Natural Resources and Environment
University of Michigan

Cisco EnergyWise

Campus Energy Management via the IP Network: A Feasibility Study for Achieving Energy Efficiency via EnergyWise

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Executive Summary

A. Introduction

As energy prices rise and more attention is focused on human environmental impacts, organizations of all types are interested in reducing their energy consumption in order to lower costs, curtail greenhouse gas (GHG) emissions, and improve the overall sustainability of their operations. In response to that demand, a number of companies are developing technologies to help organizations to better manage their energy use. This paper explores the potential for one such technology, Cisco Systems' EnergyWise software, to monitor and manage the energy consumption of network-connected IT devices on a university campus. Examining a pilot implementation of this technology at two schools on the University of Michigan campus, the paper describes the organizational and technical challenges that arose, discusses the reductions in energy use that were achieved, and presents the project team's recommendations and conclusions.

B. An Evolution in Commercial Energy Management

For this study, the project team chose to use The American Council for an Energy-Efficient Economy definition of energy management: the "systematic tracking and planning of energy use and can be applied to equipment, buildings, industrial processes, industrial or institutional facilities, or entire corporations. A thorough energy management program consists of metering and monitoring energy consumption, identifying and implementing energy saving measures, and verifying savings with proper measurements."(ACEEE 2011)

This paper focuses on energy management in buildings. Many new technologies are emerging that improve monitoring and control of major building systems including Heating, Ventilation and Cooling (HVAC), lighting and Information Technology. Advancing codes and standards like the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard 90.1 for commercial buildings are pushing the development and adoption of these energy management technologies.

Sophisticated network technologies have been developed recently for better tracking of energy consumption in buildings, enabling higher efficiency. Since society's prioritization of energy efficiency will directly impact the rates of technology development and adoption, it's important to understand why energy is consequential to large organizations and estimate its level of importance. An outreach effort was performed to gauge the importance of energy management in various industries. The outreach included interviews, conversations and a survey targeted to top-level energy or sustainability managers within leading companies in healthcare, building controls, higher education, Energy Service Companies, metals, Consumer Package Goods firms, and others.

Research indicated that energy is moderately important within the organizations surveyed. There are many reasons, though most interest is driven by financial considerations. Buildings, which are composed of complex independent systems operated by unique and independent controls, are a central concern for increasing commercial energy efficiency. In order for decision makers to set more efficient operational parameters for building components, feedback data needs to be as close to real-time as possible. However, many building operators and energy managers do not have access to granular energy information for individual devices whose, but only back-dated utility meter data for the entire facility.

Energy Information Systems provide a hardware and software solution for monitoring energy consumption in buildings. Inputs to these systems include data acquisition hardware such as submeters and utility meters, formal Energy Management Systems, exported energy data from Building Management Systems, or other energy data points. This data can be normalized against weather, user behavior and other variables to more clearly indicate consumption trends and the impacts of efficiency measures.

In most organizations, Energy Information Systems (EIS) bridge a gap between operations and IT, requiring a collaborative approach between departments to properly set up data inputs to an EIS and confirm that information is being properly stored. Implementation of the EIS will likely require more collaboration between these departments, which may involve overcoming interdepartmental challenges.

Government policies and programs, regional carbon market activity, reporting requirements, and other drivers will heavily influence adoption rates for information technology energy management tools in commercial and industrial settings. Since government requirements and incentives can propel markets, technology developers should stay abreast of current and expected legislation. Other factors that may affect adoption include Energy Service Company behavior, utility-driven activity such as rebate programs, and the development of a smart grid.

C. Energy Management in the University Environment

Universities across the country are moving toward more rigorous energy and resource management through independent campus initiatives as well as larger peer movements, such as the American College and University Presidents' Climate Commitment (ACUPCC). The cultural aspects of the campus environment play a large role in determining the energy use patterns and considerations that must be made when assessing and implementing energy management at a university.

The stakeholders who inhabit universities drive their institutions approach to adopting new concepts. Their motivations, needs, and characteristics vary considerably, and therefore demand a wide range of support and expertise from the university. Among these stakeholders are a few core groups: students, faculty, staff, institutes & organizations, and alumni. Each of these players strives to achieve the university's thought and action leadership mission, but in manners that result in different behaviors, needs and, ultimately, energy use.

A number of functional roles exist within the university to provide the environment and tools necessary to deliver the best educational and research experience. These groups interact in a number of ways, but also act relatively independently in pursuit of achieving their own organizational missions. As a result of these independent pursuits, there are a number of misaligned incentives around campus energy management that present operational and financial opportunities throughout the university.

D. Case Study: IT Energy Management at the University of Michigan

The central component of this project was an implementation case study of a network-based energy management solution at the University of Michigan. As part of the study, it was necessary to survey existing energy management and sustainability initiatives at the University. Three organizations coordinate related activity. At the highest level, the Office of Campus Sustainability coordinates the University's overarching approach to sustainability. At the operational level, Planet Blue optimizes building and facility efficiency. Finally, the Graham Institute coordinates the University's academic efforts around sustainability.

It was unrealistic to attempt a full building integration of an energy management solution, so the project focused on energy management of IT systems as an introduction to the University environment. Cisco Systems, the project sponsor, donated the software and expertise necessary for the project team to deploy an energy monitoring and control package, Cisco's EnergyWise (EW) and Orchestrator. EW is the underlying communication protocol for command, control and monitoring of devices that resides on Cisco brand network switches. Orchestrator is a Graphical User Interface that gives administrators the ability to manage EW enabled devices.

The software was installed at two pilot locations. Those locations include the computer labs and an administrative staff office at the School of Natural Resources & Environment's (SNRE) Dana Building, and IP phones and Wireless Access Points in the Executive Residence (ER) at the Ross School of Business. These locations were chosen in order to compare the differences between an older, although recently renovated, building, and a newly constructed building.

After installing the software, energy consumption was monitored for two weeks to create a baseline reference. This information was later used to assess energy savings. Following the baseline, the team enacted policies on computers in the labs and administrative office.

E. Results

Power management using EW and Orchestrator did not result in significant savings on the computers in the administrative office because the machines were already being power managed and the new policies were only slightly more aggressive than what was previously enforced. However, using Orchestrator to manage the computers in the computer labs resulted in a marked decrease in energy consumption. Policy implementation on lab computers caused average Sleep state (low power state) time to increase from zero to approximately 7-12 hours per day depending on user activity levels. Average Sleep state time during a seven-day week after policy implementation was approximately 30% of the day. The policies implemented in the labs were not aggressive in terms of idle time before sleep. Transitioning computers to a Sleep state after a shorter period of time could have resulted significant additional reductions in computer idle time and energy usage.

Analysis of computer energy state and user activity data for 12,500 of the university's 48,000 computers revealed that approximately one-third of the computers average 21-24 hours/day in the On state. For this group, average Idle time (time in a high power state with no user activity) was over 20 hours per day, presenting a significant opportunity for management and energy savings. The individual department with the greatest number of computers that were on 21-24 hours/day deliberately prevented its computer from entering the Sleep state in order to create a good experience for users. The department found that the login experience after its computers from the Sleep state was highly inconsistent, and this problem sometimes disrupted classes. This situation highlights an important finding: Energy management must take user experience into account in order to be accepted.

Further examination computer energy state and user activity data showed wide variation across departments in the number of hours per day that computers spend in the Idle state. This indicates that the level of computer energy management differs significantly from department to department. Coordination of computer energy management programs could improve the overall results at the university level.

Further analysis of data showed that the opportunity for energy and cost savings is fragmented across departments. This means that the economic incentive for individual departments to manage their computer energy use is much smaller than for the university as a whole. A centralized university initiative for improved management is most likely to be effective to realize the potential for reduced computer energy use. Based study results, the project team estimates that such an initiative could produce computer energy cost savings on the order of hundreds of thousands of dollars.

F. Conclusions and Recommendations

Conclusions

Current limitations in energy measurement impede efforts to incentivize energy efficiency.

The University's organizational complexity impedes implementation of energy management solutions.

A centralized Energy Information System containing university-wide data would allow energy managers to identify opportunities in complex environments.

A complete energy management solution needs to consider end-user experience.

A complete energy management solution must satisfy the needs of both IT professionals and facilities managers.

Coordination of computer energy management programs between departments could significantly improve overall results at the university level.

A centralized initiative to drive improved computer energy management is more likely to be effective in realizing the potential for reduced computer energy use.

Central PC energy management can potentially save the University several hundred thousand dollars.

Convergence of building systems would provide opportunities for even greater savings.

Recommendations

Align energy decisions and costs at the University. In particular, the project team believes that it is important to:

Investigate finance and accounting structures that better incentivize future energy management.

Map energy decision making at U of M.

Conduct a study of factors affecting user experience and their relative importance.

Implement a more robust Energy Information System at the University.

Conduct a pilot of converged building energy management.

I. Introduction

As energy prices rise and more attention is focused on human environmental impacts, organizations of all types are interested in reducing their energy consumption in order to lower costs, curtail greenhouse gas (GHG) emissions, and improve the overall sustainability of their operations. As significant consumers of energy, businesses and universities are no exception. In 2009, the commercial sector in the U.S emitted approximately one billion metric tons of carbon dioxide equivalent (Figure 1) and consumed 18% of the country's total energy, primarily electricity (U.S. Environmental Protection Agency 2011). Within the sector, building lighting, heating, cooling and ventilation systems are the largest areas of consumption (U.S. Energy Information Administration 2010). A number of technologies have been developed in recent decades to better manage the energy use of these devices. The measure of success of these products is their ability to balance energy savings and performance. Products that improve system efficiency without compromising performance have the potential to reduce organizational costs and environmental impacts.

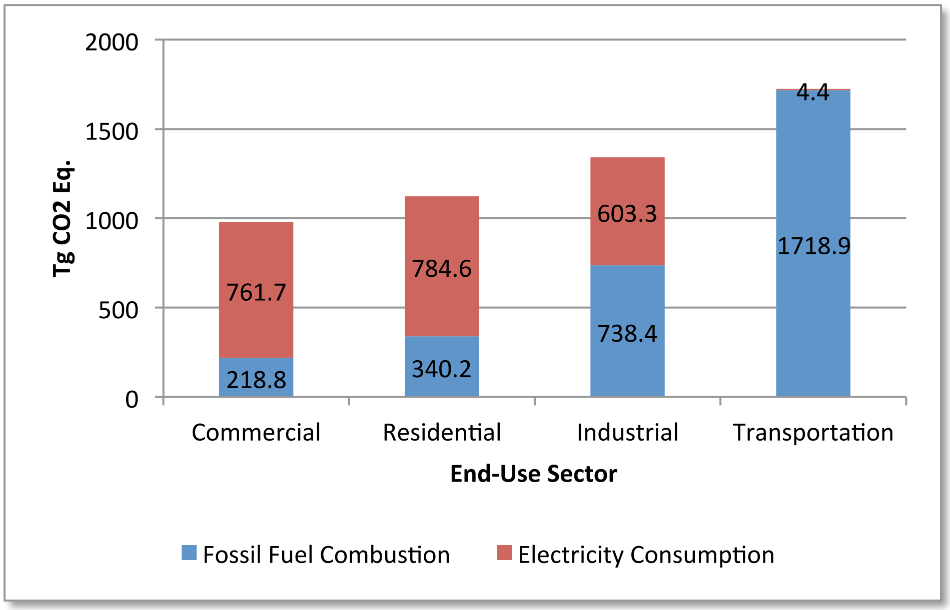


Figure 1 - 2009 End-Use Sector Emissions of CO2, CH4, and N2O from Fossil Fuel Combustion

Source: U.S. Environmental Protection Agency

Firms hold varying perspectives on the optimal approach to energy management, offering a variety of technologies and products. For example, Cisco Systems has developed EnergyWise, a network-based energy management protocol that enables building managers to monitor and control the energy consumption of network-connected devices, and Orchestrator, a centralized energy management interface. Additionally, Cisco is developing its Network Building Mediator, which is capable of connecting non-Information Technology building systems like facility heating, cooling, and lighting to traditional computer networking standards such as TCP-IP (IP-networks), and tools that operate on this standard such as EnergyWise. This will provide managers with increased control over their buildings' energy consumption. Through the use of network-based energy management (EM) solutions, technology providers can enable organizations to understand where energy is consumed and give them tools to improve energy efficiency.

Building systems that carry significant energy demands have the potential to operate more efficiently through interconnection with an Energy Management System (EMS). These efficiency measures could substantially reduce energy bills and GHG emissions. In order to have these desired impacts, technologies must first be adopted and implemented by customers. Adoption of these technologies requires ease of integration with current Information Technology (IT) and building systems, buy-in from various stakeholders within the organization who are willing to accept changes in energy usage policy, and demonstration that the EM technology is capable of reducing energy consumption at a reasonable cost.

This paper will address these issues by examining a pilot project that implemented Cisco's EnergyWise software to monitor and manage the energy consumption of network-connected IT devices at two schools on the University of Michigan campus. To provide context for the pilot, the paper begins with an introduction to commercial EM, including the forces that have historically shaped this practice, an account of modern techniques, and ways in which advanced networking capabilities are transforming EM implementation. A more focused assessment of EM within the university setting is presented, including cultural and technical aspects that will impact the adoption and implementation of network-based campus energy management. Finally, the paper will present a Cisco EnergyWise pilot study that monitored and managed energy consumption of network-connected IT devices at two schools on the University of Michigan campus. The paper will explore the organizational challenges the project team faced in deploying EnergyWise at the School of Natural Resources and the Environment and the Ross School of Business, provide an overview of the technical challenges that arose, discuss the energy reduction that was achieved, and present the team's conclusions and recommendations.

II. An Evolution in Commercial Energy Management

A. Origins of Energy Management

What is Energy Management?

The U.S. Department of Energy's (DOE) Energy Information Administration (EIA) classifies energy into four categories: Transportation, Industrial, Residential and Commercial (Figure 2). These are further divided into building-based (i.e. Industrial, Residential, and Commercial) or vehicle-based (i.e. Transportation) sectors. This paper focuses on building-based opportunities with particular attention on Commercial buildings. Within Commercial buildings, electricity is the dominant and fastest growing source of energy use (Figure 3). Therefore, our discussion will center reducing electricity use.

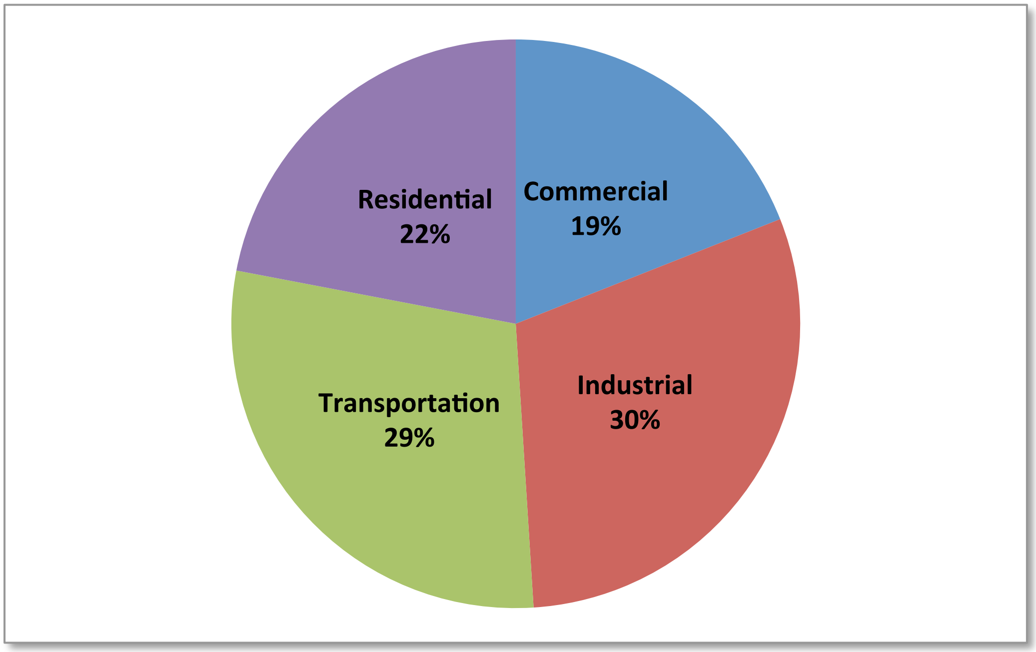


Figure 2 - End-Use Sector Shares of Total Consumption, 2009

Source: U.S. Energy Information Administration

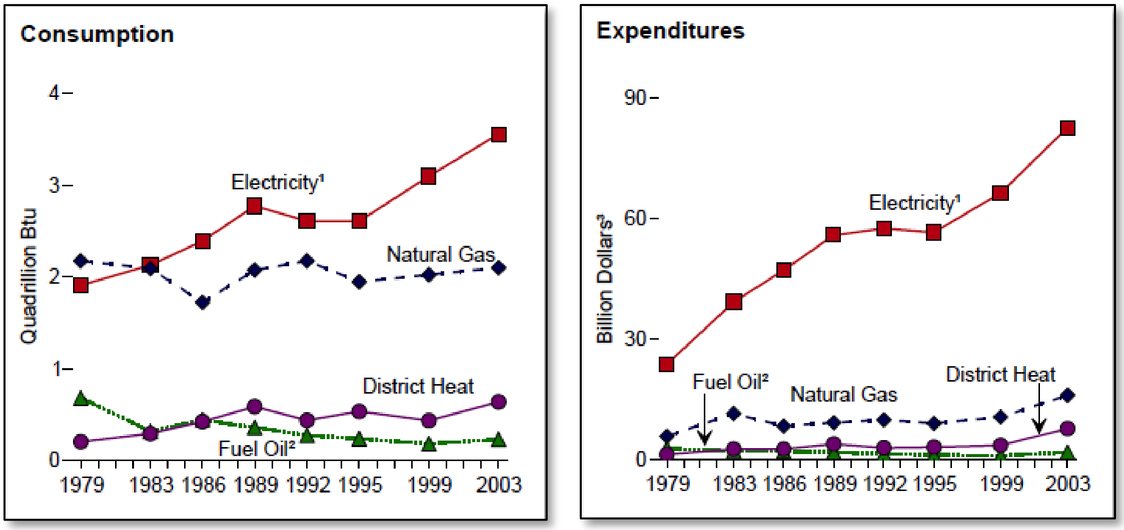


Figure 3 - Commercial Buildings Energy Consumption and Expenditure

Source: U.S. Energy Information Administration

In order to discuss this topic, it is necessary to define relevant energy reduction terms. Broadly speaking, energy reduction efforts can be classified as either *energy conservation* or *energy efficiency*. Energy conservation means reducing overall use of particular services or systems in order to decrease energy consumption. In contrast, energy efficiency means using less energy to provide the same service or level of system use. In other words, energy conservation saves energy by reducing the level of production of a valued output, while energy efficiency saves energy by reducing the energy wasted in producing a given valued output.

Within energy efficiency, efforts are further divided into *passive* and *active* categories. Passive measures include the installation of double- or triple- paned windows that have better insulation properties or compact fluorescent light bulbs (CFLs) that consume less power than traditional incandescent bulbs. Once installed, little to no additional effort is required to continue receiving reductions in energy consumption.

Active Energy Efficiency measures are also known as Energy Management (EM). The American Council for an Energy-Efficient Economy defines EM as the:

> *"systematic tracking and planning of energy use [that] can be applied to equipment, buildings, industrial processes, industrial or institutional facilities, or entire corporations. A thorough energy management program consists of metering and monitoring energy consumption, identifying and implementing energy saving measures, and verifying savings with proper measurements"*(ACEEE 2011).

EM involves a series of key steps:

1. Initial measurement of energy use (data collection).
2. Analysis of energy use data to identify opportunities for savings.
3. Development of control plans to reduce energy use and estimate the size of potential savings.
4. Implementation of energy control plans.
5. Comparing reductions to baseline data to verify effectiveness of controls and inform further adjustments.
6. Continuous monitoring of energy consumption to detect anomalies that can lead to excess energy consumption(Unger 2010).

Examples of EM include reducing ventilation in rooms or buildings that are unoccupied, turning off lights when no one is present, or placing computers in a low power state when they are not being used.

Figure 4 - Energy Management Framework

Historical Perceptions of Energy

Until the early 1970s, public perception was that real energy prices would fall continually over time (Wulfinghoff 2000). Over the previous two decades real fossil fuel production prices had slowly and steadily declined (Figure 5), and in the 1960s there was a significant decrease in real electricity prices (Figure 6). Aside from technical work done by engineers to make their equipment, system and building designs more efficient, there was little effort or incentive to reduce energy consumption (Wulfinghoff 2000).

Concerted efforts to reduce energy consumption began in 1973 with the onset of the Arab Oil Embargo. In response to U.S. Middle Eastern foreign policy, oil producing Arab countries imposed an embargo primarily directed at the U.S. The result was an energy crisis associated with a dramatic rise in energy prices (Figure 5, Figure 6). The sudden reduction in oil supply shocked the public in to the realization that energy supplies might not always exceed energy use (Wulfinghoff 2000). As a consequence, energy conservation efforts emerged. Reduction efforts were no longer just the concern of engineers, but also society as a whole. Efforts during the 1970s were largely characterized by a “save it” mentality – everyone should make do with using less. The spirit of the era could be summarized by Jimmy Carter’s 1977 fireside chat, in which he encouraged everyone to wear sweaters and turn down their thermostats. While the crisis generated a great deal of attention around energy conservation, there was little consistency across programs during this period. Few organizations monitored their energy use or set goals for reduction. Conservation efforts were composed of awareness campaigns that made use of reminders like stickers and posters to prompt people to turn things off when they were not being used (Fawkes 2001). In 1975, the Department of Energy (DOE) set energy efficiency targets for appliances through the Energy Policy Conservation Act (EPCA), the first significant regulatory step towards improving Commercial energy efficiency (GlobalData Analysts 2010b). In 1978, the National Energy Conservation Policy Act (NECPA) established the foundation for federal energy management standards and targets.

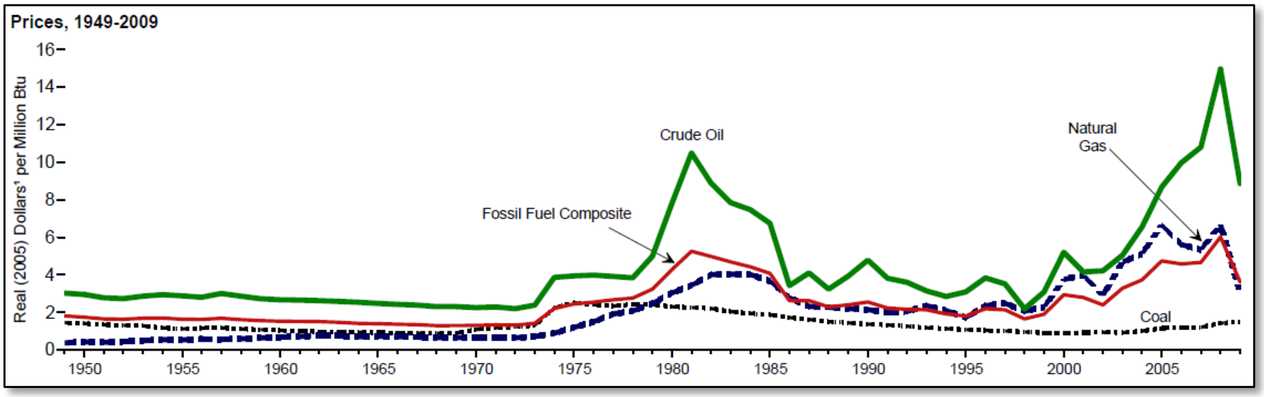


Figure 5 - Fossil Fuel Production Prices

Source: U.S. Energy Information Administration

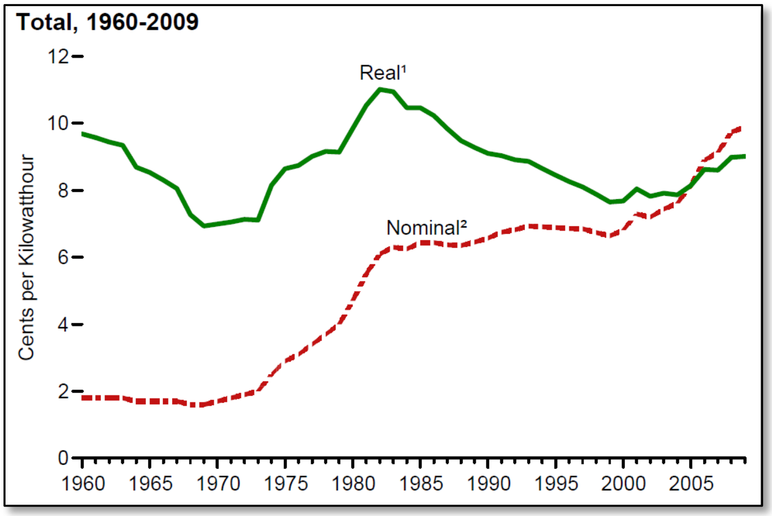


Figure 6 - Average Retail Electricity Prices

Source: U.S. Energy Information Administration

In the 1980s, energy conservation transformed into EM. Increases in computing power, including the introduction of the personal computer in the 1980s, aided this transformation. Computer-based monitoring and tracking systems were able to account for external variables that had previously been difficult to incorporate into energy analysis. Building EMS also emerged during this period (Fawkes 2001). However, steady declines in energy prices during the mid- to late- 1980s caused a significant decline in EM. Another important driver in the late 1980s was a shift away from EM to strategic energy purchasing as the primary cost reduction method.

The Natural Gas Policy Act liberalized natural gas markets, allowing energy managers to realize significant savings by buying on the spot market (Turner, Doty 2007).

EM stagnated further in the 1990s. Throughout the decade, energy prices were flat or declining. The Energy Policy Act of 1992 created the opportunity to purchase electricity from wherever it was cheapest(Turner, Doty 2007). This incentivized low-risk procurement strategies over higher risk efficiency strategies, which often required investment, as a means of cutting costs.

However, during the first decade of the 21st century, EM went through a revival. With the exception of the sharp decline experienced during the global recession of 2008, energy prices rose throughout the decade. This increase in prices was driven by expanding energy demand in developing economies like China and India and global supply disruptions due to political and military conflicts. Higher costs and increased concern about the long-term impacts of global warming created tremendous economic and environmental pressures on business, industrial and governmental organizations to reduce energy use. The combination of these factors led to an increased interest in and activity around EM. Looking forward, it seems unlikely that the value of EM will diminish as it did in the 1980s and 1990s. While energy supply volatility may subside, demand from growing economies will almost certainly continue to increase, pushing energy prices even higher. Increased regulation of GHG emissions appears probable. EM will have a growing role in society for decades to come.

B. Building Energy Management Today

This section provides an overview of the current state of building EM. It examines the systems that are important contributors to building energy consumption, the technologies that manage those systems, and the standards and codes that are driving technology development and adoption.

Energy Management Technologies for Building Systems

EM is undergoing rapid development due to advancing technology, rising energy prices, and an increasing focus on “green” infrastructure. EM in buildings, the focus of this paper, is no exception to the overall trend. The breakdown of energy use for buildings in the Commercial sector in the U.S., of which universities are a part, can be found in Figure 7. Heating, Ventilation and Air Conditioning (HVAC) systems consume over half of the energy used by the average commercial building. Energy for lighting makes up another 20% of overall use. A variety of technologies are used to manage the energy use of these systems.

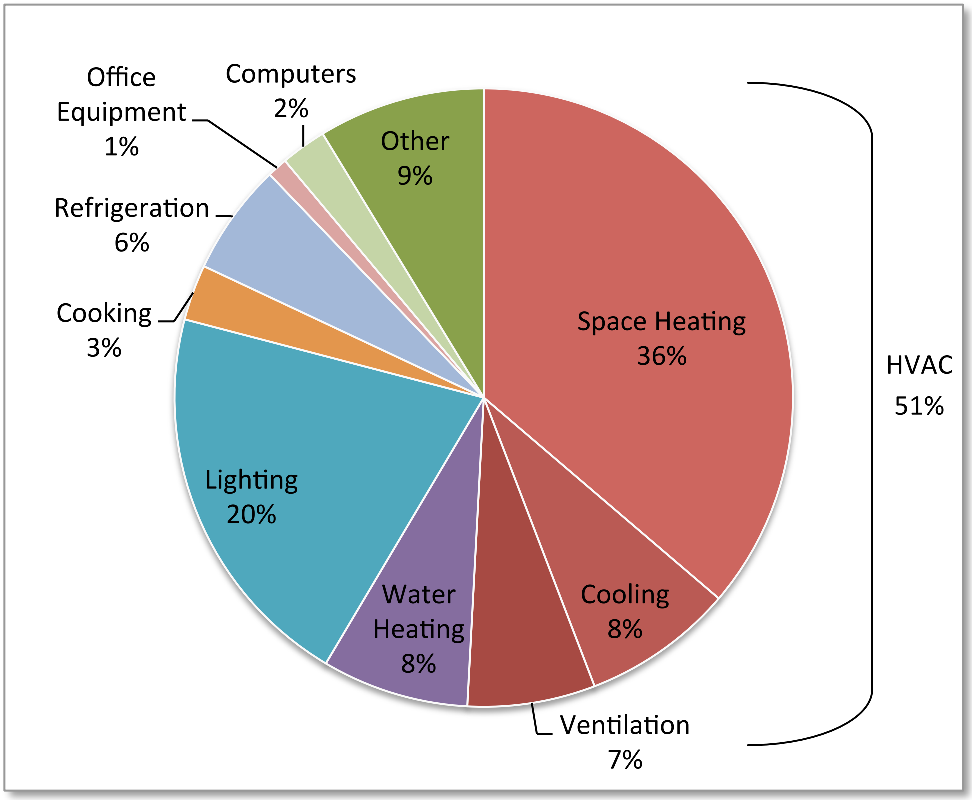


Figure 7 - Estimated energy consumption of U.S. commercial buildings
Source: U.S. Energy Information Administration

Measurement

Some organizations primarily rely on energy measurement technologies to help them manage energy consumption within their buildings. Analysis of energy use data can identify high consumption areas within a building and facilitate the selective replacement of inoperable system components or devices. Additionally, analysis can identify behaviors that cause high levels of energy consumption, which can create opportunities to save energy through changes to standard operating procedures and occupant behavior.

Without a sufficiently fine level of energy use measurement, it is impossible to determine who in an organization is responsible for energy costs. Submeters are one technology that helps improve the granularity of energy use data. Depending on installation location, these submeters can record energy consumption of a building, a portion of a building, or even individual systems or devices. In addition to identifying localized energy consumption, submeters facilitate real-time monitoring. Monitoring can show impacts on energy consumption from environmental or behavioral changes. This allows energy managers to get a better understanding of the underlying drivers of energy use.

California's Mammoth Mountain Ski Area (MMSA) is an interesting example of submetering's ability to reduce an organization's energy consumption. The year-round resort consists of three large lodges, 29 lifts, three gondolas, four hotels and other buildings on 3,200 acres. MMSA invested $12,000 to install 13 E-Mon submeters at key locations around the resort, using the existing Ethernet infrastructure for meter communications. Submetering has allowed MMSA to significantly reduced electricity costs because it allows Energy Manager Bob Bradbury to "drill down into the buildings and watch the loads to see what equipment is on and at what time, and to review the results from changes and additions to the building control system." In one highly electricity dependent building, MMSA was able to use submeters to reduce energy usage by 23% over three years. At one of its lodges, an all-electric, 100,000 square foot building, MMSA reduced electricity costs by $72,000 per year over four years. The meters have also allowed MMSA to catch temporary changes to systems operations that, when inadvertently left in place, cause large increases in energy use. For example, the increased visibility provided by the submeters allowed MMSA to identify the reprogramming of a building HVAC system to shut down seven hours later than normally scheduled, a change that could have been quite costly if it had gone unnoticed. MMSA has also been able to improve its allocation of utility services to users, providing energy users the incentive to police their own energy consumption. In the six years since MMSA started tracking its electricity usage, the resort reduced overall electricity use by more than 9% - an impressive return considering the size of the investment (Gill 2007).

Lighting

Traditional lighting systems consume considerable quantities of energy. According to the Energy Information Administration (EIA), lighting accounts for 21% of buildings energy use and 38% of total electricity use (14% and 30%, respectively, for educational buildings) (Energy Information Administration 2008). Lighting control systems and motion sensors can reduce energy use by ensuring lights are on only when they are needed. Over time, lighting technology developments have enabled a shift from manual to automatic control of lights, allowing them to be shut off or dimmed based on time of day or ambient light level. However, these automatic control systems have limitations. They have minimal intelligence and are generally independent from other building systems, meaning they do not share data or coordinate actions. Additionally, lights are typically controlled in groups, which limits the system ability to be customized to specific individuals and situations within a building. However, most modern lighting control systems make up for many of these shortfalls. Network-based technology allows light fixtures to be individually controlled via unique IP addresses. They incorporate motion and ambient light sensors to ensure proper lighting levels for occupants. The systems can be centrally managed over the network using computer software, allowing remote access, integration and data sharing with building automation systems and energy reporting (Mocherniak, Berger 2010).

HVAC

In 2008, HVAC systems accounted for 51% of total U.S. commercial building energy consumption (Energy Information Administration 2008). These systems make up the largest percentage of building energy use by a wide margin, making them an important target for EM. Advanced HVAC management systems adjust operation based on a variety of input sensors. The sensors can measure interior and exterior air quality, humidity and temperature can lower energy consumption and create a more comfortable building environment. Motion, carbon dioxide and infrared sensors can enable HVAC systems to match service levels to occupancy and can automatically power down when buildings are unoccupied. Additionally, HVAC systems can reduce energy use by communicating with other building elemets, like window shade control, to influence building temperature. For example, by automatically adjusting shades to allow for natural building heating or cooling, the HVAC system can reduce its overall load.

In designing its new headquarters, a 1.5 million square foot, 52-story office tower in Manhattan, The New York Times looked to incorporate the newest lighting technology in order to reduce lighting energy costs. The company installed a lighting control system from Lutron Electronics Co. that reduced lighting electricity use by 70%. For the 600,000 square feet of office space that The New York Times itself occupies, this amounts to an estimated savings of $315,000 in energy costs and 1,250 tons of CO2 emissions per year. Savings were made possible by a system of nearly 18,000 individually digitally addressable lighting ballasts connected b a continuous communication network to a centralized computer control program. The program makes thousands of adjustments during the course of a day based on input from ambient light sensors, occupancy sensors, and preset schedules. It also tracks power usage on a continuous basis (Jouaneh 2008).

Large building HVAC systems are complicated and can suffer performance degradation if internal components are operating at a sub-optimal level. In the past, a building commissioning process was used to detect such problems, but these periodic events only temporarily improve a building's HVAC energy performance. Network-based HVAC systems enable continuous measurement of performance, analysis of collected data, and variable management. Inefficiencies that arise in an HVAC system can be quickly detected when compared to optimal system performance. The source of the problem can then be diagnosed and addressed, preventing poor functioning of HVAC components from wasting energy for months or years(Rothman 2010).

Information Technology

In 2003, computers accounted for 4% of building electricity use, and 9% for educational buildings according to the EIA(Energy Information Administration 2008). In recent years, Information Technology (IT) equipment has increased in both availability and capability. There has been a corresponding rise in IT energy consumption. For example, in 2008, the U.S. Environmental Protection Agency (EPA) estimated that data center energy consumption was 53 billion kWh (equivalent to 5% of 2003 total electricity consumption) and increasing at 12% per year (Pouchet 2008).

Therefore, IT equipment represents a growing opportunity in commercial energy management. The possible savings are even greater when the power consumption of IT support systems, such as cooling, uninterruptible power supplies (UPS), and switchgear, are considered. When IT equipment energy use is reduced, it creates a cascade effect as energy consumption of support systems also decreases (Pouchet 2008). IT energy management software is emerging that allows devices to be placed into lower power states appropriate to their current state of use. These software programs adjust IT device power states based on inputs such as user activity, time of day, day of the week and other factors.

Significance of Green IT

The focus of this project is network-based commercial energy management, which involves incorporating elements of IT with the energy-demanding components normally under the jurisdiction of operations. As a result of the rapidly growing energy demand from the Information and Communications Technology (ICT) industry, there has recently been significant momentum in better managing energy use in IT systems, a movement known as *Green IT*.

In 2007, Gartner Research analysts estimated the ICT industry was responsible for approximately 2% of total GHG emissions, meaning their carbon footprint is roughly equivalent to the aviation industry (Gartner Newsroom 2007). In addition to the consumption of energy related to operational use, this figure included the energy of networking devices, PCs and servers, office telecommunication equipment and printers, as well as mobile communications devices (Gartner Newsroom 2007). Despite ICT's contribution to the global carbon footprint, it has potential to create solutions that address rapidly expanding emissions. For instance, a 2008 report published by the Boston Consulting Group estimated that smart technologies, or devices that fuse device energy management with IT, could drastically impact the level of total GHG emissions, with reductions as high as 22 percent by 2020 in the United States, and 15 percent globally (DESC 2011). Cisco Systems demonstrates the potential for new travel-replacement meeting technologies with their video conferencing platform *TelePresence,* and related technologies such as WebEx and MeetingPlace. In their 2010 Corporate Social Responsibility report, they report the number of Telepresence rooms in use nearly tripled from 2007 to 2010, while the total web conferencing people-hours increased from 4.7 million to 19.3 million in that same timeframe. Concurrently, travel emissions were reduced by 45% relative to 2006 levels (Cisco Systems).

The Green IT movement has advanced on several fronts over the past decade, including efforts to reduce power demands at central data centers while preserving the computing power and functional capability of the systems. As IT infrastructure grows to accommodate rapidly expanding demand, additional focus has been placed on lowering the life-cycle impact of hardware through better material design and manufacturing, as well as increased use of reverse logistics to improve recycling rates (Mines 2008). The World Resources Institute (WRI), the World Business Council for Sustainable Development (WBCSD), the Global e-Sustainability Initiative (GeSI), and the Carbon Trust are developing a common methodology for calculating the life-cycle carbon impact of devices within the ICT industry (GeSI 2011). The new guidance is intended to prompt companies to measure, report and reduce the impact of hardware, software or services. It will address the ICT Industry as a supplement to the GHG Protocol Product Accounting and Reporting Standard within the Greenhouse Gas Protocol Initiative (GeSI 2011).

Managing Data Center Power

A common adage is that “If you can’t measure it, you can’t manage it.” New methods for measuring energy usage in data centers have led to more detailed and accurate tracking of efficiency. A common industry approach for indicating relative power is the Standard Performance Evaluation Corporation (SPEC), a tool that resulted from the need for more standardized performance tests. Data center operators can use these metrics to assess servers for the amount of computing power achieved relative to the machine’s total power demand. Likewise, operators track facility-scale metrics such as power usage effectiveness (PUE) which relates the amount of energy used by the entire center to the power used to run individual computers, and its reciprocal, data center infrastructure efficiency. Other success stories for higher efficiency in the data center include server virtualization, removal of idle machines and zombie servers, and advanced resource allocations such as cloud computing. All these efforts increase server utilization and effectively achieve lower PUE ratios.

Managing Power of PCs and Network Devices

PCs manufacturers have embedded power saving features into core operating systems for years, and effective use of conservative power settings has become more predominant as laptops have become more ubiquitous. Organizations can achieve noticeable savings through employment of standard “time-based” approaches to managing PC power (Washburn 2008). Since most companies use PCs most heavily during the workday, simply powering down PCs during nights and weekends will offer immediate savings. Additionally, industry best practices include the enablement of power management tools on as many devices as possible

Roll-out of power management technologies on a large-scale has been enabled by developments such as Wake on LAN®, an Ethernet networking standard that enables computers on a network to be awakened by remote messages. Networks have evolved to incorporate more modern technologies, and thus new technologies such as Wake on Wireless LAN (WoWLAN) have been developed. In 2008, Intel® introduced Remote Wake, which “establishes and maintains a persistent connection to an authorized service on the Internet while your PC is in the sleep state (Intel Corporation).” Remote Wake enables a computer to sleep unless the user needs to download a file or receive a call via VoIP (Lamb 2009).

Codes and Standards

Federal, state and local Building codes set mandatory minimum standards for buildings construction and performance. Therefore, codes play an important role in encouraging adoption of building EM technologies. The Energy Policy Act of 1992 required states establish minimum commercial building energy codes; this led many to adopt existing voluntary standards as codes (Doty, Turner & Turner 2009). Energy standards are published by national organizations like the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) and, while not mandatory, often serve as national recommendations on how building construction can cost effectively save energy.

For more than thirty years, ASHRAE Standard 90.1 has been used by states as the basis for commercial building energy codes(Berning,M., PE, CEM,LEED AP BD+C 2010). ASHRAE 90.1 sets minimum requirements for new buildings that ensure they will be constructed, operated and maintained in a manner that minimizes the use of energy without constraining building function and occupant productivity. The standard addresses energy related building components and contains technical specifications for building envelope components, HVAC systems and equipment, water heating, power, lighting, and motors (Doty, Turner & Turner 2009). Additionally, ASHRAE 90.1 is the mandatory standard for all new Federal buildings.

The 2010 update to ASHRAE 90.1 mandates building systems integration for lighting controls, and requires submetering for HVAC, lighting and plug loads. In addition, the new standard now covers dedicated computer rooms, which were not previously covered. Examples of new standards that go even further include the new ANSI 189.1 Standard for the Design of High-Performance Green Buildings, and LEED standards that encourage development and adoption of energy management technologies.

ASHRAE standards generally serve as the basis for future building codes and can provide a glimpse of where the building management industry is headed. Given this, ASHRAE 90.1 and ANSI 189.1 beg the question: *How will the commercial building sector respond and which technologies will be used to meet these potential future codes?*

C. Approaches to Commercial Energy Management

Industry Survey

Commercial operations managers have access to increasingly sophisticated technologies for tracking energy consumption in buildings. The rates of technology development and adoption will be determined by companies' prioritization of energy efficiency. This project involved an industry outreach that included interviews, conversations, surveys, and analysis of existing studies to determine how important energy considerations are for organizations in various industries. Approximately 40 companies from twelve industries were selected, and an outreach effort was performed to make contact with energy or sustainability managers within the firms.

The outreach strategy targeted top-level energy managers at major companies. Response rate was expected to be low and direct contact was challenging. Our survey garnered twelve responses, including six that completed the survey in its entirety. While this resulted in a limited number of data points from each industry, the quality of survey respondents was high. Respondents represent a variety of industries including metals, controls, energy efficiency, higher education, energy solutions consulting, and healthcare. The following discussion provides an overview of the results.

Energy Matters to Industry

Every company representative that responded to the survey indicated that policies exist within their organizations that make EM an organizational goal. Respondents rated opportunities for energy-related cost reductions at **6.6** on a scale of 0-10 (0 = no opportunity; 10 = extremely high opportunity) (Figure 8).

Figure 8 - Importance of Energy Management

Challenges to New Practices

Since new devices and applications for managing energy and greenhouse gases are being developed, respondents were asked about internal challenges to new energy management practices. Results can be seen in Figure 9. Seven respondents ranked the importance of each category from 1-10. Total aggregate category scores are compared.

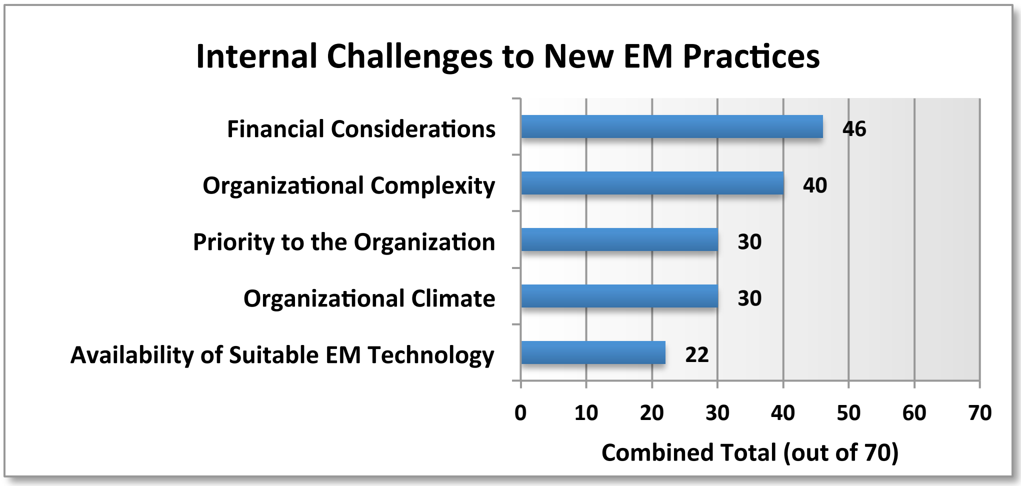


Figure 9 - Challenges to adoption of a new energy management practices or technologies (Maximum value = 70)

Cost of Energy

When asked how important energy expenses are in comparison to other elements of operational costs (scale 1-10), respondents expressed that they are moderately important, with a mean of **5**. This may indicate that energy is perceived to represent a substantial fraction of overall costs, or perhaps it is more important because it represents a "low hanging fruit" opportunity for reducing costs (Figure 10).

Figure 10 - Importance of energy expenses as a portion of overall costs

Decision Making

Internal organizational dynamics are a critical determinant of whether or not a new technology will be successful. Survey respondents indicated that the unit director was most directly responsible for implementation of new practices, followed closely by facilities managers, finance personnel and sustainability/energy managers. Personnel at higher or lower levels in the organizational structure do not play a significant role in adopting new energy practices and technologies (Figure 11). The total number of positive responses per category was counted, with a possible maximum of seven, the total number of respondents.

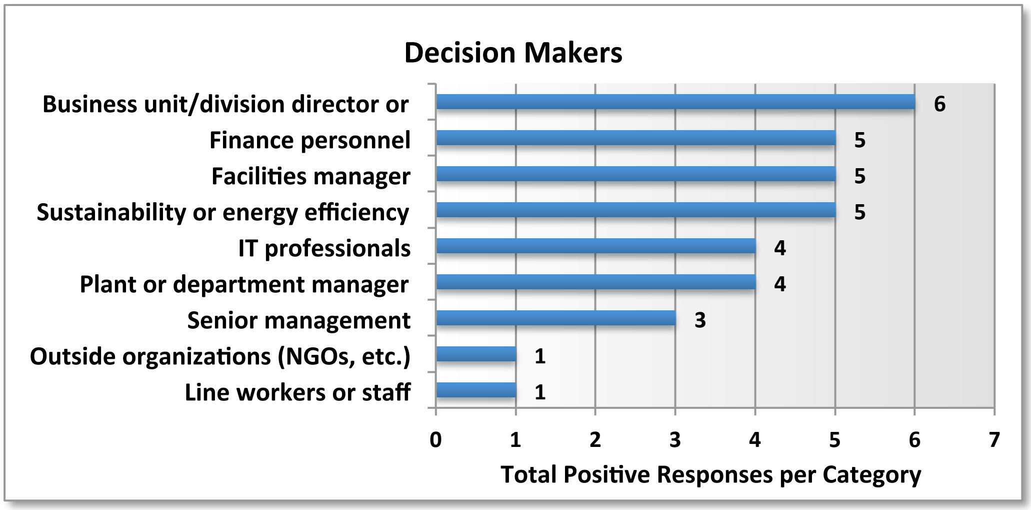


Figure 11 - Who is involved in decision to adopt a new EM practice or technology?

Implementation

Both the work and style of IT and operations departments vary, and there is little formal interplay between them. However, while network-based energy management technologies can bridge the gap between these parties, they first require collaborative planning and implementation of networks. Figure 12 shows who is responsible for implementing new energy practices once adoption has been established. The total number of positive responses per category was counted, with a possible maximum of seven, the total number of respondents.

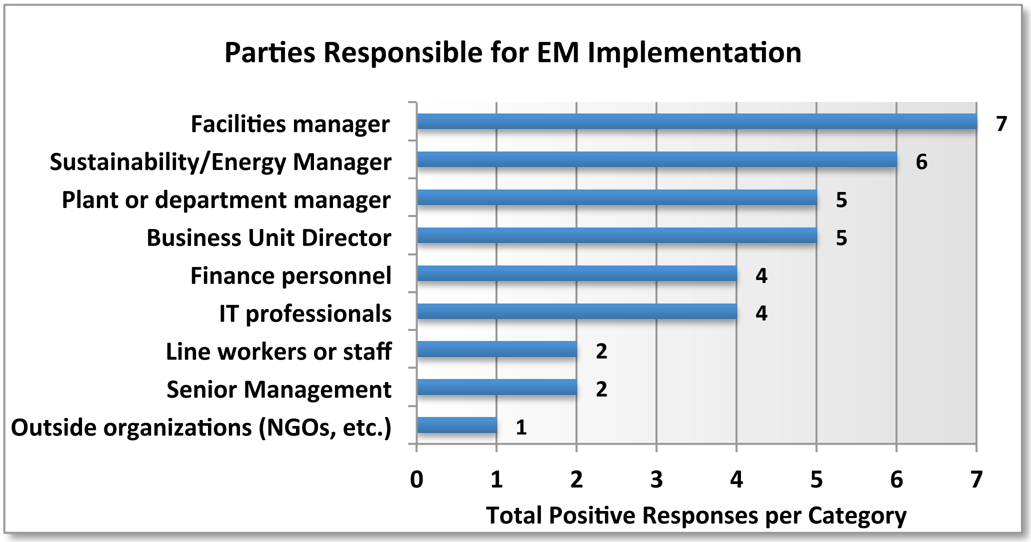


Figure 12 - Who is responsible for implementing a new energy management practice or technology once it has been adopted? (Number of total responses)

Broader Commercial Energy Trends

The Institute for Building Efficiency at Johnson Controls, Inc. collaborated with the International Facility Management Association to establish an annual commercial survey that would identify trends in the importance of energy efficiency from a wide variety of decision makers across many industries. Known as the Energy Efficiency Indicator, the 2010 survey solicited 1,435 respondents in healthcare, government, consulting, manufacturing, and many other sectors (IFMA 2010).

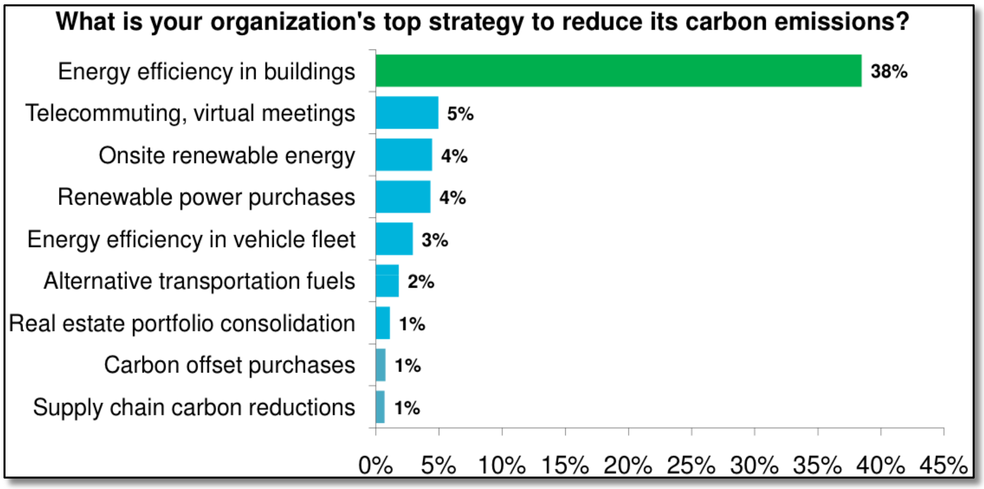


Figure 13 - The Importance of Buildings for Commercial Efficiency

Source: Johnson Controls EEI

Among respondents, building energy efficiency was listed as the most important source of GHG emissions reductions (Figure 13). The drivers for higher energy efficiency universally include cost savings, but GHG reduction and public image enhancement are also important motives (IFMA 2010).

Commercial Building Energy Management Technologies

Building Management Systems

Modern buildings contain a wide array of mechanical subcomponents including HVAC units (air-conditioning and chiller systems, boilers and heating units), pumps, lighting systems, air handling and distribution systems, water systems, electrical systems, building management systems (BMS), and others. These building systems are typically managed through proprietary control languages, and use independent wired networks to connect control hubs with network endpoints. This independence has a cost. Traditionally, most firms have developed their own proprietary communication languages and protocols to achieve both their technical and business objectives. As a result, streamlined, user-friendly data communication in multi-vendor systems is often cumbersome, if not impossible. This impediment has led to a push toward open protocols and a larger debate about the future of protocol standards and their incorporation into building EM.

With the advent of open control communication protocols, companies are increasingly enabling the cross-communication of devices on different networks. Some are taking the next step and are incorporating IT infrastructure and expertise to better manage and integrate various building elements. IT is increasingly improving business resource management through more detailed tracking and management of purchased utilities such as gas, oil, water, sewer, steam, etc., but networks will also be used to improve other important operating resources such as safety, comfort and productivity of building occupants (Capehart, Capehart 2007).

Increasing Building Management System Complexity

The BMS is the core operational technology for buildings, and has evolved significantly in the last few decades. Pneumatic controls and devices have been replaced by digital instrumentation and direct digital controls (DDC) that offer a higher degree of flexibility and information to the facility's managers. Building components are installed and upgraded in such a way that often yields a multi-vendor environment, yet many devices use communications protocols or unique computer systems that are still managed by proprietary software. As new open-protocols such as BACnet and LONWorks have boosted market share, they have enabled an influx of new open-protocol devices in the marketplace in recent years. Control interfaces that were once limited to hardwired, closed circuits are being replaced by open systems that can tie in with web-based control applications that feature scalable vector graphics that provide more realistic diagrams of systems, and offer the flexibility of being able to be resized for display on various media from PCs to large LCD monitors or small mobile devices (Bhusari, Brooks 2007).

These advances in BMS technology have increased interaction between various components. Modern buildings have a rapidly increasing number of information collection sources, and newer BMSs are becoming more reliant on data collection and management. This evolution is occurring at a rapid pace, and is challenging the ability of facilities operators to keep pace (Bhusari, Brooks 2007).

Energy Information Systems

How does a BMS facilitate energy management? By nature, BMSs have energy management capabilities embedded within their architecture, though the degree to which they lend themselves to this task can vary greatly from system to system. A BMS is a centralized system for controlling a building's core tasks on some of the components listed above. Some BMSs have highly sophisticated energy handling capabilities embedded within them and are formally considered to be Energy Management Systems (EMS). For this reason the terms EMS and BMS, and even BAS (Building Automation System) are, in many cases, used synonymously in practice. While the disparate building systems may have separate controls, an EMS is a centralized system that gives facilities managers the capability to monitor operational information from various sensor endpoints, or nodes. An EMS handles a wide number of sensor types, and can accept generic, programmable sensor types through the use of other user-created inputs such as relays. It has the ability to generate reports.

Some companies have designed their own Energy Information Systems rather than installing proprietary systems. For instance, as recently as 1997 the Disney company created their own EIS because the contemporary technologies were still nascent (Allen 2007). They used a conglomeration of devices they already had on-hand, including the server OS and hardware, and for the display of energy information through a web-based interface, they utilized web server software that had been packaged with the servers. Energy data was collected from energy management systems and meters and fed into an existing Microsoft Visual Foxpro database system, then displayed through the FoxWeb interface. The energy information that fed into Disney's EIS system came from several data collection sources, including monthly utility data (often this data can be downloaded from utility providers), SCADA power monitoring devices and local system meters, EMS data that was collected hourly, and data collection devices known as acquisuites (Allen 2007).

In the absence of energy management systems that record and display more granular data, commercial building managers can track energy consumption through monthly utility statements. Many utilities offer means of providing usage and billing information, with monthly reports and opt-in energy tracking software. For many companies, however, monthly bills provide all information for tracking energy, and these are available in as few as twelve data points per year. Some utilities will give access to more detailed data if available; in this case information is typically aggregated at 15-minute intervals. This data can be useful for showing high-level consumption over time and revealing trends, but there are many limitations to relying on utility data as the sole source since it doesn't provide insight into the usage of information.

In order for decision makers to set more efficient operational parameters for building components, feedback data needs to be as close to real-time as possible. For instance, if a building operator wishes to test the impact of adjustments to temperature setpoints, economizers or lighting timers, there may not be enough available information to correlate a change with the outcome, since many other variables such as climate data and user patterns may influence results.

A building's EMS is often administered through a standalone PC that may not networked to the enterprise LAN; in fact, networking an EMS may present challenges and even significant upgrade costs resulting from compatibility issues between proprietary EMS software and the native operating system required by the network. If networking of an EMS can be accomplished, however, EMS report data is a valuable source of information that can be delivered to a dedicated database and server that is contains energy details, known as an Energy Information System (EIS). Broadly defined, EISs are typically hardware/software solutions that allows for the monitoring of energy consumption in a building or system of buildings. Lawrence Berkeley National Lab considers EISs to include "software, data acquisition hardware, and communication protocols administered by a single company, a partnership, or a collective to provide energy information to commercial building energy managers and electric utilities" (Granderson et al. 2010). The last decade has brought a significant development in EIS that record and store a facility's energy data and allow for it to be shared over a network. EIS are widely available in the market, but terminology varies widely from vendor to vendor and feature comparisons are not available, it is challenging to understand how systems compare. The design and intention vary between brands; EIS span a broad category of devices that receive, store and organize information used by different stakeholders in a facility including operations personnel, energy or sustainability managers, or even executives. In Table 1, a few of the many popular EISs are listed.

Table 1 Some Available Energy Information Systems in the market

EIS	Vendor	User
The Resource Monitor	Agilewaves	Energy Managers
Utility Vision	Chevron Energy Solutions	Energy Managers
Automated Enterprise Management	Gridlogix	Enterprise
Building Mediator	Cisco Systems	Commercial
Enterprise Energy Dashboard	SAIC	Enterprise and Industrial Facility, Energy Managers
Vykon Energy Suite	Tridium	Facility and Energy Managers, ESCOs
Ion EEM	PowerLogic	Enterprise, Industrial

Source: (Granderson et al. 2010)

Applications for Energy Data

It is clear that more detailed building energy information will be of great value beyond simply providing a set of efficiency benchmarks. More precise levels of metering and data collection are critical for EMSs to effectively record and communicate the demand trends of a facility, and sub-facility level. The more individual building component information becomes available, the more control an operator has to adjust the power load to correspond with consumption patterns. This holds true at the individual building level, but the lesson can also be extrapolated to the scope of an entire economy. According to a report by the Federal Energy Regulatory Commission, the two most significant barriers to demand response (defined below) programs are challenges associated with measurement and verification of demand, and the lack of real-time information sharing (The Brattle Group, Freeman & Global Energy Partners 2009).

Economy-Wide Data

> *"Good data about energy efficiency in all sectors is vital to maximizing savings from the energy efficiency resource"* (Gold, Elliott 2010).

EIS Data is valuable for operations personnel and managers for planning purposes, benchmarking, and increasing operating and energy efficiency within an enterprise, but this data also has the potential to be useful for larger analysis of communities, regions and economic sectors.

At a federal level in the U.S., precise performance data could provide much more granular support for tracking efforts currently being performed by the Energy Information Administration's (EIA) *Annual Energy Outlook.* In 2009, the EIA indicated that state level data is important, and states can benefit from more itemized data expansion (Energy Information Administration 2009). The American Recovery and Reinvestment Act provided substantial funds to State Energy Offices, and better private sector data could more clearly reveal the return on these investments than utility-level data (Gold, Elliott 2010). Local governments might incentivize the sharing of this data in order to better understand local company and industry energy resource demands. With access, local governments can address unique needs of commercial ventures that are geographically specific. Municipalities will also reap the benefit of having clearer information so project prioritization can bring the highest return on investment (Gold, Elliott 2010).

The EIA publishes an *Electric Power Annual* survey, with reported information constrained to regulated and publicly owned utilities; this limitation poses a major impediment to gaining an accurate and detailed view of the productivity of demand-side programs such as energy efficiency, which are plagued by incomplete and inconsistent reporting (Gold, Elliott 2010). Good data from the field also has the ability to impact the evolution of performance-based energy building codes, offering empirical feedback regarding how design, construction and operation all influence end function (Gold, Elliott 2010). This can lead to more rapid development of higher performance buildings at a lower cost while lowering the risk associated with the investment. It is evident that robust data collected by energy information systems has potential applications far beyond the building-level, and as networks and management applications continue to develop to facilitate the sharing of this information, it will lead to more tractable community and regional energy management.

Enterprise Carbon and Energy Software

EIS information can be useful for energy and carbon reporting purposes, as well. Tools for tracking and managing these assets have long been valuable to companies, and as pressure builds across industries to better account for environmental impact, Enterprise Carbon and Energy Management software platforms have proliferated (Mines). This type of software used for tracking sustainability metrics has become readily available in the marketplace, with variations to suit the various commercial demands. Several offerings are listed below (Mingay, Miklovic & Stokes 2010):

- **AMEE-** Offers a tool for emissions management and reporting, and keeping up with the most recent changes in reporting standards and guidelines. The service aggregates tools that are publicly available from other sources into a central system.

- **Carbonetworks-** A tool for tracking and reporting GHG and energy consumption, and directly informing decision-making strategies at the executive level.

- **Lucid Design Group-** Provides a web-based dashboard of sustainability metrics including emission, energy, water, etc.

Data: The Value of Information

> *"Good energy policy is built on good data, and a sustained commitment to collecting adequate data is critical to meeting the country's future energy needs." (Gold 2010)*

In today's global economy, companies are looking to every part of their value chain to maximize margins, cut extraneous costs and use resources more efficiently. Information technologies have seeped into nearly every department in many companies, with the realization that the input for efficient and informed decisions is operating information. From a facilities standpoint, the COO is tasked with creating an environment that meets the needs of inhabitants, including communications, climate and environment, functional and safety requirements. This also involves the maintenance and commissioning of building systems. With aging properties and outdated building systems, limited information is present to assist management in knowing where the most important areas of focus are.

Getting Information

The COO needs the ability to benchmark performance. This may start with some high level questions:

- *How much energy did we use last year?*
- *How much did energy cost?*
- *How much did we pay in demand charges last year? Could manufacturing practices adapt to reduce these?*
- *What's the impact of a 1$/mcf change in natural gas prices, or a $0.01/kWh variation in electricity?*

These questions can be answered through an analysis of the utility bills, which are readily available. This information by itself is not very helpful, however, since it doesn't provide an indicator of efficiency or utilization. The next step might be to overlay the utility data against some known operating values such as building size, employees, inventory manufactured, operating hours, etc.

- *How closely does our energy consumption correlate to our productivity? To the weather?*
- *How does our equipment utilization correlate to our overall asset efficiency?*

Once this data is collected, it may provide a set of useful metrics, but the information is dated and static, and the effects of most improvement measures would require a very long verification period. Simply put, operators need better data, and much more of it. They need information that will empower them to make more informed decisions.

- *How much does it cost us to keep the building 2 degrees warmer?*
- *How much energy did we use this week? Today?*
- *How much of our energy was used for heating? How much on lighting? Running our office equipment and computers?*
- *What is the occupancy profile of each facility area? What % of the time do we light areas that are unoccupied?*

Data Management

In today's enterprise, departments throughout an organization are able to use Information Technology (IT) infrastructures to build complex solutions for data tracking and sharing, yet they are slower in fully migrating over to operations. Common practices include taking efficiency measurements in departments such as design and engineering, human resources, sales and service, procurement, fabrication, assembly, marketing and IT.

For instance, one might compare the level of detail by which energy is observed with that of how customers are tracked by human resources. HR keeps extensive information on globally dispersed employees in a database including statistics such as benefits, payroll, time keeping and performance reviews. Sales and service departments manage customer relationship databases in conjunction with marketing departments. Upon entering order information online, new customers are automatically entered into a shared system that updates in real-time, lending accessible information by all departments immediately upon entry.

IT departments use power distribution units (PDUs) that measure and record power draws of each server in a storage rack. They use that data to determine how efficiently their machines are operating by examining computing work per watt expended, or a similar metric. Aggressive sleep and power-down measures are set on PCs, but don't have the ability to verify the resulting energy savings. By contrast, a manufacturing operation's antiquated approach of tracking assembly progress manually is insufficient when compared to modern, automated techniques that rely less on human input. These take advantage of barcodes and RFID tags to precisely trace inventory flows throughout the assembly process.

Electrical energy consumption is an expense associated with every electronic device in the company, and the absence of precise and timely data about how this energy is being used impedes efforts to improve efficiency. A lighting system that possesses the ability to quantify and communicate its own energy usage at the fixture, ballast, or room level could give operators the ability to calculate power density in many terms such as of watts per ft^2 or watts per person. A lighting fixture with the capability to communicate with other systems such as motion, light or CO_2 sensors, could drive a database that enables a manager to associate on-time with user occupancy. Better data collection from HVAC systems could ensure efficient operation and guide commissioning and maintenance schedules.

The goal should be a central database that is continually populated by regular interval data from points throughout the building. Similar to the situation in other divisions of the enterprise, the data collection is only the first step. The data must then be aggregated into a centralized database and made available for analysis, pattern identification, forecasting and trending. The system would reach its potential in conjunction with a central data management system that could store the data and give flexible, remote access to the operations staff.

D. Network-Based Energy Management: Convergence of IT and Energy Management Systems

Energy Information Systems bridge a gap between operations, the organizational division normally tasked with overseeing enterprise-wide energy expenditures, and IT, the organizational division with the most proficient information and database administration. A collaborative approach is needed between energy managers and IT staff to properly set up data inputs to an EIS and confirm that information is being properly stored, and adequate implementation of the EIS will likely require more collaboration between these departments. Commercial operations stand to benefit from IT's data-handling proficiency, and IT's capacity to better integrate with building operations will become a more customary source of organizational efficiency. Despite the urgency of this transition, the organizational transformations necessary to bring together operations and IT departments are not free of hurdles.

Convergence of IT and Operations Technologies

Commercial Operations Technology

Organizations invest time, personnel and financial capital into the acquisition and administration of technologies that support their core operational functions. Gartner, a leading IT research and consulting firm, defines Operational Technology (OT) as:

> *"systems that deal with the actual running of assets and used to ensure system integrity and to meet the technical constraints of the system. They are event-driven and frequently real-time software applications or devices with embedded software. They control technology processes through devices or sensors used to manage the energy production or delivery processes. Perceived as mission-critical, the requirements frequently exceed standard solutions available for IT"* (Roberts, Steenstrup 2010).

OT is handled in various departments in an organization, controlling a variety of hardware assets- building management components, cash registers and refrigeration units, for example. IT is generally considered to include software, hardware, communications infrastructure and information processing technologies. Put another way, "OT is fundamentally about computers interacting with machines, and IT is about computers interacting with people" (Prior, Schulte & Steenstrup 2011).

OT includes a wide range of electronic equipment throughout various industries. In the transportation or freight industry, it might include navigation or tracking capabilities, mainframe computer systems or radar. In the healthcare industry, it might include imaging machinery, sensing equipment or support appliances. A common set of energy-reliant OT assets is that of commercial building system components discussed previously, including HVAC machinery, alarm systems, etc. Commercial building electronics are complex networks of components listed above, and they require large amounts of energy. In fact, they consumed approximately 19% of the total energy used in the U.S. in 2009 (U.S. Energy Information Administration 2011).

Despite challenges, operations technologies and IT are converging in a variety of industries, and the many benefits include the streamlining and optimization of organizational processes, risk management, and savings in time and money. Costs are reduced through shared standards and platforms, and common resources such as cybersecurity can reduce risks (Steenstrup 2011)(Prior, Schulte & Steenstrup 2011).

Barriers to Convergence within the Traditional Framework

Effective utilization of IT technologies for operations purposes such as EM will require the support, buy-in and expertise of both IT and operations staff. Institutional barriers such as the highly distinct cultures of the two groups (Illustrated in Table 2) impede this collaboration, so there is often very limited interactive strategy between the two divisions. A vendor with an operations-oriented device will be directed to the operations staff within an organization. Likewise, IT vendors generally meet with IT personnel. Vendors carrying devices that operate across IT and OT will have a difficult time setting up cross-divisional meeting with both groups together.

Companies such as Trane, Johnson Controls and Honeywell are proficient in the facilities engineering aspect of the business, and are adept at communicating with customers in a way that expresses that expertise. IT leaders such as Cisco or IBM converse with their clientele in a way that is uniquely suited to that audience. The communication styles and behavior of IT and operations teams have moved in a different directions over time, reinforcing the division between these departments (Roberts, Steenstrup 2009).

A common example of the convergence of OT and IT can be seen in the hospitality industry. Hotels have, for some time, been managing bookings and reservations through internal and third party websites, and using booking information to manage operational factors such as occupancy, maid service scheduling and meal preparation. During guest check-in, reservation databases communicate with in-room thermostats and heating/cooling units, prompting an uninhabited room's temperature settings to shift from standby to a thermally controlled environment.

With the assistance of occupancy sensors or key card activators, uninhabited rooms can remain in a more efficient standby mode when unoccupied, yet quickly respond upon guest arrival. The incorporation of IT into standard hotel operations saves time and coordination effort, improves guest comfort, streamlines climate control, and makes user patterns available to staff to improve the guest experience.

Table 2 Comparing the nature of IT and Operations

	Information Technology	Operational Technology
Purpose	Provide information, Provide service and information	Manage Assets, Control processes
Architecture	Enterprise-wide infrastructure and applications	Real-time, Event-Driven, Embedded Hardware/Software
Interfaces	GUI, Browsers, Terminal	Electromechanical, Sensors, Coded Displays
Ownership	Computer Science Experts, CIO	Engineers, Technicians, COO
Connectivity	Corporate Network (IP-based)	Control Networks
Role	Support People	Control Machines

Source: Adapted from (Roberts, Steenstrup 2009)

Enterprise Building Management Systems

A successful example of convergent IT and OT systems is the Enterprise Building Management System. Campuses such as office parks and universities manage controls and automation systems across many different buildings that contain an assortment of devices from many vendors. Some campuses are taking advantage of a recent development known as Enterprise Building Management Systems (EBMS), which integrate disparate automation systems into a single graphical user interface (GUI) with the help of IT (Bhusari, Brooks 2007). The power of these tools lies in the information they consolidate and organize. Numerous EBMS capabilities include preventative maintenance, scheduling, alarm management, simplification and automation of building functions, and diagnostics (Bhusari, Brooks 2007).

E. Factors Shaping the Future of Energy Management

Government policies and programs, carbon markets, and other drivers will heavily influence energy management technology development for commercial and industrial settings, as well as adoption rates for these technologies. Since government requirements and incentives can propel markets, technology developers should stay abreast of current and expected legislation.

2011 Federal Budget

A priority outlined by the President's 2011 $28.4 billion Department of Energy budget is that it

> *"[encourage] the early commercial use of new, innovative energy technologies that will reduce greenhouse gas emissions."*

Additionally, the budget provides support for DOE loan guarantees for innovative energy technologies (for a total of $54.5 billion), including

> *"$500 million in credit subsidies to support $3 to $5 billion in loan guarantees for energy efficiency and renewable energy projects. The loan guarantee program will continue to support a range of commercial renewable energy programs and other facilities that help reduce pollutants and greenhouse gases while simultaneously creating clean energy jobs and contributing to long-term economic growth and international competitiveness"* (US White House Office of Management and Budget 2011).

This budget support for energy efficiency and renewables will boost the market in the short term, but will likely have a longer lasting positive impact on demand for EM products.

Policy

The recent economic recession led to the U.S. government incentivizing energy efficiency substantially through stimulus package. Existing provisions in the American Clean Energy and Security Act of 2009 (H.R. 2454) for energy efficiency measures could save energy worth $400 billion by 2030 and nearly $470 billion by 2050.

Reporting Requirements

In an effort to effectively implement energy efficiency measures, the DOE is requiring more open reporting of energy use data for appliances in the residential and industrial sectors. By authority of the Energy Policy Conservation Act of 1975, the DOE can enforce baseline energy performance levels for appliances, and in the case of noncompliance, deliver fines or penalties to manufacturers that fail to meet standards. The DOE will, as a result of this transparency, confer certification to appliances that meet defined standards, and consumers will have more information to inform their purchasing decisions. To ensure compliance, the DOE will review certification and performance data of manufactured products.

US Energy Efficiency Standards Reinforced

A number of industry groups including the Alliance to Save Energy (ASE), the American Council for an Energy-Efficient Economy (ACEEE), the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), the Natural Resources Defense Council (NRDC) and many others, signed an agreement along with furnace and air conditioner manufacturers to establish regional energy efficiency standards for HVAC appliances, tightening new construction standards. Since climate varies dramatically with geography, the standards differ for each of three climate regions: North, South, and Southwest. Regional standards of this type are allowed under the Energy Independence and Security Act of 2007. The stricter standards require both new and old buildings be refurbished with appropriate insulation, but also attempt to provide greater regional flexibility in standards while supporting a more uniform marketplace. With regard to energy, the agreement will save an estimated 3.7 quadrillion Btu of energy, and approximately $13 billion in present value over the next twenty years. By the end of that same period, the annual abated emissions will total approximately 23 million metric tons CO_2 (Kweller 2009).

American Recovery and Reinvestment Act (ARRA)

In 2009, the US congress passed the American Recovery and Reinvestment Act (ARRA), a bill that has encouraged investments in clean energy as a means of spurring the US economy. $16.8 billion, or nearly half, of the funds were allocated to energy efficiency. The ARRA has also extended tax incentives that were part of the Energy Policy Act 2005 (EPACT). ENERGY STAR rated appliances are also eligible for Federal Tax Credits for energy efficiency measures (GlobalData Analysts 2010b, GridWise Alliance 2011a).

Modern Energy Efficiency Regulation

Economies across the globe are responding to the market opportunities associated with clean energy and more efficient operating technologies. Recent legislation, including the national energy policy delivered by the Energy Independence and Security Act, the American Clean Energy and Security Act, the American Recovery and Reinvestment Act, and the Emergency Economic Stabilization Act further supports the market for efficiency technologies. The American Clean Energy and Security Act (2009) made many provisions for energy efficiency that are estimated to save $400 billion by 2030 and nearly $470 billion by 2050 (GlobalData Analysts 2010b). The investments in energy efficiency measures will also create jobs, ensure energy security, and drive innovations by stimulating research and development of new technologies, as well as support the commercialization of many existing technologies.

EnergyStar

One of the Federal Government’s best known and organized efforts to promote energy efficiency in residential and commercial markets is the Energy Star program. Energy Star provides guidance to facilities personnel on ways to better manage energy through a programmed set of procedures including goal setting, creation of action plans, assessment and progress benchmarking and recognition of achievement. Energy Star also has a system of tools that enable tracking of water and energy consumption within buildings, rating of building performance, energy performance targeting in new and existing buildings, and carbon footprint calculation tools (US EPA, US DOE 2011).

The International Code Council (ICC) has developed a set of widely recognized building efficiency standards known as the International Energy Conservation Code (IECC). Those international codes have influenced regional codes since being developed by national experts through the ICC. The IECC codes often serve as a launching point for various groups that are producing codes or standards for efficiency(International Code Council 2010). For example, standards developed by utility companies in various regions of the United States have been shaped by the IECC, but perhaps exceed the commonly accepted requirements for efficiency performance (GlobalData Analysts 2010b).

IT Energy Efficiency & Policy

The ICT industry is seeking ways to improve efficiency across devices and infrastructure. For instance, the Digital Energy Solutions Campaign (DESC), hosted by the Information Technology Industry Council (ITI), was launched in 2008 as an effort to bring ICT companies and associations together with NGOs and other stakeholders to focus on how ICT is essential for achieving environmental impacts (DESC 2011). As ICT markets are expected to continue rapid growth, the sector will become increasingly important to target for efficiency measures.

Carbon Policy and Markets

Network-based EM technologies, including EISs, can streamline reporting of energy and carbon metrics. This is a significant advantage in geographies that have widespread carbon markets.

The global market for carbon allowances was roughly $10 billion in 2005, and two years later exceeded $60 billion. From 2007 to 2008, the market approximately doubled, but as a result of the global recession only increased marginally the following year. Many large companies sold their voluntary allowances as a means of increasing liquidity (GlobalData Analysts 2010a).

The European Union is a leading driver of expanding carbon-trading mechanisms. The potential for a cap-and-trade program in the US, as well as emerging voluntary trading systems are indicative of high future growth in the carbon market. In 2011, the global carbon market is worth approximately $200 billion, but is projected to exceed $500 billion by 2013, and $800 billion by 2017 (GlobalData Analysts 2010a). Project-based transactions in the carbon market declined annually from 2007 to 2009, but this decline was overshadowed by the continued growth of the most substantial component of the market allowances (GlobalData Analysts 2010a).

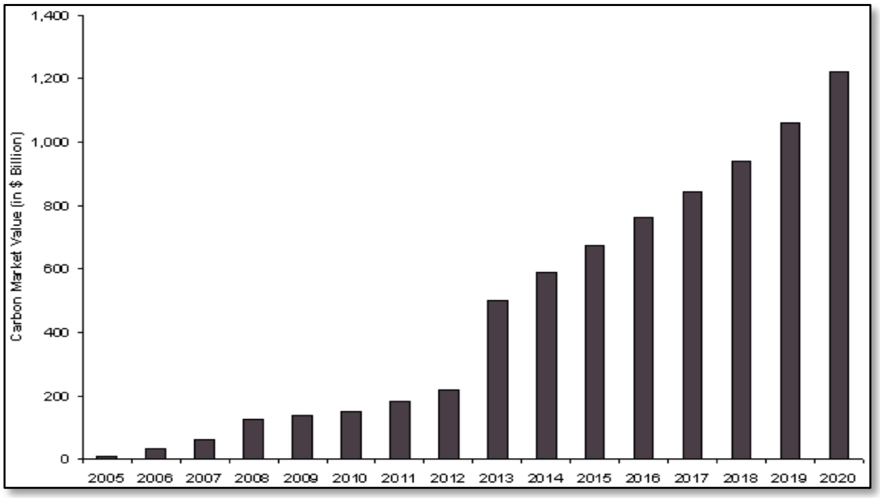


Figure 14 - Global Carbon Market Value, ($ Billion)
Source: GlobalData (GlobalData Analysts 2010a)

Carbon Regulatory Action in Europe

On April 1, 2010, the UK started the *Carbon Reduction Committee Energy Efficiency Scheme*(CRCEES), a regulatory program designed to reduce carbon emissions through increased energy efficiency. The scheme is supported by legislation that passed through the Climate Change Act of 2008 (British Department of Energy and Climate Change 2010). As a result of this bill, thousands of companies were mandated to evaluate, assess and report energy consumption data and report carbon emissions. The purpose of the scheme is to prompt reductions of 4 $MtCO_2$ per year of GHG emissions and reduce utility costs annually by £1 billion ($1.63 billion USD) by 2020. Effectively, companies must measure and assess their energy usage and carbon emissions, then report these numbers to the UK Environment Agency. Failure to report these numbers, or emissions that exceed targeted emission targets will result in a fine and/or receive a carbon tax. Revenues from this program will be used to support the carbon market and encourage more prolific trading of carbon allowances (GlobalData Analysts 2010a). As discussed previously, EIS can simplify the task of reporting this information.

Impact of Efficiency/Renewables Programs on Carbon Trading

Some areas of the US are pursuing strategies for incentivizing GHG reduction. An example of such a program is the Regional Greenhouse Gas Initiative (RGGI). RGGI is a cooperative non-profit corporation composed of ten states including Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont (RGGI 2011). The program has instated an emissions budget cap and trade system, including requirements for fossil fuel based utilities, provisions for carbon allowances and offsets. The program uses a tracking system to record and monitor emissions data among regulated power plants and market participants (RGGI 2011). Commercial program participants in the RGGI have experienced many benefits, including energy savings in various industries from healthcare and chemicals to paper manufacturing and grocery markets. Jobs have been created, and buildings have been upgraded with new technologies to boost efficiency.

Additional EM Adoption Drivers

Energy Service Companies

Fueled by aggressive Federal support of commercial energy efficiency projects through the ARRA, Energy Service Companies (ESCOs) have increased their activities to help companies save and manage energy. Lawrence Berkeley National Labs defines an ESCO as:

> *A company that provides energy-efficiency-related and other value-added services and for which performance contracting is a core part of its energy-efficiency services business. In a performance contract, the ESCO guarantees energy and/or dollar savings for the project and ESCO compensation is therefore linked in some fashion to the performance of the project* (Satchwell et al. 2010).

ESCO companies, by this definition, enter into long-term contracts with clients and are mostly dependent upon their clients' success for their own compensation. Approximately 75% of ESCO revenues are derived from Energy Efficiency projects, with onsite renewables accounting for an increasing share of remaining revenues. Consulting and master planning comprise a smaller portion of ESCO income than in the past, around 3% of total earnings (Satchwell et al. 2010). Below is a projection of earnings in the ESCO industry, showing the impact of a global recession on companies' investments in retrofits.

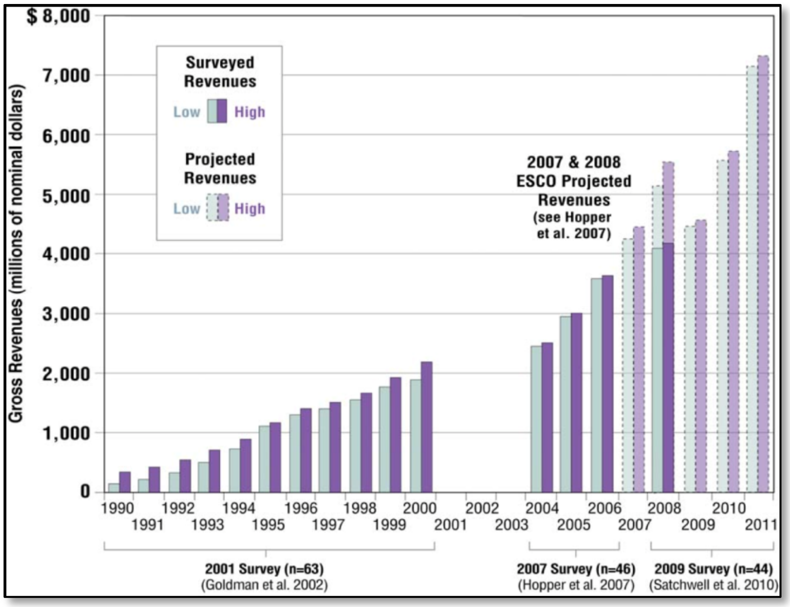


Figure 15 - Aggregate ESCO industry revenue from 1990 to 2008 with projections
Source: Lawrence Berkeley National Laboratory

The economic downturn has affected ESCO business activity in several ways. The building sector experienced its worst slump in decades after an unusually strong market. Real estate investors, as well as commercial businesses and industries, had expressed much interest in *greening* both facilities and operations through retrofits and technology upgrades, but the capital requirements for efficiency investments were a deterrent as firms tightened up on spending (Satchwell et al. 2010). In addition to a general reluctance to invest heavily in retrofits during a recession, there are much higher barriers to accessing the capital necessary to finance these projects. ESCOs seek investment financing to support projects, and tightening credit led to financing institutions freezing their loan programs, only to later reinstate them at higher rates and with shorter contract terms (Satchwell et al. 2010).

Utility Rebate Programs

In the US, many public utilities have developed energy efficiency programs that are designed to reward the cost-saving measures taken by customers to reduce energy consumption, essentially further incentivizing demand-side management (DSM) by subsidizing customer purchases of new, more efficient equipment. Incentives are often rooted in a reduction in power demand on a watt basis, or determined by projected consumption abatement on a kWh basis. For example, through a hypothetical utility, a facility operator might submit a proposal to get reimbursed $0.40 for each watt that is reduced by the replacement of existing lighting fixtures with more modern, efficient lights such as florescent fixtures or LEDs. Rebates could be given for replacing inefficient or overpowered motors, insulating windows, or simply removing unnecessary space heaters. The programs are usually funded through surcharges on utility bills, or through fees known as tariff riders that recover rebate costs from customers through another avenue.

Smart Grid

What is the Smart Grid?

Generally, smart grid refers to the collection of technologies that will comprise the next-generation electric grid. It is expected to be the marriage of an updated electrical transmission and distribution system with an IT-enabled control and communications infrastructure. There are differing visions of what a smart grid will look like. Some expect that the characteristics of the grid will vary from region to region depending on local circumstances – reliability may be most important in New York City after the failures of 2003 that led to blackouts, while power quality may be most important in Silicon Valley (The Economist 2009).(The Economist 2009, The Economist 2009)(The Economist 2009, The Economist 2009)(The Economist 2009, The Economist 2009)(The Economist 2009, The Economist 2009)(The Economist 2009, The Economist 2009) It seems to be widely agreed, however, that the smart grid will integrate hardware, software and telecommunications technology into the electric infrastructure to:

- Enable consumer participation to actively manage demand thereby reducing peak demand
- Balance consumer reliability and power quality needs
- Mine energy efficiency opportunities proactively

- Optimize asset utilization and improve overall operational efficiency
- Seamlessly integrate all clean energy generation and storage technologies
- Anticipate and respond to system disturbances (self-heal)
- Operate resiliently against attack and natural disaster(GridWise Alliance 2011b, Pratt et al. 2010)

Demand Response

The discussion of EM to this point has focused largely on reducing organizational energy use through improved internal data and control systems. The goal of demand response programs is to make aggregate energy use more efficient by providing individual customers with external data in the form of electricity prices. Demand response works by using two-way communications between utilities and electric customers to deliver real-time information about customer demand to utilities and information on electricity prices to customers. Some examples of demand response electric pricing schemes are peak pricing and real-time pricing. Customers can adjust to higher electricity prices by reducing their use, shifting use to a period when system demand is lower, or generating their own electricity (National Action Plan for Energy Efficiency 2010).

Demand response has the potential to reduce peak electricity demand and thereby reduce system wide generation capacity requirements and costs. In 2008, the Federal Energy Regulatory Commission (FERC) estimated that demand response resources (customers able to reduce usage as part of a demand response program) were 5.8% of national summer peak demand (National Action Plan for Energy Efficiency 2010). Furthermore, coordinating demand response and EM programs creates opportunities for improved efficiency and better allocation of resources. A 2009 Electric Power Research Institute (EPRI) Study estimated that by 2030 the coordination of demand response and energy efficiency programs will have the potential to reduce summer peak demand by 14-20% below projected levels (National Action Plan for Energy Efficiency 2010).

Utilities, independent system operators (ISOs), ESCOs and curtailment service providers (CSPs) are expected to drive this coordination with some additional help coming from new building codes and appliance standards. A number of ESCOs and CSPs have indicated that Total Energy Management (TEM), the integration of energy efficiency and demand response, would be beneficial for many commercial, industrial and institutional customers. As part of a TEM service, ESCOs and CSPs would improve customer EM systems and strategies to minimize peak demand charges while maintaining adequate service levels from electric systems. They would also provide energy information services and act as an overall energy advisor (National Action Plan for Energy Efficiency 2010).

While demand response has potential to reduce energy costs, some organizations with EM experience have doubts. Energy efficiency investments generally have predictable benefits, while demand response benefits vary from location to location and over time depending on the demand response program put in place by the local utility. Additionally, demand response can be disruptive if it requires participants to dim lights, raise temperatures or shutdown production processes. Over time, however, it is expected that new technologies will help address these issues and enable coordination between EM and demand response. Researchers at the Lawrence Berkeley National Laboratory state that “as demand-response enabling technologies (control and communication systems) and price information become more sophisticated and widely accessible, customers should realize direct benefits, and their perceptions of demand response should shift from the belief that demand response involves extra effort and sacrifice to the realization that it is discretionary and easy for chosen applications”(National Action Plan for Energy Efficiency 2010). Both demand response and EM depend on monitoring, communications, analytics and control technologies for systems that consume energy. Researchers expect that advances in control and communications technology will make demand response more automatic and at the same time enhance EM by enabling continuous site commissioning. As organizations make investments in each area to improve their energy efficiency and reduce costs, there will be natural incentives for the development and adoption of technologies that take advantage of the synergies between the two areas (National Action Plan for Energy Efficiency 2010).

Advanced Metering Infrastructure – Smart Meters

Advanced Metering Infrastructure (AMI) refers to new digital power metering systems capable of recording near-continuous power data with remote communications and control capabilities. These “smart meters” enable the collection and transmission of detailed, real-time energy usage data from energy customers to utilities. At the same time, they enable utilities to transmit energy pricing information to customers. AMI represents the integration of information and power technologies capable of linking consumers and electric system operators (National Energy Technology Laboratory 2008).

AMI is a foundational smart grid technology. By the end of 2009, more than 76 million smart meters were installed in the U.S., and are expected to reach 155 million by 2013 (The Economist 2009). This wide-scale deployment of AMI is expected to remove a major barrier to dynamic pricing. Dynamic pricing is the transmission of electricity price signals to small consumers. This development will increase the prevalence of demand response as a method of reducing peak electricity demand.

While the technology is developing rapidly, there are concerns about smart meter interoperability. Dozens of companies are currently producing smart meters, and in its 2008 report on AMI, the National Energy Technology Laboratory emphasized the need for open standards to ensure interoperability, drive down costs and assure utilities that large AMI investments would not become obsolete and unserviceable if their manufacturer fails in the long term (National Energy Technology Laboratory 2008).

The importance of energy use data in regard to network-based EM highlights the necessity of AMI. As AMI becomes a more prevalent and important part of the country’s energy infrastructure, EM systems will need to seamlessly interact with them in order to effectively minimize energy costs. This has implications for the adoption of open communications standards used within network-based EM systems.

Smart Grid Drivers

Linkages between network-based EM and the smart grid clearly exist. However, these linkages will not drive decision making by businesses and utilities unless there is a high degree of regulatory and financial certainty around the smart grid. So what is driving the development of the smart grid? Governments are one critical driver. Many of the world's major economies have earmarked stimulus money for smart grid development during the recent recession (The Economist 2009). In 2009, ARRA allocated $4.4 billion to modernize the U.S. electric grid (GridWise Alliance 2011a). Additionally, the Energy Independence and Security Act of 2007 prompted many government agencies, such as the DOE, FERC and EPA, to establish programs and guidelines to aid smart grid development (GridWise Alliance 2011a). The business world is also involved in making smart grid a reality. Since 2004, American venture capitalists have invested over $1 billion in smart grid start-ups. Blue chip companies are joining in as well – Siemens, IBM, Google, and Microsoft, among others, have launched smart grid initiatives (The Economist 2009). These levels of funding and involvement indicate that a smart grid is well on its way to becoming reality.

Implications for development of network-based energy management

In practical terms, creating a smart grid means incorporating sensors, digital meters, IT-based communications and control networks, and consumer information interfaces with the electric grid (Pratt et al. 2010). Since these components are also necessary for network-based EM systems, there will be increasing overlap between EM and smart grid infrastructure in the future (GridWise Architecture Council 2007). Demand response initiatives will create incentives for an ever-wider array of energy-consuming devices to be enabled for real time pricing and remote control. In order for devices operating under disparate network-based EM systems in different organizations to respond in a coordinated way to grid signals, there needs to be a common form of communication. An interoperability framework and associated standards and protocols that focus on communications between the various participants in the smart grid, including the Independent System Operator/Regional Transmission Organizations, utilities and end customers, will be necessary. An open communications protocol that is used by both smart grid and network-based EM systems will be essential for making the energy infrastructure as efficient as possible.

III. Network-based EM at Universities

Understanding the University Environment

University and college campuses, similar to the commercial building sector, are increasingly engaging in energy management (EM). As research and implementation of EM approaches in this area grow, it is important to understand the hallmarks of a university environment and their impact on campus EM adoption. Factors such as the mission of the institution, unique stakeholders, and the technical needs of the campus each play important roles in determining the nature of technology selection and long-term management.

In many ways, universities resemble small cities. They may generate and distribute their own energy, have independent governing structures, large land holdings, a population that rivals many towns and infrastructure to support their many facets. For this reason, some in the EM arena see campuses as prime ground for exploring systematic, and sometimes network-based, EM approaches. As a group of information technology professionals from the University of California system express:

> *"Today, those of us in higher education have the opportunity to recommit ourselves to enabling societal transformation by using our campus "cities" as proofs of concept for the green infrastructure revolution. By focusing not only on how we can make our campus cyberinfrastructure more energy-efficient, but also on how we can use that cyberinfrastructure for even larger energy savings in our building and transportation infrastructure…"* (St. Arnaud et al. 2009).

With a city-like level of opportunity comes the associated complexity. In order to understand how EM approaches can best be assessed and implemented in a university setting, it is necessary to establish an understanding of both its cultural and technical nuances.

The University's Role in Society

Universities have long held an esteemed position as bastions of progressive thought, the training grounds of future leaders and trend spotters in a world of rapid change and innovation. Dr. Franz Todtling, of the University of Vienna, aptly describes universities as "antennas", capable of capturing knowledge and diffusing it through their many connections with students, researchers and industry (Todtling 2006). This role in society provides universities with the opportunity and responsibility to pursue new thought and solutions to a wide range of challenges. The movement toward improved EM is one such solution set that the university 'antenna' has registered. The ways this new knowledge is distributed throughout the community, internalized operationally and educationally, and collaborated upon with industry are varied, but decidedly active. How are universities viewing and responding to this trend?

Campus EM activity exists both at individual institutions and across higher education as a whole. Groups of peer universities interested in EM have emerged on the regional and national level. The American College and University Presidents' Climate Commitment (ACUPCC) is one such movement. With over 670 signatory institutions, the ACUPCC represents a significant move toward improved campus resource use and climate change mitigation planning. Membership in this alliance requires the implementation of detailed action plans and regular reporting on goal achievement. This coalition also fosters the development of a network of institutions that are able to share best practices across universities. The ACUPCC mission "…is to accelerate progress towards climate neutrality and sustainability by empowering the higher education sector to educate students, create solutions, and provide leadership-by-example for the rest of society" (Presidents' Climate Commitment 2011). While EM is just one facet of the work being done by ACUPCC signatories, it is at the heart of the emerging university action plans.

As awareness of sustainability grows in society at large, so it has as a competitive factor among peer universities in the effort to attract students. The 'green' metric has been quantified and applied to universities in critically received publications like the Princeton Review (Educause 2009). Students' perception of the value of this element of their educational experience, and their relative satisfaction with that education are an indicator of how well the university is fulfilling its educational mandate (see student stakeholder discussion for further detail). Students represent not just the cultural core of the university, but their primary revenue source. Therefore, the university's ability to recognize this increasingly important element of their mission will determine their success both educationally and financially. In the end, recognizing and addressing this trend will assist universities in maintaining their established societal role.

University Stakeholders

The stakeholders who inhabit universities drive their institutions approach to adopting new concepts. Their motivations, needs, and characteristics vary considerably, and therefore demand a wide range of support and expertise from the university. Among these stakeholders are a few core groups: students, faculty, staff, institutes & organizations, and alumni. Each of these players strives to achieve the university's thought and action leadership mission, but in manners that result in different behaviors, needs and, ultimately, energy use.

This diversity of stakeholder actions and perspectives has an impact on the university's approach to EM, both from an acceptance and execution point of view. For example, how might the activities of an undergraduate student impact energy usage as opposed to an electrical engineering professor? How do we understand what energy means to an administrative staff member, versus a facilities professional? Most importantly, how can we use current and developing technology to get a better picture of the implicit and explicit connections that exist among these groups with regard to campus energy at large? These questions just scratch the surface of a network of interdependent, though not always recognized, energy-related questions at play at universities as a result of their diversity.

Universities have attempted to knit together this network of often disparate stakeholders in order to pursue sustainability efforts, but have encountered a handful of relatively ubiquitous challenges. Among these are uncoordinated or duplicative efforts as a result of lack of communication, disconnect between action and incentives, and a general lack of high-level leadership or political will (Kinsley, DeLeon 2009).

An overview of two of the primary cultural stakeholder groups unique to universities, students and faculty, is necessary to understand the nature of this environment and what differentiates it from the larger commercial building arena. This will be followed by an overview of two of the technical groups, Information Technology and Facilities Management that are tied to energy management in this environment.

The Role of Students

In most universities, students are the single largest stakeholder group. Their influence comes from a dominance of numbers, their role as the university's primary revenue source and their group norms and 'personality'. While most commercial settings are predominantly populated with employees paid to be there, students are unique in that they provide tuition for their experience. As such, their demands of the university are two-fold: that they receive the best possible education and at the greatest value for the tuition. This theme of balance between user experience and efficiency is common throughout EM, and is solidly present with students in the campus environment.

One of the primary challenges of EM is establishing and understanding energy use norms and patterns. This is a difficult proposition in a student-dominated environment. Students' often-erratic use patterns present a challenge for university energy managers. While other commercial employee occupants may have a regular nine-to-five use pattern, student life lends itself to far more sporadic energy demands. For example, a student may spend a couple of hours in a dormitory, attend class, meet a group at a student union for coffee, attend an athletic event and then study in the library until 2am, only to have a completely different schedule the next day. Unlike most commercial settings, all the actions that take place on a university campus are powered, and supported by, university infrastructure and staff. Developing an EM system that allows the university to be nimble enough to respond effectively to erratic student patterns is no easy feat. Increasingly 'smart' technologies such as network-based EM are necessary to achieve a more holistic view of these behaviors and to orchestrate appropriate responses to these needs.

Students also play a key part in driving the nature of conversations at the university. They can be one of the most sensitive elements of Todtling's antenna. As the primary 'customer' of the university, student requests for information, their perspective on campus dynamics and role as proponents of change are critical to the real and perceived success of the institution as a whole. Understanding their mindset about sustainability generally, and EM in particular, are key pieces of a university's EM efforts.

A recent study conducted by IBM investigates what that mindset looks like. This study provides a perspective not only on students' views of sustainability, but does so in comparison to current CEOs and leaders in the larger commercial setting. This is a window into the views of future leaders in the context of existing perspectives and management. The study identifies several predominant themes relevant to EM. The first is the students' perception of the importance of future natural resource scarcity, as seen in Figure 16 and Figure 17 - Students are substantially more focused on sustainability than CEOs (IBM Institute for Business Value 2010). (IBM Institute for Business Value 2010). Second, is the value of an understanding of sustainability as a critical leadership trait (Figure 18). Third, is the perception that data is the key to mitigating future risks and challenges and a preference toward data-driven decision making (Figure 19). Lastly, the study provides an indicator of how well students believe that universities are preparing them to face various challenges, including sustainability (Figure 20).

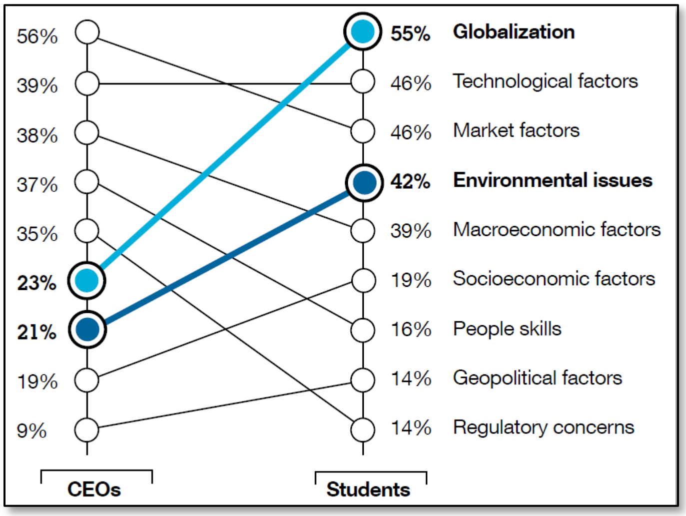


Figure 16 - Respondents' choices for the top three factors that will impact organizations (IBM Institute for Business Value 2010).

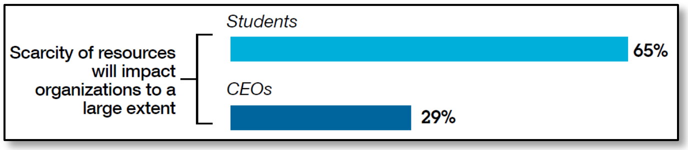


Figure 17 - Students are substantially more focused on sustainability than CEOs (IBM Institute for Business Value 2010).

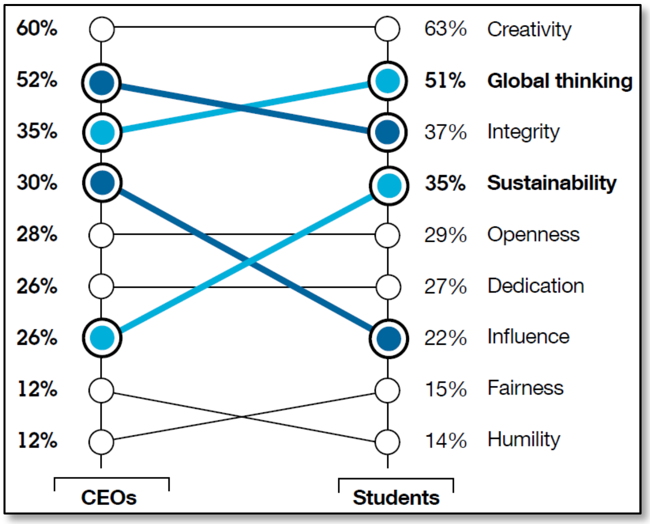


Figure 18 - Respondents' choices for top three leadership qualities (IBM Institute for Business Value 2010).

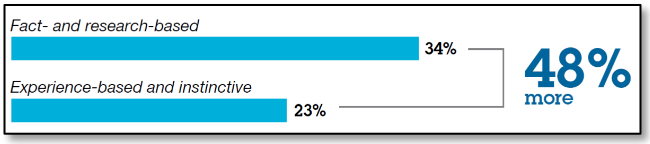


Figure 19 - Students' preferred style of decision-making (IBM Institute for Business Value 2010).

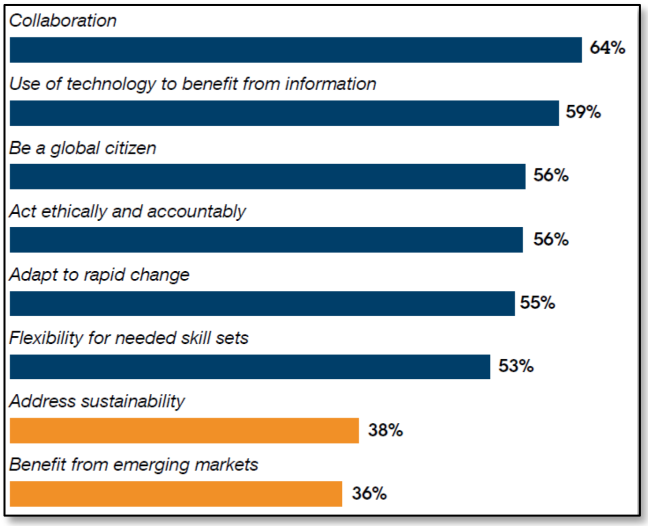


Figure 20 - Students who feel that education has prepared them well in these areas (IBM Institute for Business Value 2010).

This foundation provides insight into the kinds of reaction students may have to various EM approaches. The belief in the power of data and their comfort with data-driven decision making lends itself to a system that allows for a granular and comprehensive view of energy use. EM, as a subset of sustainability and resource concerns, is something that universities can improve upon and thereby meet an increasingly desired educational experience for the student. As a true operational bonus, these approaches will also likely benefit the university financially. This positive feedback loop of improved user experience leading to greater efficiency that can then provide another user benefit is an appealing opportunity that can be seized through network-based EM.

The Role of Faculty

University faculty members are one of the primary human resources at work on campus. They represent a wide range of expertise, resource needs and a desire for personalization and relative autonomy that must be considered in any campus energy management scheme. As the university seeks to fulfill its role, it must provide for the needs of its faculty in order to maximize its educational and research potential. The needs of this group may range from an English professor who requires desktop IT support, a simple office and library access, to a mechanical engineering professor who requires large, energy-intensive lab space, a private computer network and support for a dozen lab assistants. The implications of this range on the energy use of buildings across campus are difficult to overstate and the need for personalization to these missions and personalities is equally important to consider.

Yet again, the theme of user experience comes into play. Energy management approaches that interfere with the faculty's ability to educate students and perform the research necessary for the university to fulfill its societal mandate are essentially out of the question in a university environment. As the group of University of California experts explains with regard to IT expectations, for example:

> *"Researchers and educators will not tolerate computing or network services that are intermittent and/or unreliable—no matter how green they purport to be"* (St. Arnaud et al. 2009).

The Roles of Information Technology and Facilities

A number of functional roles exist within the university to provide the environment and tools necessary to deliver the best educational and research experience. These groups interact in a number of ways, but also act relatively independently in pursuit of achieving their own organizational missions. Historically, facilities management and IT groups have lived in separate realms within commercial buildings at large, as discussed previously. The development of building management systems tied to information systems has brought these two groups closer together over time, however. As solutions like network-based EM become more prevalent, their ability to work together to efficiently manage campus resources while providing an excellent user experience will likely grow.

Information Technology

The development of network-based EM is dependent upon the ability of the university IT organization to innovate, adapt, and play a growing role in the larger campus sustainability plans. Campus IT organizations are only beginning to become an integral part of the strategic planning and execution of campus-wide efforts. In 2009, a summit of IT professionals met to discuss this emerging role and concluded that "most [campuses] have not looked past simple efforts aimed at energy reduction to truly understand the transformative role that IT might play" (Educause 2009). Why might this be and what does that mean for their interactions with other EM related groups such as facilities management? An overview of the campus IT landscape and the current view of EM is helpful in approaching this issue.

As of 2010, an estimated 74% of universities and colleges in the US have or are developing programs to manage and reduce energy use in IT (CDW, 2010). While this number lags its business counterparts by 6% in the same report, this number represents a significant awareness of and action toward improved energy management among campus IT professionals.

The wide array of customers within a university tests the technical and managerial mettle of IT groups. DePaul University CIO Vince Kellen says:

> *"…the biggest difference is in our customer base and the range of services we have to offer. We have students that eat, sleep, socialize, attend sporting events and go to school, so we have a lot of services that need to be provisioned quickly and work properly. In this regard, we're more like a destination resort or a Disney Theme park." (Kogut, 2007)*

Both internal and external collaboration, an essential feature of university life, create one of the primary challenges in a university environment: security (Kogut 2007). Such collaboration requires a large amount of identity tracking and provisioning of thousands of users and profiles with all of the complexity and variation previously discussed. As Rich Kogut, University of California-Merced CIO explains:

> *"Collaboration is a way of life, primarily between students and faculty internally, and between faculty and researchers at other institutions externally, but in a myriad of other combinations. The idea of putting the entire university behind a firewall is unthinkable, and the concept of an extranet, irrelevant. This has caused universities to adapt security models that focus on islands of security, and the hardening of individual applications and servers, but mostly open borders"* (Kogut 2007).

He goes on to discuss the kinds of unique skill sets that this kind of challenge creates within university IT organizations, specifically with regard to tracking thousands of unique users. "Beyond the support of collaboration …, there aren't many other enterprises where 10,000 new users might show up on a single day and have to be provisioned" (Kogut 2007).

How might these core skills of provisioning, collaboration, security and personalization be leveraged for the pursuit of network-based EM? Such an EM approach requires that the IT management group maintain the trust of multiple user groups, ensure system integrity and be flexible to the needs of a variety of environments and demands. If the university is seeking a systematic approach to energy data gathering that creates operational improvements and increases stakeholder satisfaction, network-based EM appears to meet these needs. Network-based EM has the capability of gathering data from disparate sources across a large and complex network. This provides energy managers with a perspective unfettered by existing university organizational complexity and allows energy use patterns to emerge on the systemic level. Perhaps most importantly, university IT departments may be uniquely qualified from a skills perspective to become front-runners in this arena.

Energy Billing and Incentives

The results of 2008 and 2009 reports conducted on behalf of CDW, Inc., showed there were notable differences in incentives for EM as well as the portion of IT departments that were directly responsible for managing their energy use. See Figure 21 and Figure 22. The difference in direct responsibility for IT energy budgets in the university versus business environment is quite dramatic, with 17% more business IT departments responsible for their energy bill compared to their university counterparts in both years.

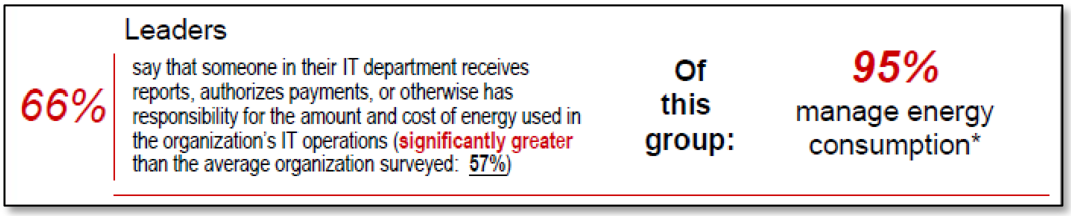
Also notable, however, is the portion of universities that provide incentives for energy savings (Figure 23). It could be that because there is no direct business 'win' for university IT organizations to save energy, incentives are provided by the university as a whole or by budgetary groups (buildings, departments, functional groups, etc.) that do benefit from these energy use reductions. In the business arena the reduction in costs is seen as a benefit in and of itself and any incentives act as an accelerator for change.

If the IT departments aren't tracking and paying for their energy, who is? In many cases, energy use is captured only on the per-building level with a monthly meter reading. In a university environment, this most often means that energy is billed per department that occupies that building. Depending on the utility agreement, the expenses may then be split among multiple users within a building based on square footage allocations. In order for IT to be billed independently for energy use, sub-metering of some sort must be conducted to accurately assess energy use and cost.

Misaligned incentives such as this exist across many university group interactions. On many campuses, the budgetary unit is the school or department (e.g. Psychology department, etc.), meaning that the dean's office provides budgetary oversight and payment for services and resources, including energy. While this group controls the purse strings, they may not directly control the use of energy-consuming devices, or be aware of the device settings and resulting cost implications of those choices. Combined with a lack of granular use-source data, this means that a dean is unable to determine the points of energy inefficiency caused by malfunctioning mechanical systems, device settings, user behaviors or a combination of all three. As a result of this data blindness, a dean is unable to identify opportunities for budgetary savings, including incorporating ideas like demand response and other more traditional EM approaches.

Both the dean and the facilities management group are working to achieve their missions, and may even feel that they are meeting them, but can do so without connecting the EM dots. The dean may be delivering excellent educational content in a school that is functioning well financially. The facilities manager may receive few occupant complaints about environmental comfort. And yet, the cost of achieving each of these missions, both of which center on the complex demands of stakeholders like students and faculty, may be building energy inefficiencies.

Business



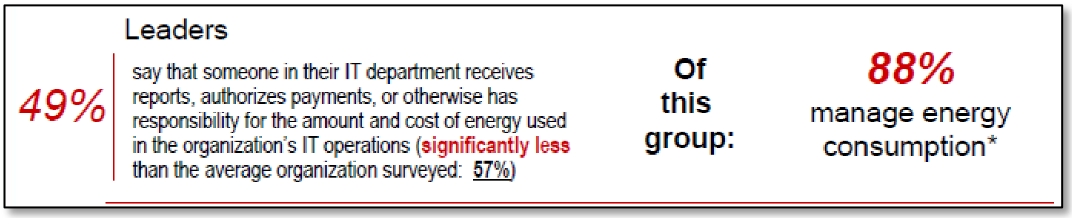
Leaders

66% say that someone in their IT department receives reports, authorizes payments, or otherwise has responsibility for the amount and cost of energy used in the organization's IT operations (**significantly greater** than the average organization surveyed: 57%)

Of this group: 95% manage energy consumption*

Figure 21 - Business IT energy use data availability and billing
Source: ()

University

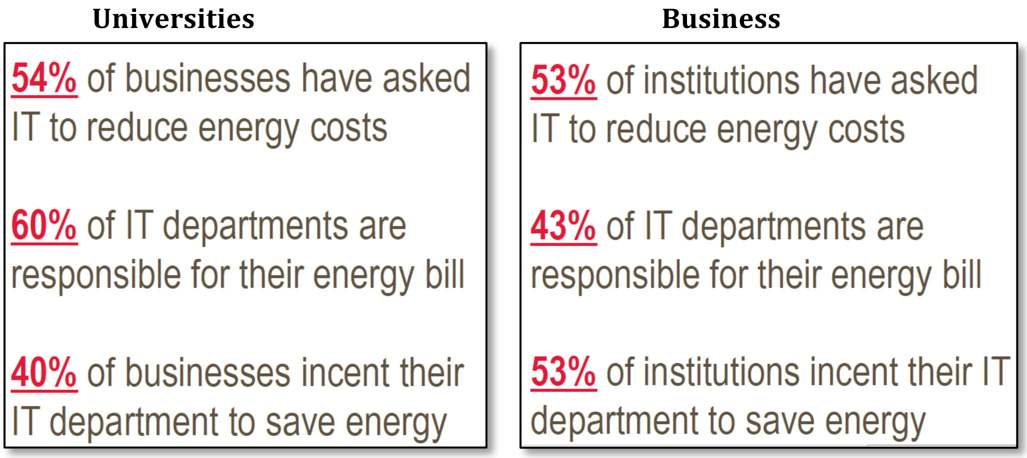


Leaders

49% say that someone in their IT department receives reports, authorizes payments, or otherwise has responsibility for the amount and cost of energy used in the organization's IT operations (**significantly less** than the average organization surveyed: 57%)

Of this group: 88% manage energy consumption*

Figure 22 - University IT energy use data availability and billing
Source: (CDW Government Inc. 2008)



Universities

54% of businesses have asked IT to reduce energy costs

60% of IT departments are responsible for their energy bill

40% of businesses incent their IT department to save energy

Business

53% of institutions have asked IT to reduce energy costs

43% of IT departments are responsible for their energy bill

53% of institutions incent their IT department to save energy

Figure 23 - Business and Higher Education organizational support comparison
Source: (CDW Government Inc. 2009)

Whether directly managing their energy bills or not, university IT groups find that actually identifying and tracking energy usage can be very difficult (

Figure 24). This issue of energy use transparency is at the heart of what network-based EM aims to directly address.

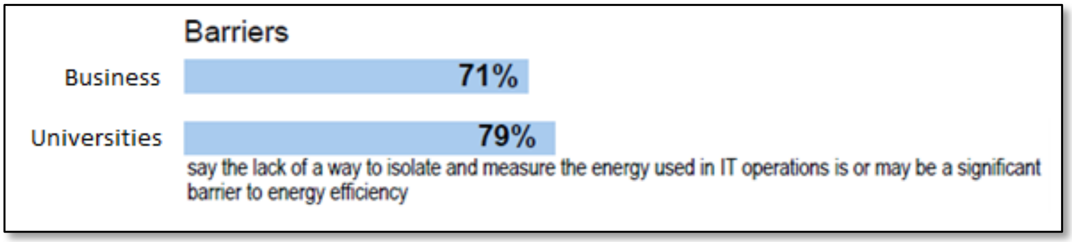
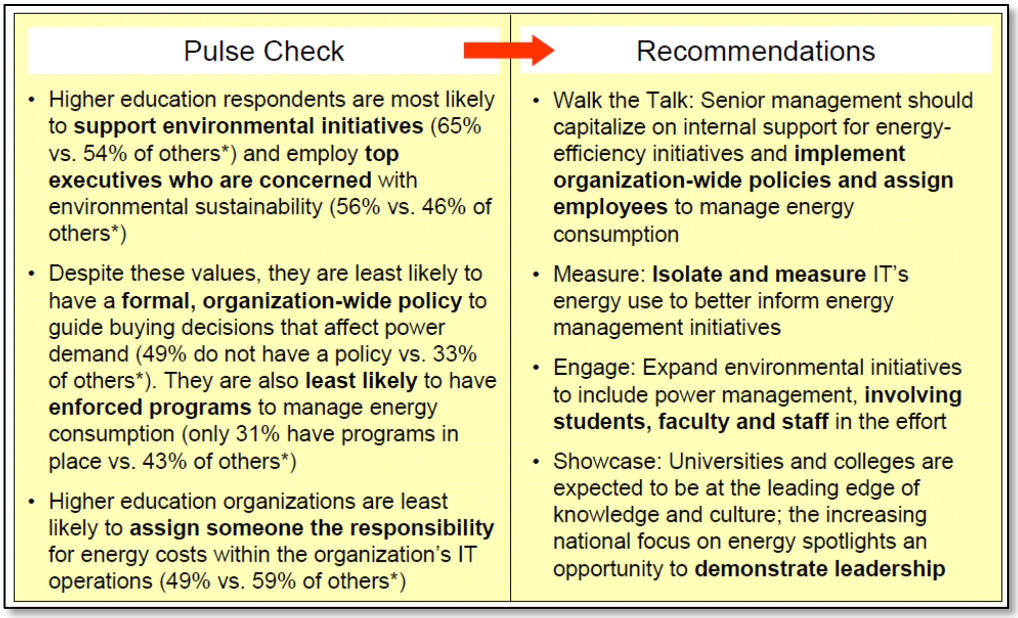


Figure 24 - Perception of lack of available energy use as an impediment to IT energy management
Source: (CDW Government Inc. 2008)



Pulse Check

- Higher education respondents are most likely to **support environmental initiatives** (65% vs. 54% of others*) and employ **top executives who are concerned** with environmental sustainability (56% vs. 46% of others*)
- Despite these values, they are least likely to have a **formal, organization-wide policy** to guide buying decisions that affect power demand (49% do not have a policy vs. 33% of others*). They are also **least likely** to have **enforced programs** to manage energy consumption (only 31% have programs in place vs. 43% of others*)
- Higher education organizations are least likely to **assign someone the responsibility** for energy costs within the organization's IT operations (49% vs. 59% of others*)

Recommendations

- Walk the Talk: Senior management should capitalize on internal support for energy-efficiency initiatives and **implement organization-wide policies and assign employees** to manage energy consumption
- Measure: **Isolate and measure** IT's energy use to better inform energy management initiatives
- Engage: Expand environmental initiatives to include power management, **involving students, faculty and staff** in the effort
- Showcase: Universities and colleges are expected to be at the leading edge of knowledge and culture; the increasing national focus on energy spotlights an opportunity to **demonstrate leadership**

Figure 25 - Higher education energy management differentiators

Source: (CDW Government Inc. 2008)

Intermediary University Sustainability Groups

Campuses across the country have convened multi-disciplinary groups of staff, faculty and outside professionals to create "green teams" to aid the push towards sustainable practices. Their scope may be at the building level, or may reach across an entire campus, depending on the approach taken by the given institution. For example, Carnegie Mellon has convened a voluntary group of staff, students and faculty to seek out sustainability solutions for each building, whereas the University of Michigan has a larger group of paid members tasked with investigating and implementing sustainability practices on a wider level. Each of these approaches and their hybrids require different funding and organizational models.

These teams occupy a unique space in the fabric of the university and can be generally autonomous change advocates and effective implementers. In university environments, where there are generally a number of independent or semi-independent decision makers, this ability to float between parties is valuable. Such groups exist in industry as well, and these attributes can serve similar purposes in that environment.

IV. Case Study: IT Energy Management at the University of Michigan

A. Introduction

The central component of this project was an implementation case study of a network-based EM solution at the University of Michigan. Cisco Systems, the project sponsor, donated the software and expertise necessary for the project team to deploy an energy monitoring and control package, Cisco's EnergyWise (EW) and Orchestrator pro, at two pilot locations. These products allowed the team to monitor and manage the energy consumption of network-enabled devices including personal computers, Power over Ethernet (PoE) phones, network switches and wireless access points.

Before discussing the implementation process, it is necessary to describe the university's energy infrastructure and sustainability efforts to provide context. Additionally, since the implementation focused on IT devices, the University IT structure is discussed. After this background is established, scope, implementation methodology and results are presented.

B. University of Michigan Context

Energy Supply & Demand

The Central Campus of the University of Michigan in Ann Arbor consumes roughly 275,000 MWh of electricity every year. This is equivalent to the power consumption of roughly 25,000 average American homes. A power plant at the Central Campus provides the necessary electricity and steam through a district heating, cooling, and power distribution system. The plant's primary goal is to provide heating and cooling services through the generation and distribution of steam. Before the steam is distributed, it can be used to generate electricity. Therefore, power plant electricity generation is dependent on steam generation. Purchasing electricity from the local utility, DTE, satisfies the remaining electricity demand. Figure 26 displays the University's total power consumption and source of origin over the past ten years.

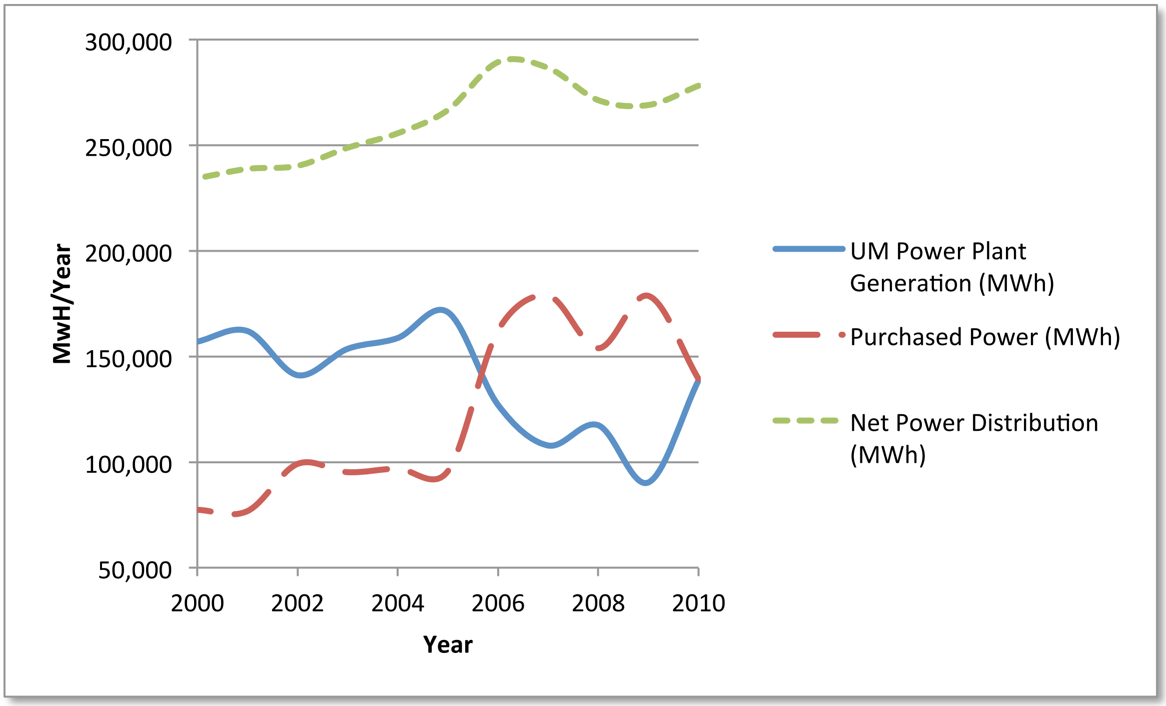


Figure 26 - U of M Annual Electricity Consumption
Source: (UM Utilities & Plant Engineering 2010)

At a cost of approximately $.08/kWh, the University spends around $22 million on electricity annually for the central campus. This represents only a fraction of energy budget as it does not include water or steam use or other UM campuses. Reducing energy consumption just a few percentage points will translate into meaningful savings. Despite the large sums being expended on electricity, there is limited ability to identify where power consumption is occurring with any granularity. The University recently began deploying new smart meters to its campus buildings that provide real time consumption feedback. This aids in observing where power demand exists at a building level, but it is extremely difficult to pinpoint energy use within buildings. It is challenging to manage power use without adequate information about how it is being consumed. As discussed earlier, a network-based Energy Management (EM) system could increase data granularity.

University power managers also need to contend with the variety of stakeholders discussed in the previous section. Numerous building types and use profiles are required to accommodate such a diversity of stakeholders. The campus building environment includes dorm rooms, classrooms, faculty offices, staff and administrative offices, and technical labs, just to name a few. All these disparate environments have different power profiles and needs. For example, an administrative office can reliably be powered down (office equipment, lights, HVAC) at night since the staff operates on a nine-to-five schedule. However, a computer lab or study space needs to be available at all times, or at least be equipped with technology that recognize when the space is in use. Despite the variety of use cases, lack of a network-based EM systems mean power administrators are blind to many of the nuances of campus power use on. This shortage of information prevents managers from locating the highest power consuming devices quickly or implementing demand response programs.

Sustainability and Energy Management Initiatives

Notwithstanding a lack of granular data, the University of Michigan is broadly pursuing sustainability and EM initiatives. In particular, three organizations coordinate related activity. At the highest level, the Office of Campus Sustainability coordinates the University's overarching approach to sustainability. At the operational level, Planet Blue analyzes building and facility efficiency, and suggests actions for improvement. Finally, the Graham Institute coordinates the University's academic efforts around sustainability.

Office of Campus Sustainability

The Office of Campus Sustainability (OCS) represents the highest-level commitment to sustainability at the University of Michigan. The University President, Mary Sue Coleman, created the OCS in 2004 to advise the President on sustainability initiatives and to begin coordinating the University's sustainability efforts. The OCS mission has four key components:

1. "Work with the Sustainability Executive Council to set goals and standards for sustainable operations on our campus and then work with the operational units across campus to ensure those goals and standards are met.
2. Identify, support, and coordinate opportunities to reduce energy consumption and increase sustainable operations on campus that may go beyond what is required to meet campus and regulatory standards.
3. Work together with the Graham Environmental Sustainability Institute to provide support to the Sustainability Executive Council and develop the Sustainability Task Force.
4. Provide information exchange and be responsible for communicating to internal and external constituents about efforts underway and challenges we face in mounting sustainable campus operations. One primary tool will be the annual environmental sustainability report" (UM Office of Campus Sustainability 2011).

The OCS also collects and publishes raw data of 140 sustainability metrics (http://www.ocs.umich.edu/10AERrawdata.shtml#) ranging from electricity production to procurement numbers to waste use in order to evaluate its ongoing sustainability efforts. The OCS demonstrates the University's commitment to sustainability issues.

Planet Blue

While OCS directs sustainability at the University's executive level, a more visible effort to reduce energy consumption and increase campus sustainability is the Planet Blue (PB) initiative.

While the PB website describes their efforts as "a campus-wide educational and outreach campaign with a mission to actively engage the University of Michigan community to conserve utilities and increase recycling thereby saving money and benefiting the environment," there are also considerable behind the scenes efforts (Planet Blue Organization).

PB operations teams move from building to building looking for opportunities to save energy. The teams perform energy audits, install sensors, and improve a building envelope's efficiency. After improving operational efficiencies and installing new hardware, PB holds "open houses" in order to educate the student, faculty and staff occupants about the conservation measures implemented, the importance of energy conservation, and the building's impact on the environment. It is important to note that while PB efforts are ostensibly focused on reducing energy consumption and the University's environmental impact, improving building efficiency has a direct impact on the University's bottom line. PB estimates that "a one percent reduction in utility usage translates to over $1,000,000 in annual savings for the University" (Planet Blue Organization). Therefore, the university has a serious financial incentive to increase operational efficiency.

Graham Institute
The Graham Institute (GI) is a coordinating body that attempts to unify the University's sustainability related academics and initiatives. Their mission "is to connect academics, policy-makers, and practitioners by facilitating sustained and vibrant interactions to solve wicked sustainability problems"(Graham Environmental Sustainability Institute 2011). In order to accomplish this mission, the GI pursues three broad efforts: Student Programs, Integrated Assessment and Sustainability Centers. Student Programs provides students with a comprehensive list of all sustainability related coursework on campus and also coordinates the Student Sustainability Initiative (SSI). The SSI coordinates student groups with a sustainability focus and solicits student input on general sustainability initiatives. The Integrated Assessment program is designed to bring scientists and policy makers together in order to encourage the development of sound sustainable policies at the University. Finally, Sustainability Centers coordinates faculty research of sustainability issues. These goals give Graham a broad role and authority to facilitate and guide the University of Michigan's disparate sustainability efforts.

C. IT structure

University of Michigan Overview

Befitting a university of its size, the University of Michigan has a number of IT departments, services, and devices. A recent audit by Accenture, found that the Ann Arbor campus had nearly 50,000 computers (See Table 3). There are more than eighteen independent IT departments managing these computers, resulting in a highly decentralized IT system. Appointed to her role in 2009, the Chief Information Officer is heading an initiative to streamline the disparate groups and encourage centralization of IT services (Thomas 2010).

Table 3 Computers by Department (Source: Accenture Audit)

Unit	# of Managed Desktops	%
College of Engineering	5,123	10.61%
College of Literature, Science, and the Arts	10,000	20.71%
College of Pharmacy	254	0.53%
Institute for Social Research	2,000	4.14%
Law School	711	1.47%
Life Sciences Institute	600	1.24%
Medical School	20,000	41.42%
School of Art and Design	177	0.37%
Ross School of Business	1,140	2.36%
School of Dentistry	1,200	2.49%
School of Education	900	1.86%
School of Graduate Studies (Rackham)	245	0.51%
School of Information	485	1.00%
School of Kinesiology	250	0.52%
School of Music	366	0.76%
School of Natural Resources	241	0.50%
School of Nursing	245	0.51%
School of Public Health	650	1.35%
School of Public Policy	170	0.35%
School of Social Work	250	0.52%
Taubman College of Architecture & Urban Planning	203	0.42%
University Libraries	1,314	2.72%
EVP Finance (except ITS)	913	1.89%
Office of the Provost	682	1.41%
Office of the President	166	0.34%
Total	48,285	100.00%
Note: The number of managed desktops does not necessarily represent the total number within the specified unit. Unit IT Directors often do not have comprehensive visibility in all departments within their units or in individual faculty research labs.		

D. IT Energy Management

Climate Savers

The primary University green computing initiative was Climate Savers (CS). Launched in March 2008, CS was central Information Technology Services' (ITS) inaugural power saving initiative. While the program's funding and mandate have expired, the CS staff continue to work for central ITS on projects related to reducing IT-based energy consumption. CS was created in order to identify, prioritize, and develop "green" IT projects. In addition, the program increased awareness of IT energy management best practices and published recommended power saving settings (Table 4). The CS staff graded individual IT departments on their green computing efforts. To accomplish this, the program has criteria for what constitutes "green computing" and grants Gold, Silver and Bronze awards based on meeting certain thresholds of activity. Judgment is based upon a checklist of activities or programs in the following categories: Increasing Awareness (Education), Purchasing Wisely (energy efficiency as a selection criteria), Power and Natural Resource Conservation (implementing sleep settings), Green Printing Initiatives, Recycling Efforts, Server Optimization, Server Consolidation, and Data/Server Management (UM.Lessons 2011).

Climate Savers has achieved moderate success. Their website shows they have awarded fourteen Golds, sixteen Silvers, eleven Bronze awards (Michigan Climate Savers Program 2008). There are only seven departments left that do not have awards. For Award criteria see website for details (UM.Lessons 2011).

Table 4 Climate Savers Recommended Power Settings

PC Component	Time to Sleep
Monitor/Display	15 minute idle (or less)
Hard Drives	15 minute idle (or less)
CPU	30 minute idle (or less)

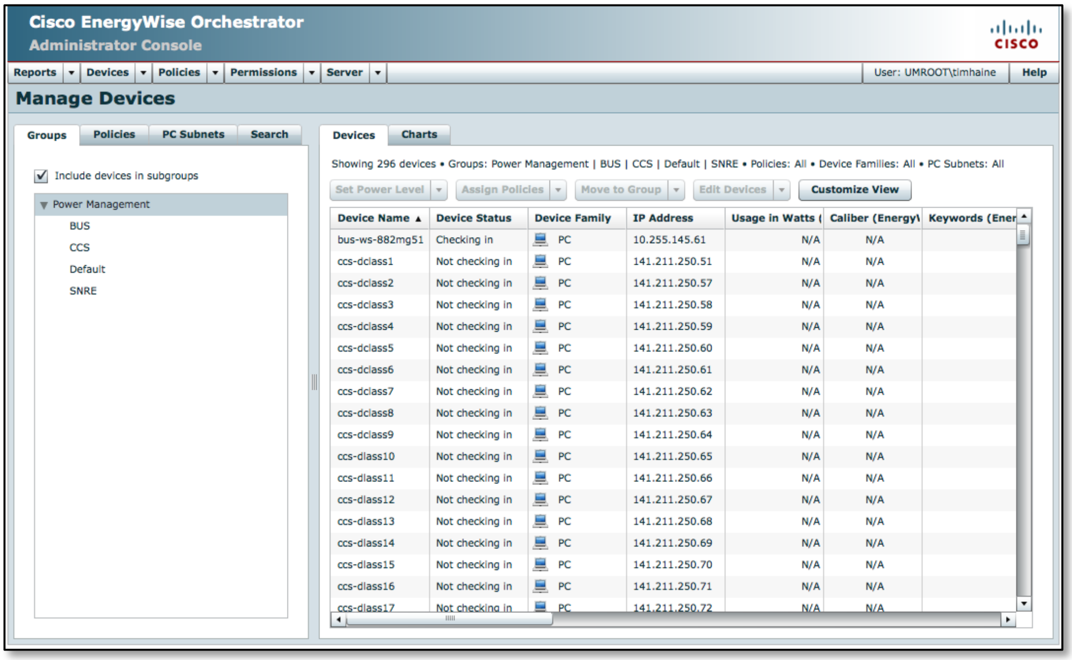
Big Fix Central Patch and Power Management

Climate Savers encourages individual IT departments to adopt the Big Fix software suite in order to manage power settings on their PCs. Big Fix is a centralized patch and power management system that is capable of pushing necessary software updates and power management settings to large numbers of machines quickly and efficiently. It also allows individual departments the flexibility their require to manage their own deployments. Big Fix is currently installed on nearly 15,000 out of 50,000 computers at the university. Of those 15,000 machines, roughly 64% are using climate saver's recommended power saving settings (Stuenkel March 14, 2011).

E. Pilot Software: EnergyWise and Orchestrator

The project pilot implementation used two pieces of Cisco Software, EnergyWise (EW) and Orchestrator. EW is the underlying communication protocol for command, control and monitoring of devices that “lives” on Cisco brand network switches. The protocol is integrated into Cisco’s Internetwork Operating System that manages network switches and routes data traffic on them. It is capable of measuring the power consumption of any device connected to a switch, and controlling the power state of compatible or enabled devices. While this project was limited to PCs, IP phones and Wireless Access Points, future iterations of EW will be capable of controlling lighting fixtures, HVAC units and other building systems.

The second software component is Orchestrator (Figure 27). Orchestrator is a Graphical User Interface that gives administrators the ability to manage EW enabled devices.



Showing 296 devices • Groups: Power Management | BUS | CCS | Default | SNRE • Policies: All • Device Families: All • PC Subnets: All

Device Name ▲	Device Status	Device Family	IP Address	Usage in Watts (	Caliber (Energy\	Keywords (Ener
bus-ws-882mg51	Checking in	PC	10.255.145.61	N/A	N/A	
ccs-dclass1	Not checking in	PC	141.211.250.51	N/A	N/A	
ccs-dclass2	Not checking in	PC	141.211.250.57	N/A	N/A	
ccs-dclass3	Not checking in	PC	141.211.250.58	N/A	N/A	
ccs-dclass4	Not checking in	PC	141.211.250.59	N/A	N/A	
ccs-dclass5	Not checking in	PC	141.211.250.60	N/A	N/A	
ccs-dclass6	Not checking in	PC	141.211.250.61	N/A	N/A	
ccs-dclass7	Not checking in	PC	141.211.250.62	N/A	N/A	
ccs-dclass8	Not checking in	PC	141.211.250.63	N/A	N/A	
ccs-dclass9	Not checking in	PC	141.211.250.64	N/A	N/A	
ccs-dlass10	Not checking in	PC	141.211.250.65	N/A	N/A	
ccs-dlass11	Not checking in	PC	141.211.250.66	N/A	N/A	
ccs-dlass12	Not checking in	PC	141.211.250.67	N/A	N/A	
ccs-dlass13	Not checking in	PC	141.211.250.68	N/A	N/A	
ccs-dlass14	Not checking in	PC	141.211.250.69	N/A	N/A	
ccs-dlass15	Not checking in	PC	141.211.250.70	N/A	N/A	
ccs-dlass16	Not checking in	PC	141.211.250.71	N/A	N/A	
ccs-dlass17	Not checking in	PC	141.211.250.72	N/A	N/A	

Figure 27 - Orchestrator Graphical User Interface

Orchestrator also displays relevant power information in a centralized location, and can produce reports about energy consumption. This allows administrators to identify locations in need of power management, enforce EM policies tailored to specific locations, and see results of those policies. Data includes total power consumption, network devices, sub-groups, and policy enforcement information. In addition to utilizing the EW protocol to control PoE devices, Orchestrator can manage individual PCs on which the Orchestrator client is installed.

F. Deployment

Outreach, Scoping, and Implementation

The project team formed in early 2010 around the project proposed by Cisco and sponsored by Central ITS's green computing initiative, Climate Savers. The team anticipated working primarily with those two stakeholders at deployment locations in the School of Natural Resources & Environment's (SNRE) Dana Building and the Executive Residence (ER) at the Ross School of Business. These locations were chosen in order to compare the differences between an older, although recently renovated, building, and a newly constructed building. As the University operations structure was investigated, a number of IT and network services groups were discovered. Ultimately, the groups that played a critical role in deploying EW and Orchestrator were Ross IT at the Executive Residence (ER), and Sites Computing, ITCOM and Dana IT at the Dana building, with coordinating responsibilities handled by Central ITS.

Ross Deployment

Ross IT is responsible for all computing at the School of Business, including faculty, staff, and student computing needs, along with networking needs. It represents a centralized service provider. Ross IT facilitated the deployment of EW and Orchestrator at the ER. The ER is essentially a full service hotel for visiting professors, executive MBA candidates and other guests affiliated with the Ross School of Business with 105 rooms. The IT equipment involved in the EnergyWise test includes 13 switches, 153 IP phones and 47 wireless routers.

Dana Deployment

The computing environment at the School of Natural Resources is more fragmented than that of the Business School. Dana IT is responsible for all faculty and staff computing needs. ITS Sites, a campus-wide computer lab services provider, manages student computing services in the form of a computer lab and computer classroom. The Dana Building's network is managed by the central network service ITCOM.

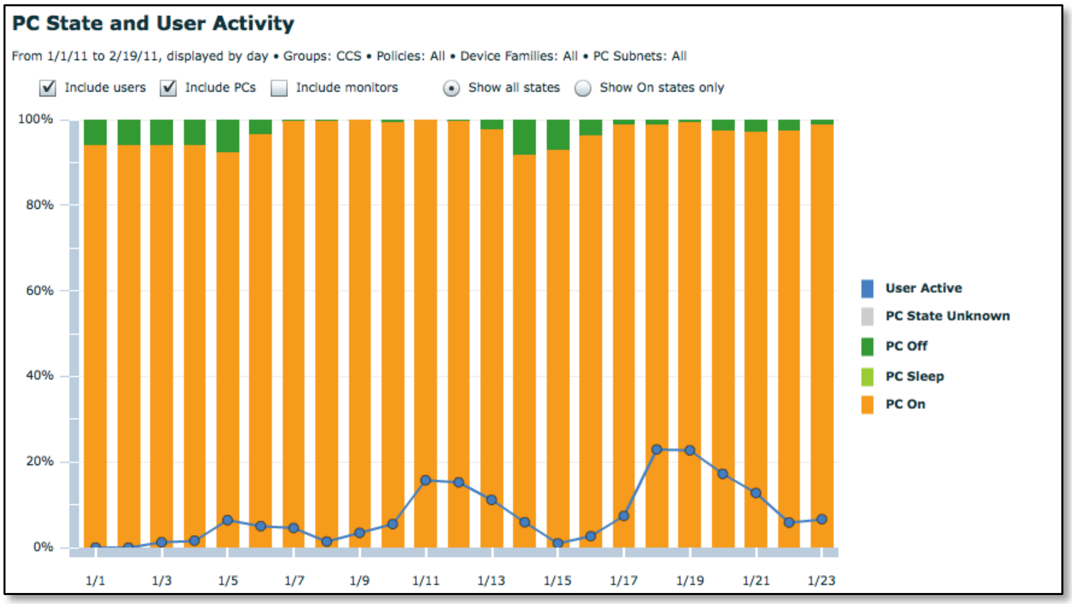
Dana IT made eleven computers in the Office of Academic Planning (OAP), an administrative office, and 19 switches available for management. The Sites central campus computing service made a computer lab and classroom available for pilot use. The general-purpose lab has twenty-six computers and classroom has twenty-three computers.

Table 5 - Total Deployment

Device	Number
Computers	62
Switches	32
Wireless Access Points	47
IP Phones	153
Total	**295**

Baseline results

Despite deploying EW to three environments, the pilot only actively managed computers in OAP and Sites labs. Orchestrator was installed on sixty-two Dana building computers in early January. The team ran a “baseline” monitoring phase from January 10 through January 23, 2011 to establish minimum energy consumption data. The preliminary baseline information provided an interesting comparison between managed and unmanaged environments. Figure 28 shows an unmanaged environment, the Sites computer lab and classroom. The graph shows that the computers are on all day, every day, and that user activity does not correlate with the power state.



PC State and User Activity

From 1/1/11 to 2/19/11, displayed by day • Groups: CCS • Policies: All • Device Families: All • PC Subnets: All

☑ Include users ☑ Include PCs ☐ Include monitors ● Show all states ○ Show On states only

Figure 28 - Unmanaged Environment: SITES lab & Classroom

However, Figure 29 shows PCs that are properly managed. This chart details OAP's computers, which are managed according to Climate Savers suggested settings. Here the PC power state tracks user activity well.

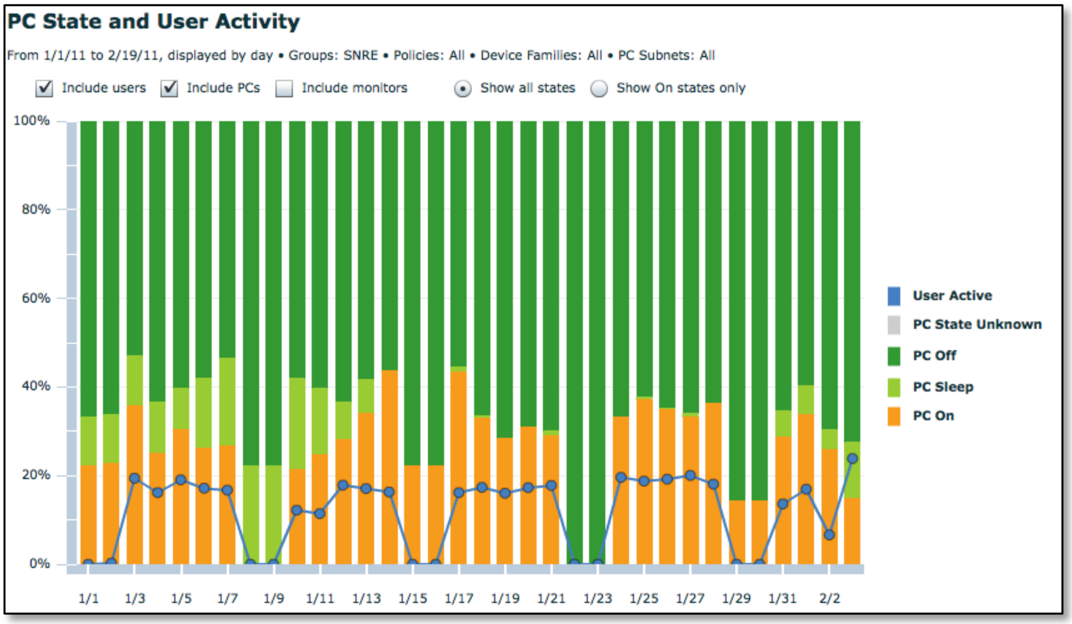


Figure 29 Managed Environment: SNRE OAP (Managed to Climate Savers Specifications)

Policy Enactment

Following a baseline period of two weeks, the team enacted policies on computers in the Sites labs and OAP. Given the IT department's preference for maintaining overall user experience, policies were designed with minimal disruption in mind. To accomplish this, conservative policies were adopted during the building's business hours and more aggressive policies adopted after business hours.

OAP

Table 6 - PC Power Management Policies

	Business Hours/Conservative 7AM – 5PM	After Hours/Aggressive 5PM – 7AM
Old Policy	Monitor: 15 Min Sleep CPU: 30 Min Sleep	Monitor: 15 Min Sleep CPU: 30 Min Sleep
New Policy	Monitor: 15 Min Sleep CPU: 30 Min Sleep	Monitor: 5 Min Sleep CPU: 15 Min Sleep

Total Computers: 11

Sites Classroom & Student Lab

Table 7 SITES Classroom Implemented Policies

	Business Hours/Conservative 7AM - 10 PM	**After Hours/Aggressive 10PM - 7AM**
Old Policy	Monitor: 20 Min Sleep CPU: Never Sleep	Monitor: 20 Min Sleep CPU: Never Sleep
New Policy	Monitor: 20 Min Sleep CPU: 60 Min Sleep	Monitor: 10 Min Sleep CPU: 30 Min Sleep

Total Computers: 49

User Experience Problems

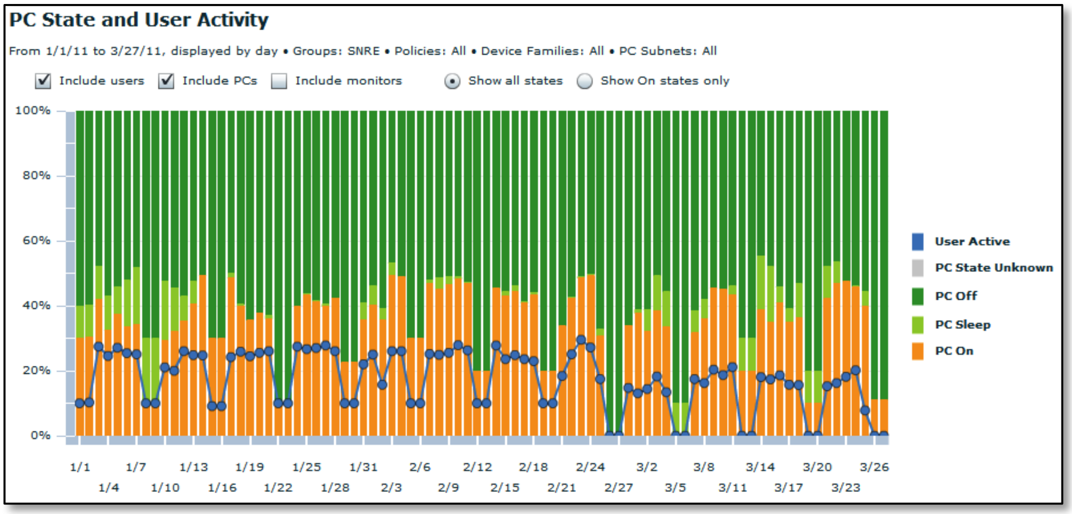
After policy implementation, computers coming out of the Sleep state caused user experience problems in the Sites labs. When waking from sleep, users sometimes experienced issues with the App-V or OpenAFS clients on the machines. App-V allows various programs to be streamed to individual PCs (rather than being stored locally) and OpenAFS allows students to save files to a folder that can be accessed anywhere on campus. These clients operate in the background of the operating environment and if not given enough time to cycle, will not function properly. The result is that students may not see the programs they need or be able to access the files they have saved. Ultimately, sleep policies were revoked in the computer classroom because of the problems. The Sites IT manager suspects similar problems are occurring in the computer lab as well, but because the simultaneous login associated with the start of a class is not present, it may not be noticed or reported.

Troubleshooting the issue required several days of consulting with Microsoft Support, and was ultimately not entirely resolved. The University's computing environment represents a unique amalgamation of programs, services, clients and machines. This combination means that the wake from sleep issues may be specific to the University and not widely experienced. Therefore, the effort required by all parties to ensure smooth operation may not be financially prudent. Since user experience is a top priority for IT managers, issues of this nature have the potential to derail PC energy management practices at the university.

G. Deployment Results

Realized Energy Savings

Power management using Orchestrator did not result in significant savings at the OAP since the machines were already being power managed and the new policies were only slightly more aggressive than what was previously enforced. Figure 30 shows that policy implementation on March 7 resulted in little if any change in energy use.



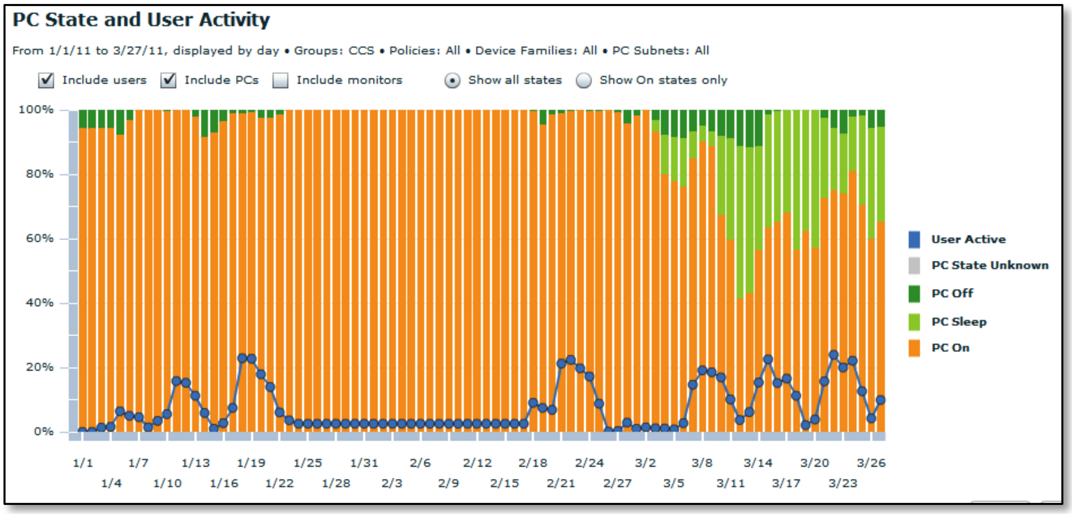
PC State and User Activity

From 1/1/11 to 3/27/11, displayed by day • Groups: SNRE • Policies: All • Device Families: All • PC Subnets: All

☑ Include users ☑ Include PCs ☐ Include monitors ● Show all states ○ Show On states only

Figure 30 - PC State and User Activity for OAP (1/1/11 to 3/27/11)

However, using Orchestrator to manage the computers in the Sites Lab and Classroom resulted in a marked decrease in energy consumption (Figure 31). Beginning on March 3, the policies outlined in Table 4 were implemented on the twenty-three computers in the Sites Classroom. On March 9, these policies were also applied to the twenty-six computers in the Sites Lab. Figure 31 shows the average time that Sites computers collectively spent in each of the three energy states tracked (Off, Sleep and On). Prior to March 3, the computers never entered the Sleep state. During the period from March 3-9 when policies were implemented on the Sites Classroom computers only, average Sleep state time across all computers (including those Sites computers with no policy implemented) ranged from approximately 1-3.5 hours per day depending on User Activity. After March 9, when policies were implemented on all Sites computers, average time in the Sleep state increases to approximately 7-12 hours per day depending on User Activity.



PC State and User Activity

From 1/1/11 to 3/27/11, displayed by day • Groups: CCS • Policies: All • Device Families: All • PC Subnets: All

☑ Include users ☑ Include PCs ☐ Include monitors ● Show all states ○ Show On states only

Figure 31 - PC State and User Activity for Sites Lab and Classroom (1/1/11 to 3/27/11)

On March 18, Orchestrator was removed from the Sites Classroom computers due to a systematic login problem that was noticed when, but not caused by, large numbers of students simultaneously waking computers from the Sleep state as they attempted to log in for class.

Examining the data for the week from March 10-16, the complete week when policies were implemented on all Sites computers, the average time in the Sleep state for the Lab and Classroom computers was 35.8% of the day. Since these computers never entered the Sleep state prior to implementing policies, this represents a significant improvement. Average time in the Sleep state is dependent on User Activity, so comparing User Activity levels during this week to User Activity levels in other weeks is important in order to judge if these results would be typical. For the week of March 10-16, average User Activity was 12.8%. During the week of February 19-25, prior to policy implementation, average User Activity was somewhat higher at 14.8%. This would suggest that the average Sleep state time for March 10-16 might be higher than would be expected over a longer period. Over the three complete weeks for which data was collected prior to policy implementation (January 10-23 and February 19-25) average User Activity was 12.2%. Data was collected from only 35 of the 49 computers in January, however, and it is possible that the smaller data set impacted the average User Activity.

In order to get a more conservative estimate of the average Sleep state time that is possible with the policies used, average User Activity and Sleep state time were calculated for the highest activity two-week period after policy implementation. During the period from March 14-27, average User Activity was 13.9% and average Sleep state time was 30.6%. The data from this period is not directly comparable to previous data due to the removal of Orchestrator from the Sites Classroom computers on March 18. On March 14, activity and energy state data were recorded for 46 computers; on March 27 data were recorded for only 17 computers.

Another variable that must be considered is the average Off state time. This is important in assessing the opportunity for EM since the larger the Off state time the smaller the idle On state time during which a computer can be placed in a Sleep state. Over the period prior to policy implementation, the range of average Off state times was 0-8.4%. During the period following policy implementation, average Off state times ranged from 0.1%-11.9%. It is therefore assumed that Off state times during the policy implementation period did not cause a positive bias in average Sleep state times.

The changing sample size due to Orchestrator deployment and policy implementation issues make it impossible to produce a statistically significant result for average Sleep state time. However, the project teams believes that under the conditions present in the Sites Classroom and Lab, an average Sleep state time of 30% of the day is a good estimate of the potential to reduce energy usage. This estimate is likely conservative. The policies implemented in the Sites Classroom and Lab were not aggressive in terms of idle time before sleep. Transitioning computers to a Sleep state after 20 or 30 minutes of idle time, rather than an hour, would be more typical in many organizations according to Sriram Balasubramanian, a Cisco EnergyWise expert(Balasubramanian March 29, 2011). Mr. Balasubramanian believed that significant reductions in energy usage could be realized with more aggressive policies.

Key Findings

As mentioned in the IT Energy Management section, the Big Fix software suite that provides centralized patch and power management services is deployed on a number of computers at the University. The project team used Big Fix to obtain energy state and user activity data for approximately 12,500 of the university's 48,000 computers. This data was analyzed to sort the computers into eight groups based on their average daily On time and the average Active and Idle/Logged Off times were calculated for each of these eight groups (Figure 32).

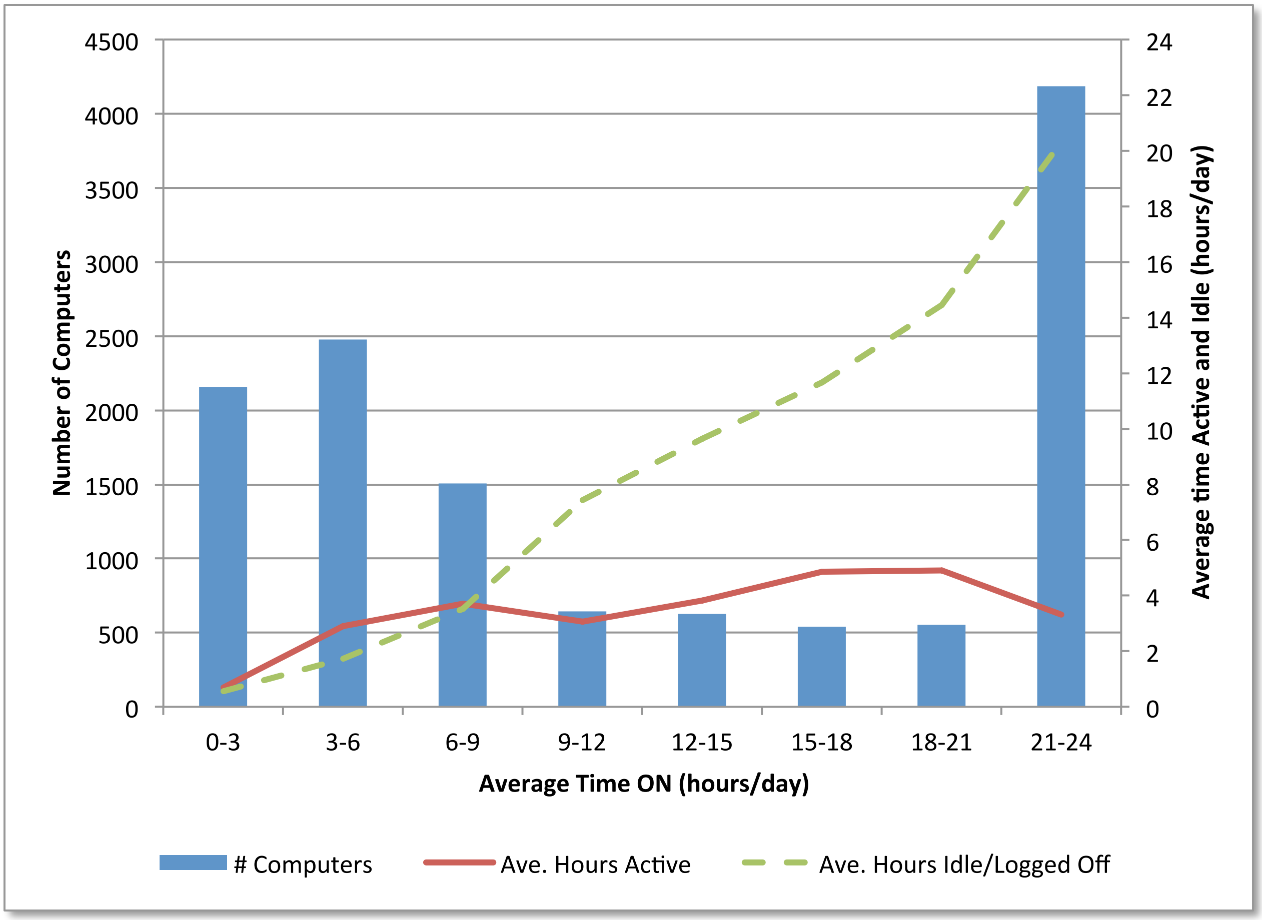


Figure 32 - Time On and Activity Levels for University Computers

Figure 32 shows a number of interesting results. First, regardless of the average time the groups of computers spend in the On-state per day, average time Active never exceeds 5 hours/day. For groups that are in the On-state for an average of 6 hours/day or more, average time Active is relatively constant across the groups. As a consequence, average Idle time increases roughly linearly with average time in the On-state across the eight groups since computers are either Active or Idle when On. Ideally, a computer would be either in the Off- or Sleep-state whenever it is not Active, so Idle time represents an opportunity for management and energy savings. Approximately one-third of the computers represented in the data analyzed (nearly 4200) fall into the group that average 21-24 hours/day in the On state. For this group, average Idle/Logged Off time was over 20 hours per day, presenting a significant opportunity for management and energy savings.

Figure 33 provides a breakdown by department of the nearly 4,200 computers from the Big Fix data that are On 21-24 hours/day. The departments with the largest number of computers that fall into this category are included on the chart along with SNRE for comparison. The Other group is the largest with over 1,200 computers indicating that there are many departments not included on the chart with a significant number of computers that are, on average, On most of the day. Sites is the individual department with the greatest number of computers in this category, and greater than 95% of its computers in the Big Fix data fell into the category. As mentioned in the Implementation Issues section, Sites found that the login experience after waking one of its computers from the Sleep state was highly inconsistent. In some cases it created no problems at all, while in others users found themselves unable to access programs or personal files stored remotely on servers. A number of Sites labs are used for classes, and such login problems are highly disruptive to a class. For the Sites department, providing a reliable computing service is the primary mission – saving energy is secondary. As a result, the department prevents its computers from entering the Sleep state until this technical issue can be resolved. This situation highlights an important finding: EM must take user experience into account in order to be accepted.

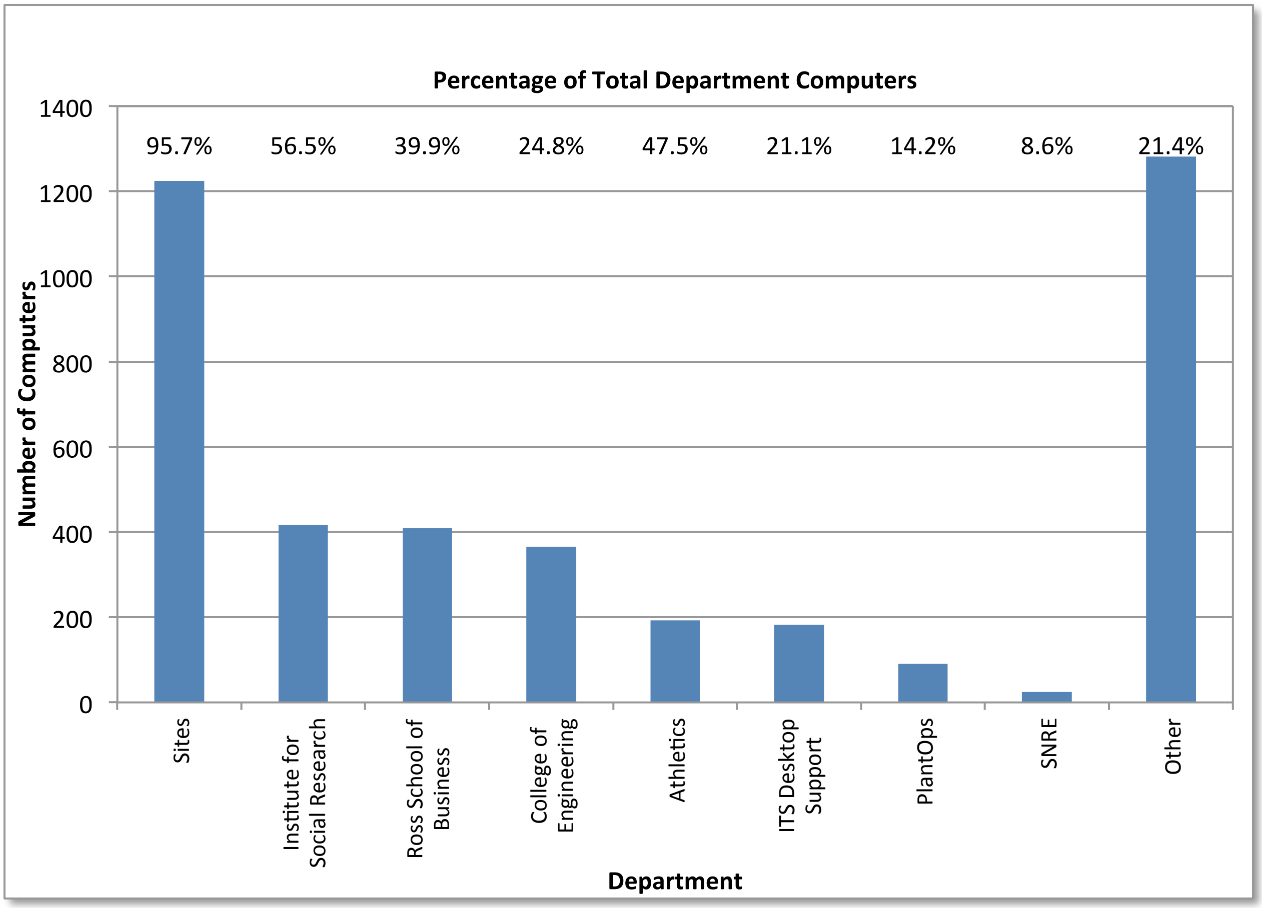


Figure 33 - Number of Computer on 21-24 hours per day by Department

Figure 34 shows the average number of hours per day that computers from selected departments spend in each of four possible energy states: Off, Sleep, Idle and Active. It is clear from the chart that there is wide variation across departments in the number of hours per day that computers spend in the Idle state. This indicates that the level of computer energy management differs significantly from department to department. For example, SNRE manages its computer's energy use more aggressively than Athletics does. Individual department's operational requirements and attitudes regarding EM determine the degree of management. However, knowledge about computer EM technologies and organizational policies that achieve desired behavior also play an important role. Standardized tools and training, organized communication and sharing of best practices among departments can help to disseminate this knowledge throughout the University. Therefore, coordination of computer EM programs could improve the overall results at the University level.

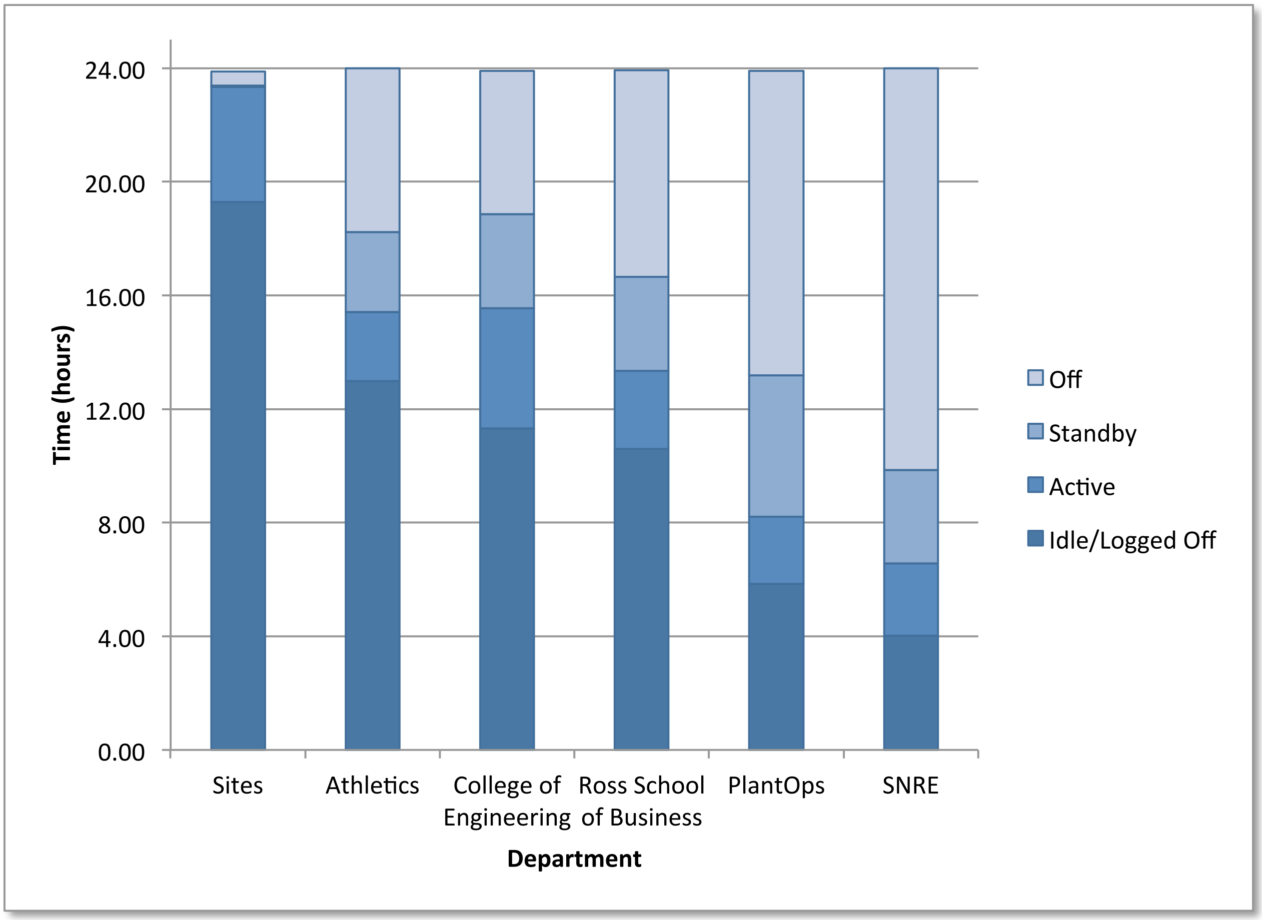


Figure 34 - Average Computer Time in Energy States by Department

The differences in current EM efforts from department to department suggest that the opportunity for increased energy savings through improved management varies across departments. For selected departments' computers that were included in the Big Fix data set, Figure 35 plots the average number of hours that computers spend in the On state against the percentage of On state time spent Idle. The bubbles on the chart represent different departments, with the size of the bubble indicating the number of computers from that department in the data analyzed. A large bubble in the upper right of the chart would represent a department with many computers that were, on average, On and Idle all day – this department would present high potential for significant reductions in energy use through management. The sizes and distribution of the bubbles in Figure 35 indicate that the opportunity for savings is fragmented across departments. This means that the economic incentive for individual departments to manage their computer energy use is much smaller than for the university as a whole. A centralized push for improved management is most likely to be effective to realize the potential for reduced computer energy use.

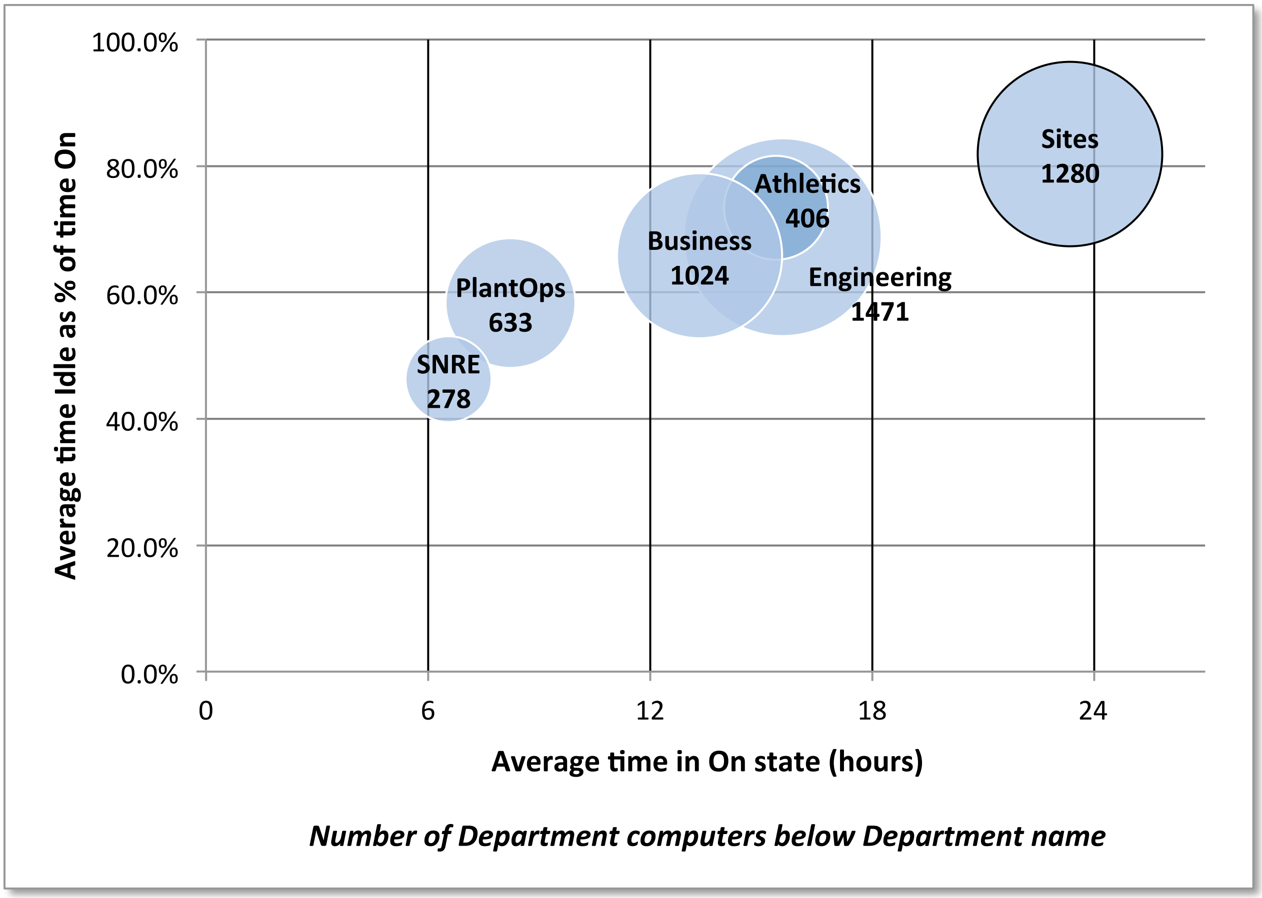


Figure 35 - Opportunity for Energy Savings by Department

Projected Energy Savings

While the sample size and statistical reliability of the energy savings data collected by Orchestrator from the Sites Lab and Classroom computers at SNRE does not allow for an accurate extrapolation of potential campus-wide savings, an informative "back-of-the-envelope" calculation is possible. Assuming policies similar to those implemented at the Sites Lab and Classroom could be enforced on the 4,000 computers that are On 21-24 hours/day group from the Big Fix data, we can conclude these policies will increase average time in Sleep state to 30% of the day. By also assuming an average Idle state power consumption value of 55W (the actual average for the 49 Sites Lab and Classroom computers was 57W), and an average Sleep state power consumption value of 5W (these generally range from 2-5W depending on the computer), 50Wh of energy can be saved for each hour that one computer is in Sleep state rather than Idle state. Over the course of a year, the energy savings for this group of computers would amount to 525,000 kWh. At $0.08/kWh, this results in a $42,000 reduction in energy costs.

It is important to note that this rough estimation only considers 4,000 of the university's 48,000 computers, though the subset considered is certainly a high potential group. Opportunities vary by department according to the use circumstances of their computers and the importance of computer power management to the department. It seems likely, however, that coordinated efforts across the university driven by a central body could produce energy cost savings on the order of hundreds of thousands of dollars.

IT manager satisfaction

Ultimately, the IT managers involved with our project were satisfied with and intrigued by the results of our project. We conducted exit interviews with the IT managers of the two principal departments we worked with, Dana IT and Sites. The Sites manager, Terry Miller, had some interesting insights into the software and the issues related to wake from sleep. Mr. Miller thought that while the software was likely a "best-of-breed" energy management suite, it was not well suited for only managing IT related energy use. This is because that IT managers prefer to see bundling of control suites, like Big Fix, which can manage software upgrades, anti-virus protection and power management from a single program. While Orchestrator is only single faceted, its ability to monitor and control a range of devices beyond IT provides a good value proposition. Phil Ray, the Dana IT manager, expressed similar sentiments.

H. Challenges & Lessons Learned

Executive Residence Issues

In the ER, technological limitations prevented power management, and the need for converged building systems quickly became apparent. The ER is essentially a hotel and the devices (i.e. IP phones) in the individual rooms are currently unaware of the room's occupancy status. Despite standard electronic card readers and check-in information provided by reservation management, ingress/egress information is not being transmitted to the local network or the IP phones. Without the critical information of knowing if a room is occupied or not, power-managing devices in the ER is functionally not possible. Ultimately, we have the capability to measure the power, but not to control it. This issue highlights the need for better communication among systems.

Organizational Issues

As mentioned earlier, the Dana building has three separate IT departments in charge of various portions of the building's network and IT infrastructure. Sites/ITS manages the computer labs (and more than 23 others across campus) and relevant network switches, Dana IT manages all of the office and faculty computers, and ITCOM, the central network service, operates the network switches in Dana. Having multiple departments in charge of various pieces of IT infrastructure presents several challenges.

In the initial phases of the project, a significant amount of time was devoted to a stakeholder discovery process in order to determine which departments had responsibility for which areas. While staff were amenable to our requests, shared time and contact information, and pointed us in the right direction, the stakeholder diversity involved required significant expenditure of time and effort to locate the appropriate administrators.

The business school represents the opposite situation. Ross IT is the only department that manages all devices across multiple environments (i.e. faculty, staff, student). This arrangement is beneficial because stakeholder outreach is greatly simplified and, if approved, changes are swiftly implemented. However, singular control creates a "black box effect" that reduces decision-making transparency.

Overall, there are at least 18 IT departments on campus. This decentralized approach has two implications. First, decentralization makes it difficult to push comprehensive power saving policies across the whole University. For example, Climate Saver's recommended power-saving settings have only been voluntarily enforced on roughly 9,600 of the 50,000 computers at the University. Though this is not an insignificant number in aggregate, significant opportunity remains. Second, while a more centralized IT service could more effectively articulate a power saving vision, implement policies and incentivize deployments, total centralization reduces management flexibility among individual departments who may have different computing needs. The University is taking a hybrid approach to address the problem. The office of the CIO is currently attempting to streamline IT departments, eliminate redundancy and centralize key operations, while allowing individual departments to retain operational flexibility.

Existing Initiatives & Duplicity

The EW/Orchestrator package is redundant with the Big Fix power saving initiative, and slightly inferior in some regards. While Orchestrator offers a comprehensive power management solution capable of managing large numbers of devices, and eventually building systems like HVAC and lighting, as a standalone PC management product it is lacking. Orchestrator does not have the patch or anti-virus management features that represent IT department's primary incentives for adopting Big Fix. Furthermore, it is also not currently OS X or Linux compatible, another Big Fix feature. The products are not truly comparable since each serves different functions, but at this stage in its development, EW/Orchestrator may be underdeveloped and might not represent a compelling enough value proposition for the university at large.

Misaligned Incentives: User Experience & University Billing Structure

Although some University IT departments have implemented modest power saving initiatives, they remain voluntary and secondary to the IT department's main objective. In interview after interview, UM IT professionals stressed the need to provide a good user experience. If EM solutions negatively affect user experience, as they did in the Sites Computer Classroom, IT managers will not enable them.

In addition to other priorities, it is also important to consider that IT departments at UM do not pay power bills and are therefore not responsible for energy costs associated with the devices they manage. This lack of a price signal reduces the incentive to save power and can make it difficult to justify the costs of marginal reductions in energy consumption. Furthermore, the power plant cannot "see" where power demand is greatest within buildings. While this highlights the need for a network-based EM system with greater granularity, it also prevents individual departments and buildings from being billed their peak overall demand. As a result, power demand charges are simply divided among all departments regardless of their peak power consumption. The rate structure does not discriminate between heavy and light power users and therefore does not incent heavy users to reduce their loads.

The Master's Project Structure

There are pros and cons of using a Master's Project as a method for implementing an operational pilot project. Initially, the students had some difficulties navigating the organizational complexity of the University bureaucracy. The students' lack of experience in regard to IT operations makes them less qualified to make recommendations about or request changes to operating protocols in the eyes of the professional IT managers. In addition, attempting to locate the relevant IT managers with operational authority from the student's perspective took considerable time and effort. Finally, it appeared at times that the project lacked an internal operational champion on the University side who could help shepherd the process along. Once a champion was located, the University parties were more receptive to the project. Achieving stakeholder participation prior to project formation needs to be a future priority for university-focused master's projects.

Despite some initial difficulties, the project proceeded smoothly once trust was established the relevant administrators. The IT managers the team worked with ultimately found value in the project and were willing to provide the time and effort necessary for success. Phil Ray, the SNRE IT Manager thought that future projects should focus on the academic aspects of exploring the university's operational side, in contrast with trying to make operational changes. Both Mr. Ray and Mr. Miller thought the project provided worthwhile insights and that the students had a valuable outside perspective on the University's organizational and cultural issues. They suggested future projects should not try to implement change from the bottom-up of the university structure, but should work with officials at higher levels in the University.

V. Conclusions and Recommendations

A. Conclusions

The following is a summary of the conclusions drawn by the master's project team based on the research and case study that were conducted as a part of the project.

Current limitations in energy measurement impede efforts to incentivize energy efficiency. Groups below an existing budgetary unit are largely blind to opportunities for improvement. Increased data granularity would enable better financial accountability for energy use by allowing more targeted billing and savings recognition.

The University's organizational complexity impedes implementation of energy management solutions. Understanding the interrelationships among managers and seeking ways to simplify the organizational structure as it relates to energy decision-making could greatly ease implementation.

A centralized Energy Information System containing university-wide data would allow energy managers to identify opportunities in complex environments. Current data resolution and fragmentation hinder managers' ability to recognize conflicts between mission-driven choices and energy use. A comprehensive EIS would facilitate informed, data-driven decisions capable of incorporating both the cultural and technical landscape.

A complete energy management solution needs to consider end-user experience. Having a solid understanding of the factors that affect end-user experience is critical for the acceptance of energy management technology.

A complete energy management solution must satisfy the needs of both IT professionals and facilities managers. Facilities management requires a single solution that can monitor and control multiple building systems for performance and efficiency. IT requires a single solution that not only manages computer energy use, but also updates virus software, manages applications, and enables patch management.

Coordination of computer energy management programs between departments could significantly improve overall results at the university level. Standardized tools and training, organized communication and sharing of best practices across departments would help to disseminate knowledge about computer energy management technologies and organizational policies that effectively achieve desired behavior.

A centralized initiative to drive improved computer energy management is more likely to be effective in realizing the potential for reduced computer energy use. The economic incentive for individual departments to manage their computer energy use is much smaller than for the university as a whole, so a group that views the savings opportunity comprehensively will act more aggressively.

Central PC energy management can potentially save the University several hundred thousand dollars. This is an order of magnitude estimate based on the data collected in this study.

Convergence of building systems would provide opportunities for even greater savings. Seamless information sharing allows building systems to respond to actual occupant energy demands in a coordinated way. Buildings that only respond to actual needs are more efficient.

B. Recommendations

Additionally, the project team makes the following recommendations for further work to be done, either by other master's project groups or the university.

Align energy decisions and costs at the University. In particular, the project team believes that it is important to:

- *Investigate finance and accounting structures that better incentivize future energy management.* This requires examining the disconnect between energy consumption choices and the resulting costs. It is important to understand the appropriate level of accounting data required for managers and users to make efficient decisions.
- *Map energy decision making at U of M.* In order to make meaningful improvements, it is necessary to understand who the important decision makers are, how they interact with one another, the energy data they use now, and what data would most help them to be effective in the future.

Conduct a study of factors affecting user experience and their relative importance. The effects of energy management on computer use experience would be one focus. Its effects on perception of the physical environment due to lighting levels and building temperature could be another.

Implement a more robust Energy Information System at the University. Expand the scope and granularity of energy-related data that is collected and analyzed.

Conduct a pilot of converged building energy management. This would provide an opportunity to gauge the energy savings that would be possible at the university with an integrated data and control infrastructure for buildings.

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