Impact of different LEED versions for green building certification and energy efficiency rating system: A Multifamily Midrise case study

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HIGHLIGHTS

• Energy consumption change from applying different LEED versions were investigated.
• Four analysis scenarios were compared using different versions of ASHRAE Standard.
• A case study of a mid-rise multi-family building was conducted using energy simulation.
• Residential buildings could benefit from LEED v4 due to the low prerequisite.
• Renovation buildings are highly incentivized regardless of LEED version used.

ARTICLE INFO

Keywords:
Leadership in Energy and Environmental Design (LEED)
ASHRAE Standard 90.1
Building energy simulation
Multifamily Midrise

ABSTRACT

Various versions of the Leadership in Energy and Environmental Design (LEED\textsuperscript{®}) have been introduced with the addition of more stringent sustainability parameters and credit scoring schemes over the past decade. Such changes in LEED versions strongly affect the energy performance and LEED scores of the target building in the LEED certification process. Therefore, to validate and improve the current LEED version, it is crucial to investigate and compare the impact of different LEED versions on the building energy performance and scoring scheme. However, researches comparing the sustainability metrics for mid-rise multi-family buildings are rare. Therefore, this paper investigates the potential changes in the energy performance resulted from applying different LEED versions (i.e., LEED v3 and v4) for the Energy and Atmosphere (EA) category. Towards this end, a case study was carried out with energy modeling and simulation using TRACE 700 to compare the changes in the energy performance of four analysis scenarios applied to an existing mid-rise multi-family building located in Ohio. Results showed notable changes in LEED points when different versions of LEED using different ASHRAE Standards (i.e., ASHRAE Standards 90.1-2007 and 90.1-2010) are applied for the building energy analysis. In particular, mid-rise multi-family buildings could benefit from LEED v4 in terms of LEED credits as the prerequisite for the minimum energy performance improvement in EA category became significantly lenient compared to LEED v3. On the contrary, when the percentage energy performance improvement is over 34\%, mid-rise multi-family buildings would benefit from LEED v3 as it becomes difficult to gain more points for similar energy performance improvement in LEED v4 compared to LEED v3. Various stakeholders including USGBC and government can benefit from using the key findings of this study for improving the LEED certification and national energy standards.

1. Introduction

Buildings accounts for 30–40 percent of the total energy use in developed countries. The U.S. consumed about 40 percent of the total energy in residential and commercial buildings in year 2015 [1,2]. Besides, the building energy demand is growing every year because of the population growth, increasing services, and desired comfort resulting in increase of energy bills [3–5]. One way to mitigate the increased energy demand and cost is to shift the supply towards renewable and to realize energy efficiency in buildings [6]. To address the most important factors of energy efficiency measures in the existing and new buildings, various green building standards and certifications...
have been developed by different institutes in various countries [7,8]. The main goal of these standards and certifications is to evaluate the sustainability and energy performance of the building. Such green building standards and certifications are adjusted to the temporal, spatial, and cultural environment where the building was originally designed and tend to have own means of awarding scores to the building [9].

The most widely known and utilized green building certification in the U.S. is the Leadership in Energy and Environmental Design (LEED®) developed by the United States Green Building Council (USGBC) [10]. LEED offers a variety of rating systems based on the market, building, and construction. Depending on these criteria, the LEED certification is classified into the following five types: “LEED Building Design & Construction”, “LEED Interior Design and Construction”, “LEED Neighborhood Development”, “LEED Building Operations and Maintenance”, and “LEED for Homes”. LEED’s adaptability outside the U.S. is also gaining momentum and accordingly, LEED has been partially customized and applied in various countries around the world [11]. Since the inception of LEED in 2000, various versions of LEED have been introduced with the addition of more stringent sustainability parameters and credit scoring schemes. The most recent version is LEED version 4 (v4) which supersedes all older versions such as v2.0, v2.2, and v3. Among five types of LEED certification, the residential rating system referred as “LEED for Homes” has gone through three major changes. First, in year 2008, the oldest version for “LEED for Homes” was introduced to evaluate the energy performance of the residential building based on the International Energy Conservation Code (IECC) [12]. Second, in year 2010, it was modified and recognized as a separate rating system under “LEED for Homes Multifamily Midrise” (i.e., LEED v3) to compare the energy performance with a baseline set by American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2007 instead of the IECC [13,14]. Applying ASHARE Energy Standard 90.1-2007 to the newer version of “LEED for Homes” made it more relevant to mid-rise multi-family buildings, since ASHARE Energy Standard 90.1-2007 was established for buildings more than four stories. Third, the latest version, released in year 2015, utilizes ASHRAE Standard 90.1-2010 for designing the baseline building and predominately addresses following residential constructions; single-family homes, low-rise multi-family (up to three stories) buildings, and mid-rise multi-family (up to six stories) buildings, under “LEED BD+C (Building Design and Construction): Homes and Multifamily Lowrise | Multifamily Midrise” (i.e., LEED v4) [15,16]. Such changes in LEED versions would very much affect the calculated energy performance and LEED scores of the target residential building in the LEED certification process. Therefore, to validate the current LEED version and improve the LEED certification in a positive way, it is crucial to investigate and compare the impact of different LEED versions on the building energy performance and the scoring scheme.

In this regard, there have been many previous studies dealing with the LEED certification and other relevant green building certifications. Researchers have compared various green building certifications such as Building Research Establishment Environmental Assessment Method (BREEAM) for the United Kingdom (UK) [17,18], LEED for U.S. [19,20], Building Environmental Assessment Method (BEAM) Plus for Hong Kong [18,21], the Institute for Innovation and Transparency of Contracts and Environmental Compatibility (ITACA) protocol for Italy [22], Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) for Japan [23], and Green Standard for Energy and Environmental Design (G-SEED) for South Korea [9,24]. Some studies have compared these certifications focusing on the scoring scheme related to the reduction of the building energy consumption. In addition, previous studies have utilized various building energy simulation tools such as the QUick Energy Simulation Tool (eQUEST) [25], EnergyPlus [26], Integrated Environmental Solutions-Virtual Environment (IES-VE) [27] and Thermal Analysis Simulation (TAS) [28] to calculate LEED scores with a focus on the high-rise multi-family buildings [29]. However, studies comparing different versions of a single green building certification related to the mid-rise multi-family building are rare. Therefore, this paper mainly focuses on a specific category in LEED for Homes, the Energy and Atmosphere (EA), with an aim to compare and investigate any potential changes in the annual energy consumption and cost resulting from applying different versions of ASHRAE Standard 90.1 used for LEED v3 and v4, respectively. To show the impact of applying different versions of the LEED certification, this study conducted a case study of a mid-rise multi-family building in the U.S. Towards this end, this study used the building energy simulation tool to model and compare the energy performance of four different analysis scenarios generated according to building construction types and LEED versions. In addition, this study aims to help understand the implication of changes in the energy performance of the mid-rise multi-family building on LEED credits.

2. LEED energy and atmosphere (EA) category

LEED is heavily weighted to encourage energy efficiency in the building performance by allocating the maximum points to the EA category (i.e., 37 out of total 110 points in LEED v4 and 38 out of total 136 points in LEED v3). In general, for all LEED certifications, there are some mandatory requirements referred as “prerequisites” and optional requirements referred as “credits” against which the points are awarded [30]. Within the EA category, prerequisites entail “minimum energy performance” and “testing & verification” while credits entail “optimize energy performance”, “domestic hot water distribution”, and “refrigerant management”. About 34 points (25%) and 30 points (27%) of the total points are allocated towards achieving the EA Credit: “optimize energy performance” for LEED v3 and “annual energy use” for LEED v4, respectively. Therefore, this paper focused on an assessment of prerequisite and credit related to this energy performance. A project is eligible for scoring points towards this credit after meeting the prerequisite for the minimum energy performance improvement in the proposed building by 15% for LEED v3 and 5% for v4 over the baseline building as shown in Table 1.

The baseline building is the reference building, against which the performance improvement of the proposed building is calculated. The baseline building is calculated according to the building performance rating method of USGBC’s residential midrise simulation guidelines based on Appendix G of ANSI/ASHRAE/IESNA Standard 90.1 (with errata but without addenda) using a building energy simulation tool for the whole building project. An proposed building includes all the design change and improvement anticipated based on the construction drawings. A proposed building should meet the mandatory provisions in Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 of ASHRAE Standard 90.1 and should exceed the minimum code compliance requirement under Performance Rating Method (PRM) [31,32]. The major distinction between different LEED versions, LEED v3 and v4, lies in using different versions of ASHRAE Standard 90.1 for setting a baseline building. In order to achieve a maximum LEED certification points, various building energy simulation tools are required to perform energy analysis. Tools such as Trane Air Conditioning Economics (TRACE) 700 by Trane [33], eQUEST, EnergyPlus, IES-VE, and TAS are few suggested simulation tools by the USGBC. Among these various simulation tools, TRACE 700

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<th>LEED v3</th>
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<td>% Reduction above Standard 90.1-2007</td>
<td>LEED Points</td>
</tr>
<tr>
<td>15%</td>
<td>prerequisite</td>
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<td>16–50%</td>
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