Case Study: Evaluation of Renewable Energy Strategies Using Building Information Modeling and Energy Simulation

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ABSTRACT

This case study focuses on the operational performance of a Leadership in Energy & Environmental Design (LEED)-rated building with the application of Building Information Modeling (BIM) to evaluate its capacity to achieve Zero Net Energy (ZNE). Retrofit options for renewable energy implementation are examined in conjunction with scenarios of building operation. In this study, two different BIM processes have been conducted for the energy modeling: object-oriented geometric information modeling (e.g., envelope, doors, windows, zones, etc.) with a BIM tool and energy modeling (e.g., materials, heat resistance, location, weather data, renewables, etc.) with an energy simulation tool. The simulation model is compared to the real building performance and alternative renewable energy scenarios are evaluated. The results are used to make recommendations for the optimization of building performance and consideration of energy-efficient strategies for building performance enhancement. The research points to discontinuities between photovoltaic panel degradation over time and the LEED credit.

Keywords: Building Information Modeling (BIM), Energy Modeling, EnergyPlus, Leadership in Energy & Environmental Design (LEED), Photovoltaic Panel Degradation, Zero Net Energy (ZNE)

INTRODUCTION

The global contribution from buildings towards energy consumption, both residential and commercial, has steadily increased, reaching figures between 20% and 40% in developed countries, and has exceeded the other major sectors: industrial and transportation (Perez-Lombard, Ortiz, & Pout, 2008). In the United States buildings consume close to 40% of all energy used and account for 40% of global CO2 emissions (Schlueter & Thesseling, 2009). Growth in population, increasing demand for building services and comfort levels, together with the rise in time spent inside buildings, assure the upward trend in energy demand will continue in the future. For this reason, energy efficiency in buildings is a prime objective for energy policy at regional, national and international levels.

In addition, the rising cost of energy and growing environmental concerns have pushed the demand for sustainable building facilities with minimal environmental impact through the use of environmental sensitive design and construction practices (Azhar, Brown, & Farooqui, 2009). In efforts to alleviate resource depletion...
and environmental damages, the Architecture, Engineering, and Construction (AEC) industry has adopted Integrated Project Delivery (IPD) as a highly collaborative building procurement process supported by some prominent technological solutions and tools, such as the United States Green Building Council (USGBC) Leadership in Energy and Environment Design (LEED) rating system and Building Information Modeling (BIM) (Garzone, 2006).

LEED is a green building certification system which encourages a building or community to be designed with consideration of environmental impact, energy savings, and human comfort (Gowri, 2004). A LEED rating rewards designers for using strategies that can improve performance in metrics such as CO$_2$ emissions reduction, water efficiency, energy savings, indoor environmental quality, and other environmental impacts. Although LEED does not guarantee most efficient performance of a building or community, it is one method to help towards this goal (Todd, Crawley, Geissler, & Lindsey, 2001).

Building Information Modeling (BIM) represents the development and use of computer-generated building model to support the planning, design, construction and operation of a facility. This technology helps architects, engineers and constructors collaborate and visualize what is to be built and identify potential design, construction or operational problems in a simulated environment (Azhar & Brown, 2009). Linking the building model to energy analysis tools allows for evaluation of energy use and can reduce the costs associated with traditional energy use patterns during building operation.

BIM can support the study of alternatives more quickly, to achieve LEED certification, and make timely decisions (Patel, 2012). Despite the LEED certification process for the new construction, it is required to evaluate the building performance during its operation phase and recertify the building under LEED points. In cases when LEED certified buildings do not perform as expected in the filing period, building performance needs to be analyzed and optimized during operation (Newsham, Mancini, & Birt, 2009). Buildings can apply for recertification as frequently as each year but must file for recertification at least once every five years to maintain their LEED for Existing Buildings: Operations & Maintenance status (Council, 2008).

The research points to discontinuities between photovoltaic panel degradation over time and the LEED credit. Alternative renewable energy scenarios are evaluated to make recommendations for the optimization of building performance and its capacity to achieve Zero Net Energy (ZNE), in terms of energy consumed vs. energy generated during building operation.

**CONSIDERATION OF RENEWABLE ENERGY IN LIFE CYCLE ASSESSMENTS TOWARDS LEED RATING**

The ability to accurately predict power delivery over the course of time plays an increasingly important role in the lifecycle of a sustainable building facility. Two key cost drivers in the performance of this type of renewable energy systems involve the efficiency with which sunlight is converted into power and how this relationship changes over time. An accurate quantification of power decline over time, also known as degradation rate, is essential to all the project stakeholders—utility companies, investors, architects, engineers, and researchers alike. Financially, the degradation of a PV module or system is equally important, because a higher degradation rate translates directly into less power produced and, therefore, reduces future cash flows (Short, Packey, & Holt, 1995). Technically, degradation mechanisms are important to understand because they may eventually lead to failure (Meeker & Escobar, 1998).

The National Renewable Energy Laboratory (NREL), has collected data for 2000 degradation rates, measured on individual modules or entire systems; this research shows a mean degradation rate of 0.8%/year and a median value of 0.5%/year (Jordan & Kurtz, 2013). The majority, 78% of all data, reported a degradation rate of <1%/year. Thin-film degradation rates have improved significantly during the last decade; they are statistically closer to 1%/
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