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A Framework for Cloud-based Energy Evaluation and Management for Sustainable Decision Support in the Built Environments

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Abstract

This paper introduces a framework which can advance traditional building auditing and energy management methods in terms of cost, convenience of automatic and remote data (e.g., 3D geometry and thermal values) collection, system control, and comprehension and dissemination of results using a proposed cloud-based software as a service (CSaaS) system as a decision support tool. The decision support tool can help decision makers improve their buildings by providing reliable and visualized information of the building's energy performance through an easy-to-use interactive virtual evaluation system in a publicly accessible cyberspace. The proposed open decision-support platform is expected to ultimately reduce the public's energy consumption and invigorate the nation's economy by vitalizing sustainable product manufacture and retrofit construction industries.

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1. Introduction

Buildings account for approximately 40% of our primary energy usage and 71% of the electricity used in the United States [4, 9]; however, they receive less public attention than fuel economy or new technologies for automobiles or alternative sources or distribution systems for power generation. The average age of a building in the United States is over 50 years, and about 85% of buildings were built before 2000 [4]. Therefore, any effort to significantly improve the performance of buildings in the near term must consider existing buildings. Furthermore, the concept of integrated design and operations is geared toward large commercial buildings where development projects involve architectural, engineering, and construction firms. Yet, 118 million of the 120 million buildings in the United States are classified as small commercial and residential, consuming about 50% of the overall energy in the building sector [9]. In fact, more energy is consumed by residential (22%) than commercial buildings (18%) [4, 9]. Due to the large number of building owners and the slow pace of building replacement, it is extremely difficult to make significant improvements in overall performance within the building sector. New technologies for buildings must receive widespread acceptance by a large number of decision makers before there can be a significant impact. Owners of large commercial buildings may have an engineering staff that can consider options through building energy management and control systems. However, smaller building owners have relatively little information and practically no tools to make informed decisions. Millions of end-users (e.g., homeowners) are currently faced with a dizzying number of product and service choices offered through local dealerships and service providers, and lack independent and unbiased information which can demonstrate that the net benefits of more expensive technologies can pay back. This situation leads to a lack of trust and a tendency of building end-users to use familiar safe, reliable, and low-cost solutions.

Sustainable retrofits of the existing built environment are considered to be among the most effective ways for the nation to reduce depleting natural resources and carbon emissions. However, the building industry has been notorious for slow adoption of new technologies due to its fragmented nature. Its structure and marketplace have not changed appreciably in decades. The marketplace has numerous stakeholders and currently there are tremendous gaps and barriers to the delivery of the technologies needed to realize the aforementioned opportunities for building products and services. Local distributors (e.g., dealerships and service providers) lack the software tools and pathways that could help them to better promote, support, and service higher efficiency products and that would lead to lower costs and greater customer confidence, satisfaction and adoption. Original suppliers (e.g., product manufacturers) lack the pathways for selling products directly to end-users and tend to be risk-adverse with respect to new technology development. Innovators (e.g., researchers and developers) have limited resources and pathways for bringing their products to market in this fragmented and closed marketplace. Policymakers lack the information for promoting and incentivizing the products and services that make the most sense. As a result, the market value for smart operations and retrofits & services is difficult to be unleashed within the current marketplace structure.

In particular, there is still a lack of: 1) metrics and measurements for evaluating overall building performance, 2) adequate measurements and integrated intelligence for evaluating component performance, 3) tools and information geared to non-expert decision makers (e.g., owners, occupants), and 4) evidence that buildings audited as high performance actually perform well. This barrier results in a lack of connectivity between building performance information and decision makers. Therefore, a breakthrough innovation in measuring as-is building energy consumption status through an easily accessible and understandable form for the retrofit decision makers is necessary to meet these challenges.

In this research, a cloud-based open and transparent platform was developed to enable a paradigm shift within the marketplace for building products and services that will provide decision support for empowering all stakeholders while connecting end-users directly to product and service providers. This platform interacts with devices, appliances, and equipment in the home through low-cost home automation hardware and software; provides intuitive decision support software through cloud computing technologies to engage and empower stakeholders to pursue energy and environmental solutions; and offers innovative building energy efficiency products, technologies and services. In this paper, the overall perspective of the proposed framework shown in Figure 1 will be mainly discussed.