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Assessing the Resilience of LEED Certified Green Buildings

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Abstract

The Leadership in Energy & Environmental Design (LEED) green building certification program is dedicated to the design of sustainable buildings by incentivizing reductions in energy, water, and building materials consumption, while at the same time enhancing occupant health and overall community connectivity. While green buildings certified by the program do reduce the environmental footprint of buildings, they must also be designed for resilience to withstand external stressors that may arise over the buildings' lifetime for it to be truly sustainable. Therefore, a resilient building should be able to adapt and remain functional while under pressure from more frequent and severe climatic events. The goal of the study was to analyze existing inherent overlaps between resilient design principles and the LEED certification system. Synergistic opportunities together with improvements for better integrating resilient design into the LEED checklist, and hence green buildings, by modifying existing or proposing new credits were discussed. The use of climate projections instead of historical climate data during design was recommended. Regional priority credits need to be specified further to address the unique regional needs of each project to improve resilience in light of a particular region's future climate outlook.

Keywords: LEED; Green building; Resilience; Natural disaster, Regional priority

1. Introduction

Both in the United States and throughout the rest of the globe, human populations are increasing. As more people inhabit the world, more buildings are needed for homes, workplaces, and services. Especially in developed countries, current infrastructure has been designed and built using codes or design constraints that were adapted from past climate data. However, the climate of the near future is predicted to be drastically different than climate trends of a few decades ago. It is imperative that new buildings, such as those to accommodate the expanding population, are designed to withstand stresses and loads that would be imposed by the future climate, rather than designed for past conditions.

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The societal and economic impacts of a short-term approach to the problem could result in inflated problems for future generations. A real solution to the problem would be to incorporate resilience into the design and construction of buildings and infrastructure so that structures are able to withstand and recover from such events rather than fail and crumble.

The goal of the study was to assess the current emphasis the Leadership in Energy & Environmental Design (LEED) green building certification system places on building resilience, and to integrate resilience into the certification system to better reflect the needs for resilient structures due to a changing global climate. Improvements in the form of credit modification or new credits were proposed. As more buildings are designed to be resilient, the social and economic consequences of natural disasters would be dampened, and major structural catastrophes caused by severe weather could be eliminated.

An example of severe weather resulting in structural failures in the U.S. would be hurricanes. Hurricane Katrina, a category 5 hurricane, devastated the southeastern region of the U.S. in 2005. The preliminary damage report estimated structural damages within the commercial and residential sectors to total around $100 billion mainly throughout the three states that suffered the greatest damages: Louisiana, Mississippi, and Alabama [1]. Hurricane Sandy, a category 3 hurricane, struck the U.S. east coast in 2012 either damaging or destroying almost one million structures within the commercial and residential sectors [2]. By incorporating resilience within the LEED rating system, the devastating effects of these types of disasters could be lessened.

2. Background

LEED is a green building certification program developed and administered by the United States Green Building Council (USGBC). The USGBC was established in 1993 to promote sustainability in the building and construction industry [3]. The LEED certification system was initially released in March 2000 and has been updated and revised since then. The latest version of the rating system is LEED v4, which was used as a basis in this study.

The LEED rating system places strong emphasis on sustainability, defined by the United Nations as providing a decent standard of living for everyone today without compromising the needs of future generations [4]. Investigation of individual credits reveals that most are tied to either reducing resource consumption, or to promote and strengthen communities.

There are multiple rating systems under LEED, in order to provide flexibility and to cover a wide range of different projects and building types, from building design and construction, to building operations and maintenance, or neighborhood development. Each of these rating systems further breaks down into separate scorecards such as new construction, retail, hospitality, or healthcare, as the needs and design of each of these buildings would be distinctly different from each other. While there are variations in the credits and the distribution of points within each scorecard, the scorecard for new building design and construction was analyzed in this study. The maximum number of points a project can earn is 110. Points within the scorecard has been divided into the following eight categories, where each carries different number of prerequisites and potential number of credits [5;6]:

1. Location and Transportation – 16 credits
2. Sustainable Sites – 10 credits
3. Water Efficiency – 11 credits
4. Energy and Atmosphere – 33 credits
5. Materials and Resources – 13 credits
6. Indoor Environmental Quality – 16 credits
7. Innovation – 6 credits
8. Regional Priority – 4 credits

Within these categories, there are prerequisites and credits. Prerequisites are requirements that must be fulfilled for a project to be considered for LEED certification. Credits are requirements that earn a project points towards certification. Credits can be worth a single point, or multiple points depending on the importance and complexity of the credit itself. To calculate a project's score, all of the points awarded via credits are summed. This score is then compared to set ranges and awarded the appropriate certification [5]. The point ranges set for each level of certification in LEED v4 are: Certified for 40-49 points; Silver for 50-59 points; Gold for 60-79 points; Platinum for 80-110 points.

Beyond sustainability in the form of resource consumption reduction, it is also important to provide a high level of resilience to buildings. Resilience was defined by the United Nations Development Programme as the tendency to maintain integrity when subject to disturbance [7]. While there are other definitions proposed for building resilience [8], it is defined as a building's ability to withstand severe weather and natural disasters along with its ability to recover in a timely and efficient manner if it does incur damages. There is a strong relationship between sustainability and resilience as they complement each other and aim to suppress the environmental repercussions of the future through its cause and effect, respectively [9]. Achour et al. [10] have also pointed out the close relationship between sustainability and resilience in the built environment, especially in light of increasing frequency of natural hazards due to the effects of climate change. Ahern [11] discussed resilience at the urban scale and its ties to sustainability, and argued that resilience must be explicitly based on environmental, social, and economic drivers and dynamics of a place, and that these variables need to be well integrated.

Building resilience is becoming increasingly important as the earth's climate continues to change and deviate from historical climate data. By mid-century, a timeframe within the design lifetime of any building or infrastructure project constructed today, severe weather events are expected to become more intense and frequent [12], thereby imposing additional stresses on structures and, hence, decreasing robustness [13]. While not all regions were expected to be affected negatively, still, some regions are predicted to experience an increase in precipitation and related flooding, whereas others may experience more severe and prolonged droughts. In both cases, more emphasis on water management and efficiency in the LEED rating system would be appropriate. In addition, natural disasters such as hurricanes, tornadoes, and blizzards are expected to become more frequent and severe, and affect regions that are not historically affected by such weather events. If current trends continue, the majority of infrastructure in the U.S. could experience weather conditions and loads that it was not designed to withstand by mid-century.

Resilient design principles were surveyed as part of the study and criteria to applicable to buildings were established from literature [8;14-16]. While the cumulative list of principles proposed by different sources may be exhaustive, they have been condensed and listed below. Resilient design of buildings have been evaluated based on the following criteria in this study.

- Drainage design based on future climate models
- Environmentally-friendly communities
- HVAC systems designed for future, warmer, capacities
- Local, inexpensive materials and resources
- Low energy inputs
- Reduction of greenhouse gas emissions
- Renewable energy for less reliability on grid power
- Strong building envelope
- Water capture and storage
- Water usage reduction to counter increasing temperatures
- Water, fire, and pest resistant materials
- Weather resistant pavement design
- Wildfire air quality control

3. Methods

The LEED rating system thrives in the sustainable design aspect, but has not sufficiently defined the requirements of a resilient system. Determining synergies between resilient design principles and the LEED rating system were investigated and improvements to better integrate the two concepts were recommended in this study. LEED v4 for Building Design and Construction was used as a baseline to perform all analyses and recommendations. Criteria established as resilient design principles, as listed in section 2, were used as a basis in this study. Upon identifying the criteria linked to building resilience, these were then compared to the requirements for LEED v4 Building Design and Construction certification and all absent criteria was identified. Recommendations were then made to better integrate resilience into the LEED rating system.

In order to efficiently incorporate the remaining resiliency strategies into the LEED v4 Building Design and Construction certification system, the remaining criteria was first classified into different categories related to the respective climate change impacts that each requirement contests. These categories include the following impacts of climate change that are predicted for the United States:

- Flood Risk
- Drought Risk
- Water Availability
- Storm Frequency & Intensity
- Air Quality
- Pest Infestation Risk
- Wildfire Risk

Next, each region of the United States was evaluated based on published climate prediction data to determine which climate change impacts will most likely affect each individual region. Because each region will experience different effects of climate change, the LEED resiliency strategies should be tailored to specific regions by means of the Regional Priority credits.

Lastly, based on the climate prediction study, each United States region was assigned four of the climate change impact categories (categories were combined or duplicated if a region is expected to experience more or less than four of the climate change impact categories), and the respective resilient design principles listed in section 2 that accompany the selected categories. Detailed results of this process are examined next in section 4.

4. Results

Upon close analysis of the LEED scorecard and the resilient design principles listed in section 2, it was observed that about half of the principles have already been incorporated or addressed by the existing LEED rating system. For example, supplying renewable energy and reductions in greenhouse gas emissions were directly addressed through LEED’s Renewable Energy Production credit, and Green Power and Carbon Offsets credit, respectively. Low energy input criteria were addressed in the Building Life-Cycle Impact Reduction credit and the Optimize Energy Performance credit, where credits can be earned for reusing existing building resources, demonstrating a reduction in materials use, and by establishing an energy performance target based on the scope of the project [5]. The need for environmentally-friendly communities may be tied with LEED’s Neighborhood Development Location credit. A project can gain a credit by locating the project within the boundary of a development certified under LEED for Neighborhood Development. Also, both the water capture and storage and the water usage reduction to counter increasing temperatures criteria may be directly addressed within the existing rating system. However, while the LEED v4 rating system currently addresses some aspects of building resilience, it still does not address about half of the identified principles, and therefore creates a significant gap to fulfill a goal of sustainable and resilient buildings.

The remaining criteria of resilient buildings that were unaccounted for were analyzed and integrated into the current LEED rating system through credit modifications and proposals. The Site Assessment credit and Rain Water Management credit, contained within the Sustainable Sites category, were both amended because the LEED v4 rating system requires projects to use historical climate and rainfall data during design calculations. As the future climate is projected to be different than in the past, the site assessment and rain water management design should both utilize projected climate data. The Site Assessment credit should require that projected changes in temperature, precipitation, and severe weather events for that region are used in design considerations. Likewise, the drainage system designed to satisfy the Rain Water Management credit should be designed for the future demand based on future precipitation projections.

The most drastic changes that need to be made to the LEED green building certification system occur within the Regional Priority category. Currently, Regional Priority credits are awarded for addressing geographically specific priorities; however, these credits simply consist of other credits that already exist elsewhere within the scorecard in a different category of the LEED certification system [5]. Essentially, no additional work is needed to achieve these credits if the credit has already been fulfilled in its respective category. On the contrary, Regional Priority credits could be more efficiently utilized to incorporate region-specific resilience credits into the LEED certification system, assigned based on future climate projections.

A report published by the U.S. Global Change Research Program has analyzed projected climate change trends for the U.S. on a regional basis [17]. The report also presented anticipated changes in frequency of natural disasters on a regional basis. While the scope of the report was extensive, those impacts that were relevant to buildings were summarized and reported in Table 1. These identified impacts were then used to define regional priority credits in the LEED scorecard.

Table 1. Projected Regional Climate Change Trends [14;17]

	AVERAGE & EXTREME TEMP.	PRECIPITATION					COASTAL EFFECTS	AIR QUALITY	PESTS	FIRE
		Flood Risk	Drought Risk	Storm Frequency	Storm Intensity	Water Availability	Sea Level Rise		Infestation Risk	Wildfire Risk
Northeast	INCREASE	INCREASE	INCREASE	INCREASE	INCREASE		ABOVE AVERAGE			
Southeast	INCREASE				INCREASE	DECREASE	INCREASE			
Midwest	INCREASE	INCREASE					REDUCTION IN LAKE LEVELS	DECREASE	INCREASE	
Great Plains	INCREASE		INCREASE			DECREASE		DECREASE	INCREASE	
Northwest	INCREASE	INCREASE				DECREASE	INCREASE	DECREASE	INCREASE	INCREASE
Southwest	INCREASE	INCREASE	INCREASE			DECREASE	INCREASE	DECREASE	INCREASE	INCREASE
Alaska	INCREASE			INCREASE	INCREASE		INCREASE	DECREASE	INCREASE	INCREASE
Islands	INCREASE			INCREASE	INCREASE	DECREASE	INCREASE			

Each region of the United States has been assigned 4 new Regional Priority credits based on the projected regional climate change trends. The new credits address issues that will benefit the wellbeing of projects when faced with probable natural events of the future in that particular area. New priority assignments can be seen in Table 2. Each of these priority credits were defined in Table 3, and were developed by building on the work done by Wholey [18], which describes the ability of resilient design to offset the safety concerns of a changing climate, and strategies for increasing resiliency, and the study by Boers et al. that analysed drought-prone areas specifically [19].

Table 2. Revised Regional Priority Credits

	Regional Priority Credits			
	1	2	3	4
Northeast	FLOOD	DROUGHT	STORM	STORM
Southeast	STORM	STORM	WATER	WATER
Midwest	FLOOD	FLOOD	AIR	PEST
Great Plains	DROUGHT	WATER	AIR	PEST
Northwest	FLOOD	WATER	AIR	PEST & FIRE
Southwest	FLOOD & DROUGHT	WATER	AIR	PEST & FIRE
Alaska	STORM	AIR	PEST	FIRE
Islands	STORM	STORM	WATER	WATER

Table 3. Revised Regional Priority Requirements

Regional Priority Credit	Satisfaction Options	Regional Priority Credit	Satisfaction Options
FLOOD	Design above 500-year flood plain	FLOOD & DROUGHT	Design above 500-year flood plain
	Use permeable pavement		Use permeable pavement
	Raise critical equipment		Raise critical equipment
	Reduce soil compaction		Reduce soil compaction
	Safeguard toxic materials		Safeguard toxic materials
	Install sewage backflow valve		Install sewage backflow valve
	Use water resistant materials		Use water resistant materials
DROUGHT	Treat and utilize greywater		Treat and utilize greywater
	Harvest rainwater		Harvest rainwater
	Reduce landscape water use		Reduce landscape water use
WATER	Reduce consumption of indoor water use	STORM	Strengthen envelope
	Reduce consumption of outdoor water use		Use local, replaceable, and inexpensive materials
PEST	Use pest resilient materials		Use resilient building materials
FIRE	Control environmental wildfire smoke		Use weather resilient pavement
	Use fire resilient materials	AIR	De-couple systems
PEST & FIRE	Use pest resilient materials		Use heat recovery ventilation system
	Control environmental wildfire smoke		Increase ventilation
	Use fire resilient materials		Use low emitting materials

The Great Plains region have been assigned Drought, Water, Air, and Pest as Regional Priority credits in Table 2. To satisfy each of these credits, a project in the Great Plains region must fulfill at least one option from each respective Regional Priority assignments presented in Table 3. Therefore, treating and utilizing greywater within the building project, reducing consumption of indoor water use, using low emitting materials, and using pest resilient materials would all contribute 1 point each towards a total of 4 points under the Regional Priority category in the LEED scorecard. The benefit of this approach is that multiple regional priorities can be specified and addressed within LEED rather than the free form priority credits being given in its current form. This would also be in line with the remainder of the scorecard in writing specific requirements for each credit.

5. Conclusion

Resilience of infrastructure and buildings has become increasingly important as climate change continues to progress and severe weather events become more frequent and intense. Ensuring that new buildings are built to withstand stresses and loads imposed by future weather patterns, and are able to easily recover from any damages incurred during such climatic events needs to be a top priority in construction design. LEED rating system developed and administered by USGBC has become the dominant means of evaluating green buildings in the U.S. While the LEED rating system has diversified over the years and is able to adequately address many sustainability concerns and criteria, a closer investigation as to integration of LEED and resilient design principles revealed that there are significant gaps in LEED that could be addressed by modifying certain credits and by revising the structure of the Regional Priority category altogether. LEED v4 needs to be revised to better address resilience as a requirement and the following recommendations were made to address the issue:

- Revision of Site Assessment credit to use future climate projections instead of historical data
- Revision of Rainwater Management credit to use future climate projections instead of historical data
- Complete overhaul of Regional Priority credits to address regional resilience based on regional climate projections

Should these changes be adopted into the next version of the LEED rating system, designers will receive the incentive that is necessary to incorporate resilience into the design of new infrastructure and buildings. If resilience is not better integrated into green buildings, then environmental, economic, and societal costs that may arise following a severe weather event may render the ultimate goals of LEED questionable.

6. References

[1] M.L. Burton, M.J. Hicks, Hurricane Katrina: Preliminary Estimates of Commercial and Public Sector Damages, Marshall University Center for Business and Economic Research, (2005) 1-12.

[2] D. Rice, A.E. Dastagir, One Year after Sandy, 9 Devastating Facts, USA Today, 29 Oct. 2013

[3] USGBC, USGBC History, United States Green Building Council, (2015)

[4] UN, What Is Sustainability, *United Nations News Center*, (2015)

[5] USGBC, LEED v4 for Building Design and Construction, United States Green Building Council, (2015)

[6] USGBC, LEED v4 for Building Design and Construction Checklist, United States Green Building Council, (2015)

[7] E. Levina, D. Tirpak, Adaptation to Climate Change: Key Terms, Organization for Economic Co-Operation and Development, (2006)

[8] H. Mallawarachchi, L. De Silva, R. Rameezedeen, Green Buildings, Resilience Ability and the Challenge of Disaster Risk, International Conference on Building Resilience, (2013)

[9] Y.W. Al-saeed, A. Ahmed, M. Gaterell, Investigating the Inter-relationships between Resilience and Sustainability of Built Environment, International Conference on Urban Sustainability and Resilience (2014)

[10] N. Achour, E. Pantzartzis, F. Pascale, A.D.F. Price, Integration of Resilience and Sustainability: from Theory to Application, International Journal of Disaster Resilience in the Built Environment, 6(3) (2015) 347-62.

[11] J. Ahern, From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world, Landscape and Urban Planning, 100(4) (2011) 341-343.

[12] Mills, P. "Lessons Learned From Summer Floods 2007." Water UK (2009): n. pag. Knovel. Web. 2 Mar. 2016.

[13] Pantelidou, Heleni, Duncan Nicholson, and Asim Gaba. "Sustainable Geotechnics." CE Manual of Geotechnical Engineering (2012): n. pag. Knovel. Web. 2 Mar. 2016.

[14] L. Larsen, N. Rajkovich, C. Leighton, K. McCoy, K. Calhoun, E. Mallen, K. Bush, J. Enriquez, C. Pyke, S. McMahon, A. Kwok, Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions, (2011)

[15] N. Wilding, Exploring Community Resilience in Times of Rapid Change, Carnegie UK Trust, (2011),

http://www.carnegieuktrust.org.uk/getattachment/75a9e0c4-8d75-4acb-afac-6b1cbd6f2c1e/Exploring-Community-Resilience.aspx

[16] J. Bilello, Design for Resilience: Mitigation, Adaptation and Transformative Design, Architectural Research Centers Consortium (2014) 229-37.

[17] USGCRP, Climate Change Impacts in the United States: The Third National Climate Assessment, J.M. Melillo, T.T.C. Richmond, G.W. Yohe (Eds.), U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

[18] F. Wholey, Building Resilience: A Framework for Assessing and Communicating the Costs and Benefits of Resilient Design Strategies, Perkins+Will Research Journal 7.1 (2015) 7-18.

[19] T.M. Boers, J. Ben-Asher, A Review of Rainwater Harvesting, Agricultural Water Management, 5(2) (1982) 145-58.