THE GREEN STATUS OF FIRE STATIONS IN THE UNITED STATES: AN ANALYSIS OF LEED-NC V3

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ABSTRACT

Fire protection is an essential public service but also one of the costliest ones. Considerable resources are devoted to fire protection including equipment, staff, training, and the facilities to house them. Fire stations, in particular, have a significant cost impact on state and municipal budgets. Fire stations are required in most local governments and like other municipal buildings are central to identity. To limit the cost of operating a fire station, municipalities have looked to more green building options. Green-rating systems such as the Leadership in Energy and Environmental Design (LEED) system have been used in the U.S. to assess green buildings. Thus, this paper aims to analyze 95 certified fire stations under the LEED-NC 2009 version (v3) that are located in the United States. A scorecard analysis (credits and points) of public data available serve as the foundation to describe the status of the green design and construction of these fire stations. The findings indicate that the points in the Material Resources (MR) category are achieved at the lowest rate compared to the other categories, on average 38% of 14 available points were earned. In addition, the points in the Energy and Atmosphere (EA) category are one of the lowest achievement rates, equal to 40.2%. The data also shows that 82% of LEED-certified fire stations belong to career or mostly career type, which are municipality fire departments funded by local governments. The significance of this study is to demonstrate the importance of both MR and EA categories for the design and construction phases of green fire stations.

KEYWORDS

Fire Station, LEED Certification, Material and Resources Credits, Energy and Atmosphere Credits, Green Design

1. INTRODUCTION

Fire stations have long provided essential fire protection and various other emergency services to communities throughout the United States (U.S.). Fire stations are complex facilities that must provide for a diversity of functional spaces, ranging from housing and community meeting

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spaces to areas for equipment, vehicle, and hazardous material storage (Mion 2017). The unique requirements of living spaces with vehicle exhaust and changes in personal protection equipment (PPE) storage requirements create many challenging opportunities in the design and operation of these facilities. Further operational requirements include speed of access throughout the facility to aid firefighters in exiting the living space, adorning PPE, and maneuvering the engines out of their bays. Moreover, fire stations can be used as "placemaking" by identifying the locale through its unique aesthetic using their antiquated towers. Although towers were once necessary for communication from station-to-station and for hanging hoses to dry, they are no longer necessary but are iconic. This is highlighted in Firehouse Station Awards, which acknowledges aesthetics, functionality and sustainability (Firehouse 2017). Stakeholders for a fire station can include the firefighters, municipal or state government, and the community. Community support is often required for funding either by a property tax levy, municipal bond or sales tax. Involving these stakeholders in the continuing conversation can be vital to success.

In a 2015 United States' Fire Department Profile, the National Fire Protection Association (NFPA) reported that there were 29,727 Fire Departments and approximately 1,160,450 firefighters in the U.S., a less than 1% decrease from 2014 (Haynes and Stein 2017). The U.S. Fire Administration (USFA), an entity of the U.S. Department of Homeland Security's Federal Emergency Management Agency, reported that about 91% of those fire stations were registered under their fire department census and represented about 51,008 fire stations (USFA 2017). The commitment to insuring public safety through these facilities has significant costs that are typically borne by public funding and support mechanisms that demand systematic and effective oversight (Murray 2009). Research conducted by Murray in 2013 estimate the initial cost to build and equip a new fire station is approximately $2 million, with ongoing costs of staffing and maintenance roughly matching the initial fixed costs. Further, as public capital improvement projects, the budget is typically set and cannot be easily changed (Mosier and Gransberg 2013). As new fire stations are designed and constructed in response to changing demographics and service demands, the governmental agencies responsible for the implementation and management of these facilities are looking to leverage the environmental, economic, and social benefits that green buildings can provide. Particularly, newly constructed fire stations offer society an opportunity to incorporate service efficiencies through strategic system enhancements (Murray 2009).

An article published by the National Volunteer Fire Council in 2010, entitled "A Guide for Going Green in the Fire Service" highlights the many benefits of green practices, which can save money as well as reduce environmental effects, and can positively impact operational costs throughout the life of the building. The article introduces the LEED rating system as the accepted standard for determining the environmental friendliness of a building (NVFC 2016). As this public safety sector of the built environment incrementally evolves in response to changing demographics and service demands, and new fire stations are being constructed, the residents and users of those facilities are experiencing benefits from the LEED certification of the buildings (Kriss 2013). The national emphasis on green strategies in the built environment, as a direct benefit to building owners through lower energy bills, reduction in water usage, and a healthier occupant environment, has re-focused attention on the implementation of green design and building practices, as well as green building certification systems, particularly the United States Green Building Council (USGBC)'s LEED system, which is the prominent green building rating system in the U.S. The transformation to sustainable design and construction can have a measurable impact on conserving water and energy and optimizing efficiency in the

usage of non-renewable resources in these facilities. Sustainable features and practices in design have shown industry-wide movement by government agencies in the adoption of industry standard LEED certification systems, with design objectives of a LEED high performance facility (Suttell 2005).

This research focuses on LEED certified fire stations in the U.S. The credits and points achieved by 95 fire stations certified under LEED New Construction (NC) v3 (v2009) certification system are analyzed. The study presented in this paper concentrates on the Materials and Resources as well as the Energy and Atmosphere credit categories. The analysis also briefly summarizes the changes in LEED certification system from v3 to v4 and the effect of these changes in perusing the LEED certification in these two credit categories. Finally, the study includes an analysis of fire stations based on the personnel type classification, which include career, mostly career, volunteer, and mostly volunteer to understand if there were any trends regarding achieving the LEED certification.

2. LITERATURE REVIEW

The LEED system, designed by the USGBC, establishes benchmarks that define and measure green buildings of different sectors, typologies, and scopes, using a standardized set of building metrics and rating criteria. The LEED 2009 Green Building rating system for new construction and major renovations addresses the design and construction of public and private commercial, institutional, and high-rise residential buildings through a set of certification performance standards (USGBC 2009). Buildings can achieve certification at certified, silver, gold, or platinum levels, depending on the standard of performance and the rigor desired. The standards are defined as a program of credits to earn points, which are based on their relative importance, with the credits typically assigned to seven categories that address a building project's impact on human health and the environment (USGBC 2009). The seven credit categories in the LEED v2009 for New Construction and Major Renovations are shown below along with the respective possible points:

- Sustainable Sites (SS), 26 possible points.
- Water Efficiency (WE), 10 possible points.
- Energy and Atmosphere (EA), 35 possible points.
- Materials and Resources (MR), 14 possible points.
- Indoor Environmental Quality (IEQ), 15 possible points.
- Innovation in Design (ID), 6 possible points.
- Regional Priority (RP), 4 possible points.

These seven credit categories are further divided into sub-categories that help define strategies to achieve the credits points. Most of the sub-categories include pre-requisites that need to be met before applying for any of the credits. In addition, each credit may have one or more points available. For instance, the Materials and Resources category has one pre-requisite and 8 credits; specifically, Credit MR 1.1, which refers to maintaining existing walls, floors, and roof can achieve between 1 to 3 credit points. For more details about these categories please refer to the USGBC website.

The LEED Rating System is the accepted standard for determining the environmental friendliness of a fire station (NVFC 2016). The U.S. Green Building Council (USGBC) notes

within this report that an investment increase of 2% in the initial project costs leads to a 20% savings in the operational costs over the life of the building (NVFC 2016). Sustainable features and practices in design have shown industry-wide movement by government agencies in the adoption of industry standard LEED certification systems, with design objectives of a LEED high performance facility (Suttell 2005).

A study about the 'Dallas Green Building Initiative' in which 6 LEED and 3 non-LEED fire stations built were analyzed, reports a reduction in the initial costs by 4% in the construction of LEED fire stations (Basora and Meckfessel 2013). The study was conducted from 2009–2012 and the energy savings in that period was estimated to be around $30,949 with a slightly less consumption of electricity and natural gas. The study found a significant difference in water consumption for LEED fire stations of almost 47% less than those in non-LEED fire stations (Basora and Meckfessel 2013). Fire Station #8 located in Norman, Oklahoma, was recognized for an ECO-Construction Award 2011 by the Keep Oklahoma Beautiful Affiliate Network. This fire station was completed with a budget of $2.1 million. According to Rosenthal et al. (2012), the Norman FS#8 construction cost was slightly higher than the non-LEED building that was used for comparison in their analysis, but the higher cost was compensated as operating costs were comparatively lower. However, for the success of this project, the researchers believed that there were two key factors; (i) strong local leadership by municipal staff, elected officials and the citizens and (ii) the support of this leadership in acquiring the required funding by adding a temporary sales tax and providing additional funding to make the project a reality (Rosenthal, O'Leary et al. 2012). In addition, a fire station in Issaquah, Washington, with the goal of having net zero energy in a cost effective manner achieved 70% reduction in energy and was built with a cost of $6.6 million that was under the original cost projection by $1.4million (Cejudo 2013). The design team used utility bills from a similar fire station, which was LEED silver certified, to calibrate an eQuest model reflecting actual fire station energy use patterns and used this to develop an optimized energy-efficiency package with enough budget left to incorporate an electric grid-tied 30 kW solar energy (Cejudo 2013). Similar to the Oklahoma fire station, the design team for this fire station also believed that it was essential for the designers, owners and the occupants to collaborate in an efficient manner to achieve all these goals (Cejudo 2013).

The Sustainable Sites (SS) category is almost entirely determined prior to construction contract letting by the owners and designers. Fire stations may not see changes to typical design requirements for the Indoor Environment Quality (IEQ) category credits, as fire stations are non-smoking and have requirements for separation of the apparatus bays from the living space to promote healthy living. Previous studies have shown that the Material and Resource (MR) category credits are challenging to achieve the LEED certification (France 2007 and Mosier et al. 2017). One reason for the design professionals and/or owners to shy away from these credits is the reliance on the contractor for completion. The MR category is comprised of eight credits with a total of fourteen points available along with a pre-requisite credit. As the pre-requisite is a requirement, is it not evaluated separately or discussed herein. Table 1 shows a brief description of these credits and the credit points offered. The MR category requires that the contractor perform complex calculations to determine the compliance with the credit. For example, the MR 7 Certified Wood credit requires a calculation of all the certified wood permanently installed in the project as a percent of total wood used (France 2007).

The Energy and Atmosphere (EA) category has the most credit points available (USGBC 2009), making it an important category to review. In addition, the EA category consists of 3 pre-requisite credits and six credits with 35 credit points available. Table 2 shows a brief description

TABLE 1. LEED-NC v3—Material and resource credit category.

Credit	Points	Description
MR1.1	1–3	Maintain existing building structure & envelope
MR1.2	1	Using existing interior non-structural elements
MR2	1–2	Recycle and/or salvage nonhazardous construction and demolition debris
MR3	1–2	Use salvaged, refurbished or reused materials, the sum of which constitutes at least 5% or 10%, based on cost, of the total value of materials on the project
MR4	1–2	Use materials with recycled content such that the sum of postconsumer recycled content plus 1/2 of the pre-consumer content constitutes at least 10% or 20%, based on cost, of the total value of the materials in the project.
MR5	1–2	Use building materials or products that have been extracted, harvested or recovered, as well as manufactured, within 500 miles of the project site for a minimum of 10% or 20%, based on cost, of the total materials value
MR6	1	Use rapidly renewable building materials and products for 2.5% of the total value of all building materials and products used in the project, based on cost
MR7	1	Use a minimum of 50% (based on cost) of wood-based materials and products that are certified in accordance with the Forest Stewardship Council's principles and criteria, for wood building components.

of these EA credits. The EA1 credit, Optimize Energy Performance, has the maximum credit points in the rating system and hence is crucial for certification (USGBC 2009). Additionally, the EA category typically has the highest cost associated with it. Additional equipment is required for EA2, On-Site Renewable Energy, which might not otherwise be considered by the owner because it is an expensive strategy.

Tables 1 and 2 include the credits that have room for improvement and might be considered for fire stations. For the purpose of this research, the authors focus on the MR and EA categories in the LEED rating system. These two categories were the least achieved compared

TABLE 2. LEED-NC v3—Energy and atmosphere credit category.

Credit	Points	Description
EA1	1–19	Achieve Energy Performance beyond prerequisite standard.
EA2	1–7	On-Site Renewable Energy
EA3	2	To perform commissioning early in the design phase and execute additional activities post completion
EA4	2	Early compliance with Montreal Protocol by enhanced refrigerant management
EA5	3	Provide ongoing measurement and verification of building performance
EA6	2	Use of grid sources, renewable energy technologies on net zero pollution basis

with the other LEED-NC v3 categories. In addition, the results and discussion section provides further details about the relevance of these two categories for the design and construction of green fire stations.

3. RESEARCH APPROACH

A scorecard analysis of the LEED credits awarded and their points inform the research questions in this study. The data for the LEED credits awarded was obtained from the public database of the USGBC. The scorecard data (credits and points) was evaluated and mapped in relation to specific facility data such as location, type of fire stations, and the arithmetic mean of credit achieved across all certification levels. Research objectives includes:

- Determine the different certification levels achieved by the fire station to identify the distribution of fire stations across all certification levels.
- Identify the locations of all fire stations to check the data distribution and significant regional trends.
- Analyze the credits achieved by all the LEED fire stations to identify the percentage of points achieved for each credit category.
- Identify the least achieved credit category based on points and analyze each credit within the category to understand the associated challenges.
- Identify the most varying category in terms of average achievement and study the individual credits.
- Identify the type of fire stations based on the personnel (career, mostly career, volunteer, and mostly volunteer) to analyze any significant trends in LEED certified fire stations.
- Compare LEED v3 to LEED v4 to understand the impact of the changes on the least achieved and statistical varying credit categories.

The data acquired from the public USGBC database was recorded in Microsoft Excel. This public database consists of information such as LEED certification level, credit category scores, and individual credit scores for all the fire stations. The database provides a brief summary of the project for most of the fire stations and the detailed addresses for the projects. Any missing information such as physical address was retrieved via web search. Then, the National Fire Protection Association (NFPA) data resources were used to identify the career, mostly career, volunteer, or mostly volunteer status of the fire stations.

4. RESULTS AND DISCUSSION

As of August 2017, 95 fire stations received LEED NC v.2009 certification under the New Construction rating system, which includes major renovations. A scorecard analysis of these certified fire stations was performed to determine the credits and points achieved by the fire stations, frequency of points achieved, and any evident trends. The fire stations selected for the project represents all certification levels for LEED-NC v3. Table 3 shows the breakdown of the 95 fire stations by LEED certification levels.

To begin the analysis, the highest and lowest credit points achieved were identified for each of the main five categories. To do so, percentages were calculated by identifying the arithmetic average points achieved by the fire stations and dividing these by the total possible points in each category. The analysis of 95 fire stations reveals that the Indoor Environmental Quality (IEQ)

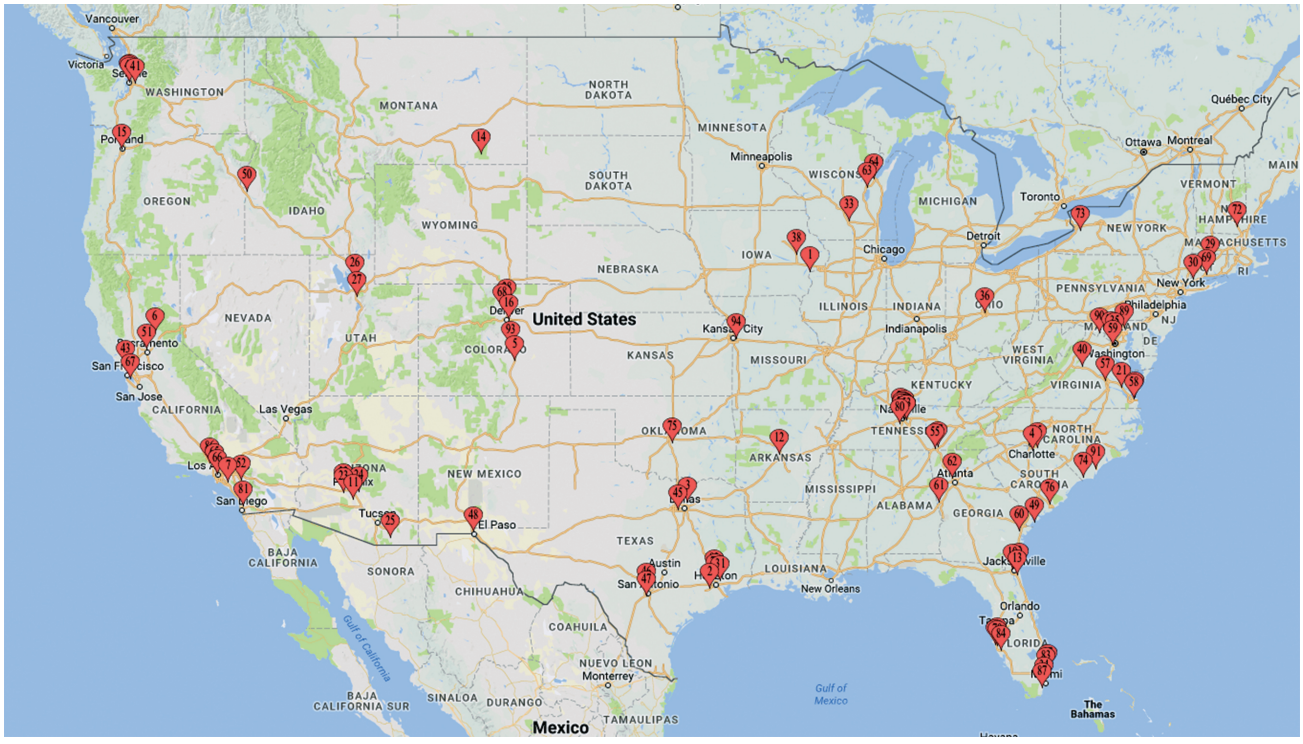
TABLE 3. Breakdown of fire stations by LEED-NC v3 certification level (n = 95).

Certification Level	No. of Projects	%
Certified (40–49 points)	15	16
Silver (50–59 points)	51	54
Gold (60–79 points)	23	24
Platinum (>80 points)	6	6
Total	95	100

category on average achieved 9.6 points of 15 possible points and the Water Efficiency (WE) category on average achieved 6.4 points of 10 possible points. These two categories were obtained at the highest rate or on average about 64% in both cases. On the other hand, the points of the MR category were achieved at the lowest rate or on average 38% of the MR points were achieved, meaning the average points achieved was 5.3 of 14 possible points. The EA category is the second least achieved at 40.2% with 14 points of 35 possible points. As indicated in the literature review section, there are reasons why designers and owners might shy away from the credits in these categories. They either require more investment or more contractor involvement.

Regional trends were analyzed for the 95 fire stations. Figure 1 shows that the fire stations are evenly distributed across the U.S. and no regional trends were found in terms of achievement

FIGURE 1. Distribution of LEED v. 2009 fire stations across U.S.
(Location of fire station in Alaska is not shown in the map)



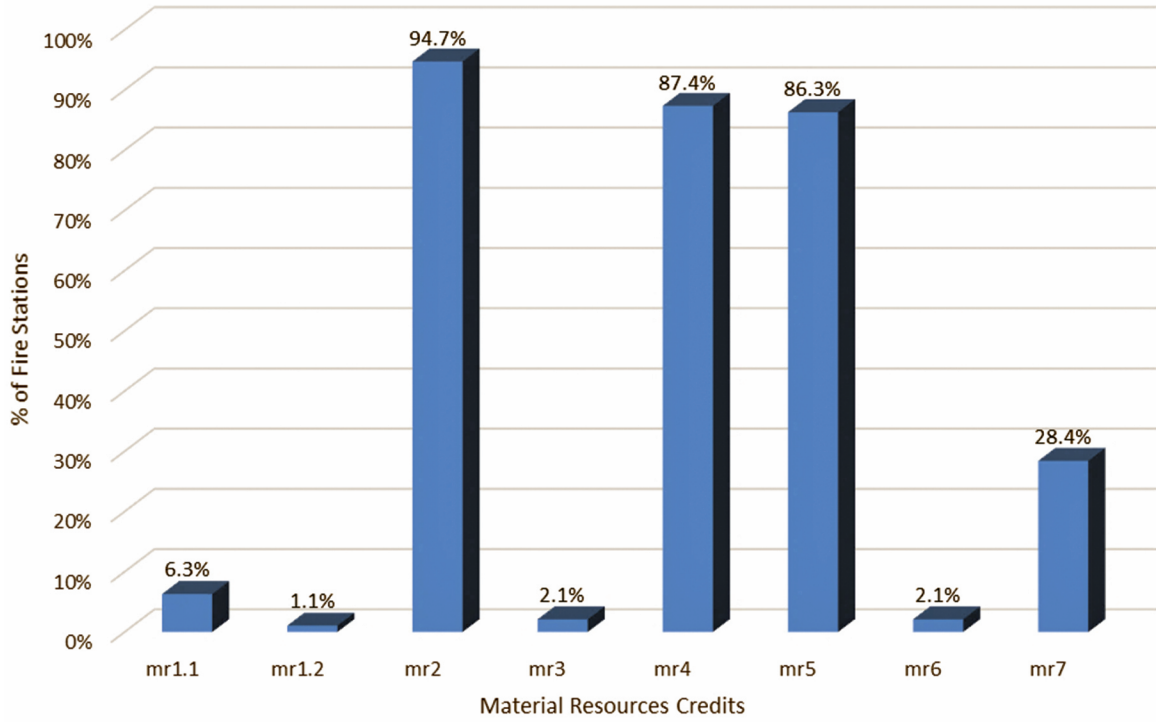
level by region. Most importantly, the figure helps to understand the data distribution for the fire stations analyzed in the study. The map was created using the online software MapCustomizer.

4.1 Analysis of the Material & Resources Credits (MR)

When analyzing the points achieved by each credit, the MR category did not have a significant variance for fire stations across all certification levels. Figure 2 shows the percentage of the fire stations that achieved the material and resources credits. The analysis of material and resource credits achieved by the 95 fire stations shows that MR 1.1 was achieved by 6 of the 95 fire stations, which approximately represents 6.5%. In addition, MR 1.2, MR 3, and MR 6 were achieved by less than 2.1% of the fire stations, meaning only one or two achieved these credits. The means also indicate fire stations across all certification levels did not choose to pursue half of the MR credits available.

The possible factors for low achievement of these credits can be explained by studying the credit requirements in detail. A detailed analysis of these credits helps to understand the challenges to achieve these credits. In the LEED rating system, the material and resource category consists of eight subcategories including one pre-requisite. The pre-requisite focuses on reduction of waste generated by building occupants. As a measure to achieve the credit, the building must have designated and segregated areas to collect recyclable waste, compostable waste, and other waste. The same can be achieved by provisioning recycle waste bins and storage areas for the building occupants (USGBC 2009, USGBC 2016). Overall, the mean of MR credits varies less than one point and did not have any statistical significance.

FIGURE 2. Percentage of material and resource credit achieved by fire stations (n=95).



4.1.1 Lowest MR credits achieved by the fire stations

MR 1.1 credit requires the building to maintain its existing structure or envelope. This requirement is possible only when a building is reused or remodeled. Therefore, when a fire station undergoes a major renovation to accommodate new equipment and technologies, it can target this credit by re-claiming the building structure. Out of the total 95 fire stations considered for this study, the majority of the fire stations were new construction. Hence, this credit was not applicable for most of the fire stations. Only six fire stations were major remodels and could consider this credit with only three successfully achieving all 3 points. These fire stations were either major rebuilds or extensions of the existing fire stations, but were large enough by scope to qualify as new construction. The fire stations that achieved this credit includes:

- Indian Land Volunteer Fire Department—1 point
- Seattle Fire Station 14—2 points
- Portland Fire Station 18—3 points
- James City County Fire Administration HQ—3 points
- West Miami Fire Rescue St. 40 Addition—3 points
- Loudoun County Fire Station No 16—3 points

In the case of MR 1.2 credit, the credit focuses on reuse of non-structural interior elements in the existing building. Even though there were six fire stations with either renovation or redevelopment as their scope, only Loudoun County Fire Station No 16 was able to achieve this credit. The requirement of the credit is to retain 50% of area of the completed building, which restrains the designer to repurpose the space and improve its functionality. In addition, the credit cannot be attempted if the addition is two times the square footage of existing structure (USGBC 2009).

MR 3 credit requires the usage of salvaged, reused or repurposed material in construction. To achieve the credit a minimum of 5% to 10% of material by cost should be salvaged, reused or repurposed (USGBC 2009). Only two fire stations were successful in achieving this credit, including Portland Fire Station 18 and Neenah Menasha Fire Station 36. One possible reason for not achieving this credit at the highest rate is the perception among owners and contractors that salvaged or repurposed materials are not as strong and efficient as new materials (Earle et al. 2014). Also, the strength of the repurposed or salvaged material needs to be tested and verified before using the material. There may also be a question of additional cost for repurposed material. The Portland Fire Station attempted the MR 3 credit and not the MR 1.2 credit. The reasoning for this is that MR 1.2 requires retention of 50% of area including the addition. However, MR requires 5% by cost of material. Hence, it can be assumed that the Portland fire station retained some of the interior elements, which were 5% of total material cost but not 50% of total area.

MR 6 credit requires the use of rapidly renewable products and materials for 2.5% of total value of building materials and products. The definition of rapidly renewable products as per LEED guidelines indicates that the materials are harvested in a cycle of 10 years or less (USGBC 2009). For example, use of fast growing bamboo instead of pine wood. The available data shows that only two fire stations were able to achieve this credit. The explanation for projects not achieving this credit can be that the rapidly renewable materials are uncommon and thus difficult to source within a project's schedule. Since the material is not widely used and

has a low demand, the price of the material is also higher than conventional products. With a maximum of only one point obtainable in this credit, most of the fire stations do not attempt it.

MR 7 credit is worth one point and requires use of 50% of all wood-based material to be Forest Stewardship Council's (FSC) certified wood for the project (USGBC 2009). Only 28.4% of fire stations achieved this credit. The explanation for lower achievement rates can be that, FSC certified wood can sometimes be more expensive than non-certified wood (Moog et al. 2015).

4.1.2 Highest MR credits achieved by the fire stations

MR 2 credit requires salvaging or recycling of the non-hazardous construction materials or demolition debris in a new construction. A proper waste management plan at the construction site is required to attain this credit (USGBC 2009). The credit seeker, or contractor, is expected to maintain a record of debris and waste leaving from the site and the amount recycled or salvaged by the waste management company. The credit seeker also should obtain and retain the waste records as documentation to verify that the waste material is recycled or salvaged. If the salvaged or recycled material for a project is 50% or more by weight/volume, one point is awarded. Two points are awarded on achieving 75% recycling/salvaging. Frequently, MR 2 credit is achievable since the majority of contractors already have a waste management plan in place and a waste management company responsible for recycling and salvaging the construction waste. In addition, many local and state governments in the US have building laws ensuring that the construction waste is disposed responsibly and properly. The contractors, regardless of LEED certification, performs most of the activities related to this credit. Hence, 94.7% of the fire stations have attempted and achieved this credit.

MR 4 credit requires the usage of materials with recycled contents, such that the sum of post-consumer recycled content plus half of the pre-consumer content constitutes at least 10% or 20%, based on cost, of the total value of materials used in the project (USGBC 2009). The materials considered for the calculations should be permanently used in the construction of the building. However, materials used for Mechanical, Electrical, and Plumbing (MEP) cannot be considered for achieving the credit (USGBC 2009). As per the analyzed data for the research, 87.4% of fire stations successfully achieved the MR 4. This can be explained by availability of certified products in the market. A majority of vendors now possess all the documentation required with regards to LEED certification and thus attempting this credit is much more feasible.

MR 5 credit emphasizes the usage of material manufactured within 500 miles from the construction site. Similar to the previous credit, MEP components used in the project cannot be calculated towards this credit (USGBC 2009). The materials permanently used in the project are only allowed to be used for calculation. Furniture can also be used for calculations if it is consistent with use based on MR 3 and MR 6 credits. The MR 5 credit requires the credit seeker to use a minimum of 10% by cost of the project to achieve one credit point. Using 20% by cost of the project will result in two points. As per the data analyzed for this study, 86.3% fire stations successfully achieved this credit.

4.1.3 MR—LEED v3 vs LEED v4

While all the fire stations in the data set are certified under LEED v3 2009, the USGBC introduced the LEED v4 in 2016. The new version of LEED has numerous improvements over the past version, making it more stringent to achieve. For example, MR 1.1, MR 1.2 and MR 3, which are the least achieved credits in the category are now combined into a single category

titled, *Building Life Cycle Impact Reduction*. These credits were challenging individually, but now can be achievable as a combined category. In addition, MR 4, MR 5, MR 6, and MR 7 are also removed from the credit list and their requirements are combined into other various new credit categories. The new credits introduced are '*Building Life Cycle Impact Reduction*', '*Building Product Disclosure and Optimization—Environmental Product Declarations*', '*Building Product Disclosure and Optimization—Sourcing of Raw Materials*', and '*Building Product Disclosure and Optimization—Material Ingredient Reporting*'. A brief description of the changes in MR credits in LEED v4 can be found in Appendix 1.

4.2 Energy and Atmosphere Credit (EA)

EA category is the second least achieved category in the data set at 40.2%. EA category consists of three prerequisite credits and six credits, which include a total of 35 credit points. This category has the most number of credit points on offer and thus can be considered an important category for achieving LEED certification. Figure 3 shows means of EA credit achieved across all certification levels by the 95 fire stations.

All the EA credits have a respectable achievement rate above 25%. The EA category offers 35 credit points, which is a significant amount to reach the 50 credit points required for LEED certification. A further analysis of the EA category indicates fire stations with different certification levels have achieved varying credit points under each individual credit. Figure 4 shows that there is a progressive increase in the mean of the credit achieved across all certification levels.

Specifically, Figure 4 indicates that for the EA 1 credit the mean increases from certified to platinum certification. The difference between the means is approximately 4 points between LEED silver, gold, and platinum certification levels. Overall, the EA1 and EA 2 credits offer 26 points out of the 35 total credit points in this category. Additionally, the t-tests indicate a significant statistical difference between different certification levels and the points achieved

FIGURE 3. Percentage of energy and atmosphere credits achieved by fire stations (n = 95).

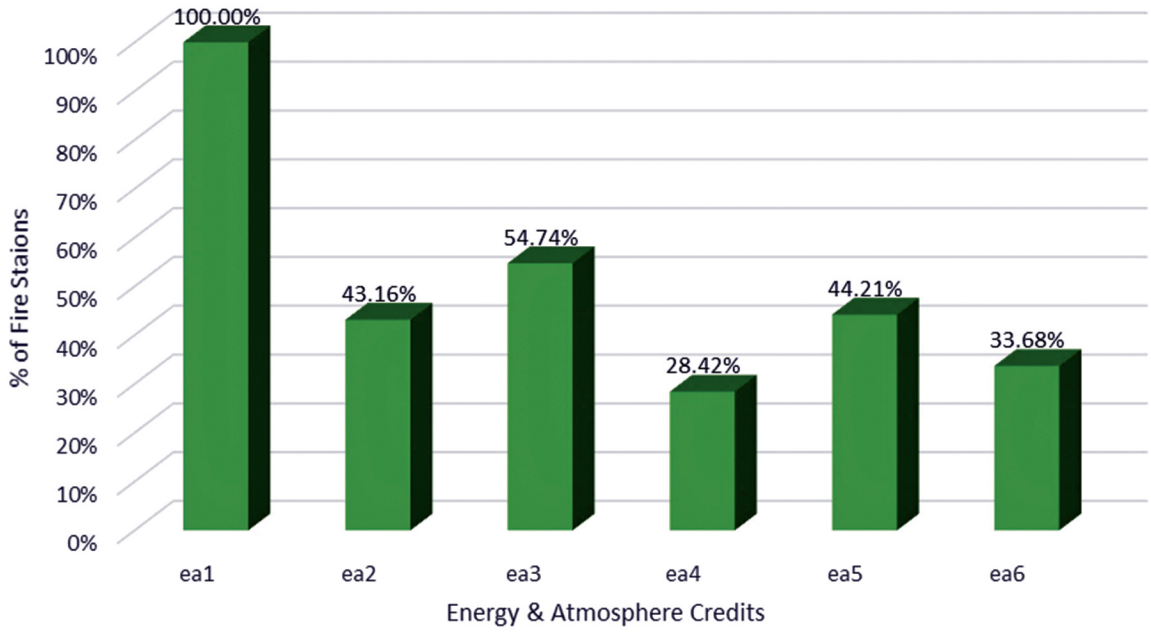
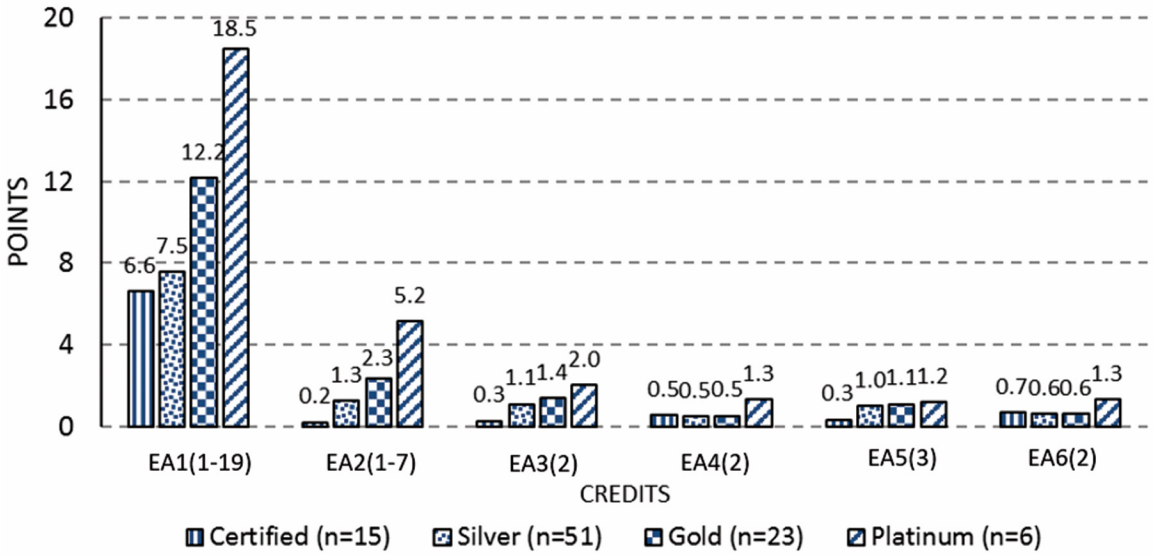


FIGURE 4. Means of EA credit achieved across all certification levels (n = 95).



under these two credit sub-categories. Hence, for this study, an analysis of EA1 and EA2 is presented below to understand their level of achievement.

For EA 1, a t-test was performed between silver and gold certification levels, and between gold and platinum certification levels. For silver and gold certification levels, the t-test was performed at a significance level of .01 and a two tailed hypothesis. The results indicate that there is a significant variance between the gold and silver certification level for EA 1, where t-value is 4.6277 and the *p* value is .00002. A t-test was also performed for EA 2 between silver and gold certification levels, and between gold and platinum certification levels. For silver and gold certification levels, the t-test was performed at a significance level of .10 and a two tailed hypothesis. The results indicate that there is a significant difference between the gold and silver certification levels for EA 2, where t-value is 1.9382 and the *p* value is .05652. Similar t-tests were performed for the rest of EA credits, but no statistical difference was found between any certification levels.

4.2.1 Credits with the highest variance between certification levels.

Optimize Energy Performance (EA 1) credit requires energy level performance beyond the prerequisite requirements. The credit offers three pathways and 19 points to comply with the credit. Pathway one requires calculation of building performance as per ASHRAE Standard 90.1-2007. Points are awarded for exceeding standards by percentage in comparison with pre-requisite requirements and a maximum of 19 points can be achieved by adopting this path. Pathway 2 requires utilizing the ASHRAE Advanced Energy Design guidelines based on the square footage and usage of the building and awards a maximum of 1 point. Pathway three requires compliance with the perspective measures identified in the Advanced Buildings Core Performance guide by the New Building Institution and awards a maximum of 3 points. This credit was not achieved by all the fire stations and the points achieved by each fire station differs since there are 19 possible points. As per pathway one, one must improve the building performance over the pre-requisite credit. According to Park et al. (2017), showing improvement

above the pre-requisite is a costly and a difficult process to achieve. Hence, it can be assumed that the fire stations with lower budgets were are not able to achieve all 19 points in this credit and this approach also dictates the certification level achieved by the fire stations.

The intent of On-Site Renewable Energy (EA 2) credit is to encourage and recognize on-site renewable energy initiatives. The energy produced by the on-site renewable sources is calculated by percentage of a building's annual energy cost. Seven points are awarded based on the percentage of on-site renewable energy ranging from 1% to 13%. This credit is also difficult to achieve and requires a significant cost to implement the renewable energy technology (Park et al. 2017). The type and scale of the on-site renewable strategy can differ based on local government policies and incentives. Due to the complexity of the technology and the high cost, it can be assumed that this credit was also attempted with a cost restraint. Thus, the fire stations may have chosen their strategy based on these circumstances.

4.2.2 EA—LEED v3 vs LEED v4

LEED v4 has more stringent requirements to comply with the EA category. For example, the EA1 credit is updated to meet the ASHRAE 90.1.2010 standards. However, the new version offers three additional pathways to achieve the EA1 credit. In the case of EA 2, the credit has been modified to allow community scale renewable energy, but the new version has adjusted the credit points significantly. EA 3 now provides an option to use monitoring-based commissioning and envelope commissioning. LEED v4 also adds two new credits under 'Advanced Energy Metering' and 'Demand Response'. These changes in the LEED certification system can change the approach towards designing buildings. A brief description of the changes in EA credits in LEED v4 can be found in Appendix 2.

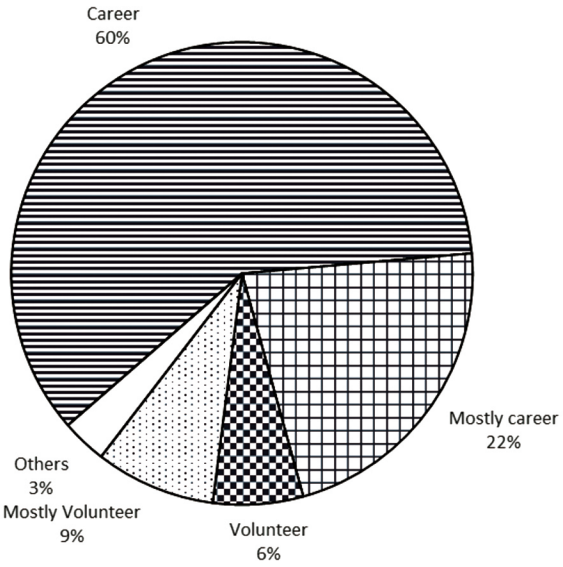
4.3 Career vs Volunteer Analysis

Career fire departments are part of a municipality and are funded by local governments. Local governments' goals and missions drive them. Career fire departments can embrace a green vision from their respect local governments. However, volunteer fire departments either are special districts or associated with rural government. They have limited funding from the government, and they heavily rely on volunteer participation to operate. According to National Fire Protection Association data, as of January 2016, eight percent of fire departments are career, five percent are mostly career, 16 percent are mostly volunteer, 71 percent are volunteer. A total of 82% of LEED fire stations in the study belong to career or mostly career type fire departments. It was found that 3% are from privately owned or federal owned fire departments. Only 15% of the fire stations fall under volunteer and mostly volunteer fire departments. Figure 5 shows the distribution of fire stations across types of fire departments.

5. CONCLUSION

The results show that more than half of the LEED v3 certified fire stations in the U.S. are certified at the LEED silver level. There are only six fire stations certified at the platinum level from 2009 to 2016. The location plotting of the LEED fire stations show that these fire stations are distributed evenly across the U.S. and there are no significant regional trends. The analysis shows that the Materials and Resource category have the lowest achievement rate at 38%. Both Water Efficiency and Indoor Environmental Quality categories are achieved at the highest rate of 64%. While some of the material and resource credits have lower achievement

FIGURE 5. Distribution of fire stations across types of fire departments (n = 95).



due to non-applicability, other credits such as MR 3 and MR 6, with lower achievement are described based on the challenges to achieve these credits.

The EA category, which is the second least achieved credit category, is a decisive category for achieving different LEED certification levels, as the data shows significant statistical mean variance for EA 1 credit between certified and gold levels that constitutes up to 19 points in the category. Also, the new LEED v.4 certification system can change the way LEED certification is persued by the fire stations, since it has stringent requirements and some additional requirement to achieve the credits. The research also concludes that the majority of LEED certified fire stations belong to career or mostly career type of fire departments. This trend may exist due to the budget constraints on the volunteer and mostly volunteer fire departments as opposed to the career and mostly career departments.

Further research to identify the reasons for this trend is required. In addition, for future research, the results for these credits can be validated by contacting the designer and builders of these fire stations. In addition, conducting case studies of those fire stations that have achieved the highest certification levels to better understand how they achieved these levels is recommended. The sample size of LEED platinum certified fire stations is lower than the other fire stations, and this is one of the limitations of the study. The research focuses on only LEED certified fire stations. Fire stations certified under other certification systems are not included in the study. Other fire stations built green but not certified under the LEED certification system or any other sustainable certification system might exist.

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APPENDIX 1.

MR category changes LEED v3 vs LEED v4

CREDITS	LEED v3	LEED v4
MR1.1	Maintain existing building structure & envelope	Credit requirements **moved to** "Building Life Cycle Impact Reduction" credit.
MR1.2	Using existing interior non-structural elements	Credit requirements **moved to** "Building Life Cycle Impact Reduction" credit.
MR2	Recycle and/or salvage nonhazardous construction and demolition debris	**Added** an option for waste reduction strategy.
		Requires waste diversion from multiple material types.
MR3	Use salvaged, refurbished or reused materials.	**Credit removed.** MR 3 credit is now included in "Building Life Cycle Impact Reduction."
MR4	Use materials with recycled content	**Credit removed.** MR 4 credit is now included in "Building Product Disclosure and Optimization—Sourcing of Raw Materials."
MR5	Use building materials or products that have been extracted, harvested or recovered, as well as manufactured, within 500 miles of the project site	**Credit removed.** MR 5 credit is now included in "Building Product Disclosure and Optimization" credits.
MR6	Use rapidly renewable building materials and products	**Credit removed.** MR 6 credit is now included in "Building Product Disclosure and Optimization—Sourcing of Raw Materials."
MR7	FSC Certified Wood	**Credit removed.** MR 7 credit is now included in "Building Product Disclosure and Optimization—Sourcing of Raw Materials."
Building Product Disclosure and Optimization—Sourcing of Raw Materials	NA	**New credit** that rewards products that meet the MR5 criteria. Addresses transparency issues with material sourcing. The new credit also encourages information on land use practices, extraction location, labor etc. from the manufacturers.
Building Life Cycle Impact Reduction	MR1.1 + MR 1.2 + MR3	**Added** provision or the reuse of historic and blighted buildings. **Added** option for a whole building life-cycle assessment of the project's structure and enclosure.
Building Product Disclosure and Optimization—Environmental Product Declarations	NA	**New credit** that encourages selecting products with improved life-cycles and the use of products with Environmental Product Declarations. Also, the new credit rewards local products.

APPENDIX 2.

EA credit changes LEED v3 vs LEED v4

CREDITS	LEED v3	LEED v4
EA1	ASHRAE 90.1.2007	Standard updated to ASHRAE 90.1-2010.
	Three compliance paths	Six compliance paths
EA2	On-site renewable energy	Added provision for community-scale renewable energy systems.
		Credit points adjusted significantly.
EA3	Commissioning agent based commissioning	Added options for monitoring based commissioning and envelope commissioning.
	No requirement for training building operator	Added requirements to prepare the building operators for the intended operation of building systems
EA4		No significant changes
EA5	Measurement and verification of performance	**Credit Removed**
EA6	Based on total electricity used.	Credit based on total building energy usage.
	No carbon offsets allowed	Carbon offsets allowed for scope 1 or 2 emissions
	Contract length extended 2 years.	Contract length extended 5 years.
	Online presence not required	Eligible resources must have come online after January 1, 2005.
Advanced Energy Metering	NA	**New credit**
		Requires all energy end-uses that represent 10% or more of the total energy consumption of the building to be metered
		Meters must be connected to the building automation system and log data at appropriate intervals.
		Core and Shell projects required to address future tenant spaces
Demand Response	NA	**New credit.**
		Added requirement to include demand response processes in the commissioning scope.
		Also available to projects located in areas without demand response programs
		Encourages projects to design and install systems necessary to participate in a demand response program.