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FINAL PROJECT REPORT

ENERGY EFFICIENCY IN SMALL SERVER ROOMS

National Lab Buildings Energy Efficiency Research Projects, Task 2.13

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PREFACE

The California Energy Commission Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

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- Renewable Energy Technologies
- Transportation

Energy Efficiency in Small Server Rooms is the interim report for the National Lab Buildings Energy Efficiency Research Projects (grant number EP 1164415) conducted by Lawrence Berkeley National Laboratory. The information from this project contributes to PIER's Buildings End-Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

ABSTRACT

A little less than half of the servers in California (and the US) are located in data centers, while the remaining servers are housed in "small server rooms," widely distributed across a range of institutions. Energy efficiency in small server rooms has largely been overlooked, even though these facilities are responsible for significant energy use. This project investigated how IT equipment was deployed, powered, and cooled in small server rooms, and developed strategies to improve energy efficiency.

This project had three phases:

1. We surveyed 30 small server rooms across eight institutions, to identify typical room and equipment configurations, understand existing barriers/disincentives, and develop potential energy efficiency strategies.
2. We selected four server rooms for further assessment/detailed power measurements, and identified additional efficiency measures and potential energy savings.
3. We engaged stakeholders through the Silicon Valley Leadership Group and the Consortium for Energy Efficiency, and co-authored two fact sheets with efficiency measures ready for adoption by small server room owners and operators.

Significant inefficiencies in these small server rooms mainly resulted from organizational rather than technical issues. We identified significant savings opportunities -- ranging from virtualizing and consolidating underutilized servers to raising cooling set points. Small server rooms vary from large data centers in the differing computational mission, power and cooling configurations, and economic drivers. Economically justifiable efficiency opportunities in small server spaces may be limited to low or no cost measures.

Future work includes expanding the analysis to a broader group of small server rooms to investigate additional configurations and possible efficiency measures. Server utilization software tools should be evaluated to determine their effectiveness in reducing server energy use; in parallel, low utilization levels should be verified at field sites with actual measurements to confirm savings. Also, the effectiveness of recommended efficiency measures should be demonstrated through case studies.

Keywords: Server Closets, Small Server Rooms, Data Centers, Energy Efficiency, Power Utilization Effectiveness (PUE)

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EXECUTIVE SUMMARY

Introduction and Background

This document is a draft of the final deliverable of Task 2.13: Energy Efficiency in Small Server Rooms in PIER project 500-10-052. This task investigates current IT practices and available resources when servers are deployed in small server closets and rooms, with the goal of developing strategies to improve energy efficiency.

In the past, energy efficiency efforts and public attention have focused on larger data centers that house large quantities of energy intensive IT equipment, while small server rooms (usually housed in commercial buildings) have received little attention. A 2007 study conducted by the International Data Corporation (IDC) (Bailey et al.) revealed that 43% of U.S. servers are located in data centers, which occupy 0.7% of all server spaces, and the other 57% of servers are housed in the remaining 99.3% of server spaces, in what are commonly referred to as "small server rooms." These data suggest that the energy efficiency of small server rooms is equally important as the efficiency of larger data centers.

In big corporations where server operations comprise a core part of their business, significant resources can be dedicated to data center design and operation to ensure efficiency and minimize operating costs. On the other hand, many server rooms are brought into operation by organizations that do not have the resources or desire to focus on energy efficiency. In some situations server rooms are added on an ad hoc basis, driven by an organization's growth in computing needs, and energy efficiency often is not a primary consideration in their design and operation. Not surprisingly, server rooms come in many sizes and configurations, and are widely distributed in various types of organizations ranging from academic institutions, businesses of various sizes, hospitals, government entities, etc., which further complicates finding solutions that can apply to all server rooms.

Purpose and Objectives

With the goal to reduce the energy use for spaces housing more than half of the servers in California (and the US), this project investigated energy efficiency issues applicable for small server rooms. Specifically, the project objectives were to:

1. Survey a sample of small server rooms found in a variety of institutions, investigate whether there were common efficiency issues, and identify any technical and institutional barriers to efficiency;
2. From the overall survey and preliminary assessments, select four room configurations for detailed assessments and energy measurements;
3. Based on initial and more detailed assessments, develop efficiency measures and potential savings estimates that can be applied to similar small server room spaces.

Results of the research are intended to provide resources to begin improving the energy efficiency of existing small server rooms, and serve as a guide for the design and configuration of new spaces.

Preliminary Survey, Assessments, and Findings

The research team conducted a survey of 30 small server rooms across eight different institutions, including high-tech companies, academic institutions, health care, local governments, and small businesses. A 30-minute walk-through assessment of the server space was conducted with the owner/operator, and data was collected on room configuration, equipment operations, and background information about the room with an eye to determining potential barriers to energy efficiency improvements. The server spaces surveyed varied significantly in room configurations, server types and volume, software applications, rack arrangements, and power and cooling schemes. Nonetheless, the following common efficiency issues were identified across the rooms and institutions surveyed:

1. Most small server rooms were not initially designed to operate as server spaces. As a result, room and equipment configurations and cooling schemes were suboptimal in regards to energy efficiency.
2. Principal-agent problems: Utility bills were not paid by server operators/owners. Since small server rooms are often not submetered, utility bills are paid for by the larger organization, or by the landlord in the case of full-service leases, and server owners are provided little to no feedback on energy cost, which provides no incentive to implement energy efficiency improvements.
3. Business operations took priority over energy efficiency. Servers in small server rooms often support internal business or operational functions, in contrast to high-tech web based companies whose profits depend on operating servers efficiently.
4. IT specific issues:
    a. Because of limited budgets and lack of regular IT equipment refresh policy, equipment in small server rooms was often older, occupied a larger footprint, and consumed more energy.
    b. In addition, the equipment often had low utilization; server consolidation and in some cases virtualization could have greatly improved energy efficiency.
    c. Larger, centralized data centers often achieve much higher energy efficiency than small server rooms, and small server room owners may save on labor and energy costs by moving servers from local to centralized operations. A major barrier that we observed was that server owners wanted to keep their servers physically close to them, and they had little incentive to relocate servers because of the principal-agent problem.
5. Cooling specific issues:
    a. Small server rooms are often operated at low room temperature setpoints, resulting in overcooling with unnecessarily high energy use.
    b. One efficiency feature found in large data centers is the separation of hot and cold air to minimize cooling requirements. This was often not the case in the observed small server rooms, in which the room size and configurations were not set up for hot/cold air separation, creating suboptimal cooling.
    c. Furthermore, the observed small server rooms often operated dedicated mechanical cooling around the clock. Using outside air to cool server spaces, during times of the day when outside conditions allow, could have generated large energy savings throughout the year. In some situations, the need to cool server room(s) could drive the need to operate the whole building's cooling system even when the building was unoccupied.

Detailed Assessments

Four configurations were selected for more detailed assessment from among the 30 server spaces initially assessed. The project team chose spaces that broadly represented observed room configurations and had the highest potential for efficiency improvements. Two other selection factors included ease of site access and the operators' interest in participating in further studies, as these considerations would likely affect data collection quality. Table ES-1 and ES-2 summarizes the main characteristics and power use breakdown for the four detailed assessment sites, respectively; Power Utilization Effectiveness (PUE) is defined as total server room power use (including IT, cooling, lighting, and power conversion losses) divided by IT power use. Many opportunities to significantly improve the energy efficiency at these sites were observed including: better airflow management; lowering room temperatures; consolidating and virtualizing servers; moving servers to a more centralized, energy-efficient location; and eliminating or optimizing power backup and conditioning whenever possible.

Table ES-1: Detailed Site Assessment Summary

Description	Stanford Univ., 333 Bonair Siding	Stanford Univ., Alumni Center	Lawrence Berkeley National Lab (LBNL) Rm 90-2094	City of Walnut Creek
Area, square feet	760	100	200	575
Raised floor	12”	none	none	none
No of racks	12	3	3	23
Uninterruptible Power Supplies (UPS)	In rack (mostly A and B feeds)	In rack	Only a few equipment connected to individual UPSs	Main UPS for all equipment
UPS efficiency	0.85 (assumed)	0.85 (assumed)	0.9 (estimated)	0.92 (measured)
Cooling	3 Split system units	Fan coil w/ house chilled water system	3 window mounted units	2 roof mounted package units
Supply Air Temperature, degF	42	65	N/A	72
Lighting	26 – 32 Watt, T8	4 – 32 Watt, T8	8 - 60 Watt, T8	17 - 54 Watt, T5
Lighting density, Watt/square foot	1.1	1.3	0.51	0.21

1 Assumed lighting was on 10% of the year.

Table ES-2: Detailed Assessment Sites - Power Use Breakdown (in kilowatt (kW))

Server Room	Stanford Univ., 333 Bonair Siding	Stanford Univ., Alumni Center	Lawrence Berkeley National Lab (LBNL) Rm 90-2094	City of Walnut Creek
IT Load, kW	10.2	9.9	6.9	15.1
Cooling, kW	8.5	5.5	3.3	14.9
Lighting, kW	0.8	0.1	0.1	0.1
UPS loss, kW	1.8	1.7	0.1	1.3
Total load, kW	21.3	17.2	10.4	31.3
PUE	2.1	1.8	1.5	2.1

Efficiency Measures and Potential Savings

Based on the assessments and energy measurements, a number of efficiency measures and their estimated annual savings were determined for each site, as shown in Table ES-3. The measures ranged from simple measures (such as server consolidation and identifying unused servers) to measures that would involve a higher initial cost but would generate energy savings over time, (such as changing cooling to include "free cooling" using an air economizer). These sample efficiency measures, in conjunction with the extensive list developed for the Improving Energy Efficiency in Server Rooms and Closets Fact Sheet, provide a useful guide for existing and new small server room owner/operators.

Table ES-3: Energy Efficiency Measures (EEMs) and Estimated Annual Energy Bill Savings

EEM	Stanford Univ., 333 Bonair Siding	Stanford Univ., Alumni Center	Lawrence Berkeley National Lab (LBNL) Rm 90-2094	City of Walnut Creek
EEM-1 **Turn off unused computers, virtualization, and consolidation**	With 10% IT energy use reduction - $1,300	With 10% IT energy use reduction - $1,400	With 10% IT energy use reduction - $500	With 10% IT energy use reduction - $1600
EEM-2 Increase temperature set point.	If one unit is off -$500	Not measurable.	Not considered (difficult to estimate in conjunction with EEM-5)	Not considered (difficult to estimate in conjunction with EEM-5)
EEM-3a **Assumed 50% removal of UPS**	$900	$1000	Not considered (low savings)	Not applicable (see EEM-3b)
EEM-3b **Switched from double conversion to bypass mode**	Not applicable	Not applicable	Not applicable	$800[1]
EEM-4 **Install lighting control**	$200	$35	Not applicable (low savings)	Not applicable (low savings)
EEM-5 **Install air-side economizer**	Not applicable	Not applicable	$600[2]	$11,600[3] (plus $8,700 PG&E 1st year rebate)

See Table 5 in report for table footnotes.

Market Connections

As part of the effort to raise awareness on server room energy efficiency, a workshop was held at the 2011 Silicon Valley Leadership Group (SVLG) Data Center Summit. An objective of the workshop was to recruit participants to take part in our small server room survey. In collaboration with Stanford University (Stanford) and the Natural Resources Defense Council (NRDC), the Improving Energy Efficiency in Server Rooms and Closets fact sheets (Appendices E and F of this report) were developed. Available in both a short and detailed version, the fact sheet describes efficiency measures that server room operators can adopt to significantly reduce energy use. Project findings and copies of this fact sheet were provided at the October, 2012 Consortium for Energy Efficiency (CEE) meeting in Portland, Oregon, and at the 2012 SVLG Data Center Summit. Participants in both events provided feedback that the information was very useful.

Conclusions and Recommendations

This project took the first steps in identifying and characterizing energy efficiency issues found in small server rooms. A key conclusion was that improvements in efficiency in small server rooms was not restricted by technology, but primarily resulted from organizational disincentives:

- Principal-agent problem: Owners of small server rooms often do not pay the energy bill directly, creating disincentives to achieve high efficiency.
- Server room operators' job descriptions do not include energy efficiency as an objective.
- Few organizational policies are in place to create and promote efficiency incentives.
- Owners and operators prefer to keep their equipment in close proximity for security reasons, even though centralized data centers may be more secure and reliable.
- Lack of training and awareness in server room operation.

Suggested future work includes efforts to raise awareness about server room energy efficiency and convey efficiency practices such as the ones listed on the Improving Energy Efficiency in Server Rooms and Closets Fact Sheet, developed as part of this project. Further research on the effectiveness of vendor-based and open platform tools that track server utilization has the potential to greatly improve server energy use. Finally, demonstrations or case studies of actual improvements made by consolidating and/or virtualizing IT equipment, improving power or cooling performance, or eliminating server closets by relocating equipment to central data centers or cloud operations can inform server room operators and provide assurance that these actions will not have a negative effect on their mission.

CHAPTER 1: Background and Introduction

Background

This project investigates current IT practices and available resources when servers are deployed in small server closets and rooms, with the goal of developing strategies to improve energy efficiency.

An IDC study conducted in 2007 grouped server spaces into five categories (Bailey et al): 1. server closets, 2. server rooms, 3. localized data centers, 4. mid-tier data centers, and 5. enterprise-class data centers. An Electric Power Research Institute (EPRI) analysis of the IDC data found that 43% of U.S. servers are located in mid-tier and enterprise-class data centers, however these categories comprise only 0.7% of all server spaces. The remaining 57% of servers are located in server closets, server rooms, and localized data centers, in what are commonly referred to as "small server rooms."

Mid-tier and enterprise-class data centers are increasingly designed and operated with energy efficiency as a goal. Many of these servers spaces are owned by large corporations, and server operations comprise a core part of their business. In addition, larger organizations can dedicate resources to ensure efficient operation. Server rooms, however, are widely distributed in many different organizations, ranging from academic institutions and businesses of different sizes, to hospitals and government entities. Business or operational needs often drive the acquisition of additional servers, and because many organizations develop server rooms on an ad hoc basis, server spaces are shoehorned into existing available space. Rarely are they configured with energy efficiency as a primary objective.

This project consisted of three major parts:

1. To survey small server spaces across a range of institutions,
2. To perform detailed assessments and energy measurements for four selected configurations, and
3. To develop a list of efficiency measures and potential saving estimates that can be applied to server spaces with similar configurations in the "small server room" category.

Results of the research will improve the energy efficiency of existing server spaces, and guide the design and configuration of new server rooms.

Report Organization

This document is a draft of the final deliverable of Task 2.13: Energy Efficiency in Small Server Rooms in PIER project 500-10-052. The organization of this report largely follows the sub-tasks and deliverables completed as part of this project. In Chapter 2, we describe the survey of 30 server rooms across eight different organizations. From the survey, the research team selected four configurations for detailed assessments and measurements, as discussed in Chapter 3. Chapter 4 outlines the proposed efficiency measures and estimated energy savings for the four configurations. In Chapter 5 we discuss outreach with collaborators and stakeholders who work in the server technology and IT energy efficiency area. Finally, project conclusions and recommended future work for this area can be found in Chapter 6. References are listed in Appendix A, and Appendices B, C, and D contain the three previous deliverables for this project. Finally, the short and detailed versions of the Server Room Energy Efficiency Fact Sheet, developed as part of this project, are included as Appendices E and F.

CHAPTER 2: Surveys and Preliminary Assessments

Site Identification

The first task of the project was to identify and survey server room sites, from which four configurations were selected for detailed assessments. Each site survey took approximately 20-30 minutes per space for the walk-through, and the following data was gathered: 1) a sketch of the room configuration, 2) background information about the closet/room; 3) IT equipment layout and utilization; 4) power conditioning, cooling systems and layout; and 5) any barriers to energy efficiency improvements. To facilitate the data collection effort, the research team drafted a Server Room Assessment Protocol, which underwent several revisions and improvements throughout the project. The final version can be found in Appendix C.

The surveys included a diversified range of institutions, including high-tech companies, financial, legal, and academic institutions, health care, local governments, utilities, and retail and small businesses. The research team recruited participants through a workshop at the 2011 Silicon Valley Leadership Group Data Center Summit, and supplemented this with existing contacts. The workshop was conducted in partnership with collaborators from Stanford and NRDC. Table 1 summarizes the final list of organizations and the corresponding number of server rooms included in the survey.

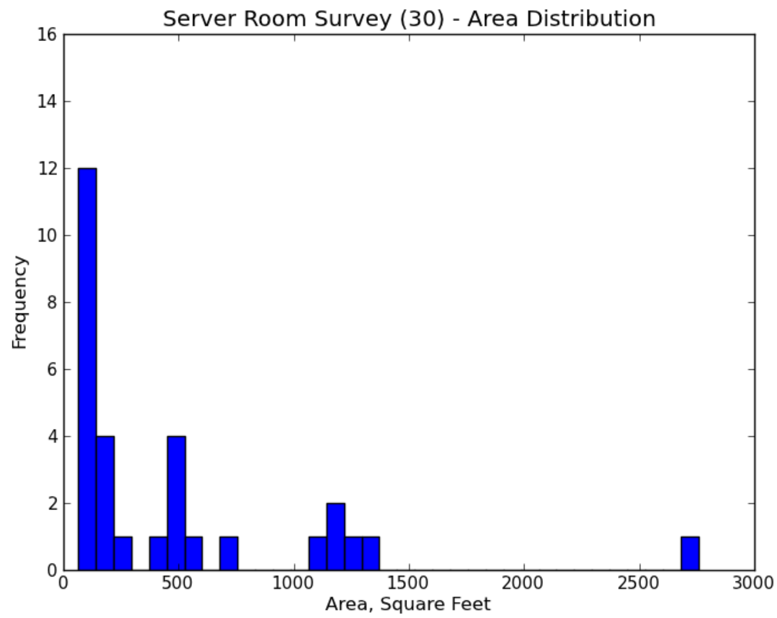
Table 1: Server Room Survey List

	Organization Type	Organization	Rooms/Closets Surveyed
1	Academic & Research	LBNL	6
2	Academic & Research	Stanford University	10
3	Healthcare	John Muir Hospital	1
4	High-Tech	Applied Materials	6
5	High-Tech	Intel	1
6	Local Government	City of Benicia	3
7	Local Government	City of Walnut Creek	2
8	Small Companies	Alfa Tech	1

Surveys

Figure 1 presents the floor area distribution of the 30 server rooms surveyed. Most measured 500 square feet or less, with several over 1,000 square feet.

Figure 1: Server Room Survey - Area Distribution Histogram



As shown in the "Small Server Room Survey - Detailed Summary" table in Appendix C, the surveyed rooms exhibited significant variation in the number of servers, software applications, rack arrangement, and power and cooling schemes. Most spaces contained either dedicated cooling or a mix of dedicated cooling and house air, although a few spaces depended solely on house air for cooling. Dedicated cooling types ranged from wall mounted AC units and fan/cooling coils in smaller spaces, to Computer Room Air Conditioners/Handlers (CRACs or CRAHs) and roof mounted AC units in larger spaces. Some CRAC/H units utilized chilled water loops if the facility had a central chilled water plant. The spaces also relied on various backup power configurations - some servers were connected to a central Uninterruptible Power System (UPS), some were connected to rack-level UPS units, and some of the server rooms were connected to the building backup generators. Still other servers had no backup power at all. Most servers were fed from the electric utility.

Common Efficiency Issues

The 30 server spaces we surveyed were not intended to be a representative sample, yet the research team observed a number of common issues and practices that were barriers to energy efficiency. These are described individually below; note that these issues were often linked and are discussed together when possible. Based on the configurations and efficiency issues we observed, we developed a list of common efficiency recommendations targeted toward small server rooms in collaboration with Stanford and NRDC. One outcome of these efforts is the Improving Energy Efficiency in Server Rooms and Closets fact sheets included in Appendix E and F.

Most Small Server Rooms Were Not Designed To Operate As Server Spaces

Many of the small server rooms and closets started with just a few servers in a repurposed area. As the organization's computing needs gradually expanded, new servers were incrementally added, resulting in the current configurations. In other words, the rooms started out to be a temporary location for servers and were not designed to be server spaces. For example, many of the rooms had no hot/cold air separation; warm air exhausting from the servers was often mixed with cooled air from the HVAC units, thus undercutting the cooling efficiency. Sometimes, as a result of the limited square footage and legacy configurations, potential options for cost-effective upgrades were limited, and owners/operators saw no cost effective alternatives to operate the server rooms more efficiently.

Principal-Agent Problem - Utility Bill Not Paid By Server Owner/Operator

Unlike large data centers, small server rooms are rarely sub-metered and therefore energy consumption cannot be easily measured. In many of the small server rooms we surveyed, the power bill was simply paid by the department or the larger organization with little or no feedback on cost provided to the people who operate the equipment. In some cases (e.g. LBNL), even though server spaces were energy intensive, the energy bill was allocated on a per-square-foot basis and paid by the respective organization occupying the spaces. Since the energy costs were not seen by server owners, there was little incentive for efficiency improvements.

Business and Operational Needs Take Priority Over Energy Use/Efficiency

Servers in small server rooms usually support critical internal business or operational functions, in contrast with high tech web-based companies where the core business involves server operations (e.g. Facebook, Google). In some of the interviews, server owners understood that server room efficiencies would likely increase with changes in server IT and cooling configurations. Server owners also assumed that the energy savings would not be substantial enough to fund up-front equipment purchases and labor costs. They did not find the configuration changes to be worthwhile, considering the uncertainties and risks. Since server owners may not directly pay the energy bill and in light of the barriers and uncertainties, owners preferred to maintain the status quo.

IT-Specific Observations

Few server spaces had implemented high degrees of consolidation and virtualization (i.e. placing many applications on one physical server). Significant reduction in IT energy use could be realized through consolidating under-utilized servers, identifying and shutting down unused servers, and virtualizing when appropriate. Barriers included the lack of incentives discussed above, lack of knowledge and awareness of opportunities, and limited resources for server operations.

Bigger organizations usually operate larger, central server rooms, but also have small server spaces. In most cases, servers in the less efficient, small server rooms could be moved to more energy efficient central facilities, however the following factors often prevented such centralization:

- The lack of incentives as discussed in "Principal-Agent Problem," above;
- Operators prefer to locate their equipment nearby for easy access, even though in some cases this is not necessary.

Some operators of the small server rooms are using cloud computing to reduce server footprint. A number of server owners, however, elected not to use cloud computing, because of the following barriers:

- Cloud computing is not permitted for some government applications, including those related to municipal police operations.
- Organizations that deal with sensitive data, either personally identifiable information (PII) or personal health information (PHI), are reluctant to store these data outside of a facility that they own and control. This limits the type of consolidation or migration to the cloud that can be employed.

- Some organizations desire a high level of security for their file storage and applications, and they are skeptical about the degree of cyber security that can be attained in cloud computing.

In organizations such as city governments, where the computational workload was relatively constant (i.e. not growing year to year), typical refreshing of IT equipment enabled a reduction in the amount of IT equipment and overall energy use. Since modern equipment has much added computational capability the city governments were able to host all of their IT services on fewer servers.

Cooling-Specific Observations

The research team made three observations related to cooling:

Low Operating Temperature

Most IT equipment sold today is designed to operate with inlet temperatures up to 80°F - or even higher (ASHRAE 2011). However, most server spaces visited by the research team were over-cooled and maintained a temperature of 74°F or lower, using unnecessary energy. The research team identified several underlying reasons: 1) there was a common misconception that server spaces should be kept at temperatures of around 72°F - and that colder is better; 2) operators were concerned that higher temperatures may not provide adequate buffer in the event cooling equipment fails in these relatively small spaces; 3) the owner and operator were not responsible for paying the energy costs, and over-cooling was therefore not a primary concern (the principal-agent problem), and 4) the cooled air was sometimes poorly directed in small server spaces and resulted in local hot spots; to compensate, operators relied on extra cooling.

No Use of Free Cooling

All server spaces surveyed were located in the San Francisco Bay Area, where the climate is temperate, and outside air temperature is low enough to provide cooling for most of the year. However, a majority of the server spaces in the survey utilized dedicated closed cooling systems, without taking advantage of free cooling. This was partially because the rooms were not designed to be server rooms, and were served by existing building HVAC systems; cooling options were often restricted by the existing duct configuration. Typically, as server heat loads increased, dedicated cooling was added to offset heat loads without much consideration for efficiency. Adding an air economizer would potentially be cost effective in the long run, but the upfront cost and ductwork reconfiguration often served as disincentives.

No Hot/Cold Air Separation

Many small server spaces were not designed to operate as server rooms. As a result, some of them were too small to allow for air separation, and exhaust air from the servers often mixed with cooler inlet air, requiring more cooling energy than necessary. The small square footage of some spaces limited the possible options for retrofit or room rearrangement. Physical barriers (e.g. plastic screen/curtain) to separate hot and cold air, and blanking panels to block off empty server spaces in racks could be installed to maximize hot and cold air separation.

Observations Across Institutions

Although the sample was not intended to be representative, we observed some differences among the institutions in this study - academic, small business, healthcare, high-tech, and local government. The differences boil down to the following factors: 1) business functions (i.e. how do business functions relate to server computing?), 2) the organization's culture regarding energy efficiency, 3) incentives provided by management to encourage efficiency, and 4) the server room operator's knowledge and training.

In the two academic/research institutions, different research units operated quite independently. Without question, core research activities took precedence over energy efficiency of server spaces, and efficiency practices were not prioritized because of limited resources and principal-agent problems. Equipment procurement and operation were also highly dependent on research funding, which occurs in unpredictable cycles. The research team also observed that providing centralized incentives at the organizational level, as well as technical assistance and resources, effectively promoted energy efficiency at the departmental level.

With small businesses and healthcare, servers support business activities, rather than constitute the core business. Energy efficiency may be implemented just to the point that adequately supports business activities, depending on staff knowledge and training, and reflecting the awareness and value that the organization's culture places on efficiency. If the organization values energy efficiency and considers the long-term benefits, more complex energy conservation strategies may be undertaken. Certain operations associated with high tech, small businesses, and healthcare may not move to cloud computing, due to security concerns or mandatory restrictions such as Protected Health Information (PHI).

In large companies needing only limited computational capabilities, energy efficiency in server rooms is dependent on organizational factors, similar to a small business. However, for operations with extensive computing needs employing hundreds or thousands of servers (e.g. computer chip design, etc.) energy efficiency is instrumental in lowering costs, developing a competitive profit margin, and ultimately maintaining business success. These server spaces are usually operated by knowledgeable and well trained staff, actively pursuing energy efficiency. For server rooms of this type, energy efficiency measures have typically been assessed and attractive alternatives implemented. Operators had explored and identified the limitations to efficiency strategies which had not yet been implemented.

In the two local governments surveyed, the server operators' awareness of efficiency and knowledge of server room operation was relatively high. The room configurations limited the cooling efficiency options. The room temperature setpoints were lower than necessary, but the operators were involved and aware of IT systems efficiency opportunities such as consolidation, equipment upgrades, and virtualization. One contributing factor may have been the fact that local government staff have dedicated roles in the cities' IT procurement and server operations, and thus the available time and accumulated experience resulted in more dedication and higher awareness. Our sample was limited to two, and it would be interesting to learn more about the similarities and differences of server operations in other local government entities.

CHAPTER 3: Detailed Assessments

Selection Criteria

The research team selected four configurations for detailed assessments from the 30 surveyed server spaces, choosing spaces that broadly represented other small server rooms configurations and had the highest potential for efficiency improvements. Two other factors that were considered in the selection included 1) site access and 2) operators' interest in participating in further studies, as these factors would likely affect data collection quality for IT and cooling measurements, as well as institutional data.

Measurement Methods and Procedures

The main goal of the detailed assessments was to examine the infrastructure and IT systems in more detail. This included power measurements of IT, cooling, and other power consuming equipment in each server space, in order to determine actual power consumption and efficiency opportunities. Data-logging power meters were installed on the circuits that supplied power to the IT and cooling equipment, and the meters remained in operation for a period of one week, recording measurements at 15-minute intervals. In cases where time-series measurement of IT or cooling power use was not feasible due to metering equipment or site constraints, field researchers collected one-time measurements of the actual power feed, or power draw was estimated from equipment design information. Ideally, energy use would be measured over a longer period of time to capture seasonal and other operational variability, but this was not possible due to the scope of the project. However, since the selected sites had relatively constant IT power consumption throughout the year, and were located in a temperate climate zone, seasonal variation is not expected to vary significantly throughout the year. To determine the effectiveness of the cooling systems and whether the appropriate level of cooling was provided, field researchers collected spot measurements of room temperatures or reviewed existing temperature records.

In order to calculate the Power Utilization Effectiveness (PUE) for each site, the total server room power use was needed. Researchers measured lighting, power distribution, and UPS losses wherever possible, and estimated power consumption or losses if measurements were not possible due to site constraints. For example, when more than one end use was supplied by a single circuit, we were unable to differentiate the amount of power consumed by the different end uses; in similar cases we estimated power losses.

Some server owners did not have detailed records of their equipment inventory, and accessing make, model, and other inventory info was not always possible. In addition, operators often did not track server utilization rates over time due to the absence of a cost-effective and user-friendly platform to access utilization data, which further complicated decisions to improve energy efficiency. This particular issue is discussed further in Chapter 5 of this report.

In addition to power measurements, we also collected information on organizational policies and server room operational practices, which often described the evolution of the server space and the current operational schemes. This information was gathered through observations and in-depth interviews with the server room owners/operators, and included the following:

- Applications run on each server
- Current virtualization, consolidation, and cloud computing schemes
- Who owns and operates the servers?

- Is power separately metered?
- Who pays the energy bill?
- Are there any organizational guidelines or rules for starting a new server room?
- How did IT and infrastructure evolve to the current state?
- What cooling systems were employed?
- What equipment was on backup power and why was this necessary?
- What configurations of UPS systems were used?

Findings Summary

Based on the above criteria, the following server spaces were selected for further evaluation:

1. Stanford University - Arrillaga Alumni Center
2. Stanford University - 333 Bonar Siding
3. LBNL - Building 90, Room 2094
4. City of Walnut Creek

Major characteristics of the four server spaces are summarized in Table 2.

Table 2: Detailed Site Assessement Summary

Description	Stanford Univ., 333 Bonair Siding	Stanford Univ., Alumni Center	Lawrence Berkeley National Lab (LBNL) Rm 90-2094	City of Walnut Creek
Area, square feet	760	100	200	575
Raised floor	12”	none	none	none
No of racks	12	3	3	23
Uninterruptible Power Supplies (UPS)	In rack (mostly A and B feeds)	In rack	Only a few equipment connected to individual UPSs	Main UPS for all equipment
UPS efficiency	0.85 (assumed)	0.85 (assumed)	0.9 (estimated)	0.92 (measured)
Cooling	3 Split system units	Fan coil w/ house chilled water system	3 window mounted units	2 roof mounted package units
Supply Air Temperature, degF	42	65	N/A	72
Lighting	26 – 32 Watt, T8	4 – 32 Watt, T8	8 - 60 Watt, T8	17 - 54 Watt, T5
Lighting density, Watt/square foot	1.1	1.3	0.51	0.21

1 Assumed lighting was on 10% of the year.

Some of the UPS efficiencies listed in Table 2 were estimated or measured, while others were assumed. (Note: Actual UPS efficiency was measured whenever possible.) In the case of LBNL's Rm 90-2094, there were only a few pieces of equipment connected to individual UPSs, and since the equipment could not be disconnected from the UPS to measure their power consumption, the associated UPS losses were estimated based on reading the load indicator lights on the operating UPS, and researching the corresponding efficiency at that load in the operation manual for that specific UPS model.

In Stanford's 333 Bonair Siding, more than half a dozen widely varying UPSs were located downstream of the room IT circuits, and some did not display their loading conditions. In this case, UPS efficiency was assumed to be 85%. Similarly, we assumed the UPS efficiency at Stanford's Alumni Center server room to be 85%. UPS efficiency at the City of Walnut Creek was based on readouts from the UPS displays. This led to another finding of the study - it is difficult to accurately measure PUEs in server spaces unless the end uses are tied to separate circuits, and meters are installed at appropriate measurement points to determine electrical conversion losses in individual downstream equipment such as UPSs and Power Distribution Units (PDUs) containing transformers.

Site Descriptions

Lawrence Berkeley National Laboratory - Bldg. 90, Room 2094 (90-2094)

This 200-sf server room supported the Earth Sciences Division and was located in a four-story office building on the LBNL campus. The east wall had exterior windows, and the only access door was located on the west wall, which also had interior windows. Three racks of servers were housed at the south end of the room, with other desktop and blade servers distributed along the west and east sides of the room. The room was cooled by the building air conditioning and three window mounted AC units that operated continuously; the amount of house air supply was negligible.

Detailed assessment of this server space revealed a server operation scenario commonly found in institutions supported by research grants. The server room held server and storage equipment procured by individual researchers. Equipment was purchased as funding was received at the beginning of the project; however, due to the often limited funding situations, little to no money would be left to maintain, consolidate, or upgrade equipment. In addition, the server room was not separately metered; instead, electricity cost was allocated on an average per-square-foot basis, for the building. Interviews with the server room's IT manager provided additional insights. Since individual server owners did not pay server room operating expenses directly, there was little incentive to improve energy efficiency. Secondly, the option of housing servers in LBNL's data center would require an additional management fee, a further disincentive. Thirdly, server owners and IT managers wanted to have equipment in close proximity for more convenient access.

There was no record of an equipment inventory for the room, so a detailed inventory of the IT and cooling equipment was performed. Server utilization rates were not tracked, but the IT manager indicated that servers and storage equipment were utilized at high rates, due to a shortage of computing capacity. The possibility of equipment sharing as a way to optimize IT equipment operation was suggested, but individual researchers preferred to operate their own equipment, and make sure they had immediate access at all times. The building housing this server room had a building energy monitoring system, which greatly facilitated energy measurements. Additional monitoring points at the room's electrical panel were added to separately meter some end uses. The building monitoring system then tracked and stored measurements for retrieval, and over six months of power data for this space was recorded.

Figure 2: LBNL 90-2094 -- Three Server Racks

Source: LBNL

Figure 3: LBNL:2094 -- Miscellaneous IT Equipment

Source: LBNL

Figure 4: LBNL 90:2094 -- Exterior View of Three Window-Mounted AC Units

Source: LBNL

City of Walnut Creek Server Room

Having gone through major equipment refresh several years ago, the City of Walnut Creek server room (housed inside the City Hall building) was well managed compared to other small server spaces we surveyed. With a refreshment policy of roughly every four to five years, most of their equipment was relatively new, with the exception of one rack of networking equipment and half a rack of servers awaiting changeover. Many of the Walnut Creek servers were also virtualized, and they had a detailed record of the mapping between physical and virtual machines. In one case, one of their physical machines was hosting more than 20 virtual servers. The overall utilization rate of the servers in this space is not available.

The 600-sf server room was cooled by two roof-mounted cooling units without economizer capability, although it would have been straightforward to add economizers at the time the units were installed. The units were controlled by temperature in the room, which was set at about 72F. Despite the fact that this room was designed to be a server space, it had no hot/cold air separation. There was a main UPS unit located upstream of all IT equipment; a small portion of the UPS also fed the 911 dispatch center. We were able to subtract this part of the UPS loss in order to calculate the losses attributed to the server room only.

Figure 5: City of Walnut Creek Server Racks

Source: LBNL

Figure 6: City of Walnut Creek - Server Racks, Exhaust Side

Source: LBNL

Figure 7: City of Walnut Creek -- Temperature and Relative Humidity Sensor Sets

Sensor sets control the AC units, and have readouts for local monitoring. These sensor sets are located in the common area instead of IT inlet.

Source: LBNL

Stanford University - 333 Bonair Siding Server Room

Between our initial field survey on the 333 Bonair Siding server room in November 2011 and the detailed assessment in October 2012, the room underwent significant improvements. A number of servers with critical applications had been moved to Stanford's central data center; the room also acquired more transient equipment. Before the change, there were occasional overheating issues because the three wall mounted split units were not able to handle the cooling load and additional fans had to be brought in. Because of the equipment inventory change, the room could now be cooled with two instead of three wall-mounted AC units.

This server room was managed by a team of IT staff, who also supported other IT functions as part of the Land, Buildings, and Real Estate group at Stanford. Interviews with one of the operators revealed that a portion of their servers had been virtualized, and they continued to move more mission-critical equipment to Stanford's central data center for higher reliability, though there was still significant opportunity for more virtualization and consolidation. While they did not keep an inventory of all the server equipment, they used "Ganglia," an open-platform software program to gather information on server utilization.

Figure 8: Stanford University Bonair Siding -- Server Racks

Source: LBNL

Figure 9: Stanford University Bonair Siding -- Two Split Cooling Fans Facing Exhaust Side of Server Racks

Source: LBNL

Figure 10: Stanford University Bonair Siding -- Third Split Unit

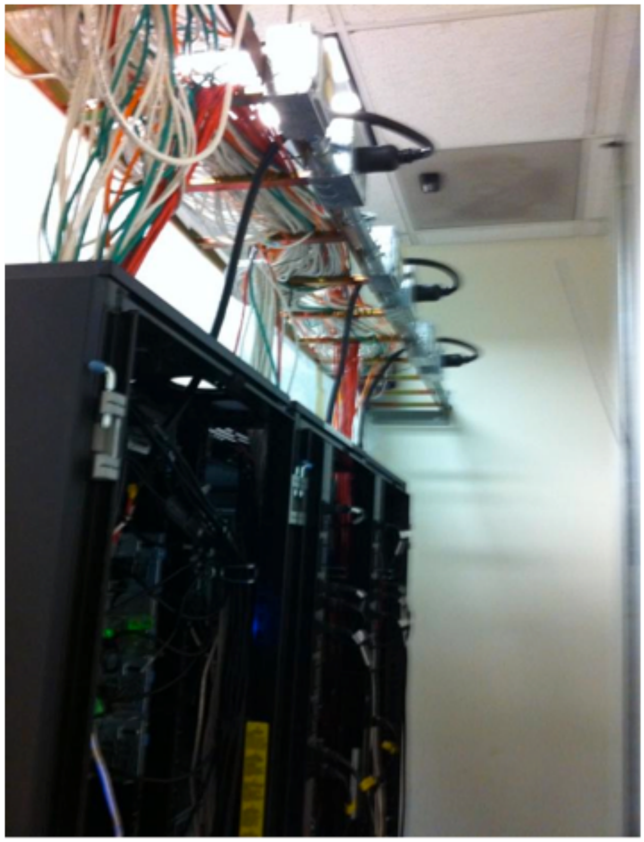
At left, note access ramp to raised floor.

Source: LBNL

Stanford University - Arrillaga Alumni Center Server Room

This 100-sf server room was housed inside the Alumni Center and was not originally designed to be a server space. When the room was first deployed, it was cooled with house air, but later switched to a dedicated fan coil unit for cooling. The fan coil unit received cooling from the campus wide chilled water loop, and house air remained available as a backup. There were three racks of servers, each about half to two-thirds filled, which primarily ran alumni databases and administrative applications. A study was launched to measure the PUE of this room several years ago. As a result of that study, efficiency measures were identified which included installation of a plastic curtain behind the server exhaust to better separate hot and cold air in the room. Operations have since improved significantly. Like the other three detailed assessment sites we evaluated, electricity use in the room was not separately metered.

Figure 11: Stanford University Alumni Center --Exhaust Side of Server Racks



Hot aisle is contained with a plastic curtain. An exhaust register is visible in upper right.

Source: LBNL

Power Measurements

IT Power

Table 3 summarizes measurements of the average IT loads for all four sites. For both the Bonair Siding and Alumni Center server rooms at Stanford, average IT load was obtained by time-series measurement of the IT circuits for a period of one week at 15-minute intervals, in October 2012. At LBNL, a building monitoring system was available in Building 90 to record IT measurements over a period of six months. In the City of Walnut Creek's server room, researchers collected a one-time measurement of all the IT circuits, as we dedicated our available data-logging meters to the two cooling units.

Table 3: IT Power Summary

Server Room	Stanford, University 333 Bonair Siding	Stanford, University Alumni Center	LBNL 90-2094	City of Walnut Creek
IT Load (kW)	10.2 [1]	9.9 [1]	6.9 [1]	15.1 [1]

[1] Directly measured

Power End Use Breakdown

Table 4 illustrates the individual loads that contributed to the PUE calculation and the corresponding PUE value for each site. Note that PUE can be used as a power or energy metric, however in this case it represents power use. Power use breakdowns for the four detailed assessment sites are shown in Figure 12.

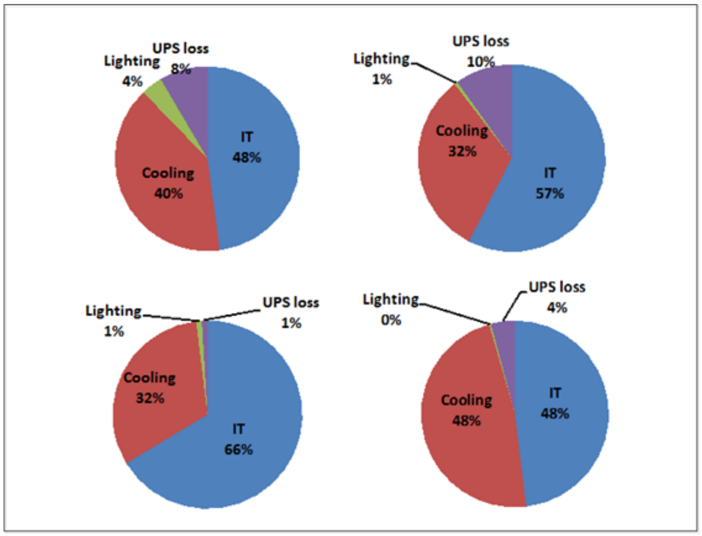
In the Bonair Siding server room, the field researchers monitored one of the two operating cooling units for a one week period at 15-minute intervals; both units were identical in rating and operational scheme. At the Alumni Center room, cooling was provided by a fan coil that utilized Stanford's central chilled water loop. To obtain actual measurements, the field researchers would have to measure the change in chilled water temperature upstream and downstream of the fan coil, along with the efficiency of Stanford's central plant; this was not possible. Instead, the total cooling power was calculated by combining the nominal fan power, and the estimated cooling load (assuming an efficiency loss in cooling the IT load). In LBNL's 90-2094, the cooling load was measured over a period of six months. Finally, at the City of Walnut Creek server room, cooling power was measured over a period of one week at 15-minute intervals.

Table 4: PUE Breakdown

Server Room	Stanford, University 333 Bonair Siding	Stanford, University Alumni Center	LBNL 90-2094	City of Walnut Creek
Cooling, kW	8.5 [1]	5.5 [2]	3.3 [1]	14.9 [1]
Lighting, kW	0.8 [2]	0.1 [2]	0.1 [2]	0.1 [2]
UPS loss, kW	1.8 [2]	1.7 [2]	0.1 [2]	1.3 [1]
Total load, kW	21.3	17.2	10.4	31.3
PUE	2.1	1.8	1.5	2.1

[1] Directly measured
[2] Assumed or estimated

Figure 12: PUE Breakdown



From left to right: Stanford University Bonair Siding, Stanford University Arrillaga Alumni Center, LBNL 90:2094, City of Walnut Creek.

CHAPTER 4:
Efficiency Measures and Potential Savings

Based on the measurements and evaluations conducted at each detailed assessment site, in Chapter 4 we describe proposed efficiency measures for each of these spaces. Although the four sites were very different in configuration, they shared a number of available opportunities for efficiency improvements. Through collaboration among LBNL, NRDC, and Stanford, the "Improving Energy Efficiency in Server Rooms and Closets Fact Sheet" was created to summarize efficiency opportunities, which could be broadly applied to many server rooms, and the document also serves as a useful guide for estimating efficiency potential.

Efficiency Measures - Overview

Lawrence Berkeley National Laboratory - Bldg. 90, Room 2094

The room was cooled by three window mounted air conditioners that operated continuously at a constant setting. Cool air from the air conditioners and hot air from the IT equipment discharged into the same space, which lowered cooling efficiency. The research team suggested reconfiguring equipment in the room to achieve better airflow management. In addition, since the local climate is temperate, outside air could be used for cooling most of the year. Instead of operating three window AC units with compressors on at all times, one or more existing AC units could operate on fan mode. For short periods in the year when outside air temperature is not sufficient to cool the space, a maximum room temperature setpoint can trigger an alert for IT staff to manually turn on the AC compressor.

A number of servers in the room appeared unused and could be turned off. Also, most servers were more than five years old, and an equipment refresh schedule could significantly improve computing and storage efficiency as funding become available. This could result in fewer machines needed to provide the same functions, and more reliable servers which were also candidates for relocating to a more centralized location with higher operating efficiency. Prior to implementing improvements, organizational disincentives would first have to be resolved, by establishing server operation policies and eliminating the principal-agent problem.

In summary, LBNL's Rm 90-2094 had substantial potential for efficiency improvements, including: server refresh; moving a portion of the IT equipment to a more centralized location; resolving organizational disincentives to encourage efficiency; IT and cooling equipment reconfiguration to improve airflow management; and the direct use of outside air to save cooling energy. Estimated savings for a number of these measures are discussed in section 4.2.

City of Walnut Creek Server Room

The server room temperature was set at a constant 72°F at a specific location in the room; however temperature varied throughout the room due to mixing of hot and cold air streams. Most of the equipment likely received adequate cooling, but hot spots may exist. The IT manager expressed concerns that two racks of equipment were older models and may be unable to tolerate high inlet temperature -- this could be investigated further. Raising the temperature setpoint by a few degrees could generate energy savings, given that airflow and hot spots in the room are reasonably well managed. To better separate cold and hot air in the room, reconfiguring the ductwork above the ceiling to create distinct hot and cold aisles would allow higher temperature setpoints, enabling additional energy savings at a modest remodeling cost. Consequently the energy savings generated as a result of improved airflow management and exploiting allowable environmental conditions could finance replacement of the existing cooling units. The research team recommended installing a cooling system with a built-in air-side economizer. Since the server room is located in a temperate climate, the cooling system could be operated in economizer mode for most of the year, further reducing cooling energy use.

The City included energy efficiency when making IT purchasing decisions. Server equipment could benefit from further virtualization and consolidation; these practices were already part of the City's plan as new funding becomes available. Shrinking budgets at the local government level due to the economic climate may pose challenges in maintaining and improving efficiency purchases and operation. The UPS in the room was operated in double-conversion mode at all times, which may not be needed for the IT applications in this space. Instead, the UPS could be operated in bypass mode for most of the year, which would reduce conversion losses.

Finally, City staff provided the research team with a detailed server inventory and physical/virtual machine mapping. Yet it was difficult to identify additional IT efficiencies that could be realized without using more sophisticated tools to track individual server utilization and energy use. This is an area that deserves further investigation and is discussed in Chapter 6 of this report.

Stanford - 333 Bonair Siding Server Room

The server room housed a mixture of new and old IT equipment and UPSs, and a couple of the UPSs were not working properly. Researchers suggested maintaining an equipment inventory to better manage assets. This would enable the development of a prioritization plan to replace older, less efficient equipment and critical equipment as budgets allow. The team also recommended further virtualization and consolidation of servers, and retiring older machines to improve the overall IT efficiency in the server room. All the servers and storage equipment were connected to two redundant in-rack UPSs and a backup generator was connected to the building. The research team questioned whether the UPSs and especially the power supply redundancy were really necessary, especially since some of the more mission-critical systems had been moved to Stanford's central data center.

Cooling was provided by two or three split systems depending on the cooling load. Because of the room configuration and the locations of the units, little could be done to significantly improve airflow management. We observed that two of the split units discharged cold air directly into the exhaust side of a nearby row of racks - directly mixing the cold and hot air streams. Careful server rack and room reconfigurations may be able to improve airflow and reduce cooling needs, saving energy and money throughout the year.

Stanford - Arrillaga Alumni Center Server Room

A portion of the server equipment could be moved to Stanford's central data center, although IT staff wanted to keep their equipment conveniently located. In addition, many of the servers were operated with a utilization rate below 25% and could be further virtualized and consolidated. The temperature in the room was maintained around 70-72F; raising the temperature setpoint could easily generate energy savings.

Efficiency Measures and Potential Savings

Table 5 summarizes the proposed energy efficiency measures (EEM-1 to 5) and corresponding cost savings for each of the detailed assessment sites. Not all measures are applicable to every site, because of technical reasons or site-specific configurations. Table 5 provides an energy saving guide for small server spaces with similar IT and cooling configurations and components. Electricity cost at LBNL was priced at $0.09 per kWh, while costs at the other three sites were assumed to be $0.12 per kWh. Power savings as a result of the proposed efficiency measures are illustrated in Figures 13 and 14 for all four detailed assessment sites.

Table 5: Energy Efficiency Measures (EEMs) and Estimated Annual Energy Bill Savings

Annual Savings				
Energy Efficiency Measures	**Stanford, University 333 Bonair Siding**	**Stanford, University Alumni Center**	**LBNL 90-2094**	**City of Walnut Creek**
EEM-1 **Turn off unused computers, virtualization, and consolidation**	With 10% IT energy use reduction - $1,300	With 10% IT energy use reduction - $1,400	With 10% IT energy use reduction - $500	With 10% IT energy use reduction - $1600
EEM-2 **ncrease temperature set point.**	If one unit is off - $500	Not measurable.	Not considered (difficult to estimate in conjunction with EEM-5)	Not considered (difficult to estimate in conjunction with EEM-5)
EEM-3a: **Assumed 50% removal of UPS**	$900	$1000	Not considered (low savings)	Not applicable (see EEM-3b)
EEM-3b: **Switched from double conversion to bypass mode**	Not applicable	Not applicable	Not applicable	$800[1]
EEM-4: **Install lighting control**	$200	$35	Not applicable (low savings)	Not applicable (low savings)
EEM-5: **Install air-side economizer**	Not applicable	Not applicable	$600[2]	$11,600[3] (plus $8,700 PG&E 1st year rebate)

1 Energy savings assume UPS power consumption to operate in bypass mode (0.4 kW) year around instead of double conversion mode (1.2 kW), which is the case for current operational scheme.

2 Assume current air conditioning units to operate in fan mode year around, consuming an average of 2.5 kW instead of 3.3 kW.

3 Estimated energy savings based on the the following assumptions:

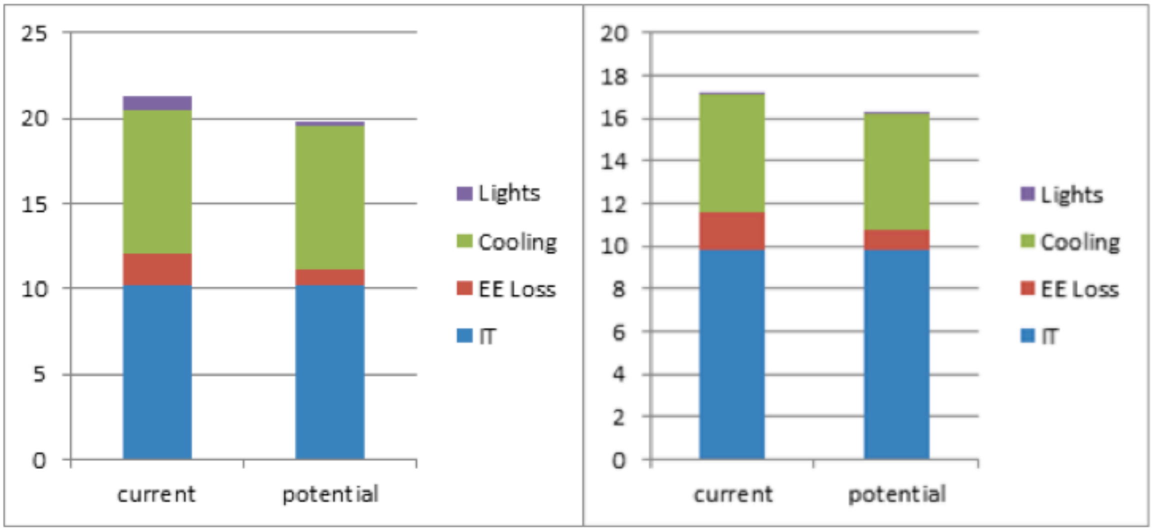
a) Two currently installed roof-mounted cooling units will be replaced with two new cooling units of the same capacity with economizers,

b) energy consumption of new cooling units based on units running in economizer mode 11 months in the year, estimated per climate conditions in Walnut Creek,

c) Estimated capital cost of $25,000 includes removal of old units and installation of two new units.

d) Customers in PG&E territories receive $0.09 per kWh for energy savings, generated during the first year of operation after retrofit is in place - equivalent to about $8,700 for this retrofit.

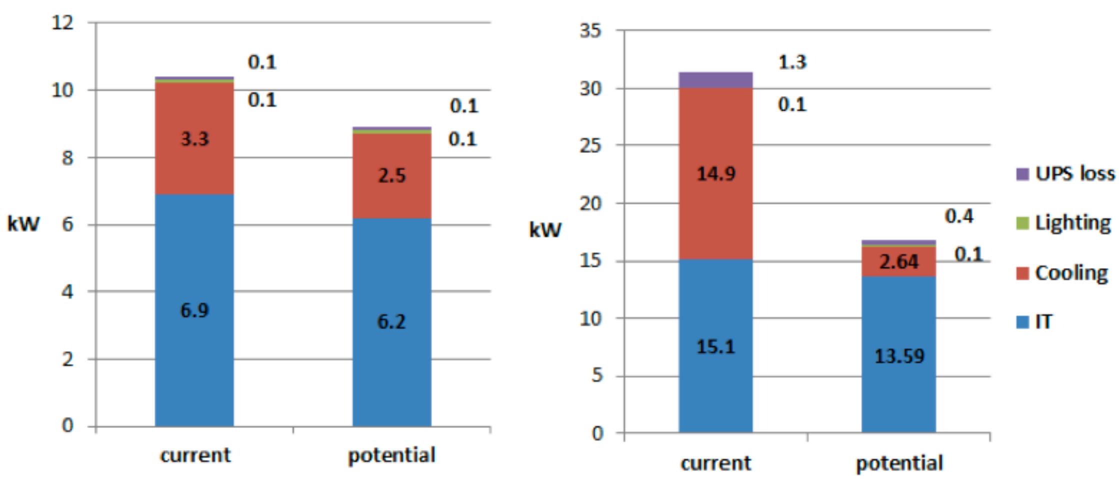
Figure 13: Current and Potential Power Usage



Left to right: Stanford University Bonair Siding, Stanford University Arrillaga Alumni Center

Source: LBNL

Figure 14: Current and Potential Power Usage



Left to right: LBNL 90-2094, City of Walnut Creek

Source: LBNL

CHAPTER 5: Market Connections

In addition to the preliminary surveys, detailed assessment, and energy savings estimations discussed in previous chapters, we also performed outreach to server room operators, data center energy efficiency professionals, industry organizations, utilities, and product vendors. The goal was to raise awareness and increase the visibility of efficiency issues surrounding server rooms and to present the findings of the study, including specific efficiency measures that can be applied to other server spaces.

Server Room Energy Efficiency Fact Sheet and Web Site

In collaboration with Stanford and NRDC, a fact sheet was developed summarizing a spectrum of energy saving solutions, ranging from simple to complex strategies; the target audience being small server room owners and operators. Henry Wong of Intel and The Green Grid, and Mark Bramfitt, an independent utility consultant, provided valuable feedback to improve content. Two versions of the fact sheet were developed:

- The short version "Improving Energy Efficiency for Server Rooms and Closets" is a three-page color handout that summarize 14 key efficiency measures and can be downloaded at http://hightech.lbl.gov/serverclosets. It is also included as Appendix E of this report.
- The long version "Fact Sheet (Web Content): Improving Energy Efficiency for Server Rooms and Closets" is a more extensive, 12-page document describing the same energy efficiency measures in more detail. It is attached as Appendix F of this report, and can be downloaded at: http://hightech.lbl.gov/documents/data_centers/fact-sheet-ee-server-rooms.pdf

Silicon Valley Leadership Group (SVLG) and the Consortium for Energy Efficiency (CEE)

With Joyce Dickerson of Stanford University and Pierre Delforge of NDRC, we collaborated on a workshop at the 2011 SVLG Data Center Summit, and moderated a discussion on server room energy efficiency issues. The goal was to collect feedback on the causes, barriers, and solutions to server room energy efficiency improvements. A lively, informative, and useful exchange with the audience provided very valuable information and feedback. The workshop and the conference also served as a productive networking opportunity to recruit potential participants for the server room surveys.

At the 2012 SVLG Data Center Summit, we organized a server room energy efficiency workshop and panel discussion. Shalini Singh of Stanford University and Pierre Delforge of NRDC along with LBNL participated in the panel, moderated by Mark Bramfitt, who formerly led PG&E's data center initiatives. Stanford provided case studies on their server room efficiency retrofit. NRDC shared their findings on utility programs and incentives, and the energy and carbon implications for local versus cloud computing, while LBNL shared results and findings from this project. As part of the workshop, copies of the short version fact sheet were distributed, along with its web link; the fact sheet was well received and the audience (over 30 stakeholders) commented that it was a very useful information tool.

At the October 2012 Consortium for Energy Efficiency (CEE) meeting that took place in Portland, Oregon, a web presentation of the small server room efficiency findings was given to utility engineers via telephone conference. The server room fact sheet was distributed at the event; and again it was well received. We believe that our study findings and the circulation of the fact sheet will continue to increase the visibility of server room energy efficiency, and to spur action on improvements.

Server Utilization Software Vendors

During the field surveys and detailed assessments, the research team observed that most small server room owners and operators did not have access to tools that track server utilization over time. Based on our survey responses from server operators, servers were often under-utilized. When asked about the utilization rates of their machines, most operators would provide an estimated range recalled from memory. For servers that run on virtual machines, utilization status is more readily available through the virtual machine software platform. For other servers, utilization rates over time are difficult to track without the use of vendor-based or open-platform tools.

The research team reached out to vendors who market server utilization and management software. We contacted vendors including Joule-X and Sentila, who provide software tools and services to better manage server assets. LBNL had collaborated with Joule-X on a previous data center case study; consequently the research team was able to obtain ample information through renewed conversations and gained a good understanding of the Joule-X software capabilities. Joule-X was also willing to participate in our study and perform a comprehensive assessment on IT equipment, if we could obtain the server owners' consent. Unfortunately, due to the limited scope of our project, we were unable to include Joule-X testing in our detailed assessments. We learned of another open-platform tool, Ganglia, though we were unable to conduct any testing due to the scope of our project. Because server utilization directly impacts the energy usage of other components in server rooms (i.e. number of servers needed, server energy use, and cooling needs), future research efforts could verify the server utilization rate in a bigger sample size of server rooms, and explore the cost- and energy-saving effectiveness of server utilization software.

CHAPTER 6: Conclusions and Next Steps

Conclusions

The research team surveyed 30 server spaces; the information indicated that many different configurations are possible, common energy efficiency issues abound, and many factors contribute to energy inefficiencies. We concluded that the energy inefficiencies commonly observed in small server rooms are not limited by current technology, but rather due to factors such as limited resources, disincentives, and misconceptions. Consequently, there are many opportunities for efficiency improvements, ranging from simple, low-cost options to more intensive retrofits. The "Improving Energy Efficiency in Server Rooms and Closets Fact Sheet" developed as part of this project describes some of the efficiency opportunities available in small server rooms, and also separately lists the measures based on difficulty of implementation. The solution for each space depends on the specific configuration, which involves factors such as room size, IT and cooling equipment configuration, and local climate. While energy savings potential in any particular small server room may be small, the aggregated total energy savings potential on a national scale is very large due to the large quantity of servers that operate in these spaces.

The efficiency barriers we observed were often not technical in nature, but resulted from organizational disincentives. First, owners of small server rooms often do not pay the energy bill directly. Secondly, performance goals of server room operators may not include energy efficiency as an objective. Thirdly, organizational policies can play major roles, for example: a) providing incentives to move distributed server equipment to a centralized data center within the organization or to the cloud, b) restricting the creation or operation of small server rooms, and c) providing technical guidance for existing server spaces to be operated more efficiently. Fourth, server room operators prefer to keep their equipment in close proximity for security and in the event of unexpected power outages. Yet centralized, better managed locations often have more sophisticated security, backup systems, and redundancies that could ensure more reliable and efficient operations. Finally, maintaining a small server room usually only comprises part of the small server room operator's job responsibilities. Operators may not be well trained in energy efficiency concepts in IT, cooling, and power distribution. Server room energy efficiencies could improve significantly through increased energy efficiency visibility and training coupled with organizational support via aligned incentives and policies.

Next Steps

Raising awareness and closing the disincentive gap

A public awareness campaign has the potential to heighten knowledge and disseminate resources, enabling server owners to improve their server room and equipment setup, or to eliminate small server spaces altogether by utilizing more centralized resources. In tackling the disincentive problem, utility programs may be an effective avenue to encourage energy efficiency; suggestions for program design and evaluation can be found in a recent NRDC publication (Bramfitt and Delforge, 2012). Currently, a number of electric utilities offer server related incentives; for example, promoting server virtualization and equipment refresh. We recommend that future research efforts explore and address challenges in program implementation and effectiveness.

Evaluate additional small server spaces

The limited scope of this initial study should be broadened to include other configurations. In particular, small business applications could be examined in more detail to determine opportunities and barriers in that sector.

Server utilization

Most small server room owners and operators did not have access to tools that track server utilization over time. There appeared to be little use of tools to assess utilization in small server spaces - likely as a result of budget constraints and disincentives described earlier that discourage efficiency decisions. Most tools that we encountered during the project were tailored for larger server spaces, and the energy savings generated may not cover the purchase cost of these tools. We recommend that future research investigate server-utilization assessment tools in the market, evaluate their capabilities and costs, and determine the usefulness of such tools in improving server utilization in small server rooms. Future case studies that document measured server power draw, nameplate power, and the respective server utilization rate would also provide valuable insight.

Case studies of improvements

Assembling information on actual energy efficiencies gained as result of improvements could be extremely useful to server operators, owners, and utilities, who are trying to maximize energy savings for a given amount of funding. Documenting case studies which implement various approaches -- for example, reconfiguring server rooms, relocating assets to more efficient spaces, consolidating, and implementing IT efficiency measures, etc. -- could yield hands-on knowledge of improvement details by category. Accurately and systematically tallying the savings resulting from each improvement could lead to credible case studies, and a rich reference that utilities, owners, or operators could consult as needed.

APPENDIX A: References

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 2011. 2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance Whitepaper prepared by ASHRAE Technical Committee (TC) 9.9 Mission Critical Facilities, Technology Spaces, and Electronic Equipment

Bailey, M., M. Eastwood, T Grieser, L. Borovick, V. Turner, and R.C. Gray. 2007. Special Study: Data Center of the Future. New York, NY: IDC. IDC #06C4799. April.

Bramfitt, M. and Delforge, P. 2012 "Utility Energy Efficiency Program Design: Server Room Assessments and Retrofits" The Natural Resources Defense Council. Available at http://docs.nrdc.org/energy/files/ene_12041101a.pdf

APPENDIX B:
Server Room Assessment Protocol

Server Rm Walk-through Assessment Form

Date	
Team	

Space description

Building Name - room #	
Main function of building	
Room size	
Exterior wall/roof	
Space type/use/level	
Room/rack/equipment layout - space utilization, hot/cold aisle (sketch)	
# of network drops	

Space Authority / Configuration

Person responsible for space	
Server owner(s)	
Person authorized to implement EE measures	
Reasons for this space configuration? -- Schedule or protocol for when new servers are added & retired?	
Specific rules to follow when starting a server room?	

A. Computing

- **Rack/IT asset inventory**

Who manages the IT equipment?	
What is the IT equipment used for?	
How many racks of IT equipment? -- Estimate % servers/storage/networking equipment	
Rack space utilization (% of U occupied)	
Existing power metering equipment?	
Ok to install meters?	
Possible future upgrade plan	
Possible consolidation plans	
Possible efficiency recommendations	

- <u>Equipment utilization</u>

Redundant power? -- If yes, is the back up unit inside the room or outside?	
Voltage of equipment?	
Any transformer?	
Possible efficiency recommendations	

B. Cooling

- **House Air**

Estimate air flow (VAV terminal, diffusers, air flow measurement)	
Is there dedicated temperature control in the room?	
Where is temperature sensor located?	
Temperature setpoint and schedule	
Is there humidity control?	
Possible efficiency recommendations	

- **Dedicated Cooling**

Type: CRAC, CRAH, in-row cooling, rack cooling, rear door cooler, split AC, or other system used? If so, please identify type, quantity, and if possible, rating of unit(s) used.	
How is temperature controlled?	
Where is temperature sensor located?	
Temperature setpoint and schedule	
How redundancy is provided if any?	
Possible efficiency recommendations	

- **Free Cooling**

Type of system (windows or ducted ventilation)	
Operating schedule (season ambient temperature)	
Possible efficiency recommendations	

APPENDIX C:
Selected Content - Deliverable 2 - Summary of Configuration Features

Energy Efficiency in Small Server Rooms:
Summary of Configuration Features
PIER TASK 2.13 - Deliverable 2
Bill Tschudi, Rich Brown, Rod Mahdavi, Iris Cheung
June 4, 1012

This project investigates current IT practices and available resources when servers are deployed in small server closets and rooms. The project goal is to develop strategies to improve energy efficiency.

This summary is the second deliverable of Task 2.13: Energy Efficiency in Small Server Rooms in the PIER project 500-10-052.

Report Organization

This report is divided into four main sections. Section I summarizes the work done to date as part of the project. In Section II, we describe the sites where we conducted the preliminary surveys, followed by a summary table noting key characteristics. In Section III, we discuss the efficiency issues we observed from the surveyed sites. Finally, for Section IV, we describe the criteria for selecting the four room configurations for detailed assessment, and their respective configurations.

I. Introduction - Project Progress

Project Progress

From the start of the project, we have completed major activities listed below.

1. Attended workshop at the Silicon Valley Leadership Group (SVLG) - Data Center Summit in November 2011

At the SVLG Data Center Summit, we conducted a workshop jointly with Joyce Dickerson of Stanford University and Pierre Delforge of Natural Resources Defense Council (NRDC) to present the energy use and operation challenges associated with small server rooms, and invited participants to share insights on potential solutions. The workshop was well attended with participants from a variety of organizations and valuable feedback was collected during the open discussion. This feedback, along with our field findings, will be included in the final report.

Another purpose of holding the workshop was to recruit potential participants for the server room survey. We established a number of contacts at both the Data Center Summit and the workshop for general information sharing; and this widened the list of potential participants for our survey. Another valuable experience from the Data Center Summit was learning about the innovative design and operation of highly efficient data centers, and vendor solutions for power and energy monitoring. The Data Center Summit for the most part focused on large data center operations, further confirming the need to raise awareness for small server room efficiency opportunities and to devise strategies that owners and operators could adopt to improve efficiency.

2. Developed *Field Data Collection Protocol*

To standardize and facilitate data collection in the various server rooms, we developed a server room assessment protocol. The data collection included the following: 1) background information about the closet/room; 2) IT equipment layout, applications, and utilization; 3) power conditioning, cooling systems, and environmental conditions; 4) questions to investigate the barriers to energy efficiency improvements. As we gained experience in the surveys, we revised the protocol as needed to better focus our research efforts.

3. Completed server room surveys in various institutions

We completed surveys in 30 server rooms and closets, at eight organizations across five institution types, including academic and research, high-tech, local government, healthcare, and small business. We surveyed between one and ten server closets and rooms in each organization. The summary list of organizations surveyed is shown in Table 1; detailed descriptions of the survey are discussed in Section II of this report.

4. Developed *Small Server Room Fact Sheet*

A PG&E representative we met through the SVLG workshop suggested that a small server room fact sheet would be a helpful tool to easily distribute to their small business customers who operate small server rooms and closets. With this in mind, we collaborated with Joyce Dickerson and Pierre Delforge and put together a fact sheet summarizing efficiency practices that small server room owners could employ to improve energy efficiency, ranging simple to more involved strategies. The Green Grid (TGG) was also consulted for comments and feedback to improve the fact sheet contents. We created two versions of the fact sheet - a web page version contains the detailed information and can be posted on a website, and an abridged version comprises a one-page flyer for distribution to server room owners and operators. The Small Server Room Fact Sheets is included as Appendices E and F.

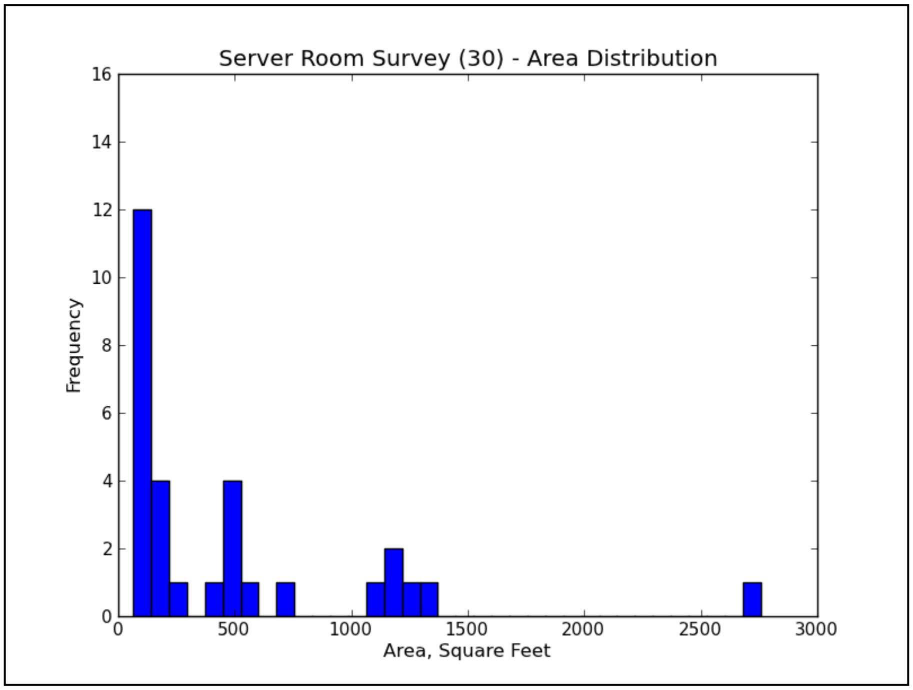
5. Selected four server room configurations for detailed assessment

Finally, based on the server rooms we surveyed, we selected four room configurations to conduct detailed measurements and assess potential efficiency savings. The selection process and configuration descriptions are discussed in Section IV of this report.

II. Server Room Survey - Site Descriptions

Figure 1 presents the floor area distribution of the 30 server rooms we surveyed. Most measured 500 square feet or less, with several over 1,000 square feet, which arguably may not belong to the small server room category. Below we describe the server rooms we surveyed in eight different organizations; the list of organizations and the respective number of server rooms and closets surveyed are presented in Table 1, and their IT and cooling characteristics summarized in Appendix C-1.

Figure 1 - Server Room Survey - Area Distribution Histogram



1. Stanford University

We visited a total of ten server spaces at Stanford University, ranging from a server closet that houses only a few servers, to server rooms designed to be server spaces with enclosed hot/cold aisle separation; details of the server spaces can be found in Appendix C-1. Note that Stanford offers efficiency incentives in the form of both technical and financial assistance to improve efficiency of their small server spaces. They also developed a design guide that provides tested strategies, which could be adopted by other similar institutions. The efficiency barriers encountered in the server spaces surveyed can be grouped into the two categories described below.

- Principal-Agent Problem: In most of the spaces, the energy bill is not paid by the server owners directly, but rather at the departmental level. For example, the utility bill of several rooms we surveyed are paid for by the Dean of Engineering. Without directly paying the costs to power and cool the spaces, server owners have little incentive to improve energy efficiency.

- Research Closeout Mechanisms: In academic institutions, projects are usually funded by research grants with term limits. Equipment is purchased upon receiving the grants, but due to funding limits, insufficient funding toward the end of the project may rule out proper data archiving and equipment retirement. Combined with the

Principal-Agent Problem described above, legacy servers are often left running, consuming unnecessary server energy and cooling power.

2. Lawrence Berkeley National Laboratory (LBL)

At the time of our small server room survey, LBL was simultaneously conducting a Lab-wide server room survey to increase understanding of the number of server rooms spread across the Lab and to better manage server assets. The ongoing Lab-wide server room survey offered an information sharing opportunity. The 14 scientific divisions within LBL act independently when securing research funds and procuring equipment. The Lab has a central IT division, which manages several central server rooms located on-site. The IT group also offers some efficiency incentives for research divisions, e.g. machines used for virtualization can be provided free of charge.

Lab divisions have the option to house their servers in the central server rooms for a management fee. Compared to small server rooms and closets, these central server rooms are more efficient (have a lower power utilization effectiveness (PUE)), and are operated by highly trained staff. For the survey, we visited six server rooms and closets in three different buildings on the LBL campus - two on the main LBL campus and one at the Emeryville site: 1) Bldg. 90, Rm 2094; 2) The Joint BioEnergy Institute (*JBEI*), Bldg. 977; and 3) Bldg. 2, Rm 455; details of the server spaces can be found in Appendix C-1.

3. Applied Materials, Inc. (AMAT)

At the AMAT campus in Santa Clara, we visited one building with a total of five server rooms -- four measuring under 100 SF, and one greater than 500 SF. None of these rooms was designed or built to be server rooms. There were several other server rooms in the same building; however, since our contact person was not directly responsible for these other server rooms, we were unable to gain access to them. All of the five server rooms we surveyed were cooled by the central HVAC system using fan coils connected to their central chilled water system; the large room was also cooled by two split unit systems, one of which was not actively cooling during our visit. Each smaller room had from four to 20 active servers, with typical utilization ranging from 5 to 20%, while the large room had over 60 servers.

With a relatively small number of servers separated into different rooms, we naturally asked why the servers could not be consolidated into a large room. AMAT staff responded that some of the servers ran different parts of production, e.g. software development versus quality control, and due to legal and security issues could not be housed in the same room. The four small rooms also did not have temperature sensors due to budget constraints. Instead, the server manager physically entered the space a few times a day to monitor and regulate the operating temperature. Because of budget issues, the servers appeared to be much older than their ideal replenishment cycle of four to five years. In addition, the rooms had no hot/cold aisle separation or raised floors. Because the rooms were not optimally operated, the power and

HVAC systems were approaching limits, hence limiting IT equipment expansion beyond current capacity.

4. Intel

We visited several server spaces at two Intel campuses in Santa Clara. Server operations are the core of Intel's business, as engineers utilize servers for chip design and other related applications. Consequently, Intel has strong incentives to make their server rooms and data centers energy and cost efficient to improve business processes. The server managers at Intel provide management guidance for servers, including: organizational rules that encourage servers to be placed in central locations, custom-designed software used to monitor the utilization and power usage of servers in the rooms, equipment replenishment cycle at three years or less, and their design and operation of highly efficient server rooms. The staff are keenly aware of efficiency measures that could be implemented and any limitations. Although we surveyed a number of rooms, only one was considered a small server room and considered as a candidate for the detailed assessment (shown in picture below, with features listed in Appendix C-1).

Intel Server Room

5. City of Benicia

The City of Benicia operated three server rooms located: 1) in the police station, 2) in the City Council chamber building, and 3) in a temporary building next to City Hall. The server room in the police station was an 11’x7’ room located next to the dispatch center, with dedicated cooling and backup generator. Three racks of servers ran the police and fire radio, dispatch, video surveillance, and other police applications. Some servers were virtualized while others held applications that did not support virtualization. Temperature for the room was set at 64F, but upon our recommendation, the server manager increased the temperature set point after our visit.

The second server room located above the Council chamber measured 10’x8’, and the space was conditioned by the central building system, and a portable air conditioning unit. The thermostat was set between 70-75F in the server room. Servers and equipment were used for fire and police communications and run throughout the day. The third server room was located in a “temporary” building and housed servers for city operations. Because of equipment renewal, consolidation, and virtualization, equipment footprint in the room decreased 50% in the past two years. For all three server rooms, the energy bill was paid directly by the City and energy consumption in these rooms was not a primary operational concern. Nonetheless, the server managers appeared to be knowledgeable in IT operations and were connected with IT information sharing organizations such as the The Municipal Information Systems Association of California (MISAC).

6. City of Walnut Creek

The City of Walnut Creek operated two server spaces for municipal operations: 1) in City Hall, and 2) in the garage level of the library. The server room inside City Hall measured approximately 600-SF and was part of a building retrofit on top of the original City Hall; construction was completed in 2003. The room was designed to be a server space and housed 23 racks of servers that were about 30% filled, with a utilization of 60%. Several years ago, the City had no server refreshment policy, and much of the equipment was obsolete. Since then, the City implemented a refresh cycle of four to five years for major equipment, and they were also able to incorporate virtualization in much of their new inventory.

Server applications were mainly divided into two categories - 1) law enforcement, and 2) all other applications, including email, standard word processing, building permits, map data, and engineering drawings. The latter was largely virtualized, while law enforcement applications will gradually move to virtualization in the next 18 months. Some internet e-commerce applications were already on cloud computing; however, law enforcement applications related to the Department of Justice were restricted from doing so.

Cooling was provided by two dedicated roof HVAC units. In the event of failure, backup cooling would be provided by the HVAC system normally used for surrounding offices. The space had no raised floor or hot/cold aisle separation, and the room thermostat was set at 72F.

Temperature readings were periodically taken at different areas of the room to detect hot spots, and ceiling tiles were then moved as needed to eliminate hot spots.

The server closet in the library garage housed eight racks of servers and was cooled by the library's central cooling system. Server racks were 10% filled, and were enclosed cabinets with fans that ran continuously at the top. Much of the equipment in the City Hall and library could potentially be consolidated into one server space. However, because the library's phone system was required to run for an extended period of time using UPS after a power outage, communication equipment must be permanently housed within the library.

7. John Muir Hospital

The John Muir Hospital server room was located at the Walnut Creek medical center. It was a 1200-SF room with roughly 15 racks of servers, located in the basement of an older tower of the medical center. All servers were connected to a UPS which was more than 20 years old. Cooling features included a 10-inch raised floor, perforated tiles, and two air handling units, supported by a chilled water plant with a water-side economizer. Staff experimented with hot/cold aisle separation, but this proved to be ineffective due to air-gap openings in the room. Applications run in this server room accessed patient records and imaging file storage. Some virtualization was exercised but cloud computing could not be implemented because of the restrictions related to Protected Health Information (PHI).

John Muir Hospital Server Room

The Medical Center is currently building a new server room to replace this existing one, which will be located on the same level in the newer wing of the hospital. There are several reasons for the relocation and redesign, including improved fire suppression capabilities, UPS system upgrade, seismic reinforcement, and replacing the double air handling units which currently make the room either too hot or too cold.

8. Alfa Tech

We visited the headquarters of Alfa Tech, an engineering design firm in San Jose, and surveyed their 200-SF server room, which was not designed to be a server space. A rapid company expansion around 2005 resulted in a demand for enterprise servers, and consequently, the IT manager started building up the server room. There were two aisles of servers, each containing five racks of equipment. One consisted mostly of servers and UPS and the second aisle houses networking equipment. The space between the two aisles had an AC unit on each end, blowing into the aisle space; one AC unit was set to run full-time at 68F while the other served as a backup unit and provided cooling only when the temperature went above 80F. Although there was no raised floor or official hot/cold aisle in the room, the rack and cooling placements simulated a hot/cold aisle, especially since empty server racks were filled with blanking panels to improve temperature separation. We recommended that a short curtain barrier be installed between the ceiling and the top of server racks to improve hot/cold air separation.

Upon entering the room, a big screen displayed internal and external network traffic going through the main switches, though the software connected to the display did not monitor server utilization. The room housed 30 servers, with an average utilization of about 30%. Virtualization was used on some machines, but since most machines were being run for file storage, the application of virtualization was limited. Refresh cycle of servers depended on performance and budget; the IT budget was limited to 10% of company profits, with some flexibility depending on equipment needs. Equipment acquisition and operation seemed carefully planned for this space, with consideration for future growth. The three-year-old UPS typically ran at 45% capacity and was rated at 20kW, which allowed adequate time to shut down machines in the event of a power outage.

No software applications currently run in the cloud, and the IT manager indicated that they want to maintain high security and control on their assets and therefore would not trust other services to run their applications. However, they would consider employing “Internal Cloud” computing, as this technology becomes more proven.

III. Findings

1. Common efficiency issues in Small Server Rooms

Although the 30 server rooms and closets we surveyed were not intended to be a representative sample, several issues and practices were observed to be common barriers to energy efficiency. These are described individually below; note that these issues were often linked and are discussed together when possible.

a. Most small server rooms were not designed to operate as server spaces

Many of the small server rooms and closets started with just a few servers in a repurposed area, but as the organization's computing needs gradually expanded, new servers were added, leading to the current configurations. In other words, the rooms started out to be a temporary location for servers and were not designed to be server spaces. For example, many of the rooms contained no hot/cold air separation, and warm air exhausted from the servers was often mixed with cooled air from the HVAC units, undercutting cooling efficiency. Sometimes, due to the limited square footage and existing configurations, cost-effective upgrades were limited, and owners/operators saw no other option to operate them more efficiently.

b. Lack of incentives to improve efficiency

i. Principal-Agent Problem - Power bill not paid by server owner/operator

Although the principal-agent problem was specifically discussed for academic institutions in Section II above, it was certainly widespread across the other types of institutions we surveyed. Unlike in a data center, small server rooms are usually not sub-metered and therefore energy consumption cannot be easily measured. In some of the small server rooms we surveyed, the power bill was simply paid by the department head or the larger organization without feedback on cost provided to the people that operate the equipment. In some other cases (e.g. LBNL), although server spaces were more energy intensive, the energy bill was divided on a per-square-foot basis and paid by the respective division occupying the spaces. Since the energy costs were not seen by server owners, there was little incentive for efficiency improvements.

ii. Business/operation takes priority over energy use/efficiency

Unlike some high tech companies in which server operations are their core business functions (e.g. Facebook, Google), servers in small server rooms usually support other more important business or operational purposes. In some of the interviews, server owners understood that server room efficiencies would likely increase with changes in server IT and cooling configurations. However, they also assumed that the energy savings would not be significant enough to make up for up-front equipment and labor costs, or for the configuration changes to be worthwhile considering the uncertainties and risks. Given all these barriers and uncertainties, and that server owners may not directly pay the energy bill, owners preferred to operate the servers as they were.

c. Operations - IT

i. Consolidation and Virtualization

Many of the server spaces we visited already implemented various degrees of consolidation and virtualization, but some of them could push further with consolidating under-utilized servers, identifying unused servers, and virtualizing when it makes sense. Barriers likely include the lack of incentives discussed above, and the limited resources that can be devoted to server operations.

ii. Central and Cloud Computing

Bigger organizations usually have both larger, central server rooms and small server spaces at the same facility. In most cases, servers in the less efficient, small server rooms can be moved to central facilities; however the following factors could prevent such centralization:

- The lack of incentives as discussed above;
- Operators like to have their equipment located nearby for easy access, even though in some cases this is not necessary.

Cloud computing is known among server operators, and some of the small server rooms are already taking advantage of this to reduce server footprint. A number of server owners preferred not to utilize cloud computing, and we observed the following barriers:

- Cloud computing is not yet allowed for Department of Justice applications, including those related to municipal police operations.
- Some organizations desire a high level of security for their file storage and applications, and they are skeptical about the degree of cyber security that can be attained in cloud computing.

d. Operations - Cooling

i. Low operating temperature

Most server equipment sold today is designed to operate at inlet temperatures of at least 80F. However, most server spaces we visited were over-cooled and maintained a temperature of 74F or lower, resulting in unnecessary cooling energy use. There were several reasons for this trend: 1) a common misconception was that server spaces should be kept at temperatures of around 72F; 2) operators were concerned that higher temperatures may not provide adequate buffer in the event cooling equipment fails in these relatively small spaces; 3) the principal-agent problem in which the owner and operator were not responsible for paying the energy costs, and extra cooling was therefore not a primary concern; and 4) the cooled air was sometimes not well circulated in these small server spaces and resulted in local hot spots so operators used extra cooling to compensate for potential hot spots.

ii. No use of Free Cooling

All server spaces we surveyed were located in the San Francisco Bay Area, where the climate is temperate, and outside air temperature is low enough to provide cooling for most of the year. However, a majority of the server spaces we surveyed utilized dedicated cooling alone, without taking advantage of free cooling. This is partially because these rooms were not designed to be server rooms, and were served by existing building HVAC systems. Cooling options were often restricted by existing duct configuration. Typically, as server heat loads increased, dedicating cooling was added to offset heat loads without much consideration for efficiency. Even though it may have been more cost effective in the long run, adding an air economizer would have incurred upfront cost, and reconfiguring the ductwork may not have been straightforward.

iii. No hot/cold air separation

Many small server spaces were not designed to operate as server rooms. As a result, some of them were too small to allow for air separation, and exhaust air from the servers often mixed with cooler inlet air, requiring more cooling energy than necessary. The small square footage of some spaces limited the extent of retrofit or room rearrangement possible. Physical barriers (e.g. plastic screen/curtain) to separate hot and cold air, and slots to block off empty server spaces in racks should be utilized as much as possible to maximize hot and cold air separation.

2. Observations across different institutions

While our sample size was not intended to be representative, we describe in this section the observations made among the different institutions surveyed, namely - academic, small business, healthcare, high-tech, and local government. In summary, the differences we observed boil down to the following factors: 1) business functions (i.e. how directly business functions are related to server computing), 2) the organization's culture regarding energy efficiency, 3) incentives provided by management to encourage efficiency, and 4) the server room operator's knowledge and training.

For the two academic/research institutions on our survey list, different research units operated very independently. Equipment procurement and operation was also highly dependent on research funding which occurs in unpredictable cycles. Without question, core research activities take precedence over energy efficiency of server spaces, and efficiency practices may not have been implemented because of limited resources and the principal-agent problem. However, we also observed that centralized incentives at the organizational level, providing technical assistance and resources, are effective in promoting energy efficiency at the departmental level.

With small businesses and healthcare, servers support business activities rather than the core business. Depending on staff knowledge and training, and the organization's desire and awareness of efficiency, efficiency may be implemented just to the point that it sufficiently supports business activities, or to a higher level if the organization sees the value and long-term benefits of energy efficiency. Along with high tech companies, certain operations associated with small businesses and healthcare may not move to cloud computing, due to security concerns or mandatory restrictions such as PHI.

In high tech companies, for operations with only a small computational component, energy efficiency in server rooms is dependent on organizational factors, similar to small business. However, for operations with extensive computing needs in which hundreds or thousands of servers are used, such as computer chip design, energy efficiency is key to business success and profit margin. These server spaces are usually operated very efficiently, by knowledgeable and well trained staff. When we visited server rooms of this type, cost-effective efficiency measures usually have been implemented, or operators were already well aware of limitations to the approaches that have not yet been exercised.

In the two local governments, server operators' awareness of efficiency and knowledge of server room operation was relatively high. The room configurations limited the maximum cooling efficiency and the temperature setpoints were lower than necessary, but the operators were involved and aware of ideas like consolidation, equipment upgrades, and virtualization. One contributing factor may be the fact that local government staff have a dedicated role in the cities' IT procurement and server operations, and thus the available time and accumulated experience resulted in more dedication and higher awareness. Our sample was limited to two, and it would be interesting to learn more about the similarities and differences of server operations in other local government entities.

IV. Room Configurations Selected for Detailed Assessments

To identify efficiency measures and estimate potential energy savings, we selected four server room configurations for detailed assessments, based on a number of factors: 1) configurations in which results can be applied to other small server rooms (with more consideration on cooling), 2) setups with potential for efficiency improvements, 3) the server operators' interest in participating in further studies, 4) an appropriate range of equipment such that effort for IT equipment inventory and assessment is reasonable. Using these selection criteria, we developed the list below:

1. LBL - Bldg. 90, Rm 2094
   - Window Mounted AC Units

This server room housed a small portion of the servers used for research computations in the Earth Science Division, and is located in Building 90 of the LBL campus. Its unique cooling configuration and the following factors made it a prime candidate for detailed assessment:

- The LBL staff for this project also occupy the same building and have unrestricted access to this room.
- Building 90 has undergone a building submetering project, and one of our team members has extensive knowledge of the electrical wiring and energy metering. As a result, it will be efficient and cost effective to measure the room's IT and cooling energy consumption, and to calculate its PUE.

The server room measured about 200 square feet in size, and was located on the second floor in an office building with four levels. The east wall had exterior windows, and the west wall had both interior windows and the only access door. (Note that west and east were the longer sides of the room.) Three racks of servers were located on the south end of the room, with several other desktop servers scattered near the north end. The room was cooled by the building air conditioning and three window mounted AC units operated continuously. No temperature control was available in the room, but a temperature sensor located near an interior window set off an alarm when the temperature exceeded 86F. This is one of four unique cooling configurations we want to evaluate for energy savings.

2. Stanford University - Frances C. Arrillaga Alumni Center, Server Room
   - Fan Coil with Chilled Water Loop from Central Plant

This 12'x8' server room was located on the second floor of the Arrillaga Alumni Center, which consisted of mostly conference spaces and offices. The room had three racks of servers that were roughly 50% filled, and was not designed to be a server room. The Alumni Center wanted to keep their alumni database located close to daily operations and converted the space into a server room. Cooling was served by building AC which operates during office hours, and a dedicated fan coil (with chilled water circulated from a central plant on campus). At the time of our survey, the room was kept at 66F, and the operator indicated the operating temperature was set at below 70F to safeguard the servers. The room also experienced some cooling issues, and the potential reasons were: 1) airflow inefficiency, and 2) insufficient cold air. To identify the cause of the problem, a plastic curtain/barrier was installed before our initial visit to improve hot/cold air separation. The curtain installation (as shown in the picture below) has alleviated the cooling problem, which proved to be poor airflow management. Based on the room features and the fan coil/chilled water cooling configuration, we determined it would be a good candidate for detailed assessment to evaluate further efficiency options.

Stanford Arrillaga Alumni Center Server Rm

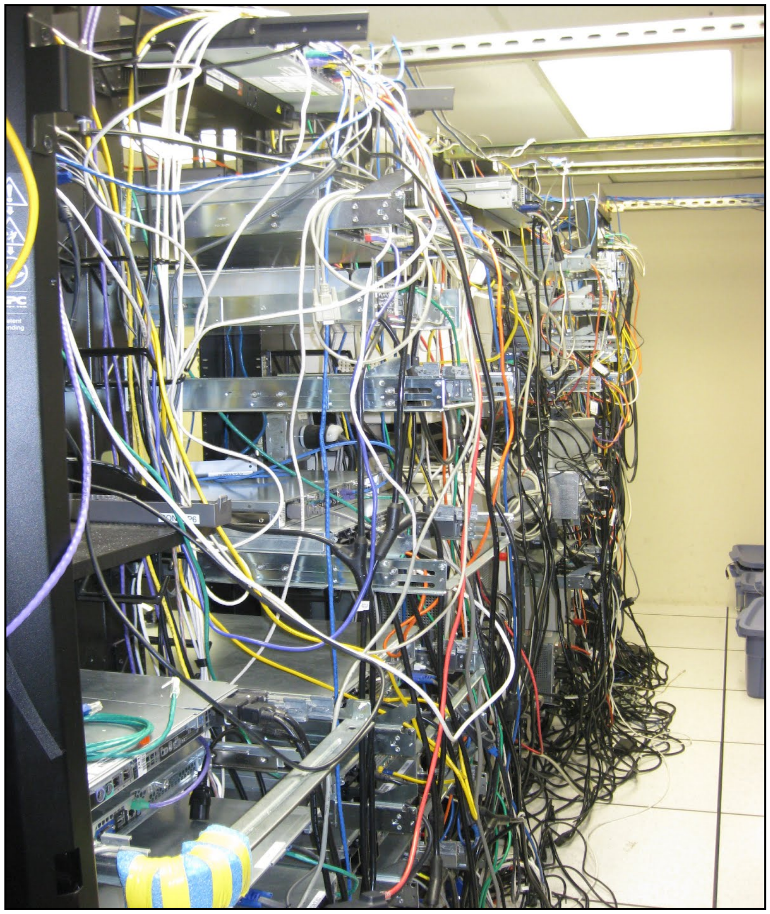
3. City of Walnut Creek - City Hall Server Room
   - Roof Mounted Package AC Unit

The third site we selected for detailed assessment is the server room in the City Hall building in Walnut Creek, described in detail in Section II of this report. Unlike most of the other rooms we surveyed, the City Hall room was actually designed to be a server room, but there are still measures that can be implemented to improve efficiency. While this room meets our selection criteria, the 23 racks of servers (30% filled) may be too many for us to perform a detailed IT inventory; as a result, we will select a representative sample of the servers to perform the assessment. This site also provides an opportunity to evaluate the roof mounted package cooling units that are found in other small server rooms.

4. Stanford University - 333 Bonair Siding - Rm 110
   - Split AC Units

The fourth site we selected for detailed assessment was located in 333 Bonair Siding at Stanford University. This 27’x28’ (750 SF) server room held 15 server racks, more than half of which in parallel rows and others scattered in the room, and was cooled by three split AC units, providing a fourth unique cooling configuration for the detailed assessment. IT and cooling equipment were connected to two separate electrical panels, making it easier for power measurements in determining the room’s PUE. The room had no hot and cold air separation and contained a raised floor used for cabling only. From our interview with room operators, they used a certain software to track server utilization, with which we may use to measure utilization rates.

333 Bonair Siding, Rm 110



In the next project phase, we will conduct detailed assessments on the four selected sites and develop a list of efficiency measures and potential savings for each configuration. Findings will be summarized in our next deliverable “Efficiency Measures and Potential Savings List,” due on November 30, 2012. Appendix D summarizes the information we plan to collect for the detailed assessment, though we may revise this list to capture unique characteristics and as our understanding improves during the efficiency measurements. Upon completion of this task, we will compile findings from the entire study in the “Energy Efficiency in Small Server Rooms” Final Report.

V. List of Appendices

1. Appendix C-1 - Server Room Survey - Detailed Summary

Appendix C-1 - Server Room Survey - Detailed Summary

Number	Date of Survey	Institution	Bldg./Room	Type (1)	Area (square feet)	Server Racks	Rack Config.	Rack Space Utilization	Raised Floor?	Hot/Cold Aisle Separation?	Cooling (House air, Dedicated cooling, and/or Free cooling)	Cooling Config.
1	Nov 2011	Stanford	333 Bonair Siding - Rm 110	Localized Data Center	27' x 28'	15	scattered	0.4	Yes (for cabling only)	No	Dedicated cooling	3 Split Systems
2	Nov 2011	Stanford	Gates - B14	Mid-tier Data Center	52' x 24'	42	parallel rows	0.5	Yes	No	Dedicated cooling	4 CRAHs (chilled water)
3	Nov 2011	Stanford	Gates - B27	Mid-tier Data Center	106' x 26'	73	scattered	0.4	Yes	No	Dedicated cooling	4 CRAHs (chilled water)
4	Nov 2011	Stanford	Packard - Rm 111	Server Room	25' x 10'	7	2 rows	0.15	No	No	House air + Dedicated cooling	Zone VAV (house) + Fan coil (dedicated)
5	Nov 2011	Stanford	Allen - Rm 220	Mid-tier Data Center	1100	28	parallel rows	0.2	Yes	No	Dedicated cooling	2 CRACs
6	Nov 2011	Stanford	Arrillaga - Main	Server Closet	12' x 8'	3	1 row	0.5	No	Yes	House air + Dedicated cooling	1 Fan coil
7	Nov 2011	Stanford	02-250	Server Closet	18' x 10'	1	scattered		No	No	House air + Dedicated cooling	1 Mini Split
8	Nov 2011	Stanford	02-500-500R	Server Room	30' x 15'	12	parallel rows	0.8	No	Yes	Dedicated cooling	In-row RC cooling at every other rack
9	Nov 2011	Stanford	550-1T1	Server Closet	8' x 8'	5	scattered		No	No	House air + Dedicated cooling	1 Mini Split
10	Nov 2011	Stanford	Huang - 002	Mid-tier Data Center	1200	44	parallel rows	0.1	No	Yes	Dedicated cooling	1 CRAH & many in-row (IROC) cooling
11	Apr 2012	LBL	977 - Rm 151	Server Closet	16' x 8'	4	1 row	0.3	No	No	House air	
12	Apr 2012	LBL	977 - Rm 237A	Server Closet	11' x 11'	2	1 row	0.8	No	No	House air + Dedicated cooling	AHU w/ DX cooling coil
13	Apr 2012	LBL	977 - Rm 256	Server Closet	15' x 5'	1	1 row	0.7	No	No	House air + Dedicated cooling	AHU w/ DX cooling coil
14	Apr 2012	LBL	977 - Rm 298	Server Room	500	5	1 row	0.3	No	No	House air	
15	May 2012	LBL	2-455	Server Room	500	4	1 row	0.8	No	No	House air	
16	Feb 2012	LBL	90-2094	Server Room	200	3	1 row	0.8	No	No	House air + Dedicated cooling	Window mounted AC
17	Apr 2012	AMAT	1F08-02	Server Closet	<100	5	1 row	0.5	No	No	House air + Dedicated cooling	Fan coil (chilled water)
18	Apr 2012	AMAT	1F08-01	Server Closet	<100	3	1 row & some scattered	0.8	No	No	House air + Dedicated cooling	Fan coil (chilled water)
19	Apr 2012	AMAT	1F07-02	Server Closet	<100	2	1 row	0.5	No	No	House air + Dedicated cooling	Fan coil (chilled water)
20	Apr 2012	AMAT	1F07-01	Server Closet	<100	2	1 row & some scattered	0.5	No	No	House air + Dedicated cooling	Fan coil (chilled water)
21	Apr 2012	AMAT	1F06-01	Server Closet	<100	4	1 row	0.2	No	No	House air + Dedicated cooling	Fan coil (chilled water)
22	Apr 2012	AMAT	1F07-03	Server Room	500	9	1 row & many scattered	0.8	No	No	House air + Dedicated cooling	2 CAHUs
23	Dec 2011	Intel	SC2 - 250	Mid-tier Data Center	1300	48	parallel rows		6"	partially	Dedicated cooling	2 CRAC units; 1 CRAH unit (chilled water); 2 AHUs
24	Dec 2011	City of Benicia	Police Station	Server Closet	11' x 7'	3	1 row		No	No	Dedicated cooling	1 Mini Split
25	Dec 2011	City of Benicia	City Chamber	Server Closet	10' x 8'	5	scattered		No	No	House air + Dedicated cooling	1 Portable AC
26	Dec 2011	City of Benicia	Temp. Bldg.	Server Closet	15' x 10'	3	1 row		No	No	House air + Dedicated cooling	1 Wall Unit
27	Jan 2012	City of Walnut Creek	City Hall - 2nd Flr	Localized Data Center	600	23	parallel rows	0.3	No	No	House air + Dedicated cooling	2 Roof mounted ACs
28	Jan 2012	City of Walnut Creek	Library Garage	Server Room	20' x 20'	8	parallel rows	0.1	No	No	House air	
29	Apr 2012	John Muir	Main	Mid-tier Data Center	1200	15	scattered		10"	No	Dedicated cooling	2 CRAHs (chilled water)
30	Apr 2012	Alfa Tech	Main	Server Room	200	10	2 rows	0.4	No	No	House air + Dedicated cooling	2 Split AC units

APPENDIX D:
Server Room Detailed Assessment Data Collection List

Appendix D - Server Room Detailed Assessment - Data Collection List

1. IT systems assessment
    a. Full inventory of (partial if we are only analyzing part of the room) -- Servers, Data Storage, and Network Equipment. Collect:
        i. Brand
        ii. Rated power
        iii. Voltage
        iv. Year of Manufacture
    b. IT equipment layout
    c. Measure server utilization rates
    d. Institutional Data
        i. Applications run on each server
        ii. Current virtualization, consolidation, and cloud computing scheme
        iii. Who owns and operates the servers
        iv. Is power separately metered
        v. Who pays utility bill
        vi. Any guidelines or rules for starting new server room
        vii. How IT and infrastructure evolved to the assessed condition
    e. IT equipment power/energy use
    f. Power supply redundancy

2. Power distribution efficiency
    a. Power loss in UPS equipment
    b. UPS load capacity/design efficiency/actual loading
    c. Power loss in transformers (if any)
    d. UPS redundancy

3. HVAC assessment
    a. Cooling system configuration
        i. House air and/or dedicated cooling
        ii. HVAC system design/equipment type
        iii. Rated cooling capacity
        iv. Operating capacity and efficiency
        v. Operating temperatures
        vi. Controls and operating schedule
        vii. Potential for free cooling
        viii. Potential for use of waste heat
    b. IT equipment layout
        i. Hot/cold aisle
        ii. Air management issues

iii. Hot spots

4. Efficiency Evaluation
    a. IT equipment opportunities
        i. Virtualization / Consolidation / Migration to cloud computing model
        ii. Equipment refresh interval and specs
        iii. Power management
        iv. Power supply redundancy
        v. Turn off unused servers and storage disks
        vi. Equipment designed to operate at elevated temperatures
    b. Other IT recommendations
    c. Power distribution opportunities
        i. Efficiency of UPS
        ii. Need for backup?
        iii. Redundancy of UPS
    d. Cooling efficiency options?
        i. Higher temperature set point
        ii. Use outside air (economizer)
        iii. Reuse waste heat
        iv. Improve hot/cold air separation (e.g. blanking panels)
        v. VFDs on cooling units
    e. Other recommendations
        i. Lighting efficiency and controls

5. Energy Saving Estimation
    a. Estimate IT and Cooling savings, based on recommended efficiency measures (compared to baseline)

APPENDIX E:
"Improving Energy Efficiency for Server Rooms and Closets"

October 2012

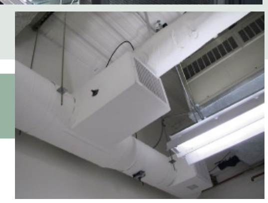
Improving Energy Efficiency for Server Rooms and Closets

Top 14 Measures to Save Energy in Your Server Room or Closet

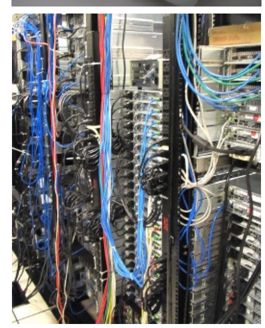
Introduction

Is there a ghost in your IT closet? If your building has one or more IT rooms or closets containing between 5 and 50 servers, chances are that they account for a significant share of the building's energy use (in some cases, over half!). Servers, data storage arrays, networking equipment, and the cooling and power conditioning that support them tend to draw large amounts of energy 24/7, in many cases using more energy annually than traditional building loads such as HVAC and lighting.

The good news is that there are many cost-effective actions, ranging from simple to advanced, that can dramatically reduce that energy use, helping you to save money and reduce pollution.



A. Simplest, No-Cost, Or Very-Low-Cost Measures



1 Determine computational functions/Turn off any unused servers

An Uptime Institute survey suggests that close to 30% of servers in data centers are consuming power but not doing any useful work. To better manage server usage and utilization, create and regularly update a server hardware and application inventory that will help you track the number of applications running on each server. Mapping applications to the physical servers on which they are running helps identify unused servers and opportunities for consolidation. Just make sure to migrate any remaining data or workloads before shutting down.

2 Increase temperature setpoints to the high end of ASHRAE's recommended limit

ASHRAE temperature guidelines allow much broader operating ranges than those commonly used, allowing the air temperature at the IT equipment inlet to be raised—up to 80°F or higher—which considerably reduces cooling energy usage.

3 Examine power backup requirements (do you really need UPS equipment, and if so, how much is enough?)

Many IT applications are not so critical that they cannot be shut down if there is a power disturbance and restarted without adverse effects. Analyzing your power backup requirements can help you eliminate capital costs for unnecessary or oversized redundant power supplies or Uninterruptible Power Supply (UPS) equipment. It can also help you save energy lost in power conversion in those devices as well as energy to cool them. Anything that needs high reliability should be a candidate for moving to a true data center or cloud solution.

4 Airflow management: Install blanking panels and block holes between servers in racks

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

B. A little More Work, But Still Fairly Simple

5 Refresh the oldest equipment with high-efficiency models

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

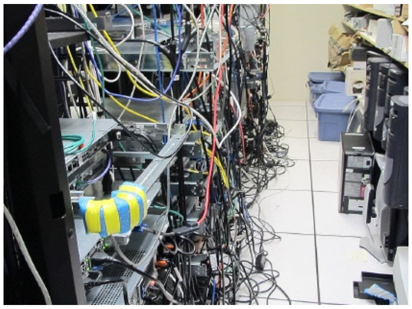
6 Move to a more energy-efficient internal or external data center space, or to cloud solutions

Distributed server rooms are typically not very energy efficient. If a central data center is available, you may be able to save energy and reduce your utility bill, by moving your servers to that location. When a data center is not available, many organizations are moving their equipment to co-location or cloud facilities (public or private cloud facilities both typically provide much better efficiencies than on-premise server rooms). Data centers, colocation and cloud facilities typically offer better security, redundancy, and efficiency than is usually available in server rooms.

7 Energy-efficiency awareness training for IT custodial and facility staff

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

C. Higher Investment, But Very Cost Effective



8 Implement server power management

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

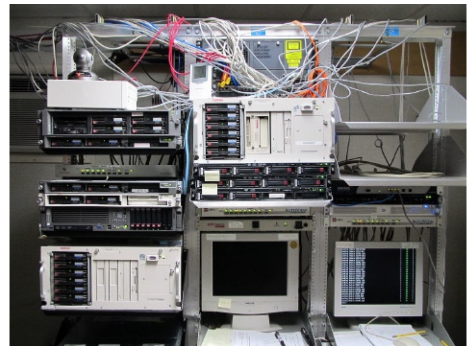
9 Consolidate and virtualize applications

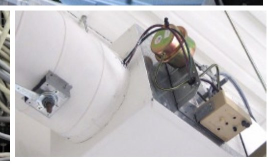
Typical servers in server rooms and closets run at very low utilization levels (5-15% on average), while drawing 60-90% of their peak power. Consolidating multiple applications on a smaller number of servers accomplishes the same amount of computational work, with the same level of performance, with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

10 Implement rack/infrastructure power monitoring

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

11 Install variable frequency drives on cooling units





If your server room is cooled with a Computer-Room Air Handler (CRAH) or Computer-Room Air Conditioner (CRAC) unit, then it is highly likely that the unit has a single-speed fan, and that it provides more airflow than your IT equipment needs. Units with variable frequency drives (VFDs) have the capability of providing only the amount of air that is required by the IT equipment. To maximize potential energy savings, coordinate the implementation of airflow management measures and airflow isolation systems with the installation of a VFD on the cooling unit fan. See item 4 for air management suggestions. Ideally the fan speed should be dynamically controlled to maintain IT inlet temperature within the recommended range.

12 Install rack- and row-level cooling

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

13 Use air-side economizers

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

14 Install dedicated cooling for the room, rather than depending on building cooling

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

Fact sheet developed by: Mark Bramfitt, Rich Brown, Hoi Ying (Iris) Cheung, Pierre Delforge, Joyce Dickerson, Steve Greenberg, Rod Mahdavi, and William Tschudi

Energy Star:
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DC

Climate Savers Computing Initiative Server Catalog:
http://www.climatesaverscomputing.org/csci-certification-output/product-catalog

BERKELEY LAB

For information on how to implement each of these actions, refer to:
http://hightech.lbl.gov/documents/data_centers/fact-sheet-ee-server-rooms.pdf

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APPENDIX F:
"Fact Sheet: Improving Energy Efficiency for Server Rooms and Closets"

LBNL-5935E

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Fact Sheet: Improving Energy Efficiency for Server Rooms and Closets

Hoi Ying (Iris) Cheung, Rod Mahdavi, Steve Greenberg, Rich Brown and William Tschudi, Lawrence Berkeley National Laboratory (LBNL)

Pierre Delforge, National Resources Defense Council (NRDC)

Joyce Dickerson, Google

Environmental Energy Technologies Division

September 2012

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Fact Sheet: Improving Energy Efficiency for Server Rooms and Closets

September 2012

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Top 14 Measures to Save Energy in Your Server Room or Closet

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

Fact Sheet (Web Content): Improving Energy Efficiency for Server Rooms and Closets

September 2012

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The good news is that there are many cost-effective measures, ranging from very simple to more advanced, that can dramatically reduce that energy use, helping you to save money and reduce pollution. Some measures also "recapture" IT equipment and cooling system capacity, giving you headroom for additional IT equipment installations.

Top 14 Measures to Save Energy in Your Server Room or Closet

A) Simplest, No-Cost, or Very-Low-Cost Measures

1. Determine computational functions / Turn off any unused servers

An Uptime Institute survey suggests that close to 30% of servers are unused in data centers, with each one costing over $4,000 per year in energy, space, and maintenance costs, without adding business value. To save energy and important business resources, the following measures can be implemented on a regular basis to better manage server utilization.

- **Server Inventory and Application Mapping.** Create and regularly update a server hardware and application inventory to track the number of applications running on each server, and identify unused servers or servers with low utilization. These servers can then be consolidated, with some servers eventually turned off or reassigned. Depending on the level of complexity you desire, the inventory can be a simple spreadsheet or vendor-based software that automates the process.

- **Logical-to-Physical Server Tracking.** Because of the high volume of machines running in the server room, and the fact that server room operators may not be the users running the applications, it is easy to lose track of the connections between the systems/applications and the servers that run them. Having knowledge of these connections makes it easier for operators to track their equipment and its functions, and identify unused servers and redundant applications, thus further facilitating server management. Mapping these connections requires the same inventory tools described above as well as some information gathering from the application users.

2. Increase the air temperature at IT equipment inlet to 80 degrees

The American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) Thermal Guidelines for Data Processing Environments recommend a temperature range of 64ºF to 80ºF for air cooling. This is the condition **at the inlet to the IT equipment**. Although this wide range may feel uncomfortable, it is endorsed by IT equipment manufacturers.

Raising the supply air temperature set point can enable significant energy savings -- especially if your cooling system features an economizer. The easiest way to track inlet temperature is to purchase a digital thermometer and stick it to the front of one of your racks. It's best to put it on the hottest rack, so try it in several places and adhere it at the hottest spot. Then, reduce the cooling in the room until the thermometer shows that temperature has raised to 80 ºF. Check it periodically with several measuring points, as your cooling needs may change over time, and the hottest spots may migrate depending on loads. There are also a variety of temperature data loggers that can help automate the monitoring process.

Note that the supply air temperature needed to cool the server room is closely linked to airflow management in the space; as airflow improves to minimize hot and cool air mixing (between supply and return air), the higher the supply air temperature can be and still meets the higher part of the recommended temperature range. See #4 for detailed descriptions on airflow management.

ASHRAE Data Center Environmental Condition Recommendations

Classes	Equipment Environmental Specifications				
	Dry-Bulb Temp (ºF)	Humidity Range, non-Condensing	Maximum Dew Point (ºF)	Maximum Elevation (ft)	Maximum Rate of Change (ºF/hr)
Recommended					
A1 to A4	64.4 to 80.6	41.9 ºF DP to 60% RH and 59 ºF DP			
Allowable					
A1	59 to 89.6	20 to 80% RH	62.6	10,000	9/36
A2	50 to 95	20 to 80% RH	69.8	10,000	9/36
A3	41 to 104	10.4 ºF DP & 8% RH to 85% RH	75.2	10,000	9/36
A4	41 to 113	10.4 ºF DP & 8% RH to 90% RH	75.2	10,000	9/36
B	41 to 95	8% RH to 80% RH	82.4	10,000	NA
C	41 to 104	8% RH to 80% RH	82.4	10,000	NA

Source: ASHRAE's "2011 Thermal Guidelines for Data Processing Environments"

For short periods of time it is acceptable to operate outside this recommended envelope and approach the extremes of the allowable envelope. All manufacturers perform tests to verify that their hardware functions at the allowable limits. For example, if during the summer months it is desirable to operate for longer periods of time using an economizer rather than turning on the chillers, this should be acceptable, as long as this period of warmer inlet air temperatures to the IT equipment does not exceed several days each year (otherwise the long-term reliability of the equipment could be affected). Operation near the upper end of the allowable range may result in temperature warnings from the IT equipment.

For more information, see ASHRAE's "2011 Thermal Guidelines for Data Processing Environments": http://www.eni.com/green-data-center/it_IT/static/pdf/ASHRAE_1.pdf. The recommendations in this 2011 white paper divided the data center equipment into four classes (A1 through A4). In this version, guidance was provided to determine the impact on reliability when operating A2 class equipment within its allowable range, i.e., 50 to 95 ºF. Generally following this guidance shows that operating in the allowable range for part of the year has an insignificant reliability impact.

For more information, see http://www1.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf.

3. Examine power backup requirements (do you really need UPS equipment and dual power supplies, and if so, how much is enough?)

Redundant equipment in the power delivery chain increases capital cost and consumes additional energy, as power conversions create heat which must then be removed. Not all IT equipment needs backup power; for example, some applications can simply be restarted without significant adverse effects when an electrical power disruption occurs. Some applications failover to other

IT equipment, so dual individual power supplies are not required. As these examples show, utility customers should analyze these systems to determine whether or not power conditioning or backup is needed; this helps to avoid costly redundant equipment that consumes additional energy.

Redundancy is sometimes provided for IT equipment power supplies, uninterruptible power supplies (UPSs), power distribution units (PDUs), or other transformers in the distribution chain. Any of these devices that provide power conversion from one voltage to another, or from alternating current to direct current or vice versa, have higher conversion losses (as a fraction of the power delivered) when they are lightly loaded, which is what occurs when redundant equipment is provided. More redundancy always equates to less efficiency, and should therefore be justified.

In addition, UPS and PDU sizing should be reviewed after hardware refresh or consolidation. If the consolidation reduces the overall IT equipment load, these devices may then become oversized with very poor efficiency.

Even when UPSs cannot be completely eliminated (e.g. when a UPS may be needed to bridge the startup time of a standby generator or allow an orderly shutdown), it is often possible to limit the level of redundancy to what is really required. For example a large 30-minute UPS for a rack and a 45-minute UPS for network may be the best thing for brownouts and ride-throughs, whereas a UPS per corded system would be overkill. Review uptime requirements, fault failover, and disaster recovery plans to determine appropriate UPS or redundancy requirements.

4. Airflow management: Install blanking panels, plug holes, install “chimneys”, and consider airflow isolation measures

Airflow management is conceptually simple and surprisingly easy to implement. Your challenge: ensuring that the cool air from your cooling equipment gets to the front of your IT gear, without getting mixed up with the hot air coming from the back, or short-circuiting back to the cooling unit.

How do you get this done? In an ideal world the cold supply air would be directly ducted to your IT equipment, and the hot return air would be ducted directly back to the intake of the cooling unit(s). In practice, you only need to do one or the other, and there are interim improvements you can make that take far less effort. (See section 9 for a description of containment.)

For example, unused portions of IT racks act as airflow “short circuits”; cool air simply flows through the rack and back to the cooling units without having done anything effective.

The solution? Diagram and review the airflow. Check for cabling clutter and tight rack placement in an under-provisioned rack. Sketching out where air is coming from and going to and clearing up the path is simple, and it may eliminate overheating issues altogether. For some closets a $100 trip to the hardware store and a few hours of cleanup will make a big difference.

Next, install blanking panels -- cheap strips of sheet metal or plastic that block off unused portions of your racks. Don’t let air bypass between or around the IT equipment.

Do you have an underfloor air distribution system in your server room? Be sure that all supply air comes out of the perforated or grate tiles in front of your racks, by plugging holes and blocking off power distribution units and other equipment that don't require direct cooling. Also check columns, cracks, and holes around the periphery of the raised floor. And about those perforations/grates: they should only be in front of racks where cool air can enter the front of IT gear, never in the back where the air will simply mix with hot exhaust before returning to the cooling units. It's fine for the hot aisle to be uncomfortably hot.

Also consider adding "chimneys" to your cooling units. These simple sheet metal extensions raise the return air intakes closer to the ceiling of the server room, where they can pull in only return air, not supply air. (Chimneys can impede access to cooling unit filters, though the filter units can be relocated to the top of the chimney, or access panels can be provided in the sides of the chimney.)

The airflow management techniques described above increase the effectiveness of other energy-saving measures, such as raising the supply air temperature (with hot/cold air mixing now minimized) and reducing the volume of air that is circulated by reducing fan speeds. These measures in turn provide higher temperature differential at the computer room air conditioners, leading to better heat exchange performance, which then improves the efficiency in the chilled water or refrigerant heat exchange. Thus, airflow management not only improves energy efficiency, it ensures that you can get the full cooling capacity from your system, avoiding the need for new cooling units prematurely.

B) A little More Complex, But Still Fairly Simple

5. Refresh the oldest equipment with high-efficiency versions

The energy efficiency of industry-standard servers improves dramatically from generation to generation, driven by customer concerns about the cost and availability of power in data centers. The latest servers deliver much higher "performance per watt" than three- to four-year-old servers do.

Establish server refresh policies that take into account increases in generation-on-generation energy-efficiency and power manageability improvements. The savings in energy and software costs can sometimes justify a faster refresh than expected. Purchasing high-temperature-tolerant servers can also save energy by reducing cooling needs.

Refreshing servers is a good opportunity to consider consolidation, as new servers usually have much more capacity than the ones they replace. When purchasing new equipment, servers with solid-state drives (SSD), rather than hard disk drives, may be considered, as they feature faster speeds, are generally considered to be more reliable, and consume less power.

Power supplies

Power supply efficiency is the output power divided by the input power. If a 700-watt power supply is 70% efficient, then it needs 1000 watts of input power to provide 700 watts of output power. The "lost" 300 watts is converted to heat, and so in addition to losing 300 watts of power, you have to provide additional cooling to remove the waste heat.

The 80 PLUS® certification for power supplies specifies efficiency levels at various loadings for both non-redundant and redundant internal power supplies. Most servers use redundant power supplies, and redundant power supplies typically operate at a less-efficient point on the efficiency curve. Be sure to specify the appropriate redundancy for your application and the highest level of efficiency that is economically reasonable for new server purchases.

80 PLUS Certification	115V Internal Non-Redundant			230V Internal Redundant			
% of Rated Load	20%	50%	100%	10%	20%	50%	100%
80 PLUS	80%	80%	80%	N/A			
80 PLUS Bronze	82%	85%	82%	---	81%	85%	81%
80 PLUS Silver	85%	88%	85%	---	85%	89%	85%
80 PLUS Gold	87%	90%	87%	---	88%	92%	88%
80 PLUS Platinum	90%	92%	89%	---	90%	94%	91%
80 PLUS Titanium	---	---	---	90%	94%	96%	91%

Source: http://www.plugloadsolutions.com/80PlusPowerSupplies.aspx

Specifying efficient power supplies with high efficiency (80 PLUS Gold or better) at their normal operating points can improve the efficiency of the power distribution chain by several percentage points. This also results in lower cooling requirements, producing further energy savings.

Power distribution and conditioning

Refreshing power distribution equipment (UPS, PDU) can also lead to substantial efficiency gains. Here are some important considerations:

- Select high-efficiency components (for example, refer to the upcoming Energy Star for UPS when it is available).
- Minimize power conversions: every power conversion (AC-DC, DC-AC, AC-AC, DC-DC) decreases overall efficiency and creates heat.
- Distribute higher voltage (e.g. 208v in lieu of 120v equipment may save 2-3.5% energy)
- Right-size your power distribution equipment: efficiency decreases when systems are lightly loaded.
- Review your need for redundancy and minimize redundancy levels.

Resources:

- Energy Star-qualified servers: www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DC
- Climate Savers Computing Initiative procurement requirements and product catalog: www.climatesaverscomputing.org/.
- Climate Savers Computing Initiative Power Supply Efficiency Requirements: http://www.climatesaverscomputing.org/csci-certification-output/technical-specs-2

6. Move to a more energy-efficient internal or external data center space, or to cloud solutions

Distributed server rooms are typically not very energy efficient. If a central data center is available, you may be able to save energy and reduce your utility bill, by moving your servers to that location. When an internal data center is not available, many organizations are moving their equipment to co-location or cloud facilities, which offer better security, redundancy, and efficiency than is typically available in small server rooms and closets.

It takes as much energy to cool and condition a typical server room as it does to run the servers themselves. As a simple example, the chart below shows representative data, assuming your server room contains 10 servers, with an average power consumption of 500W each, and that the cost of electricity is $0.01 per kilowatt-hour (kWh).

Space	Typical Room PUE	Server Power Consumption (10 servers), kW	Total Power Consumption (IT and Infrastructure), kW	Estimated Annual Energy Cost, $/year	Estimated Annual Savings if Moved to Data Center, $/year
Server Room	2	5	10	9,000	2,000
Converted Closet	2.5	5	12.5	11,000	4,000
Central Data Center	1.5	5	7.5	7,000	-

In the example above, although the computers are using the same amount of energy, the cost to power the room varies based on the efficiency of the cooling and power infrastructure. By moving gear to a central location, you not only save on operating costs every year, but also regain the space to use as an office or a conference room. Additionally, the data center space likely has a more robust infrastructure, which will keep your servers running in case of a power outage, cooling equipment failure, or other emergency.

There are, however, cases when moving the servers is just not possible. If that is the case, then use the information here to maximize efficiency of the server space.

7. Energy efficiency awareness training for IT custodial and facility staff

The staff responsible for operating and maintaining IT equipment in small server spaces are often not as immersed in the IT world as their counterparts in larger data centers. IT evolves rapidly and there are many advances to track. For this reason, server room operators should attend server room energy-efficiency awareness classes offered by utility companies, ASHRAE, and others. There are a lot of misconceptions around the powering and cooling of IT equipment, and communication and collaboration between IT and facility staff is essential.

For example, the air temperature entering IT equipment can be provided at 80 ºF or higher. But often in IT closets or small server spaces, temperature is read and controlled at a location in the room that has no bearing on the air entering the IT equipment, and consequently is set colder than necessary.

There are a number of resources available to assist in understanding energy efficiency options for data centers. Consult the following resources:

- Lawrence Berkeley National Lab (LBNL) - Benchmarking, case studies, best practices, demonstrations
  http://hightech.lbl.gov/datacenters.html
- U.S. Department of Energy (DOE) - DC Pro Assessment tools, case studies
  http://www1.eere.energy.gov/industry/datacenters/
- ASHRAE - Datacom book series, ASHRAE-DOE Awareness Training
  http://tc99.ashraetcs.org/

- The Green Grid - Web based resources http://www.thegreengrid.org/library-and-tools
- Pacific Gas and Electric (PG&E) - Best Practice Guidelines http://www.pge.com/hightech/
- U.S. Environmental Protection Agency (EPA) - Energy Star equipment http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency

C) More Complex, But Cost-Effective

8. Implement server power management

Enable Power Management Features if Possible. Modern IT equipment has many power management features which are sometimes disabled. Since some applications do not run continually, enabling power management saves energy effectively with low effort; this is especially true for storage equipment that is only accessed infrequently.

Implement Power Cycling. If servers are unused for long periods (hours at a time), a power-cycling system can be implemented to put unused servers in a light sleep mode (e.g., 1e system for “drowsy” mode).

Other Resources and Information. Check the Energy Star site for more information on enabling power Management. Also check with equipment vendors for specific design and features of power management of product models.

Remote Power Control. In addition, the ability to power-on a server remotely should be considered. Modern servers can be equipped with built-in (or add-on) cards, or after-market power-on adaptors, which allow system administrators to power servers on or off remotely. This remote power control may allow some under-utilized servers that would otherwise be running continuously to be switched off. In this case, an added benefit would be increased security, as systems not running cannot be attacked. This feature is also valuable when a server needs to be restarted remotely to restore functionality.

9. Consolidate and virtualize applications

Server rooms and closets typically run at low load levels (5-15% on average), while drawing 60-90% of their peak power. Servers draw a lot of power simply by being on. Consolidating multiple applications on a single server accomplishes the same amount of computational work, with the same level of performance, but with much less hardware (there may be just as many servers, but many will be virtualized onto other hardware), and therefore much lower energy consumption.

The most basic form of consolidation requires no virtualization software. Provided that the performance requirements of each application are well understood and modest (which is the case of most typical applications in small server rooms), and that they don’t have conflicting software requirements (e.g., applications using two different versions of the same reporting software), you can consolidate multiple applications on a single server. More complex situations can be solved through virtualization, as covered below.

The simplest way to identify unused servers is to map applications to servers, as discussed in #1 above. Another way is to monitor server utilization. There are many Original Equipment Manufacturers (OEMs) and third-party solutions that offer monitoring functionality, from manual spot checks in the console to continuous monitoring and activity logging. Monitoring server utilization is a common best-practice in IT equipment management.

Before turning off "under-utilized" servers, find the task or machine owners. Determine the purpose for which the provisioning was intended (this prevents shutting down dedicated security, backup, or data compliance systems). Before shutting down the servers, ensure that the data archives and workload migration has occurred.

Server virtualization is a software solution that enables the hosting of multiple application workloads on a single physical server, with each workload running within its own operating system instance (aka, "virtual machine"). This prevents resource conflicts between workloads and can enable load balancing and failover between multiple machines. Virtualization reduces the number of physical servers required to run, considerably reducing the energy required to run applications.

Virtualization is a similar concept to consolidation, but it is implemented using a more sophisticated and flexible software solution. The separation of application workloads in their own virtual machines eliminates the risk of resource conflict and potential impacts on service availability. Virtualization works for the vast majority of applications, however there are situations where applications can only run on a certain set of systems due to hardware or security reasons. Major virtualization solutions provide means to check whether applications can be virtualized.

For more information on virtualization, see the Energy Star Server Virtualization web page.

10. Implement rack/infrastructure power monitoring, if possible

Power monitoring identifies the energy use and efficiencies of the various components in an electrical distribution system. Power meters can be installed at the panels serving the cooling units, or directly on IT and HVAC equipment. Another alternative is to read IT power from UPS display, and to estimate cooling power from the nameplate, taking into account unit efficiency and operating hours. Often power distribution products will have built-in monitoring capability; look for products with this feature when replacing equipment. When inefficiencies are detected, then steps can be taken to improve the system.

The main benefit of power measurement is to benchmark the server room such that the energy efficiency of the room can be compared with other server rooms through Power Usage Effectiveness (PUE) calculations, and the savings from future energy-efficiency measures can be evaluated. PUE and other metrics of the room can also be tracked over time to help identify operational problems and opportunities.

11. Install variable frequency drives on cooling units

If your server room is cooled with a Computer-Room Air Handler (CRAH) or Computer-Room Air Conditioner (CRAC) unit, then it is highly likely that the unit has a single-speed fan, and that it provides more airflow than your IT equipment needs. Units with variable frequency drives (VFDs) have the capability of providing only the amount of air that is required by the IT equipment.

Many CRAH unit manufacturers and others now offer retrofit kits for variable-speed fan drives that allow you to lower the airflow. If you are purchasing new cooling equipment, consider specifying units with variable-speed capabilities.

The implementation of airflow management measures and airflow isolation systems should be done in conjunction with the installation of a variable-speed drive on the cooling unit fan to maximize potential energy savings. See item 4 for air management suggestions.

12. Install rack/row level cooling

If you are installing a new server room or buying new racks, consider local cooling. Some infrastructure modification will be required, including chilled or cooling water piping.

In-rack cooling refers to a cooling system that is located within an individual server rack and only provides cooling to the contained rack, with the possibility of extending the cooling system to one or more adjacent racks. Often cooling water (sometimes refrigerant) is provided to cooling coils placed directly in the rack, and air is circulated by integral fans within that individual server rack (and possibly to one or more adjacent racks).

In-row cooling refers to a cooling system that is located to serve an individual row of server racks. Often chilled water (or sometimes refrigerant) is provided to cooling coils placed directly in or on the row of servers, and air is circulated by integral fans.

Rear Door Heat Exchangers (RDHXs) are a highly efficient option for cooling server racks. RDHXs involve installing a cooling coil directly on the rear (exhaust) section of the server racks. Cooling water (or refrigerant) is run through the coils to absorb the exhaust heat and provide the needed cooling. Air circulation through the cooling coil is provided by the internal server fans themselves; there are no external fans.

13. Use cooling systems with economizers, if practical

An air-side economizer simply draws in outside air for cooling when conditions are suitable - if it is less than 75 ^{0}F outside, why run the air conditioner?

If your server room is located on the building perimeter or in a single-story building, consider using a cooling system with an economizer feature to dramatically reduce energy use. This can be in the form of an exhaust fan at one location and an opening in another location that allows cool outside air to enter. Alternatively, it can be in form of a fan coil or CRAC/H with air side economizer capability. **Depending on the climate zone in which the server closet is located, this can save a significant amount of energy by reducing compressor cooling energy use.**

If you are able to improve airflow management sufficiently to have a 78 ^{0}F supply air set point, an economizer-equipped cooling system will use outside air for the majority of the year, depending on the climate conditions at your location. Many operators of utility-scale data centers are now building facilities that run only on outside air, sometimes supplemented with evaporative cooling.

Many existing server rooms are located in the interior core of buildings (especially in high-rise offices), so it can be difficult or impossible to use outside air for cooling, due to structural limitations. If you are designing or adding a new server room or closet, be sure to include a cooling system design that features economizers, to maximize energy efficiency.

14. Install a dedicated cooling for the room, rather than depending on building cooling

If your server room or localized data center relies on the building cooling system, it may make sense to install cooling equipment solely for the use of the room, so that the building system does not have to operate around the clock.

Many buildings rely on a central cooling plant that provides chilled water to a cooling loop. For many facilities, like office buildings, the cooling plant can be turned off overnight-, and on weekend- and holiday periods because there is no need to provide cooling at those times. However, if server room or localized data center cooling equipment draws from the same cooling loop, the central plant will have to operate continuously. Chillers, condensers, and circulation pumps will always be on, often at partial loading (which is where they operate at the lowest efficiency).

Installing dedicated cooling equipment (like a packaged air conditioning unit) for your server room(s) avoids this situation, and can result in significant energy savings. Specify a high-efficiency unit with a high SEER rating and 100% outside air capability. In addition, by setting a higher room temperature set point and disabling humidity control features, the dedicated unit can operate more efficiently.

Alternatively, server rooms running off a central Air Handling Unit (AHU) can be reasonably efficient if the air to all of the unoccupied spaces served by the AHU are turned off and the AHU has a variable-speed fan (these capabilities are common for modern variable-air-volume systems). If the server room is the only load on the AHU, the supply air temperature can be reset much higher than normal, greatly increasing the number of hours of compressor-free cooling over the year.

Glossary

- AHU: Air Handling Unit
- CRAC: Computer Room Air Conditioner
- CRAH: Computer Room Air Handler
- HVAC: Heating, Ventilation and Air Conditioning
- PDU: Power Distribution Unit
- PSU: Power Supply Unit
- PUE: Power Usage Effectiveness, a ratio comparing the total energy use for a data center (or server room) to the energy used solely by the information technology equipment.
- SEER: Seasonal Energy Efficiency Ratio
- SSD: Solid-State Drives
- UPS: Uninterruptible Power Supply
- VFD: Variable Frequency Drive
- VSD: Variable Speed Drive