Case Study of Implementation of Web-Based Energy Management and Control System onto Campus Buildings

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ABSTRACT

Energy efficiency is a critical issue for campus buildings as it is associated with students' comfort and indoor air quality. The Case-A university has more than 9,000 students and 12 campus buildings with a total floor area of 165,187 m^2. The electric usages are always increasing rapidly during the summer period. As a result, Case-A spends US$1.6 million dollars annually on electricity consumption including the fines in excess of the contracted capacity for more than US$31,000. The electric energy use intensity (EUI) in 2008 was 139.8 kWh/m^2-yr exceeded the average EUI of 29%. It is imperative that Case-A implements energy management policies to promote the energy conservation.

Industrial Technology Research Institute assisted Case-A to install Web-based Energy Management and Control System (Web-EMCS) for energy conservation of campus building. The Web-EMCS was complete in February 2009. Case-A has managed several demand load relief programs in Web-EMCS to evaluate potential energy reduction. The main program is to curtail chillers loads alternately from individual buildings during peak demand, and the indoor thermal comfort is satisfactory. The campus demand between March-to-July-2009 period has reduced by 450,400kWh comparing to the corresponding period one year before. Visualization of energy use data and benchmarking functions from Web-EMCS are useful to find abnormal energy usage. For example, an energy manager did find that the Recreation Center heat pump had malfunctioned, causing an increase consumption by 25%. The total energy savings were more than US$94,000, the estimated payback period was 1.6 years.

Introduction

The Importance of Energy Management within Buildings

Energy usages of commercial buildings are growing and energy conservation issues are getting more attention in the world. According to ABI Research's study (ABI Research, 2010), the market for building automation systems will reportedly grow 3 percent globally from 2009 to 2015, and the total market will reach a value of more than $36 billion dollars.

Pike Research (Pike Research, 2009) investigated Energy Management Systems for commercial buildings. Building energy management system vendors are promoting a new generation of energy management systems (EMS) for reducing commercial buildings energy usage and its associated costs and carbon emissions. The Energy management system is a combination of building management systems and advanced software solutions that assist in managing the building functions in a more energy efficient way. Pike Research forecasts that all of these factors will help drive the commercial demand response market to over 75,000 megawatt hours and the commercial building energy efficiency market to over $6.3 billion dollars by 2020.

Development of Energy Information and Management System

The Climate Group on behalf of the Global eSustainability Initiative (The Climate Group, 2008) presented a report about Information and Communications Technology (ICT) industry. ICT industry has a role to play in reducing greenhouse gas emissions by 15% as of 2020 compared to 2002. There are five major opportunities for reducing emissions – dematerialisation, smart motor systems, smart logistics, smart buildings and smart grids. Smart buildings (European Commission, 2009) mean that buildings empowered by ICT in the context of the merging of Ubiquitous Computing and the Internet of Things. ICT helps citizens take decisions for energy conservations by obtaining information on energy consumption of appliances and equipments in a building in real-time, in a user friendly way.

Lawrence Berkeley National Laboratory (California Energy Commission, 2003) used Energy Information System (EIS) for buildings energy conservation. The EIS is a combination of software program, data acquisition hardware, and communications systems. The process is to collect and display building information to aid managers in reducing energy use and costs. The Energy Information System can help building operators reduce buildings energy conservation by understanding hourly load profile and equipment schedules.

Energy Information System retrieves and plots hourly or sub-hourly trend data, but does not provide detailed data analysis or allow remote system control. Energy Management and Control Systems (EMCS) are control systems to optimize operations of Heating, Ventilating, and Air Conditioning (HVAC) equipments, through a series of sensors, communications, and controllers. Many EMCS are designed to control HVAC only, and have limited capabilities in integrating with other building systems via the Internet. Web-EMCS is defined as an EIS that emphasizes system integration capabilities and has the ability to monitor and retrieve data from EMCS or similar system via the Internet.

It is necessary to reveal sufficient electricity usage information to building managers for energy conservation. Several counseling cases have demonstrated that energy usage can be reduced by 15% to 20% or more by identifying and correcting operational issues on electricity, lighting, air conditioning, service equipments and others. Meyers et al. (Meyers et al., 1996) have pointed out that accurate, appropriate information is essential to understand the dynamics of energy use, control strategies, and occupant comfort in buildings. Performance data for a building are valuable at all stages of its life cycle – design, commissioning, and operation.

University College Dublin (The IRISH Energy Centre) installed building energy management system (BEMS) to control heating in the existing Agriculture building. It proved successful and made an immediate improvement in environmental conditions of the building.

Uenoa et al. (Uenoa et al., 2006) have proposed a method of reducing the energy consumption in residential buildings by providing household members with information on energy consumptions. It used an on-line interactive ‘‘energy-consumption information system’’ that displays power consumptions of 18 different appliances, gas consumption and room temperature. The experiment showed that energy-saving consciousness was raised and energy consumption was in fact reduced by the energy-saving activities of the household members.

Buildings energy consumption can be visualized in a user friendly way. Siddiquee et al. (Siddiquee et al., 2009) have made an approach on the analysis of the buildings energy consumption by using geo-information systems (GIS). The objective of the study deals with structuring a system where building energy consumption data such as electricity and heating and renewable energy supply are to be managed with the help of geo-information systems. The users can have access to the building energy consumption data through the Internet and hereby they can evaluate the status of their respective energy consumption and supply. This will increase the awareness about energy consumption along with the efficiency of energy use among the users.

The electricity data visualization programs can help building operators detect and diagnose problems. Seem (Seem, 2005; 2007) develops a novel method for detecting abnormal energy consumption in buildings based on daily readings of energy consumption and peak energy consumption. The data analysis method could reduce operating costs by detecting problems that previously would have gone unnoticed. Building energy costs will decrease because control, system, or operation problems will be detected and corrected by data analysis method.

Energy Saving and Carbon Reduction Action Plans in Taiwan

Taiwan lacks energy resources and has high dependence on imports for more than 98 percent of its energy. It is necessary to conduct activities to promote energy conservation. The Executive Yuan, the highest administrative organ of the Republic of China, approved the Framework of Taiwan's Sustainable Energy Policy (Bureau of Energy, Ministry of Economic, 2008) in June 2008. The goal is to improve energy efficiency by more than 2% per annum, so that when compared with the level in 2005, energy intensity will decrease 20% by 2015. One of the Energy Saving and Carbon Reduction Action Plans is to develop the consumption reduction programs of electricity and oil for the governments, institutions and schools, to achieve the 7% reduction target for 2015.

According to the Energy Audit Annual Report for Non-manufacturing Industries 2008 (Taiwan Green Productivity Foundation, 2008), presented by Taiwan Green Productivity Foundation, schools in Taiwan are major energy consumers. There are 236 schools in Taiwan and the electricity usage reached 2.4 billion kWh. There is obviously great potential to work for energy savings in schools, especially for universities.

Energy Use Intensity (EUI) (California Building Energy Reference Tool) is a measure of total energy use normalized for building floor area. It is used to compare the energy use of different buildings for efficiency and verification. Electricity use is expressed as annual kWh per square meter per year (kWh/m^2.year). EUI is a suitable energy benchmarking index for identifying the worst energy consumption buildings. The 2008 Energy Audit Annual Report for Non-manufacturing Industries database is investigated as a source for energy benchmarks for schools in Taiwan. The database contains 169 schools that fall under different categories shown in Table 1. The building type with the highest EUI value is universities buildings (99.9 kWh/m^2.year), and the second is university of Science and Technology (83.4 kWh/m^2.year). The Energy Saving and Carbon Reduction Action Plans for schools in Taiwan is that the Executive Yuan asks the schools with high EUI values to achieve the reference value (98.2kWh/m^2.year) target for 2015.

Table 1. 2008 Taiwan School Electricity EUI Statistics (unit: kWh/m^2.year)

School type	Accounts	Mean	Max	Min	Standard Deviation
University	81	99.9	194.7	25.3	32.1
University of Science and Technology	34	83.4	101.4	63.3	10.8
Senior high school	37	67.4	111.8	28.2	20.6
Vocational High School	17	58.6	91.8	19.6	21.7

Scheduled maintenances and suitable operations management are major energy saving actions for schools in Taiwan. There is 10-20% energy saving potentials for applying these actions. In general, the air-conditioning system consumes more than 40-50% of the building total energy use, followed by 30% of lighting equipments, and 20% of miscellaneous pumping systems. The energy-saving actions for major building systems are described as following:

- Air-conditioning system: to choose high-efficiency equipments; to control chiller pump efficiently and cooling tower fan with inverter; and to enhance management in conditional on-off controls, etc.
- Lighting system: to choose high-efficiency luminaries; to use electric ballast; to adjust luminary numbers with respect to luminance; to change luminary switch allocation; and to add human-sensing or daylight-sensing switch, etc.
- Management: to select optimal contract capacity; to setup demand control system with energy management system (EMS); to add automatic power factor corrector; to refill water tower at off-peak period; to heat dormitory bathing water by using heat pumps, and to promote "power efficiency and energy saving" propaganda, etc.

Overview of this Research

This research provides a web-based energy management system for campus buildings. With measurement and control interface, communication network, database management system, and Web server and portal, a complete application platform was established case-A university. The following sections describe the background of case-A university, practical implementation, findings and future work.

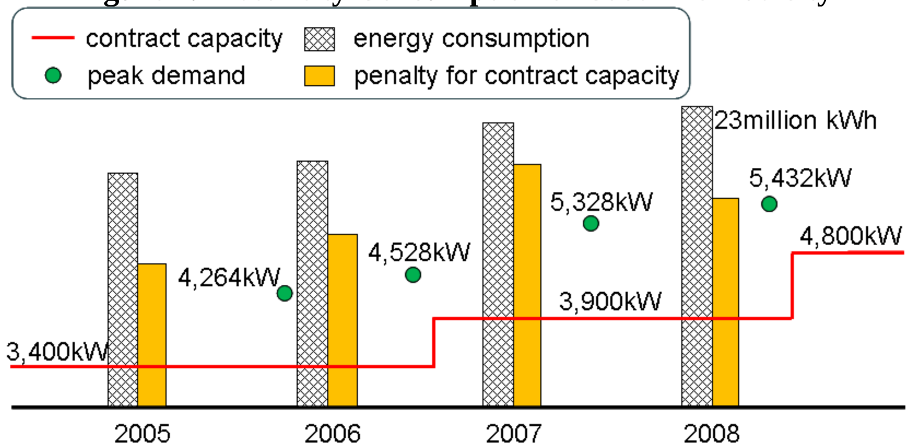
Implementation of Web-Based EMCS at Case-A University

Background of Case-A University

Energy efficiency is a critical issue for campus buildings as it is associated with students' comfort and indoor air quality. The majority of energy consumption is due to Heating, Ventilating, and Air Conditioning (HVAC) systems. More than one third of energy consumption is spent on HVAC systems in school buildings. Case-A university at Chung-Li City in Taiwan is home to more than 9,000 with a 2:1 ratio between undergraduate and graduate students on campus. The campus is composed of 12 buildings, totaling 165,187 sq. m. of building space. Rising electric rates and increased student enrollment all work against the campus's administration operating budget.

Figure 1 shows the electricity consumption per year of the Case-A university. Electricity use had been increasing for the last few years. Case-A spends US$1.6 million dollars annually on electricity consumption including the fines in excess of the contracted capacity for more than US$31,000. The whole-campus electric energy use intensity (EUI) in 2008 was 139.8 kWh/m^2-yr exceeded the average EUI of 29%. It is imperative that Case-A implements energy management policies to promote the energy conservation.

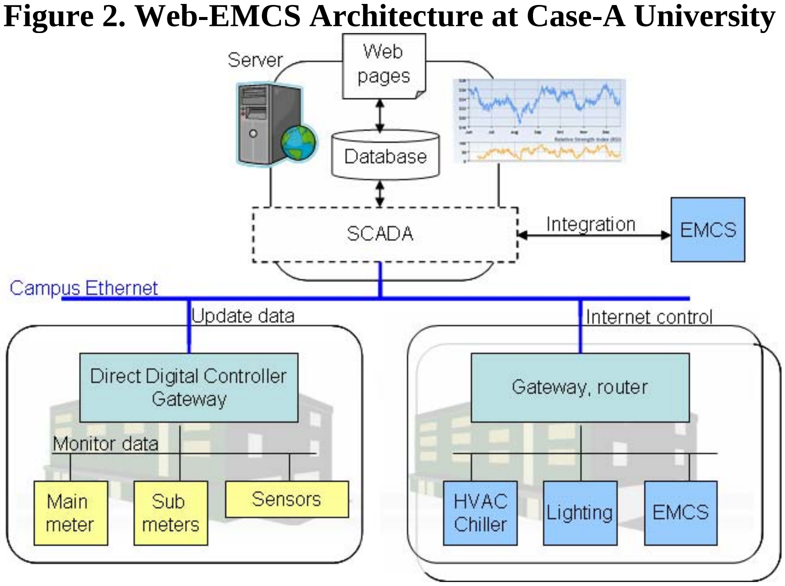
Figure 1. Electricity Consumption of Case-A University



The System Architecture of Web-EMCS at Case-A University

Industrial Technology Research Institute (ITRI) assisted Case-A to install Web-based Energy Management and Control System (Web-EMCS) for campus buildings' energy conservation. The Web-EMCS used in Case-A integrate multiple systems, including smart meters, building automation system, on-site generation, and EMCS. Figure 2 shows the system architecture of Case-A Web-EMCS. Energy consumption data of total campus and each building are collected by metering devices installed at substation sites. Data are dispatched by SCADA (Supervisory Control and Data Acquisition) (WebAccess SCADA/HMI) via a Direct Digital Controller (DDC-Online) or other communication device through campus Ethernet to a server. The database server stores data and provides user-friendly web pages for building operator, staffs and students. The energy manager can implemented a series of changes in control strategy based on findings from the Web-EMCS.

Figure 2. Web-EMCS Architecture at Case-A University



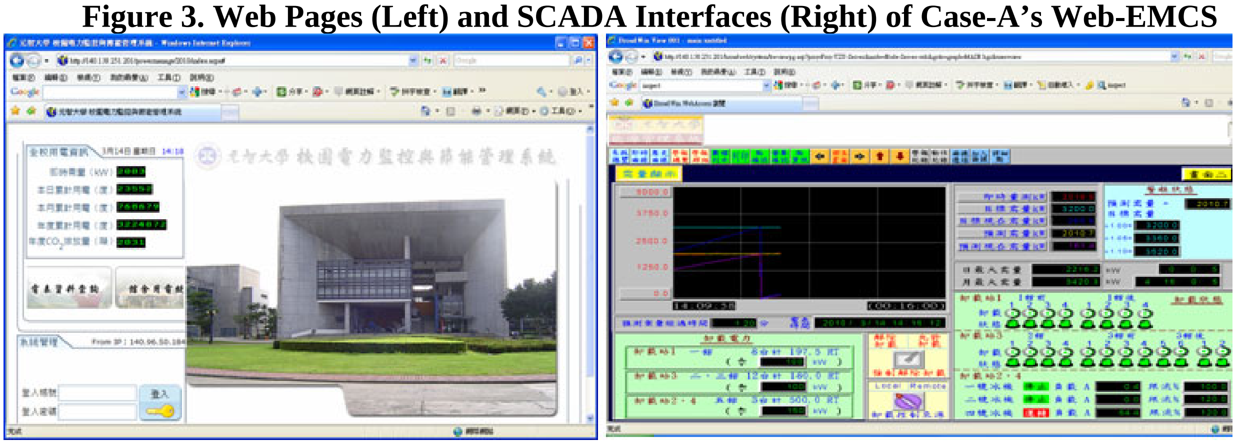
The Web-EMCS's necessary functionalities are described as follows:

- Power consumption and tariff calculations: kWh (kilowatt hour) is defined as the electric tariff unit, and total fee can be obtained by multiplying kilowatt hours and unit tariff.
- Power system control and data acquisition (SCADA): The SCADA subsystem provides power consumption trend and histogram to monitor each circuit loop for safety. For power consumption electric equipments, the SCADA automatically records kWh data and exports reports.
- Equipment load shedding: Proper strategies are adopted to control lighting and HVAC equipments in power consumption, so as to suppress peak demand effectively.
- Equipment information integration: With communication techniques, all equipments on the power distribution loop are connected and exchange data with central database.
- Internet Integration: The graphical console provides real time information display and monitoring functions. Furthermore, the user can use a Web-browser to remotely access the database for the historical data and manage the equipment operations.

Findings from the Web-EMCS

Figure 3 shows the web pages and SCADA interfaces of Case-A's Web-EMCS website. The first version of Web-EMCS was installed on the Case-A campus in February 2009. The Web-EMCS is used by one energy manager and several facility managers. The energy manager is responsible for campus energy management and use Web-EMCS interfaces. The facility managers are responsible for building system operations and trouble shooting for the buildings in Case-A campus. The facility managers would check the operational status of HVAC systems using the Web-EMCS and modify set points if necessary. The energy manager and facility managers spend at least an hour per day and more using the system, and be able to access the data form home at any time. Case-A university academic staffs and students could remotely browse the campus energy consumption from any place at any time. The Web-EMCS programmers would also check the data and operational settings from ITRI office at any time.

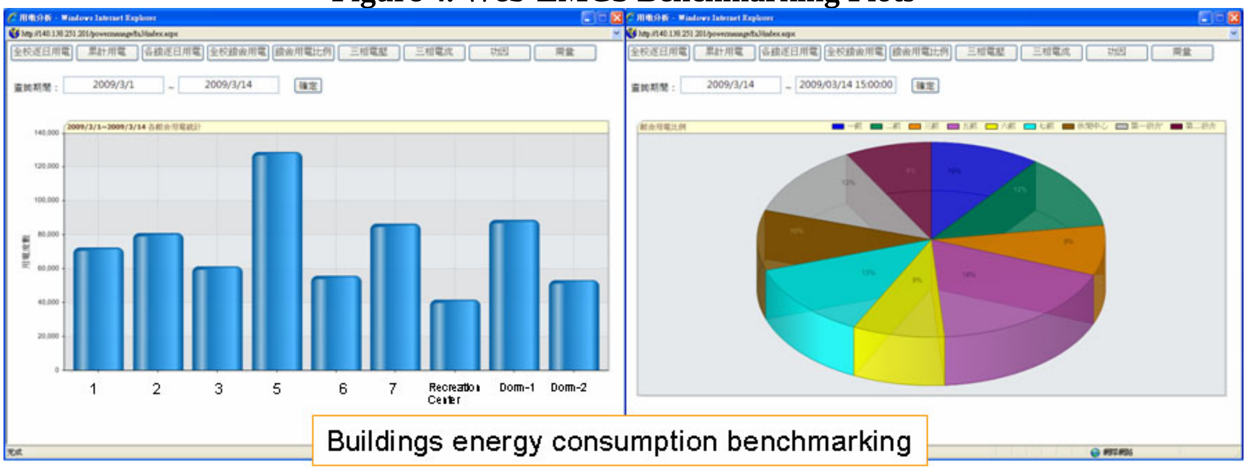
Figure 3. Web Pages (Left) and SCADA Interfaces (Right) of Case-A's Web-EMCS



Opportunities for campus energy conservation through operational changes have been found in the daily routine of analyzing time-series data on the Web-EMCS. Case-A managed several demand load relief programs in Web-EMCS to evaluate potential energy reduction. Below are some examples of energy conservation opportunities:

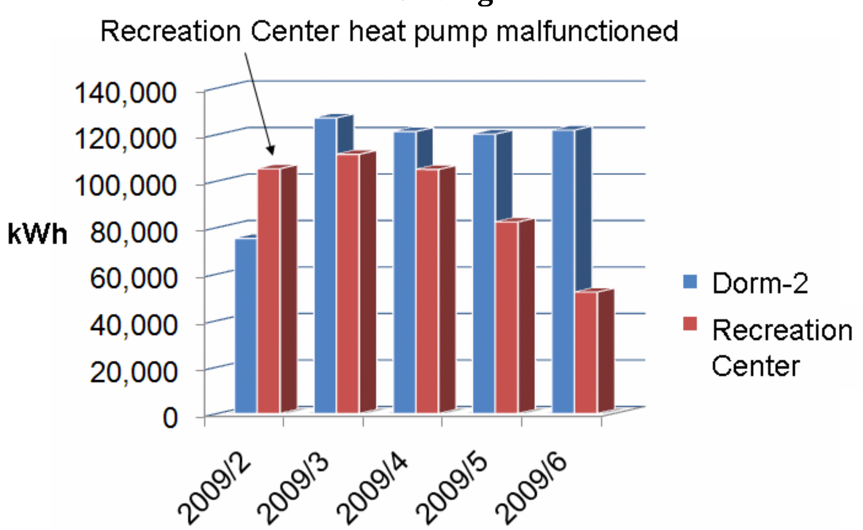
Historic baseline energy use. The energy manager finds the Web-EMCS data summarization features useful. Graphs of the Web-EMCS help building managers identify major changes in energy consumption. As shown in Figure 4, energy manager can view energy usage for each building, to identify which building is the most energy-intensive.

Figure 4. Web-EMCS Benchmarking Plots



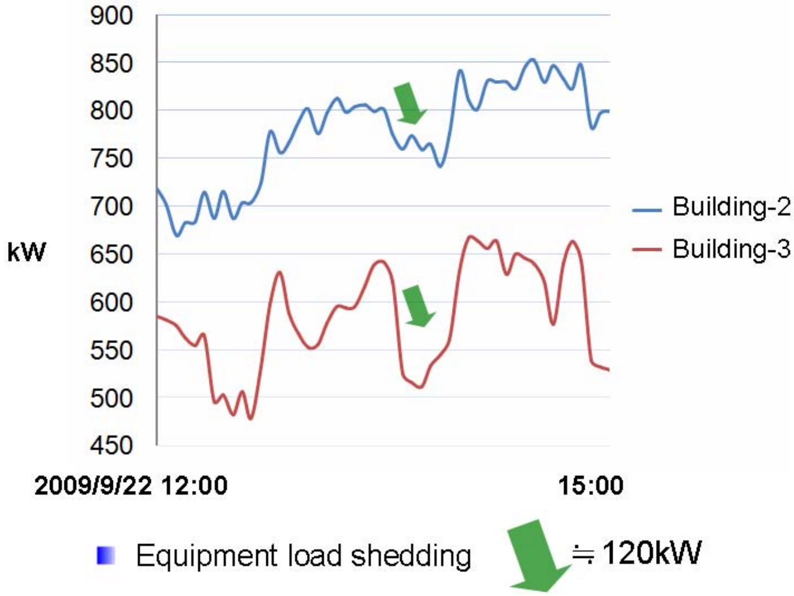
Visualization of energy use data and benchmarking functions from Web-EMCS are useful to find abnormal energy usage. The energy manager did find that the Recreation Center heat pump had malfunctioned, causing an increase consumption by 25%. The Recreation Center heat pump was operated everyday at 100% load, even though it is not occupied at night. The problem was remedied in May 2009. Figure 5 presents the comparison of energy use in Recreation Center to energy use in Dorm-2 building.

Figure 5. Comparison of Energy Use in Recreation Center to Energy Use in Dorm-2 Building



Timing and magnitude of peak electric demand. The load relief program is to curtail chillers loads alternately from individual buildings during peak demand, but otherwise the indoor thermal comfort is satisfactory. Proper strategies are adopted to control HVAC equipments and pumps in power consumption, so as to suppress peak demand effectively. Figure 6 presents the results of the curtailment of chillers loads from individual buildings.

Figure 6. The Curtailment of Chillers Loads from Individual Buildings



Energy Conservation Analysis

Case-A's Web-EMCS was installed in March 2009. The benefits of Web-EMCS can be separated into (1) energy savings and (2) peak electric demand reduction savings. Table 2 summarizes the campus demand between March-to-July-2009 period has reduced by 450,400kWh compared with the corresponding period last year.

Table 2. Energy Cost Saving

2009	Electricity [kWh]	Compared with 2008 [kWh]
July	2,345,600	-206,400
June	1,756,800	-220,000
May	1,734,400	-43,200
April	1,628,000	+99,200
March	1,288,800	+393,600
February	1,060,000	-473,600
Total		-450,400

The contract capacity for Case-A university is 4,800kW. Table 3 summarizes the peak demand reduction between March-2008-to-July-2008 period and March-2009-to-July-2009 period. The result shows that campus peak demand is suppressed effectively by operating Web-Energy Management and Control System.

Table 3. Peak Demand Reduction

2009	March	April	May	June	July
Monthly bill [kW]	3384	3488	3672	4512	4688
Web-EMCS data [kW]	3381.7	3479.6	3655.8	4503.2	4675.7
2008	March	April	May	June	July
Monthly bill [kW]	3272	4512	5424	5432	4384
penalty for contract capacity (US dollar)	0	6,285	7,260	9,643	0

The cost savings were estimated by applying $0.0625/kWh for electricity consumption. The total energy savings were more than US$94,000, resulting in an estimated payback period of 1.6 years.

Conclusion

The global de-carbonization and energy-saving trend evokes the new wave of environmental protection activities in all campuses. Case-A university is a high EUI value school and has great potential to work for energy conservation. The Web-EMCS provides a clear view of the electricity use for the Case-A university. Energy consumption data from Web-EMCS helps campus building operators and managers identify if the building systems are working properly. All academic staffs and students can understand where the energy used and how much energy they use. This prompt can not only remind the users, but also encourage their willing energy-saving actions. The Web-EMCS for Case-A university is completed successfully and running online smoothly. In the future, the electricity usage information can be further analyzed for equipments diagnosis and demand predictions, and contribute more benefits to the campus energy conservation.

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