ENERGY EFFICIENCY IN SMALL SERVER ROOMS


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PREFACE

The California Energy Commission Energy Research and Development Division 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.

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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)

Please use the following citation for this report:

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EXECUTIVE SUMMARY

Introduction and Background
This document is 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>
<thead>
<tr>
<th>Description</th>
<th>Stanford Univ., 333 Bonair Siding</th>
<th>Stanford Univ., Alumni Center</th>
<th>Lawrence Berkeley National Lab (LBNL) Rm 90-2094</th>
<th>City of Walnut Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, square feet</td>
<td>760</td>
<td>100</td>
<td>200</td>
<td>575</td>
</tr>
<tr>
<td>Raised floor</td>
<td>12&quot;</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>No of racks</td>
<td>12</td>
<td>3</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>Uninterruptible Power Supplies (UPS)</td>
<td>In rack (mostly A and B feeds)</td>
<td>In rack</td>
<td>Only a few equipment connected to individual UPSs</td>
<td>Main UPS for all equipment</td>
</tr>
<tr>
<td>UPS efficiency</td>
<td>0.85 (assumed)</td>
<td>0.85 (assumed)</td>
<td>0.9 (estimated)</td>
<td>0.92 (measured)</td>
</tr>
<tr>
<td>Cooling</td>
<td>3 Split system units</td>
<td>Fan coil w/ house chilled water system</td>
<td>3 window mounted units</td>
<td>2 roof mounted package units</td>
</tr>
<tr>
<td>Supply Air Temperature, degF</td>
<td>42</td>
<td>65</td>
<td>N/A</td>
<td>72</td>
</tr>
<tr>
<td>Lighting1</td>
<td>26 – 32 Watt, T8</td>
<td>4 – 32 Watt, T8</td>
<td>8 - 60 Watt, T8</td>
<td>17 - 54 Watt, T5</td>
</tr>
<tr>
<td>Lighting density, Watt/square foot</td>
<td>1.1</td>
<td>1.3</td>
<td>0.51</td>
<td>0.21</td>
</tr>
</tbody>
</table>

1 Assumed lighting was on 10% of the year.

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

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

<table>
<thead>
<tr>
<th>EEM</th>
<th>Stanford Univ., 333 Bonair Siding</th>
<th>Stanford Univ., Alumni Center</th>
<th>Lawrence Berkeley National Lab (LBNL) Rm 90-2094</th>
<th>City of Walnut Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEM-1</td>
<td><strong>Turn off unused computers, virtualization, and consolidation</strong></td>
<td>With 10% IT energy use reduction - $1,300</td>
<td>With 10% IT energy use reduction - $1,400</td>
<td>With 10% IT energy use reduction - $1,600</td>
</tr>
<tr>
<td>EEM-2</td>
<td><strong>Increase temperature set point.</strong></td>
<td>If one unit is off - $500</td>
<td>Not measurable.</td>
<td>Not measurable (difficult to estimate in conjunction with EEM-5)</td>
</tr>
<tr>
<td>EEM-3a</td>
<td><strong>Assumed 50% removal of UPS</strong></td>
<td>$900</td>
<td>$1,000</td>
<td>Not considered (difficult to estimate in conjunction with EEM-5)</td>
</tr>
<tr>
<td>EEM-3b</td>
<td><strong>Switched from double conversion to bypass mode</strong></td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not considered (difficult to estimate in conjunction with EEM-5)</td>
</tr>
<tr>
<td>EEM-4</td>
<td><strong>Install lighting control</strong></td>
<td>$200</td>
<td>$35</td>
<td>Not applicable (low savings)</td>
</tr>
<tr>
<td>EEM-5</td>
<td><strong>Install air-side economizer</strong></td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>$6002 (plus $8,700 PG&amp;E 1st year rebate)</td>
</tr>
</tbody>
</table>

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 These measures can result in significant energy savings and reduced operating costs.
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

1.1 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.
1.2 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 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

2.1 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 B.

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

2.2 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.
As shown in the “Small Server Room Survey - Detailed Summary” table in Appendix B, 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.

2.3 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.
2.3.1 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.

2.3.2 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.

2.3.3 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.

2.3.4 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.

2.3.5 Cooling-Specific Observations
The research team made three observations related to cooling:

2.3.4.1 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.

2.3.4.2 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.

2.3.4.3 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.

2.3.6 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 has 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

3.1 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 room 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.

3.2 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?

### 3.3 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 Assessment Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Stanford Univ., 333 Bonair Siding</th>
<th>Stanford Univ., Alumni Center</th>
<th>Lawrence Berkeley National Lab (LBNL) Rm 90-2094</th>
<th>City of Walnut Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, square feet</td>
<td>760</td>
<td>100</td>
<td>200</td>
<td>575</td>
</tr>
<tr>
<td>Raised floor</td>
<td>12”</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>No of racks</td>
<td>12</td>
<td>3</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td><strong>Uninterruptible Power Supplies (UPS)</strong></td>
<td>In rack (mostly A and B feeds)</td>
<td>In rack</td>
<td>Only a few equipment connected to individual UPSs</td>
<td>Main UPS for all equipment</td>
</tr>
<tr>
<td>UPS efficiency</td>
<td>0.85 (assumed)</td>
<td>0.85 (assumed)</td>
<td>0.9 (estimated)</td>
<td>0.92 (measured)</td>
</tr>
<tr>
<td>Cooling</td>
<td>3 Split system units</td>
<td>Fan coil w/ house chilled water system</td>
<td>3 window mounted units</td>
<td>2 roof mounted package units</td>
</tr>
<tr>
<td><strong>Supply Air Temperature, degF</strong></td>
<td>42</td>
<td>65</td>
<td>N/A</td>
<td>72</td>
</tr>
<tr>
<td>Lighting1</td>
<td>26 − 32 Watt, T8</td>
<td>4 − 32 Watt, T8</td>
<td>8 - 60 Watt, T8</td>
<td>17 - 54 Watt, T5</td>
</tr>
<tr>
<td><strong>Lighting density, Watt/square foot</strong></td>
<td>1.1</td>
<td>1.3</td>
<td>0.51</td>
<td>0.21</td>
</tr>
</tbody>
</table>

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.
3.4 Site Descriptions

3.4.1 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
3.4.2 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
3.4.3 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 were needed. 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

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

Source: LBNL
At left, note access ramp to raised floor.

Source: LBNL

3.4.4 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.
3.5 Power Measurements

3.5.1 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>
<thead>
<tr>
<th>Server Room</th>
<th>Stanford, University 333 Bonair Siding</th>
<th>Stanford, University Alumni Center</th>
<th>LBNL 90-2094</th>
<th>City of Walnut Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Load (kW)</td>
<td>10.2 (^1)</td>
<td>9.9 (^1)</td>
<td>6.9 (^1)</td>
<td>15.1 (^1)</td>
</tr>
</tbody>
</table>

\(^1\) Directly measured

3.5.2 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

<table>
<thead>
<tr>
<th>Server Room</th>
<th>Stanford, University 333 Bonair Siding</th>
<th>Stanford, University Alumni Center</th>
<th>LBNL 90-2094</th>
<th>City of Walnut Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling, kW</td>
<td>8.5 1</td>
<td>5.5 2</td>
<td>3.3 1</td>
<td>14.9 1</td>
</tr>
<tr>
<td>Lighting, kW</td>
<td>0.8 2</td>
<td>0.1 2</td>
<td>0.1 2</td>
<td>0.1 2</td>
</tr>
<tr>
<td>UPS loss, kW</td>
<td>1.8 2</td>
<td>1.7 2</td>
<td>0.1 2</td>
<td>1.3 1</td>
</tr>
<tr>
<td>Total load, kW</td>
<td>21.3</td>
<td>17.2</td>
<td>10.4</td>
<td>31.3</td>
</tr>
<tr>
<td>PUE</td>
<td>2.1</td>
<td>1.8</td>
<td>1.5</td>
<td>2.1</td>
</tr>
</tbody>
</table>

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.

4.1 Efficiency Measures - Overview

4.1.1 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.

4.1.2 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.

4.1.3 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.
4.1.4 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 70-72°F; raising the temperature setpoint could easily generate energy savings.

4.2 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

<table>
<thead>
<tr>
<th>Energy Efficiency Measures</th>
<th>Stanford, University 333 Bonair Siding</th>
<th>Stanford, University Alumni Center</th>
<th>LBNL 90-2094</th>
<th>City of Walnut Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEM-1</td>
<td>With 10% IT energy use reduction - $1,300</td>
<td>With 10% IT energy use reduction - $1,400</td>
<td>With 10% IT energy use reduction - $500</td>
<td>With 10% IT energy use reduction - $1,600</td>
</tr>
<tr>
<td><strong>Turn off unused computers, virtualization, and consolidation</strong></td>
<td><strong>If one unit is off - $500</strong></td>
<td>Not measurable.</td>
<td>Not considered (difficult to estimate in conjunction with EEM-5)</td>
<td>Not considered (difficult to estimate in conjunction with EEM-5)</td>
</tr>
<tr>
<td>EEM-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase temperature set point.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEM-3a: Assumed 50% removal of UPS</td>
<td>$900</td>
<td>$1000</td>
<td>Not considered (low savings)</td>
<td>Not applicable (see EEM-3b)</td>
</tr>
<tr>
<td>EEM-3b: Switched from double conversion to bypass mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>$8001</td>
</tr>
<tr>
<td>EEM-4: Install lighting control</td>
<td>$200</td>
<td>$35</td>
<td>Not applicable (low savings)</td>
<td>Not applicable (low savings)</td>
</tr>
<tr>
<td>EEM-5: Install air-side economizer</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>$6002</td>
<td>$11,600 (plus $8,700 PG&amp;E 1st year rebate)</td>
</tr>
</tbody>
</table>

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 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.

5.1 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

5.2 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 of 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.

5.3 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

6.1 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.

6.2 Next Steps

6.2.1 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.

6.2.2 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.

6.2.3 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.

6.2.4 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.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Economizer</td>
<td>A HVAC unit that provides cooling to a building using outside air</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigeration and Air Conditioning Engineers</td>
</tr>
<tr>
<td>Computer Room Air Conditioner/Handler (CRAC/H)</td>
<td>A HVAC unit that monitors and maintains the temperature, air distribution, and humidity in a room with IT equipment. The Computer Room Air Conditioner consists of a compressor that removes heat from the room, while the Computer Room Air Handler includes only fans and a coiling coil, and often uses chilled water to remove heat from the room</td>
</tr>
<tr>
<td>EEM</td>
<td>Energy efficiency measure</td>
</tr>
<tr>
<td>Energy Commission</td>
<td>California Energy Commission</td>
</tr>
<tr>
<td>CEE</td>
<td>Consortium for Energy Efficiency</td>
</tr>
<tr>
<td>Fan Coil</td>
<td>A HVAC device consisting of a heating or cooling coil and fan</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, ventilation, and air conditioning</td>
</tr>
<tr>
<td>IDC</td>
<td>International Data Corporation</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>LBNL</td>
<td>Lawrence Berkeley National Laboratory</td>
</tr>
<tr>
<td>NRDC</td>
<td>Natural Resources Defense Council</td>
</tr>
<tr>
<td>PG&amp;E</td>
<td>Pacific Gas and Electric</td>
</tr>
<tr>
<td>PIER</td>
<td>Public Interest Energy Research</td>
</tr>
<tr>
<td>Power Distribution Unit (PDU)</td>
<td>A device fitted with multiple outputs designed to distribute power to racks of computers and networking equipment located within server rooms or data centers</td>
</tr>
<tr>
<td>Power Usage Effectiveness (PUE)</td>
<td>A ratio comparing the total energy use for a data center (or server room) to the energy used solely by the information technology equipment</td>
</tr>
<tr>
<td>RD&amp;D</td>
<td>Research development and demonstration</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Server Consolidation</td>
<td>A practice to reduce the total number of servers or server locations that an organization requires, by combining applications and computing functions from multiple servers to a smaller number of physical servers</td>
</tr>
<tr>
<td>Server Virtualization</td>
<td>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”)</td>
</tr>
<tr>
<td>SVLG</td>
<td>Silicon Valley Leadership Group</td>
</tr>
<tr>
<td>Uninterruptible Power Supply (UPS)</td>
<td>An electrical apparatus that provides emergency power to a load when the input power source fails</td>
</tr>
</tbody>
</table>
REFERENCES


## Server Room Assessment Protocol

### Server Rm Walk-through Assessment Form

<table>
<thead>
<tr>
<th>Date</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
<td></td>
</tr>
</tbody>
</table>

### Space description

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

### Space Authority / Configuration

<table>
<thead>
<tr>
<th>Person responsible for space</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Server owner(s)</td>
<td></td>
</tr>
<tr>
<td>Person authorized to implement EE measures</td>
<td></td>
</tr>
<tr>
<td>Reasons for this space configuration? — Schedule or protocol for when new servers are added &amp; retired?</td>
<td></td>
</tr>
<tr>
<td>Specific rules to follow when starting a server room?</td>
<td></td>
</tr>
</tbody>
</table>
# A. Computing

## Rack/IT asset inventory

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who manages the IT equipment?</td>
<td></td>
</tr>
<tr>
<td>What is the IT equipment used for?</td>
<td></td>
</tr>
<tr>
<td>How many racks of IT equipment? — Estimate %</td>
<td></td>
</tr>
<tr>
<td>servers/storage/networking equipment</td>
<td></td>
</tr>
<tr>
<td>Rack space utilization (% of U occupied)</td>
<td></td>
</tr>
<tr>
<td>Existing power metering equipment?</td>
<td></td>
</tr>
<tr>
<td>Ok to install meters?</td>
<td></td>
</tr>
<tr>
<td>Possible future upgrade plan</td>
<td></td>
</tr>
<tr>
<td>Possible consolidation plans</td>
<td></td>
</tr>
<tr>
<td>Possible efficiency recommendations</td>
<td></td>
</tr>
</tbody>
</table>

## Equipment utilization

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redundant power? — If yes, is the back up unit inside the room or outside?</td>
<td></td>
</tr>
<tr>
<td>Voltage of equipment?</td>
<td></td>
</tr>
<tr>
<td>Any transformer?</td>
<td></td>
</tr>
<tr>
<td>Possible efficiency recommendations</td>
<td></td>
</tr>
</tbody>
</table>
B. Cooling

- **House Air**

<table>
<thead>
<tr>
<th>Estimate air flow (VAV terminal, diffusers, air flow measurement)</th>
<th>Is there dedicated temperature control in the room?</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Where is temperature sensor located?</td>
<td>Temperature setpoint and schedule</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Is there humidity control?</td>
<td>Possible efficiency recommendations</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- **Dedicated Cooling**

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

- **Free Cooling**

<table>
<thead>
<tr>
<th>Type of system (windows or ducted ventilation)</th>
<th>Operating schedule (season ambient temperature)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Possible efficiency recommendations</td>
<td>-</td>
</tr>
</tbody>
</table>
APPENDIX B:
Selected Content - Deliverable 2 - Summary of Configuration Features

| Number | Date of Survey | Institution | Building | Type (1) | Area (square feet) | Server Pools | Rack Config | Rack Space Utilization | Raised Floor | HVAC/ASU Separation? | Cooling (House air, Dedicated cooling, and/or Free cooling) | Cooling Capacity |
|--------|----------------|-------------|----------|----------|-------------------|--------------|-------------|-----------------------|--------------|----------------------|---------------------------------|----------------|----------------|
| 1      | Nov 2011       | StarNet    | 3333 Biermi Building | Localized Data Center | 2,300 x 3,800 | 15 | 30 | Focused | Yes | No | Dedicated cooling | 2,200 kWh |
| 2      | Nov 2011       | StarNet    | 3333 Biermi Building | Localized Data Center | 2,300 x 3,800 | 15 | 30 | Focused | Yes | No | Dedicated cooling | 2,200 kWh |
| 3      | Nov 2011       | StarNet    | 3333 Biermi Building | Localized Data Center | 2,300 x 3,800 | 15 | 30 | Focused | Yes | No | Dedicated cooling | 2,200 kWh |
| 4      | Nov 2011       | StarNet    | 3333 Biermi Building | Localized Data Center | 2,300 x 3,800 | 15 | 30 | Focused | Yes | No | Dedicated cooling | 2,200 kWh |
| 5      | Nov 2011       | StarNet    | 3333 Biermi Building | Localized Data Center | 2,300 x 3,800 | 15 | 30 | Focused | Yes | No | Dedicated cooling | 2,200 kWh |
| 6      | Nov 2011       | StarNet    | 3333 Biermi Building | Localized Data Center | 2,300 x 3,800 | 15 | 30 | Focused | Yes | No | Dedicated cooling | 2,200 kWh |
| 7      | Nov 2011       | StarNet    | 3333 Biermi Building | Localized Data Center | 2,300 x 3,800 | 15 | 30 | Focused | Yes | No | Dedicated cooling | 2,200 kWh |
| 8      | Nov 2011       | StarNet    | 3333 Biermi Building | Localized Data Center | 2,300 x 3,800 | 15 | 30 | Focused | Yes | No | Dedicated cooling | 2,200 kWh |
| 9      | Nov 2011       | StarNet    | 3333 Biermi Building | Localized Data Center | 2,300 x 3,800 | 15 | 30 | Focused | Yes | No | Dedicated cooling | 2,200 kWh |

(1) Assignment of room type solely according to square footage based on ULC definitions of server spaces, in which server closet = 1000 SF, server room = 5000 SF, localized data center = 5000 SF, and enterprise-class data center = 5000 SF.

APPENDIX C:
Server Room Detailed Assessment Data Collection List

Appendix C - Server Room Detailed Assessment - Data Collection List

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

- Power distribution efficiency
  - Power loss in UPS equipment
  - UPS load capacity/design efficiency/actual loading
  - Power loss in transformers (if any)
  - UPS redundancy

- HVAC assessment
  - Cooling system configuration
    - House air and/or dedicated cooling
    - HVAC system design/equipment type
    - Rated cooling capacity
    - Operating capacity and efficiency
    - Operating temperatures
    - Controls and operating schedule
    - Potential for free cooling
- Potential for use of waste heat
  - IT equipment layout
    - Hot/cold aisle
    - Air management issues
    - Hot spots

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

- Energy Saving Estimation
  - Estimate IT and Cooling savings, based on recommended efficiency measures (compared to baseline)
APPENDIX D:
“Improving Energy Efficiency for Server Rooms and Closets”

D-1
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 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 url 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.
the recommended range.
APPENDIX E:
“Fact Sheet: Improving Energy Efficiency for Server Rooms and Closets”

Fact Sheet: Improving Energy Efficiency for Server Rooms and Closets

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ACKNOWLEDGEMENT

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Fact Sheet: Improving Energy Efficiency for Server Rooms and Closets

September 2012

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.

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 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 Complex, 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, 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) More Complex, 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 into a shut-down mode. Lastly, consider built-in or add-in cards that enable to power servers 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 (6-15% on average), while drawing 80-90% 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 airflow 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, intrack 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 economizers: air-side economizer

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

September 2012

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6. Move to a more energy-efficient data center space
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9. Consolidate and virtualize applications
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14. Install a dedicated cooling for the room, rather than depending on building cooling

Glossary

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 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 64°F to 80°F 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°F. 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 cold 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.
<table>
<thead>
<tr>
<th>Classes</th>
<th>Dry-Bulb Temp (°F)</th>
<th>Humidity Range, non-Condensing</th>
<th>Maximum Dew Point (°F)</th>
<th>Maximum Elevation (ft)</th>
<th>Maximum Rate of Change (°F/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Recommended</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1 to A4</td>
<td>84.4 to 93.6</td>
<td>41.5 °F DP to 85% RH and 59 °F DP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Allowable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>59 to 89.6</td>
<td>20 to 80% RH</td>
<td>62.6</td>
<td>10,000</td>
<td>9/36</td>
</tr>
<tr>
<td>A2</td>
<td>50 to 85</td>
<td>20 to 80% RH</td>
<td>69.8</td>
<td>10,000</td>
<td>9/36</td>
</tr>
<tr>
<td>A3</td>
<td>41 to 104</td>
<td>10.4 °F DP &amp; 5% RH to 85% RH</td>
<td>75.2</td>
<td>10,000</td>
<td>9/36</td>
</tr>
<tr>
<td>A4</td>
<td>41 to 113</td>
<td>10.4 °F DP &amp; 5% RH to 90% RH</td>
<td>75.2</td>
<td>10,000</td>
<td>9/36</td>
</tr>
<tr>
<td>B</td>
<td>41 to 95</td>
<td>5% RH to 90% RH</td>
<td>75.2</td>
<td>10,000</td>
<td>NA</td>
</tr>
<tr>
<td>C</td>
<td>41 to 104</td>
<td>5% RH to 90% RH</td>
<td>75.2</td>
<td>10,000</td>
<td>NA</td>
</tr>
</tbody>
</table>

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.ansi.org/green-data-center/PDF/ASHRAE.pdf](http://www.ansi.org/green-data-center/PDF/ASHRAE.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°F. 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/ep/tdfsleedgcenterbestpractices.pdf](http://www1.eere.energy.gov/ep/tdfsleedgcenterbestpractices.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 (PDU's), 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 desked system would be overkill. Review uptime requirements, fault failover, and disaster recovery plans to determine appropriate UPS or redundancy requirements.

4. Airlow 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 is 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 airflows "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 cable clutter and tight rack placement in an under-provisioned rack. Sketching out where air is coming from and going to and cleaning 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 or 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 intake 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 differentials 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 Gold 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.

<table>
<thead>
<tr>
<th>80 PLUS Certification</th>
<th>115V Internal Non-Redundant</th>
<th>230V Internal Redundant</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Rated Load</td>
<td>20%</td>
<td>50%</td>
</tr>
<tr>
<td>80 PLUS</td>
<td>80%</td>
<td>80%</td>
</tr>
<tr>
<td>80 PLUS Bronze</td>
<td>82%</td>
<td>85%</td>
</tr>
<tr>
<td>80 PLUS Silver</td>
<td>85%</td>
<td>88%</td>
</tr>
<tr>
<td>80 PLUS Gold</td>
<td>67%</td>
<td>90%</td>
</tr>
<tr>
<td>80 PLUS Platinum</td>
<td>90%</td>
<td>92%</td>
</tr>
<tr>
<td>80 PLUS Titanium</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>


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:

- Climate Savers Computing Initiative procurement requirements and product catalog: [www.climatesaverscomputing.org/](http://www.climatesaverscomputing.org/)

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).

<table>
<thead>
<tr>
<th>Space</th>
<th>Typical Room PUT</th>
<th>Server Power Consumption (10 servers), kW</th>
<th>Total Power Consumption (IT and Infrastructure), kW</th>
<th>Estimated Annual Energy Cost, $/year</th>
<th>Estimated Annual Savings if Moved to Data Center, $/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server Room</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>9,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Converted Closet</td>
<td>3</td>
<td>5</td>
<td>12.5</td>
<td>11,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Central Data Center</td>
<td>1.5</td>
<td>5</td>
<td>7.5</td>
<td>7,000</td>
<td>-</td>
</tr>
</tbody>
</table>

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 reap the benefits of a more efficient 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°F 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 cooler 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://national-lbnl.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://ite99.ashraeics.org/
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., the 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 60-80% 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 °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 °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.
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<tr>
<td>AHU</td>
<td>Air Handling Unit</td>
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<tr>
<td>CRAC</td>
<td>Computer Room Air Conditioner</td>
</tr>
<tr>
<td>CRAH</td>
<td>Computer Room Air Handler</td>
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<tr>
<td>HVAC</td>
<td>Heating, Ventilation and Air Conditioning</td>
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<tr>
<td>PDU</td>
<td>Power Distribution Unit</td>
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<td>PSU</td>
<td>Power Supply Unit</td>
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<tr>
<td>PUE</td>
<td>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</td>
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<tr>
<td>SEER</td>
<td>Seasonal Energy Efficiency Ratio</td>
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<td>SSD</td>
<td>Solid-State Drives</td>
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<td>UPS</td>
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<td>VFD</td>
<td>Variable Frequency Drive</td>
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<td>VSD</td>
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