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Modeling Occupant-Building-Appliance Interaction for Energy Waste Analysis

Triana Carmenate[a,*], Peeraya Inyim[b,*], Nupoor Pachekar[a], Geeticka Chauhan[a], Leonardo Bobadilla[a], Mostafa Batouli[b], Ali Mostafavi[b]

[a]*School of Computing an Information Sciences, College of Engineering and Computing, Florida International University, 11200 SW 8th Street, Miami, FL 33199, USA*

[b]*OHL School of Construction, Department of Civil and Environmental Engineering, Florida International University, 10555 W Flagler St, Miami, FL 33174, USA*

Abstract

The objective of this paper is to discover the emergent energy performance and determinants of energy waste in buildings. Electricity consumption in the U.S. attributes to 73% of energy waste in buildings and much of this waste is due to improper design, operation, and use of appliances. In particular, the operation or use phase of buildings and the way occupants behave significantly contribute to energy waste. Understanding the determinants of energy waste during the operation phase of buildings is a challenging task due to the complex interactions between the occupants, building units, and appliances. To decode these complex interactions and facilitate a better understanding of the determinants of energy waste, a simulation approach is used in this study. An agent-based simulation model was developed to capture the diverse attributes and dynamic behaviors of building occupants at the interface of human-building-appliance interactions. The application of the proposed model is demonstrated in a case study. Using simulation experiments, the interactions between occupant, building unit and appliance on energy consumption were investigated. The simulation model also was used for estimating determinants of energy waste. In addition, the simulation model includes a visualization interface that facilitates communication of strategies between the buildings users and facility managers. The results will highlight the significant attributes and effective strategies for energy waste reduction at the interface of human-building-appliance interactions. This information has potentially significant implications for building designers, facility managers, and users through a better understanding of emergent energy performance of buildings.

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Keywords: human building appliance interaction; building energy; agent-based modeling; emergent energy perfromance; occupant behavior; energy efficiency

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1. Introduction

Energy waste is a major sustainability challenge in buildings in urban areas. During the last decade, primary energy consumption has been increasing annually and the building sector accounts for significant part of energy consumption nationally and globally. Buildings consume 20-40% of primary energy in developed countries [1]. In the United Kingdom, buildings are responsible for 39% of energy consumption which is slightly higher than average energy consumption in other European countries (37%). Similarly, in the United States, 41% of total energy consumption and 74% of energy used for electricity in 2014 were from the residential and commercial building sectors [2]. Accordingly, several studies have been conducted to investigate ways to improve energy efficiency and reduce energy wastes in buildings. However, improving the energy performance of buildings has remained as a major challenge due to the complex nature of buildings and lack of information related to energy factors, occupancy, and occupant decision indicators [3-5]. In particular, occupant behaviors have been identified as one of the major determinants of energy waste in buildings. Accordingly, various studies have investigated phenomena influencing occupant behaviors and its impact on energy waste [6,7]. The operation phase of buildings and the way occupants behave significantly contribute to energy waste. Occupant behaviors affect the decisions in the operation of appliances and contribute to energy consumption and waste in buildings. Despite the growing literature in this area, there is a gap in knowledge regarding occupant-building-appliance interactions and its impact on energy performance of buildings. In fact, building energy performance can be investigated from two aspects: baseline energy performance and emergent energy performance, as shown in Fig. 1. Baseline energy performance is influenced by factors such as building materials, climate zones, and building envelope. Emergent energy performance is affected by the dynamic behaviors at the interface of occupant-building-appliance interactions. In order to better understand emergent performance, there is a need for understanding how different attributes of occupants, buildings, and appliances lead to certain behaviors and how the interactions between the occupants, building, and appliance cause energy waste. To address this important gap in the body of knowledge, the objective of the study presented in this paper is to utilize simulation to investigate emergent energy performance in buildings.

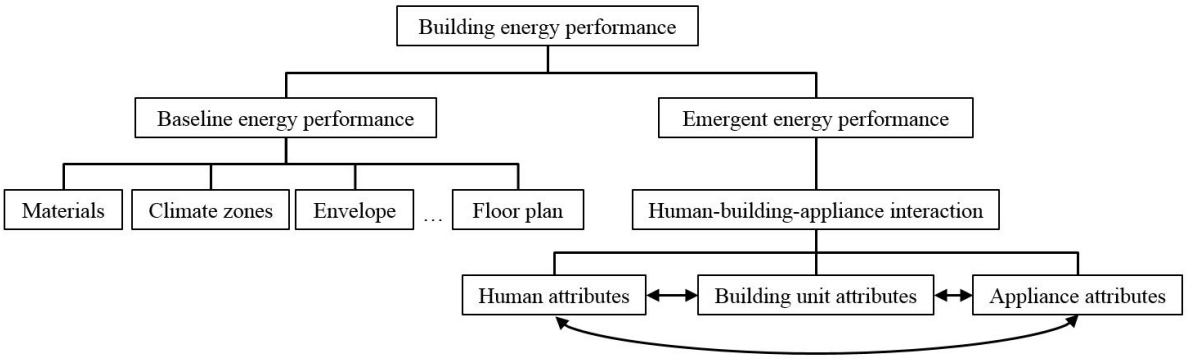

Fig. 1. Building energy performance

2. Research Objectives

Understanding the determinants of energy waste during the operation phase of buildings is a challenging task due to the complex interactions between occupant behaviors, building unit characteristics, and appliance characteristics. The main objective of this paper is to discover the emergent energy performance and its influencing factors in order to investigate human-building-appliance interactions and to estimate determinants of energy waste in buildings. This study utilizes a simulation approach to decode these complex interactions and facilitate a better understanding of the determinants of energy waste. An agent-based simulation model is developed to capture the diverse attributes and dynamic behaviors of building occupants at the interface of human-building-appliance interactions. The application