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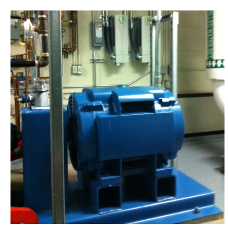
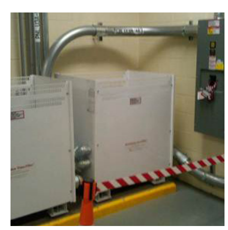
CASE STUDY

Chiller System Optimization:

Project Impacts on Data Center Sustainability

May 2013






Highlights

- eBay decided to change its chiller configuration and install a new smart controller to support a reduction in power consumption at its Phoenix 1 data center.
- The company closely tracked its power usage effectiveness (PUE™) and realized annual power savings of US$176,215 upon completion of the project.
- Phoenix 1 went from consuming 0.623 kilowatts (kW) per ton to 0.468 kW/ton, achieving an annual reduction of 2,517,361 kilowatt hours (kWh).
- eBay also noted a significant impact to water usage effectiveness (WUE™) as a result of the new configuration. Despite the increase of up to 33 percent in annual water consumption, the data center's enhanced PUE and associated energy cost savings more than made up for the additional water costs.
- The company determined that tracking and maintaining at least a full year's worth of baseline data would show the maximum before-and-after differences in energy consumption and help it garner the highest possible rebate from local utilities.
- eBay came to the conclusion that considering all potential impacts—not PUE alone—and carefully weighing them prior to taking any action would result in more accurate projections for return on investment in the future.

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Executive Summary

As part of an overall optimization effort across its owned data centers, eBay Inc. saw that one of its earliest flagship data centers, known as Phoenix 1, offered ample opportunity for improved energy efficiency. The challenge was to maintain the Tier IV facility's high level of reliability while reducing its environmental impact and operating costs.

The company began with projects such as installing ultrasonic humidifiers, electronically commutated fans, and variable-speed drives at each computer room air handler in Phoenix 1. Following their successful completion, eBay identified the data center's chiller system as the next step to enhance energy efficiency. The primary aim of this optimization project was to unify all chiller equipment so that it operated as a holistic system. eBay examined several options, landing upon the installation of a new smart controller as the most logical and effective means to support a reduction in power consumption. The company came to its decision after measuring the data center's existing power usage effectiveness (PUE™), estimating potential improvements in PUE following the installation, and conducting cost-benefit analyses. eBay also noted that the project would help it qualify for a financial rebate—based on a reduction in kilowatt hours—from the local public utility.

eBay began the chiller optimization project in September 2011, adding variable-frequency drives to condenser water pumps and primary chiller-water pumps through December 2011 and bringing the new controller online in January 2012. The company also changed its chiller configuration, which originally consisted of four active chillers and two offline back-up chillers; the new plan called for all six chillers to remain active. The company had to work around various obstacles such as existing minimum flow requirements for its onsite thermal storage tank, a lack of common piping headers for its chillers, and integration of components from disparate manufacturers, all of which added layers of complexity to the project.

Following the installation, eBay closely tracked its PUE and water usage effectiveness (WUE™) and compared those measurements with pre-installation measurements. Results include the following efficiency gains:[1]

- Chiller system efficiency increases of 0.155 kilowatts/ton
- Power demand reduction of 287 kilowatts
- Annual kilowatt hour reduction of 2,517,361
- Annual power savings of US$176,215

1. eBay immediately realized the chiller efficiency gains and power demand reductions in Jan 2012 when the company initially commissioned the system. The annual savings are the projections based upon comparisons between baseline and optimized operations; they will be realized annually as a result of the implementation of the chiller optimization.

However, eBay also noted a significant jump in water usage, resulting in a potential 33-percent increase in annual water consumption, which offsets PUE savings. That change in WUE affected the project's time to ROI, which went from less than three years to five years. eBay came to the conclusion that taking into account all potential impacts—not PUE alone—and carefully weighing them would result in more accurate ROI projections in the future.

The Importance of Data Centers

Most people know eBay as a global marketplace, where anybody can buy or sell just about anything. The company, founded in 1995 with the sale of a broken laser pointer, now has a worldwide market and, as of Q1 2013, more than 116 million users on the eBay Marketplaces business alone. Having expanded through acquisition, eBay Inc. owns PayPal, GSI Commerce, and a host of other ventures. With its enormous global presence, eBay must have adequate infrastructure to support millions of transactions every day. The company estimates that, at any given moment, there are more than 400 million listings live on eBay Marketplaces globally, which is why eBay maintains a portfolio of highly efficient data centers serving the globe.

The Importance of Data Center Efficiency

eBay considers its global data centers essential to its business success; they supply space, power, and stability for all its internal business units throughout the Unites States, Asia Pacific, and Europe. "Data centers house eBay's entire infrastructure—they're the engine that makes the company run," says Richard Reyher, eBay Senior Manager in Data Center Services. "Understanding that criticality, we hold our data centers to an uptime of five nines across all tiers."

Although keeping those data centers up and running 24/7 is one of eBay's highest priorities, the company strives to operate them not just reliably, but efficiently, too. "Our challenge is to shrink our data centers' footprint as we grow the capacity that runs our businesses, all while ensuring the highest level of reliability," says Dean Nelson, Vice President, Global Foundation Services, at eBay. "My team is constantly pushing the envelope in data center management, allowing us to process more online activity with less energy. It's the right thing to do, both economically and ecologically. In other words, it's good for both eBay's bottom line and the planet."

About eBay's Phoenix 1 Data Center

As eBay looked across its data center spectrum, its Phoenix 1 data center presented opportunities for efficiency improvements. Located in Arizona, the facility is one of the company's three Tier IV[2] facilities. It was built in 2004 and is one of the company's early flagship data centers, with 141,000 square feet and 6 megawatts of available power, redundancy, and resiliency by design. The company has a newer, state-of-the-art data center located at the same site, which takes advantage of key energy efficiency advancements in data center design. But back when it designed Phoenix 1, eBay—along with the rest of the data center industry—focused on reliability, fault tolerance, and resilience. The redundancies built into Phoenix 1 caused certain equipment to sit idle and unutilized, resulting in a higher-than-optimal power usage effectiveness (PUE™) for the data center. (See "The Green Grid's *x*UE Metrics" insert.)

"We built Phoenix 1 like Fort Knox—paying attention to every detail when it came to ensuring that systems were safe and service uninterrupted," says Reyher. "However, efficiency was not one of the main design goals back then. Our original PUE reflects that, since PUE is a direct correlation of IT load to mechanical load, and the emphasis on redundancy made our mechanical load quite extensive. All the chilled-water components and the electrical side combined to result in a higher PUE than would be acceptable now." Because its construction predated the availability of certain advanced equipment and design techniques used in eBay's newer data centers, Phoenix 1 represented a prime subject for optimization.

2. Tier levels are defined by The Uptime Institute, "Data Center Site Infrastructure Tier Standard: Topology," http://uptimeinstitute. com/component/docman/doc_download/5-tiers-standard-topology, The Uptime Institute, 2009.

Initial Efficiency Improvement Projects at Phoenix 1

eBay sought to decrease the total load consumed by Phoenix 1 as part of the company's overarching objective of reducing its global carbon footprint. "We launched an ongoing effort to understand how we could enhance data center efficiency on the mechanical side without affecting service," recalls Reyher. "We took note of what we were hearing and seeing from others within the industry, then started with the 'low-hanging fruit.'" eBay installed blanking panels on all the racks and wireless controls at the data center's rack level (to understand demand better and allow us to decrease motor speeds). The company made sure floor tiles in the cold aisles were the right types and that Phoenix 1 was not oversupplying air or mixing hot and cold air aisles. "These made sense to attack first to gain some efficiencies and start saving on the mechanical/electrical side," continues Reyher. "It's been a journey for us in this facility, understanding that we can provide the same level of service and reliability to our internal customers yet boost operational efficiency and drive reductions in our overall demand, consumption, and utility costs."

The company went on to address other mechanical systems, installing room-mounted ultrasonic humidifiers and variable-speed drives (VSDs) along with electronically commutated fans on the computer room air-handling (CRAH) units, which allowed them to consume less power. "The measures we've taken to save energy on the mechanical side all contribute to achieving our long-term goal of improving PUE," says Reyher. "The earlier projects offered relatively fast returns on investment (ROIs), some serving as prerequisites for subsequent projects."

Chiller Optimization Options

One of those subsequent projects was a reorganization of Phoenix 1's chiller components, improving the way that the data center generates and distributes chilled water in response to the requirements of the load it serves. Figure 1 illustrates the data center's cooling system energy consumption in relation to its other systems. Because chillers consumed the most power among the data center's mechanical components, reducing that load even by a fraction would likely have a dramatic impact on overall facility efficiency. eBay had to work within Phoenix 1's existing chiller design, taking care not to affect availability and performance, and find the most efficient operating parameters.

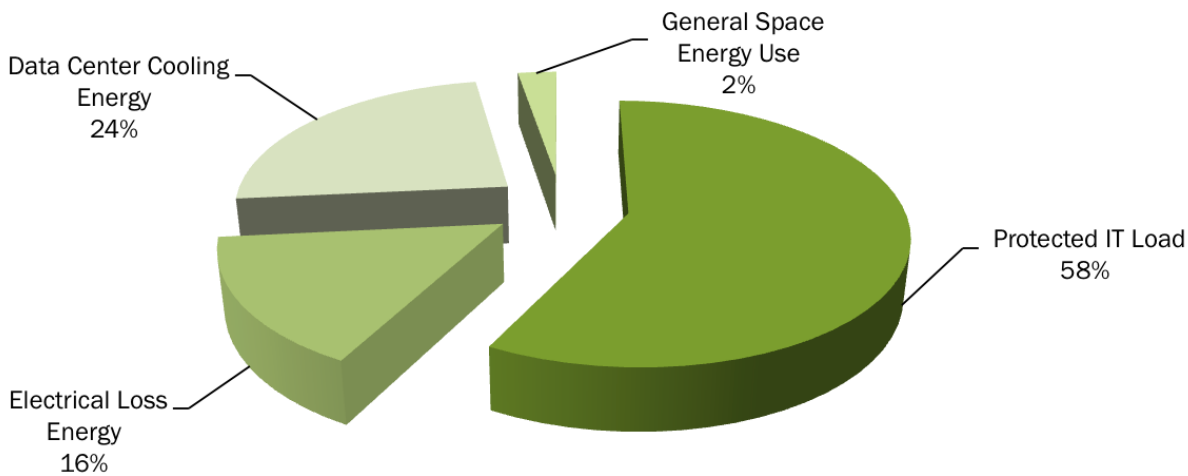

Figure 1. Breakdown of Phoenix 1 energy consumption in 2011

eBay started the project by shifting to view its data center's multiple independent chillers as components of an overall system, whose pumps, cooling towers, and other distribution elements needed to be integrated and operated in a holistic manner, rather than as individual siloed components. "The separate chiller components had efficiencies in and of themselves, but they operated in an inefficient manner when viewed as a system," says Scott Harris, McKinstry Energy Manager assisting eBay in its energy efficiency efforts. McKinstry has handled data center facility management for eBay since 2010.

eBay considered several chiller system improvement paths. For example, it looked into waterside economizer options for its chillers, but those required facility expansion for additional cooling towers and/or heat exchangers, and the Phoenix 1 site lacked the necessary space. “Plus, the ROI for a waterside economizer in Phoenix is not as attractive as in cooler climates,” says Harris.

eBay discussed various ideas with their vendor responsible for the building management system (BMS) at Phoenix 1. One option was custom development, but the vendor noted that, in this case, a custom-built solution would likely deliver only half the savings achievable with a ready-built solution, such as the new smart controller, which acts as an operating system that both unites and takes advantage of the pumps, chillers, and fans and their exclusive characteristics. “eBay decided to integrate the new controller with the existing BMS Controls system, because its proprietary control algorithm has a proven industry track record that could achieve higher returns,” says Harris.

Making a Case for Chiller System Optimization

First, however, eBay needed to ensure that such an implementation made sense from both financial and operational perspectives. It started by putting together cost-benefit and ROI analyses and presenting them to project stakeholders for consideration. eBay drew on key resources from The Green Grid Association, a non-profit, open industry consortium of end users, policy makers, technology providers, facility architects, and utility companies that works to improve the resource efficiency of information technology and data centers throughout the world. The Green Grid’s members have developed a set of metrics, including PUE, carbon usage effectiveness (CUE™), and water usage effectiveness (WUE™). Known as the *x*UE family of metrics, these enable data center operators to more accurately assess the respective energy, water, and carbon usage in their data centers, compare the results, and determine energy efficiency and/or sustainability improvements to make.

The Green Grid’s *x*UE Metrics

Power Usage Effectiveness (PUE): PUE is defined by the ratio of total facility power divided by IT equipment power, and is unitless. An ideal value is considered to be 1.0 which indicates all power consumed at the site goes directly to the IT equipment loads.

Carbon Usage Effectiveness (CUE): CUE is equivalent to the PUE multiplied by the Carbon Emissions Factor (CEF) of the local utility. An ideal value is considered to be 0.0, which indicates no carbon is consumed to support the IT equipment loads.

Water Usage Effectiveness (WUE): WUE is defined as the ratio of annual water usage divided by the IT equipment power, and is displayed in L/kWh. An ideal value is considered to be 0.0, which indicates no water is consumed to support the IT equipment loads.

The company used the PUE metric to help ascertain its then-current state, make rough projections about future savings, and, ultimately, measure success. “The eBay stakeholders appreciated having a measurable attribute that they could see in the cost-benefit analysis and the expected decrease in PUE,” says Harris.

How an organization collects, processes, and reports PUE data is important. In presenting the stakeholders with the data center’s 2011 baseline PUE of 1.732_{L1YC}, eBay followed the nomenclature guidelines laid out in The Green Grid’s White Paper #49, PUE: A Comprehensive Examination of the Metric.[3] This Phoenix 1 PUE value is L1YC, which means that eBay recorded the data at the uninterruptible power supply, or UPS, output level (“Level 1” or “L1”) averaged annually (“Y”) and measured on a continuous basis (“C,” sampled at least every 15 minutes).

That PUE was influenced by the data center’s existing N+2 chiller configuration, in which it ran four of its six chillers in order to maintain full load capacity; it kept two chillers offline in case one of the other four failed. eBay decided to switch to a scenario in which all six chillers simultaneously operated online but at a lower capacity, essentially a shift from an offline to an online redundancy configuration. “Instead of running chillers in a lead/lag scenario and maintaining that N+2 configuration, our analysis suggested that if we run all six chillers at the same time, we could maintain N+2 capabilities while taking advantage of a better efficiency curve,” says Reyher. (See “Pump Affinity Law for Power Consumption” insert.) While the new configuration allows for all six chillers to operate to meet load demands, eBay will stage offline chillers (and associated pumps/towers) as required to operate the system at its most efficient power curve. The new configuration typically results in five of the six chillers operating during the winter months. For every percentage point that a chiller’s or pump’s speed is lowered, it decreases power consumption by a factor of three.

3. www.thegreengrid.org/en/Global/Content/white-papers/WP49-PUEAComprehensiveExaminationoftheMetric

Pump Affinity Law for Power Consumption

The power ratio is equal to the speed ratio, cubed, displayed as follows:
$P1/P2 = (N1/N2)^3$, where P is the shaft power and N is the shaft rotational speed.

If, for example, an organization reduced its pump speed to 80 percent, the resulting power reduction would be equal to $(.80)^3$, or 0.51, thus 51 percent of the original power required.

Assuming a theoretical full load of 100 kilowatts (kW) per chiller, four chillers operating at 80 percent would result in a total of 204 kW, or 51 kW per chiller. With six chillers operating at 50 percent, the resultant total power consumption would be 75 kW, or 12.5 kW per chiller.

As this example illustrates, the operation of more units at lighter loads can produce significant power savings.

The potential impact of reduced power consumption at Phoenix 1 was boosted by a rebate program offered by the local electric utility, Arizona Public Service (APS), to encourage such optimization efforts. The utility based its rebate calculations on the delta between kilowatts consumed before and after the implementation, offering money back per kilowatt saved.

Next, eBay tackled operational concerns. Project stakeholders contacted the data center's original design engineer to get his input on how the proposed chiller system optimization might affect operations. After reviewing the new design, the engineer confirmed that such changes would not put the data center's Tier IV service at risk because of the way the new controller was set up to work in conjunction with the data center's existing control sequence.

"Most changes to a data center's operating model are going to be met with some hesitation," says Harris. "We assured stakeholders that turning on the two offline chillers would not affect the data center's failover capabilities. It's actually more effective to have all chiller components online than to have two of them offline in the event we need more chilling capacity quickly. It took very little convincing that this would be a positive, not detrimental, change."

Project Limitations and Challenges

As with any change to an existing site, eBay needed to carefully evaluate the challenges and limitations presented by its current setup. eBay learned that the new controller delivered maximum efficiencies in certain scenarios. For example, when the chillers it controls share common piping headers on both the condenser and chilled-water sides, it can fine-tune cooling towers and chillers to reach maximum efficiency. Unfortunately, all six chillers at Phoenix 1 were independent of each other, with no common piping among them, except at the white-space floor level. eBay considered re-piping the data center, changing the design to put common headers on the roof, along with all the cooling towers, but the company concluded that the costs of such an undertaking would be greater than the potential benefits. The existing piping design did not prevent eBay from implementing the chiller system solution; it simply limited the maximum amount of savings possible with the new control algorithm.

The company encountered another obstacle with its existing pumping system; it had constant-velocity primary/condenser pump motors and variable-velocity secondary pump motors, which posed a problem because eBay could not ramp down the primary chilled water pump speeds due to their nature of maintaining a single, constant speed. Each of the data center's six chillers has a primary chilled-water pump and a condenser water pump. To maximize the controller's possible efficiency, eBay installed variable-frequency drives (VFDs) on all 12 pumps so that pump speed became a controllable factor. The pumping mechanisms did not change, but they could now be adjusted by the drives so that they no longer wasted energy by moving more water than necessary.

It should also be noted that although the flow switches originally installed on the Phoenix 1 pumps worked well within the data center's initial design, they were unreliable in a variable-flow system. eBay replaced them with differential pressure switches to ensure pump flow could be accurately monitored and controlled.

When retrofitting equipment, existing parameters must be accommodated. For the chiller optimization project, these included maintaining a minimum flow of 400 gallons per minute (gpm) of water through the data center's onsite thermal storage tank to ensure that enough pumping energy was available to keep the thermal storage tank at the proper temperature and recharge rate. The VFDs helped eBay save energy by pumping water at speeds that met changing demands while simultaneously enabling the pumps to be set to run at the necessary minimum speed to maintain the required gpm flow.

In addition, the various system components—chillers, VFDs, pumps, etc.—all came from different manufacturers, adding a potential layer of complexity to the project. But because the data center had a common BMS for all the components, their data could be easily pulled in by the BMS and analyzed by the new controller, despite their disparate manufacturers.

Implementation

eBay stakeholders granted approval and funding for the chiller optimization project to proceed in September 2011, and the company set out to identify and collect detailed baseline data. It needed data for comparison with post-project results, not only for its own ROI and other analysis purposes but also because specific data was required to qualify for the utility rebate from APS. eBay presented the project to APS at the outset to alert the utility that eBay planned to participate in its rebate program.

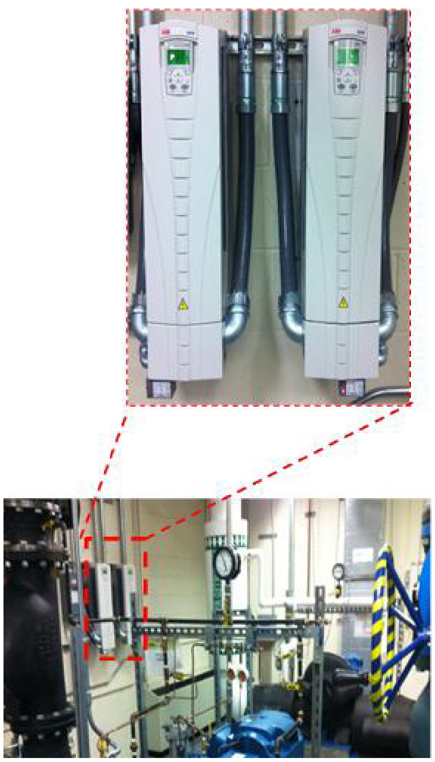

Figure 2. Images of the new pump VFDs installed at Phoenix 1 to allow the new controller to actively analyze and adjust pump speeds

When eBay discovered that the Phoenix 1 BMS lacked certain trend data necessary for the rebate submittal, the company spent several weeks integrating chiller loads, kilowatts-per-ton metrics, and other data into the BMS system to ensure that it could meet the utility's requirements. Ideally, this baseline data would consist of 12 months' worth of measurements to cover the full range of seasons, but the data available covered October through December 2011, which affected the potential rebate amount. eBay did not extrapolate a 12-month baseline because APS required actual measured values and did not allow for calculated estimates.

eBay also found that the BMS could not provide the controller with fan and pump speed data for the cooling towers and secondary chilled-water pumps. The company installed additional control wiring and integrated new data points into the BMS for the controller to analyze to more accurately fine-tune the chiller system's operations.

In October 2011, eBay turned its attention to installing VFDs on the condenser water pumps and primary chilled-water pumps (shown in Figure 2), working with a local electrical company. Throughout the VFD installation, the company took great pains to ensure that none of the project's phases would affect any of the necessary utility baseline data and thereby diminish the potential amount of the rebate. eBay completed the VFD installation in December 2011 but waited to take advantage of the chillers' new variable-frequency capabilities to ensure the baseline operational data could be maximized in addition to avoiding system changes during the high point of the shopping season. Instead, the company continued to run the chillers at 100-percent speeds as before.

The new controller deployment involved installing the hardware, adding communication cabling into the BMS local area network (LAN), and turning it on. (See Figure 3.) "Installing the new system controller was quick and seamless, in large part because our BMS vendor had configured equipment in its testing lab to mimic the Phoenix 1 BMS system," says Harris. "That lab carried out a lot of the analysis and integration pre-testing to address potential issues."

By mid-January 2012, eBay had completed the installation and integration of the data, drives, and the new controller. The company brought its new holistic chiller system online on January 19, 2012. eBay had worked with the controls vendor to finalize the installation and test all the pumps and VFDs to ensure the BMS was receiving the correct data from the right sources throughout the system. From that point on, the data center operated with all six chillers online.

Post-Installation Rebate

Next, eBay fulfilled the APS requirement of conducting post-installation monitoring, measurement, and verification to determine the data center's actual power savings versus its initial, pre-installation predictions. In September 2012, eBay collected the installed data set, analyzed it, and shared it with the utility, which then finalized eBay's rebate application and sent eBay a check in early January 2013.

Current-State Operations

With the new control system enabled, eBay has an integrated chiller system that it can control for efficient energy use. "eBay invested time and resources in Phoenix 1, taking individual pieces of chiller equipment, making them as efficient as possible, and applying the controller's algorithm to analyze set points and motor efficiency curves to tie them together to work harmoniously as a system," says Randy Ridgway, Critical Facility Director at McKinstry.

The controller receives operating data from the BMS on the various chiller system components. That data includes current condenser loop temperatures, primary chilled-water loop temperatures, speeds of the condenser and primary chilled-water pumps, and fan speeds from the cooling towers, in addition to the actual temperature set points at which the chillers are operating.

Figure 3. Smart controller (right) integrated with vendor BMS (left) at Phoenix 1

Although the new controller conducts performance analyses on all that data to determine where the pump motors, chillers, fans, and other system components are operating on their respective power curves, it does not have direct control over some of those components. It cannot change the cooling tower fan speeds, for instance, but it uses the fan speed data as a feedback signal when calculating the most efficient operating conditions for the rest of the system. The controller draws upon its proprietary algorithm to analyze numerous data parameters and pinpoint the settings that will achieve optimum operational efficiency for the system as a whole. Those include the number of chillers to operate and speed settings for the condenser water pumps and primary chilled-water pumps, along with the set point temperature for the chilled water. For example, maintaining water at 55.3°F versus 55°F could make it possible to slightly decrease chiller compressor lift and reduce overall power consumption.

In response to external climate and internal IT load influences, onboard chiller controls will cause the compressors to run at a higher speed to maintain the necessary chilled-water temperature. The controller may not tell specific chillers to ramp up their speeds, but it does determine how many of the system's chillers need to be on at any given time and at what speeds the primary chilled-water and condenser water pumps should run. The other controlling portions of the chiller system are handled at the chillers and cooling towers themselves.

The controller may tell the BMS to operate condenser pumps faster than they typically run, for example, but it does that to positively affect some other part of the chiller system and make the whole operate more efficiently. It changes operations to match Phoenix 1's specific scenario, continually monitoring and performing its analyses. It does not make fast changes but rather adjusts settings over a period of time to avoid rapid, unexpected actions that could affect overall system operation. For instance, the controller does not constantly ramp pump speeds up and down, trying to find the ideal speed point; instead it raises or lowers them a percentage at a time, then waits for five minutes and reassesses.

Although the chillers essentially manage their individual operations internally in response to load, eBay has made it possible for them to work in concert. A key aspect of the new approach is that chillers now share the load and use less power, according to the Pump Affinity Laws. Operating in a parallel fashion means that one chiller is no longer running at high capacity while another is not. Plus, when a piece of large rotating equipment such as a chiller sits idle, flat spots on bearings can result, so running all the chillers as opposed to keeping some offline will actually extend the longevity of those assets.

Preserving Tier IV Reliability

In all its efficiency enhancement efforts, eBay never loses sight of the fact that Phoenix 1 is a Tier IV data center with high levels of availability and reliability to maintain. For instance, in the event of a loss of communication from the controller, the BMS system will revert to its previous programming without issue and continue to operate the chiller system. This failsafe measure ensures that the data center's chillers and components will continue to operate in the event of a controller failure. It should be noted that the controller has been online at Phoenix 1 for more than 12 months, functioning without problems; the data center has never had to revert to its original N+2 configuration. If it did, however, there would be no detrimental impact on the system's ability to serve the data center's IT load, even though the old configuration is less efficient than having all six chillers online and running at lower capacity.

Project Results

After measuring PUE both before and after the chiller optimization project, eBay determined that it had indeed reduced the amount of power required to cool its data center. Phoenix 1 went from consuming 0.623 kW/ton to 0.468 kW/ton, an annual reduction of 2,517,361 kilowatt hours (kWh), as shown in Table 1. The data center's IT load was relatively stable throughout the baseline and final reporting periods.

Table 1. Baseline versus post-implementation efficiency data

Baseline Data	
Chiller System Efficiency	0.623 kW/ton
Chiller System Capacity	1,854 tons
Final Data	
Chiller System Efficiency	0.468 kW/ton
Efficiency Gains	
Chiller System Efficiency Increase	0.155 kW/ton
Power Demand Reduction	287 kW
Annual kWh Reduction	2,517,361 kWh
Annual Power Savings	$176,215

Figure 4 contains the 12-month trend for chiller plant efficiency (kW/ton) at Phoenix 1, based on daily readings. Note the dramatic step change that occurred when the controller was brought online on January 19, 2012. While the kW/ton increases in the summer months due to rising outside air temperatures, it trends back down in the fall/winter. Comparing the kW/ton in summer 2012 (post-installation) with the previous 2011 winter months (pre-installation), even the 2012 summer months with the new controller online were lower than the winter months of 2011.

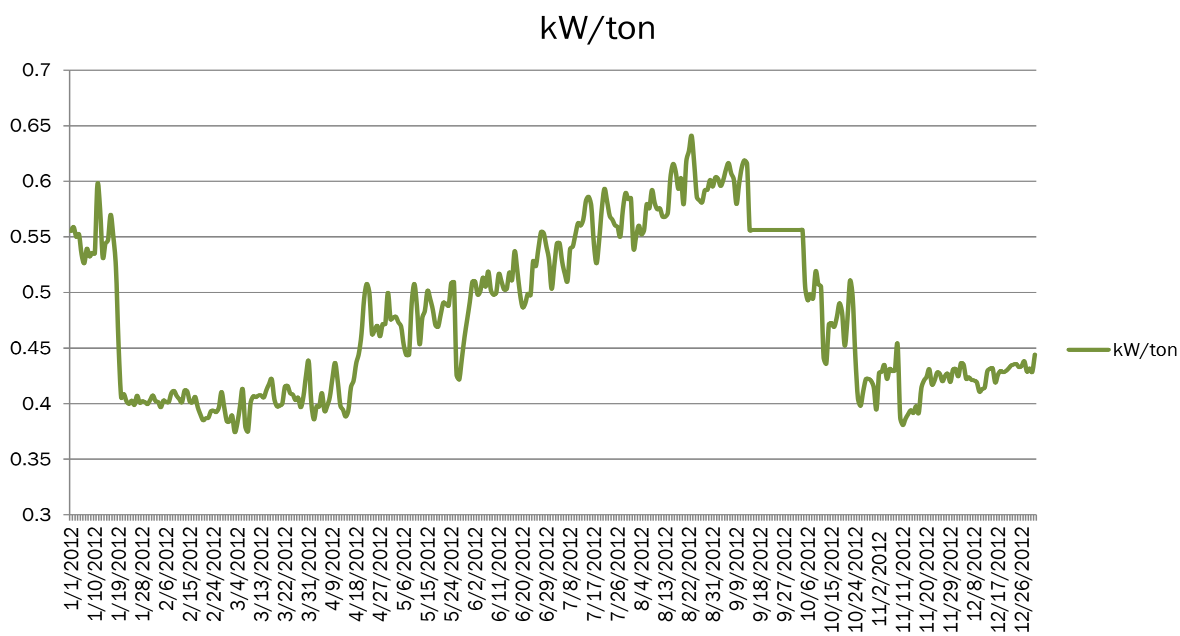

Figure 4. Chiller system efficiency in 2012 at Phoenix 1, based on daily kW/ton readings

PUE Findings

Examining Phoenix 1's PUE after completing the chiller optimization project, eBay found a marked improvement as compared with the previous year's measurement. Although overall annual weather-based trends remained consistent, the actual PUE improvement ranged from a mere .009 decrease between September 2011 and 2012 to a significant .121 decrease in February 2011 and 2012, as illustrated in Figure 5.

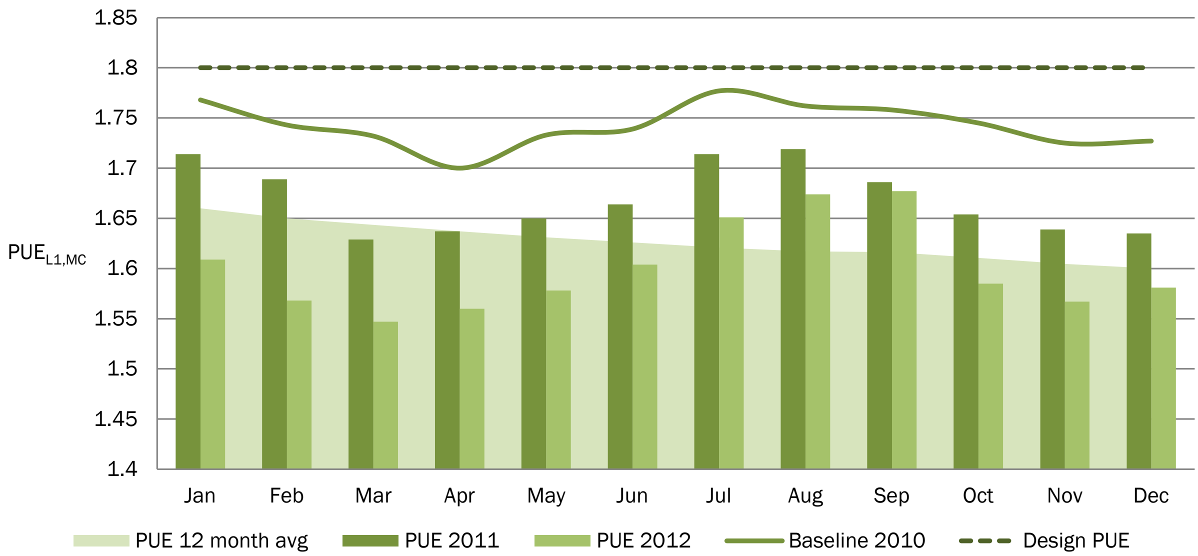

Figure 5. Three-year PUE trend at Phoenix 1, based on monthly averages of data continuously recorded at the UPS

CUE Findings

eBay also measured CUE both before and after optimizing the chiller system. (See Figure 6.) Although the decrease in CUE is a notable result, CUE was not an area of focus for this particular project.[4]

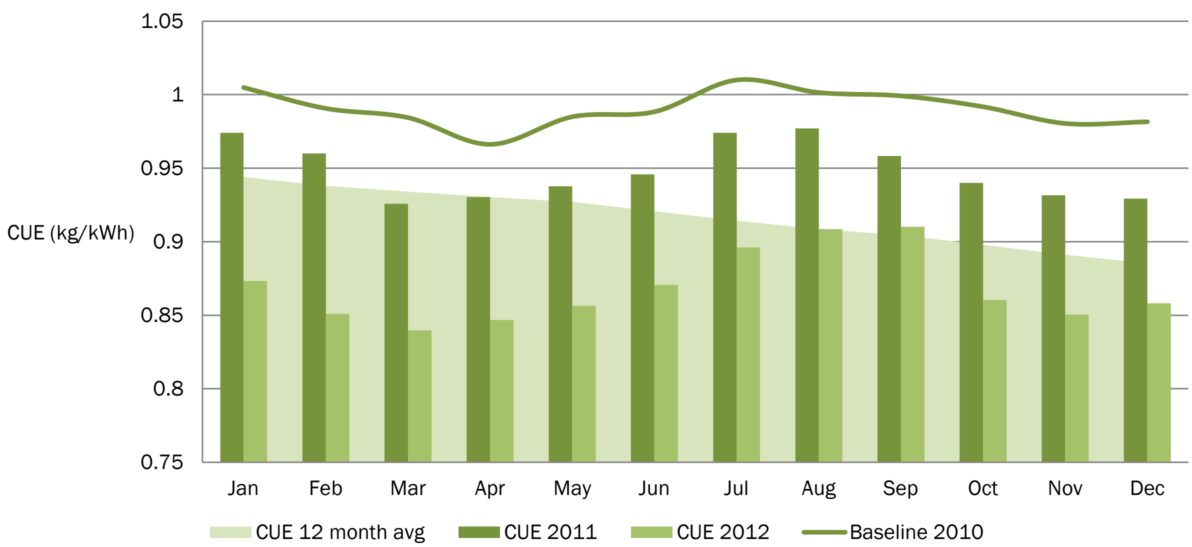

Figure 6. Three-year trend of Phoenix 1 CUE monthly averages

4. For more information about CUE, please see The Green Grid's White Paper #32, *Carbon Usage Effectiveness (CUE): A Green Grid Data Center Sustainability Metric*, www.thegreengrid.org/~/media/WhitePapers/CarbonUsageEffectivenessWhitePaper20101202.ashx?lang=en

WUE Findings

Upon reviewing the data center's WUE after the chiller system solution had been installed for a year, eBay noticed a marked increase when compared with its 2011 WUE data. (Figure 7 depicts the data center's three-year WUE trend.) The company determined that operating the two additional chillers active, rather than keeping them offline, accounted for the approximately 33-percent increase in water use. In 2011, Phoenix 1 had four chillers online and used approximately 22,000 kilogallons of water; in 2012, with the two additional chillers online, the total amount used was around 31,000 kilogallons—an annual increase of 9,756 kilogallons at an average cost per kilogallon of $8.25. "The WUE uptick correlates with what we would expect from having two more chillers operating through their normal cycles," says Harris. "Although WUE is the major metric we use to track our monthly water usage, unfortunately it was not part of our initial calculations when forecasting the optimization project's cost-benefit ratio and ROI."

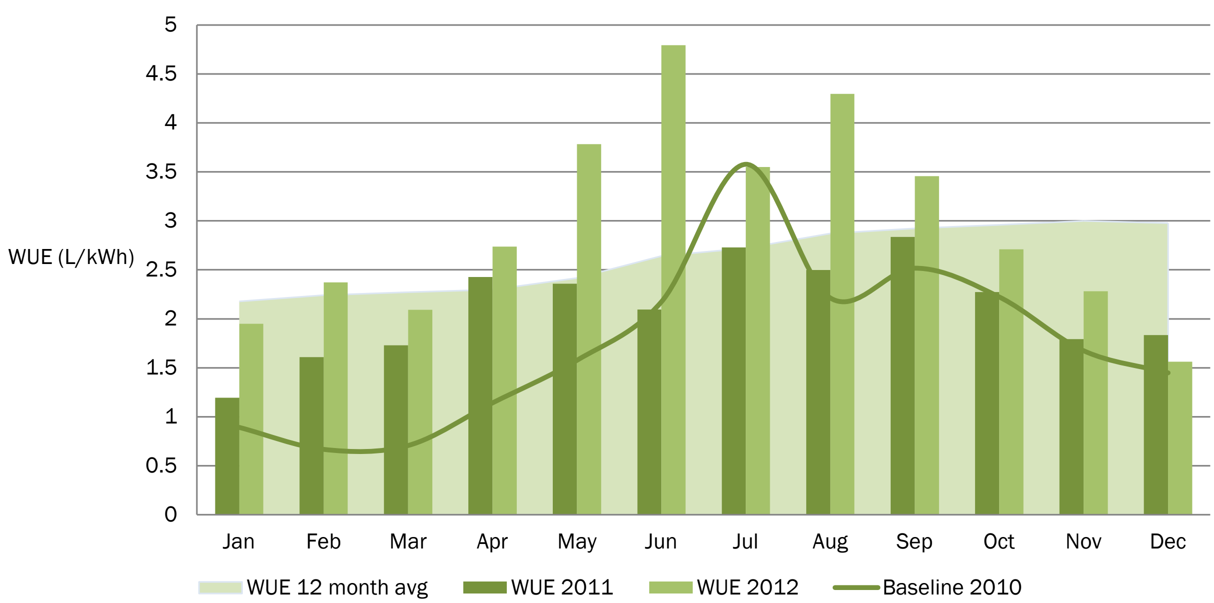

Figure 7. Three-year WUE trend at Phoenix 1, averaged monthly

Despite the increase in water usage, the enhanced PUE and associated energy cost savings more than made up for the additional water costs. The PUE/WUE analysis in Figure 8 illustrates the importance of evaluating all aspects of a project's design, not just focusing on the potential power reduction. "The financial impact of the WUE increase was significantly less than the savings from the data center's power reduction, but in the future, WUE should be considered ahead of time to pursue sustainable designs and fully understand a project's possible impacts," says Harris.

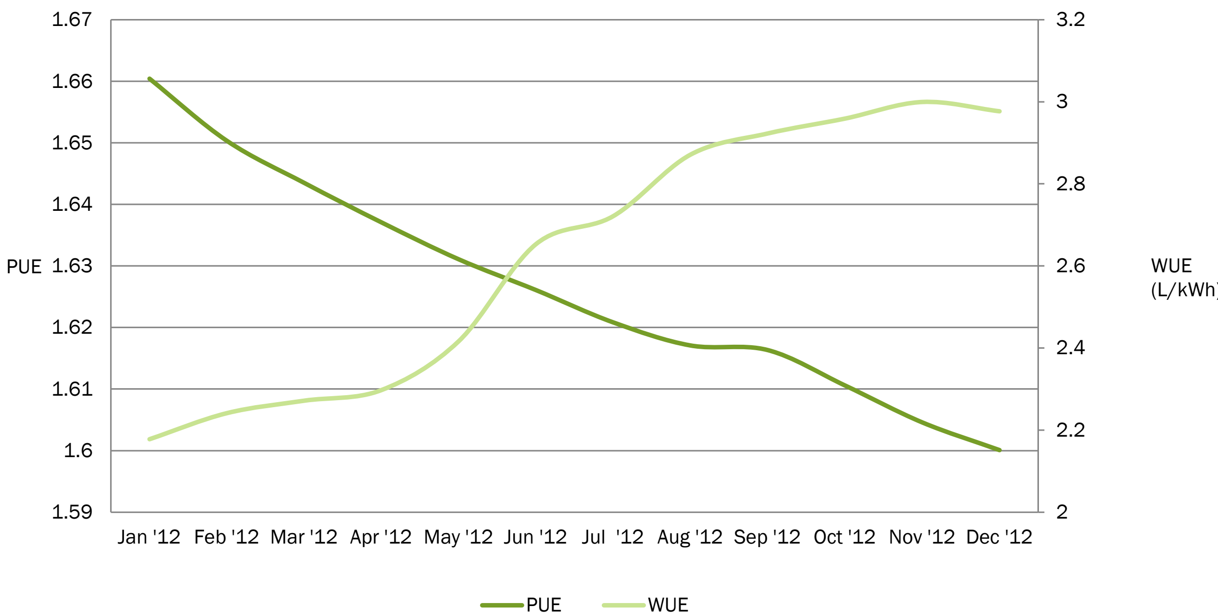

Figure 8. Comparison of monthly PUE and WUE trends at Phoenix 1 in 2012

WUE Impact on ROI

After performing its post-project review, eBay saw that the rise in water usage substantially increased the project's ROI time, which it originally estimated at less than three years. With the additional water costs, the actual ROI time is five years. (See Table 2.) "Although the ROI turned out to be closer to five years than the three we anticipated, this project was still a valuable step to have taken at Phoenix 1," says Harris.

Table 2. Breakdown of project costs, savings, and ROI timelines, both possible and actual

ROI Impacts	
Project Costs	$673,466
Annual Power Savings	$176,215
Annual Additional Water Costs	$80, 487
ROI - Power Savings Only	3.8 years
ROI - Power Savings/Water Costs Only	7.0 years
ROI - With Full Rebate and Power Savings	2.3 years
ROI - With Actual Rebate and Power/Savings	2.7 years
ROI - With Full Rebate and All Costs/Savings	4.1 years
ROI - With Actual Rebate and All Costs/Savings	5 years

Further ROI Impacts

Investigating the root causes for the savings discrepancy, eBay realized that, in addition to the increase in water consumption, there were several other issues that ultimately affected its expected ROI. For instance, when first discussing the project with its controls vendor, eBay requested assurances that the implementation would achieve the promised results. In response, the vendor provided data from similar implementations elsewhere. That data had been based on best-case measurements, scenarios in which every piece of existing infrastructure was in peak condition. "We trust our infrastructure quality and maintenance practices, but we might have benefitted from a closer review of our equipment to ensure it would deliver the highest possible efficiency results," says Reyher.

In addition, eBay did not have fully accurate baseline data regarding its mechanical load when it calculated the project's expected ROI. During an initial survey, the controls vendor took only nameplate ratings of the equipment, rather than determining the equipment's actual load with an ammeter. The difference in the nameplate data and the actual mechanical load accounted for a sizable difference in the calculated versus realized energy savings.

For example, using the pumps' posted horsepower data implied that each pump was drawing its full load of amps, an assumption made frequently throughout the industry. "Our baseline calculations had included a much higher power draw for the pumps than their actual draw," says Harris.

The project's overall cost savings were also affected by the amount of data in the Phoenix 1 BMS and the trend information eBay could give the utility. The BMS data that eBay had available to provide as its baseline for the rebate application came only from October through December 2011, months in which temperatures are cool, even in Phoenix. During that timeframe, the data center's existing chiller configuration operated most efficiently. Had eBay been able to provide a full 12 months of baseline operational data to average, it could potentially have received a larger rebate. For instance, the summer months would likely have shown that the data center was operating at a lower efficiency of 0.8kW/ton, but the rate reflected in the rebate application from the fall was 0.62kW/ton.

Recommendations Based on Lessons Learned

- Ensure that your facility has a state-of-the-art maintenance regime before embarking on this kind of project—operating at an industry-standard maintenance level can substantially elevate your efficiency. Closely review the individual pieces of equipment involved in the given system and remove any potential for each to operate at less-than-maximum efficiency.
- Research all the local utility rebate programs that might pertain to your facility.
- Alert your utility that you intend to participate in its rebate program and review all measurement and verification requirements with that utility.

- To show the maximum before-and-after differences in energy consumption and garner the highest possible rebate, track and maintain at least a full year's worth of baseline data, including the following key mechanical system attributes:

  — Chiller power consumption

  — Pump power consumption (both primary and secondary chilled-water pumps and condenser pumps)

  — Cooling tower power consumption

  — Sump sweep and filtering system power consumption

  — Chilled-water system ton demand

  — A system equation for total mechanical plant power consumption (chillers, pumps, fans, and filter systems)

  — A system efficiency equation of kW/ton

  — Temperature and humidity:

    - Condenser loop temperatures (supply and return)
    - Chilled-water supply temperatures (supply and return)
    - Outside air temperature and humidity

- Consider infrastructure design and its potential impacts on project costs and ROI. For instance, had Phoenix 1 been designed with common headers for its chillers, eBay could have achieved greater system efficiencies through the new controller and received a larger rebate.
- Before making changes to your facility's mechanical systems, perform a thorough review of existing control components and ensure that those components will operate properly in the proposed scenario.
- Rather than relying on nameplate data, use an ammeter to determine your equipment's actual amp load for a more accurate initial analysis of your existing mechanical systems.

- If you need to make a series of incremental changes to your mechanical equipment prior to achieving final efficiency gains that you will report to your utility, be careful not to affect any of the necessary baseline data and diminish the potential amount of your rebate.
- Determine your facility's existing WUE and take water usage and costs and their effects on ROI into consideration at the outset of any proposed chiller system optimization project.
- Consider drawing up performance contracts so that all the entities participating in a capital project—including equipment vendors—have a financial stake in its success.
- Be open to the idea that even things that are good often can and should be altered. Challenge your original designs and be comfortable with change.

Ongoing Enhancements at Phoenix 1 and Other eBay Data Centers

Because the chiller system optimization project was just one in a long continuum, eBay intends to make further efficiency strides at Phoenix 1. For example, the company plans to improve the data center's WUE by augmenting its chiller filtering capabilities so that the system conducts fewer flushes and refills yet maintains water quality. "We're pleased overall with the initial results of the chiller system optimization project at Phoenix 1," says Reyher. "That said, I've challenged the team to continue to work with our controls vendor to tweak the system to squeeze out even more efficiency. The results are good but can be even better."

As evidence of the company's drive for ongoing improvement, it already has conducted a project to augment the operation of the data center's fans. In June 2012, eBay installed 30 electronically commutated fan assemblies in CRAH downflow units in the facility's electrical rooms, and it installed eight variable-speed drives in the CRAH upflow units located in the electrical rooms and point-of-presence spaces. eBay integrated the fans with the BMS, which now manages them. The fans will operate at

60-percent speed for 8,760 hours year-round, for an estimated annual energy savings of 1,605,358 kWh.

Phoenix 1 has redundancies originally built into its UPS system, so eBay is considering a project that would shut down some of its UPS modules to gain potential kilowatt savings of 240kW/year. eBay will conduct a design review later in 2013, followed by a potential improvement project in 2014.

Although most of eBay's newer data centers incorporate the sorts of energy efficiency improvements that the company has conducted at Phoenix 1, eBay does plan to apply the *x*UE metrics and lessons learned from its Phoenix 1 experience to its other data centers. "We know that our energy journey does not begin and end with one data center, and that our efforts to drive efficiency are only one piece of our overall commitment to being the best environmental stewards we can be," says Nelson.

eBay mandates the continued tracking of *x*UE metrics on a monthly basis at its data centers. In addition, the company plans to report its PUE data to The Green Grid, which has developed a database in which organizations record key data center information as well as measurement results and contextual information about those results.[5] "It's essential to continue to collect the *x*UE metrics because you can't affect things that you don't measure," states Harris. "Most engineers share the philosophy that, until you truly understand how you're operating at a given time, you cannot make effective changes and improve efficiency."

5. For more information about reporting PUE results to The Green Grid, please visit www.thegreengrid.org/Global/Content/Tools/PUEReporting.

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