Analytics for Smarter Buildings

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ABSTRACT

Buildings consume about 40% of the total energy in most countries contributing to a significant amount of greenhouse gas (GHG) emissions and global warming. Therefore, reducing energy consumption in buildings, making buildings more energy efficient and operating buildings in more energy efficient manner are important tasks in today’s world. Analytics can play an important role in identifying energy saving opportunities in buildings by modeling and analyzing how energy is consumed in buildings. In this paper, a set of analytics which can assist building owners, facility managers, operators and tenants of buildings in assessing, benchmarking, diagnosing, tracking, forecasting, simulating and optimizing energy consumption is presented.

Keywords: Building Energy Analytics, Energy Performance, Energy Simulation, Global Warming, Greenhouse Gas (GHG) Emissions, Visualization

INTRODUCTION

A significant amount of energy consumed in today’s world is by buildings, and it contributes to the greenhouse gas (GHG) emissions and global warming. In the United States, 40% of the nation’s total energy consumption is due to commercial and residential buildings (U.S. Dept of Energy, 2006), and this figure is constantly increasing. Therefore, reducing energy consumption in buildings, making buildings more energy efficient and operating buildings in more energy efficient manner are important tasks in today’s world. Analytics can play an important role in identifying energy saving opportunities in buildings by modeling and analyzing how energy is consumed in buildings. Analytics model can help us understand the patterns of energy usage and how heat is transferred between inside and outside of buildings and between inner spaces as well as how characteristics of building structures, operations and occupants’ behavior influence energy consumption. The models can be based on physics, mathematics and statistics. The models can then be used to simulate the impact of possible changes that can be made to buildings on energy consumption, energy costs and GHG emissions, optimize energy consumption and provide decision support for making buildings more energy efficient.

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Energy consumption in buildings can be reduced through various actions. One simplest way is to simply consume less energy. For instance, unnecessary lightings should turn off, and buildings shouldn’t be overheated in the heating seasons and overcooled in the cooling seasons, and computers should be turned off when they are not used etc. Analytics can estimate energy savings opportunities for these conservation measures. Another way is making buildings more energy efficient. For instance, building envelope insulation can be improved, and boilers and chillers can be upgraded to be more energy efficient. Analytics can also be used here to estimate the impact of various retrofits that can make building more energy efficient on energy consumption, energy cost and GHG emission. Another way is to operate buildings in more energy efficient manners. For example, Heating Ventilation and Air Conditioning (HVAC) equipment can be operated with desirable set point profile so that the energy consumption is minimized and peak electricity consumption is reduced. Also energy consuming activities can be scheduled during off-peak times or when renewable energy such as solar and wind energy is available. Analytics can compute the optimal control strategy of HVAC systems, and optimal schedule for energy consuming activities.

ASHRAE Handbook (ASHRAE, 2009) describes various analytics techniques for modeling building energy. The modeling approach is categorized into two types: forward modeling and inverse modeling. Forward modeling tools such as EnergyPlus (2011) and TRYNSYS (2010) predict energy consumption of a specific building with known structure, equipment and known parameters when subject to specific conditions. Forward modeling models requires many geometric and physical parameters, and take a long time to build, are more appropriate in the design and analysis of new buildings rather than operational analysis of existing buildings. Inverse modeling approach, also called data-driven approach, is to start with a mathematical description of the system and estimate the parameters in the mathematical model using available input and output data, often from sensors and meters in the buildings. The inverse modeling approach is more appropriate for existing buildings with performance data already available. Inverse model can be a statistical model (Kissock et al., 2003) or physics based model (Chaturvedi & Braun 2002). For energy analyses that can be applied quickly for many buildings which have building performance data available without spending a substantial modeling effort for each building, the inverse modeling can be a very efficient approach. When properly calibrated, these inverse models can provide reasonably accurate and computational efficient energy predictions for a specific building, and are more appropriate for the operational phase of the existing buildings. In addition to operational analysis, real-time control and fault identification, these types of models can be used in analyzing retrofit opportunities (Cai & Braun 2012). In this paper, we introduce several analytics techniques in inverse modeling and describe the results.

The rest of the paper is organized as follows. In the next section, a physics based inverse modeling approach for estimating heat transfer coefficients are described. Then, the next section shows statistics based inverse modeling approach that integrates multiple regression models and a time series model of building energy is introduced. In the subsequent section, examples of simulation and optimization are shown followed by a section on visualization examples of energy performance modeling. Finally, conclusions are provided in the last section.

**HEAT TRANSFER INVERSE MODEL**

This section describes a model that shows how thermal energy is used to provide a comfortable climate, e.g., temperature and humidity, inside a building using thermal physics principles. Figure 1 shows a simplified view of heat transfer in a building. Building occupants desire comfortable temperature and humidity inside the