Review

Adaptive or Absent: A Critical Review of Building System Resilience in the LEED Rating System

Danielle De Castro and Amy Kim *

Department of Civil and Environmental Engineering, University of Washington, Campus Box 352700, Seattle, WA 98195, USA; danidc@uw.edu

* Correspondence: amyakim@uw.edu

Abstract: Since people living in developed nations across Europe, North America, and Australia spend most of their lives indoors, protecting indoor environmental quality is critical for protecting human health. As stressors such as COVID-19 and climate change further complicate living conditions, conflicting system priorities underscore the need for resilience in all building systems. In the engineering and architectural fields, sustainability rating frameworks are used to note, reward, and motivate the use of sustainable practices. As such, it is crucial to ensure that these frameworks genuinely encourage resilience in building systems. This paper conducts a review of the Leadership in Energy and Environmental Design–Building Design and Construction (LEED BD+C v4.1) framework for New Construction through a credit-level analysis, to determine the extent to which the framework encourages the resilience of building systems beyond the scope of structure. Researchers identified, tabulated, and deconstructed relevant credits according to four key resilience factors: diversity, efficiency, adaptability, and cohesion. Findings indicated that, while efficiency is well supported, diversity, adaptability, and cohesion can be enhanced. The existing rating system provides a strong base upon which improvements can be made, but falls short of adequately encouraging the wide adoption of resilience needed for long-term sustainability. In short, while the LEED credits do reward resilient designs, they do not yet actively inspire them.

Keywords: resilience; building systems; sustainability; rating framework; LEED; diversity; efficiency; adaptability; cohesion

Citation: De Castro, D.; Kim, A. Adaptive or Absent: A Critical Review of Building System Resilience in the LEED Rating System. *Sustainability* **2021**, *13*, 6697. <https://doi.org/10.3390/su13126697>

Academic Editor:
Ali Bahadori-Jahromi

Received: 13 April 2021
Accepted: 9 June 2021
Published: 12 June 2021

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1. Introduction

Human health and the natural environment are both significantly influenced by the built environment. The vast amount of time we spend inside links the indoor environment inextricably to our wellbeing [1,2]. As our understanding of these relationships has grown, so has our desire to improve them in tandem with sustainability. Sustainability is a broad concept that, in the context of buildings, is both relatively new to modern discussion and often equated with environmental protection. Yet, among those actively concerned with the subject, “sustainability” cannot be bound to such a narrow scope. Indeed, within the field, the concepts of social and financial wellbeing are increasingly included in discussions of sustainability, while the concept of resilience extends these considerations over a longer time frame. Rating systems comprise the leading mechanisms by which these multiple facets of sustainability are incentivized within the industry.

Rating systems act as grading schemes through which projects can be awarded certifications for commendable sustainability or healthfulness. Typically, a rating system is organized as a framework comprised of categories that reflect a general theme or element of building design. Individual credits under these categories specify desired intents or outcomes and a set of requirements that must be met to earn points towards each credit. A threshold, defined by the achievement of prerequisites, credits, and a specified point total or percentage, usually determines whether certification is granted.

Such rating systems have been developed and employed all over the globe. The first among them was the United Kingdom's Building Research Establishment Environment Assessment Method (BREEAM) in 1990. More systems have been developed as interest in sustainability has grown. While BREEAM remains popular in the UK, the system is now deployed internationally [3], as are other rating systems including the Living Building Challenge (LBC), WELL, and LEED.

Globally, LEED is currently the most widely employed framework and plays a key role in influencing what is defined as sustainable design [4]. First launched in 1998 by the United States Green Building Council (USGBC), the framework is periodically updated to better reflect developing strategies [5] and is structured around nine credit categories: Integrative Process (IP), Location and Transportation (LT), Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (EQ), Innovation (IN), and Regional Priority (RP) [6]. Pilot credits are introduced on a trial basis in the online credit library on the USGBC website to reflect emerging practices. Achieving these pilot credits can earn project points under the Innovation credit category. In this way, the USGBC has consistently shown awareness of the need for continuous evolution and evaluation of rating systems.

Researchers, too, have recognized this need. Studies that have evaluated the performance of LEED-certified buildings have appeared in the past decade's published literature. Assessments of energy performance in LEED buildings and comparisons between LEED and non-LEED buildings, such as those conducted on Navy buildings by Menassa et al. [7] in Arizona by Oates and Sullivan [8], and in Australia by Tilton and El Asmar [9], highlight a need to inspect the substance of the LEED framework to ensure that it accurately assesses achievement of sustainability goals. In the same vein, the structures of rating systems have come under scrutiny as well. Particularly for prescriptive-based rating systems, the desired outcomes of certification can be diluted in projects that bypass impactful practices. Both Orr's [10] position paper and Amiri's [11] review have highlighted this problem in the LEED system.

Resilience is another concept that has gained popularity in research. Often discussed under the context of natural disasters and climate-change hazards, resilience refers to a building's ability to withstand and rebound from stressors. As climate change brings rising sea levels and increasingly frequent severe storms, floods have become a common focus of resilience discussions. Papers such as those by Barabaro et al. [12] and Chester et al. [13] present findings focused on physical and structural design to improve pre- and post-disaster flood risk mitigation. While these findings and similar investigations are significant, they often lack formal consideration of building systems. In 2020, Abraham and Anumba identified this gap in the literature, calling out a need to approach resilience "from an interdisciplinary perspective" so that "every component of the building . . . can absorb disturbance" [14].

Building systems are critical components responsible for the performance of many building functions. The general ambit of building systems traditionally encompasses lighting, ventilation, heating, and plumbing, but is expanding as new systems and technologies develop. While building systems vary, Fiksel defined four key properties of resilient systems in 2003: diversity, efficiency, adaptability, and cohesion. In this context, diversity is characterized as "the existence of multiple forms and behaviors", efficiency as "performance with modest resource consumption", adaptability as "the flexibility to change in response to new pressures", and cohesion as "the existence of unifying forces or linkages" [15].

For example, redundancies such as back-up generators may constitute a diversity tactic, while the use of LEDs instead of incandescent bulbs may qualify as efficiency. Feedback loops may be one adaptability characteristic, and modularity, which allows change and reconfiguration, another. Finally, cohesion may be exemplified by a central control station. Resilient building system practices (RBSPs) that embody these four resilience properties

can be found among the growing literature in research and industry. Table 1 presents some of the most common.

Table 1. Resilient building system practices relating to the four properties of resilient systems.

Diversity	Efficiency	Adaptability	Cohesion
<ul style="list-style-type: none"> • Multiple energy sources (onsite) • Multiple water sources (onsite) • Daylighting • Passive survivability (supplemental to mech.) • Variable settings 	<ul style="list-style-type: none"> • Reducing energy load • Reducing water consumption (esp. potable) 	<ul style="list-style-type: none"> • Modular design • Monitoring with response plan or automation • Consideration of future trends (e.g., hazard assessment) • Renewable energy (onsite) 	<ul style="list-style-type: none"> • Building management systems • Centralized controls • Centralized data collection • Inter-system coordination

Upon examining RBSPs, the interrelationship among resilience properties becomes apparent. Passive survivability, for example, creates a redundancy in behavior when designed as a supplement to mechanical system operations. The same feature can therefore be characterized as diversity, as well as the immediately apparent adaptability. In fact, diversity can be thought of as a specific subset of adaptability. Yet, when used as *typical operation*, passive designs contribute to reducing energy loads, and thus efficiency as well. Similarly, monitoring and responding to system performance supports adaptability, but is often integrated into building management systems, and thus can also tie into cohesion.

The need for building systems that embody these characteristics is perhaps most starkly shown by the convergence of natural disasters and COVID-19 over the past year. Indeed, the shroud of wildfire smoke that blanketed many skies in recent summers is set to become a permanent fixture of our warm summer months, consequently stressing ventilation systems in homes and buildings. COVID-19 in 2020 presented a conflicting stressor to ventilation systems in these regions. While the management of smoke ingress called for the separation of outdoor and indoor air, the management of COVID-19 called for the opposite: an increase in outdoor air intake [16,17]. Both responses, however, increase the energy demand on mechanical ventilation systems, while dense overhead smoke obscures the sun and impedes solar power. For example, in California, the 2020 wildfires resulted in a decrease in solar power generation of approximately 30% [18].

These issues pertain to the west coasts of North America and Australia in particular, but air quality is an issue that affects many countries. London has long struggled with air pollution, and while local policies are improving the problem [19], other cities continue to grapple with it. Air pollution generated in the cities of China, for example, not only impacts local cities, but also poses a transboundary problem for neighboring countries such as South Korea [20]. Furthermore, conflicts such as those for ventilation systems between COVID-19 and air pollution are not the only instance of multiple-hazard events we are likely to see in the future. This paper does not intend to identify a comprehensive list of such events, but rather to identify how well the LEED framework is preparing for them. Incorporating resilience into systems can prepare buildings and occupants to better manage similar pressures.

This paper presents a critical review of building system resilience under the LEED Building Design and Construction (BD+C) v4.1 rating system for New Construction. Specifically, a qualitative evaluation of the language presented for the established and pilot credits is undertaken using Fiksel's definition of resilience. The goal of this evaluation is to determine whether the four properties are intentionally encouraged, and whether they are fully or partially integrated within credits. The properties of resilience that are adequately supported and areas for improvement are identified to inform future advancement of the framework.

2. Materials and Methods

To analyze the LEED Building Design and Construction v4.1 framework for New Construction, three phases of evaluation were conducted:

1. Evaluation of relevant credits;
2. Identification of overall correlation and patterns; and
3. Identification of possible improvements.

In phase 1, we analyzed each credit using the rating system manual and accompanying online credit library based on the literature, probing qualitatively for RBSPs that support the four fundamental properties of resilience. The practices listed in Table 1 were collected from existing literature on resilience in buildings, including papers by Mallawarachchi [21], Awadh [4], and Phillips et al. [22] as well as the authors' knowledge. Where appropriate, practices were reframed in the context of building systems. The list is intended not to be exhaustive, but to represent the field's current understanding of resilient practices and features. As discussed in the Introduction, the RBSPs can overlap with more than one resilience principle. In order to address this complexity and standardize the evaluation process for each credit, each RBSP was sorted under a single resilience property. In particular, RBSPs that addressed adaptability through creating diversity were categorized under diversity only.

Both credit requirements and intents were considered. As such, credits that were intentionally designed to encourage these properties and credits that did so inadvertently were each noted. Specifically, the evaluation identifies a credit's support of each property as one of the following:

- Intentional, Full (I, F): at least one RBSP is specified under the credit Intent statement and is required under *all* possible routes to earning credit points.
- Intentional, Partial (I, P): an RBSP is specified under the credit Intent statement but not *required* to earn credit points.
- Unintentional, Full (U, F): an RBSP is *not* specified under the credit Intent statement but is required under *all* possible routes to earn credit points.
- Unintentional, Partial (U, P): an RBSP is *not* specified under the credit Intent statement but is required under *at least one* requirement route.
- Not Supported: no RBSP is specified under the credit Intent statement and no RBSP is required under any route.

The process through which each credit was evaluated to determine the above classifications is illustrated as a decision-based flowchart in Figure 1. This analysis was completed and organized into a review table (Table 2), in which each row marks an individual credit and results are entered under columns corresponding to the four properties.

In phase 2, the results from phase 1 were reviewed to identify which of the four properties were (or were not) supported, where in the framework, and in what manner. The number of credits earned for each designation under individual properties was counted and graphed comparatively in order to inform the discussion.

Phase 3 covered the material to be found in the Discussion and Conclusion sections of this paper. Here, the results from both previous phases were considered and, most importantly, discussed in relation to the details of the credits and RBSPs themselves. As such, conclusions were drawn and suggestions that offer a chance to build upon the current rating system framework were made. These suggestions, however, are intended not to be exhaustive but to provide a starting point for a more thorough deliberation.

Figure 1. A process flowchart showing the evaluation process for determining the type of support given by a credit to a resilience property.

Table 2. Summary of correlations between credits and resilience properties.

Credit	Diversity	Efficiency	Adaptability	Cohesion
IP Credit: Integrative Process		I, F		I, F
SS Credit: Light Pollution Reduction				
WE Prerequisite: Outdoor Water Use Reduction		I, F		
WE Prerequisite: Indoor Water Use Reduction		I, F		
WE Credit: Outdoor Water Use Reduction		I, F		
WE Credit: Indoor Water Use Reduction		I, F		
WE Credit: Cooling Tower and Process Water Use		I, F		
WE Credit: Water Metering			I, P	
EA Prerequisite: Fundamental Commissioning and Verification				
EA Prerequisite: Minimum Energy Performance		I, P		
EA Credit: Enhanced Commissioning			U, P	
EA Credit: Optimize Energy Performance		I, F		
EA Credit: Advanced Energy Metering			I, P	U, F
EA Credit: Grid Harmonization			U, P	
EA Credit: Renewable Energy			U, P	
EQ Prerequisite: Minimum Indoor Air Quality Performance			U, F	
EQ Credit: Enhanced Indoor Air Quality Strategies		U, P		
EQ Credit: Thermal Comfort	U, F			
EQ Credit: Interior Lighting	U, P			
EQ Credit: Daylight	I, F	I, F		
Pilot Credit: Assessment and Planning for Resilience	U, P		I, P	
Pilot Credit: Design for Enhanced Resilience	I, P	I, P	I, P	
Pilot Credit: Passive Survivability and Back-up Power During Disruptions	I, F			

3. Results

As the results of the evaluation in Table 2 indicate, unintentional full support (U, F) is markedly uncommon, occurring under only three credits. In other words, when an RBSP is not specified under the Intent of a credit, it is unlikely to be fully supported in the credit Requirements. This is perhaps unsurprising; however, it is surprising to note that an RBSP's presence in the Intent statement does not always translate to full support. Intentional partial support (I, P) was encountered seven times in the evaluation, particularly under the adaptability property. This finding indicates that paths to earning credits allow a project to either bypass the RBSP, scope out building systems, or alter the language describing the practice in a way that diminishes the integrity of the practice in relation to the resilience property.

Our evaluation shows that the existing LEED BD+C credits support some properties of resilient building systems better than others. This inconsistency is particularly evident in Figure 2. Existing energy and water sustainability goals under the framework advance efficiency, as expected, for these two major resources in building system operations. In both prerequisites and credits, water efficiency is supported intentionally and fully. Adaptability appears the second-most frequently throughout the framework, behind efficiency, but is concentrated mostly in the Energy and Atmosphere (EA) category and typically only partially supported. Prerequisites also fail to include diversity and cohesion, intentionally or otherwise. Furthermore, it is clear that RBSPs for cohesion crop up rarely throughout the LEED rating system overall, but when they do, they have been fully supported.

Figure 2. Summary of results: (a) Credit support for resilience properties (includes Prerequisites); (b) prerequisite only support for resilience properties.

As a group, the three pilot credits intentionally support diversity, efficiency, and adaptability, but do so in a partial manner. Diversity is supported under all three credits, at least partially, and is the only property to receive full support under one of these pilot credits.

4. Discussion

As can be readily seen in Table 2, efficiency is well supported for energy and water systems. Credits and prerequisites alike in the Water Efficiency (WE) and Energy and Atmosphere (EA) credit categories encourage project designers to reduce building demand for potable water and GHG-heavy energy, or to seek alternative sources.

Nonetheless, the resilience of energy systems in the LEED BD+C is not limited to efficiency and diversity RBSPs. EA Credit: Grid Harmonization, particularly Case 3, calls

for flexibility in the electricity loads of building operations. From an energy perspective, the requirements focus on shifting and reducing peak load, and thus naturally support adaptability in building systems.

Although energy is often an integral commonality among building systems, energy functions are wide-ranging and becoming increasingly complex as technology develops. Varying disciplines and areas of expertise can apply to different building systems. As such, inter-system cohesion benefits from collaborative design and cross-disciplinary communication, which is explicitly supported by the Integrative Process (IP) credit category. Moreover, “synergies across disciplines and building systems” [6] is specifically called for under the IP credit.

Inter- and intra-system cohesion is supported by monitoring requirements for energy. EA Credit: Advanced Energy Metering calls for remote sensors to be placed to measure building- and system-level electricity consumption on a periodic basis. To earn points toward the credit, the data are to be collectively stored and remotely accessible. This practice helps to unify system data and diagnostics, thus explicitly supporting cohesion.

Carbon dioxide (CO₂) monitoring for ventilation systems appears under the Indoor Environmental Quality (EQ) credit category within the Minimum Indoor Air Quality Performance prerequisite and Enhanced Indoor Air Quality Strategies credit for natural and mechanically ventilated systems, respectively. CO₂ sensors must be equipped with an alarm or be capable of alerting a building automation system when levels exceed the set point by 10%. This element supports adaptability explicitly by requiring an alert to allow timely adjustment of the system or occupant behavior.

Again, the EQ credit category shows that diversity in lighting systems is well-encouraged both in behavior and form. In behavior, diversity is supported via EQ Credit: Interior Lighting, whereby control systems with at least three lighting levels are required within multi-occupant spaces. Diversity in form is seen under EQ Credit: Daylight, which rewards projects for increasing access to sunlight inside the building.

Diversity in form is also seen in the pilot credit Passive Survivability and Back-up Power During Disruptions which, as its name suggests, encourages buildings to include redundancies [23]. This and two related pilot credits, Assessment and Planning for Resilience and Design for Enhanced Resilience, can earn a project points toward the Innovation credit. While established credits such as WE Credit: Outdoor Water Use Reduction call for the use of historical regional and climate data, these two latter pilot credits require predictive modeling data to inform design decisions [24,25]. This element supports the spirit of adaptability in response to natural disasters by encouraging detailed forethought to climate hazards.

While support for resilience properties can be found within the framework, and existing supplements (e.g., pilot credits) do indicate a promising direction for their development, a deeper consideration of the implications and structure of credit requirements reveals three key areas for improvement to better support the diversity and adaptability of systems.

Firstly, explicit support for diverse systems is needed. The rating system indirectly supports the diversification of building energy sources by rewarding designs for the incorporation of renewable energy, as does LEED Zero, an add-on framework to LEED requirements which encourages projects to meet net-zero carbon and energy goals [26]. However, this support is not inherent. In fact, while projects receive points based on GHG reductions, the framework does not distinguish among projects that achieve that reduction by reducing energy demand, transitioning to a single renewable energy source, or using a combination of energy sources. Making such a distinction by rewarding projects more for incorporating multiple renewable sources would prioritize diversity in the EA credit category. The same principle should be applied across the board.

In terms of behavior, mechanical heating, ventilation, and air conditioning (HVAC) systems have a rather well-established amount of diversity as they incorporate adjustable set points and the ability to heat, cool, and filter air. EQ credits for indoor air quality, however, do not support mixed-mode systems over single-mode natural or mechanical

ventilation. As such, neither diversity of behavior nor diversity of systems are supported here. These credits could easily be adjusted to prioritize mixed-mode ventilation designs.

Secondly, the expansion of monitoring requirements is essential to supporting adaptability. Data collected via monitoring through sensors provides critical information that supports intelligent responses. EA Credit: Enhanced Commissioning specifies sensor placement that “assess[es] performance of energy- and water-consuming systems” and requires the development of an action plan in response to errors [6], but does so only under Option 1, Path 2. Meanwhile, EA Credit: Advanced Energy Metering centralizes collected data but falls short of requiring a system or plan that actively responds to this data. Expanding these requirements to include formalizing such a system or plan would help to encourage the closed-loop energy and water systems needed for adaptability.

On the other hand, CO₂ monitoring in the Minimum Indoor Air Quality Performance prerequisite and Enhanced Indoor Air Quality Strategies credit does address monitoring more explicitly by requiring an alert when conditions exceed the threshold. However, under both the prerequisite and credit, CO₂ monitoring is just one of several listed strategies, only one of which must be met for a project to receive points, thus reducing the degree of encouragement this strategy receives from the rating system. As such, requiring the implementation of monitoring regardless of path or option would more clearly support adaptability for ventilation systems.

Designed to complement LEED accreditation are a number of data-focused rating systems and platforms, such as RESET and Arc [27,28]. These emergent rating systems expand the scope of LEED monitoring requirements by tracking more resources and conditions, while more explicitly supporting adaptability and cohesion, respectively. The former supports adaptability by necessitating response on the part of owners, and both support cohesion by providing centralized data platforms. Furthermore, these data-rich platforms facilitate comparison and benchmarking among projects around the globe, therefore facilitating intelligent adaptation through cohesion on a much larger scale [27,29]. While the USGBC, and by extension LEED, recognizes these rating systems and platforms, the current LEED manual omits specific encouragement to use them. Ideal as it may sound to incorporate these systems and platforms, we would be naïve to ignore the downside of doing so. Adding on supplementary rating systems or platforms increases the complexity of certification and can present additional paywalls for registration and maintenance. These are all important issues that deserve further deliberation as the framework evolves.

Thirdly, in order for long-term adaptability to be better supported in the framework, consideration of natural disasters and climate change should be expanded. Sporadic circumstances arising from climate change are not yet well discussed in the manual, but do appear as a key concern addressed in three pilot credits in the online credit library. Unfortunately, the focus for two of these pilot credits lies solely on mitigating physical damage to structures and systems. Without question, such mitigation is important; however, more in-depth consideration of system behavior, particularly under multiple or overlapping stressors, is also needed. The third pilot credit, Passive Survivability and Back-up Power During Disruptions, comprises an excellent addition in this way by supporting system diversity in cases of emergency. However, overall adaptability to stressor conditions must be more clearly encouraged.

Unfortunately, as climate change increases the frequency of disruptions, our baseline operations will come to more closely resemble circumstances currently considered exceptional, requiring building systems to be adaptive under these strenuous conditions. Key to supporting such adaptability is the integration of future climate conditions (rather than historical) for baseline calculations such as those conducted for the WE Credit: Outdoor Water Use Reduction. This shift is essential, but should be performed in a manner that respects the accuracy limitations of prediction. Likewise, adaptive strategies such as modular design and foresight for expansion or remodeling of building systems could easily be supported by a devoted credit, along the same lines as the healthcare-specific MR Credit: Design for Flexibility.

5. Conclusions

Diversity, efficiency, adaptability, and cohesion are key properties that describe the resilience of systems. Under the LEED BD+C framework for New Construction, the efficiency of building systems is intentionally supported by the existing credits from an energy and water perspective. Diversity, adaptability, and cohesion are sporadically represented in the framework, but call for more attention and stronger endorsement. Adjustments that explicitly support the diversity of energy sources and system forms can easily be included to the betterment of existing credits. Likewise, the expansion of monitoring requirements to create closed-loop systems can be readily included. Finally, the consideration of long-term adaptability through the integration of predictive, rather than historical, climate data is needed. All in all, the LEED BD+C v4.1 rating system currently rewards resilient building systems but, in some respects, falls short of actively encouraging their development. Minor adjustments and additions that build off the existing goals and trajectory of the framework's development will better inspire resilience in LEED-standard building systems and effect major change. While these recommendations are specific to LEED, the gaps identified are substantial enough to inspire similar investigations into other rating systems internationally, and to express caution to communities looking to adopt them into policy or practice.

Author Contributions: Conceptualization, D.D.C., and A.K.; methodology, D.D.C., and A.K.; formal analysis, D.D.C.; data curation, D.D.C.; writing—original draft preparation, D.D.C.; writing—review and editing, A.K.; supervision, A.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Australia State of the Environment Indoor Air Quality. Available online: <https://soe.environment.gov.au/theme/ambient-air-quality/topic/indoor-air-quality-2> (accessed on 18 May 2021).
2. Schweizer, C.; Edwards, R.D.; Bayer-Oglesby, L.; Gauderman, W.J.; Ilacqua, V.; Juhani Jantunen, M.; Lai, H.K.; Nieuwenhuijsen, M.; Künzli, N. Indoor Time–Microenvironment–Activity Patterns in Seven Regions of Europe. *J. Expo. Sci. Environ. Epidemiol.* **2007**, *17*, 170–181. [CrossRef] [PubMed]
3. BRE Worldwide. Available online: <https://www.breeam.com/worldwide/> (accessed on 17 May 2021).
4. Awadh, O. Sustainability and Green Building Rating Systems: LEED, BREEAM, GSAS and Estidama Critical Analysis. *J. Build. Eng.* **2017**, *11*, 25–29. [CrossRef]
5. USGBC About: Brand | U.S. Green Building Council. Available online: <https://www.usgbc.org/about/brand> (accessed on 24 March 2021).
6. USGBC. *LEED v4.1 BD+C Rating System 2019*; USGBC: Washington, DC, USA, 2019.
7. Menassa, C.; Mangasarian, S.; El Asmar, M.; Kirar, C. Energy Consumption Evaluation of U.S. Navy LEED-Certified Buildings. *J. Perform. Constr. Facil.* **2012**, *26*, 46–53. [CrossRef]
8. Oates, D.; Sullivan, K.T. Postoccupancy Energy Consumption Survey of Arizona's LEED New Construction Population. *J. Constr. Eng. Manag.* **2012**, *138*, 742–750. [CrossRef]
9. Tilton, C.; El Asmar, M. Assessing LEED versus Non-LEED Energy Consumption for a University Campus in North America: A Preliminary Study. *ICSI* **2014**, *2014*, 1071–1076. [CrossRef]
10. Orr, R. The Problems with LEED. Available online: <https://leanurbanism.org/publications/the-problems-with-leed/> (accessed on 17 May 2021).
11. Amiri, A.; Ottelin, J.; Sorvari, J. Are LEED-Certified Buildings Energy-Efficient in Practice? *Sustainability* **2019**, *11*, 1672. [CrossRef]
12. Barbaro, G.; Miguez, M.G.; de Sousa, M.M.; Ribeiro da Cruz Franco, A.B.; de Magalhães, P.M.C.; Foti, G.; Valadão, M.R.; Occhiuto, I. Innovations in Best Practices: Approaches to Managing Urban Areas and Reducing Flood Risk in Reggio Calabria (Italy). *Sustainability* **2021**, *13*, 3463. [CrossRef]
13. Chester, M.; El Asmar, M.; Hayes, S.; Desha, C. Post-Disaster Infrastructure Delivery for Resilience. *Sustainability* **2021**, *13*, 3458. [CrossRef]

14. Abraham, Y.S.; Anumba, C.J. Identifying Operational Considerations for Sustainable and Resilient Building Systems. *Constr. Res. Congr.* **2020**, 2020, 875–884. [\[CrossRef\]](#)
15. Fiksel, J. Designing Resilient, Sustainable Systems. *Environ. Sci. Technol.* **2003**, 37, 5330–5339. [\[CrossRef\]](#) [\[PubMed\]](#)
16. City of Seattle Smoke Ready Seattle—Mayor. Available online: <https://www.seattle.gov/mayor/wildfire-smoke> (accessed on 24 March 2021).
17. US EPA Ventilation and Coronavirus (COVID-19). Available online: <https://www.epa.gov/coronavirus/ventilation-and-coronavirus-covid-19> (accessed on 24 March 2021).
18. EIA. Smoke from California Wildfires Decreases Solar Generation in CAISO—Today in Energy—U.S. Energy Information Administration. Available online: <https://www.eia.gov/todayinenergy/detail.php?id=45336> (accessed on 22 March 2021).
19. Font, A.; Guiseppe, L.; Blangiardo, M.; Gherzi, V.; Fuller, G.W. A Tale of Two Cities: Is Air Pollution Improving in Paris and London? *Environ. Pollut.* **2019**, 249, 1–12. [\[CrossRef\]](#) [\[PubMed\]](#)
20. Kim, M.J. The Effects of Transboundary Air Pollution from China on Ambient Air Quality in South Korea. *Heliyon* **2019**, 5, e02953. [\[CrossRef\]](#) [\[PubMed\]](#)
21. Mallawarachchi, H.; Silva, L.; Rameezdeen, R. Green Buildings, Resilience Ability and the Challenge of Disaster Risk. In Proceedings of the International Conference on Building Resilience 2013, Ahungalla, Sri Lanka, 17 September 2013.
22. Phillips, R.; Troup, L.; Fannon, D.; Eckelman, M.J. Do Resilient and Sustainable Design Strategies Conflict in Commercial Buildings? A Critical Analysis of Existing Resilient Building Frameworks and Their Sustainability Implications. *Energy Build.* **2017**, 146, 295–311. [\[CrossRef\]](#)
23. USGBC. Passive Survivability and Back-up Power During Disruptions | U.S. Green Building Council. Available online: <https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-28> (accessed on 1 April 2021).
24. USGBC. Assessment and Planning for Resilience | U.S. Green Building Council. Available online: <https://www.usgbc.org/credits/assessmentresilience> (accessed on 23 March 2021).
25. USGBC. Design for Enhanced Resilience | U.S. Green Building Council. Available online: <https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-27?return=/credits/New%20Construction/v4.1> (accessed on 23 March 2021).
26. USGBC. *LEED Zero Program Guide 2020*; USGBC: Washington, DC, USA, 2020.
27. GIGA RESET®Standard. Available online: <https://www.reset.build/> (accessed on 9 April 2021).
28. Palanki, G. Arc for LEED | Arc Skoru. Available online: <https://arcskoru.com/arc-leed> (accessed on 9 April 2021).
29. Long, M. Arc: New Technology Venture Launched to Facilitate LEED Certification, Measure Performance and Benchmark Green Building Projects | U.S. Green Building Council. Available online: <https://www.usgbc.org/articles/arc-new-technology-venture-launched-facilitate-leed-certification-measure-performance-and-b> (accessed on 18 May 2021).