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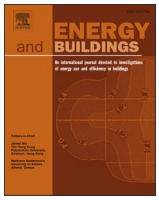

Trends and challenges in LEED v4.1 healthcare certification: A comprehensive analysis of U.S. hospital scores in 2024

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ABSTRACT

This study evaluates the strengths and weaknesses in LEED-HC (Healthcare) version 2024 by analyzing the scorecards of 120 healthcare projects completed in the United States between 2020 and 2024. The research focuses on the relationship between achieved scores, LEED categories, and certification levels, providing insights for improving sustainable healthcare construction. Energy Efficiency Challenges: LEED-HC v.2024 places increased emphasis on energy efficiency, yet scores in the Energy and Atmosphere category remain low, indicating persistent challenges in optimizing energy performance. Strong Performance in Site and Water Efficiency: Healthcare projects consistently scored high in the Sustainable Sites and Water Efficiency categories, demonstrating effective integration of sustainability measures. Projects compensated for lower energy scores by achieving higher marks in Indoor Environmental Quality and Innovation, helping maintain certification levels. There is a growing trend of utilizing points from Innovation and Regional Priority categories to enhance overall scores. The study offers a benchmark for LEED-HC performance, guiding healthcare facility designers and policymakers in advancing energy-efficient and sustainable practices tailored to healthcare environments. The findings aim to support the development of greener healthcare facilities and inform future refinements of green building certification standards.

1. Introduction

Climate change is a pressing global issue, characterized by rising temperatures, sea level rise, extreme weather events, and ecosystem disruption. To address this challenge, we must reduce emissions, enhance energy efficiency, promote renewable energy, and adopt sustainable practices [1,2]. Major energy consumers include industry, buildings, and transportation [3]. Buildings significantly contribute to greenhouse gas emissions [4], making the residential sector a focal point for energy efficiency and resource conservation policies [5]. To mitigate climate change, it is crucial to implement suitable building design strategies that effectively reduce energy consumption and emissions. Many nations are aligning their practices with global efforts to combat climate change [6], particularly through policies and regulations that promote energy-efficient buildings [7]. Building resilience to climate change involves preparing buildings to withstand and adapt to its impacts, which includes sustainable design, renewable energy use, and occupant awareness [8]. Energy-efficient buildings not only combat climate change but also reduce energy costs and improve the built environment for the future.

Solutions include insulation, efficient win-dows, energy-efficient HVAC (Heating, ventilation, and air condition-ing) systems, appliances, and optimized lighting [9]. The European Union (EU) has been promoting energy efficiency since the 1970s, with a strong focus on buildings since the 1980s. Policies have been reinforced to combat climate change and enhance energy security through EU directives, national regulations, energy efficiency policies and standards. Key directives include the Energy Efficiency Directive [10], Since its introduction in 2009, the LEED-HC certification has evolved, with the latest version, LEED-HC v.2024, reflecting the latest advancements and priorities in sustainable healthcare construction [4]. Analyzing the achieved scores of LEED-HC certified projects provides valuable insights into the application and effectiveness of different LEED categories, highlighting strengths and areas for improvement. This research focuses on evaluating the performance of healthcare projects under LEED-HC v.2024, providing a comprehensive analysis of achieved scores to guide future efforts in sustainable healthcare construction.

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for making health promotion a standard consideration and priority within the real estate industry [5,6]. Green rating systems, such as LEED, provide familiar, proven, and scalable platforms for using sustainability as a lens to guide design, construction and operation decisions for buildings, neighborhoods, and cities. More than 79,000 projects are participating in LEED worldwide and 201,000 professionals have received a LEED professional accreditation since its inception in 2000 [7].

Human health is a longstanding value of the green building movement [8] and there are proven linkages between green building strategies and health determinants [9,10]. However, given its historical focus on core environmental sustainability topics like energy use and water utilization, health promotion has not yet been operationalized as a primary intent of the green building movement [5,11]. New health-focused building and community rating systems, designed to provide practice-oriented guidance and incentives specific to human health, are emerging [12,13]. Yet, LEED green rating systems remain the primary and predominant mechanism used by private and public sector organizations to pursue social and environmental objectives through the design and operation of built environments [14]. Adapting existing, mainstream green building tools, such as LEED, to help green building practitioners adopt a more intentional approach to health promotion within their projects could provide an important near-term, high impact push towards a new culture of health within real estate while maintaining a critical focus on climate change mitigation.

1.2. Structure of LEED v4

Building and neighborhood projects become LEED certified by successfully achieving a number of prerequisites and optional credits. At the building scale, rating systems have been defined for design and construction as well as operations and maintenance. LEED can be applied to all building types including commercial office, retail, school, healthcare and single- and multi-family housing settings. At the neighborhood scale, separate certifications are available for planned and built projects. Each rating system is comprised of prerequisites and credits that define aspects of green building practice. LEED v4 prerequisites and credits are organized into categories including Location and Transport, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation and Regional Priority for building scale certification. The level of LEED certification - Certified, Silver, Gold, Platinum - is determined by the number of credits and associated points a project achieves. LEED project teams are able to choose the specific combination of credits they'd like to pursue in order to achieve the number of points required to meet these certification thresholds. The number of points available within a single credit varies from 1 to 25 [15].

1.3. Use of current LEED v4 rating system to promote health

There is strong justification for utilizing LEED to inform and incentivize population health-oriented decision making within the real estate sector. A previous health analysis of LEED 2009 found that health and well-being are expected outcomes of many green building strategies. However, the study also highlighted the absence of a consistent health promotion framework within LEED and the inconsistent use of health terminology in practice-oriented guidance materials [11].

The objectives of this exploratory analysis are: a) identify and characterize potential opportunities for population health promotion within current LEED v4 rating systems, b) assess the usability of current health promotion opportunities within LEED v4, c) quantify current market incentives (i.e. LEED points) associated with health-relevant LEED credits. This analysis aims to help green building practitioners intentionally promote population health within their approach to green building certification.

2. Methods

A review of technical guidance for current LEED v4 green building rating systems was used to identify and catalog existing health promotion opportunities available for immediate use by green building project teams. LEED products included in the analysis were: LEED v4 Building Design and Construction (BD + C), Interior Design and Construction (ID + C), Operations and Maintenance (O + M) and Neighborhood Development (ND). Within these rating systems, specific adaptations for healthcare, school, and core and shell projects were also reviewed. Associated reference guides for each LEED rating system were reviewed in order to assess the presence of health terminology within broadly available, practice-oriented guidance. Within this analysis, the Regional Priority credit category was treated as an individual credit with 4 available points. This review did not include consideration of LEED for Homes.

2.1. Populations considered

Decisions regarding the design, construction and operation of buildings and communities have the ability to impact the health and well-being of populations at a variety of scales [9]. Therefore, this analysis considered the potential population-level health impacts of LEED credits on four distinct spatial scales:

- **Site users,** defined as employees, residents, or visitors to the building as applicable, construction employees, and/or the design team. For LEED v4 ND, "site user" was defined as the intended user group of the neighborhood in its entirety.
- **Surrounding community,** defined as those who live, work, or play in the area surrounding the site, but are not the primary intended users of the site or building. For LEED v4 ND, the surrounding community was understood to be the community surrounding the site boundary, not users of the neighborhood within the site boundary.
- **Supply chain and waste stream communities,** defined as populations impacted by the creation of services, products and materials required by a project as well as populations impacted by the disposal of waste generated by a project.
- **Global population,** defined as the global population potentially impacted by building and neighborhood scale strategies through mechanisms such as stratospheric ozone depletion, climate change, global potable water access, and global food access.

2.2. Definition of health and well-being

This analysis focused on assessing opportunities to influence health and well-being throughout the entire timeline of a built environment project, including both health protection and health promotion efforts. Such a project timeline includes but is not limited to project definition, site selection, team selection, contract development, stakeholder engagement, design development and finalization, materials selection, construction, and operations.

To ensure its full potential as a health promotion tool was captured, an intentionally broad definition of health was used in the review of LEED v4 rating system credits. This included consideration of aspects of built environment design, development and operation known to be relevant to the health of the populations described in section 3.1 such as:

- The impact of landscape and building physical form on environmental exposures, safety and health behavior [9,16–18].
- The impact of meaningful stakeholder engagement and the consideration of health in decision making on the social and economic determinants of health [19–21].
- The impact of materials and resource selection on supply chain and waste stream communities, including toxic exposures [22].

- The direct and indirect impact of climate change (e.g. increasing temperatures, rising sea level, spread of infectious disease, etc.) on global health [23].

2.3. Research questions

The following questions were explored when analyzing LEED v4 rating systems:

- What current opportunities for health promotion exist across LEED v4 rating systems?
- How do health promotion strategies within LEED address health outcomes at different population scales (i.e. site users, surrounding community, supply and waste chain, and global community)?
- How likely is it that an individual without formal public health training could identify and act on these opportunities as currently described in LEED v4?
- How are health-relevant LEED v4 credits distributed throughout the rating system? Are they concentrated in one or more credit categories?
- How many LEED points are currently achievable using health promotion strategies in LEED v4?
- How could green building strategies be better organized to enable effective health promotion through green building practice?

2.4. Methodology

Technical documentation for LEED v4 rating systems was reviewed to identify LEED prerequisites and credits with a potential impact on population health. The LEED documentation and supporting guidance was also reviewed to assess the legibility and usability of individual LEED prerequisites and credits as health promotion tools. Most LEED credits and systems are not developed using a formal health promotion framework. Therefore, the research team hypothesized that many credits with positive potential for health promotion might not have health explicitly listed as a primary intent of the credit. A manual review of all written technical guidance for each LEED v4 prerequisite and credit was performed including a) credit intent language, b) credit requirements, and c) supporting information (i.e. reference guide materials and 'behind the intent' resources).

Evaluation of the LEED v4 rating systems was conducted by two independent reviewers; each with formal training in public health and extensive experience in the application of the LEED v4 rating system. Literature review and consultation with topic specific public health and green building experts were used to resolve any disagreement between the two initial reviewers.

Study researchers applied two analytic frames to identify, categorize, and evaluate opportunities for health promotion within existing LEED v4 rating systems:

- **Public health relevance:** Does meeting the requirements of a given LEED v4 prerequisite or credit address a health determinant and therefore represent a positive intervention to promote or protect health and well-being among populations impacted by a given real estate project?
- **Legibility and usability:** Does a given LEED v4 prerequisite or credit explicitly describe its potential heath impacts on population health?

LEED credits were considered health relevant if they made progress towards protecting and/or promoting health at any population scale, regardless of the level of impact. Researchers reviewed the LEED v4 rating systems and documented the presence of strategies known to impact human health and well-being at the four population scales described in section 2.1. The total number of population health-relevant credits was tallied by rating system, including prerequisites as well as credits that are only available for use within specific settings such as school and healthcare. Potential LEED points (i.e. incentive structure) available for health-relevant credits were calculated using results from the LEED v4 for New Construction & Major Renovations rating system as it is the most widely used version of LEED.

3. Results

3.1. Existing opportunities to promote population health in LEED v4

There are abundant opportunities to promote health through the strategies currently available and required within LEED v4 green building rating systems. Nearly every pre-requisite and credit within LEED BD + C, ID + C, O + M and ND rating systems has some potential direct or indirect impact on human health and well-being when applying a broad definition of health. However, many of these credits would require practitioners to possess some degree of public health expertise in order to recognizeand implement the credits in a health-oriented manner.

To reflect these differences in required public health expertise, LEED credits with positive health promotion potential were organized into three categories distinguished by the language used to describe a credit's potential health benefits and whether practitioners must deliberately choose to achieve the credit in a health-oriented manner. These credit categories include:

- **Stated health and well-being benefit**: The credit states an intent to address health and well-being, and the potential health and well-being impact is clearly stated within the credit language.
- **Un/understated health benefit**: Successful achievement of the credit will promote population health. However, potential health and well-being benefits of the credit are either understated or not mentioned at all within the credit language. "Understated" refers to credits that mention the credit's potential impact on health but don't describe the full scope of potential health value.
- **Pathway-dependent health benefit**: Based on the credit requirements, a project could positively impact health and well-being if they chose a specific pathway towards achieving that credit, whether or not the potential benefits of a possible achievement pathway were specifically stated within the credit language. Innovation (IN) and Regional Priority (RP) credits were considered pathway dependent due to the nature of these credit categories.

Credits across each of the major LEED v4 rating systems were reviewed and assigned to one of the three categories listed above for each population listed in section 2.1 (see Fig. 1). The strategy or strategies recognized by one credit may be associated with a variety of different potential health impacts that fall into different categories. When this occurred, the credit was only assigned one category per population scale. In this case, the category assigned represented the "highest" level of health opportunity present within the credit. For example, if a credit contained health-related strategies that could be categorized as both understated and pathway dependent at the site user scale, the credit was categorized as un/understated for site user. Examples of each type of health-related credit identified are provided in Table 1.

3.1.1. LEED v4 Building Design and Construction

Within the LEED v4 BD + C rating system, 65% (n = 44) of prerequisites and credits contain strategies that protect or promote health and well-being of site users (see Fig. 1a). However, from a usability perspective, only 28 of these prerequisites and credits state their potential health benefit or co-benefit in the credit language or technical guidance documentation. Fifty-eight percent (n = 39) of BD + C prerequisites and credits contain strategies with potential health relevance at a global population scale. Only 18 of these explicitly state their

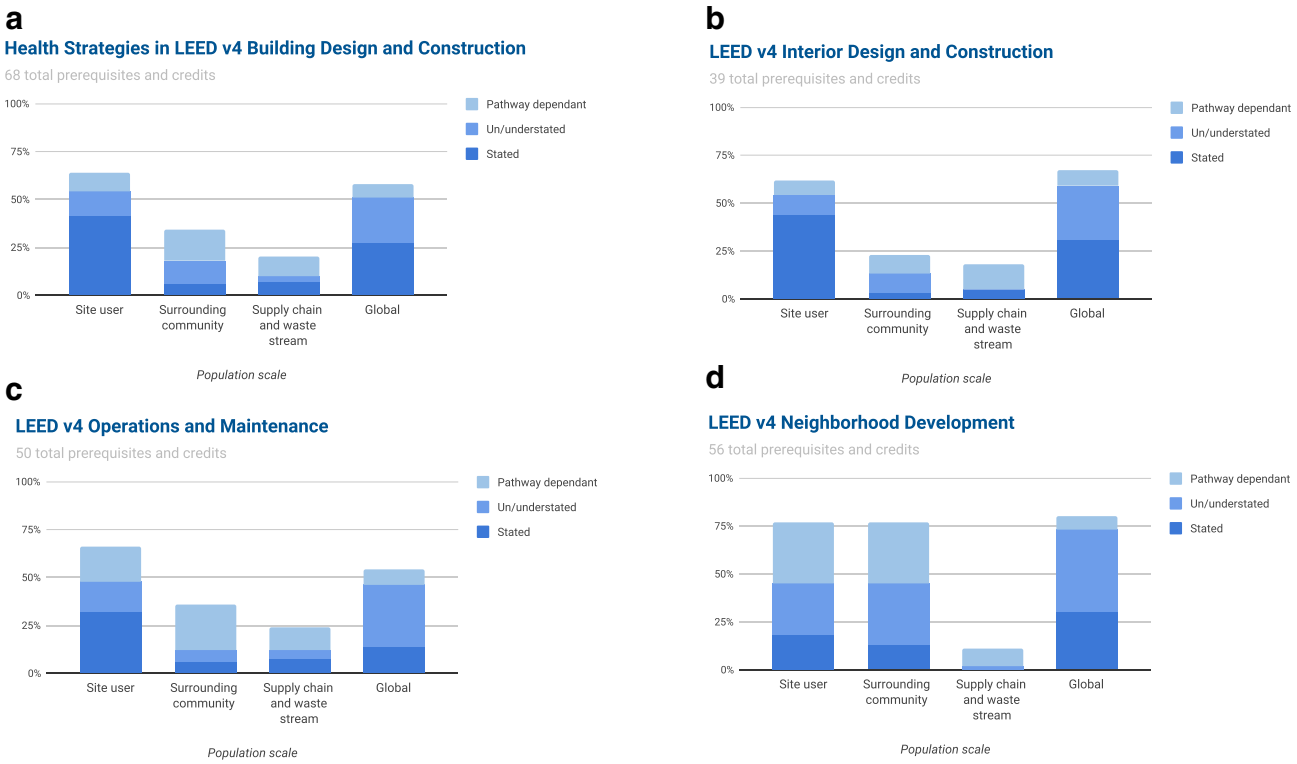

Fig. 1. Percentage of rating system related to health and well-being by population scale and health opportunity type within LEED v4 rating systems.

potential health benefit. At the surrounding community scale, 34% (n = 23) of BD + C prerequisites and credits contain health relevant strategies. Four of these strategies explicitly call out their potential health benefit. Finally, fourteen (21%) LEED v4 BD + C prerequisites and credits contain health relevant strategies for supply chain and waste stream populations. Similar to other categories, the legibility and usability of strategies relevant to supply chain and waste stream communities is low and only 5 prerequisites and credits include explicit mention of their health benefit.

3.1.2. *LEED v4 Interior Design and Construction*

A little over 65% (n = 26) of prerequisites and credits within the LEED v4 ID + C rating system have potential health promotion when analyzed at the scale of global populations (see Fig. 1b). However, only 12 of these prerequisites and credits fully state their potential population health benefit. Twenty-four (62%) of ID + C prerequisites and credits have health promotion benefit for site users. Explicit statement of potential health benefit was more consistent for these credits than others with 17 explicitly addressing health promotion in the technical guidance and other credit resources. Twenty-three percent (n = 9) of ID + C prerequisites and credits have potential health promotion benefits for surrounding communities. However, legibility and usability is currently low with only 1 credit explicitly describing this potential health promotion benefit. Almost 20% (n = 7) of prerequisites and credits within LEED v4 ID + C contain health relevant strategies for the supply and waste stream. Only 2 of these clearly state their health benefit in the guidance available to LEED v4 users.

3.1.3. *LEED v4 operations and maintenance*

The LEED v4 O + M rating system contains 33 prerequisites and credits (66% of the rating system that protect or promote site user health (see Fig. 1c). Approximately half of these (n = 16) credits clearly describe their potential health benefit. Considering health promotion strategies relevant at a global scale, fifty-four percent of LEED v4 O + M (n = 27) prerequisites and credits were found to be health relevant but usability was low. Only 7 of these explicitly describe their potential health benefit. Eighteen prerequisites and credits within LEED v4 O + M (36% of the rating system) were found to be health relevant for surrounding communities but only 3 contained credit language directly referencing the credit's health promotion value. The frequency of LEED v4 O + M prerequisites and credits that protect or promote the health of supply chain and waste stream communities was similar; 12 (24% of the rating system) were identified to have health promotion potential but only 4 fully state this health benefit.

3.1.4. *LEED v4 Neighborhood Development*

The LEED v4 ND rating system contains the highest frequency of prerequisites and credits that protect or promote health for site users (n = 43), surrounding community (n = 43) and the global population (n = 45) (see Fig. 1d). However, legibility and usability (i.e. statement of health benefit or co-benefit) varied considerably in credit language and technical guidance. Ten credits stated health benefit to site users (23%), only 7 stated their potential community-level health benefit and 17 credits stated potential global health benefit. Only 6 LEED ND prerequisites and credits were found to protect or promote health at the supply chain and waste stream scale; none of these clearly state their potential health benefit in user-facing credit language or technical guidance materials.

3.1.5. *Project context and offsite populations*

In addition to the pathway dependent opportunities for health promotion recognized by the pathway-dependent category, a number of LEED strategies become health relevant if they are deployed in a specific context. Prerequisites and credits found within the Energy and Atmosphere category of the BD + C, ID + C and O + M rating systems contribute to a reduction in air pollution that benefits the site user and surrounding community when the building is located in an area reliant on combustion based energy sources. Strategies within the Water Efficiency categories of the same rating systems contribute to conserving water in a manner that could immediately benefit water scarce

Table 1
Examples of health-related credits from LEED v4 BD + C and O + M.

Credit type	Credit name	Stated credit intent	Health relevance
Stated health benefit for site user/occupant	LEED v4 BDC: NC Indoor Environmental Quality Thermal comfort	To promote occupants' productivity, comfort, and well-being by providing quality thermal comfort.	Stated in credit intent and supporting guidance.
Unstated health benefit for supply chain and waste stream communities	LEED v4 OM: EB Indoor Environmental Quality Green cleaning – products and materials	To reduce the environmental effects of cleaning products, disposable janitorial paper products, and trash bags.	The supporting guidance for this credit describes the co-benefit that green cleaning products and materials offer to the site user. However, the language does not mention that green cleaning products also benefit supply chain and waste stream communities by reducing exposure to harmful chemicals.
Pathway dependent health benefit for surrounding community	LEED v4 BDC: NC Sustainable Sites Open space	To create exterior open space that encourages interaction with the environment, social interaction, passive recreation, and physical activities.	This credit could promote health for the surrounding community if the surrounding community is able to access the open space, which is not an explicit requirement of the credit. Additional health benefits could be associated with specific uses of the open space. For instance, if the open space is used for healthy food production.

communities. In both cases, these benefits of the combined 18 prerequisites and credits in both BD + C and O + M and 11 in ID + C are more directly experienced by the site user and surrounding community in addition to the consistent global health benefit that is documented within the categorization of credits presented in this analysis. There are also off-site populations impacted by building and neighborhood level decisions such as populations living downwind or down watershed of a project that should be recognized. For instance, credits requiring management of stormwater runoff protect water sources in downstream communities which could lead to protection of drinking water sources as well as additional health benefits associated with agriculture production and/or economic activity in certain contexts.

3.2. Distribution of health-relevant LEED strategies

The LEED prerequisites and credits containing strategies that protect or promote population health are located throughout LEED rating systems and aren't confined to one specific credit category. Looking specifically at the New Construction project type within LEED v4 Building Design and Construction, population health relevant strategies are distributed across all credit categories as shown in Fig. 2. However, the number of health-related strategies in each credit category varies by population scale. At the site user scale, the Indoor Environmental Quality section contributes 11 health-related prerequisites and credits, followed by the Location and Transportation section with 8 health-related strategies and the Sustainable Sites section with 6. At the surrounding community scale, Location and Transportation contributes 8 health-related strategies followed by the Sustainable Sites section with 7 and the Materials and Resources section with 1. Materials and Resources is the only credit category that contains health relevant strategies for supply chain and waste stream communities and offers 5 prerequisites and credits. Finally, at the global scale, the Energy and Atmosphere credit category offers 11 prerequisites and credits, followed by 8 within Location and Transportation and 7 health-related strategies within Water Efficiency.

3.3. Incentives for health promotion within LEED v4

As described in section 1.2, projects become LEED certified by achieving a specific number of required prerequisites and optional credits. Each credit is associated with a specific number of points, ranging from 1 point to 25 points. The level of LEED certification a project achieves is dictated by the number of points a project achieves. Within the LEED v4 BD + C: New Construction & Major Renovation rating system, this analysis identified 27 credits at the site user scale (63% of available credits), 17 at the surrounding community scale (40% of available credits), 6 impacting supply chain and waste stream communities (14% of available credits) and 29 credits at the global scale (67% of available credits). These credits represent a potential 60 points achievable through credits that are health-relevant for site users (55% of all possible points), 40 points at the surrounding community scale (36% of possible points), 17 points for supply chain and waste stream communities (15% of possible points) and 88 points at the global scale (80% of possible points).

Comparing the number of available points to the point thresholds for different LEED certification levels reveals the incentive structure associated with health-related LEED credits in LEED v4. As shown in Fig. 3, the most heavily incentivized strategies are those associated with health of global populations which provide a potential 88 LEED points, allowing a project to reach LEED Platinum certification. LEED credits associated with site user health are associated with 60 potential LEED points, allowing a project to reach LEED Gold certification. Strategies associated with health of the surrounding community also provide meaningful point opportunities and would allow a project to achieve 40 points and reach the bottom level of certification, LEED Certified. However, LEED credits associated with health of the supply chain and waste stream provide far fewer opportunities to earn LEED points with only 17 points available.

4. Discussion

4.1. Health in LEED v4

This exploratory analysis identifies a large and diverse set of LEED v4 prerequisites and credits with the potential to promote health for a project's site users, the surrounding community, the supply chain and waste stream communities as well as the global community. However, language clearly stating the potential to achieve these health benefits and technical guidance for ensuring maximum health benefit of relevant LEED credits is frequently lacking. Additionally, there are a large number of credits that require practitioners to actively choose a specific compliance pathway (pathway-dependent credits), particularly at the surrounding community and supply chain/waste stream scale for all rating systems as well as the site user scale within LEED for Neighborhood Development. This weakens the legibility and usability of these health promotion opportunities (as currently presented) for green

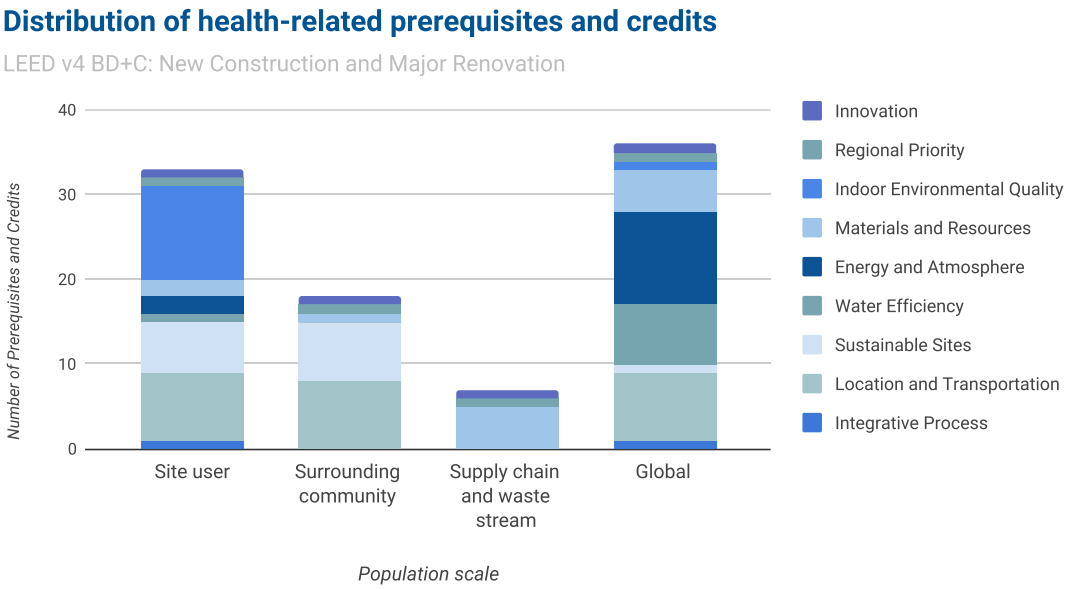

Fig. 2. All health-related prerequisites and credits by population scale & credit category within LEED v4 BD + C: New Construction & Major Renovation (55 total prerequisites and credits).

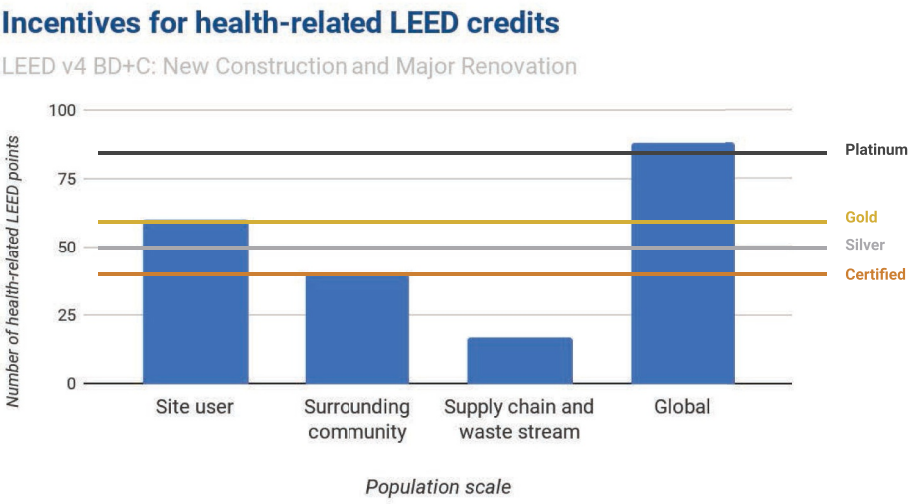

Fig. 3. Available health-related LEED points within LEED v4 BD + C: New Construction & Major Renovation compared to point thresholds for LEED Certified, Silver, Gold and Platinum. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

building practitioners, particularly those without formal public health training.

While opportunities to promote health are found across all aspects of green building,different aspects of green building emphasize different population scales. For instance, the Materials and Resources section of LEED v4 BD + C offers more opportunities to promote supply chain and waste stream health as compared to site user health. The Indoor Environmental Quality section offers a number of strategies related to site user health and none related to the health of the surrounding community. The number of population scales implicated by green building strategies strengthens the potential of LEED and other systems to be deployed as population health promotion tools. However, the varying emphasis placed on site user, surrounding community, supply chain and waste stream, and global populations requires project teams to decide, whether implicitly or explicitly, which population scale to prioritize.

Furthermore, practitioners are able to prioritize human health and well-being without "sacrificing" LEED points. The LEED framework is powerful due to the market value associated with specific levels of LEED certification. Additionally, it is common for organizations and jurisdictions to require newly constructed buildings to meet LEED Silver or higher [24]. This analysis offers opportunities to encourage an intentional approach to health promotion within existing LEED requirements. For instance, a project is able to reach LEED Gold within LEED v4 BD+C: New Construction simply by successfully implementing all of the LEED credits associated with site user health and well-being.

4.2. Implications for green building practice

The number of population scales impacted by LEED strategies makes green building a valuable platform for promoting population health and social equity. Although certain population scales are currently underrepresented, the overarching structure of LEED allows green building practitioners to consider the health of site users as well as populations outside of an individual building or neighborhood project. Applying a

social equity lens, the ability to promote global health should not be undervalued as lower income and minority populations are particularly vulnerable to the negative health impacts of climate change [23]. However, the decreased usability and legibility of credits that benefit the health of surrounding communities and the small number of credits that consider the health of supply chain and waste stream communities limits green building's ability to address broader population health and social equity concerns.

Green building practitioners must intentionally pursue LEED certification in order to harness LEED's full potential value as a health promotion tool. Within LEED v4 BD+C, practitioners without public health knowledge are likely to miss 36% of the opportunities to promote health at the site user scale, 83% for the surrounding community, 64% for supply chain and waste stream communities and 54% at the global scale. Practitioners must thoughtfully consider the potential health benefits of individual credits when deciding which LEED credits to pursue. Strengthening the health value of LEED v4 will require prioritization of credits and, critically, specific credit implementation pathways in order to meet population health needs. Additionally, the Innovation category of every LEED rating system allows project teams to select up to four additional credits from the LEED Innovation Catalogue and Pilot Credit library, both of which contain a large number of additional health relevant strategies for practitioners to choose from. Practitioners must take an intentional approach to selecting specific LEED credits, specific credit implementation pathways and choosing additional health-related Innovation and Pilot Credits in order to take full advantage of LEED's health promotion potential.

Green building project teams and owners would also benefit from engagement with the public health sector to help them take advantage of existing health promotion opportunities within LEED v4. Engagement could come in the form of direct partnership on green building projects and/or written guidance. Public health guidance would help project teams take advantage of the understated or pathway-dependent health promotion opportunities present within credits which comprise a meaningful portion of the health relevant credits within all rating systems at all population scales. In the case of pathway-dependent credits, public health engagement would help LEED practitioners identify and select specific health-related compliance pathways. Concerning un/understated health benefit credits, the public health community is equipped to help green building practitioners recognize the health value of credits that don't clearly articulate their full potential health benefit. Engagement with the public health community could also help green building practitioners balance the risks and benefits posed by certain LEED credits. For instance, incentivizing a bicycle network may reduce air pollution levels regionally, but those using the bicycle network may experience increased exposure to air pollution because they are now cycling instead of using a car or public transit which typically provide the rider with protection from outdoor air pollution. Many built environment strategies are interlinked and require a holistic, systems level consideration of how they interact with each other. In the example provided, a green building practitioner may be able to counteract the potential increased exposure to air pollution by investing in strategies to improve outdoor air quality such as green landscapes.

A systematic process, such as the one described in the LEED Integrative Process for Health Promotion Pilot Credit, can increase the utility of LEED as a health promotion tool [25]. An overarching health promotion process allows green building practitioners to engage a diverse set of health-oriented stakeholders, set intentional population health goals, prioritize health-relevant LEED credits and consider how to monitor impact of those credits on health determinants. This process helps green building practitioners understand the project site and population context and establish appropriate health goals. The presence of explicit, intentional population health goals allows LEED project teams and owners to advocate for health-relevant strategies during the inevitable value engineering process. An intentional health promotion process can also help practitioners leverage and align health opportunities found throughout LEED v4 rather than focusing only on specific credit categories or individual credits. Additionally, a systematic process can assist project teams and owners develop a practical monitoring plan to evaluate the impact of prioritized strategies on population health. Monitoring of impact is increasingly important given the shift to performance-based building certifications within the real estate sector [26].

4.3. Leveraging the green building movement

The number and variety of health promotion opportunities offered by LEED v4 adds potential public health value to existing green building policies, incentives and champions. The positioning of LEED as a standard, expected component of built environment practice increases its value as a health promotion tool as does its ability to impact health at a variety of population scales. However, this analysis has uncovered a number of recommendations to guide future development of LEED and other green building rating systems. These recommendations include:

1. Increase clarity of language used to describe the benefits of individual credits to ensure that any existing public health value is easily identifiable.
2. Define new compliance pathways for highly flexible credits and ensure that the health-relevant pathways identify themselves as such.
3. Define entirely new health promoting credits and/or create opportunities for project teams to gain recognition for using existing, distinct strategies from other rating systems, particularly those focused purely on health promotion. Specific attention should be given to increasing the number of strategies available to promote health at the surrounding community, supply chain and waste stream population scales as they are currently underrepresented in comparison to the site user and global populations.
4. Provide new forms of health-focused recognition to increase the incentive associated with intentional health promotion through green building practice.

4.4. Limitations and next steps

This review has a number of important limitations. First, this review treats health impact as a binary variable and does not include a weighting of impact of individual strategies. This could be addressed by developing a health index that includes consideration of the relative magnitude and impact of individual strategies. Second, this review does not define the scope of health addressed by LEED strategies. While there are a large number of health-related strategies within LEED, this does not necessarily mean that LEED contains a holistic approach to health promotion that sufficiently considers all of the known environmental, social and economic determinants of health. Third, while this paper explores the potential health benefits of LEED prerequisites and credits, it does not consider the potential health and well-being risks associated with LEED strategies. And fourth, the presence of health promoting strategies within LEED prerequisites and credits does not guarantee that the populations impacted will experience the associated health benefits. All of these limitations should be addressed by future research.

5. Conclusion

The LEED rating system provides an existing, scalable framework for influencing decision making within the real estate sector at a national and global scale. Analysis of health promotion opportunities within LEED v4 rating systems reveals that opportunities are numerous and varied across site user, surrounding community, supply chain and waste stream, and global population scales. A large number of these health promotion opportunities require additional decision-making and green building practitioners must be intentional in their selection and

application of LEED strategies in order to benefit from their full potential health value. A systematic health promotion process could help LEED practitioners identify, prioritize and implement the LEED strategies most relevant for their project type and context. Future LEED development should focus on increasing the clarity of language used to describe health-related credits and increasing the number of available strategies to promote the health of surrounding communities as well as supply chain and waste stream communities. Future development should also consider how to provide additional incentives for intentional health promotion through green building practice.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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