Case study analysis of green building certifications

by

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B.S., Kansas State University, 2024

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

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Carl R. Ice College of Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2024

Approved by:

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Abstract

This report intends to provide a detailed comparison of two major green building certifications: Leadership in Energy and Environmental Design (LEED) and Living Building Challenge (LBC). The study examines the specific requirements, criteria, and standards of each certification, focusing on their approaches to promoting environmentally responsible construction. The report outlines the distinct features of both LEED and LBC, analyzing their strengths and weaknesses. It emphasizes the stringent nature of the LBC certification compared to LEED, particularly in reducing the environmental impact of the built environment.

This report includes a focused case study on the Kendeda Building, a project that holds the dual distinction of being certified under both the LBC 3.0 and achieving LEED Platinum certification. The analysis of this building shows the criteria of the LBC, and the established standards of LEED can coexist within a single project. This report explores how both certifications align with the sustainability goals of reducing environmental impact, through the analysis of a building that has achieved both LBC 3.0 and LEED Platinum standards. This case study contributes to the understanding of the strengths and challenges associated with the application of these two prominent green building certifications.

The report concludes that the Living Building Challenge is a more rigorous and impactful building certification than Leadership in Energy and Environmental Design, highlighting the importance of choosing certifications that significantly contribute to mitigating the built environment's impact on the natural environment.

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Acknowledgements

To Katie Loughmiller, my major professor, for helping me through the entire process of writing my report, despite the many topic changes. To Ray Buyle, Derek Clements, and Kyle Larson, my committee members, for your dedication to my success.

To Riley for every research consultation, late night, and keeping me on track. To Makenna and Taylor, for keeping me on the straight and narrow.

To the girls at 908, for listening to me, your willingness to help whenever necessary, and allowing me to stand in your room and cry for the last 18 months.

Dedication

To Mom & Dad for raising me to be the person I am today. To Heather, my built-in best friend. To Cameron, for your support and contagious determination.

Chapter 1 - Introduction

“A green building certification verifies that a building has met environmental, energy, human health, and other standards in its design, construction, and performance” (Simon & Jackson, 2020) Sustainable building design is an environmentally conscious way of approaching the architectural process that puts sustainability at the forefront of each building phase to ensure optimal building performance and minimize the negative human and environmental impacts associated with the built environment (Biro, 2023).

Sustainable design is known by many different names: ecological design, green design, green architecture, eco-effective, holistic, and environmentally friendly design (McLennan, 2004). In the building industry, a more common meaning is to meet the needs of the present without compromising the needs of the future. Sustainability design is a design philosophy that seeks to maximize the quality of the built environment while minimizing the negative impact on the natural environment (McLennan, 2004). If we want to change a result, we must first change the process that led to the result (McLennan, 2004). Sustainable design helps instill a sense of responsibility and higher purpose back into design (McLennan, 2004).

What is a green building? “Green building” is a comprehensive concept that acknowledges the significant impact of the built environment on both the natural surroundings and the well-being of its occupants, emphasizing the potential for positive or negative consequences. (U.S. Green Building Council, 2022). The foundation of green buildings is to enhance positive effects and alleviate negative impacts throughout a building’s life cycle. While various definitions of green building exist, it is generally recognized as encompassing the planning, design, construction (and demolition), and ongoing operations of buildings. Key considerations include energy efficiency, water conservation, indoor environmental quality, material choices, and the site's relationship with the surrounding community. These considerations are the framework for many green building certifications, including LEED and LBC. “The Living Building Challenge rests squarely on the idea that real and profound change requires raising expectations dramatically higher than they’ve ever been set” (Thomas, 2016). The concept of the Living Building Challenge was to distance the standard from LEED’s credit-oriented format to ensure the two codes would stand apart from one another. The intention was not for LBC to compete with LEED, but as tools serving different purposes (Thomas, 2016). For analysis, this paper is focused on LEED v4 and LBC 4.0.

There are many green building certifications and programs for measuring how “green” a building is. WELL Building Standard is a performance-based system for measuring, certifying, and monitoring features of the built environment that impact human health and well-being, through air, water, nourishment, light, fitness, comfort, and mind (International WELL Building Institute, n.d.). Energy Star Certified Buildings is a joint program between the Environmental Protection Agency and Department of Energy that rates buildings on their energy usage (ENERGY STAR, n.d.). Green Building Initiatives GBI’s Green Globes® is a science-based, three-in-one whole building certification system that evaluates the environmental sustainability, health & wellness, and resilience of commercial buildings (Green Building Initiative, n.d.). Building EQ, powered by ASHRAE, is a level 1 energy audit rating system (ASHRAE, n.d.). The focus of the following report is only on LEED and LBC.

After the formation of the U.S. Green Building Council (USGBC) in 1993 with the goal of advancing sustainability in the construction sector through training and certification initiatives, Leadership in Energy and Environment Design (LEED) was formed and is now the world’s most used building rating system (Archiroots, 2023). In 2006, a new, more rigorous green building standard was launched, the Living Building Challenge (LBC) (The Kendeda Fund, 2023).

Recognized nationally, LEED certifications signify a commitment to comprehensive sustainability, covering energy efficiency, water conservation, and materials selection. Chapter 2 aims to provide an in-depth understanding of the LEED framework, unraveling the criteria and principles that guide the development of environmentally friendly and sustainable buildings (Moss & Scheer, 2013).

Conversely, Living Building Challenge certifications, distinguished by their rigorous standards, surpass traditional green building measures. This certification sets ambitious goals for buildings to not only minimize negative impacts but actively contribute to a regenerative environment. Chapter 3 endeavors to delve into the meticulous criteria of the Living Building Challenge, offering insights into how it pushes the boundaries of sustainable design and construction.

Chapter 2 - LEED

Leadership in Energy and Environmental Design (LEED) is a widely recognized green building certification system. It was developed by the U.S. Green Building Council (USGBC) to encourage sustainable and environmentally friendly building practices. Projects pursuing LEED certification go through a verification and review process by the Green Business Certification Incorporated (GBCI) and are awarded points. The points each building accrues have a corresponding level. There are four LEED certification levels: Certified (40-49 points), Silver (50-59 points), Gold (60-79 points), and Platinum (80+ points) (U.S. Green Building Council, n.d.-b).

LEED certification involves a comprehensive evaluation of a building's design, construction, and operation across various categories such as energy efficiency, water conservation, indoor environmental quality, materials selection, and sustainable site development. Points are awarded based on meeting specific criteria within each category (U.S. Green Building Council, n.d.-b). The process starts with project registration, then design is completed and documented, documents are submitted for review, construction components are documented during construction, and there is a final construction review. There is no on-site verification process for LEED. Documents submitted for certification will be reviewed by LEED reviewers.

LEED professionals can be either LEED Green Associates (LEED GA) or LEED Accredited Professionals (LEED AP). The LEED GA credential is for those who understand the current green building principles and practices. It is a foundational credential and is typically the first step before earning an advanced credential such as LEED AP with specialty. LEEP AP also requires application of knowledge, since the design professional has to show their involvement in

LEED projects. LEED AP credentials represent an advanced knowledge of green building practices and a commitment towards sustainable buildings (Green Building Research Institute, 2020). Earning AP credentials requires specialization in a specific field, meaning New Construction, Existing Buildings, or Operation and Maintenance.

LEED promotes the use of energy-efficient technologies, renewable energy sources, and environmentally responsible materials. It also encourages the implementation of strategies for water conservation, waste reduction, and improved indoor air quality. Additionally, LEED-certified buildings often incorporate green spaces and innovative design features to enhance sustainability.

Beyond environmental benefits, LEED certification is also associated with economic advantages. Green buildings typically have lower operating costs, higher property values, and improved occupant satisfaction (U.S. Green Building Council, n.d.-b). The certification reflects a commitment to responsible and forward-thinking building practices, contributing to the global effort to create more sustainable and resilient communities.

LEED-certified buildings are designed to deliver lower operating costs and increased asset value, reduce waste sent to landfills, conserve energy and water, create more healthful and productive environments for occupants, and reduce greenhouse gas emissions (U.S. Green Building Council, 2013). By participating, owners, operators, designers, and builders make meaningful contributions to the green building industry. Not every credit or category is required. There are prerequisites in most categories that must be met, but each project team can determine which credits to pursue.

The analysis of the LEED requirements in this report focuses specifically on new construction using LEED v4.0 and is shown in Figure 2-1. The following sections will be discussed in this chapter, 2.1 Minimum Program Requirements, 2.2 Integrative Project Planning and Design, 2.3 Location and Transportation, 2.4 Sustainable Sites, 2.5 Water Efficiency, 2.6 Energy and Atmosphere, 2.7 Materials and Resources, 2.8 Indoor Environmental Quality, 2.9 Innovation, and 2.10 Regional Priority.

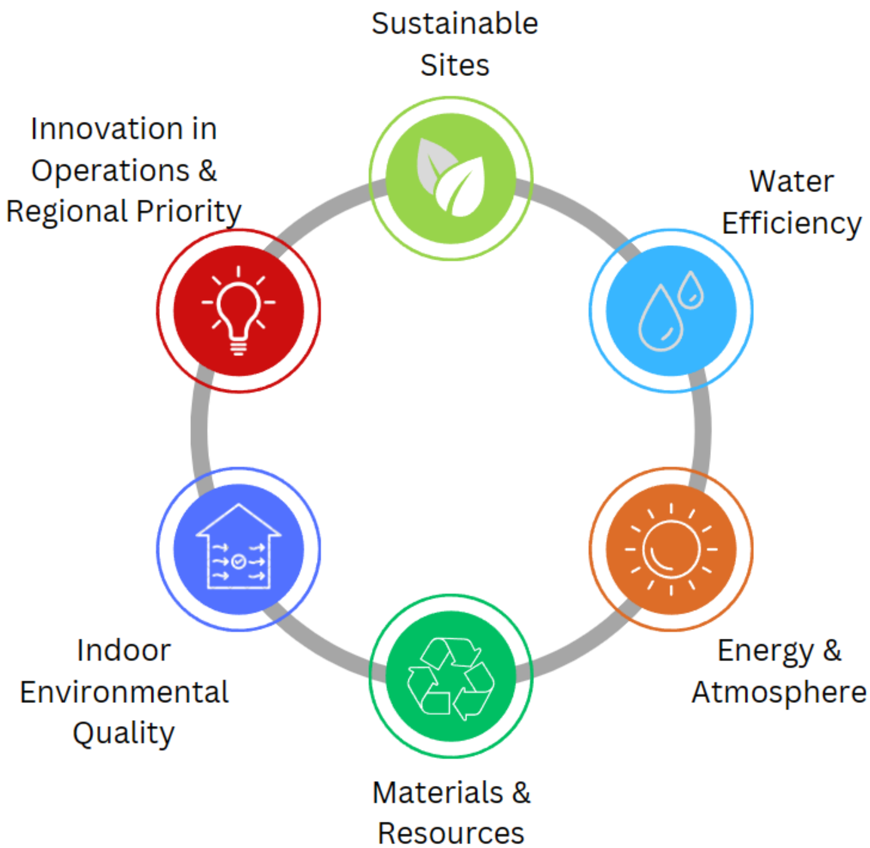

Figure 2-1: LEED Categories

2.1 Minimum Program Requirements

The Minimum Program Requirements (MPRs) are the minimum characteristics or conditions that make a project appropriate to pursue LEED certification. These requirements are the foundation of all LEED projects and define the types of buildings, spaces, and neighborhoods that the LEED rating system is designed to evaluate (U.S. Green Building Council, 2023).

2.1.1 MPR1

The first minimum program requirement is that the project must be in a permanent location on existing land. The LEED rating system is designed to evaluate buildings in the context of their surroundings (U.S. Green Building Council, 2023). A significant portion of LEED requirements are dependent on the project's location; therefore, LEED projects are evaluated as permanent structures (U.S. Green Building Council, 2013).

2.1.2 MPR2

The second minimum project requirement is that the project must use reasonable LEED boundaries. The LEED project boundary must include all adjacent land that is associated with the project and supports its typical operations (U.S. Green Building Council, 2013). This includes the land altered during construction and used by occupants, such as hardscape (parking and sidewalks), septic or stormwater treatment equipment, and landscaping.

2.1.3 MPR3

The third, and final, minimum project requirement is that the project must comply with project size requirements. The LEED rating system is designed to evaluate buildings of a certain size. The LEED requirements do not accurately assess the performance of projects outside these requirements (U.S. Green Building Council, 2013). The LEED project must include a minimum of 1,000 SF of gross floor area (U.S. Green Building Council, n.d.-a)

2.2 Integrative Project Planning and Design

Integrative Process is intended to support high-performance, cost-effective project outcomes through an early analysis of the interrelationships among systems. An integrative process is a comprehensive approach to building systems and equipment (Grainger, 2021). The process should involve rigorous questioning and coordination and challenge typical project assumptions. A fully integrated process accounts for the interactions among all building and site systems (U.S. Green Building Council, 2013). This credit serves as an introduction to the comprehensive process by rewarding project teams that apply an integrative approach to energy and water systems.

2.2.1 IPc1 Integrative Process

The intent of Integrative Project Planning and Design is to maximize opportunities for integrated, cost-effective adoption of green design and construction strategies, emphasizing human health as a fundamental evaluative criterion for building design, construction, and operational strategies (U.S. Green Building Council, 2013). It urges design teams to use innovative approaches and techniques for green design and construction.

2.3 Location and Transportation

Location and Transportation (LT) credits are designed to focus on the integration of smart growth principles such as revitalization, reuse of existing infrastructure, mixed-use development, and pedestrian-friendly design to minimize carbon emissions which improve energy efficiency and advance human health (U.S. Green Building Council, 2013). This category rewards thoughtful decisions about building location, with credits that encourage compact development, alternative transportation, and connection with amenities such as restaurants and parks. The LT category is an outgrowth of the Sustainable Sites category, Section 2.4. Well-located buildings take advantage of existing infrastructure (public transit, street networking, pedestrian paths, bicycle networks, and even existing utilities) (Grainger, 2021). If integrated into the surrounding community, a building can offer distinct advantages.

2.3.1 LTc1 LEED for Neighborhood Development location

LEED for Neighborhood Development Location is intended to avoid development in inappropriate sites, reduce vehicle miles traveled, and improve human health by encouraging daily physical activity (U.S. Green Building Council, 2013).

2.3.2 LTc2 Sensitive land protection

One strategy for lessening the environmental consequences of a building is to select a site that has previously been developed and to limit the building’s footprint to the previously developed area. Ecologically sensitive areas provide a variety of human health and environmental benefits (U.S. Green Building Council, 2013). Agricultural areas produce food and assist with rainwater management. Floodplains support diverse flora and fauna, supply rich agricultural soil, and provide food protection. Development of this land not only harms ecology but also places people and property in danger.

2.3.3 LTc3 High-priority site

High-priority site credits are awarded to encourage project location in areas with development constraints and promote the health of surrounding areas. Many communities and governments have identified high-priority redevelopment sites. Putting these sites back into productive use has many environmental advantages over development in greenfields and environmentally sensitive areas. Building on a high-priority redevelopment site can revitalize the neighborhood and bring social and economic benefits to the surrounding community.

2.3.4 LTc4 Surrounding density and diverse uses

This credit intends to conserve land and protect farmland and wildlife habitat by encouraging development in areas with existing infrastructure [to promote walkability, and transportation efficiency, and reduce vehicle distance traveled]. It also seeks to improve public health by encouraging daily physical activity.

2.3.5 LTc5 Access to quality transit

Access to quality transit is intended to encourage development in locations shown to have multimodal transportation choices to reduce greenhouse gas emissions, air pollution, and other environmental and public health harms associated with motor vehicle use. Nearly all forms of public transit create fewer greenhouse gas emissions per passenger than single-occupancy vehicles.

2.3.6 LTc6 Bicycle facilities

This section intends to promote bicycling and transportation efficiency and reduce vehicle distance traveled. It strives to improve public health by encouraging utilitarian and recreational physical activity. To promote bicycle-friendly design, this credit rewards the provision of long and short-term bicycle storage and access to bicycle networks (paths, trails, designated bike lanes, and slow-speed roadways).

2.3.7 LTc7 Reduced parking footprint

This credit is to minimize the environmental harm associated with parking facilities, including automobile dependence, land consumption, and rainwater runoff. Parking demand can be reduced by locating projects in high-density, mixed-use areas or in places well-served by transit. To complement the use of alternative modes or vehicle-sharing arrangements, vehicular parking itself can be limited by designing fewer spaces.

2.3.8 LTc8 Green vehicles

This credit is intended to reduce pollution by promoting alternatives to conventionally fueled automobiles. This credit addresses vehicle emissions by rewarding local and regional infrastructure that incentivizes the purchase of green vehicles. The first half of the credit is the provision of preferred parking spaces closest to a building’s entrance rewards building users who drive green vehicles. Other parts of green vehicles is the installation of EV chargers or alternative fuel source fueling facilities.

2.4 Sustainable Sites

The intent of the Sustainable Sites category is to encourage good stewardship of the land and ensure any adverse project impacts on surrounding areas during and after construction are minimized (U.S. Green Building Council, 2013). This category rewards decisions about the environment surrounding the building, with credits that emphasize the vital relationships among buildings, ecosystem, and ecosystem activities (Grainger, 2021).

2.4.1 SSp1 Construction activity pollution prevention

This prerequisite is to reduce pollution from construction activities by controlling soil erosion, airborne dust, and waterway sedimentation. The prerequisite promotes environmental protection measures that reduce construction project disturbances (U.S. Green Building Council, 2013). These disturbances can be to neighboring properties, rainwater systems, or the site itself.

2.4.2 SSc1 Site assessment

The Site assessment credit encourages project teams to carefully consider the environmental, social, and economic aspects of a site before proceeding with construction (U.S. Green Building Council, 2013). The goal is to promote responsible land use and site selection, ensuring that the project is well-integrated with the surrounding environment and community.

2.4.3 SSc2 Site development – protect or restore habitat

Site development strategies that focus on protecting or restoring habitat play a crucial role in sustainable and environmentally responsible projects. This approach aims to minimize the impact of development on natural ecosystems and biodiversity while fostering a balance between human activities and the preservation of habitat for various species. It is to conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.

2.4.4 SSc3 Open space

This credit underscores the significance of creating accessible, well-designed outdoor areas that prioritize environmental sustainability and community well-being. Projects earning this credit prioritize careful site selection, integrating greenery, landscaping, and water features to enhance aesthetics and ecological value. Emphasis is placed on accessibility, connectivity, and community engagement, ensuring that open spaces cater to diverse user groups and encourage social interaction. Sustainable landscaping practices, such as native plantings and water-efficient design, are employed to promote biodiversity and reduce environmental impact. Additionally, considerations include the provision of public amenities, reduction of light pollution, innovative design elements, and the development of comprehensive maintenance plans, ensuring the long-term viability and usability of the open spaces. Overall, achieving the Open Space credit reflects a commitment to creating vibrant, sustainable, and community-oriented outdoor environments that contribute to the well-being of both occupants and the surrounding ecosystem.

2.4.5 SSc4 Rainwater management

This credit emphasizes sustainable stormwater practices, including green roofs, permeable pavements, and rain gardens to control runoff quantity and quality. Rainwater harvesting systems reduce demand on municipal water supplies, and permeable surfaces facilitate groundwater recharge. Vegetated roofs and walls contribute to stormwater management and biodiversity. Erosion control plans during construction prevent soil erosion, and compliance with local regulations demonstrates sustainability efforts. Monitoring and maintenance plans ensure ongoing effectiveness, aligning with LEED's goals of environmental stewardship and resource efficiency.

2.4.6 SSc5 Heat Island Reduction

This credit addresses the urban heat island effect, a phenomenon where built environments absorb and retain heat, leading to elevated temperatures in urban areas. The credit encourages strategies to mitigate this impact, promoting cooler and more sustainable urban spaces. Common approaches include the use of cool or reflective roofing materials to reduce heat absorption, the incorporation of shade-providing vegetation, and the utilization of cool pavements and surfaces that reflect rather than absorb sunlight. Additionally, projects can earn this credit by implementing green roofs, which contribute to temperature regulation through evapotranspiration. Overall, the Heat Island Reduction credit aims to create more comfortable and energy-efficient urban environments while minimizing the strain on local ecosystems.

2.4.7 SSc6 Light Pollution Reduction

This credit emphasizes strategies to minimize light pollution, which can disrupt natural ecosystems, affect human health, and hinder astronomical observations. To earn this credit, projects employ thoughtful outdoor lighting design, utilizing fixtures with shielding to direct light where it is needed while minimizing spillage and glare. Implementation of controls, such as timers or motion sensors, ensures that lighting is only used when necessary. By minimizing the impact of artificial light on the surroundings, the Light Pollution Reduction credit contributes to creating more sustainable, healthier, and ecologically responsible environments that support both human well-being and natural ecosystems. It strives to increase night sky access, improve nighttime visibility, and reduce the consequences of development for wildlife and people.

2.5 Water Efficiency

Water efficiency credits focus on reducing water use inside and outside the building as well as the importance of metering for better water management (U.S. Green Building Council, 2013). Water efficiency involves attaining a desired outcome or level of service, or the successful completion of a function, task, or process, using the minimum amount of required water (Grainger, 2021). It reflects the relationship between the amount of water needed for a particular purpose and the amount of water actually used or delivered. This section of LEED addresses water usage holistically, investigating indoor and outdoor use as well as specialized uses and metering (BuildingGreen, n.d.).

2.5.1 WEp1 Outdoor water use reduction

The first prerequisite in the section is to reduce outdoor water consumption. This can be done by reducing the need for irrigation by at least 30% or by eliminating the need for irrigation. Landscaping irrigation consumes large quantities of potable water, which is a precious resource globally.

2.5.2 WEp2 Indoor water use reduction

The second prerequisite in the water efficiency category is to reduce indoor water consumption. The aggregate water consumption must be reduced by 20% from the baseline outlines by LEED. Strategies to reduce indoor potable water consumption include selecting efficient plumbing fittings, fixtures, and equipment. Requirements in this prerequisite include a WaterSense® label on all fixtures. WaterSense® labels were developed by the EPA to identify efficient fixtures and ensure higher efficiency does not come at the cost of performance.

2.5.3 WEp3 Building-level water metering

The final prerequisite in this category is intended to support water management and identify opportunities for additional water savings by tracking water consumption. Buildings must have permanent water meters installed that measure the total potable water use for the building and associated grounds. The meter's data must be compiled into monthly and annual summaries and the reading may be either manual or automated. Whole-project water data for a five-year period must be shared with USGBC upon acceptance of LEED certification, or date of typical occupancy, whichever comes first.

2.5.4 WEc1 Outdoor water use reduction

This credit is an advancement of WEp1. A building may receive credits in this category by reducing the landscape water requirement by at least 50%. This reduction must be done first through plant species selection and irrigation system efficiency.

2.5.5 WEc2 Indoor water use reduction

This credit awards points further reducing fixture and fitting water use from WEp2. Additional points are awarded for a 25% reduction up to a reduction of 50%.

2.5.6 WEc3 Cooling tower water use

The intent behind this section is to conserve water used for cooling tower makeup while controlling microbes, corrosion, and scale in the condenser water system. For cooling towers and evaporative condensers, a one-time potable water analysis must be conducted measuring the specified parameters.

2.5.7 WEc4 Water metering

Similar to the Building-level water metering discussed in section 2.5.3, water metering should support water management and identify opportunities for additional water savings by tracking water consumption. This requires permanent water meters to be installed for two or more subsystems. This can be chosen as appropriate for the project to be irrigation, indoor plumbing fixtures and fittings, domestic hot water, boilers, reclaimed water, or other processed water. Metering water usage by subsystem helps facilities managers better gauge a building's water efficiency. Submetering the major building water systems provides a way to formulate independent system baselines, track usage against the baselines, isolate and identify potential sources of waste, and take appropriate corrective action.

2.6 Energy and Atmosphere

The Energy and Atmosphere (EA) category approaches energy from a holistic perspective, addressing energy use reduction, energy-efficient design strategies, and renewable energy sources (U.S. Green Building Council, 2013). Energy efficiency in green buildings starts with a focus on design that reduces overall energy needs, such as building orientation, glazing selection, and the choice of climate-appropriate building materials. Additional strategies such as passive heating and cooling, natural ventilation, and high-efficiency HVAC systems can further reduce energy use.

2.6.1 EAp1 Fundamental commissioning and verification

The first prerequisite in this category is to support the design, construction, and overall operation of a project that meets the owner’s project requirements for energy, water, indoor environmental quality, and durability. The commissioning process is an integrated set of activities intended to ensure the project meets both the design intent and the owner’s operational needs.

2.6.2 EAp2 Minimum energy performance

Another prerequisite in the section is to reduce the environmental and economic harms of excessive energy use by achieving a minimum level of energy efficiency (5% improvement for new construction from ASHRAE 90.1) for the building and its systems.

2.6.3 EAp3 Building-level energy metering

This prerequisite is intended to support energy management and identify opportunities for additional energy savings by tracking building-level energy use. The requirement is to install building-level energy meters, or submeters, to provide building-level data representing total building energy consumption (electricity, natural gas, chilled water, steam, fuel oil, propane, biomass, etc). Utility-owned meters capable of aggregating building-level resource use are acceptable. At a minimum, energy consumption must be tracked at one-month intervals.

2.6.4 EAp4 Fundamental refrigerant management

The intent for the last prerequisite in this section is to reduce stratospheric ozone depletion. Chlorofluorocarbon (CFC)-based refrigerants in new HVAC&R systems are not to be used. CFCs and other refrigerants contribute to the depletion of the stratospheric ozone layer. Though both CFCs and hydrochlorofluorocarbons (HCFCs) both contribute to ozone depletion, LEED only requires that CFCs be addressed in this section.

2.6.5 EAc1 Enhanced commissioning

This credit is to further support the design, construction, and eventual operation of a project that meets the owner's project requirements for energy, water, indoor environmental quality, and durability. The design team should implement or have in place a contract to implement, commissioning process activities in addition to those required under EA Prerequisite Fundamental Commissioning and Verification.

2.6.6 EAc2 Optimizing energy performance

Optimizing energy performance credit has the largest opportunity for points. It rewards up to 18 points for energy performance beyond the prerequisite standard. An energy-efficient building reduces environmental and economic harms associated with excess energy use, which LEED strives to avoid.

2.6.7 EAc3 Advanced energy metering

The intent of this credit is to support energy management and identify opportunities for additional energy savings by tracking building-level and system-level energy use. Meters must be permanently installed, recorded at intervals of one hour or less, and transmit data to a remote location. Electricity meters must record both consumption and demand. The data collection must use a local area network, building automation system, wireless network, or comparable communication infrastructure. The system must be capable of storing the data for at least 36 months, and the data must be remotely accessible. All meters in the system must be capable of reporting hourly, daily, monthly, and annual energy use.

2.6.8 EAc4 Demand response

This credit is to increase participation in demand response technologies and programs that make energy generation and distribution systems more efficient, increase grid reliability, and reduce greenhouse gas emissions. Design buildings and equipment for participation in demand response programs through load shedding or shifting. It should be noted that on-site electricity generation does not meet the intent of this credit.

2.6.9 EAc5 Renewable energy production

The points in this credit are awarded to reduce the environmental and economic harms associated with fossil fuel energy by increasing the self-supply of renewable energy. Renewable energy generation can reduce carbon emissions and offer local environmental benefits by reducing air pollution. Some renewable energy systems capture wind or sunlight, others utilize materials that might otherwise be wasted.

2.6.10 EAc6 Enhanced refrigerant management

This credit is to reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to climate change. The 2 options to pursue in this credit are to (1) use no refrigerants or low-impact refrigerants or (2) calculate the refrigerant impact. This credit addresses the two main threats to the environment posed by refrigerants: their ozone depletion potential (ODP) and global warming potential (GWP). Careful consideration of the refrigerant requirements of energy systems can improve performance and reduce operating costs. Refrigerants vary in operating pressure, material compatibility, flammability, and toxicity. The refrigerant impact calculation addresses the overall effect of each refrigerant's ODP and GWP combined by accounting for these interrelated factors.

2.6.11 EAc7 Green power and carbon offsets

This credit intends to encourage the reduction of greenhouse gas emissions through the use of grid-course, renewable energy technologies, and carbon mitigation projects. The voluntary market can be an effective catalyst for encouraging energy generators and utility companies to develop clean energy sources and help address climate change. Purchasing renewable energy certificates (RECs) allows buildings that use nonrenewable power to create market demand for renewable energy. Carbon offsets allow buildings or companies to fund activities that seek to decrease carbon emissions or remove carbon from the atmosphere such as methane abatement, energy efficiency projects, and reforestation of land-use changes.

2.7 Materials and Resources

The Materials and Resources (MR) credit category focuses on minimizing the embodied energy and other impacts associated with the extraction, processing, transport, maintenance, and disposal of building materials. The requirements are designed to support a life-cycle approach that improves performance and promotes resource efficiency (Grainger, 2021). Each requirement identifies a specific action that fits into the larger context of a life-cycle approach to embodied impact reduction.

2.7.1 MRp1 Storage and collection of recyclables

The first prerequisite in this credit category is to reduce the waste that is generated by building occupants and hauled to and disposed of in landfills. Dedicated areas accessible to waste haulers and building occupants should be provided for the collection and storage of recyclable materials for the entire buildings. A factor that often inhibits recycling efforts within buildings is the lack of convenient, physical spaces for doing so. Incorporating recycling infrastructure early in the design process encourages successful recycling once operations begin.

2.7.2 MRp2 Construction and demolition waste management planning

The intent of this prerequisite is to reduce construction and demolition waste disposed of in landfills and incineration facilities by recovering, reusing, and recycling materials.

2.7.3 MRc1 Building life-cycle impact reduction

The intent of this credit is to encourage adaptive reuse and optimize the environmental performance of products and materials. This credit requires demonstrating reduced environmental effects during initial project decision-making by reusing existing building resources or demonstrating a reduction in materials use through life-cycle assessment.

2.7.4 MRc2 Building product disclosure and optimization – environmental product declarations

This credit is to encourage the use of products and materials for which life-cycle information is available and that have environmentally, economically, and socially preferable life-cycle impacts. It also rewards project teams for selecting products from manufacturers who have verified improved life-cycle impacts. This credit recognizes the selection of products for which the environmental impacts are well known because of industry-standard life-cycle information and reporting protocols. Environmental product declarations (EPDs) are a standardized way of communicating the environmental effects associated with a product or system’s raw material extraction, energy use, chemical makeup, waste generation, and emissions to air, soil, and water.

2.7.5 MRc3 Building product disclosure and optimization – sourcing of raw materials

The intent of this credit is to encourage the use of products and materials for which life cycle information is available and that have environmentally, economically, and socially preferable life-cycle impacts. The credit rewards project teams for selecting products verified to have been extracted or sourced responsibly. Raw material extraction has a direct environmental impact on ecosystems. This credit encourages the use of responsibly sourced and extracted materials through reporting and demonstration of responsible extraction processes. In addition to seeking the responsible source of virgin materials, teams are also encouraged to reduce raw material usage by selecting reused and recycled materials.

2.7.6 MRc4 Building product disclosure and optimization – material ingredients

This credit’s intention is to encourage the use of products and materials for which life cycle information is available and that have environmentally, economically, and socially preferable life-cycle impacts. The credit rewards project teams for selecting products for which the chemical ingredients in the product are inventoried using acceptable methodology and for selecting products verified to minimize the use and generation of harmful substances. The credit seeks to reward raw material manufacturers who produce products verified to have improved life-cycle impacts. By adhering to the precautionary principle and supporting green chemistry, this credit encourages project teams to avoid products containing potentially harmful chemicals.

2.7.7 MRc5 Construction and demolition waste management

The last credit in this category intends to reduce construction and demolition waste disposed of in landfills, and incineration facilities by recovering, reusing, and recycling materials. The diversion of construction waste has increased greatly in recent years because of new market incentives, better recycling and reuse infrastructure, and more sophisticated sorting technology. However, the majority of diverted materials are those that occur in high volume, namely structural waste, or are easily resold, valuable materials such as metals.

2.8 Indoor Environmental Quality

The Indoor Environmental Quality (EQ) category rewards decisions made by project teams about indoor air quality and thermal, visual, and acoustical comfort. Green buildings with good indoor environmental quality protect the health and comfort of building occupants. High-quality indoor environments also enhance productivity, decrease absences, improve the building's value, and reduce liability for building designers and owners (US EPA, 2024). The EQ category combines traditional approaches, such as ventilation and thermal control, with emerging design strategies, including a holistic, emissions-based approach, source control and monitoring of user-determined contaminants, requirements for lighting quality, and advanced lighting metrics.

2.8.1 EQp1 Minimum indoor air quality performance

The first prerequisite in this section is to contribute to the comfort and well-being of building occupants by establishing minimum standards for indoor air quality (IAQ). Intelligent ventilation design is only the first step. Monitoring, as required by this prerequisite, helps maintain IAQ during all stages of a building's operation.

2.8.2 EQp2 Environmental tobacco smoke control

This prerequisite is to prevent or minimize exposure of building occupants, indoor surfaces, and ventilation air distribution systems to environmental tobacco smoke.

2.8.3 EQc1 Enhanced indoor air quality strategies

This credit is to promote occupants' comfort, well-being, and productivity by improving indoor air quality. Indoor pollutants and particles are brought indoors by occupants, through ventilation system intakes or building openings, and from activities conducted within the building. Designing for effective IAQ can help produce a comfortable indoor environment for building occupants and prevent human health problems associated with poor indoor air quality.

2.8.4 EQc2 Low emitting materials

The intent of this credit is to reduce concentrations of chemical contaminants that can damage air quality, human health, productivity, and the environment. This credit includes requirements for product manufacturing as well as project teams. It covers volatile organic compound (VOC) emissions into indoor air and the VOC content of materials, as well as the testing methods by which indoor VOC emissions are determined.

2.8.5 EQc3 Construction indoor air quality strategies

This credit is to promote the well-being of construction workers and building occupants by minimizing indoor air quality problems associated with construction and renovation. Construction activities adversely affect IAQ when they generate dust, toxic substances, or other contaminants, which can cause health problems not only for construction workers but also for those who occupy the building after construction is complete. Incorporating IAQ best practices during construction has many benefits including the protection of building occupants from airborne pollutants associated with construction, the protection of construction workers from toxins and dust during build-out, and the building materials and HVAC last longer and perform better over time.

2.8.6 EQc4 Indoor air quality assessment

This credit is to establish better quality indoor air in the building after construction and during occupancy. Many building materials contain substances that are hazardous to human health. Construction activity can introduce contaminants into the indoor environment. Harmful substances include formaldehyde and VOCs. Dust, ozone, and fine particulate matter generated by construction activity, diesel engines, or unfiltered outdoor air can also be harmful. Reducing indoor air contaminants has significant human health benefits and typically improves occupant comfort.

2.8.7 EQc5 Thermal comfort

The intent of this credit is to promote occupants' productivity, comfort, and well-being by providing quality thermal comfort. Many factors affect thermal comfort, including surface temperature, air temperature, humidity, air movement, metabolic rate and clothing (Fisk, 2001). Occupants who are able to modify their thermal environment through thermal controls perceive more comfort regardless of conditioning. Because of this, the thermal comfort credit requires individual thermal comfort controls to be provided for at least half of the individual occupant spaces.

2.8.8 EQc6 Interior lighting

This credit focuses on optimizing the energy efficiency of interior lighting systems within a building. To achieve this credit, project teams must implement strategies that contribute to reduced energy consumption, such as using energy-efficient light fixtures, employing advanced lighting controls, and integrating natural daylighting techniques. By emphasizing efficient interior lighting design, LEED aims to minimize the environmental impact of artificial lighting, decrease energy usage, and create healthier and more comfortable indoor environments. Successfully earning the Interior Lighting credit not only advances a project's sustainability goals but also underscores a commitment to responsible resource utilization and the well-being of building occupants.

2.8.9 EQc7 Daylight

This credit encourages the integration of natural daylight into building spaces to reduce the reliance on artificial lighting during daylight hours. Project teams can achieve this credit by strategically designing and arranging spaces to maximize daylight penetration, implementing shading devices to control glare and heat gain, and utilizing daylight-responsive controls for electric lighting systems. By prioritizing access to natural light, this credit aims to enhance visual comfort, promote circadian rhythm, and reduce energy consumption associated with electric lighting. Successfully meeting the criteria for this credit not only contributes to a healthier and more pleasant indoor environment but also aligns with sustainable design principles, supporting both human well-being and energy efficiency goals.

2.8.10 EQc8 Quality Views

To achieve this credit, project teams must provide occupants with access to views that enhance the overall visual experience and connection to nature. The credit encourages the strategic placement of windows and design elements to optimize views of the outdoors. High-quality views contribute to improved mental well-being, reduced stress, and increased productivity among building occupants. Additionally, the credit emphasizes the importance of managing glare and controlling direct sunlight exposure to ensure visual comfort. Successfully earning the Quality Views credit underscores a commitment to creating indoor environments that prioritize occupant satisfaction, health, and a harmonious integration with the surrounding landscape.

2.8.11 EQc9 Acoustic performance

This credit emphasizes the importance of controlling noise levels to enhance occupant comfort and well-being. Project teams can achieve this credit by implementing strategies that minimize sound disruptions and create a balanced acoustic environment. Common measures include using acoustically absorbent materials, optimizing room layouts for sound isolation, and employing noise reduction technologies. The credit recognizes the significance of controlling reverberation, speech intelligibility, and background noise levels to create spaces that foster concentration, communication, and overall satisfaction among occupants. By prioritizing acoustic quality, the section contributes not only to the comfort of building users but also to increased productivity and a healthier indoor environment. Successfully meeting the requirements of the Acoustic Performance section in LEED underscores a commitment to creating indoor spaces that prioritize occupant well-being, making them conducive to focused work, collaboration, and overall satisfaction.

2.9 Innovation

The Innovation section of LEED certification serves as a dynamic and forward-thinking component, providing a platform for project teams to showcase inventive strategies and solutions that go beyond the standard prerequisites and credits (U.S. Green Building Council, 2013). Recognizing that sustainability is a continuously evolving field, the Innovation category, often labeled IN, encourages creativity, experimentation, and the implementation of pioneering approaches to address unique challenges (Grainger, 2021). This section allows projects to earn extra points for demonstrating exemplary performance, introducing innovative technologies, or developing groundbreaking practices that contribute to the overall sustainability and environmental responsibility of the building. This section shows LEED's commitment to staying at the forefront of sustainable design and construction practices, acknowledging that the pursuit of green building excellence involves embracing new ideas and pushing the boundaries of conventional norms.

2.9.1 INc1 Innovation

These credits encourage projects to achieve exceptional or innovative performance. A project can earn up to five innovation credits. Sustainable design comes from innovative strategies and thinking. Institutional measures that reward such thinking, such as this credit, benefit the environment. When project teams innovate beyond LEED requirements, they not only achieve measurable environmental benefits beyond this rating system but also can explore cutting-edge pilot credit and contribute to the development of future LEED credits.

2.9.2 INc2 LEED Accredited Professional

To receive this point, one principal participant of the project team must be a LEED Accredited Professional with a specialty appropriate for the project (U.S. Green Building Council, 2013). A LEED AP is necessary for LEED projects for their comprehensive understanding of the LEED rating system. Their certification ensures the project team adheres to certification requirements. LEED APs assist during the documentation and submission of credits (Baulding, 2023). Additionally, having a LEED AP on the team enhances professional credibility, signaling a commitment to environmentally responsible building practices. (Green Building Research Institute, 2020)

2.10 Regional Priority

The Regional Priority section in LEED certification is a crucial aspect that tailors the rating system to address regional environmental priorities and challenges. Acknowledging the diverse climates, ecosystems, and sustainability concerns across different regions, this section provides a mechanism to highlight and reward strategies that are particularly relevant and impactful within a specific geographic context. Projects can earn additional points by addressing locally significant environmental issues and adopting measures that align with regional sustainability goals. This section encourages project teams to engage with local communities, understand regional environmental priorities, and implement solutions that contribute to the overall well-being of the area. By allowing for region-specific adaptations, the Regional Priority section ensures that LEED remains adaptable and responsive to the unique challenges and opportunities present in various locations. This approach fosters a more comprehensive and nuanced approach to sustainable building practices, promoting a greater positive impact on both the environment and the communities within which the projects are situated.

2.10.1 RPc1 Regional priority

These four credits are to provide an incentive for the achievement of credits that address geographically specific environmental, social equity, and public health priorities. LEED projects are designed, built, and operated in many different contexts. Climate, population density, and local regulations can differ significantly from one project location to another, making certain environmental issues more critical than others. LEED projects can be more transformative if teams recognize their location's priority environmental issues and address them through design, construction, and operating choices.

LEED certification sets a benchmark for sustainable and environmentally responsible building practices. The overall goals of LEED are to promote the design, construction, and operation of high-performance green buildings that reduce environmental impact, enhance occupant health and well-being, and achieve energy and resource efficiency. By adhering to LEED standards, projects aim to minimize carbon emissions, conserve water, optimize energy efficiency, and prioritize the use of environmentally friendly materials. LEED certification not only contributes to a healthier and more sustainable built environment but also provides a recognizable and globally accepted green building certification, enhancing a project's marketability, reducing operating costs, and fostering a commitment to long-term sustainability.

Chapter 3 - Living Building Challenge

The International Living Future Institute's (ILFI) Living Building Challenge is split into seven performance areas called petals. The petals, a symbolic component of a flower, originate from the concept that a flower serves as a perfect representation of the built environment (Elizondo, 2018). Like buildings, flowers are literally and figuratively rooted to a place, able to draw resources from the square inches of earth and sky they inhabit. The flower must receive all its energy from the sun, all its water from the sky, and all its nutrients from the soil (McLennan, 2004).

The petals are subdivided into 20 imperatives that address specific issues through detailed requirements (International Living Future Institute, 2019b). As an extremely rigorous, performance-oriented, third-party-validated program, the Living Building Challenge was designed to eliminate the possibility of greenwashing (McLennan, 2004). Similar to the Prerequisites for LEED, Imperatives are a requirement for LBC. To achieve Living Building status, the building must meet all 20 Imperatives of the challenge (Straka & Sousedova, n.d.). Unlike LEED, the LBC does not have a size requirement. The Imperatives can be applied to almost every building project, of any scale and any location, new or existing (International Living Future Institute, 2019b)

The Living Building Challenge is structured around the precautionary principle that no action should be taken that poses a potential risk to environmental or human health, even when definitive scientific evidence does not exist to prove or quantify the extent of that risk (McLennan, 2004). An overview of the petals can be seen in Figure 3-1.

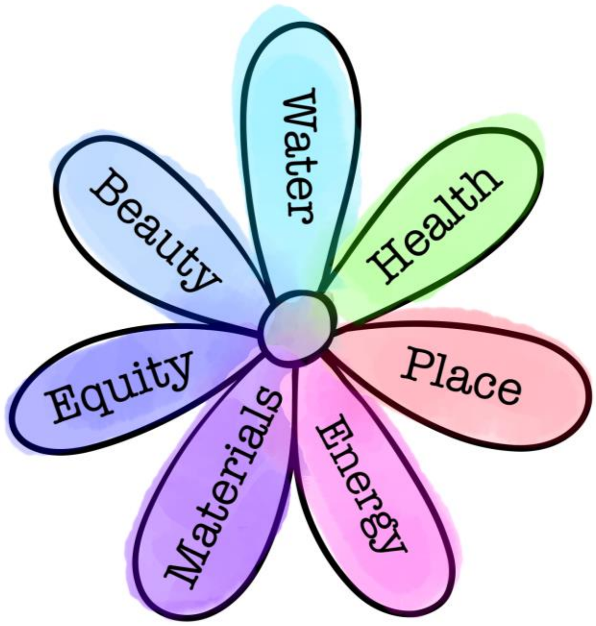

Figure 3-1: LBC Petals

To achieve Living Building Certification, a building must complete all 20 imperatives in the 7 petals, there are no optional petals. There is a cost associated with Living Certification, and varies between buildings. Another requirement for certification is a 12 month performance review. Review starts from date of substantial completion and building occupancy and monitors water and energy usage to verify the building is meeting or exceeding the water and energy goals for 12 consecutive months. Once projects have completed construction and a 12-month performance period, they can certify under one of the certification paths shown in Figure 3-2. Petal Certification can be achieved through the LBC as part of the pathways to living product certification. Petal Certification requires all of the core imperatives to be met, this includes Imperative 01, 04, 05, 07, 09, 12, 17, 18, 19, and 20. For Petal Certification, three of the seven petals must be achieved, one of which must be the Water, Energy, or Materials petal.

	Core Green Building	Petal	Living
01 Ecology of Place*	●	●	●
02 Urban Agriculture			●
03 Habitat Exchange			●
04 Human Scaled Living*	●	●	●
05 Responsible Water Use*	●	●	●
06 Net Positive Water		●	●
07 Energy + Carbon Reduction*	●	●	●
08 Net Positive Carbon		●	●
09 Healthy Interior Environment*	●	●	●
10 Healthy Interior Performance			●
11 Access to Nature			●
12 Repsonsible Materials*	●	●	●
13 Red List		●	●
14 Responsible Sourcing		●	●
15 Living Economy Sourcing		●	●
16 Net Positive Waste		●	●
17 Universal Access*	●	●	●
18 Inclusion*	●	●	●
19 Beauty + Biophilia*	●	●	●
20 Education + Inspiration*	●	●	●

* Indicates a Core Imperative

Figure 3-2: LBC Certification Levels

3.1 Place

The Place Petal aims to transform people's relationship with their natural surroundings by emphasizing the connection between the built environment and local ecology. It advocates for respecting and enhancing each community's unique stories. The guidelines it provides focus on suitable development areas, preserving and restoring developed places and promoting pedestrian-friendly communities over car-centric ones. These communities can benefit from local and regional agriculture, promoting the consumption of fresh, seasonal produce.

The unrestrained growth of sprawling developments and rapid expansion of global metropolises threaten remaining natural spaces. Decentralized communities hinder sustainable self-sufficiency, leading to increased pollution and transportation impacts. Dense urban centers may overshadow natural systems, disrupting the link between culture and a sense of place. Limited available land often results in construction encroaching on sensitive areas, posing potential harm. Invasive species further stress ecosystems already strained by human activities. Addressing the significant impact of single-occupancy fossil fuel vehicles on global climate change requires exploring alternatives, such as public transit, car-sharing, electric vehicles, and bicycles, for a more environmentally conscious future.

3.1.1 Imperative 01 – Ecology of Place

The intent of this Imperative is to protect wild and ecologically significant places and encourage ecological regeneration of the communities where the project is located. Imperative 01 prevents projects from building on pristine greenfields, wilderness, prime farmland, or in a floodplain. Projects must preserve thriving vibrant ecological environments and habitats. Projects must also demonstrate their positive contribution to the ecology of their place and restore the ecological performance of the site towards a healthy ecological baseline. The on-site landscape should be designed to mature, evolve, and emulate the functionality of the reference habitat.

All project teams must assess cultural and social equity factors and needs in the community and consider those identified needs to inform design and process decisions. No petrochemical fertilizers or pesticides can be used for the operation and maintenance of the on-site landscape, including urban agriculture.

3.1.2 Imperative 02 – Urban Agriculture

The intent of this Imperative is to integrate opportunities for connecting the community to locally grown fresh food (International Living Future Institute, 2019b). All projects must dedicate a portion of their total project area to growing food. They must also directly provide weekly community access to healthy local food that addresses a community need, through farmers' markets or other local food producers (International Living Future Institute, 2019a).

3.1.3 Imperative 03 – Habitat Exchange

The intent of this Imperative is to protect land for other species as more and more land is taken for human use. All projects must set aside land equal to the project area away from the project site, through an approved Land Trust organization or the Institute’s Living Future Habitat Exchange Program (International Living Future Institute, 2019b).

3.1.4 Imperative 04 – Human-Scaled Living

The Imperative's objective is to contribute to the development of pedestrian-friendly communities that prioritize walking over the use of fossil fuel vehicles (International Living Future Institute, 2019b). All projects are required to either maintain or increase site density and promote a human-powered lifestyle, with construction tailored to the neighborhood's human scale. Key aspects include creating communal spaces for occupants to gather, offering secure storage for human-powered vehicles, and providing facilities like showers and lockers to encourage biking. Additionally, projects must demonstrate efforts to address on-site bike storage opportunities. They should also incorporate at least two electric vehicle charging stations or one per thirty spaces, whichever is greater. Limiting impervious surface parking is crucial, with specific percentages allocated based on transects. Projects must also either reduce single-occupancy vehicle (SOV) trips and trips by fossil fuel-based vehicles by 30% from a baseline or implement four best practices. These include enhancing pedestrian routes, advocating for human-powered and public transportation, offering transit subsidies, coordinating carpooling, providing access to subsidized car-sharing or hybrid/EV fleet vehicles, and regularly surveying occupants on their current fossil fuel-based SOV trips.

Using previously developed areas does not come without potential problems. Present and future liability associated with the need for potential clean-up may limit available development finance. Other potential problems include cost overruns and delays due to lack of information, uncertain market potential, and environmental regulations (Hes & Plessis, 2015)

3.2 Water

The Water Petal focuses on developing projects that align with the water balance of a specific location and climate (International Living Future Institute, 2019b). It aims to change how people value water, addressing the energy and chemicals used in water processes and redefining "wastewater" as a valuable resource. Global water scarcity is a significant concern, affecting many countries due to climate change. Even regions with abundant water historically face risks from climate impacts, unsustainable water use, and aquifer depletion. Closed-loop systems with localized treatment can help mitigate these problems for a more resilient water future.

The Living Building Challenge envisions a future where developments align with a site's capacity, harvesting enough water for the population while respecting natural hydrology, ecosystem needs, and community ecosystems. Water can be used, purified, and reused in a cycle. Current regulations often restrict such practices due to health, land use, and building code rules. To achieve ideal water use, it's necessary to challenge outdated attitudes with decentralized, appropriately scaled, elegant, and efficient solutions at the site or district level.

3.2.1 Imperative 05 – Responsible Water Use

The purpose of this Imperative is to instill a mindset in projects that regards water as a valuable resource, emphasizing the reduction of waste and potable water usage while preventing downstream impacts and pollution (International Living Future Institute, 2019b). A crucial element is the prohibition of potable water for irrigation, with projects required to use less water than a baseline regional building of the same type, specifically 50% less for new constructions. Additionally, all stormwater must be managed on-site, employing either natural or mechanical methods without the use of chemicals. Compliance extends to addressing pre-development hydrology and current ecological conditions, as determined by a qualified professional. For projects located in Combined Sewer (CS) systems or floodplains, stormwater detention is mandatory, and any sheet flow of water off the project site must be avoided (Thomas, 2022).

3.2.2 Imperative 06 – Net Positive Water

The objective of this Imperative is to align project water usage and discharge with the natural water flows of the site and its surroundings (International Living Future Institute, 2019b). All projects are mandated to fulfill one hundred percent of their water needs through captured precipitation or other closed-loop water systems, or by recycling used project water. Purification of water, as necessary, should be carried out without the use of chemicals, and non-potable applications must not utilize potable water. In cases where captured precipitation is insufficient after implementing efficiency measures, connecting to the municipal water system is permissible. Effective on-site treatment and management of all grey (wastewater excluding human waste) and black water (human waste) is mandatory, either through reuse, a closed-loop system, or infiltration. Connection is allowed where regulations prohibit on-site treatment, or if the municipal system proves more environmentally beneficial. Additionally, projects must integrate a resilience strategy ensuring a one-week supply of drinking water for all regular building occupants through on-site water storage.

3.3 Energy

The Energy Petal focuses on reliance on renewable resources. The intent of the Energy Petal is to create new sources of renewable energy that allow projects to operate year-round in a resilient, pollution-free manner (International Living Future Institute, 2019b). In addition, the Energy Petal prioritizes energy efficiency as a means to reduce wasteful use of energy, resources, and capital. The cumulative adverse effects of the current energy infrastructure are increasingly apparent, with rising carbon emissions impacting the climate and posing potential risks to global communities. The Energy Petal aims to redefine the relationship between humans and energy, envisioning places of residence, work, and recreation as contributors to a robust and sustainable future (Thomas, 2016).

The Living Building Challenge envisions a decentralized and resilient energy infrastructure exclusively powered by renewable sources. The goal is for the energy grid to distribute power equitably to energy-efficient buildings, minimizing the negative impacts associated with combustion or fission. Despite progress in enhancing the cost-effectiveness and performance of renewable energy technologies, certain projects still depend on fossil fuel energy due to cost constraints or regulatory obstacles. To fully realize the social, ecological, and economic advantages of clean energy, the Living Building Challenge advocates a shift away from combustion-based sources. Energy storage through batteries or advanced materials is also encouraged to enhance on-site energy utilization and facilitate the gradual reduction of short-term combustion reliance on the utility grid.

3.3.1 Imperative 07 – Energy + Carbon Reduction

The intent of this Imperative is to treat energy as a precious resource and minimize energy-related carbon emissions that contribute to climate change (Thomas, 2016). All projects must achieve a reduction in total net annual energy consumption (after accounting for on-site renewable power), as compared to a typical existing building with comparable climate, size, use, and occupancy, and combustion must be limited. All projects must use building-level energy metering. New projects must demonstrate a 20% reduction from the given standard in the embodied carbon of primary building materials compared to an equivalent baseline and select interior materials with lower than industry average carbon footprint for product categories for which embodied carbon data is readily available (International Living Future Institute, 2019b).

3.3.2 Imperative 08 – Net Positive Carbon

The objective of this Imperative is to promote the adoption of carbon-free renewable energy resources, aiming to mitigate the adverse effects associated with fossil fuel usage, particularly the emissions contributing to global climate change (International Living Future Institute, 2019b). Every project is required to meet 105% of its energy needs through on-site renewable sources on a net annual basis, excluding combustion. Additionally, projects must consider the total embodied carbon emissions (measured in tCO_2e) stemming from construction, which includes energy consumption during the construction phase. Total embodied carbon is the sum of greenhouse gas emissions, measured in metric tons of carbon dioxide equivalent (tCO_2e), associated with all the stages of a building's life cycle, including raw material extraction, manufacturing, construction, and eventual demolition (Thomas, 2016). This should be addressed through the use of carbon-sequestering materials, meaning materials or processes that can capture and store carbon dioxide, or a one-time carbon offset purchase from an ILFI-approved carbon offset provider (International Living Future Institute, 2019b). Furthermore, each project must devise and implement a resilience strategy, ensuring the building's habitability for one week or contributing to local community support during disasters, utilizing methods such as batteries and energy storage.

3.4 Health + Happiness

Health + Happiness hopes to achieve an environment that optimizes physical and psychological health and well-being. The intent of the Health + Happiness Petal is to create healthy spaces that allow all species to thrive by connecting people to nature and ensuring that our indoor spaces have healthy air and natural daylight. The Living Building Challenge envisions a nourishing, highly productive, and healthy built environment where everyone has fresh air, daylight, and views of the outdoors (International Living Future Institute, 2019b). This allows occupants to be sensitive to the weather, the seasons, and the time of day. However, even the best available solutions require acceptance and engagement by the occupants and the project owner. For buildings to be healthy over time takes a commitment from the project occupants and owners.

3.4.1 Imperative 09 – Healthy Interior Environment

The objective of this Imperative is to enhance indoor air quality and establish a healthy interior environment for project occupants (International Living Future Institute, 2019b). To achieve this, all projects are required to adhere to the current version of ASHRAE 62. Smoking is strictly prohibited within any buildings or enclosed spaces. Additionally, projects must develop a Healthy Indoor Environment Plan, encompassing cleaning protocols, preventive measures against particulates and toxins through an entry approach, and the implementation of at least one strategy to improve air quality. Furthermore, projects are obligated to offer views outside and ensure daylight reaches at least 75% of regularly occupied spaces. Direct exhaust systems are also mandatory for kitchens, bathrooms, and janitorial areas.

3.4.2 Imperative 10 – Healthy Interior Performance

This Imperative aims to ensure consistently high-quality indoor air and maintain a healthy indoor environment. To achieve this, projects must meet various criteria. Initially, projects are required to submit the results of an Indoor Air Quality test conducted one to six months after occupancy or provide readings from an ILFI-approved continuously monitored indoor air quality system. Additionally, projects must adhere to the CDPH Standard Method v1.1-2010 (or international equivalent) for 90% of interior building products with the potential to emit volatile organic compounds (VOCs). Implementing a cleaning protocol that uses EPA Safer Choice label-compliant cleaning products (or international equivalent) is also mandatory.

All projects must ensure access to views and daylight from 95% of regularly occupied spaces, with opportunities for occupants in the remaining 5% of regularly occupied spaces to move to compliant spaces for part of their day. Furthermore, projects must provide two of the following options: sufficient operable windows for natural ventilation for at least six months of the year, the ability for occupants to influence local airflow and temperature through direct input or controls, flexible options for working and learning, such as sit/stand options and varied sensory experiences for living, working, or learning.

3.4.3 Imperative 11 – Access to Nature

The intent of this Imperative is to provide opportunities for project occupants to directly connect to nature, and to assess their implementation (International Living Future Institute, 2019b). This imperative emphasizes the creation of spaces that facilitate a strong connection with nature, fostering physical, mental, and emotional benefits. Projects are encouraged to provide access to nature through strategies such as incorporating green roofs, gardens, or courtyards, ensuring that a significant portion of regularly occupied spaces has direct views of the outdoors. This approach aligns with the broader goal of harmonizing human habitats with the natural world, contributing to a healthier and more sustainable living environment. By prioritizing access to nature, the Living Building Challenge seeks to inspire a shift towards more regenerative and restorative design practices that prioritize the well-being of both people and the planet.

3.5 Materials

The intent of the Materials Petal is to help create a materials economy that is non-toxic, ecologically restorative, and transparent. Throughout their life cycle, building materials are responsible for many adverse environmental issues, including personal illness, habitat and species loss, pollution, and resource depletion. The Imperatives in this section aim to remove the worst offending materials and construction practices and to drive the building industry toward responsible materials. When impacts can be reduced but not eliminated, there is an obligation not only to offset the damaging consequences associated with the construction process but also to strive for corrections in the industry itself. Over the past decade, the Red List has transformed the building industry from one where ingredients were held in secret to one where transparency is becoming the new normal. In simple terms, the Red List refers to a list of materials or substances that are considered harmful or unhealthy for people and the environment. These materials are often avoided in construction or manufacturing because they may contain toxins, carcinogens, or other substances that can have negative effects on human health or the environment. The goal of avoiding Red List materials is to create safer and more sustainable products and buildings.

The Living Building Challenge envisions a future where all materials in the built environment are regenerative and have no negative impact on the health of humans and our ecosystem. The precautionary principle guides all material selection when impacts are unclear. There are significant limitations to achieving the ideal for the materials realm. Product specification and purchases have far-reaching impacts. Declare®, the Institute's ingredients label for building products, is a publicly accessible label and online database and is embedded within the Materials Petal. Not only does Declare® provide a clear solution to both transparency and documentation for projects, and a means to verify when exceptions are no longer needed, it also provides a forum for sharing the information compiled by a project team as part of their documentation requirements for certification.

3.5.1 Imperative 12 – Responsible Materials

The intent of this Imperative is to set a baseline for transparency, sustainable extraction, support of local industry, and waste diversion for all projects (International Living Future Institute, 2019b). The Responsible Materials Imperative advocates for the thoughtful selection of materials with minimal adverse effects on human health and the environment throughout their life cycle. A key tool in achieving this imperative is the Declare® label, which promotes transparency and responsible sourcing.

Projects are encouraged to prioritize materials with a Declare® label. This third-party product transparency platform provides detailed information about a product's composition and its impact on human health and the environment. The label discloses whether the product contains any Red List materials, fostering informed decision-making and encouraging the use of materials that align with sustainability goals.

In essence, the Responsible Materials Imperative, through tools like Declare® strives to elevate the construction industry's standards, prompting the adoption of materials that are non-toxic, ethically sourced, and environmentally responsible. This approach contributes to creating healthier indoor environments, reducing environmental impact, and advancing overall sustainability in building practices.

Declare was designed to promote full transparency in the manufacturing industry. Similar to a nutrition label, a product's Declare label clearly states its full ingredient list, region of origin, and end-of-life options. Theoretically, it would simplify the process of searching for Red-List-compliant supplies (Thomas, 2016).

3.5.2 Imperative 13 – Red List

The intent of this Imperative is to foster a transparent materials economy free of toxins and harmful chemicals. All projects must avoid the following Red List chemical classes in 90% of the project's new materials by cost. A simplified list of Red List materials can be found in Figure 3-3, a full list can be found at https://living-future.org/red-list/.

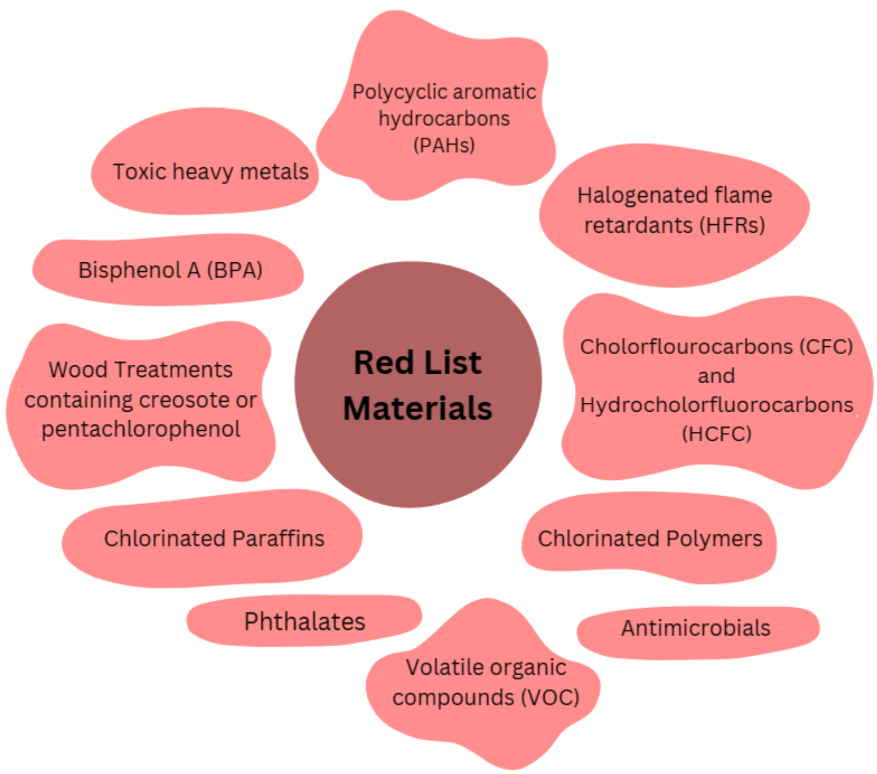

Figure 3-3: Red List Materials

3.5.3 Imperative 14 – Responsible Sourcing

The intent of this Imperative is to support sustainable extraction of materials and transparent labeling of products. All projects are required to champion the establishment and adoption of third-party certified standards promoting sustainable resource extraction and fair labor practices, particularly for the extraction of rock, metal, minerals, and timber. Additionally, projects must advocate for the certification of all dimension stone products used within the project under the Natural Stone Council (NSC) 373 Standard by quarries and/or manufacturers.

Regarding wood sourcing, projects have two options: they must either obtain 80% or more of all wood, by cost or volume, as Forest Stewardship Council (FSC) certified, salvaged, or from intentional on-site timber harvest for construction or ecological restoration. The remaining 20% of wood must come from low-risk sources. Alternatively, a project may achieve FSC Project Certification.

Furthermore, projects are mandated to incorporate two Declare® labeled products per 200 sq m of gross building area (or project area, whichever is smaller) up to forty products. Projects must also encourage all manufacturers not yet in Declare® to register their products in the Declare® database. In addition, all projects, excluding residential ones, must include one product labeled under the Living Product Challenge per 1,000 sq. m of gross building area or project area (whichever is smaller), up to three products. These measures collectively ensure responsible material sourcing and environmentally conscious choices throughout the project.

3.5.4 Imperative 15 – Living Economy Sourcing

The intent of this Imperative is to support local communities and businesses while minimizing transportation impacts. The project must incorporate place-based solutions and contribute to the expansion of a regional economy rooted in sustainable practices, products, and services. Manufacturer location for materials must adhere to the series of restrictions. The first requires 20% or more of the materials construction budget must come from within 500 kilometers of the construction site. Declare products and salvaged materials may be counted at twice their value. Certain natural building materials may include labor costs in their calculation. Projects must have 30% of the total materials construction budget come from within 1000 kilometers of the construction site or closer and an additional 25% of the materials construction budget must come from within 5000 kilometers of the construction site. The remaining 25% of materials may be sourced from any location.

3.5.5 Imperative 16 – Net Positive Waste

The goal of this Imperative is to embed waste reduction practices across all project phases and stimulate creative repurposing of salvaged materials. Projects are mandated to actively minimize or eliminate waste generation during design, construction, operation, and end-of-life stages. This approach aims to conserve natural resources and explore ways to reintegrate waste into either an industrial loop or a natural nutrient loop. Every project must incorporate at least one salvaged material for every 500 square meters of gross building area, or it should involve the adaptive reuse of an existing structure. Additionally, projects must develop a Materials Conservation Management Plan detailing how materials are optimized throughout the design, construction, operation, and end-of-life phases.

Projects must divert waste materials away from landfills during the construction phase. This ensures that waste reduction is a central consideration throughout a project's lifecycle, promoting sustainability and responsible material management.

3.6 Equity

The Equity Petal within the Living Building Challenge seeks to make equity a primary objective in projects, aiming to reshape developments into communities that are just, inclusive, and supportive of individual growth and participation. The central goal is to create a built environment that embraces diversity, ensures equal access, and promotes fair treatment, contributing to effective decision-making for environmental preservation and regeneration.

The belief underlying this imperative is that a society recognizing and upholding the dignity of every individual, while facilitating their full engagement, is best positioned to address environmental challenges. The Equity Petal challenges practices such as infrastructure privatization, externalizing negative impacts, and limiting access to nature, asserting that true community participation arises from acknowledging our interconnectedness.

Living Buildings, as envisioned by the Living Building Challenge, are meant to be accessible and inviting to all, celebrating cultural diversity while ensuring equitable access to essential elements like fresh air, sunlight, clean water, and soil. Additionally, the process of designing, constructing, and operating Living Buildings should contribute positively by generating employment opportunities and including all individuals.

The Equity Petal is supported by the Just℠ transparency platform, a publicly accessible label and online database, highlighting the Institute's commitment to social justice. The Living Building Challenge envisions a built environment that not only welcomes and accommodates everyone but also promotes inclusive design and construction processes.

3.6.1 Imperative 17 – Universal Access

The intent of this Imperative is to allow equitable access to Living Building projects (International Living Future Institute, 2019b). All projects must make all non-building infrastructure, including parks, plazas, and other outdoor spaces, that are considered externally focused equally accessible to all members. The project should take reasonable steps to ensure that all people can benefit from the project. All projects must safeguard access for those with physical disabilities through designs meeting either the Principles of Universal Design (United States Access Board), the Americans with Disabilities Act (ADA), and the Architectural Barriers Act (ABA) Accessibility Guidelines, or the international equivalent. No project may block access to, nor diminish the quality of, fresh air, sunlight, and natural waterways for any member of society or adjacent developments. Projects must also appropriately address any noise audible to the public.

Fresh Air

Projects must protect adjacent property from any noxious emissions that would compromise its ability to use natural ventilation. All operational emissions must be free of Red List items, persistent bio-accumulative toxicants, and known or suspected carcinogenic, mutagenic, and reprotoxic chemicals.

Sunlight

Projects may not block sunlight to adjacent building facades and rooftops above a maximum height allotted for the Transect. The project may not shade the roof of an adjacent building unless that building was built to a lesser density than acceptable for the Transect.

Natural Waterways

Projects may not restrict access to the edge of any natural waterway, except where access can be proven to be a hazard to public safety or would severely compromise the function of the project. No project may assume ownership of water contained in these bodies or compromise the quality of water that flows downstream. If the project's boundary is more than sixty meters long parallel to the edge of the waterway, it must incorporate and maintain an access path to the waterway from the most convenient public right-of-way.

3.6.2 Imperative 18 – Inclusion

The objective of this Imperative is to contribute to the establishment of stable, safe, and well-compensated job opportunities within the local community, while also supporting a diverse range of local businesses (International Living Future Institute, 2019b). To meet this imperative, every project is required to obtain a Just® label for a minimum of two project team organizations that play integral roles in decisions during both the design and construction phases. Additionally, an extra five organizations involved in the project are mandated to complete a self-assessment, ensuring a comprehensive evaluation of their social and equity practices.

Projects are directed to either actively involve diverse stakeholders from disadvantaged populations in the design, construction, and operations and maintenance phases, fostering inclusivity throughout the project's lifecycle, or alternatively, contribute 0.1% of the total project cost to a regional, community-based nonprofit organization focused on promoting equity and inclusion. This multifaceted approach ensures that projects not only prioritize the well-being and equitable representation of local community members but also foster economic growth and diversity by supporting organizations committed to social justice and inclusion (McLennan, 2004).

3.7 Beauty

The intent of the Beauty Petal is to recognize the need for beauty and the connection to nature as a precursor to caring to preserve, conserve, and serve the greater good. The key to creating beautiful buildings is to embrace a biophilic design process that emphasizes that people and nature are connected and the connection to place, climate, culture, and community is crucial to creating a beautiful building. A biophilic design process is about making buildings and spaces feel more connected to nature (McLennan, 2004). This involves using things like natural light, plants, and materials that remind us of the outdoors. The goal is to create environments that make people feel good, healthy, and happy by bringing elements of nature into the places where they live and work (McLennan, 2004).

The Living Building Challenge envisions designs that foster a positive connection to nature and other living systems, aiming to inspire without imposing a specific definition of beauty (International Living Future Institute, 2019b). Instead of mandating beauty, the Living Building Challenge emphasizes the use of a biophilic design process. In this Petal, the Imperatives are grounded in the belief that a connection to nature, place, community, and climate will naturally result in good design. The objective is to communicate this design process to facilitate replication (McLennan, 2004). The approach does not assume the ability to judge beauty or impose personal aesthetic values on others. Rather, the emphasis is on understanding people's objectives and ensuring an effort is made to enhance lives with each square meter of construction in every project. The intentional pursuit of good design and its graceful execution should extend into a program that educates the public about the environmental qualities of each Living Building Challenge project.

3.7.1 Imperative 19 – Beauty + Biophilia

The purpose of this Imperative is to foster a connection between project teams and occupants with the advantages of biophilia while integrating meaningful biophilic design elements into the project (International Living Future Institute, 2019b). Projects should be conceptualized to include features that nurture the inherent human-nature connection. Each project team is required to participate in at least one full-day exploration to uncover the biophilic design potential for the project. This exploration is intended to generate a comprehensive biophilic framework and plan for the project, detailing strategies and implementation ideas (McLennan, 2004). Specifically, the plan should articulate how the project will be enhanced by incorporating nature, natural patterns, and a connection to its specific place, climate, and culture. It must encompass a detailed record of the exploration day, project goals, and comprehensive studies exploring the site's historical, cultural, ecological, and climatic context. The plan should incorporate methods for tracking biophilia at each design phase to ensure the effective implementation of the framework.

3.7.2 Imperative 20 – Education + Inspiration

The intent of this Imperative is to provide educational materials about the operation and performance of the project to the occupants and the public to share successful solutions and catalyze broader change (International Living Future Institute, 2019b). All projects must provide a case study, an annual open day for the public, a copy of the operation and maintenance manual, a brochure highlighting the features of the project, education signage, and an educational website about the project. As part of the requirements for Imperative 20, graphics and material is released for educational use. Some of the graphics cited are from the provided educational website.

The Living Building Challenge stands as a comprehensive and demanding green building certification program, surpassing conventional sustainability standards. This certification sets an ambitious benchmark for projects, pushing them to achieve net-zero energy and water usage, prioritize the use of non-toxic materials, and establish a profound connection to nature. Beyond the technical aspects, Living Building Challenge certification embodies a commitment to regenerative design principles, social equity, and environmental stewardship. The benefits of attaining this certification are extensive, encompassing net-zero environmental impact, improved health, and well-being for occupants, a focus on regenerative design practices, recognition for innovation and leadership, educational opportunities for the broader community, and positive impacts on local communities through job creation and engagement with diverse stakeholders. Overall, achieving Living Building Challenge certification signifies a bold and comprehensive commitment to sustainable, regenerative, and socially responsible building practices.

Chapter 4 - Case Study: The Kendeda Building

4.1 Project Overview

Located on the Georgia Institute of Technology campus in Atlanta, GA, the Kendeda Building is the first timber building on campus since the early load-bearing masonry and timber structures from the 1880s (Pintos, 2021). It is both Living Building Challenge Certified and LEED Platinum Certified. The 47,000 SF building was completed in 2019 and includes classrooms, teaching laboratories, a maker space, an office, an auditorium, student commons, and a rooftop garden with an apiary and pollinator garden (Edelstein, 2017). The project's namesake was funded by the Kendeda Fund, a private family foundation that supports environmental initiatives (McKnight, 2021). The Kendeda Building is registered under version 3.1 of the Living Building Challenge (Edelstein, 2017). This chapter explores how the project team approached each Petal and the associated Imperatives.

According to LBC founder, flowers are an accurate representation of a truly regenerative building which receives all of its energy from the sun, nutrients from the soil, and water from the sky (McLennan, 2004). Similarly, The Kendeda Building lives within its site. Its seeds are the students who take classes in the building, the thousands of people who tour or attend an event in it, and all the project teams that gain inspiration from it.

Mass timber was selected due to the significant reduction in embodied carbon footprint compared to concrete and steel systems (Lau, 2017). Glu-lam queen-post trusses with steel bottom chords are used to span the large spaces where timber alone would be uneconomical (Pintos, 2021).

25,000 linear feet of 2x4 material was salvaged from the Lifecycle Building Center in Atlanta (Pintos, 2021). Off-cuts from new lumber were assembled into the seat steps that descend into the atrium. Countertops and furniture were constructed from trees on campus that had fallen from a storm (Pintos, 2021).

4.2 Living Building Challenge Certification

Unlike other green building standards, the Living Building Challenge is non-prescriptive (Thomas, 2022). It is up to each team to determine the most suitable ways to accomplish the Challenge Imperatives given the specifics of their project. While this approach promotes innovation, it means there are few, if any, direct roadmaps to a Living Building.

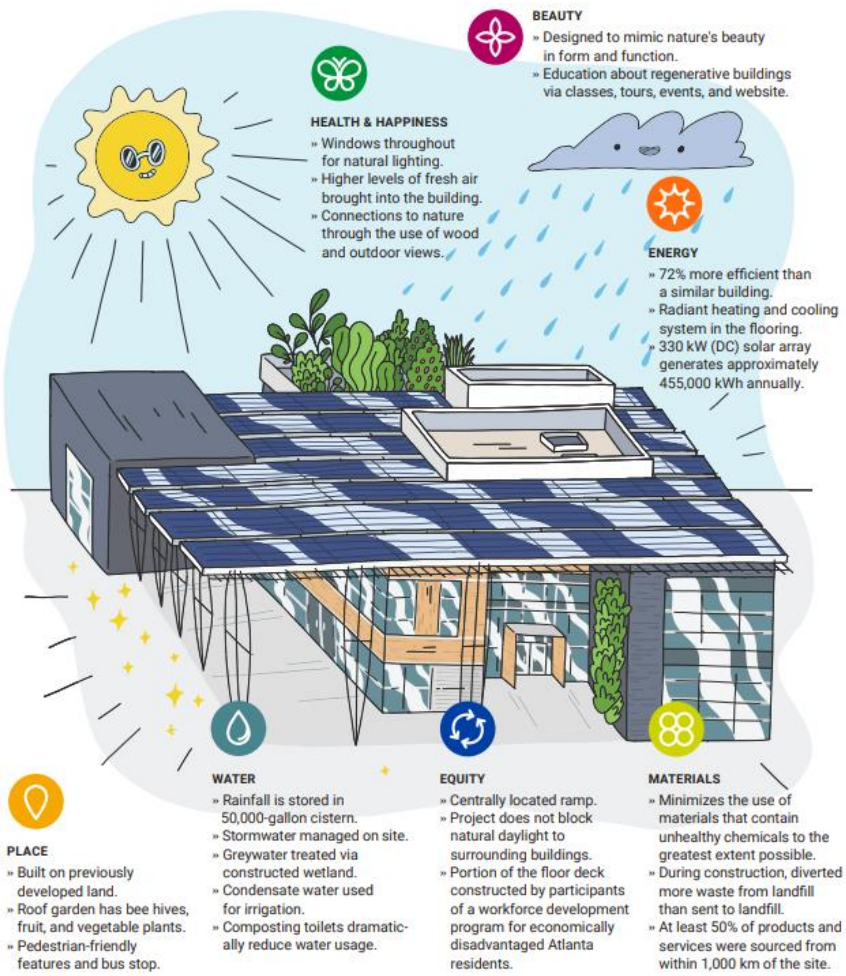

Figure 4-1: The Kendeda Building Petals (Georgia Tech, 2019f)

The Living Building Challenge recognizes that the impact of building on land that has not been previously developed is much greater than building on land that has been developed. To meet the goals of the place petal, the Kendeda Building is built on the site of a former parking lot on Georgia Tech's Campus. The design intent is to restore the site as it existed before human development (Georgia Tech, 2019f).

The Kendeda Building focused on pedestrian-oriented mobility by providing protected bike parking instead of a parking lot on site. Additionally, several bus routes stop at the Kendeda Building, including the Georgia Tech Shuttle that connects the building to public transportation (International Living Future Institute, 2019a). The LBC required that twenty percent of the site be used for agriculture. A rooftop farm consisting of pollinator gardens, and a blueberry orchard, grows food while capturing stormwater (American Society of Landscape Architects, 2019).

Rainwater is harvested from the green roof, roof deck, and 913 photovoltaic panel array is captured and used to serve as the sole potable water source for the project (International Living Future Institute, 2019a). After water is collected, it is filtered and routed to a 50,000-gallon tank located in the basement for holding. The cistern treats 41% of the annual rooftop runoff collected, the remaining runoff is released and directed to onsite stormwater systems (Georgia Tech, 2019g). The rainwater stored in the cistern is treated and used for drinking, washing, showering, lab uses, and the composting toilets use only a teaspoon of water per flush (International Living Future Institute, 2019a). The outdoor areas have been designed to assist in the management of rainwater. For example, the porch terraces as appropriate location to follow the site's natural slope (Georgia Tech, 2019g).

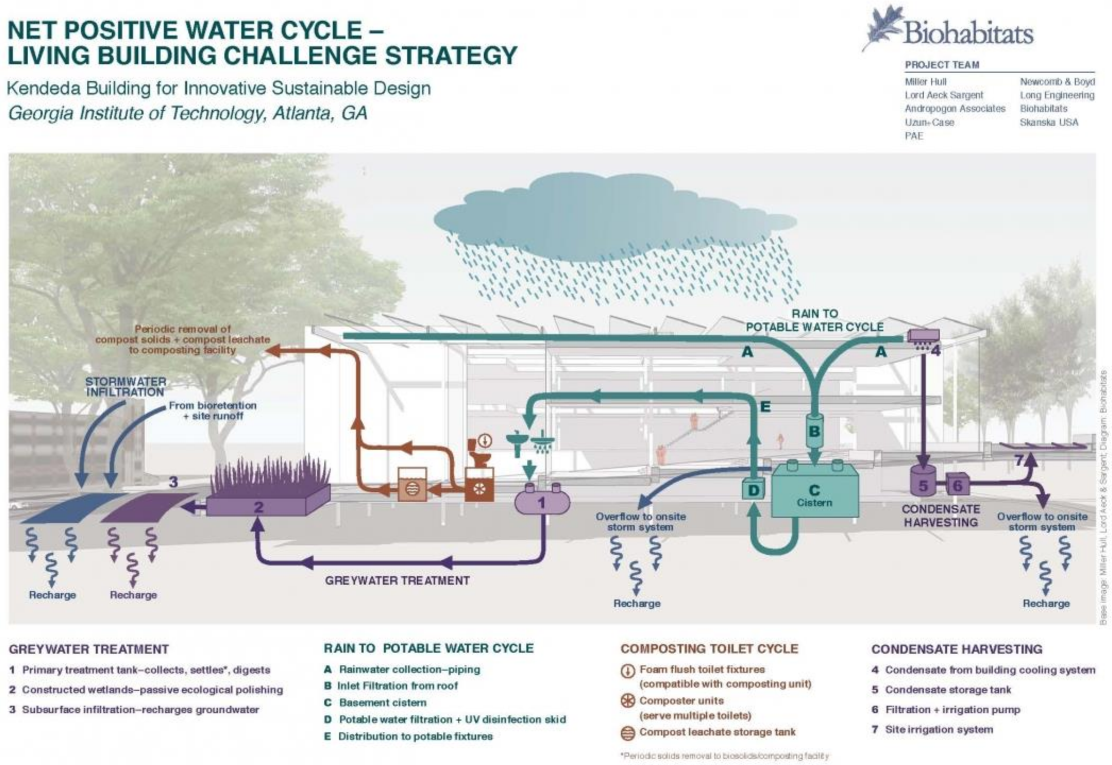

Figure 4-2: The Kendeda Building Water Processes (Georgia Tech, 2019g)

The Energy Petal requires net positive energy, meaning at least 105% of the project's energy needs must be supplied by on-site renewable energy on an annual basis (International Living Future Institute, 2019b). For the Kendeda Building, consideration was first given to climate-appropriate passive design, then energy conservation matters to reduce the size of renewable energy systems needed, and finally to on-site renewable energy.

The project used Building Information Modeling (BIM) to construct the physical aspects of the building while also having information embedded for the owner for use during the life of the project (International Living Future Institute, 2019a). Several innovations were utilized to achieve the high energy efficiency of the building. To drive down energy consumption, the energy load on the building was reduced with the integration of the PV array acting as a porch roof over the side of the building (International Living Future Institute, 2019a).

Passive design is a technique used by designers to leverage the natural climate, solar, and energy characteristics of a building to lower energy demands. For The Kendeda Building, designers prioritized an efficient building envelope, shading, daylight, air infiltration, and thermal comfort to achieve the ability for the building to operate passively in Atlanta's climate (Georgia Tech, 2019b). The performance of the envelope is critical to the energy efficiency of the building. The envelope design includes continuous insulation in walls and under slabs, as well as triple plane window glazing to reduce building loads in both winter and summer. The PV canopy harnesses energy, collects rainwater, and provides shade for the south and west facades, which receive most of the solar gain. The shading helps create a microclimate to ease the transition between the inside and the outside of the building (International Living Future Institute, 2019a). Additionally, exterior blinds on the west facade help manage cooling requirements in the summer. Skylights and clerestory windows were designed in the large atrium space for continuous daylighting in the building. Vestibules, air curtains, and an efficient envelope help prevent the movement of hot air and humidity into the building (Georgia Tech, 2019b).

Every variable of the building's passive design is evaluated using energy models. The energy model demands for The Kendeda Building are higher than other certified living buildings. The building is open 15 hours a day Monday through Friday for 51 weeks of the year (Pintos, 2021). It is home to regularly scheduled classes, labs, tours, and additional evening and weekend events. The radiant heating and cooling system in the floors is used with additional condensation and temperature reset strategies to mitigate moist floors. An energy-efficient dedicated outdoor air system (DOAS) provides heated or cooled, and dehumidified, ventilation air to most of the building's spaces (International Living Future Institute, 2019a). The auditorium has a dedicated variable air volume HVAC to accommodate larger audiences. Ceiling fans are also used throughout the atrium space and classrooms to provide continuous air circulation. When the building needs to provide cooling, the mechanical system draws chilled water directly from the campus loop. When the building needs to provide heating, the mechanical system uses the campus heat recovery chiller to provide heat. Both the water and energy (in the form of heat) borrowed from the campus central plant are metered and reflected in the annual net positive calculations (Georgia Tech, 2019b).

The building has a solar canopy of 917 PV panels capable of producing 400 MWh per year (Skanska, n.d.). An emergency backup battery is charged using the PV panels in case of power outages. Georgia offers a net-metering program so The Kendeda Building can send energy back to the grid when the PV array produces more electricity than needed (Georgia Power, n.d.). Water from the campus connection is metered, energy is calculated, and an energy offset is provided to the grid to help meet the annual net positive requirements. By capturing sunlight for more energy than the building needs, the system is a net positive energy facility on an annual basis.

The Civilized Environment Imperative, now included in the Healthy Indoor Environment (Section 3.4.1) requires that every regularly occupied space must have operable windows that provide access to fresh air and daylight (International Living Future Institute, 2019b). Regularly occupied spaces have been defined by ILFI as spaces that are used frequently, for extended periods of time, or that contain one or more staffed workstations (International Living Future Institute, 2019a). The Kendeda Building addresses this Imperative by providing operable windows in classrooms, offices, and the auditorium. Large folding glass doors in the maker space are operable when humidity, temperature, and pollen count are ideal. Additionally, the team studied the ideal balance of daylight and light fixtures to reduce glare, improve views, and find the correct balance of direct and ambient lighting (Georgia Tech, 2019d).

To meet the air quality requirements of the Healthy Interior Environment Imperative, the Living Building Challenge requires teams to put together a Healthy Indoor Environment plan (Section 3.4.1). The Kendeda Building's design addresses this by using a DOAS to ensure the building exceeds the required amount of outside air circulated. The project has dedicated exhaust for the catering, restrooms, and janitorial areas to ensure the air in these spaces is not recirculated through the building. Walk-off mats at doors prevent pollutants from entering the building. Using fewer, natural materials, like wood, low VOC finishes, and materials with no coatings/adhesives ensures the project design reduces emissions traditionally coming from building materials.

To avoid the use of Red List materials, the design-built team must thoroughly investigate the proposed materials during the design phases by selecting and specifying products that are documented as being free of Red List materials (International Living Future Institute, 2019b). To comply with the Red List Imperative, Section 3.5.2, the design team worked for more than two years to identify products that did not contain Red List chemicals (Georgia Tech, 2019e).

The Embodied Carbon Footprint Imperative, which was absorbed into Living Economy Sourcing, strives to minimize a project's carbon footprint. The carbon footprint is the carbon associated with the materials used to construct the building. To meet this Imperative, the design-build team incorporated carbon reduction strategies early in the design phase (Georgia Tech, 2019e). For example, wood is the primary structural element because of the significant reduction in embodied carbon compared to concrete or steel. The Kendeda Building recycled over 99% of construction waste, incorporated salvaged and low-carbon materials and ultimately has a carbon intensity of nearly 30% below the Carbon Leadership Forum's embodied carbon median for educational buildings (International Living Future Institute, 2019a). The Kendeda Building then achieved zero carbon footprint for construction through a one-time carbon offset.

The Responsible Industry Imperative, (Section 3.5.3), aims to reduce the damaging environmental and social impacts related to industries that rely on natural resource extraction and plant cultivation. The design-build team was able to salvage some of the stone used in The Kendeda Building from the former Georgia Archives Building. The stone needed for the structural slab came from the Forest Park Stone quarry. All wood used on the project was either salvaged or FSC-certified (Edelstein, 2017).

The Kendeda Building incorporated locally sourced wood and brick for the project. The carpet, steel, glulam, nail laminated timber (NLT), and rigid insulation were all manufactured or fabricated in Georgia. This was done to meet the requirements of the Living Economy Sourcing Imperative (Section 3.5.4). The Imperative requires that projects must incorporate place-based solutions and contribute to the expansion of a regional economy rooted in sustainable practices, products, and services (International Living Future Institute, 2019b). There are additional distance parameters for the manufacturing of materials and services.

The Net Positive Waste Imperative, Section 3.5.5, aims to reduce the environmental burden associated materials during the construction process. From the beginning of the construction phase, the construction team compiled a list of expected waste streams from each trade to target the waste diversion goals. All salvageable material was either incorporated into the project or donated to the local Lifecycle Building Center for their retail salvage operation.

The Kendeda Building stands as a testament to the deliberate promotion of human interaction and sustainable design principles (Georgia Tech, 2019c). Forgoing on-site parking spaces, the building relies on shared campus resources like the Dalney Parking Deck, a well-equipped facility featuring 784 spaces and 20 electric charging stations, aligning with a commitment to eco-friendly practices (International Living Future Institute, 2019a). Signage follows Georgia Tech's standard specifications, ensuring a harmonious integration into the campus environment. The architectural design maintains a careful balance, with curtain wall openings and doors adhering to a proportionate scale, not exceeding the maximum distance of 30 meters. Although the building's footprint surpasses 19,000 square feet, exceeding the designated maximum before articulation, the commitment to a balanced and thoughtful design remains unwavering.

Internally, the Kendeda Building provides spaces crafted for human scale, providing gathering areas for students, faculty, and visitors. The basement level invites exploration, offering unique tour opportunities to showcase elements such as a captivating mural on the south wall and the operational intricacies of various systems. On Level 1, breakout spaces, an occupiable stair, and live edge tables create an environment conducive to spontaneous interactions and study sessions. Nanowalls seamlessly connect the interior and exterior spaces, facilitating a fluid and engaging movement experience. The second floor expands these opportunities with additional gathering areas and a green roof, emphasizing the building's dedication to fostering engagement and social interactions. Thoughtfully placed benches and seating along the building's edges contribute to the promotion of human-scale articulation, reinforcing the commitment to creating a space that not only embodies sustainable design but actively encourages a sense of community and connection (Georgia Tech, 2019c).

The design approaches for these imperatives were to meet the intent of the beauty petal – to recognize the need for beauty as a precursor to caring enough to preserve, conserve, and serve the greater good (Georgia Tech, 2019a).

Public Art

The infusion of public art is evident throughout the building. In the basement, local Atlanta artist Beardy Glasses crafted a mural on the south wall, illustrating the water treatment process within the building. Additionally, the building features rotating art exhibits. In the Fall of 2019, works by artists Virginie Drujon-Kippelen and Shannon Davis were showcased, exploring nature through the contrasting lenses of "urban wilderness" and "man-made" nature. Free-standing signage, disseminating information about each petal, moves throughout the building, aligning with the Living Building Challenge's sustainability goals (International Living Future Institute, 2019a).

Georgia Tech is leading an art program for the installment in the building that was finalized upon building completion. Interpretive signage was installed throughout the building to assist in explaining specific design features (Okamoto, 2024). A website was developed for more information on the design process. Tours were offered during construction and continued after the building was opened. The building is to serve as a case study and inspiration for future projects.

Stair and Atrium

The circulation through the site and building act as the connective tissue of discovery, linking the Kendeda Building with the adjacent EcoCommons (International Living Future Institute, 2019a). The two-story central atrium serves as the heart of the building, providing flexible circulation and program space while flooding the interior with daylight. The monumental stairs, ramp, and occupiable stairs, adorned with salvaged materials, not only serve their functional purpose but also contribute to the overall beauty of the space, encouraging interaction and movement (Georgia Tech, 2019a).

Materials

Construction emphasizes simple methods and a palette primarily sourced from nature, regionally appropriate, low carbon, durable, non-toxic, and cost-effective (Georgia Tech, 2019e). The strategic use of high-carbon materials, like steel and concrete, minimizes environmental impact. Sustainable and/or salvaged wood from the Southeast, chosen for beauty, durability, and regional relevance, creates an appealing composition for building occupants (International Living Future Institute, 2019a).

Regional Design Influence

The southeast's vernacular architecture, specifically the porch typology, profoundly influences the design. The porch serves as a familiar transitional space connecting the built and natural environments, fostering a connection between building occupants and the community. Wrapping around the façade, the porch provides welcoming, covered open spaces with access to the south, west, and north, blurring the line between indoors and outdoors (Georgia Tech, 2019a). The west porch steps integrate with the landscape, connecting directly to the constructed wetlands, while the north porch, a green roof area on Level 2, establishes a strong connection to outdoor spaces beneath the canopy of oak and pecan trees. The west porch roof overhang not only shields against western solar gain but also creates sheltered outdoor spaces that seamlessly blend the indoors with the outdoors.

4.3 LEED Certification

In addition to attaining Living Building status, the Kendeda Building earned sufficient points to secure LEED Platinum certification. The building accomplished this with a scorecard totaling 89 out of 110 points across nine distinct categories (U.S. Green Building Council, 2021).

The building had a unique path to LEED certification. Instead of modeling energy and water performance, The Kendeda Building could provide 12 months of actual performance, monitored for certification as a Living Building.

The Kendeda Building earned all 10 points in the Sustainable Sites category. The construction team worked diligently to reduce pollution from construction activities. The design team considered environmental, social, and economic aspects of the site, as it was built on a former parking lot to prevent disturbing previously undeveloped land. To protect and restore habitat, the Kendeda Building participated in the International Living Future Institute's habitat exchange program. There are many natural spaces provided outside the building and on the roof for occupants to explore and connect back with nature. All rainwater is collected, filtered, and stored in a 50,000-gallon holding tank in the basement of the building. All rainwater is directed to stormwater systems and helps water the plants on the green roof and outdoor spaces. Trees were planted surrounding the building to provide shade and help reduce heat island effects. Outdoor lighting was placed strategically to reduce light pollution while still providing necessary light for safety.

The Kendeda Building earned all 11 available points in the water efficiency category. All water the Kendeda Building uses is produced from its site. The Kendeda Building relies upon rainwater, greywater, and stormwater systems to achieve the Net Positive Water requirement. Collectively, these systems supply all the potable water demands for the building while recycling wastewater and stormwater to recharge the surrounding aquifer. All water is metered to ensure the building is meeting its annual water goals. For safety reasons, the building's fire suppression system is always connected to the City of Atlanta water system. Greywater (or water that does not contain organic matter) is collected from shower drains, sink drains, and water fountains and directed to a primary tank for infiltration on site. This recycled water is pumped to a constructed wetlands at the south end of the site, gravity fed to other filtration and disinfection tanks, and ultimately allowed to infiltrate back into the soil via leach fields at the north end of the site to recharge the surrounding groundwater. Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality. In addition, condensate collected from HVAC system is used for irrigation. A blackwater (water with organic matter) system is not present on the project. A total of 12 composting toilets and four urinals throughout the building separate liquids and convert solids into fertilizing soil, which is used for uptake by plants.

The Kendeda Building earned 29 of the 53 available Energy and Atmosphere points. The building continues to meet project requirements for energy and water by producing 105% of its needs on an annual basis. Energy is produced from the PV panels located above the building. The building's 330 kW (DC) solar canopy is comprised of 917 PV panels and generates over 400,000 kWh per year that directly serves the building's energy demands, including lighting, HVAC system, water system, and plug loads. A lithium-ion battery is charged exclusively by the PV array and serves as the emergency backup system for the building in the case of power outages. The sizing of the PV array included the building's system energy demands, a safety factor of 10 percent, plus the 5 percent net positive factor that is required for

Living Building Challenge certification. The project earned all 18 points in the Optimize energy performance category for energy performance beyond the prerequisite standard.

The building earned 6 of the 11 available Material and Resources points. All materials used in the building are disclosed, including their selection of products that are well known, use of materials that are environmentally preferable, and disclosing all material ingredients. The building structure is made of locally sourced engineered wood. All materials from LBC's red list were avoided. Each material has a label inside the building disclosing what material was used, and its environmental impact.

The Kendeda Building earned 11 of the 16 available Indoor Environmental Quality points. Every regularly occupied space must have operable windows that provide access to fresh air and daylight. Operable windows are provided in classrooms, offices, and the auditorium. Large folding glass doors in the maker space are operable during times when humidity, temperature, and pollen count are ideal. To further improve indoor environmental quality, a dedicated outdoor air system (DOAS) was used to ensure the building greatly exceeds the required amount of outside or fresh air circulated to building occupants. Dedicated exhausts for the catering, bathrooms, and janitorial areas to ensure the air in these spaces does not recirculate through the building. Walk-off mats at doors prevent dust, debris, and pollutants from entering the building, and using fewer materials, natural materials (like wood), low VOC finishes, and materials with no or greatly reduced coatings/adhesives reduce emissions from building materials.

The building earned all 6 of the Innovation points. The design team strived to create a truly sustainable building, not just one that met LEED or LBC credits. The design team had a design charrette to further connect the building to the natural environment. Georgia Tech's

Biophilia charrette took place over two days in September of 2016. As a result of the charrette and other discussions, the Kendeda Building's exposed wood helps provide a visual connection to the natural world. Large windows and glass walls on the west side of the building provide a visual connection to future greenspace (Eco-Commons), and a rooftop garden with apiaries (beehives), pollinator plants, and blueberry bushes provides an area of connection to nature. The building also earned one point for a LEED accredited professional on the design team.

It earned all 4 points in the Regional Priority Credits. These were awarded for the occupants access to daylight, rainwater management, outdoor water use reduction, and indoor water use reduction. Implementing water-efficient landscaping and irrigation systems tailored to the Southeast's climate and water availability, using locally-sourced materials to reduce transportation-related carbon emissions, designing the building envelope to minimize heat gain and optimize energy performance in the Southeast's hot and humid climate, incorporating renewable energy technologies suitable for the Southeast region, such as solar or geothermal systems, and implementing strategies to manage stormwater runoff in accordance with regional regulations and best practices.

The building earned 11 of the 20 available Location and Transportation points. These points came from developing on land that had already been developed. The site was that of a former parking lot. The building encourages daily physical activity through its network of walking and biking routes. There are regular bus stops near the project location. Many of these points came from the provided bicycle facilities, green vehicles, and reduced parking footprint that were also required by the LBC.

The Kendeda Building earned the Integrative Process Credits point. The architects involved engineers, landscape architects, GA Tech, Kendeda, and the construction company early in the process. The entire design team was brought together as early as September 2016.

Chapter 5 - Conclusion

The Living Building Challenge (LBC) and Leadership in Energy and Environmental Design (LEED) are two prominent green building certification programs that share a common goal of promoting sustainability in the construction and operation of buildings. Both certifications address key environmental factors such as energy efficiency, water conservation, and sustainable materials, offering multiple certification levels to recognize varying degrees of environmental performance. However, they differ significantly in their approaches. LBC adopts a performance-based certification, necessitating actual performance data to demonstrate compliance and placing a strong emphasis on regenerative design principles. In contrast, LEED employs a prescriptive approach, offering a set of criteria with flexibility for projects to choose from various options within each category, relying on predicted or modeled performance. LBC sets strict requirements for net-zero energy and water, avoiding materials on the Red List, and prioritizing community and ecosystem impact. While LEED encourages sustainability, it may not mandate such stringent performance levels or regenerative design principles. Overall, the choice between LBC and LEED depends on the desired level of environmental commitment and the specific approach preferred by the project team.

As mentioned in previous chapters, there is a cost associated with certification of both LEED and LBC. A building is more marketable with a sustainability label on it, but anyone can build an energy-efficient building without a certification. Owners, architects, and engineers should pursue sustainable building practices because they care, not because they want a label. The benefit of third-party building certification systems is proving the building is operating as intended, validating sustainability claims. LEED is often characterized as aiming to "do less bad," focusing on minimizing the negative impacts of the built environment and enhancing building performance beyond standard benchmarks. In contrast, the LBC promotes "regenerative" design practices, seeking to generate positive impacts on people, communities, and the planet rather than reducing harm.

The choice between LEED, LBC, or any green building certification depends on the owner’s values and objectives. LEED is suitable for those aiming to improve upon past standards, offering well-established practices and a straightforward path to sustainability. LBC is ideal for those seeking to make a statement, as it sets more rigorous requirements and pushes the boundaries of sustainability beyond conventional practices. Organizations must fully commit to meeting the LBC's requirements and embrace sustainability wholeheartedly.

Finally, between the two certifications, the most important conclusion is that Equity is necessary for all buildings. The Equity Petal in the Living Building Challenge is critical in sustainable design because it focuses on fairness and community well-being. While protecting the environment is important, true sustainability also means making sure everyone has equal access to resources and opportunities, no matter who they are. Prioritizing equity creates spaces that are inclusive and accessible to everyone, empowering communities and improving overall quality of life. Regardless of the decision to pursue third-party green certification or not, a building should be sustainable because the design team cares, not for a label.

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Glossary of Terms

Adaptive reuse - The process of reusing a structure or building for a purpose other than the original purpose for which it was built or designed.

Blackwater - Discharged water containing solid and liquid human waste from toilets and urinals.

Business as usual (BAU) - Business as usual is the baseline reference point for hand printing. In simplest terms, BAU refers to a repeat of last year. More formally, it refers to responding to this year's external forces with last year's approach. For companies that sell goods or services, BAU is responding to this year's demand, with last year's products and processes. For projects, BAU is addressing current demands based on typical fixtures, materials, or processes.

Biophilic design - an architectural and interior design approach that integrates elements of nature, such as natural light, views, and greenery, to enhance well-being and create spaces that foster a connection with the natural environment.

Chemical Abstracts Service (CAS) number - A unique numerical identifier for nearly every known chemical, compound, or organic substance.

Closed-loop water systems - Systems in which all water used on a project is captured, treated, used/reused, and/or released within the boundaries of the project area.

Combustion - Any burning or combustion of fossil fuels or wood products.

Consumables - non-durable goods that are likely to be used up or depleted quickly. Examples include office supplies, packaging and containers, paper and paper products, batteries, and cleaning products.

Deconstruction - The systematic removal of materials from a building or project for the purposes of salvage, reuse, and/or recycling.

Diverted waste - All items removed from the project that are then recycled, reused, salvaged, composted, or otherwise diverted from landfills or incineration.

Durables - Goods that have utility over time rather than being depleted quickly through use. Examples include appliances, electronic equipment, mobile phones, and furniture.

Energy needs - All electricity, heating, and cooling requirements of either grid-tied or off-the-grid systems, excluding backup generators.

Floor Area Ratio (FAR) – FAR = Gross Building Area / Total Project Area

Forest Stewardship Council (FSC) - An independent, non-profit, membership-led organization that protects forests for future generations and sets standards under which forests and companies are certified. Membership consists of three equally weighted chambers—environmental, economic, and social—to ensure balance and the highest level of integrity.

Furniture, Fixtures, and Equipment (FF&E) - Furniture, fixtures, or other equipment that has no permanent connection to the structure of a building or utilities and is not part of the system's furniture.

Greenfield - Land that was not previously developed or polluted.

Greywater - Water discharged from sinks, showers, laundry, drinking fountains, etc., but not including water discharged from toilets and urinals.

Halogenated flame retardants (HFRs) - HFRs include PBDE, TBBPA, HBCD, Deca-BDE, TCPP, TCEP, Dechlorane Plus, and other retardants with bromine or chlorine.

Handprints - Handprints are positive impacts, or beneficial changes, on footprint-related impact categories, measured in footprint-related units (e.g., kg CO2-equivalent, for carbon handprints). An actor can get credit for a handprint if the actor is the cause of the change, and if the handprint is voluntarily caused by the actor. Changes which are required (e.g. by law) do not count as handprints; they are considered "business-as-usual" (BAU). The actor does not need to be the only cause of the change. Credit for the handprint is shared equally and fully among all parties who jointly caused the change.

Hazardous Material - Materials that have been deemed dangerous or carcinogenic for humans or the environment and require specific measures for disposal, such as asbestos, lead paint, or materials producing ionizing radiation.

Land trust - A nonprofit organization that, as all or part of its mission, actively works to conserve land by undertaking or assisting in land or conservation easement acquisition, or by its stewardship of such land or easements.

Manufacturer location - The final point of fabrication or manufacture of an assembly or building material.

Materials Construction Budget - All the material costs delivered to the site, excluding labor, soft costs, and land.

On-site landscape - The planted area is not used to comply with the requirements of Imperative 02: Urban Agriculture. The strategies implemented for each Imperative do not require to be mutually exclusive or physically separated.

Potable water - Water that is fit for human consumption.

Primary Materials: Materials that make up most of the structural components, foundation, and envelope of projects; often mostly concrete, steel, and/or wood.

Prime farmland - Land that has been used for agricultural production at some time during the four years prior to the relevant Important Farmland Map date, or in the five years prior to the project, and where the soil meets the physical and chemical criteria for Prime Farmland or Farmland of Statewide Importance as determined by the USDA Natural Resources Conservation Service (NRCS).

Pristine greenfield - Land that has not been impacted by humans and maintains a thriving viable habitat. Land that has not been developed but has been altered and degraded through ranching, monoculture agriculture, crowding, pollution, or other means is not considered a pristine greenfield for I-01 Ecology of Place purposes.

Project Area - The entire scope of the project and all areas disturbed by the project work including areas of construction, staging, and conveyance, which is typically, but not necessarily, all land within the property line.

Project water discharge - All water leaving the building including stormwater, greywater, and blackwater.

Renewable energy - Energy generated through passive solar, photovoltaics, solar thermal, wind turbines, water-powered microturbines, direct geothermal, or fuel cells powered by hydrogen generated from renewably powered electrolysis. Nuclear energy is not an acceptable form of renewable energy.

Salvaged materials - Used building materials that can be repurposed wholly in their current form or with slight refurbishment or alterations.

Sensitive ecological habitat - Habitat that is threatened, endangered, or particularly vulnerable to changes in the local ecology. Examples include wetlands, dunes, old-growth forests, and native prairies.

Stormwater - Precipitation that falls on the ground surfaces of a property.

Systems furniture - A modular furniture system that might include work surfaces, cabinetry, file systems, flexible partitions, and desk chairs used to create or furnish a series of office workspaces.

Wetland - Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

MPR – Minimum Program Requirements

IP – Integrative Process

LT – Location & Transportation

SS – Sustainable Sites

WE – Water Efficiency

EA – Energy and Atmosphere

MR – Materials and Resources

EQ – Indoor Environmental Quality

IN – Innovation

RP – Regional Priority

Regenerative building – a building that creates more resources than they use, including energy and water.

Heat island – the heating up of a site based on the heat captured in dark-colored surfaces

EPD – environmental product declaration