Cross Case Energy Simulation Modeling Analysis in Healthcare Facilities Retrofit

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ABSTRACT

Healthcare is one of the most complex and energy intensive industries in the United States. Healthcare facilities consume 836 trillion BTUs, spending more than $8.8 billion, 1 to 3 percent of the operating cost, and 15 percent of their annual profits on energy each year. Retrofitting healthcare facilities, from a small renovation to building a new department, is considered an important approach to overcoming these challenges and provides an opportunity to implement energy conservation measures. This paper focuses on the energy consumption of three retrofit projects in three major hospitals and compares energy consumption before and after the retrofit. Based on the information collected from the Facility Departments, simulation models for the selected retrofit projects, were developed and EnergyPlus building energy simulation program was used to model the facilities. Monthly and annual energy simulation modeling results, before and after the retrofit, are compared and analyzed to identify key factors and opportunities for saving energy in existing healthcare facilities.

Keywords: Simulation Modeling Analysis, Healthcare Facilities Retrofit, Energy Efficiency.

INTRODUCTION

Increasing costs of the healthcare industry has an impact on economic growth, and patients and their families. Healthcare providers are looking for different solutions to decrease the cost of healthcare facilities' operation. As healthcare facilities are one of the main energy consumers, improving energy efficiency in current buildings can significantly reduce the cost. According to Benz and Rygielski (2011), the healthcare industry spends $8.8 billion on energy annually. Compared to other commercial buildings, healthcare facilities are operating twenty four hours a day, seven days a week, and providing services all the time.

MEP (Mechanical, Electrical and Plumbing) designers, healthcare owners, and facilities managers are looking for different ways to reduce the cost of energy, while enhancing the quality of care and functionality of hospitals. One solution is to retrofit healthcare facilities to meet current energy efficiency requirements and execute energy conservation measures (ECMs). It is important to identify and implement ECMs in healthcare retrofit projects. In this regard, this paper presents healthcare building energy models to compare energy consumption before and after the retrofit in three case study projects.

ENERGY SIMULATION MODELING IN HEALTHCARE FACILITIES RETROFIT

Under the current economic conditions to reduce the cost of energy, a solution is to retrofit healthcare facilities to have an energy efficiency-driven retrofit (Mohammadpour et al. 2012). In three case study retrofit projects, energy simulation modeling was performed to compare energy usage before and after the retrofit. DesignBuilder was used to build energy models. This program is used because of its flexibility with many input parameters (Alhafi et al. 2012). DesignBuilder is an EnergyPlus user interface that can be used in both education and the commercial sector in design process (DOE, 2013). Four steps were taken during the simulation procedure and various factors were applied in building models. A general overview of the simulation procedure is illustrated in Figure 1.

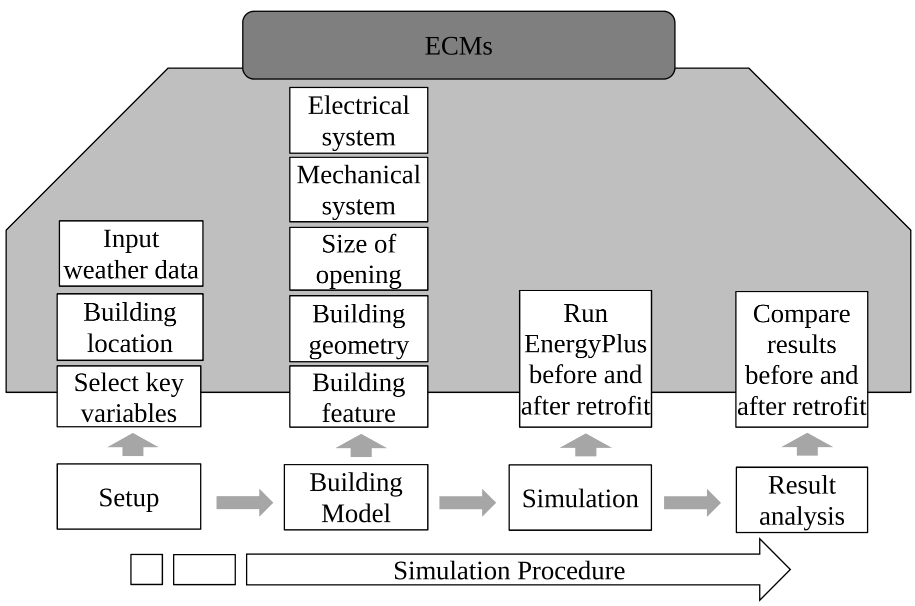

Figure 1. Simulation Procedure

The building models were based on available data on architectural drawings. Building models were created based on the real geometry and size of openings (doors and windows). The occupancy rates were based on the typical building usage. Lighting, cooling, heating, and mechanical ventilation systems were selected in DesignBuilder according to the project utilization. The models were developed for before and after the retrofit to be able to make a comparison of energy consumption, thereby establishing the effectiveness of the ECMs implemented in the retrofit. The created 3-D models can be visualized by the project team.

RESEARCH STRATEGY

Case study was used as the main research methodology to provide a comprehensive analysis of multiple cases. According to Gagnon (2010), a case study method provides an in-depth understanding of phenomena, process, and involved actors. Yin (2003) indicates that multiple case studies enable the researcher to explore similarity or contrasting result between cases. In this paper three case studies were used and studied based on their current retrofitting projects, appreciation of energy efficiency implementation by the Facilities Department, interest in embedding energy efficiency principles, availability of data, accessibility of hospitals, rapport with key participants involved in the retrofitting projects to compare total electrical energy usage before and after the retrofit. The description of three case studies is as follows:

Case Study 1. Case Study 1 was an Emergency Department project in an acute-care facility that was founded more than forty years ago. The healthcare facility has gradually grown since that time and more than $200 million were invested in construction projects, including the construction of new buildings as well as the retrofitting of existing facilities. The Emergency Department project included renovation of the existing Emergency Department and construction of a new addition. The construction project included more than 29,000 sf. of new addition as well as about 14,500 sf. renovation of the existing Emergency Department. The layout of the project is illustrated in Figure 2.

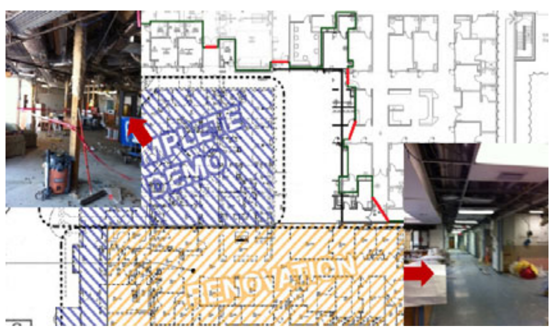

Figure 2. Layout of the Expansion, Demolition and Renovation of Case Study 1

Case Study 2. Case Study 2 was an Outpatient Clinic in an academic medical center with about 500 beds that was founded fifty years ago. The Outpatient Clinic was a shared area between two departments, Anesthesia-PreOp and Pediatric Infusion Center. The Pediatric Infusion Center was moved to the Children Hospital and the building was retrofitted and an Allergy Department permanently moved there. The layout of the Outpatient Clinic is shown in Figure 3.

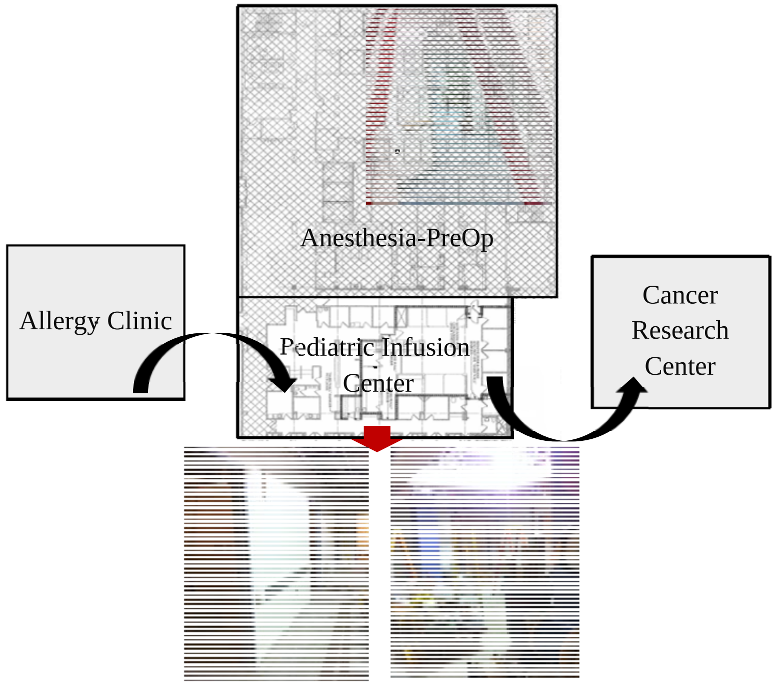

Figure 3. Layout of Relocation of Case Study 2

Case Study 3. Case Study 3 was a Neonatal Intensive Care Unit replacement in an acute care facility composed of an academic medical center, School of Medicine, and community and specialty hospitals. The construction project covered a total area of 38,000 sf. that was located on the fourth floor of one of the existing facilities. The layout of the construction project is illustrated in Figure 4.

Figure 4. Layout of Case Study 3

ENERGY SIMULATION MODELING ANALYSIS BEFORE AND AFTER RETROFIT

Simulation models were built for the three case studies. The models were created based on both default and modified values of the DesignBuilder simulation program. For example, the geographical locations of case studies were required to be setup to be able to use weather data related to each building simulation model. Weather data can be found in the Designbuilder's template. For locations of Case Study 1 and Case Study 2, where the weather data was not available in the template, it was provided from the local weather stations and imported into the program.

Case Study 1 included retrofitting of the existing Emergency Department and construction of a new addition. A Building Automation System (BAS) was used in Case Study 1 to monitor and control mechanical and electrical systems. It was used to be able to update the existing control systems. HVAC control system was improved with Variable Air Volume (VAV) air-handling units with air economizers, pre-heat coils, cooling coils, MERV 8 pre-filters, MERV final filters, ultra-violent light air sterilizer, and steam humidifiers. In addition, to reduce the cost of energy, the electricity distribution outside of the building converted to 12,000 volt system, and it helped the healthcare provider to purchase electricity with a 30% cost reduction from the utility company. This conversion had less than five year return on investment and average life expectancy for any of the equipment that was not less than twenty-five years old. Two energy models were built for Case Study 1 to be able to compare energy consumption before and after the retrofit. The energy models were created based on building features, building geometry, size of opening, mechanical systems, and electrical systems. Figure 5 illustrates the comparison between electrical energy usage before and after the retrofit. Electric energy usage decreased by 12% per square foot after the retrofit.

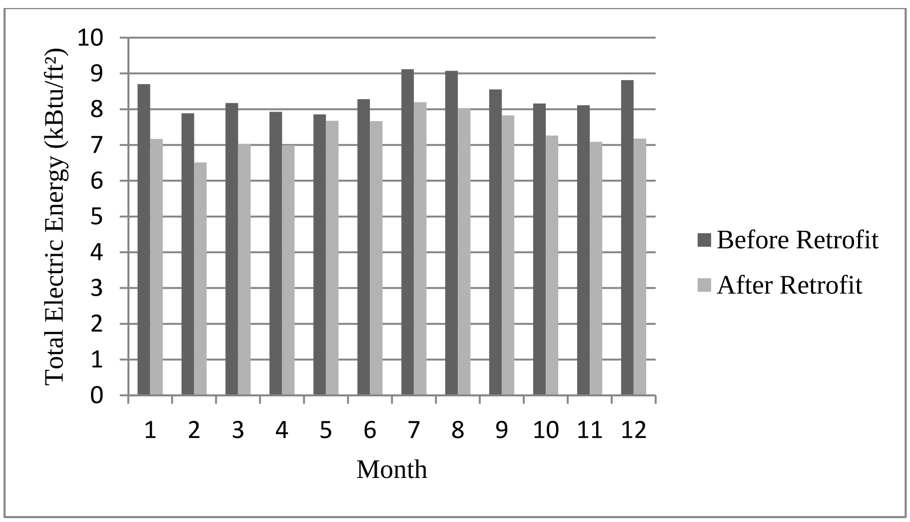

Figure 5. Comparison of simulated electrical energy usage before and after retrofit in Case study 1

As stated earlier, Case Study 2 was a shared area between two departments and, to enhance their existing facilities and improve the quality of care, it was decided to retrofit one part of the outpatient clinic. Air distribution system from CAV (Constant Air Volume) was converted to VAV (Variable Air Volume) and Lighting systems were upgraded. They replaced existing lighting ballasts, lamps and some fixtures with new higher efficiency components, resulting in energy savings without the need to reduce lighting levels. The energy models were created for Case Study 2 and it shows that the implemented ECMs saved about 5.3 % energy per square foot. Comparison of simulated electrical energy usage before and after the retrofit in Case study 2 is illustrated in Figure 6.

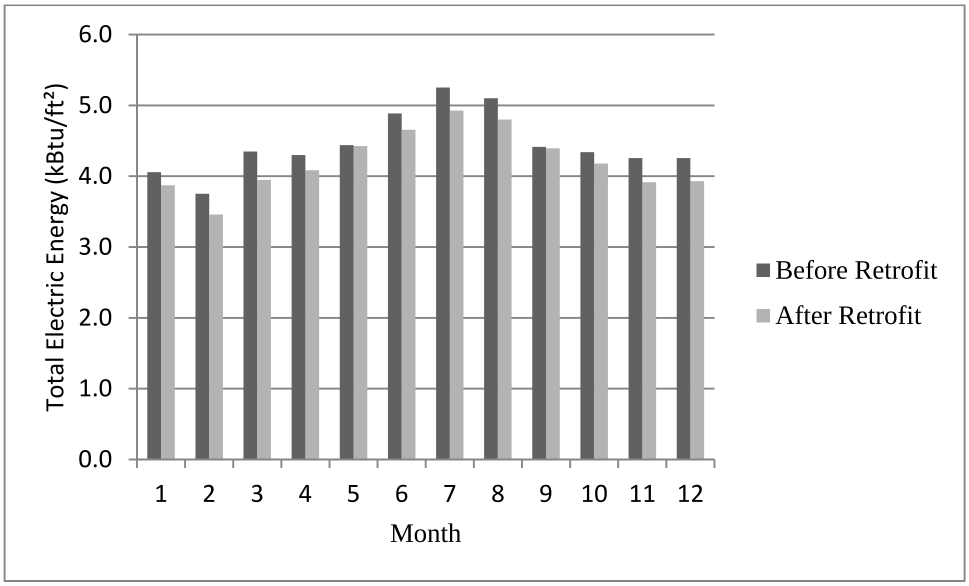

Figure 6. Comparison of simulated electrical energy usage before and after retrofit in Case study 2

Currently, there is more emphasis on the level of comfort and moving from semi-private to private room in Neonatal Intensive Care Unit. To be able to be competitive with other hospitals and accept more patients the east wing of one of the floors in an existing building was retrofitted to comply with the department requirements. Two energy models were created according to the building condition before and after the retrofit. In the first model CAV was selected in the HVAC template. The second model was built for after retrofit and the air distribution system was converted from CAV to VAV. The simulation results compared to each other. Figure 7 illustrates the comparison of simulated electric energy usage before and after the retrofit in Case Study 3. It shows that the air distribution system has a significant influence on saving energy with more than 10% saving per square foot.

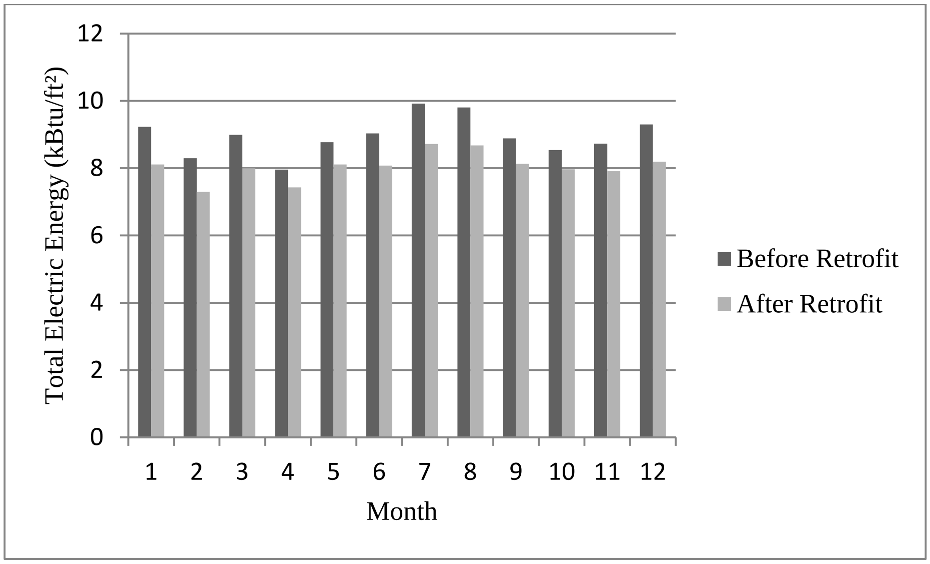

Figure 7. Comparison of simulated electrical energy usage before and after retrofit in Case Study 3

DISCUSSION AND CONCLUSIONS

This study conducted energy simulation modeling to compare electric energy usage before and after the retrofit in three case studies. The analysis shows a trend in all of the cases that energy can be saved by implementing ECMs. The amount of saving depends on several factors such as building use, building location, building orientation, size of openings, building material, and type of glazing. A significant amount of energy can be saved in healthcare facilities based on executed ECMs. The following contributions were explored in the case studies and have an influence on energy saving in the healthcare facilities:

- Decision on implementing ECMs in retrofit projects depends on the owner and the facilities department's willingness, awareness, and existing infrastructure;
- Financial resources and availability of the budget and payback time are very important for selecting ECMs and their implementation;
- Decision on saving cost or saving energy depends on the healthcare facility's priorities;
- The level of retrofit and renovation determines ECMs. Deep retrofit projects or retrofits combined with a new addition to an existing building, provide more opportunities to execute ECMs compared to small or light/shallow retrofit projects;
- The location of the projects in a metropolitan area, small city, or rural area is an important factor for the cost of energy. Energy has a higher cost in metropolitan areas.

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