



Development and analysis of Climate Sensitivity and Climate Adaptation opportunities indices for buildings

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ABSTRACT

Buildings represent long-term, capital-intensive investments designed to perform for decades into the future. Consequently, the potential for changes in climate across the design lifetime of built environments represents an immediate challenge for planning, design, and construction. In this study, we consider the opportunities to assess Climate Sensitivity and adaptive opportunities associated with green building practice. We developed a pair of complementary indicators called the *Climate Sensitivity Index* (CSI) and *Climate Adaptation Opportunity Index* (CAOI). These indicators are applied to evaluate individual strategies (“credits”) within the Leadership in Energy and Environmental Design (LEED™) for New Construction rating system. The indices provide two complementary scores for each strategy. The CSI reflects potential sensitivity to changing conditions (i.e., risks to performance outcomes), and the CAOI indicates potential adaptive opportunities (i.e., plausible strategies to adapt to changing conditions). We apply the indices to retrospectively examine the prevalence of potentially sensitive and adaptive practices among a global set of 2440 LEED-certified projects. Adaptive opportunities were more prevalent than sensitivities in the LEED-NC rating system. The CSI and CAOI indices illustrate how information can be derived by interpreting patterns of LEED credit achievement. The indices will be available within a suite of analytical tools in the Green Building Information Gateway (www.gbinfo.org).

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1. Introduction

Climate change represents profound challenges for the built and natural environments. Scientific evidence consistently documents Earth’s changing climate and indicates the potential for continued change even under the most aggressive emission reduction scenarios. Consequently we are very likely to experience significant climatic changes over the coming decades [1,2]. While strategies to reduce greenhouse gas emissions, such as by increasing energy efficiency, are familiar green building techniques, strategies for adapting green buildings to changing conditions are less common. Changes in the climate have important implications for green buildings and may mean that the eventual operating conditions of the building vary from the expectations incorporated in the planning, design, and construction phases. Therefore, green building strategies must prepare for changing conditions and thereby increase the likelihood of achieving operational performance goals across the lifetime of a project.

Climate Adaptation strategies are necessary at multiple scales, ranging from the region, the city, the neighborhood, to the site. In this paper, we focus on issues and opportunities associated with the design and construction of new buildings under the LEED green building framework. Specifically, we identify 2440 LEED-certified projects from 2007 to 2011 and retrospectively evaluate the contribution of climate-sensitive and climate adaptive strategies in these projects. These 2440 projects represent the total number of certified LEED for New Construction 2.2 buildings with complete credit achievement data at the time the study was conducted. In the first section of this paper, we introduce the LEED Framework. Our objectives include:

- Investigate connections between green building practices and climate change impact and adaptation.
- Demonstrate new approaches to identifying and prioritizing green building strategies based on their potential sensitivity to changing climatic conditions.
- Demonstrate new approaches to identifying and prioritizing green building strategies based on their relevance to climate change adaptation.

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- Develop and apply new metrics to identify potentially vulnerable or adaptive practices associated with existing and proposed buildings pursuing LEED certification.

These elements combine to further our understanding of the connections between climate change and green building practice and to provide practical tools and metrics to address potential vulnerabilities and adaptive opportunities.

2. Approach

2.1. Introduction to LEED

We use the U.S. Green Building Council's Leadership in Energy and Environmental Design for New Construction (LEED-NC™) rating system as a framework for assessment and to bound a collection of relevant sustainable design and construction practices. LEED-NC is a well-recognized and globally applied tool to promote market transformation and assess specific aspects of the achievement and performance of new buildings [3]. LEED is developed through a consensus-based process administered by the U.S. Green Building Council (USGBC). It is intended to provide a tool to promote market transformation and help assess the characteristics and performance of projects with respect to multiple criteria, including site design, energy efficiency, water use, materials, and indoor environmental quality. LEED is adapted to address circumstances associated with specific market segments and circumstances, including commercial interiors, core and shell, schools, retail, healthcare, homes, existing buildings, and neighborhood development.

LEED is composed of a collection of required and optional elements. All certified projects must meet prerequisites such as minimum levels of energy efficiency and site selection requirements. Projects must also achieve optional credits sufficient for certification or higher levels of recognition (silver, gold, or platinum). LEED helps project teams identify and evaluate potential green building strategies, while also making markets more efficient in allocating resources by recognizing and rewarding high-performing projects. This is reflected in LEED's dual role as a practical tool for project teams and an instrument for assessment and communication.

LEED's success and importance is measured through impact on people, projects, and the environment. Through 2011, over 27 million square meters of commercial buildings in over 100 countries were engaged with LEED certification as either certified or registered projects (Green Building Certification Institute). In parallel, over 150,000 people have received professional recognition as LEED Accredited Professionals, indicating their familiarity with green building practices and LEED as a tool.

2.2. LEED as an outcome-oriented rating system

LEED was originally designed as a simple tool to identify and prioritize practices based on their value for market transformation based upon the idea that building practitioners would incorporate a subset of green strategies if their efforts were recognized. In the earliest version of LEED, there was no explicit, quantitative relationship between the value assigned to an individual practice (e.g., points) and its relationship to outcomes or impacts. However, beginning with LEED 2009, LEED has incorporated an explicit analytical framework to prioritize measures and assign points. This system is called the LEED Framework, and it represents an analytical infrastructure used by USGBC for the design of rating systems while also permitting the quantification of specific issues such as climate adaptation. A full-description of the structure of LEED 2009

and the LEED Framework is available from www.usgbc.org/LEED2009/.

The Weightings Framework is a mechanism used by USGBC to develop LEED and it is not a tool that is directly used by practitioners or projects. The weighting framework is a mechanism to allocate points and understand relationships between the achievement of prerequisites, credits and specific outcomes [4]. LEED-NC 2009 is a weighted composite of 13 outcomes based on EPA's Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) impact categories [5]. Each outcome has an associated index which assigns the relative contribution of each credit to that outcome. The total value of all associations for a given index sum to 100. For example, if only one credit addresses the outcome, it would be assigned a score of 100. More typically, multiple credits each partially address an issue, and they are assigned relative fractional values totaling 100. The 13 indices are designed to be combined to guide the allocation of points to credits during the design of the rating system. However, they can also be used individually to evaluate specific outcomes based on the actual achievement of projects in the field. This is not their primary use, and it is a powerful feature that has rarely been fully utilized.

2.3. Custom outcomes for climate change sensitivity and adaptation

Using this framework, outcomes and indices can be extracted and examined for purposes other than the design of rating systems. They can be used to associate new issues, such as sensitivity and adaptation, with existing green building credits. This provides opportunities to examine the importance of different credits (strategies) and to retrospectively evaluate patterns of achievement of existing certified projects. In this study, we customized the LEED Framework by defining two new outcomes: Climate Sensitivity and Climate Adaptation Opportunity. These outcomes are not considered in the current design of the LEED rating system, but they are issues that can be linked to individual credits and evaluated with respect to existing projects. For our purposes, we defined these terms as:

- *Climate Sensitivity*: the likelihood that consequential decisions or assessment criteria (e.g., design thresholds or specifications) rely on climatic information that is anticipated to change.
- *Climate Adaptation Opportunity*: the potential for green building credits to be achieved in ways that specifically reduce sensitivity and increase the building's adaptive capacity to changing climatic conditions.

These new climate focused outcomes are described and evaluated as a pair of indicators called the *Climate Sensitivity Index* (CSI) and *Climate Adaptation Opportunity Index* (CAOI) within the LEED Framework. Developing these indices within the LEED Framework creates two complementary results. First, each index is available as a vector of coefficients that indicate the relative strength of association between the outcomes and individual credits. This information can help practitioners identify sensitivities and potential adaptive opportunities.

Second, the indices can also be applied to analyze the achievement of multiple credits by an individual project or collection of projects. This is particularly valuable because the CSI and CAOI metrics can also be retrospectively applied to thousands of projects that have used comparable credits since LEED-NC version 2.1 was adopted approximately 5 years ago. These projects most likely did not explicitly consider climate change sensitivity or adaptive opportunities; however, we can examine the consequences of the choices they did make with respect to these new outcomes of concern by evaluating their patterns of credit achievement.

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