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A Framework for Building Performance Analysis: Investment Return Approach for Energy Savings on Building Product Installation

Jalaycia O. Hughes[1], Simon Pallin[2] and Clayton J. Clark II[3]

[1] Department of Civil and Environmental Engineering, FAMU-FSU College of Engineering, Florida A&M University, Tallahassee, FL, jalaycia1.hughes@famu.edu
[2] Energy and Transportation Science Division, Building Envelope and Urban Systems Research, Oak Ridge National Lab, Oak Ridge, TN, pallinsb@ornl.gov
[3] Department of Civil and Environmental Engineering, FAMU-FSU College of Engineering, Florida A&M University, Tallahassee, FL, clayton.clarkii@famu.edu

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1 Introduction

Product installation during the construction process impacts the overall performance and durability of a building. However, when the building construction industry fails to address installation quality the product performance is affected. This research explores the importance of optimized product installation and how it affects product performance. During the installation period, standard product performance can be affected by the information known about the product and the amount of time put into the assembly of the product. The building products reviewed in the paper include insulation, A/C units, water heaters, etc. An installers' workmanship can impact standard product performance based on their knowledge about the product and its operational functionality. The products' prescribed functionality could be altered due to less than standardized installation practices. Improper installation of a product can lead to major deviations in performance that can cause inflated maintenance costs over the lifetime of the product in addition to adverse effects on the normal life cycle of the product. Labor sensitivity is an underrepresented aspect of building construction that contributes to the problem of energy inefficiency. The goal of this work is to develop a metric that can quantify how relatively sensitive a building product and overall building performance is to the efforts of time and knowledge, specifically during the installation process. From this metric, the impact of installation on performance for different products can be compared through numerical values, highlighting products that require special care during the installation process to ensure desired performance. This metric system can be used to improve the installation quality that affects building system performance and provide insight on how to better allocate resources on a project-task level while aggressively targeting current quality standards of building materials installation.

Hue and He (2014) suggest that cost is typically considered the most important factor in choosing a contractor, but often reduced cost comes with the risk of contractors using inferior materials or incapable labor. The successfulness of a chosen contactor is dependent on their acclaimed guarantee of quality service. Sullivan (2011) suggests that the concept of quality is subjective in nature, the construction industry has struggled to define and quantify quality and value. Liberatore and Johnson (2013) determined that the Project Management Body of Knowledge has adopted the ISO 9000, clause 3.1 definition of quality as the degree to which a set of inherent characteristics fulfills requirements. The importance of quality installation on the individual product level is highlighted to positively impact building performance and reduced energy consumption. Within recent decades, there has been an increasing concern for reducing energy consumption by reducing the energy demands of residential and commercial buildings. According to The Department of Energy (2015), the building sector accounts for about 76% of electricity use and 40% of all U. S. primary energy use and associated greenhouse gas (GHG) emissions, making it essential to reduce energy consumption in buildings in order to meet national energy and environmental challenges.

To address this challenge, the U.S. Department of Energy Building America program has established an agenda that targets market-relevant strategies to achieve 40% reductions in existing home energy use by 2030. A part of this strategy includes the implementation of deep energy retrofits with the expectation of meeting and exceeding all targeted goals. Less and Walker (2015) suggest that Deep Energy Retrofits (DERs) are projects that create new, valuable assets from existing residences, by bringing homes into alignment with the expectations of the 21st century. In addition to the apparent benefits that come with rehabbed buildings that meet current energy standards are the strides made towards closing the performance gap to reduce energy consumption. This performance gap highlights the increase in energy usage and decrease in energy savings; essentially there is a net energy and cost waste. Brom et. al (2019) determined that the discrepancy between actual and theoretical savings is caused (among other factors) by the energy performance gap (EPG), which is the discrepancy between actual and calculated energy consumption of a household. The EPG illustrates that it is not possible to explain residential energy consumption by solely relying on building simulation models.

Constructing buildings that have foreseeable energy demands will help with achieving the goal of decreasing energy consumption while also lowering the performance gap. To move toward this goal, we break down building performance in terms of the performance of individual products which contribute to the building and its envelope. Throughout this research, a framework is provided for analyzing the impact of product performance on building performance through an installation perspective. In this framework, we address the performance of the entire building through the scope of individual product performance. Future research includes developing a methodology to conduct experiments on how products behave differently when installed under different conditions; some factors to consider are energy inefficiencies, reduced life cycle of materials, and economical impact.

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Anna Danek: Oak Ridge National Laboratory
1 Bethel Valley Rd, Oak Ridge TN 37830

ORCID

Jalaycia Hughes: https://orcid.org/0000-0002-3278-7026
Simon Pallin: https://orcid.org/0000-0001-7197-6746

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