A Methodology for Analyzing and Reducing Building Energy Consumption

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Abstract -

Building energy usage comprises 32% of total global energy consumption and 41% of U.S. energy consumption. In order to combat growing energy demands, a focus on energy reduction in the building sector is essential. This paper outlines a methodology for reducing the energy consumption of university and commercial buildings by increasing operational efficiency. Though this methodology is developed and applied to a single building, it is designed to be applicable to a wide variety of buildings.

In this paper, The Cooper Union's engineering building, 41 Cooper Square, is studied. 41 Cooper Square is a 175,000 ft^2 academic center housing The Cooper Union's Albert Nerken School of Engineering. Constructed in 2009, 41 Cooper Square is LEED Platinum certified buildings with a fully integrated Building Management System (BMS).

Due to the complexity of the numerous factors overall building energy use is dependent on, the methodology focuses on defining metrics and profiles that reveal inconsistencies in building operation. A systematic and comprehensive process is developed to summarize overall energy consumption, energy use intensity (EUI) is used, which normalizes annual total energy use by gross floor area. To account for differences in energy sources, source EUI is used. According to the EPA, the average academic building has an average source EUI of 262 kWh/ft^2/year, which suggests that the EUI of 404 kWh/ft^2/year at 41 Cooper Square is unusually high. To investigate this problem, the annual energy consumption is broken down into its constituent subsystems, revealing HVAC is the subsystem with the highest energy usage.

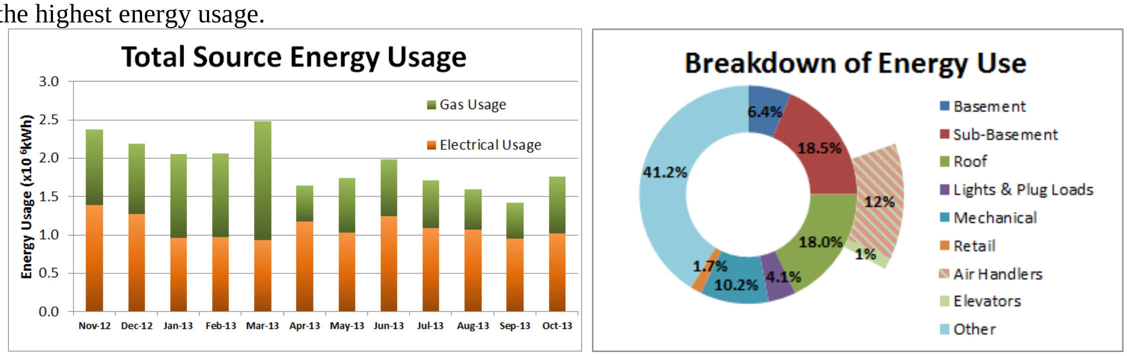

Figure 1: Breakdown of Energy Use from Nov. 2012 to Oct. 2013 for 41 Cooper Square

Though this is a good basis for further analysis of HVAC energy usage, it is important to first normalize the effects of occupancy and weather by examining energy profiles. By examining profiles for a number of different time scales, it is possible to spot anomalies in energy usage. In particular, plotting monthly (or weekly) energy consumption reveals seasonal differences, while daily usage variation is due to temperature and occupancy changes. Since it is the variation that is related to energy usage, it is crucial to integrate these factors over time, rather than averaging them. This leads to heating and cooling degree-days, which accumulate the daily difference in

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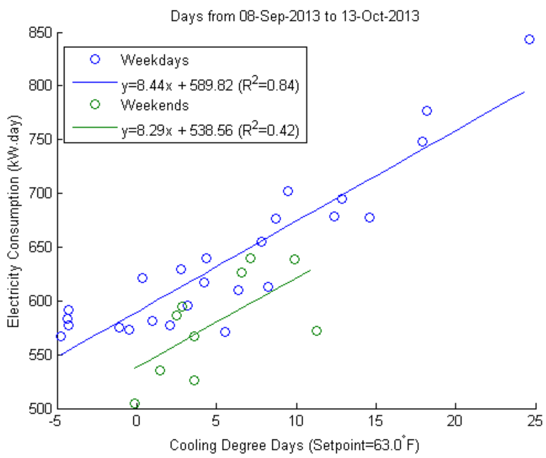
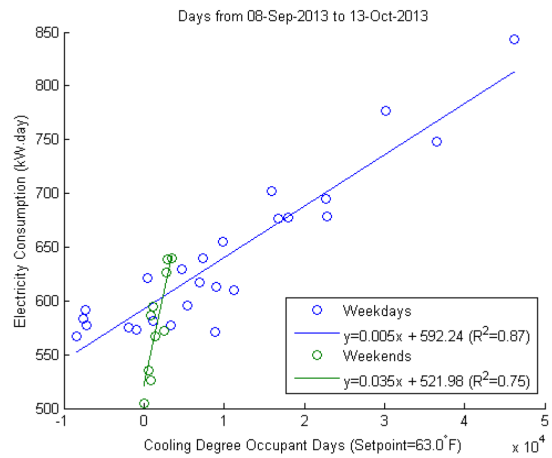
temperature between the outside air and the intended set point. When these metrics do not align with energy consumption, it may be a symptom of underlying inefficiencies.

Since energy usage due to occupancy or temperature is often interrelated, a new metric is developed to normalize for the effects of both factors simultaneously. It is calculated by picking a time period, determining the product of the temperature difference, number of occupants, and amount of time elapsed. From the units, the metric is degree-occupant-days and is similar to degree-days normalized by the number of occupants. When plotted against daily energy consumption, a regression can be performed, with the slope being watts per degree per occupant. Though it is tempting to compare this against traditional thermodynamics constants, it is apparent from the results that the slope is higher on weekends, which correlates to the greater amount of space that must be heated or cooled per occupant. In addition, this new metric has a higher correlation with energy consumption when occupancy varies significantly, and reveals the inefficiencies of lower occupant density.





Currently, the energy profiles are being investigated to determine inconsistencies with the current energy used and the subsystems responsible. By pinpointing locations of these inconsistencies, analysis specific to the subsystem can be used to improve components of the building systems directly responsible. For instance in order to determine the cause of the excessive energy use during March 2012, the building boiler system is under analysis to observe its current method of operation. Calculations are being conducted to see whether the operational efficiency of the system can be improved while still meeting its operational requirements. Using these calculations, overall strategies to improve boiler system efficiency can be developed. Following the analysis of the entirety of the building subsystems, the strategies can be prioritized based upon the amount of energy savings, cost, and difficulty of implementation and used to reduce overall building energy consumption.

Keywords: Building, Energy, Operation, BMS