QTLE NETWORK INC.

Energy Efficiency Factors

Setting the physical stage for high quality teaching and learning environments

Research Information Grid

This information list was last updated on **August 10, 2015**.

How parents and teachers are helping to create better environments for learning

Energy Efficiency and Renewable Energy U.S. Department of Energy - August 2001 DOE/GO-102001-1429

School districts around the country are finding that smart energy choices can help them save money and provide healthier, more effective learning environments. By incorporating energy improvements into their construction or renovation plans, schools can significantly reduce their energy consumption and costs. These savings can then be redirected to educational needs such as additional teachers, instructional materials, or new computers.

Many of the same improvements that help to lower a school's energy consumption also create better places to teach and learn, with better lighting, temperature control, acoustics, and air quality. In fact, recent research reveals a strong connection between the use of daylighting in classrooms and student attendance and performance.

Energy improvements can also have a positive impact on student health and comfort. Children can't concentrate if their classrooms are too stuffy or noisy. Students with asthma are likely to miss school if indoor air quality is poor. Simple energy design strategies can improve these conditions, creating a healthier, more comfortable environment for students as well as teachers.

Improved benchmarking comparability for energy consumption in schools

Sung-Min Hong, Greig Paterson, Dejan Mumovic & Philip Steadman (2014) Improved benchmarking comparability for energy consumption in schools, Building Research & Information, 42:1, 47-61, DOI: http://dx.doi.org/10.1080/09613218.2013.814746

The method behind the UK Display Energy Certificate (DEC) improves the comparability of benchmarking by accounting for variations in weather and occupancy. To improve the comparability further, the incorporation of other features that are intrinsic to buildings (e.g. built form and building services) deserve exploration. This study investigates the impact of these features and explores ways to improve further comparability in benchmarking the energy performance of schools. Statistical analyses of approximately 7700 schools were performed, followed by analyses of causal factors in 465 schools in greater detail using artificial neural networks (ANNs), each designed to understand and identify the factors that have significant impact on the pattern of energy use of schools. Changes in the pattern of energy use of schools have occurred over the past four years. This fact highlights issues associated with static benchmarks. A significant difference in energy performance between primary and secondary schools meant that it was necessary to re-examine the way non-domestic buildings are classified. Factors were identified as having significant impact on the pattern of energy use. The characteristics raise new possibilities for developing sector specific methods and improving comparability.

A FACILITY MANAGEMENT APPROACH TO REDUCING ENERGY AND CARBON FOOTPRINT OF BUILT FACILITIES

Manish Kumar Dixit Department of Architecture, Texas A&M University mandix72@hotmail.com Phone: 979-676-2446 - Charles H. Culp Department of Architecture, Texas A&M University cculp@tamu.edu - Jose L. Fernandez-Solis Department of Construction Science, Texas A&M University jsolis@arch.tamu.edu - Sarel Lavy Department of Construction Science, Texas A&M University slavy@arch.tamu.edu - CIB Facilities Management Conference 2014 Technical University of Denmark

Purpose: The main purpose of this paper is to emphasize the importance of a life cycle approach and the role of facilities management practices in reducing the environmental footprint of built facilities. An approach to holistic life cycle energy and carbon reduction is also proposed.

State of the Art: Built facilities consume over 40% of global energy annually resulting in over 33% of world's total carbon emission. According to literature, for a significant reduction in energy use and resulting carbon emissions, it is critical that both the embodied and operating energy use of a facility is optimized.

Approach: A literature-based discovery approach was applied to collect, analyze, and synthesize the results of published case studies from around the globe. The energy use results of 158 published case studies were analyzed to derive conclusions.

Results: A comparison of energy efficient and conventional facilities revealed that decreasing operating energy may increase the embodied energy components. Additionally, the analysis of 95 commercial facilities indicated that nearly 10% of the total U.S. carbon emissions was influenced by facilities management practices.
Practical Implications: The proposed approach to holistic environmental footprint reduction can guide facility management research and practice to make meaningful contributions to our efforts for creating a sustainable built environment.
CIB Facilities Management Conference 2014 Technical University of Denmark
218
Research Limitations: The results were derived from case studies that belonged to various locations across the globe and included facilities constructed with a variety of materials.
Originality/Value: This paper quantifies the extent to which a facilities management professional can contribute to the global efforts of reducing carbon emission.

Facility Type: K–12 Schools

Revised November 2006 - ENERGY STAR® Building Manual

America's schools spend more than $7.5 billion annually on energy—more than they spend on textbooks and computers combined. Energy costs are the largest operating expense for school districts after salaries and benefits, and in recent years those costs have increasingly strained their budgets. The good news is that energy is one of the few expenses that can be decreased without negatively affecting classroom instruction.
As energy has become a larger and less predictable expense, it is imperative that school districts invest in retrofits and ongoing maintenance to assert control over their utility costs. Yet school districts perpetually struggle to budget appropriately for operations, maintenance, and capital projects. High-dollar capital projects are the first to go when budgets are cut, and trimming maintenance expenditures is more palatable to school boards than cutting instructional staff. It's also not unusual for school districts to build new schools or additions without making corresponding increases to maintenance spending and staff.

The result is an accumulation of deferred maintenance, which leads to higher energy costs and more equipment malfunctions. Lack of preventive maintenance reduces the operational life of building equipment, hastening the need to invest in costly capital retrofits.

Increasingly, facility condition is being recognized as an important factor for student learning. Lawsuits regarding inadequate funding for education in dozens of states have shifted the focus from spending per school or per student to the condition of school buildings. This trend is pushing school districts to better manage their facility assets.

Several aspects of building performance are fundamental in providing an environment that is conducive to learning. Research has shown a relationship between facility conditions and absenteeism, teacher turnover rates, and occupant health. The following factors should be considered integral to your energy-saving retrofit choices. Fortunately, many upgrade choices can improve these factors while cutting energy consumption.

- Security and safety can be enhanced with proper exterior lighting as well as adequate lighting in hallways and stairwells. Security of operable windows is another consideration.
- Indoor air quality can be improved with ventilation as well as by removing the source of pollutants. Indoor pollutants may include gases (such as radon), chemicals (for example, cleaning agents), mold, and particulates. Because children have higher breathing and metabolic rates than adults, they are more vulnerable to many environmental threats. High concentrations of carbon dioxide (CO2) have been correlated with sickness as well as poor academic test performance. Ventilation may be particularly important in factory-built relocatable classrooms that incorporate pressed-wood materials containing formaldehyde.
- Thermal comfort also has an impact on student performance. Warm temperatures reduce alertness, whereas cold temperatures reduce dexterity. Frequently and widely fluctuating temperatures can hinder children's ability to focus, although broader fluctuations tend to be more acceptable with natural ventilation.
- Visual comfort depends on having an adequate amount of evenly distributed illumination. "Daylighting in Schools: Reanalysis Report" (www.newbuildings.org/downloads/ Final Attachments/A-3_Dayltg_Schools_2.2.5.pdf), a major study conducted in 2003 by the Heschong Mahone Group, found that on average daylighting improves learning by 21 percent.
- Acoustic comfort is vital because up to 60 percent of classroom activities involve spoken communication. Noise from outside the building, interior hallways, and building systems (such as fans, boilers, and compressors) can be a significant distraction. Even the way sound reverberates within a classroom can cause levels of discomfort and stress that interfere with learning.

Factors That Affect Student Performance Among Ohio LEED Schools: An Examination of LEED Credit Categories, IEQ Credits and School Typology

Ryan P. Thombs Otterbein University, ryan.thombs@otterbein.edu- Spring 4-8-2015 - Otterbein University Digital Commons @ Otterbein

This investigation examines the impact that LEED certification had on educational outcomes of K-12 school buildings in the state of Ohio during the 2012-13 academic year. The study focused on three goals. First, the overall credit categories of LEED were tested to determine whether or not they have an impact on educational outcomes, which were measured by the student performance index (SPI). The literature has generally shown that

indoor environmental quality has a significant impact on academic performance. Second, the credits that are within the Indoor Environmental Quality (IEQ) category were tested to determine which individual credits had an impact on the SPI. The third goal was to examine if typology had an impact on education outcomes. Urban and rural schools were compared to suburban schools. Only LEED schools were used in this study to investigate the differences among them.

A major finding of this study was that there does not appear to be strong associations between SPI and total points earned in each LEED credit category or with the type of credits a school decides to earn. However, EQC4 (Low-Emitting Materials), EQC7.2 (Thermal Comfort Verification) and EQC9 (Acoustic Performance) were found to have a positive, statistically significant influence on educational outcomes. EQC2 (Increased Ventilation) and EQC8.2 (Daylight & Views, Views for 90% of spaces) were statistically significant with negative coefficients. Based on the analyses, the most important influences on educational performance are socioeconomic status, attendance rates and whether or not the school is in an urban setting.

Energy consumption in schools –A review paper

Luísa Dias Pereira, Daniela Raimondo, Department of Mechanical Engineering, University of Coimbra and ADAI – Stefano Paolo Corgnati, TEBE Research Group, Department of Energy, Politecnicodi Torino, corso Ducadegli Abruzzi24,10129 Torino,Italy – Renewable and Sustainable Energy Reviews 40 (2014) 911-922, www.elsevier.com/locate/rser 2014 Elsevier Ltd. All rights reserved.

Among all public buildings, on account of their educational purpose, school buildings have a major social responsibility. Therefore energy performance in this type of building is of great importance.

The overall purpose of this research is to achieve a functional benchmarking, based on the real operation conditions of school buildings, by the exploitation of the results made public, through an intensive literature survey on energy consumptions in schools.

The survey was made to gather data that is relative to energy consumption in school buildings, documented in the most diverse fields and units: global energy consumption values, electrical energy consumption; fuel consumption for heating, energy data consumption of schools expressed in annual cost per unit of heated/cooled surface area ($/m) or per unit of heated/cooled volume ($/m) or, finally, as the annual cost per student ($/student).

The literature was analyzed to determine if a worldwide comparison among the published data could be established.

The results suggest that when attempting to determine an energy benchmark some considerations should not be forgotten: standard indoor environmental conditions (IEC) for classrooms (set- point for indoor operative temperature of 20C in winter and 26C in summer as suggested in EN 15251:2007), electrical and heating consumption values should be kept separately, different education levels usually require different energy consumption values. A good way to normalize heating energy consumption is going through a climatic adjustment based on Heating Degree Days (HDD). For an impartial data comparison, based either on an operating rating or on a simulation carried out for reference conditions, benchmark reference values should be expressed in terms of billed energy data.

School Operations and Maintenance: Best Practices for Controlling Energy Costs - A Guidebook for K-12 School System Business Officers and Facilities Managers

Princeton Energy Resources International 1700 Rockville Pike Suite 550 Rockville, MD 20852, H Powell Energy Associates 20 Acton Road Westford, MA 01886, and Alliance to Save Energy 1200 18th Street, NW Suite 900 Washington, DC 20036. August 2004

Operations and maintenance (O&M) offers not only strategies for maintaining facilities, but also opportunities for reducing energy costs and increasing energy efficiency at existing schools, regardless of age. This Guidebook provides detailed and practical guidance on how K-12 school districts can plan and implement enhancements to their current O&M programs that can successfully maintain their facilities while also reducing energy costs up to 20%. Most of the energy management strategies detailed in the Guidebook entail limited capital costs and produce rapid paybacks, in most cases, of less than two years.

This Guidebook is intended for school district facilities management staff and school business staff (including Superintendents and School Board Members) who have the authority to implement such a program. School-based maintenance and custodial managers may also use this resource to help them identify and understand program details and to see the contribution they can make to the new O&M effort.

The Guidebook is designed to meet the specific needs of school district staff for integrating energy efficiency into school building operation and maintenance by providing not only technical information, but also organizational information on barriers, challenges, and the necessary steps required to develop this type of energy management program within the school district organizational structure. In addition, it contains case studies that are essential to providing experience-based observations and "real life" approaches to which school district staff can relate.

This Guidebook identifies common strategies that have proven successful in a wide variety of American school districts, providing an overview of the broader issues raised in published O&M "literature," as well as in the real-life school-based professional experiences of its authors and contributors. It offers a clear understanding of the various staffing, program design, and other options available to school administrators as they plan and implement the details of their district's O&M effort. With a more complete knowledge of all the options and alternatives, school administrators will be better able to design and implement an energy management effort that is appropriate to, and successful in, their own district.

Major Conclusions and Recommendations:

- High energy costs are not "fixed" and can be reduced by 5% to 20% by effectively managing, maintaining, and operating school physical plants, regardless of school age.
- School organizations can readily utilize techniques to systematically assess O&M practices in their physical plant as well as the magnitude of potential energy-saving opportunities resulting from changed O&M practices.
- Substantial energy savings can be achieved from improved O&M practices without significant capital investments.
- The biggest challenges to obtaining school district cost savings are not technical. Active and continuing support by senior administrators, as well as staff training and motivation, is critical to the success of energy-efficient O&M management efforts.
- A significant number of American school districts, large and small, have had success in achieving energy cost savings by means of improved O&M.
- A number of external sources of support are often available to assist schools in enhanced O&M efforts.
- Energy-efficient O&M programs must be carefully planned and must be appropriate to the size, resources, and "culture" of each school district in order to be successful.

Identifying determinants of energy use of schools in England for benchmarking purposes

Sung-Min Honga, Sherleen Pangb, Greig Patersonb, Dejan Mumovicb, Philip Steadmana a UCL Energy Institute, University College London, Gower St., WC1E 6BT London, United Kingdom b The Bartlett School of Graduate Studies, University College London, Gower St., WC1E 6BT London, United CIBSE Technical Symposium, Liverpool John Moores University, Liverpool, UK, 11-12 April 2013

Carbon emissions from the school stock account for approximately 14% of emissions from the UK's public sector. Energy performance benchmarks play an important role in the built environment which encourage building operators to achieve higher energy efficiency. The robustness of benchmarks and the methodology in CIBSE TM46 which underpins the DEC scheme is vital to obtaining an accurate evaluation of operational performance. Potential ways to further improve comparability of buildings via complex statistical approaches are identified. Statistical analyses of the school stock and information on building characteristics and students have led to identification of determinants of energy use of primary and secondary schools in England. The ways in which the identified determinants could be utilised to improve the relevance of benchmarking process are explored.

Adaptive Frame Length Control for Improving Wireless Link Throughput, Range, and Energy Efficiency

Paul Lettieri and Mani B. Srivastava, {lettieri, mbs}@janet.ucla.edu Electrical Engineering Department University of California, Los Angeles

Wireless network links are characterized by rapidly time varying channel conditions and battery energy limitations at the wireless mobile user nodes. Therefore static link control techniques that make sense in comparatively well behaved wired links do not necessarily apply to wireless links. New adaptive link layer control techniques are needed to provide robust and energy efficient operation even in the presence of orders of magnitude variations in bit error rates and other radio channel conditions. For example, recent research has advocated adaptive link layer techniques such as adaptive error control [Lettieri97], channel state dependent protocols [Bhagwat96, Fragouli97], and variable spreading gain [Chien97]. In this paper we explore one such adaptive technique: dynamic sizing of the MAC layer frame, the atomic unit that is sent through the radio channel. A trade-off exists between the desire to reduce header and physical layer overhead by making frames large, and the need to reduce frame error rates in the noisy channel by using small frame lengths. Clearly the optimum depends on the channel conditions. Through analysis supported by physical measurements with Lucent's WaveLAN radio we show that adaptive sizing of the MAC layer frame in the presence of varying channel noise indeed has a large impact on the user seen throughput (goodput). In addition, we show how that adaptive frame length control can be exploited to improve the energy efficiency for a desired level of goodput, and to extend the usable radio range with graceful throughput degradation. We describe the implementation of the adaptive MAC frame length control mechanism in combination with adaptive hybrid FEC/ARQ error control [Lettieri97] in a reconfigurable wireless link layer packet processing architecture for a low-power adaptive wireless multimedia node.