11
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	6	4		15
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	6	12	3		21
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		2		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6	6	9		21
Grand Total	**20**	**29**	**23**		**72**

Table 70: Please indicate if you have implemented, plan to implement, or have not implemented Air side economizer at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate whether or not you are / interested in implementing the / following HVAC energy efficiency practices at your / familiar data / center.- Air-side economizer	**Column Labels**				
Row Labels	**Don't Know**	**Interested**	**Not Interested**	**(blank)**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	7	1	2		10
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	2			3
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	3	3		8
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2				2
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	2	1		5
Grand Total	**15**	**8**	**6**		**29**

Table 71: Please indicate if you have implemented, plan to implement, or have not implemented Air side economizer at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate whether or not you are / interested in implementing the / following HVAC energy efficiency practices at your / familiar data / center.- Air-side economizer	**Column Labels**				
Row Labels	**Don't Know**	**Interested**	**Not Interested**	**(blank)**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	8	6	7		21
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	6	8	4		18
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	8	15	6		29
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	3		2		5
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	8	8	10		26
Grand Total	**35**	**37**	**29**		**101**

Table 72: Please indicate if you have implemented, plan to implement, or have not implemented In row cooling at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate whether or not you are / interested in implementing the / following HVAC energy efficiency practices at your / familiar data / center.- In-row cooling	**Column Labels**				
Row Labels	**Don't Know**	**Interested**	**Not Interested**	**(blank)**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	1	1		3
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	7	4		14
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	4	7	2		13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		3		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	9	6		18
Grand Total	**13**	**24**	**16**		**53**

Table 73: Please indicate if you have implemented, plan to implement, or have not implemented In row cooling at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate whether or not you are / interested in implementing the / following HVAC energy efficiency practices at your / familiar data / center.- In-row cooling	**Column Labels**				
Row Labels	**Don't Know**	**Interested**	**Not Interested**	**(blank)**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	4	1	2		7
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)		2			2
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2		1		3
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		1			1
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4	2	2		8
Grand Total	**11**	**6**	**5**		**22**

Table 74: Please indicate if you have implemented, plan to implement, or have not implemented In row cooling at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate whether or not you are / interested in implementing the / following HVAC energy efficiency practices at your / familiar data / center.-In-row cooling	**Column Labels**				
Row Labels	**Don't Know**	**Interested**	**Not Interested**	**(blank)**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	5	2	3		10
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	9	4		16
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	6	7	3		16
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1	1	3		5
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	7	11	8		26
Grand Total	**24**	**30**	**21**		**75**

Table 75: Please indicate if you have implemented, plan to implement, or have not implemented Water side economizer at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Water-side economizer	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	1			2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	2	5	9	4	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	1	15	2	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	6	2	15	2	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)			4		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4	2	18		24
Grand Total	**16**	**11**	**61**	**8**	**96**

Table 76: Please indicate if you have implemented, plan to implement, or have not implemented Water side economizer at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Water-side economizer	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servei	6	3	2	2	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2	2	2		6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	4	3	5	1	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	1	4	2	10
Grand Total	**18**	**9**	**14**	**5**	**46**

Table 77: Please indicate if you have implemented, plan to implement, or have not implemented Water side economizer at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following HVAC energy efficiency practices at your / familiar data / center.-Water-side economizer	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2	1			3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servei	8	8	11	6	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	3	17	2	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	10	5	20	3	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		5		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	7	3	22	2	34
Grand Total	**34**	**20**	**75**	**13**	**142**

Table 78: Please indicate if you have implemented, plan to implement, or have not implemented Turn off humidifiers at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following humidification energy efficiency practices at your / familiar data / center.-Turn off humidifiers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	1			2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	7	8	4	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	7	10	3	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	6	17		25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		1	3		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	4	15	2	24
Grand Total	**8**	**26**	**53**	**9**	**96**

Table 79: Please indicate if you have implemented, plan to implement, or have not implemented Turn off humidifiers at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following humidification energy efficiency practices at your / familiar data / center.-Turn off humidifiers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	5	2	5	1	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5			1	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5	4	2	2	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)			3		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6	1	2	1	10
Grand Total	**22**	**7**	**12**	**5**	**46**

Table 80: Please indicate if you have implemented, plan to implement, or have not implemented Turn off humidifiers at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following humidification energy efficiency practices at your / familiar data / center.-Turn off humidifiers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2	1			3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	6	9	13	5	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	6	7	10	4	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	7	10	19	2	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		1	6		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	9	5	17	3	34
Grand Total	**30**	**33**	**65**	**14**	**142**

Table 81: Please indicate if you have implemented, plan to implement, or have not implemented Broaden humidity range at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following humidification energy efficiency practices at your / familiar data / center.-Broaden humidity range	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	1			2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	1	4	8	7	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	5	12	3	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3	7	14	1	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)			3	1	4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	3	18	1	24
Grand Total	**8**	**20**	**55**	**13**	**96**

Table 82: Please indicate if you have implemented, plan to implement, or have not implemented Broaden humidity range at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following humidification energy efficiency practices at your / familiar data / center.-Broaden humidity range	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	5	2	4	2	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	1	2		6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5	4	3	1	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		2		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	5	1	4		10
Grand Total	**20**	**8**	**15**	**3**	**46**

Table 83: Please indicate if you have implemented, plan to implement, or have not implemented Broaden humidity range at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following humidification energy efficiency practices at your / familiar data / center.-Broaden humidity range	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2	1			3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	6	6	12	9	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4	6	14	3	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	8	11	17	2	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		5	1	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	7	4	22	1	34
Grand Total	**28**	**28**	**70**	**16**	**142**

Table 84: Please indicate if you have implemented, plan to implement, or have not implemented Install misters, foggers, or ultrasonic humidifiers at your familiar data center. Manager responses.

Role	Manager				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following humidification energy efficiency practices at your / familiar data / center.-Install misters, foggers, or ultrasonic humidifiers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1	1			2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	1	2	12	5	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4	2	11	4	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3	5	16	1	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)			4		4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2		22		24
Grand Total	**11**	**10**	**65**	**10**	**96**

Table 85: Please indicate if you have implemented, plan to implement, or have not implemented Install misters, foggers, or ultrasonic humidifiers at your familiar data center. Vendor responses.

Role	Vendor				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following humidification energy efficiency practices at your / familiar data / center.-Install misters, foggers, or ultrasonic humidifiers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	1				1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 server	6	2	5		13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3		2	1	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5	5	3		13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		2		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6		3	1	10
Grand Total	**22**	**7**	**15**	**2**	**46**

Table 86: Please indicate if you have implemented, plan to implement, or have not implemented Install misters, foggers, or ultrasonic humidifiers at your familiar data center. Combined responses.

Role	(All)				
Count of Please indicate if you have implemented, plan to / implement, or have not implemented the / following humidification energy efficiency practices at your / familiar data / center.-Install misters, foggers, or ultrasonic humidifiers	**Column Labels**				
Row Labels	**Don't Know**	**Implemented**	**Not Implemented**	**Plan to Implement**	**Grand Total**
Don't know	2	1			3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	7	4	17	5	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	7	2	13	5	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	8	10	19	1	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		6		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	8		25	1	34
Grand Total	**33**	**17**	**80**	**12**	**142**

Table 87: How often do you refresh your servers at your familiar data center? Manager responses.

Role	Manager					
Count of How often do you refresh your servers at your familiar data center?	**Column Labels**					
Row Labels	**Don't know**	**Every 1 to 2 years**	**Every 3 to 4 years**	**Every 5 to 6 years**	**No set schedule (whenever individual server performance becomes an issue)**	**Grand Total**
Don't know	2					2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)		1	9	8	2	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	1	11	6	2	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	1	9	10	4	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		1		1	4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)		2	6	8	8	24
Grand Total	**6**	**5**	**36**	**32**	**17**	**96**

Table 88: How often do you refresh your servers at your familiar data center? Vendor responses.

Role	Vendor						
Count of How often do you refresh your servers at your familiar data center?	**Column Labels**						
Row Labels	**Don't know**	**Every 1 to 2 years**	**Every 3 to 4 years**	**Every 5 to 6 years**	**No set schedule (whenever individual server performance becomes an issue)**	**Other**	**Grand Total**
Don't know					1		1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	3	2	7	1			13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2		4				6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	1	8	1		1	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)			2		1		3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4		2	3	1		10
Grand Total	**11**	**3**	**23**	**5**	**3**	**1**	**46**

Table 89: How often do you refresh your servers at your familiar data center? Combined responses.

Role	(All)						
Count of How often do you refresh your servers at your familiar data center?	**Column Labels**						
Row Labels	**Don't know**	**Every 1 to 2 years**	**Every 3 to 4 years**	**Every 5 to 6 years**	**No set schedule (whenever individual server performance becomes an issue)**	**Other**	**Grand Total**
Don't know	2				1		3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	3	3	16	9	2		33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3	1	15	6	2		27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3	2	17	11	4	1	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	2		3		2		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4	2	8	11	9		34
Grand Total	**17**	**8**	**59**	**37**	**20**	**1**	**142**

Table 90: How many of your physical servers at your familiar data center are hosting virtual servers (virtual OS images)? Managers only.

Role	Manager			
How many of your physical servers at your / familiar data center / are hosting virtual servers (virtual OS images)?	[Number of Physical Servers] / /			
Row Labels	**Sum of How many of your physical servers at your / familiar data center / are hosting virtual servers (virtual OS images)?-TEXT**	**Count of How many of your physical servers at your / familiar data center / are hosting virtual servers (virtual OS images)?-TEXT2**	**Max of How many of your physical servers at your / familiar data center / are hosting virtual servers (virtual OS images)?-TEXT3**	**Min of How many of your physical servers at your / familiar data center / are hosting virtual servers (virtual OS images)?-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	12623	13	4000	4
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	693	14	500	0
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2024	20	340	10
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	5	3	3	0
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	60	20	10	0
Grand Total	**15405**	**70**	**4000**	**0**

Table 91: On average, how many virtual servers (virtual / OS images) are hosted in your familiar data center? Managers only.

Role	Manager			
On average, how many virtual servers (virtual / OS images) are hosted in your familiar data center?	[Number of Virtual Servers] / /			
Row Labels	**Average of Virtual servers per physical host2**	**Max of Virtual servers per physical host3**	**Min of Virtual servers per physical host4**	**Count of Virtual servers per physical host**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	10.3	30.0	0.5	7
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2.2	5.4	0.0	7
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3.8	15.0	0.0	15
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1.9	3.3	0.0	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2.6	7.5	0.0	15
Grand Total	**4.0**	**30.0**	**0.0**	**47**

Table 92: On average, how many virtual OS images per physical host server in your familiar data center? Vendors only.

Role	Vendor			
On average, how many virtual servers (virtual / OS images) are hosted in your familiar data center?	[Number of Virtual Servers Per Physical Host Server] / /			
Row Labels	**Average of On average, how many virtual servers (virtual / OS images) are hosted in your familiar data center?-TEXT**	**Max of On average, how many virtual servers (virtual / OS images) are hosted in your familiar data center?-TEXT2**	**Min of On average, how many virtual servers (virtual / OS images) are hosted in your familiar data center?-TEXT3**	**Count of On average, how many virtual servers (virtual / OS images) are hosted in your familiar data center?-TEXT**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	10.0	10	10	1
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	12.0	20	4	2
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	36.4	100	4	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	43.7	75	6	3
Grand Total	**32.3**	**100**	**4**	**13**

Table 93: What level of redundancy is applied to the installed / physical servers at your familiar data center? Manager responses.

Role	Manager				
Count of What level of redundancy is applied to the installed / physical servers at your familiar data center?	**Column Labels**				
Row Labels	**Don't know**	**Full redundancy (2N)****	**No redundancy**	**Parallel redundancy (N+**	**Grand Total**
Don't know	2				2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	2	10	2	6	20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4	5	5	7	21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2	10	4	9	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		2	1	4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	2	10	5	7	24
Grand Total	**13**	**35**	**18**	**30**	**96**

Table 94: What level of redundancy is applied to the installed / physical servers at your familiar data center? Vendor responses.

Role	Vendor				
Count of What level of redundancy is applied to the installed / physical servers at your familiar data center?	**Column Labels**				
Row Labels	**Don't know**	**Full redundancy (2N)****	**No redundancy**	**Parallel redundancy (N+**	**Grand Total**
Don't know		1			1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	4	5		4	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	2	1	1	2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	5		7	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)			1	2	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1	3	1	5	10
Grand Total	**8**	**15**	**3**	**20**	**46**

Table 95: What level of redundancy is applied to the installed / physical servers at your familiar data center? Combined responses.

Role	(All)				
Count of What level of redundancy is applied to the installed / physical servers at your familiar data center?	**Column Labels**				
Row Labels	**Don't know**	**Full redundancy (2N)****	**No redundancy**	**Parallel redundancy (N+**	**Grand Total**
Don't know	2	1			3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	6	15	2	10	33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	6	6	6	9	27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3	15	4	16	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	1		3	3	7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	13	6	12	34
Grand Total	**21**	**50**	**21**	**50**	**142**

Table 96: What is the total power draw (in kilowatts) of the physical servers at your familiar data center? Manager responses.

Role	Manager			
What is the total power draw (in kilowatts) of the / physical servers at your familiar data cer	[Kilowatts] / /			
How do you estimate the power draw of the physical / servers at your familiar / data center	(All)			
Row Labels	**Sum of kW per server**	**Count of kW per server2**	**Max of kW per server3**	**Min of kW per server4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	2043.2	6	2041.7	0.0
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0.6	2	0.5	0.1
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	41.8	11	12.7	0.0
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	37.2	5	34.4	0.2
Grand Total	**2122.8**	**24**	**2041.7**	**0.0**

Table 97: What is the total power draw (in kilowatts) of the physical servers at your familiar data center? Vendor responses.

Role	Vendor			
What is the total power draw (in kilowatts) of the / physical servers at your familiar data cer	[Kilowatts] / /			
How do you estimate the power draw of the physical / servers at your familiar / data center	(All)			
Row Labels	**Sum of kW per server**	**Count of kW per server2**	**Max of kW per server3**	**Min of kW per server4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	1.0	1	1.0	1.0
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0.2	2	0.2	0.0
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3.9	5	3.0	0.0
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	0.1	2	0.1	0.0
Grand Total	**5.2**	**10**	**3.0**	**0.0**

Table 98: What is the total power draw (in kilowatts) of the physical servers at your familiar data center? Combined responses.

Role	(All)			
What is the total power draw (in kilowatts) of the / physical servers at your familiar data cer	[Kilowatts] / /			
How do you estimate the power draw of the physical / servers at your familiar / data center	(All)			
Row Labels	**Sum of kW per server**	**Count of kW per server2**	**Max of kW per server3**	**Min of kW per server4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	2044.2	7	2041.7	0.0
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0.8	4	0.5	0.0
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	45.6	16	12.7	0.0
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	37.3	7	34.4	0.0
Grand Total	**2127.9**	**34**	**2041.7**	**0.0**

Table 99: At your familiar data center, what percent of your physical servers has power management features enabled to reduce power consumption in times of low utilization? Manager responses.

Role	Manager																			
Count of At your familiar / data center, what percent of your physical servers / has power management features enabled to reduce power / consumption in times of low utilization? (examples: processor / clocking cont...-[Select response from drop-down menu	**Column Labels**																			
Row Labels	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**	**30%**	**40%**	**45%**	**50%**	**60%**	**65%**	**70%**	**75%**	**80%**	**85%**	**90%**	**100%**	**Don't know**	**Grand Total**
Don't know	50%	0%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	0%	10%	0%	10%	5%	0%	5%	5%	5%	5%	5%	10%	15%	0%	0%	0%	5%	20%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	14%	5%	10%	5%	0%	14%	5%	0%	0%	5%	5%	0%	0%	0%	5%	5%	0%	10%	19%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	8%	8%	0%	0%	8%	4%	4%	0%	0%	28%	4%	0%	0%	4%	0%	0%	4%	4%	24%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	25%	50%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	29%	4%	0%	0%	4%	8%	4%	0%	0%	8%	4%	0%	4%	0%	8%	0%	0%	8%	17%	100%
Grand Total	**14%**	**4%**	**4%**	**1%**	**5%**	**7%**	**3%**	**2%**	**1%**	**11%**	**4%**	**1%**	**3%**	**4%**	**3%**	**1%**	**2%**	**7%**	**21%**	**100%**

Table 100: At your familiar data center, what percent of your physical servers has power management features enabled to reduce power consumption in times of low utilization? Vendor responses.

Role	Vendor															
Count of At your familiar / data center, what percent of your physical servers / has power management features enabled to reduce power / consumption in times of low utilization? (examples: processor / clocking cont...-[Select response from drop-down menu	**Column Labels**															
Row Labels	**0%**	**10%**	**15%**	**20%**	**35%**	**40%**	**45%**	**50%**	**65%**	**70%**	**75%**	**80%**	**90%**	**100%**	**Don't know**	**Grand Total**
Don't know	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	0%	0%	0%	0%	8%	0%	8%	8%	0%	23%	0%	0%	0%	54%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0%	17%	0%	0%	0%	0%	0%	0%	0%	17%	33%	0%	0%	0%	33%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	8%	0%	0%	0%	8%	8%	8%	8%	0%	8%	8%	8%	0%	8%	31%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	0%	33%	0%	0%	0%	0%	0%	33%	0%	0%	0%	0%	33%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	10%	0%	10%	20%	0%	0%	0%	10%	0%	10%	10%	0%	10%	0%	20%	100%
Grand Total	**4%**	**2%**	**2%**	**7%**	**2%**	**4%**	**2%**	**7%**	**2%**	**9%**	**15%**	**2%**	**2%**	**2%**	**37%**	**100%**

Table 101: At your familiar data center, what percent of your physical servers has power management features enabled to reduce power consumption in times of low utilization? Combined responses.

Role	(All)																					
Count of At your familiar / data center, what percent of your physical servers / has power management features enabled to reduce power / consumption in times of low utilization? (examples: processor / clocking cont...-[Select response from drop-down menu	**Column Labels**																					
Row Labels	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**	**45%**	**50%**	**60%**	**65%**	**70%**	**75%**	**80%**	**85%**	**90%**	**100%**	**Don't know**	**Grand Total**	
Don't know	33%	0%	0%	0%	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	33%	100%	
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	0%	6%	0%	6%	3%	0%	0%	6%	3%	6%	3%	6%	6%	18%	0%	0%	0%	3%	33%	100%	
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	11%	4%	11%	4%	0%	11%	4%	0%	0%	0%	4%	4%	0%	4%	7%	4%	4%	0%	7%	22%	100%	
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	8%	5%	0%	0%	5%	3%	3%	3%	3%	3%	21%	3%	0%	3%	5%	3%	0%	3%	5%	26%	100%	
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	0%	0%	14%	0%	0%	0%	0%	0%	0%	0%	0%	14%	0%	0%	0%	14%	14%	43%	100%	
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	24%	3%	0%	3%	9%	6%	3%	0%	0%	0%	9%	3%	0%	6%	3%	6%	0%	3%	6%	18%	100%	
Grand Total	**11%**	**3%**	**4%**	**1%**	**6%**	**5%**	**2%**	**1%**	**3%**	**1%**	**10%**	**3%**	**1%**	**5%**	**8%**	**3%**	**1%**	**2%**	**6%**	**26%**	**100%**	

Table 102: At your familiar data center, what percent of your virtual servers has power management features enabled in the virtualization software? Manager responses.

Role: Manager

Count of At your familiar / data center, what percent of your virtual servers has / power management features enabled in the virtualization / software? (For example, some virtualization power management saves / ene...-[Select response from drop-down menu — Column Labels

Row Labels	0%	5%	10%	15%	20%	25%	30%	40%	50%	55%	60%	70%	75%	80%	90%	95%	100%	Don't know	85%	Grand Total
Don't know	50%	0%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	5%	0%	5%	0%	15%	5%	5%	0%	10%	5%	0%	10%	10%	0%	5%	0%	0%	20%	5%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	14%	5%	5%	5%	5%	0%	5%	0%	14%	0%	0%	0%	0%	5%	0%	0%	14%	29%	0%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	12%	4%	8%	0%	12%	0%	0%	4%	16%	0%	0%	0%	4%	4%	0%	0%	16%	20%	0%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	0%	25%	50%	0%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	50%	0%	0%	0%	4%	4%	0%	0%	0%	4%	4%	0%	0%	0%	0%	4%	8%	21%	0%	100%
Grand Total	**21%**	**2%**	**4%**	**1%**	**8%**	**2%**	**2%**	**2%**	**9%**	**2%**	**1%**	**2%**	**3%**	**2%**	**2%**	**1%**	**10%**	**23%**	**1%**	**100%**

Table 103: At your familiar data center, what percent of your virtual servers has power management features enabled in the virtualization software? Vendor responses.

Role: Vendor

Count of At your familiar / data center, what percent of your virtual servers has / power management features enabled in the virtualization / software? (For example, some virtualization power management saves / ene...-[Select response from drop-down menu — **Column Labels**

Row Labels	0%	5%	15%	25%	30%	35%	50%	60%	70%	75%	90%	100%	Don't	Grand Total
Don't know	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	8%	0%	0%	0%	8%	8%	0%	8%	8%	0%	0%	62%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0%	0%	17%	17%	0%	0%	33%	0%	0%	0%	0%	0%	33%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	15%	0%	0%	0%	0%	8%	8%	8%	0%	8%	8%	8%	38%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	33%	0%	0%	0%	0%	0%	0%	33%	0%	0%	33%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	10%	10%	20%	0%	10%	0%	20%	0%	0%	0%	0%	0%	30%	100%
Grand Total	**7%**	**4%**	**9%**	**2%**	**2%**	**4%**	**13%**	**2%**	**2%**	**7%**	**2%**	**2%**	**43%**	**100%**

Table 104: At your familiar data center, what percent of your virtual servers has power management features enabled in the virtualization software? Combined responses.

Role	(All)																				
Count of At your familiar / data center, what percent of your virtual servers has / power management features enabled in the virtualization / software? (For example, some virtualization power management saves / ene...-[Select response from drop-down menu	**Column Labels**																				
Row Labels	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**	**50%**	**55%**	**60%**	**70%**	**75%**	**80%**	**90%**	**95%**	**100%**	**Don't know**	**85%**	**Grand Total**
Don't know	33%	0%	0%	0%	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%	0%	0%	0%	33%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	3%	3%	3%	0%	9%	3%	3%	3%	0%	9%	3%	0%	9%	9%	0%	3%	0%	0%	36%	3%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	11%	4%	4%	7%	4%	4%	4%	0%	0%	19%	0%	0%	0%	0%	4%	0%	0%	11%	30%	0%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	13%	3%	5%	0%	8%	0%	0%	3%	3%	13%	0%	3%	0%	5%	3%	3%	0%	13%	26%	0%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	0%	14%	0%	0%	0%	0%	0%	0%	0%	0%	0%	14%	0%	14%	0%	14%	43%	0%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	38%	3%	0%	6%	3%	3%	3%	0%	0%	6%	3%	3%	0%	0%	0%	0%	3%	6%	24%	0%	100%
Grand Total	**16%**	**3%**	**3%**	**4%**	**6%**	**2%**	**2%**	**1%**	**1%**	**11%**	**1%**	**1%**	**2%**	**4%**	**1%**	**2%**	**1%**	**8%**	**30%**	**1%**	**100%**

Table 105: At your familiar data center, what percent of your physical servers is ENERGY STAR certified? Manager responses.

Role	Manager																			
Count of At your familiar / data center, what percent of your physical servers is / ENERGY STAR certified?-[Select response from drop-down menu]	**Column Labels**																			
Row Labels	**0**	**0.05**	**0.1**	**0.15**	**0.25**	**0.3**	**0.4**	**0.45**	**0.5**	**0.55**	**0.6**	**0.65**	**0.7**	**0.75**	**0.8**	**0.9**	**0.95**	**1**	**Don't know**	**Grand Total**
Don't know	50%	0%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	0%	0%	0%	0%	5%	0%	0%	5%	0%	0%	0%	5%	25%	20%	10%	0%	5%	25%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5%	10%	0%	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%	10%	0%	0%	0%	19%	48%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	0%	0%	8%	0%	4%	4%	8%	0%	16%	4%	0%	0%	0%	8%	8%	0%	0%	12%	28%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	0%	0%	0%	25%	0%	0%	50%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4%	0%	0%	8%	0%	0%	4%	0%	8%	0%	4%	0%	4%	4%	0%	0%	4%	29%	29%	100%
Grand Total	**3%**	**2%**	**2%**	**2%**	**2%**	**3%**	**3%**	**1%**	**7%**	**1%**	**1%**	**1%**	**2%**	**10%**	**6%**	**3%**	**1%**	**16%**	**32%**	**100%**

Table 106: At your familiar data center, what percent of your physical servers is ENERGY STAR certified? Vendor responses.

Role	Vendor														
Count of At your familiar / data center, what percent of your physical servers is / ENERGY STAR certified?-[Select response from drop-down menu]	**Column Labels**														
Row Labels	**0**	**0.1**	**0.15**	**0.2**	**0.3**	**0.4**	**0.5**	**0.75**	**0.8**	**0.85**	**0.9**	**0.95**	**1**	**Don't know**	**Grand Total**
Don't know	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	8%	8%	8%	8%	0%	0%	0%	0%	0%	15%	0%	15%	38%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0%	17%	0%	0%	0%	17%	0%	0%	0%	0%	0%	0%	17%	50%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	0%	0%	0%	0%	0%	0%	15%	8%	0%	0%	15%	0%	15%	46%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	33%	0%	0%	0%	0%	0%	33%	0%	0%	33%	0%	0%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	10%	10%	0%	0%	0%	0%	10%	10%	10%	10%	0%	0%	10%	30%	100%
Grand Total	**2%**	**7%**	**4%**	**2%**	**2%**	**2%**	**7%**	**4%**	**4%**	**2%**	**9%**	**2%**	**13%**	**39%**	**100%**

Table 107: At your familiar data center, what percent of your physical servers is ENERGY STAR certified? Combined responses.

Role	(All)																					
Count of At your familiar / data center, what percent of your physical servers is / ENERGY STAR certified?-[Select response from drop-down menu]	**Column Labels**																					
Row Labels	**0**	**0.05**	**0.1**	**0.15**	**0.2**	**0.25**	**0.3**	**0.4**	**0.45**	**0.5**	**0.55**	**0.6**	**0.65**	**0.7**	**0.75**	**0.8**	**0.85**	**0.9**	**0.95**	**1**	**Don't know**	**Grand Total**
Don't know	33%	0%	0%	0%	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	33%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	0%	3%	3%	3%	0%	6%	0%	0%	3%	0%	0%	0%	3%	15%	12%	0%	12%	0%	9%	30%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4%	7%	4%	0%	0%	4%	4%	4%	0%	0%	0%	0%	0%	0%	7%	0%	0%	0%	0%	19%	48%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	0%	0%	5%	0%	0%	3%	3%	5%	0%	16%	3%	0%	0%	0%	8%	5%	0%	5%	0%	13%	34%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	0%	14%	0%	0%	0%	0%	0%	0%	0%	0%	14%	0%	0%	14%	0%	14%	14%	0%	29%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6%	0%	3%	6%	0%	0%	0%	3%	0%	9%	0%	3%	0%	3%	6%	3%	3%	0%	3%	24%	29%	100%
Grand Total	**3%**	**1%**	**4%**	**3%**	**1%**	**1%**	**3%**	**3%**	**1%**	**7%**	**1%**	**1%**	**1%**	**1%**	**8%**	**6%**	**1%**	**5%**	**1%**	**15%**	**35%**	**100%**

Table 108: At your familiar data center, what is the average annual CPU utilization level (in percent) for physical servers? Manager responses.

Role	Manager																		
Count of At your familiar / data center, what is the average annual CPU / utilization level (in percent) for physical / servers?-[Select response from drop-down menu]	**Column Labels**																		
Row Labels	**0**	**0.1**	**0.15**	**0.2**	**0.25**	**0.3**	**0.4**	**0.45**	**0.5**	**0.55**	**0.6**	**0.65**	**0.7**	**0.75**	**0.8**	**0.85**	**Don't know**	**0.05**	**Grand Total**
Don't know	50%	0%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	0%	0%	5%	0%	0%	5%	0%	0%	5%	15%	0%	10%	30%	5%	5%	20%	0%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0%	0%	10%	0%	5%	14%	14%	0%	10%	0%	0%	0%	0%	0%	0%	0%	48%	0%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	0%	0%	0%	0%	8%	8%	12%	4%	12%	0%	8%	8%	4%	4%	4%	0%	28%	0%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	0%	50%	0%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4%	4%	0%	4%	4%	4%	4%	4%	0%	0%	17%	8%	4%	4%	0%	0%	33%	4%	100%
Grand Total	**2%**	**1%**	**2%**	**2%**	**4%**	**6%**	**8%**	**3%**	**5%**	**1%**	**9%**	**4%**	**4%**	**8%**	**4%**	**1%**	**32%**	**1%**	**100%**

Table 109: At your familiar data center, what is the average annual CPU utilization level (in percent) for physical servers? Vendor responses.

Role: Vendor

Count of At your familiar / data center, what is the average annual CPU / utilization level (in percent) for physical / servers?-[Select response from drop-down menu] Row Labels	0	0.1	0.15	0.2	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.7	0.75	0.85	0.9	Don't know	Grand Total
Don't know	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	0%	8%	0%	0%	0%	15%	8%	8%	0%	8%	8%	0%	0%	0%	46%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0%	0%	0%	17%	17%	17%	17%	0%	0%	0%	0%	0%	0%	0%	0%	33%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	0%	8%	0%	8%	0%	0%	8%	8%	0%	8%	0%	0%	15%	0%	8%	38%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	33%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	67%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	10%	0%	0%	10%	10%	0%	0%	0%	0%	10%	0%	0%	10%	10%	0%	40%	100%
Grand Total	**2%**	**4%**	**2%**	**7%**	**4%**	**2%**	**9%**	**4%**	**2%**	**4%**	**2%**	**2%**	**7%**	**2%**	**2%**	**43%**	**100%**

Table 110: At your familiar data center, what is the average annual CPU utilization level (in percent) for physical servers? Combined responses.

Role: (All)

Count of At your familiar / data center, what is the average annual CPU / utilization level (in percent) for physical / servers?-[Select response from drop-down menu] Row Labels	0	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	Don't know	0.05	Grand Total
Don't know	33%	0%	0%	0%	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%	0%	0%	0%	33%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	0%	0%	3%	3%	0%	0%	0%	9%	3%	3%	3%	12%	0%	9%	18%	3%	3%	0%	30%	0%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0%	0%	7%	4%	4%	15%	4%	15%	0%	7%	0%	0%	0%	0%	0%	0%	0%	0%	44%	0%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	0%	3%	0%	3%	5%	5%	0%	11%	5%	8%	3%	5%	5%	3%	8%	3%	0%	3%	32%	0%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	14%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	29%	0%	0%	57%	0%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	6%	3%	0%	6%	3%	6%	0%	3%	3%	0%	3%	12%	6%	3%	6%	0%	3%	0%	35%	3%	100%
Grand Total	**2%**	**2%**	**2%**	**4%**	**3%**	**6%**	**1%**	**8%**	**4%**	**4%**	**2%**	**7%**	**3%**	**4%**	**8%**	**3%**	**1%**	**1%**	**36%**	**1%**	**100%**

Table 111: What is the age of your newest network switches at your familiar data center? Manager responses.

Role	Manager			
What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half	[Years] / /			
Row Labels	**Sum of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT**	**Count of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT2**	**Max of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT3**	**Min of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	18.70	17	3	0.1
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	24.33	18	4	0.1
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	23.75	17	5	0
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	10.00	4	5	1
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	35.00	20	7	0.5
Grand Total	**111.78**	**76**	**7**	**0**

Table 112: What is the age of your newest network switches at your familiar data center? Vendor responses.

Role	Vendor			
What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half	[Years] / /			
Row Labels	**Sum of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT**	**Count of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT2**	**Max of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT3**	**Min of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	11.50	6	4	0.5
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	3.00	2	2	1
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	14.95	9	5	0.2
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	14.50	7	5	0.5
Grand Total	**43.95**	**24**	**5**	**0.2**

Table 113: What is the age of your newest network switches at your familiar data center? Combined responses.

Role	(All)			
What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half	[Years] / /			
Row Labels	**Sum of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT**	**Count of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT2**	**Max of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT3**	**Min of What is the age of your newest network switches / at your familiar data / center? (Use decimals to indicate a half year. For example, / you would type "0.5" to indicate six months.)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	30.20	23	4	0.1
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	27.33	20	4	0.1
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	38.70	26	5	0
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	10.00	4	5	1
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	49.50	27	7	0.5
Grand Total	**155.73**	**100**	**7**	**0**

Table 114: What is the age of your oldest network switches at your familiar data center? Manager responses.

Role	Manager			
What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half	[Years] / /			
Row Labels	**Sum of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT**	**Count of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT2**	**Max of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT3**	**Min of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	77.90	16	7	1.9
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	109.50	15	16	2.5
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	101.80	17	12	0.3
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	18.00	4	10	1
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	96.50	20	10	1
Grand Total	**403.70**	**72**	**16**	**0.3**

Table 115: What is the age of your oldest network switches at your familiar data center? Vendor responses.

Role	Vendor			
What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half y	[Years] / /			
Row Labels	**Sum of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT**	**Count of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT2**	**Max of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT3**	**Min of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	22.50	6	6	1.5
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	11.00	2	6	5
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	53.00	10	10	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	56.50	7	20	2.5
Grand Total	**143.00**	**25**	**20**	**1.5**

Table 116: What is the age of your oldest network switches at your familiar data center? Combined responses.

Role	(All)			
What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half \	[Years] / /			
Row Labels	**Sum of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT**	**Count of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT2**	**Max of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT3**	**Min of What is the age of your oldest network switches at / your familiar data / center? (Use decimals to indicate a half year)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	100.40	22	7	1.5
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	120.50	17	16	2.5
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	154.80	27	12	0.3
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	18.00	4	10	1
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	153.00	27	20	1
Grand Total	**546.70**	**97**	**20**	**0.3**

Table 117: How many network switches are installed in your familiar data center? Manager responses.

Role	Manager			
How many network switches are installed in your / familiar data / center?	[Number of Switches] / /			
Row Labels	**Sum of How many network switches are installed in your / familiar data / center?-TEXT**	**Count of How many network switches are installed in your / familiar data / center?-TEXT2**	**Max of How many network switches are installed in your / familiar data / center?-TEXT3**	**Min of How many network switches are installed in your / familiar data / center?-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	10690	9	7500	10
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	255	12	100	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1219	18	500	2
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	28	3	15	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	122	16	30	1
Grand Total	**12314**	**58**	**7500**	**1**

Table 118: How many network switches are installed in your familiar data center? Vendor responses.

Role	Vendor			
How many network switches are installed in your / familiar data / center?	[Number of Switches] / /			
Row Labels	**Sum of How many network switches are installed in your / familiar data / center?-TEXT**	**Count of How many network switches are installed in your / familiar data / center?-TEXT2**	**Max of How many network switches are installed in your / familiar data / center?-TEXT3**	**Min of How many network switches are installed in your / familiar data / center?-TEXT4**
Don't know	6	1	6	6
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	200	1	200	200
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	1	5	5
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	170	3	100	20
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	225	4	200	2
Grand Total	**606**	**10**	**200**	**2**

Table 119: How many network switches are installed in your familiar data center? Combined responses.

Role	(All)			
How many network switches are installed in your / familiar data / center?	[Number of Switches] / /			
Row Labels	**Sum of How many network switches are installed in your / familiar data / center?-TEXT**	**Count of How many network switches are installed in your / familiar data / center?-TEXT2**	**Max of How many network switches are installed in your / familiar data / center?-TEXT3**	**Min of How many network switches are installed in your / familiar data / center?-TEXT4**
Don't know	6	1	6	6
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	10890	10	7500	10
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	260	13	100	5
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1389	21	500	2
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	28	3	15	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	347	20	200	1
Grand Total	**12920**	**68**	**7500**	**1**

Table 120: How would you describe the switch network topology at your familiar data center? Manager responses.

Role	Manager				
Count of How would you describe the switch network topology at your / familiar data / center?	**Column Labels**				
Row Labels	**A fat-tree topology**	**A typical traditional hierarchical topology**	**Don't know**	**Other topology**	**Grand Total**
Don't know			2		2
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	4	15	1		20
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	4	14	3		21
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	4	17	3	1	25
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		4			4
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	21			24
Grand Total	**15**	**71**	**9**	**1**	**96**

Table 121: How would you describe the switch network topology at your familiar data center? Vendor responses.

Role	Vendor			
Count of How would you describe the switch network topology at your / familiar data / center?	**Column Labels**			
Row Labels	**A fat-tree topology**	**A typical traditional hierarchical topology**	**Don't know**	**Grand Total**
Don't know			1	1
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	1	4	8	13
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1	3	2	6
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1	8	4	13
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		2	1	3
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)		6	4	10
Grand Total	**3**	**23**	**20**	**46**

Table 122: How would you describe the switch network topology at your familiar data center? Combined responses.

Role	(All)				
Count of How would you describe the switch network topology at your / familiar data / center?	Column Labels				
Row Labels	**A fat-tree topology**	**A typical traditional hierarchical topology**	**Don't know**	**Other topology**	**Grand Total**
Don't know			3		3
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	5	19	9		33
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	5	17	5		27
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	5	25	7	1	38
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)		6	1		7
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3	27	4		34
Grand Total	**18**	**94**	**29**	**1**	**142**

Table 123: What is the PUE of your familiar data center? Manager responses.

Role	Manager			
What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)	[PUE] / /			
Row Labels	**Average of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT**	**Count of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT2**	**Max of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT3**	**Min of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	5.57	5	20.00	1.40
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2.50	2	3.00	2.00
Grand Total	**4.69**	**7**	**20.00**	**1.40**

Table 124: What is the PUE of your familiar data center? Vendor responses.

Role	Vendor			
What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)	[PUE] / /			
Row Labels	**Average of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT**	**Count of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT2**	**Max of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT3**	**Min of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	1.62	7	2.00	1.17
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1.80	1	1.80	1.80
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1.95	5	3.00	1.40
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1.48	2	1.50	1.45
Grand Total	**1.72**	**15**	**3.00**	**1.17**

Table 125: What is the PUE of your familiar data center? Combined responses.

Role	(All)			
What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)	[PUE] / /			
Row Labels	**Average of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT**	**Count of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT2**	**Max of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT3**	**Min of What is the average annual power usage effectiveness (PUE) / of your familiar data / center? (Response cannot be less than 1)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	3.27	12	20.00	1.17
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1.80	1	1.80	1.80
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	2.11	7	3.00	1.40
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1.48	2	1.50	1.45
Grand Total	**2.67**	**22**	**20.00**	**1.17**

Table 126: What is the average efficiency (in percent) of your power transformers at the familiar data center? Manager responses.

Role	Manager						
Count of What is the average efficiency (in percent) of your / power transformers at the familiar data center?-[Select response from drop-down menu]	**Column Labels**						
Row Labels	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**	**Grand Total**
0	50%	0%	0%	4%	0%	0%	2%
0.05	0%	0%	5%	0%	0%	0%	1%
0.1	0%	0%	0%	8%	0%	0%	2%
0.2	0%	0%	10%	0%	0%	0%	2%
0.25	0%	5%	0%	0%	0%	4%	2%
0.3	0%	5%	0%	8%	0%	4%	4%
0.35	0%	0%	5%	0%	0%	0%	1%
0.4	50%	5%	0%	0%	0%	0%	2%
0.5	0%	10%	0%	0%	0%	0%	2%
0.55	0%	5%	0%	0%	0%	4%	2%
0.6	0%	5%	0%	0%	25%	0%	2%
0.65	0%	0%	0%	4%	0%	0%	1%
0.7	0%	0%	10%	8%	25%	0%	5%
0.75	0%	10%	0%	0%	0%	0%	2%
0.8	0%	0%	0%	0%	0%	8%	2%
0.85	0%	5%	0%	4%	0%	0%	2%
Don't know	0%	45%	71%	64%	50%	79%	64%
0.45	0%	5%	0%	0%	0%	0%	1%
Grand Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 127: What is the average efficiency (in percent) of your power transformers at the familiar data center? Vendor responses.

Role	Vendor						
Count of What is the average efficiency (in percent) of your / power transformers at the familiar data center?-[Select response from drop-down menu]	Column Labels						
Row Labels	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**	**Grand Total**
0.05	0%	0%	0%	0%	33%	0%	2%
0.1	0%	8%	0%	0%	0%	0%	2%
0.15	0%	0%	0%	0%	0%	10%	2%
0.25	0%	0%	17%	0%	0%	0%	2%
0.3	0%	8%	0%	8%	0%	0%	4%
0.4	0%	0%	0%	8%	0%	0%	2%
0.5	0%	0%	17%	0%	0%	0%	2%
0.6	0%	0%	17%	0%	0%	0%	2%
0.7	0%	0%	0%	8%	0%	0%	2%
0.75	0%	0%	0%	8%	0%	10%	4%
0.8	0%	0%	0%	0%	0%	10%	2%
0.85	0%	8%	0%	0%	0%	0%	2%
0.9	0%	8%	0%	8%	0%	10%	7%
0.95	0%	0%	0%	8%	0%	10%	4%
Don't know	100%	69%	50%	54%	67%	50%	59%
Grand Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 128: What is the average efficiency (in percent) of your power transformers at the familiar data center? Combined responses.

Role	(All)						
Count of What is the average efficiency (in percent) of your / power transformers at the familiar data center?-[Select response from drop-down menu]	**Column Labels**						
Row Labels	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**	**Grand Total**
0	33%	0%	0%	3%	0%	0%	1%
0.05	0%	0%	4%	0%	14%	0%	1%
0.1	0%	3%	0%	5%	0%	0%	2%
0.15	0%	0%	0%	0%	0%	3%	1%
0.2	0%	0%	7%	0%	0%	0%	1%
0.25	0%	3%	4%	0%	0%	3%	2%
0.3	0%	6%	0%	8%	0%	3%	4%
0.35	0%	0%	4%	0%	0%	0%	1%
0.4	33%	3%	0%	3%	0%	0%	2%
0.5	0%	6%	4%	0%	0%	0%	2%
0.55	0%	3%	0%	0%	0%	3%	1%
0.6	0%	3%	4%	0%	14%	0%	2%
0.65	0%	0%	0%	3%	0%	0%	1%
0.7	0%	0%	7%	8%	14%	0%	4%
0.75	0%	6%	0%	3%	0%	3%	3%
0.8	0%	0%	0%	0%	0%	9%	2%
0.85	0%	6%	0%	3%	0%	0%	2%
0.9	0%	3%	0%	3%	0%	3%	2%
0.95	0%	0%	0%	3%	0%	3%	1%
Don't know	33%	55%	67%	61%	57%	71%	62%
0.45	0%	3%	0%	0%	0%	0%	1%
Grand Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 129: What is the average efficiency (in percent) of your UPS at the familiar data center? Manager responses.

Role	Manager						
Count of At your familiar / data center, what is the average efficiency (in percent) of / your UPS/rectifier, if any?-[Select response from drop-down menu]	**Column Labels**						
Row Labels	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**	**Grand Total**
0	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.04%
0.05	0.00%	0.00%	4.76%	4.00%	0.00%	0.00%	2.08%
0.1	0.00%	0.00%	0.00%	4.00%	0.00%	0.00%	1.04%
0.15	0.00%	0.00%	4.76%	0.00%	0.00%	0.00%	1.04%
0.2	0.00%	0.00%	0.00%	4.00%	0.00%	4.17%	2.08%
0.25	0.00%	5.00%	0.00%	0.00%	25.00%	0.00%	2.08%
0.3	0.00%	0.00%	4.76%	4.00%	0.00%	0.00%	2.08%
0.35	0.00%	5.00%	0.00%	0.00%	0.00%	0.00%	1.04%
0.4	0.00%	0.00%	4.76%	0.00%	0.00%	0.00%	1.04%
0.45	50.00%	5.00%	0.00%	0.00%	0.00%	4.17%	3.13%
0.5	0.00%	10.00%	0.00%	0.00%	0.00%	0.00%	2.08%
0.6	0.00%	10.00%	0.00%	0.00%	0.00%	0.00%	2.08%
0.7	0.00%	0.00%	0.00%	8.00%	0.00%	4.17%	3.13%
0.75	0.00%	10.00%	4.76%	0.00%	0.00%	0.00%	3.13%
0.8	0.00%	10.00%	0.00%	4.00%	0.00%	8.33%	5.21%
0.85	0.00%	0.00%	0.00%	4.00%	0.00%	0.00%	1.04%
0.9	0.00%	5.00%	0.00%	4.00%	0.00%	0.00%	2.08%
0.95	0.00%	0.00%	0.00%	4.00%	25.00%	0.00%	2.08%
Don't know	0.00%	40.00%	76.19%	60.00%	50.00%	79.17%	62.50%
Grand Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 130: What is the average efficiency (in percent) of your UPS at the familiar data center? Vendor responses.

Role	Vendor						
Count of At your familiar / data center, what is the average efficiency (in percent) of / your UPS/rectifier, if any?-[Select response from drop-down menu]	Column Labels						
Row Labels	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**	**Grand Total**
0.05	0.00%	7.69%	0.00%	0.00%	0.00%	0.00%	2.17%
0.1	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	2.17%
0.25	0.00%	7.69%	0.00%	7.69%	0.00%	0.00%	4.35%
0.3	0.00%	0.00%	0.00%	7.69%	0.00%	0.00%	2.17%
0.4	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	2.17%
0.5	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%	4.35%
0.7	0.00%	0.00%	16.67%	0.00%	0.00%	0.00%	2.17%
0.8	0.00%	0.00%	0.00%	7.69%	0.00%	0.00%	2.17%
0.85	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	2.17%
0.9	0.00%	15.38%	0.00%	0.00%	0.00%	20.00%	8.70%
0.95	0.00%	7.69%	16.67%	23.08%	0.00%	0.00%	10.87%
Don't know	100.00%	61.54%	33.33%	53.85%	66.67%	60.00%	56.52%
Grand Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 131: What is the average efficiency (in percent) of your UPS at the familiar data center? Combined responses.

Role	(All)						
Count of At your familiar / data center, what is the average efficiency (in percent) of / your UPS/rectifier, if any?-[Select response from drop-down menu]	**Column Labels**						
Row Labels	**Don't know**	**Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)**	**Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)**	**Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)**	**Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)**	**Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)**	**Grand Total**
0	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.70%
0.05	0.00%	3.03%	3.70%	2.63%	0.00%	0.00%	2.11%
0.1	0.00%	0.00%	0.00%	2.63%	0.00%	2.94%	1.41%
0.15	0.00%	0.00%	3.70%	0.00%	0.00%	0.00%	0.70%
0.2	0.00%	0.00%	0.00%	2.63%	0.00%	2.94%	1.41%
0.25	0.00%	6.06%	0.00%	2.63%	14.29%	0.00%	2.82%
0.3	0.00%	0.00%	3.70%	5.26%	0.00%	0.00%	2.11%
0.35	0.00%	3.03%	0.00%	0.00%	0.00%	0.00%	0.70%
0.4	0.00%	0.00%	3.70%	0.00%	14.29%	0.00%	1.41%
0.45	33.33%	3.03%	0.00%	0.00%	0.00%	2.94%	2.11%
0.5	0.00%	6.06%	7.41%	0.00%	0.00%	0.00%	2.82%
0.6	0.00%	6.06%	0.00%	0.00%	0.00%	0.00%	1.41%
0.7	0.00%	0.00%	3.70%	5.26%	0.00%	2.94%	2.82%
0.75	0.00%	6.06%	3.70%	0.00%	0.00%	0.00%	2.11%
0.8	0.00%	6.06%	0.00%	5.26%	0.00%	5.88%	4.23%
0.85	0.00%	0.00%	0.00%	2.63%	0.00%	2.94%	1.41%
0.9	0.00%	9.09%	0.00%	2.63%	0.00%	5.88%	4.23%
0.95	0.00%	3.03%	3.70%	10.53%	14.29%	0.00%	4.93%
Don't know	33.33%	48.48%	66.67%	57.89%	57.14%	73.53%	60.56%
Grand Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 132: Which description best characterizes the cooling equipment of your familiar data center? Manager responses.

Role	Manager									
Count of Which description best characterizes the cooling equipment / of your familiar data / center?	Column Labels									
Row Labels	**Dedicated computer room air conditioner (CRAC) with DX**	**Dedicated computer room air handling unit (CRAH) or fan coil unit with chilled water from a chiller**	**Dedicated ductless split with DX**	**Don't know**	**General building air handling unit with chilled water from a chiller (not dedicated to data center space)**	**General building HVAC with DX (not dedicated to data center space)**	**Heat pump - ground source**	**Heat pump with cooling tower**	**Other**	**Grand Total**
Don't know	0%	50%	0%	50%	0%	0%	0%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	35%	35%	0%	5%	0%	10%	0%	10%	5%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	29%	38%	14%	5%	5%	5%	5%	0%	0%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	20%	44%	8%	12%	4%	0%	0%	0%	12%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	25%	50%	0%	0%	0%	0%	0%	25%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	13%	21%	50%	4%	0%	4%	0%	0%	8%	100%
Grand Total	**22%**	**34%**	**20%**	**7%**	**2%**	**4%**	**1%**	**2%**	**7%**	**100%**

Table 133: Which description best characterizes the cooling equipment of your familiar data center? Vendor responses.

Role	Vendor							
Count of Which description best characterizes the cooling equipment / of your familiar data / center?	**Column Labels**							
Row Labels	**Dedicated computer room air conditioner (CRAC) with DX**	**Dedicated computer room air handling unit (CRAH) or fan coil unit with chilled water from a chiller**	**Dedicated ductless split with DX**	**Don't know**	**General building air handling unit with chilled water from a chiller (not dedicated to data center space)**	**General building HVAC with DX (not dedicated to data center space)**	**Other**	**Grand Total**
Don't know	0%	0%	0%	100%	0%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	31%	31%	0%	38%	0%	0%	0%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	83%	17%	0%	0%	0%	0%	0%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	54%	15%	8%	8%	0%	8%	8%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	67%	33%	0%	0%	0%	0%	0%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	20%	30%	10%	10%	10%	10%	10%	100%
Grand Total	**43%**	**24%**	**4%**	**17%**	**2%**	**4%**	**4%**	**100%**

Table 134: Which description best characterizes the cooling equipment of your familiar data center? Combined responses.

Role	(All)									
Count of Which description best characterizes the cooling equipment / of your familiar data / center?	**Column Labels**									
Row Labels	**Dedicated computer room air conditioner (CRAC) with DX**	**Dedicated computer room air handling unit (CRAH) or fan coil unit with chilled water from a chiller**	**Dedicated ductless split with DX**	**Don't know**	**General building air handling unit with chilled water from a chiller (not dedicated to data center space)**	**General building HVAC with DX (not dedicated to data center space)**	**Heat pump - ground source**	**Heat pump with cooling tower**	**Other**	**Grand Total**
Don't know	0%	33%	0%	67%	0%	0%	0%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	33%	33%	0%	18%	0%	6%	0%	6%	3%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	41%	33%	11%	4%	4%	4%	4%	0%	0%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	32%	34%	8%	11%	3%	3%	0%	0%	11%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	29%	29%	29%	0%	0%	0%	0%	0%	14%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	15%	24%	38%	6%	3%	6%	0%	0%	9%	100%
Grand Total	**29%**	**31%**	**15%**	**11%**	**2%**	**4%**	**1%**	**1%**	**6%**	**100%**

Table 135: Which of the following free-cooling mechanisms do you use at your familiar data center? Manager responses.

Role	Manager					
Count of Which of the following free-cooling mechanisms do you use / at your familiar data / center?	**Column Labels**					
Row Labels	**Air Side Economizer**	**Don't know**	**Don't use free cooling**	**Other**	**Water Side Economizer**	**Grand Total**
Don't know	0%	100%	0%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	15%	30%	20%	5%	30%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	19%	43%	33%	0%	5%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	12%	40%	16%	0%	32%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	25%	0%	75%	0%	0%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	13%	33%	46%	0%	8%	100%
Grand Total	**15%**	**36%**	**30%**	**1%**	**18%**	**100%**

Table 136: Which of the following free-cooling mechanisms do you use at your familiar data center? Vendor responses.

Role	Vendor				
Count of Which of the following free-cooling mechanisms do you use / at your familiar data / center?	**Column Labels**				
Row Labels	**Air Side Economizer**	**Don't know**	**Don't use free cooling**	**Water Side Economizer**	**Grand Total**
Don't know	0%	100%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	31%	38%	15%	15%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0%	33%	17%	50%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	15%	31%	38%	15%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	33%	67%	0%	0%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	40%	30%	30%	0%	100%
Grand Total	**24%**	**37%**	**24%**	**15%**	**100%**

Table 137: Which of the following free-cooling mechanisms do you use at your familiar data center? Combined responses.

Role	(All)					
Count of Which of the following free-cooling mechanisms do you use / at your familiar data / center?	**Column Labels**					
Row Labels	**Air Side Economizer**	**Don't know**	**Don't use free cooling**	**Other**	**Water Side Economizer**	**Grand Total**
Don't know	0%	100%	0%	0%	0%	100%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	21%	33%	18%	3%	24%	100%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	15%	41%	30%	0%	15%	100%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	13%	37%	24%	0%	26%	100%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	29%	29%	43%	0%	0%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	21%	32%	41%	0%	6%	100%
Grand Total	**18%**	**37%**	**28%**	**1%**	**17%**	**100%**

Table 141: What is the age of your newest installed external storage at your familiar data center? Manager responses.

Role	Manager			
What is the age of your newest installed / external storage at your familiar data cente	[Years] / /			
Row Labels	**Sum of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT**	**Count of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT2**	**Max of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT3**	**Min of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	14.53	16.00	3.00	0.10
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	23.25	14.00	4.00	0.50
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	22.80	18.00	4.00	0.00
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	6.00	4.00	3.00	0.00
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	39.00	19.00	9.00	0.50
Grand Total	**105.58**	**71.00**	**9.00**	**0.00**

Table 142: What is the age of your newest installed external storage at your familiar data center? Vendor responses.

Role	Vendor			
What is the age of your newest installed / external storage at your familiar data cente	[Years] / /			
Row Labels	**Sum of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT**	**Count of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT2**	**Max of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT3**	**Min of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	6.50	3.00	3.00	1.50
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	1.50	2.00	1.00	0.50
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	9.70	7.00	3.00	0.20
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	5.00	1.00	5.00	5.00
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	10.00	7.00	5.00	0.50
Grand Total	**32.70**	**20.00**	**5.00**	**0.20**

Table 143: What is the age of your newest installed external storage at your familiar data center? Combined responses.

Role	(All)			
What is the age of your newest installed / external storage at your familiar data cente	[Years] / /			
Row Labels	**Sum of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT**	**Count of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT2**	**Max of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT3**	**Min of What is the age of your newest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	21.03	19.00	3.00	0.10
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	24.75	16.00	4.00	0.50
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	32.50	25.00	4.00	0.00
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	11.00	5.00	5.00	0.00
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	49.00	26.00	9.00	0.50
Grand Total	**138.28**	**91.00**	**9.00**	**0.00**

Table 144: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Automated storage provisioning? Manager responses.

Role	Manager			
Row Labels	Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*	Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*2	Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*3	Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*4
Don't know	30%	2	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	430%	20	70%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	290%	21	100%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	570%	25	100%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	4	0%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	340%	24	100%	0%
Grand Total	**1660%**	**96**	**100%**	**0%**

Table 145: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Automated storage provisioning? Vendor responses.

Role	Vendor			
Row Labels	**Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning***	**Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*2**	**Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*3**	**Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*4**
Don't know	0%	1	0%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	190%	13	70%	20%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	50%	6	30%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	190%	13	90%	10%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	20%	3	10%	10%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	90%	10	30%	10%
Grand Total	**540%**	**46**	**90%**	**0%**

Table 146: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Automated storage provisioning? Combined responses.

Role	(All)			
Row Labels	**Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning***	**Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*2**	**Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*3**	**Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Automated storage provisioning*4**
Don't know	30%	3	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	620%	33	70%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	340%	27	100%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	760%	38	100%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	20%	7	10%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	430%	34	100%	0%
Grand Total	**2200%**	**142**	**100%**	**0%**

Table 147: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Thin provisioning? Manager responses.

Role	Manager			
Row Labels	**Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning****	**Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**2**	**Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**3**	**Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**4**
Don't know	30%	2	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	570%	20	100%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	310%	21	80%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	610%	25	80%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0%	4	0%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	530%	24	100%	0%
Grand Total	**2050%**	**96**	**100%**	**0%**

Table 148: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Thin provisioning? Vendor responses.

Role	Vendor			
Row Labels	Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**	Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**2	Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**3	Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**4
Don't know	0%	1	0%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	90%	13	40%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	80%	6	50%	10%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	340%	13	100%	10%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	40%	3	20%	20%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	110%	10	40%	10%
Grand Total	**660%**	**46**	**100%**	**0%**

Table 149: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Thin provisioning? Combined responses.

Role	(All)			
Row Labels	**Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning****	**Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**2**	**Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**3**	**Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Thin provisioning**4**
Don't know	30%	3	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	660%	33	100%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	390%	27	80%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	950%	38	100%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	40%	7	20%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	640%	34	100%	0%
Grand Total	**2710%**	**142**	**100%**	**0%**

Table 150: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Data deduplication? Manager responses.

Role	Manager			
Row Labels	Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***	Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***2	Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***3	Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***4
Don't know	30%	2	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	790%	20	90%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	400%	21	100%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	580%	25	100%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	100%	4	100%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	650%	24	100%	0%
Grand Total	**2550%**	**96**	**100%**	**0%**

Table 151: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Data deduplication? Vendor responses.

Role	Vendor			
Row Labels	Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***	Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***2	Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***3	Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***4
Don't know	0%	1	0%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	200%	13	100%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	70%	6	30%	10%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	460%	13	100%	20%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	60%	3	50%	10%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	150%	10	50%	10%
Grand Total	**940%**	**46**	**100%**	**0%**

Table 152: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Data deduplication? Combined responses.

Role	(All)			
Row Labels	Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***	Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***2	Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***3	Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Data deduplication***4
Don't know	30%	3	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	990%	33	100%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	470%	27	100%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	1040%	38	100%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	160%	7	100%	10%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	800%	34	100%	0%
Grand Total	**3490%**	**142**	**100%**	**0%**

Table 153: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Tiered storage? Manager responses.

Role	Manager			
Row Labels	Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****	Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****2	Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****3	Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****4
Don't know	30%	2	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	640%	20	80%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	390%	21	100%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	480%	25	80%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	100%	4	100%	100%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	250%	24	60%	0%
Grand Total	**1890%**	**96**	**100%**	**0%**

Table 154: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Tiered storage? Vendor responses.

Role	Vendor			
Row Labels	Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****	Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****2	Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****3	Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****4
Don't know	0%	1	0%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	220%	13	90%	10%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	80%	6	50%	10%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	330%	13	80%	20%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	50%	3	30%	20%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	280%	10	70%	20%
Grand Total	**960%**	**46**	**90%**	**10%**

Table 155: In your familiar data center, what percent of your total storage capacity has already been subjected to...-Tiered storage? Combined responses.

Role	(All)			
Row Labels	Sum of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****	Count of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****2	Max of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****3	Min of In your familiar / data center, what percent of your total storage / capacity has already been subjected to...-Tiered storage****4
Don't know	30%	3	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 serve	860%	33	90%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	470%	27	100%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	810%	38	80%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	150%	7	100%	20%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	530%	34	70%	0%
Grand Total	**2850%**	**142**	**100%**	**0%**

Table 156: At your familiar data center, what is the total installed external storage capacity (in terabytes) for Tape Storage – Production? Manager responses.

Role	Manager			
Row Labels	Sum of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / <div>	Count of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / [terabytes] / -TEXT2	Max of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / [terabytes] / -TEXT3	Min of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / [terabytes] / -TEXT4
Don't know				
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	1755	5	650	0
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0	1	0	0
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	251	8	115	0
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)				
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	0.5	1	0.5	0.5
Grand Total	**2006.50**	**15**	**650**	**0**

Table 157: At your familiar data center, what is the total installed external storage capacity (in terabytes) for Tape Storage – Production? Vendor responses.

Role	Vendor			
Row Labels	**Sum of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / <div> **	**Count of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / [terabytes] / -TEXT2**	**Max of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / [terabytes] / -TEXT3**	**Min of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / [terabytes] / -TEXT4**
Don't know				
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)				
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)				
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	0	1	0	0
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)				
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)				
Grand Total	**0.00**	**1**	**0**	**0**

Table 158: At your familiar data center, what is the total installed external storage capacity (in terabytes) for Tape Storage – Production? Combined responses.

Role	(All)			
Row Labels	**Sum of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / <div> **	**Count of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / [terabytes] / -TEXT2**	**Max of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / [terabytes] / -TEXT3**	**Min of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Tape Storage - Production / [terabytes] / -TEXT4**
Don't know				
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	1755	5	650	0
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	0	1	0	0
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	251	9	115	0
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)				
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	0.5	1	0.5	0.5
Grand Total	**2006.50**	**16**	**650**	**0**

Table 159: At your familiar data center, what is the total installed external storage capacity (in terabytes) for Solid state storage - Production? Manager responses.

Role	Manager			
Row Labels	Sum of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -	Count of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -TEXT2	Max of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -TEXT3	Min of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -TEXT4
Don't know				
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	345	3	300	15
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	56	4	30	2
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	82.00	9	20	2
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)				
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	3.50	2	3	0.5
Grand Total	**486.50**	**18**	**300**	**0.5**

Table 160: At your familiar data center, what is the total installed external storage capacity (in terabytes) for Solid state storage - Production? Vendor responses.

Role	Vendor			
Row Labels	Sum of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -	Count of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -TEXT2	Max of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -TEXT3	Min of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -TEXT4
Don't know				
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)				
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)				
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	26.00	3	15	1
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)				
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	1.00	2	1	0
Grand Total	**27.00**	**5**	**15**	**0**

Table 161: At your familiar data center, what is the total installed external storage capacity (in terabytes) for Solid state storage - Production? Combined responses.

Role	(All)			
Row Labels	Sum of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -	Count of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -TEXT2	Max of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -TEXT3	Min of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Solid State Storage - Production / [terabytes] / -TEXT4
Don't know				
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	345	3	300	15
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	56	4	30	2
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	108.00	12	20	1
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)				
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	4.50	4	3	0
Grand Total	**513.50**	**23**	**300**	**0**

Table 162: At your familiar data center, what is the total installed external storage capacity (in terabytes) for Hard disk drives - Production? Manager responses.

Role	Manager			
Row Labels	Sum of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT	Count of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT2	Max of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT3	Min of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT4
Don't know				
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	10309	7	7000	1
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	265	6	75	4
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3016.0	13	1200	1
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)				
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	273.0	14	48	3
Grand Total	**13863.0**	**40**	**7000**	**1**

Table 163: At your familiar data center, what is the total installed external storage capacity (in terabytes) for Hard disk drives - Production? Vendor responses.

Role	Vendor			
Row Labels	Sum of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT	Count of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT2	Max of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT3	Min of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT4
Don't know				
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	4	1	4	4
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	120	1	120	120
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	90.0	2	50	40
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)				
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	21.0	2	20	1
Grand Total	**235.0**	**6**	**120**	**1**

Table 164: At your familiar data center, what is the total installed external storage capacity (in terabytes) for Hard disk drives - Production? Combined responses.

Role	(All)			
Row Labels	**Sum of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT**	**Count of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT2**	**Max of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT3**	**Min of At your familiar / data center, what is the total installed external / storage capacity (in terabytes) for each of the following types / of devices? [Fill in all that apply]-Hard Disk Drive - Production / [terabytes] / -TEXT4**
Don't know				
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	10313	8	7000	1
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	385	7	120	4
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	3106.0	15	1200	1
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)				
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	294.0	16	48	1
Grand Total	**14098.0**	**46**	**7000**	**1**

Table 165: At your familiar data center, what is the average percent of total capacity that is actually used for Tape Storage – Production? Manager responses.

Role	Manager			
At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)	(Multiple Items)			

Row Labels	**Average of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)**	**Count of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)**	**Max of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)2**	**Min of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)3**
Don't know	15.00%	2	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	36.88%	16	80%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	15.56%	9	50%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	31.82%	11	80%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	5.00%	2	10%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	15.38%	13	80%	0%
Grand Total	**24.91%**	**53**	**80%**	**0**

Table 166: At your familiar data center, what is the average percent of total capacity that is actually used for Tape Storage – Production? Vendor responses.

Role	Vendor			
At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)	(Multiple Items)			
Row Labels	**Average of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)**	**Count of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)**	**Max of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)2**	**Min of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)3**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	34.00%	5	70%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	25.00%	2	30%	20%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	38.00%	5	100%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	5.00%	2	10%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	18.33%	6	50%	0%
Grand Total	**26.50%**	**20**	**100%**	**0**

Table 167: At your familiar data center, what is the average percent of total capacity that is actually used for Tape Storage – Production? Combined responses.

Role	(All)			
At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)	(Multiple Items)			

Row Labels	Average of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)	Count of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)	Max of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)2	Min of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Tape storage (production)3
Don't know	15.00%	2	30%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	36.19%	21	80%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	17.27%	11	50%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	33.75%	16	100%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	5.00%	4	10%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	16.32%	19	80%	0%
Grand Total	**25.34%**	**73**	**100%**	**0**

Table 168: At your familiar data center, what is the average percent of total capacity that is actually used for Solid state storage - Production? Manager responses.

Role	Manager			
At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)	(Multiple Items)			
Row Labels	**Average of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)**	**Count of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)2**	**Max of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)3**	**Min of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)4**
Don't know	30.00%	2	60%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	28.57%	14	70%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	22.73%	11	50%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	46.67%	12	100%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	0.00%	1	0%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	11.54%	13	50%	0%
Grand Total	**26.79%**	**53**	**100%**	**0**

Table 169: At your familiar data center, what is the average percent of total capacity that is actually used for Solid state storage - Production? Vendor responses.

Role	Vendor			
At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)	(Multiple Items)			

Row Labels	**Average of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)**	**Count of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)2**	**Max of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)3**	**Min of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	42.50%	4	60%	10%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	20.00%	2	30%	10%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	51.43%	7	100%	20%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	10.00%	2	20%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	21.43%	7	60%	0%
Grand Total	**33.64%**	**22**	**100%**	**0**

Table 170: At your familiar data center, what is the average percent of total capacity that is actually used for Solid state storage - Production? Combined responses.

Role	(All)			
At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)	(Multiple Items)			

Row Labels	Average of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)	Count of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)2	Max of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)3	Min of At your familiar / data center, what is the average percent of total / capacity that is actually used for each of the following / types of external storage devices?-Solid state storage (production)4
Don't know	30.00%	2	60%	0%
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	31.67%	18	70%	0%
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	22.31%	13	50%	0%
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	48.42%	19	100%	0%
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	6.67%	3	20%	0%
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	15.00%	20	60%	0%
Grand Total	**28.80%**	**75**	**100%**	**0**

Table 171: What is the age of your oldest installed external storage at your familiar data center? Manager responses.

Role	Manager			
What is the age of your oldest installed / external storage at your familiar data center	[Years] / /			
Row Labels	**Sum of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT**	**Count of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT2**	**Max of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT3**	**Min of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	97.0	15	15	1
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	72.5	13	10	1.5
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	109.0	18	16	1
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	9.0	3	5	1
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	102.0	19	11	1
Grand Total	**389.5**	**68**	**16**	**1**

Table 172: What is the age of your oldest installed external storage at your familiar data center? Vendor responses.

Role	Vendor			
What is the age of your oldest installed / external storage at your familiar data cente	[Years] / /			
Row Labels	**Sum of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT**	**Count of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT2**	**Max of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT3**	**Min of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	11.5	3	7	1.5
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	10.0	2	6	4
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	43.0	7	10	3
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	5.0	1	5	5
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	44.0	6	15	4
Grand Total	**113.5**	**19**	**15**	**1.5**

Table 173: What is the age of your oldest installed external storage at your familiar data center? Combined responses.

Role	(All)			
What is the age of your oldest installed / external storage at your familiar data cente	[Years] / /			

Row Labels	**Sum of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT**	**Count of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT2**	**Max of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT3**	**Min of What is the age of your oldest installed / external storage at your familiar data center? (Use / decimals to indicate a half year)-TEXT4**
Enterprise Data Centers (white space greater than 20,000 sq. ft.; at least 500 servers)	108.5	18	15	1
Localized Data Centers (white space 500 to 1,999 sq. ft.; 25 to 99 servers)	82.5	15	10	1.5
Mid-Tier Data Centers (white space 2,000 to 19,999 sq. ft.; 100 to 499 servers)	152.0	25	16	1
Server Closets (white space less than 100 sq. ft.; fewer than 5 servers)	14.0	4	5	1
Server Rooms (white space 100 to 999 sq. ft.; 5 to 24 servers)	146.0	25	15	1
Grand Total	**503.0**	**87**	**16**	**1**

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