

CRITICAL ANALYSIS OF SUSTAINABILITY GOALS IN THE DESIGN-
GUIDE SCHEMES OF THE LEED CERTIFICATION IN RELATION TO
BIOMIMICRY AS A REGENERATIVE DESIGN APPROACH IN
ARCHITECTURE

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ABSTRACT

CRITICAL ANALYSIS OF SUSTAINABILITY GOALS IN THE DESIGN- GUIDE SCHEMES OF THE LEED CERTIFICATION IN RELATION TO BIOMIMICRY AS A REGENERATIVE DESIGN APPROACH IN ARCHITECTURE

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The severity of global warming and climate change bring ecologic thinking to the front. The construction industry is one of the main contributors to climate change, and ecological thinking offers solutions to reduce the negative effects of architecture on the environment with different design approaches like green building certification systems and nature-inspired design methods. LEED certification system has parameters based on environmental and building **generalizations** to guide designers, offering a systematic order of rules for sustainable design. The intention of generality is important yet limited at certain levels, especially when considering the natural context from a broader perspective. On the other hand, Biomimicry presents a conceptual vision for context-based design problems by focusing on particularization with holistic and multi-scalar design considerations as a regenerative design approach, aiming to correlate the diverse scales of natural context with the built environment.

This study intends to scrutinize the LEED certification system's general goals and guiding parameters in detail to disclose its limitations. It is further intended to contribute to the efficiency of the guiding parameter with a vision borrowed from Biomimicry. The conflation of the LEED parameters and application levels of Biomimicry is evaluated and discussed as sustainable and regenerative design approaches with the case studies of the Eastgate Shopping Center in Zimbabwe, the Pixel building in Australia, and the Bullitt Center in the USA. It is intended to analyze the efficiency and applicability of LEED certification and biomimicry approaches regarding architectural design parameters and biomimicry levels to clarify the basics of sustainable and regenerative design and how they can be incorporated.

Keywords: Sustainable Architecture, Regenerative Architecture, Biomimetic Design, LEED Certification, Natural Context

ÖZ

LEED SERTİFİKASYONUNUN TASARIM ŞEMALARINDAKİ SÜRDÜRÜLEBİLİRLİK HEDEFLERİNİN REJENERATİF BİR TASARIM YAKLAŞIMI OLAN BİYOMİMİKİRİ FİKİRİ İLE ELEŞTİREL ANALİZİ

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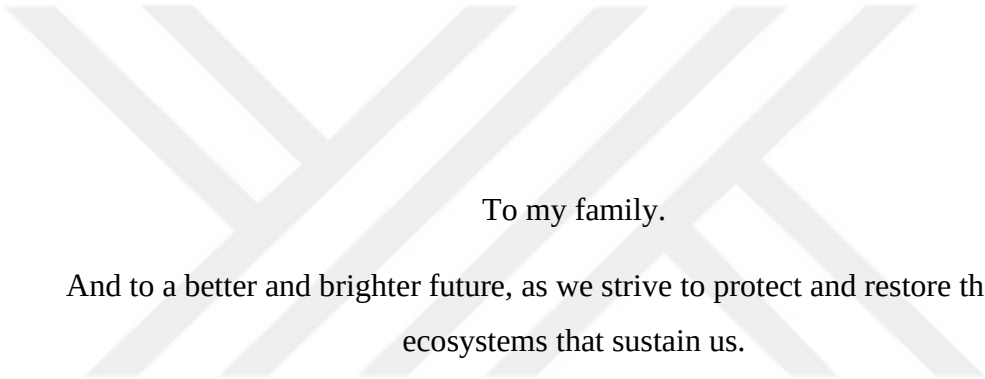
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Küresel ısınma ve iklim değışikliğı, ekolojik düşüncenin ön plana çıkarmasını sağlamıştır. İnşaat sektörünün iklim değışikliğine en çok katkıda bulunan sektörlerden biri olması ekolojik düşünce ile birlikte yeşil bina sertifika sistemleri ve doğadan ilham alan tasarım yöntemleri gibi farklı tasarım yaklaşımlarıyla mimarının çevre üzerindeki olumsuz etkilerini azaltmaya yönelik çözümler sunmaktadır. LEED sertifika sistemi, tasarımcıları yönlendirmek için çevresel ve tasarım ve inşaa genellemelerine dayanan parametrelere sahiptir ve sürdürülebilir tasarım için sistematik bir kurallar düzeni sunar. Özellikle doğal bağlamın yapılı çevre için önemi daha geniş bir perspektiften değerlendirildiğinde, sunduğı genellemeler önemli olmasına rağmen belirli düzeylerde sınırlıdır. Öte yandan Biyomimikri, doğal bağlamın farklı ölçeklerini yapılı çevre ile ilişkilendirmeyi amaçlayan rejeneratif bir tasarım yaklaşımı olarak bütüncül ve çok ölçekli tasarım düşünceleriyle özelleşmeye odaklanarak bağlam temelli tasarım sorunları için kavramsal bir vizyon sunmaktadır.

Bu çalışma, öncelikle LEED sertifikasyon sisteminin genel hedeflerini ve yol gösterici parametrelerini detaylı bir şekilde inceleyerek sınırlılıklarını ortaya koymayı amaçlamaktadır. Ayrıca, biyomimikriden ödünç alınan bir vizyonla yol

gösterici parametrelerin etkinliğine katkıda bulunmak amaçlanmaktadır. LEED parametreleri ile biyomimikrinin uygulama seviyelerinin bir araya getirilmesi, Zimbabve'deki Eastgate Alışveriş Merkezi, Avustralya'daki Pixel ve Amerika'daki The Bullitt Center örnek çalışmaları ile sürdürülebilir ve rejeneratif tasarım yaklaşımları olarak değerlendirilmekte ve tartışılmaktadır. LEED sertifikası ve biyomimikri yaklaşımlarının verimliliğini ve uygulanabilirliğini, mimari tasarım parametrelerine ve biyomimikri seviyelerine atıfta bulunarak analiz etmek ve sürdürülebilir ve rejeneratif tasarım temellerini açıklığa kavuşturmak amaçlanmıştır.

Anahtar Kelimeler: Sürdürülebilir Mimarlık, Rejeneratif Mimarlık, Biyomimikri, LEED Sertifikası, Bağlam



To my family.

And to a better and brighter future, as we strive to protect and restore the fragile
ecosystems that sustain us.

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LIST OF ABBREVIATIONS

ASGB	Assessment Standard for Green Buildings
BD+C	Building Design and Construction
BID	Biologically inspired design
BREEAM	Building Research Establishment's Environmental Assessment Method
EA	Energy and atmosphere
EDGE	Excellence in Design for Greater Efficiencies
EQ	Environmental quality
ESG	Environmental, social and governance
GB	Green Building
GBRS	Green Building Rating System
GS	Green Star
ID	Innovation and design
ID+C	Interior Design and Construction
IEA	International Energy Agency
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
MA	Millennium Ecosystem Assessment
ND	Neighborhood Development
O+M	Operations and Maintenance
SS	Sustainable sites
UNBC	United Nations Brundtland Commission
USGBC	Green Building Council
WE	Water efficiency

CHAPTER 1

INTRODUCTION

1.1 Background: Climate Change, Sustainability and Regeneration

“Climate change is a threat to human well-being and planetary health. There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all.”

- IPCC AR6 Synthesis Report 2023

Mentioned strongly in the latest *Climate Change 2023 Synthesis Report*, “unsustainable energy use, land use, and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals” contribute to climate change globally in a rapid pace despite warnings and efforts to raise awareness. (IPCC, 2023) The world warns us of the changes that affect our daily life and that we get used to because their effects progress slowly. While we face these warnings as climate change, famine, increase in population, economic crises, pandemics, and natural disasters, we continue to contribute to these factors with increased rates of consumption and industrialization. 2018 was an important year as the awareness of the negative impacts increased, and some steps were taken to take action on this issue. The United Nations published a special report on the effects of global warming in the Intergovernmental Panel on Climate Change (IPCC) in 2018. The report revealed that humans had caused 1.5°C global warming since the industrial revolution and emphasized the importance of the measures that need to be taken to overcome this problem. (United Nations, 2018) Before the report, some measures regarding the human-made effects on nature were realized in society; however, as these effects became more evident, the consciousness of environmental impacts brought along the idea of *ecological*

*thinking*¹ in every aspect of daily life. With the increasing awareness of ecological thinking, concepts such as *ecology*², *sustainability*, and *regeneration* began to gain importance. To build upon these concepts and their methods understanding of ecology and its systems is crucial.

*Ecology*³ is a system of complex patterns with the scope of habitat, population, community, and ecosystem. (Bilgin & Zeydan, 2019) The term started to be used in the 19th century, and different theoretical practices began to be developed in the 20th century. (Sarkar & Elliott-Graves, 2016) From the first definition to the current biological definition, throughout the history of ecology, different approaches and interpretations have been made about the scope of ecology, from the organism to the structure and function of ecosystems. Singularity, diversity, stability, and nature are essential concepts in the definition of ecology. (Wagg et al., 2022) The history of ecology started with Herodotus in 480 BC with the "balance of nature" concept; in 1869, Ernst Haeckel - a German zoologist – put forward the term ecology. The idea and the definition developed and changed with Ellen Swallow Richards, F. and E. Clements. Following them, Arthur Tansley, an English botanist, came up with the concept of the ecosystem in 1935. (Bilgin & Zeydan, 2019) Tansleys' introduction of his idea of an ecosystem brought a more comprehensive and holistic understanding from the organism level to the ecosystem level. (Evans, 1976) This transition from singular to whole inspired studies based on ecology and biology in design. (Mang & Reed, 2020)

The concept of ecosystem helped the definition of ecology accepted today, introduced in 1953 by Eugene Odum in his text *Introduction to Ecology* as the

¹ Reed and Lister define the understanding of *ecological thinking* as a “dynamic, systematic change and the related phenomena of adaptability, resilience, and flexibility” for decision-making. (C. Reed & Lister, 2014) The definition and interpretation of *ecology* have importance in ecological thinking as it can be interpreted to address a larger scale and broader context.

² *Ecology* is the study of relationships that investigates organisms, their interactions, and the environment. (Merriam-Webster, n.d.-c)

³ The etymology of the word comes from Ancient Greek, and it is a combination of the words -oikos (οἶκος) and -logos (-λογία), which translates as the study of house/household. (Britannica, 2023)

structure and function of ecosystems. (Golley, 2019) It is a group of living and non-living organisms together, which can be in different scales and sizes. (Odum & Barret, 2004) That means the environmental factors and physical surroundings are also a part of the ecosystem. Everything in an ecosystem is connected, so each change or activity will affect another organism or element that is contained in the ecosystem. Organisms exist in a hierarchical order with each other, which is the hierarchy of ecological levels. The ecosystem stands in the fourth level between community and biosphere, comprising community -populations that live in a designated area- and its non-living surroundings. (National Geographic, 2022)

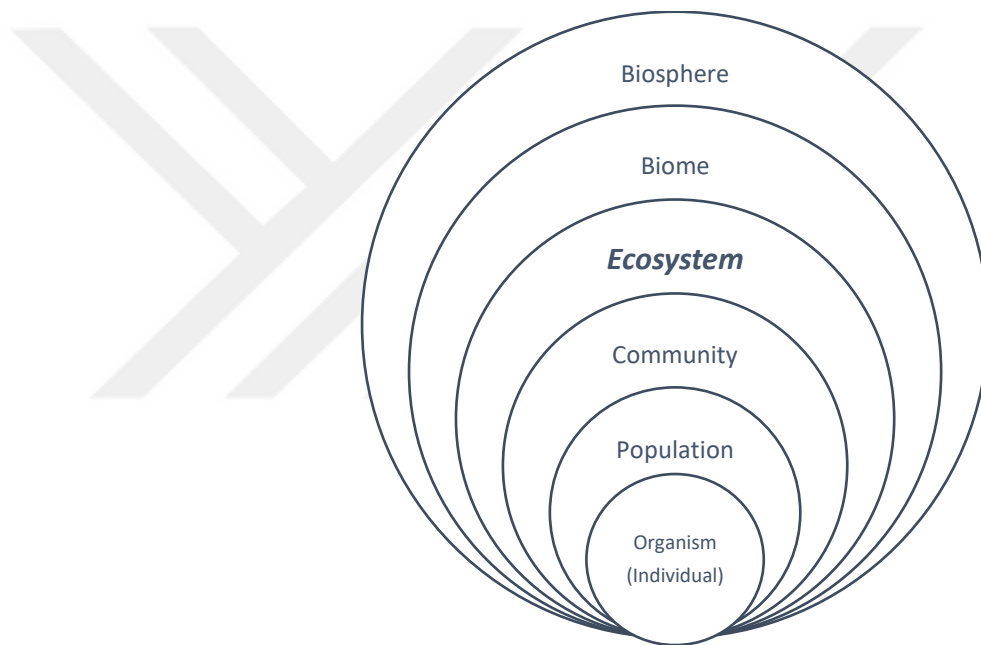


Figure 1.1. The ecological hierarchy

The definition of these systems of living and non-living organisms and their hierarchical order influenced design in many ways as a source of inspiration for new ideas from science and ecology. (Eshkol, 2023) Thinking beyond forms and considering environmental and ecological impacts is the responsibility of designers. (Margolin, 1998) Orr mentioned, *"Design is not just about how we make things, but rather how we make things that fit harmoniously in an ecological, cultural, and*

moral context." He proposed that architecture and ecology should be intertwined as they all are about systems, patterns, and connections. (Orr, 2001) When we think of ecology and architecture as a whole formed by living and non-living organisms, we can interpret buildings as non-living organisms, the people living in these buildings, and the natural environment as living organisms. While our built environments form a whole by integrating different functions in a hierarchical structure, the harmony of this whole with ecology and its effects can be questioned. (Eshkol, 2023)

The building and construction industry is one of the significant contributors to climate change. According to the International Energy Agency's (IEA) Global Status Report for Buildings and Construction (2019), the building and construction industry contributes 40% of global energy-related carbon emissions worldwide. (International Energy Agency, 2019) **Sustainable** and **regenerative design** have emerged as methods essential in mitigating these damages and reducing harmful impacts.

Sustainability means *"capable of being sustained"* or *"of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged."* (Merriam-Webster, n.d.-d) The concept of sustainability was first mentioned in Our Common Future report in 1987 by the United Nations World Commission on Environment and Development, which is also known as Brundtland Commission, as a *"development which meets the needs of the present without compromising the ability of future generations to meet their own needs."* (United Nations, 1987) Following that, the term was developed under the concept of eco-development in the World Environmental Conference Report in Stockholm in 1972. Herewith, other terms like *'green,' 'ecological,'* and *'environment-friendly'* have been used in the same manner as the term sustainable. (United Nations, 1972) United Nations maintains the exact definition in its Sustainable Development Goals for the 2030 Agenda, addressed in 17 goals. (United Nations, n.d.-b) Sustainability is a very comprehensive idea with many varying definitions and interpretations from

*environmental*⁴, *economic*⁵, *social sustainability*⁶ and *sustainable design*; it aims to keep the balance between the environment, economy, and society. (Khan & Sahabuddin, 2022) Another definition emphasizes not affecting future generations' ability to realize their demands while satisfying the current needs as “...*the process of living within the limits of available physical, natural and social resources in ways that allow the living systems in which humans are embedded to thrive in perpetuity.*” (United Nations, n.d.-a; University of Alberta, n.d.)

Sustainable design also tries to imply the principles of sustainability in to design processes while “*continuing, surviving, thriving and adapting*”. (Williams, 2007) The basic principle of sustainable design is to minimize or eliminate the negative impacts caused by design on nature and the environment, like decreasing fossil-fuel consumption and diminishing contamination. (Bergman, 2012) Sustainable design also enhances healthy and constructive environment. With a similar approach **sustainable architecture** also tries to minimize its impact on the environment and promotes efficiency. While building the new environments, it seeks to keep the balance in the nature with minimal deformations. (B. Reed, 2007)

As there are several approaches to sustainability, sustainable design and sustainable architecture also have varying interpretations. Since it is a constantly evolving and transforming subject with technological advancement and improvement, the terms and definitions of sustainable design and sustainable architecture change too. (Khan & Sahabuddin, 2022) Sustainable design, initiatives on sustainable architecture and studies on the subject paved the way for different approaches and ideas, such as *green, bioinspired, ecological, and regenerative design*. Green building certification systems and assessment tools are one of the approaches toward sustainable and green

⁴ *Environmental sustainability*; maintaining the consumption and production rate while allowing natural resource regeneration. (University of Alberta, 2013)

⁵ *Economic sustainability*; satisfying the needs of human communities while having financial independence. (University of Alberta, 2013)

⁶ *Social sustainability*; cultivating a healthy, secure, and fair environment for people, where necessities and rights for living can be accessed easily. (University of Alberta, 2013)

design and architecture. They aim to improve performance of buildings and decrease the negative impacts on nature and environment they create with systemized assessment of the environmental performances of buildings. (Cordero et al., 2019)

In addition to sustainable design and architecture, another conscious design approach is **regenerative design**. Regenerative design goes beyond reducing negative environmental impacts and aims for positive environmental benefits. (Jenkin & Zari, 2009) This approach aims to find solutions to problems by understanding the systems of nature without affecting them. Along the lines of regenerative design, **regenerative architecture** also aims minimum environmental impacts while seeing nature as a tool and initiator for design with two approaches; either focusing on contributing to nature or seeing the natural environment as an input. (Littman, 2014; Mang & Reed, 2020; B. Reed, 2007) Understanding natural systems (organisms and ecosystems) is important for the regenerative approach because they are models and examples of efficient and environmentally working systems. (B. Reed, 2007; Zari, 2018) Nature-inspired design or biologically inspired (BID) design approaches are some that influence from natural systems and use them as models or design strategies. One of these approaches, **biomimicry**, is the mimicking of organisms and ecosystems and their systems and functions as a source of design inspiration. It is a regenerative design approach with a basis of understanding and emulating nature and its systems. (Zari, 2018)

All these architectural and design approaches and concerns that affect the environment and nature have a place, the natural environment, organisms, and ecosystems in common and form **the context**⁷. The context, which constitutes living and non-living things in the entire built or unbuilt environment and our social and economic environment, can be seen as an input when we look at all sustainable and

⁷ Context is "the interrelated conditions in which something exists or occurs ENVIRONMENT, SETTING." The word's etymology comes from the Latin phrase *contextus*, which means; *coherence, to weave together*. (Merriam-Webster, n.d.-a)

regenerative design approaches. All living things and their urban environment exist within ecosystems, so context has a direct relation with ecology and nature. (Zari, 2018) This interrelation creates the contextual qualities of a place. Ken Yeang, one of the pioneering architects of ecologic architecture, states that; *"Master planning starts with an assessment of the ecology of the site and its context; we need to know what is there before we can insert anything new."* (Yeang, 2009) In this study, context refers to the natural context of a specified area. It is considered the ecology of the site and nature, adapted from the definitions of Ken Yeang.

1.2 Problem Definition

Climate change has been a concern for our future since the effects can be experienced daily. It affects our living environment, our health, and our food production; nonetheless, our future. According to the United Nations climate action definition, humankind, especially fossil fuels, has the primary accelerator role in climate change. Although the construction industry is not the only major decisive factor, it contributes circumlocutorily by reducing green lands and forests with built grounds and carbon emissions. (United Nations, n.d.-c) Ecological thinking and sustainable architecture have emerged as an idea that offers methods towards a better future as a significant step at this point and present methods to reduce the adverse effects of architecture on nature and the environment.

The increase in profit-based demands, mainly caused by mass housing and unplanned urbanization in architecture, negatively impacted the built and natural environment and cities. As an evaluation and incentive mechanism, which can be interpreted as a criticism, green building certification systems have become widespread. The certification system - Leadership in Energy and Environmental Design (LEED) has parameters that consider the environmental, social, and economic impacts of a building. LEED primarily focuses on environmental factors, promoting water and energy efficiency, renewable resources, reduction in CO²

emissions, and a healthy climate, and it established a way of promoting sustainability through public awareness. (U.S. Green Building Council, 2023b; Wheeler, 2022)

The structured framework and systematic order of rules LEED certification offers are formulated as general goals to lead the designers with guiding schemas to achieve sustainable solutions. The intention of these generalizations is fundamental yet remains limited at certain levels and has room for improvement, especially when considering context-based architectural issues from a broader perspective. Referring to the ecological relationship between the natural and built environment, the architectural design process requires more particularization and multi-scalar and holistic design considerations rather than generalizations.

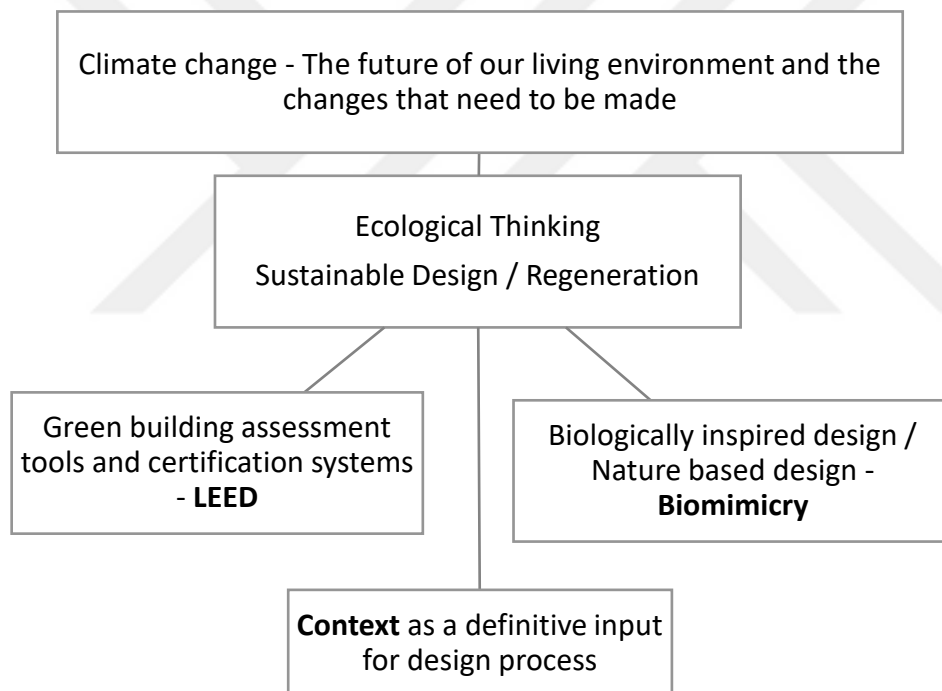


Figure 1.2. Process of problem definition

At this point, alternatives can be explored and proposed to contribute to continuous updates for developing and improving these systems or instead to adopt different design approaches and strategies. With different approaches, the design process can be improved, and its applicability in architecture can be increased with alternative solutions while the deficiencies are better identified. Instead of aiming for neutral

impacts, positive contributions to the natural environment can be achieved with biologically inspired and nature-based design, like biomimicry, as a regenerative design approach to overcome the limitations of sustainable design incentives.

1.3 Aim of the Study and Research Questions

The study first aims to understand the definitions and importance of sustainable and ecological design that have emerged with climate change. It will then present the current definitions of ecological thinking and sustainable architecture, the different design approaches, evaluation schemes, and methodologies that have emerged with these concepts. Green building certification systems, particularly the LEED certification system⁸, will be introduced, and the certificates' general objectives and design guideline schemes will be examined in detail. Then, biomimicry, a regenerative design approach that differs from these systems, will be proposed, and its application methods in architectural design will be examined. It is further intended to contribute to the effectiveness of these guideline schemes with a vision borrowed from biomimicry.

It also aims to contribute to the perception and process of context-based design by integrating the guiding steps of these approaches and bringing a more holistic and comprehensive understanding to contribute to the positive transformation of the built environment by creating an awareness that can be comprehended in concept and application design projects with regenerative design solutions. While LEED certification approaches the problem of sustainability with a generalist approach, the relationship of architectural design with the natural and built environment will be examined through the vision of biomimicry, with a more holistic and multi-scalar

⁸ LEED certification was selected for this research after researching green building certification systems worldwide. LEED certification is one of the most widely used and recognized systems worldwide, especially in Turkey. It is a leading system with its accreditation process, open-source sharing, different and the variety and number of certified buildings.

design understanding. In order to compare the differences and similarities between LEED certification and biomimetic approach, case studies of LEED-awarded and biomimicry-designed buildings will be compared.

The questions intended to be answered in this study are addressed below;

- *As a design incentive, do green building certification systems, and LEED certification in particular, provide us with sufficient outcomes in terms of sustainable design goals?*
- *Can Biomimicry be considered as design approach for more inclusive and sustainable built environments? And can Biomimetic design principles be a foundation and benchmark for architectural design?*
- *In the scope of LEED certification and Biomimicry, what is the importance of context in sustainable and regenerative architecture?*
- *What are the common strategic principles of LEED certification and biomimicry? Is it possible to integrate two approaches to develop shared frameworks and guidelines for design?*

1.4 Methodology of the Study

Nature is at the core of sustainable, ecological, biologically inspired design (BID). However, these concepts -especially sustainability- have very broad and interdisciplinary approaches and scopes. This study is focused on the built environment and context as a prominent design factor while searching for the similarities and differences between the biomimetic design approach and LEED certification systems guides and assessment points from a sustainability and regeneration framework.

The methodology of this study is analytical and conceptual evaluation. Two types of approaches will be included; LEED certification and biomimetic design. LEED certification system uses parameters mainly based on generalizations about construction, design, and materials, in order to promote sustainable design in

architecture. However, it has its own drawbacks in limitations of criteria and dealing with context-based architectural design problems. On the other hand, biomimicry presents a conceptual vision for context-based design problems by focusing on particularization and multi-scalar design considerations.

The sustainability goals, and, setbacks and limitations of LEED certification criteria will be analyzed and evaluated in relation to the regenerative approach and conceptual basis of biomimetic architecture. Furthermore, a diagrammatic comparison internalizing the concepts of both approaches with context in consideration will be proposed, and accordingly, a comparative case study with three examples of; the Eastgate Shopping Center in Zimbabwe designed by Mick Pearce, the Pixel in Australia designed by studio 505, and the Bullitt Center in USA designed by Miller Hull, is going to be held to understand the practical representation of these different approaches and their common grounds.

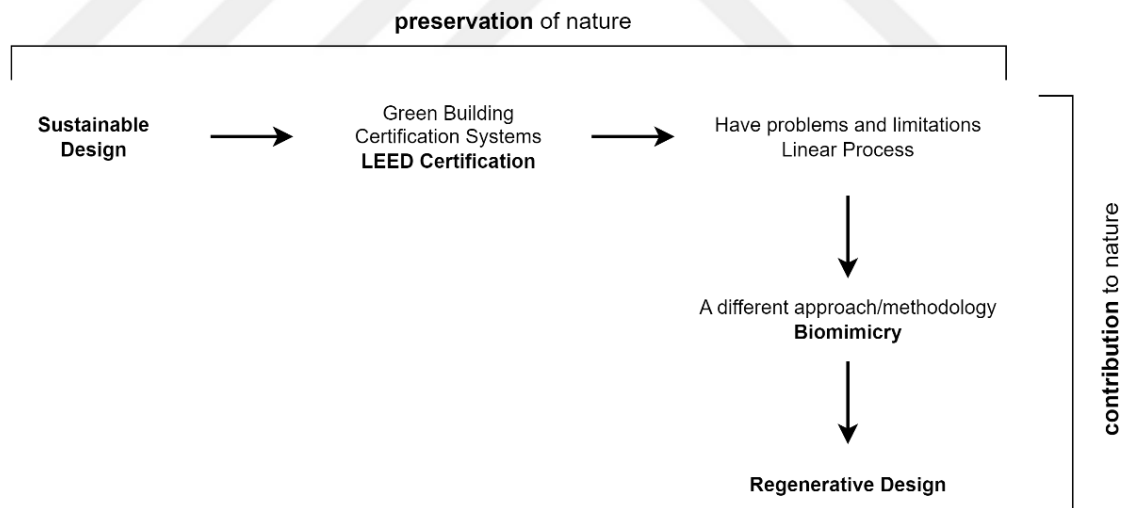


Figure 1.3. Sustainable Design to Regenerative Design approach diagram

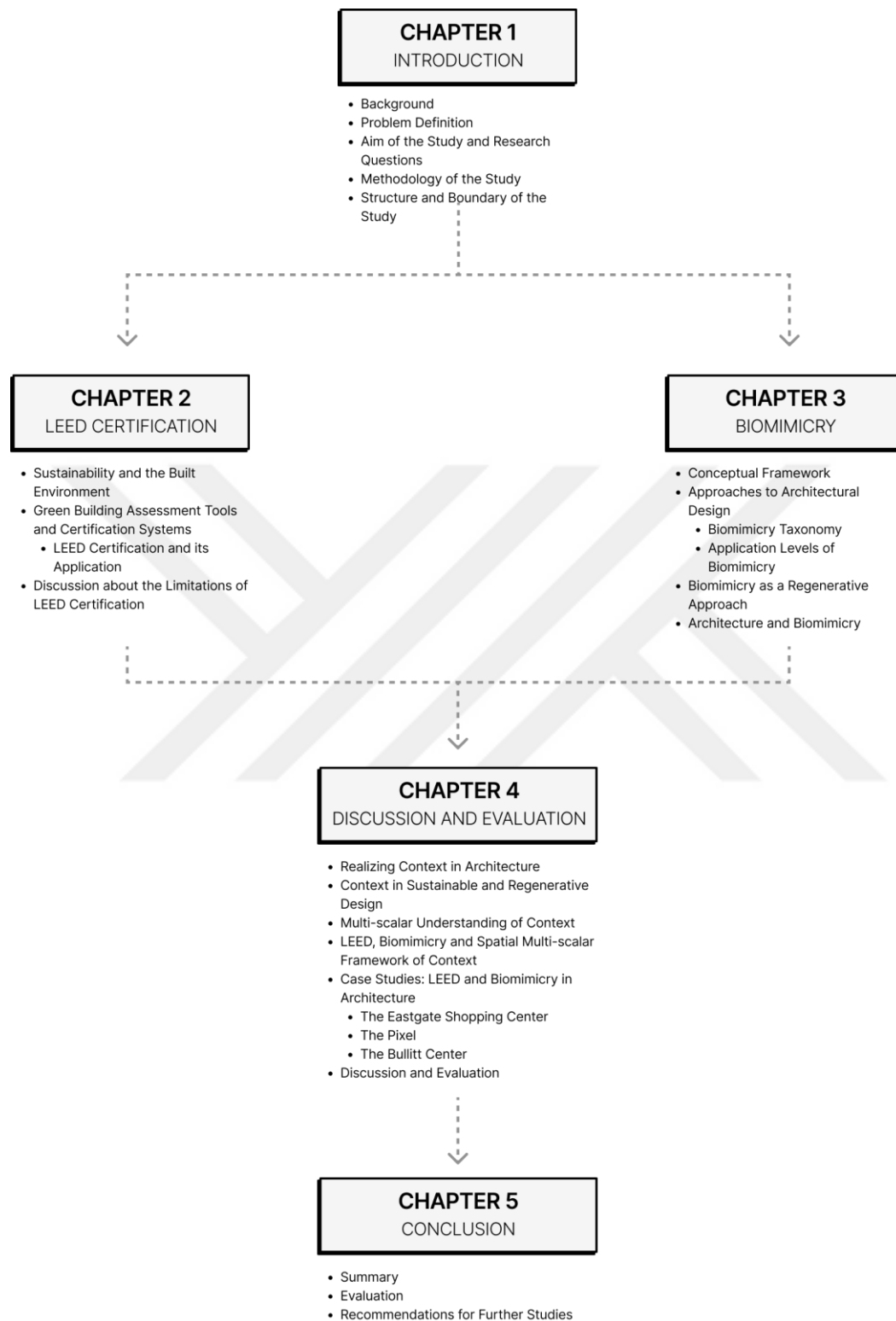


Figure 1.4. Thesis structure diagram

1.5 Structure and Boundary of the Study

This thesis is consisting of six chapters. In these chapters conflation of LEED certification and biomimicry will be discussed in the framework of context-based sustainability goals and architectural design-guide schemes of the certification system of LEED certification in relation to the concept of biomimicry in architecture.

- The **first chapter** begins with the background information and problem definition. In addition, aim of the study and methodology are explained along with the structure of the thesis in this section.
- The **second chapter** introduces the sustainable building systems and current assessment tools available, then focuses on the LEED certification system as a leading, globally recognized and adopted green building certification system. In this context, LEED certifications' specifications, related literature and discussions about LEED's guideline and limitations are presented.
- The **third chapter** explains the concept of biomimicry and biomimetic architecture as a regenerative design approach. In this respect, this chapter will elaborate on the conceptual framework of biomimicry and introduces architectural design approaches of biomimicry. Biomimicry taxonomy and levels of biomimicry will be presented. Furthermore, applicability of these approaches to architectural design and discussion regarding application levels of biomimicry will be included.
- The **fourth chapter** throws light on context as a determining factor for discussing sustainable and regenerative design in the framework of LEED certification and biomimicry. After introducing the importance of context, the chapter will present a framework to analyze and compare the case studies in terms of LEED certification criteria and application levels of biomimicry based on context, and follow with case studies and discussion.
- The **fifth chapter** will include the conclusion. Moreover, along with the possible study ideas for future, this chapter will try to offer the inclusion of

biomimicry-based design approaches in the goals and criteria of LEED Certification as a regenerative design approach.



CHAPTER 2

LITERATURE REVIEW ON LEED CERTIFICATION: CURRENT DEFINITIONS, ASSESSMENT SCHEMES AND METHODS

2.1 Sustainability and the Built Environment

The *built environment*⁹ is critical in shaping our world and future. However, our built environment is also responsible for a significant portion of the world's energy consumption, greenhouse gas emissions, and resource depletion. As concerns about the built environment's impact on the natural environment and human health grow exponentially with climate change and resource scarcity, sustainability becomes an increasingly important consideration in architecture. Sustainable design and construction practices can minimize the environmental impact of buildings and infrastructure while creating healthier, more livable communities. (B. Reed, 2007) In this context, sustainability and the built environment have become increasingly intertwined as architects, designers, builders, and policymakers seek to create a more sustainable future.

Architecture plays a significant role in shaping the natural environment as it involves creating and designing semi-permanent or long-lasting built structures. As such, it is imperative to continuously reassess each design's environmental performance and impact in terms of its long-term consequences on nature, social, and economic factors.

⁹ *The built environment*: includes all the construction, architecture, and infrastructure in the world, characterized as man-made, not found in the natural environment by itself. As Ken Yeang mentions in his 2016 interview with C. Abdi Güzer, "*There is built environment which is architecture, and there is the natural environment which is ecology.*" (Yeang & Güzer, 2016)

“Man is the most polluting creature in nature. It is also the only species capable of planning and managing its own future..” -Ken Yeang.

Ken Yeang highlights the dual nature of humanity's impact on the environment and our potential to influence our future positively. (Hart & Littlefield, 2011) In the context of sustainable architecture, this quote implies that while our built environment may have negative impacts on the environment, we have the capability to design and construct buildings in ways that minimize these impacts and promote a sustainable future. It is up to architects, designers, and building professionals to utilize their planning and management skills to create environmentally responsible and sustainable buildings. Various approaches can be employed to evaluate and improve the environmental sustainability of both existing and future architecture to achieve innovative building design approaches that prioritize environmental and social responsibility. Based on this idea, with the recognition of the significant environmental impacts of buildings, green building assessment tools and certification systems began to emerge in the 90s. (Goubran et al., 2023)

2.2 Green Building (GB) Assessment Tools and Certification Systems

The relationship between architecture and the environment is essential in sustainable design. The environmental performance and impact of each design and its social and economic effects should be considered when creating and designing the built environment. Different approaches can minimize the built environment's negative impacts and promote sustainability when designing and constructing buildings. These approaches can manifest themselves differently and be applied to buildings at different stages.

Achieving sustainable design in architecture requires different tools, techniques, and systematic schemes for assessing the performance of a building. Green building assessment tools and certification systems provide action plans and long-term goals based on social, environmental, and economic factors for different functions in

various locations worldwide and have become increasingly important in sustainable design and construction. (Krajangsri & Pongpeng, 2018)

The early ideas behind green building assessment tools and certification systems were primarily to create a framework that could be applied to design and construction. This framework is intended to assess and benchmark the environmental performance of buildings, encourage the implementation of sustainable design and construction practices, and promote the development of healthier and more efficient built environments. (Illankoon et al., 2019) In light of increasing environmental awareness and technological advances, these tools and systems aim to draw attention to the impacts of the built environment on the natural environment, such as energy use, greenhouse gas emissions, water consumption, and waste generation, while at the same time enabling occupants, designers, and investors to act on sustainability. It also aims to create a comparable uniform approach that encourages improvement and guides the construction and design process. (Bernardi et al., 2017; Ding, 2008; Ferreira et al., 2023)

Since the 90s, different certification systems and assessment tools have been created in various world regions. Certification systems, in particular, have gained widespread recognition and acceptance by demonstrating a building's sustainability levels to stakeholders as a prestige indicator. Different tools and systems have been developed to adapt to different building types and designs according to the changing needs, environments, and regions. This diversity is also essential to adapt to environmental, social, and economic contexts and to be authentic. However, due to the various numbers of these tools and systems, each with different scope, considerations, and adaptability, it can be challenging to identify which is most suitable, effective, and beneficial for a particular project. (Krajangsri & Pongpeng, 2018) Different classifications, improvements, and numbers of these systems and tools have been in the works of different professionals to overcome this challenge. (Appendix.A) In the figure below (Figure 2.1), the locations of different systems are shown on a world map, and it is possible to see different regionally specified systems established in different locations, especially in European and Asian countries.

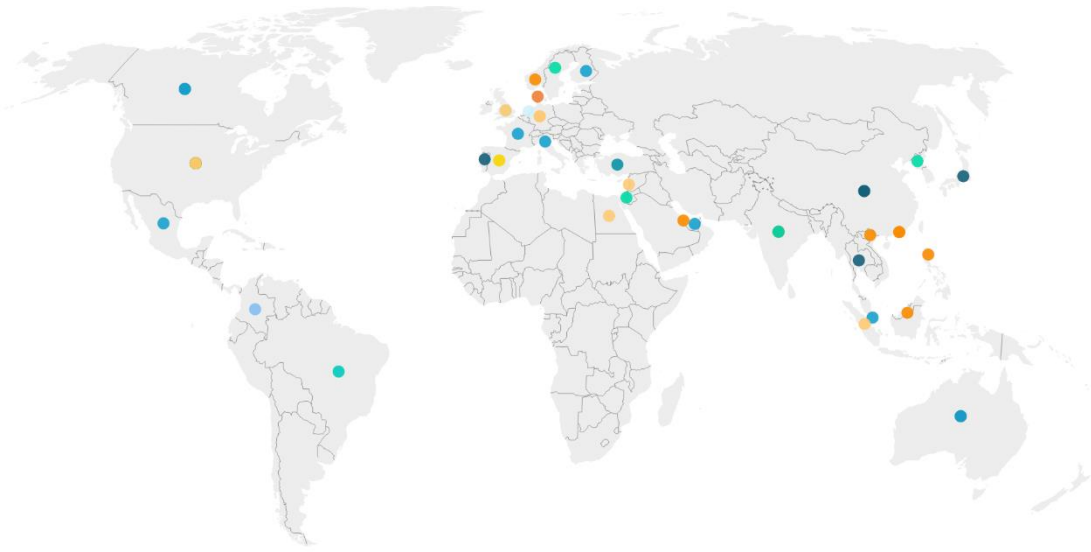


Figure 2.1. Locations of green building certification systems and assessment tools in the world¹⁰

2.2.1 Types of Green Building Assessment Tools and Certification Systems

Industrialization caused an energy crisis, and the environmental movement in the 1960s led to the *green building*¹¹ (GB) movement with the development of green buildings and research in energy-efficient and environmentally friendly building practices. (Mao et al., 2009) Green buildings define and require different characteristics, each with unique regional, cultural, sociological, environmental, and economic drivers according to different locations and countries. (Tokede et al., 2022) *Green buildings'* definitions include buildings that are sensitive to the environment

¹⁰ Graph generated from the data gathered from *Appendix A*

¹¹ *Green building*, defined by USGBC, is a holistic concept that seeks to reduce the negative impacts and increase the positive impacts of a building on the natural environment throughout its life cycle. Energy and water use, environmental quality, material and resource usage, and environmental impacts are critical considerations in green buildings. (U.S. Green Building Council, 2022c)

and resources throughout their life cycle and aim to reduce or eliminate negative environmental impacts. In addition, the welfare and health of building occupants, improvement of human life, material and energy use, and sensitivity and adaptation to the local environment are among the prominent elements in the definition of green buildings. Especially in Europe and the UK, protecting and respecting the natural environment and contributing to it is very important in green building. (Cordero et al., 2019; Yudelso, 2009)

In 1990 the first green building system Building Research Establishment's Environmental Assessment Method (BREEAM)¹², was developed by Building Research Establishment (BRE) in the UK. Following that, in 1992, The Earth Summit¹³ took place in Rio de Janeiro, Brazil, with efforts to raise attention to environmental issues and sustainable development. (Zhang et al., 2019) These developments have raised the awareness of governments in many countries and led to the development of different assessment tools. BREEAM was established to increase the sustainable design and production of buildings. Its aims are defined as achieving environmental, social, and corporate governance (ESG), health, and net zero goals by BRE. (BRE Group, 2022) Apart from pioneering other systems, its contribution to green buildings is also significant. (Ferreira et al., 2023) Subsequently, more than forty green building rating systems have emerged, and their number continues to increase. Following BREEAM, Leadership in Energy and Environmental Design (LEED) was first pilot tested by the US Green Building Council (USGBC) in 1998. LEED was created to evaluate and improve the environmental performance of buildings and has become one of the world's most

¹² BREEAM is a science-based certification system for sustainable building development, established in 1990 by BRE (Building Research Establishment), a profit-for-purpose organization in the UK. The certification aims to improve building performance through every building stage, from construction to use, to improve performance, achieve environmental, social, and governance goals, and create sustainable net-zero living environments. The assessment tool consists of six categories; *new construction, in-use, refurbishment and fit-out, communities, BREEAM infrastructure, and home quality mark*. (BRE Group, n.d.)

¹³ Also known as the United Nations Conference on Environment and Development (UNCED)

widely used green building rating systems. (Illankoon et al., 2019) After these first examples of green building systems, different rating systems were developed in different regions according to national and local requirements. A group of systems such as Green Star, CASBEE (Comprehensive Assessment System for Built Environment Efficiency), Green Globes and Edge (Excellence in Design for Greater Efficiencies) address broader sustainability issues and emphasize sustainable design with energy efficiency and environmental concerns. (Zhang et al., 2019) Established in 2003 by the Green Building Council of Australia (GBCA), Green Star¹⁴ follows in the footsteps of BREEAM, focusing on building lifecycle impacts and categories such as energy, water, indoor environment, materials, land use, ecology, emissions, and innovation. (Green Building Council of Australia, 2023) CASBEE¹⁵, part of the Japan Sustainable Building Commission, is based on sustainability issues in Japan and Asia and draws attention to air pollution, one of the biggest problems in this geography since its establishment in 2001. Energy, water, materials, indoor environment, pollution, and ecology are among the categories of this system. (Japan Sustainable Building Consortium, n.d.) Another system influenced by BREEAM and LEED criteria is Green Globes¹⁶, developed in 2000 in the United States and Canada. (Green Building Initiative, 2022) The system is mainly preferred in North America,

¹⁴ Green Star has five certification categories; *Green Star Buildings* for all building types and functions assessing environmental performance, material and resource use, and occupant wellbeing, *Green Star Homes* for residential buildings and houses assessing occupant wellbeing, health, resilience, and energy performance, *Green Star Interiors* for interior with different functions assessing the performance, efficiency, and occupant wellbeing and comfort, *Green Star Performance* for existing buildings to assess and improve efficiency, and lastly *Green Star Communities* for neighborhoods and communities to enhance sustainability. (Green Building Council of Australia, n.d.)

¹⁵ CASBEE certification divides its categories into three scales and four classifications in total. *City scale: CASBEE-City*, *urban scale: CASBEE-Urban Development*, and *housing and building scale: CASBEE-Housing* and *CASBEE-Building*. The assessment process includes the design process, pre-design, design, and post-design within the building lifecycle, focusing on environmental performance and quality, efficiency, and occupant comfort. (CASBEE, n.d.)

¹⁶ Green Globes differs from other certification systems with its self-assessment process. It aims to improve environmental and building performance but focuses more on occupants and their well-being. It is eligible for four types of buildings; commercial, institutional, residential, and existing; however, these buildings must be occupied to be certified. (UGreen, 2023)

offering ease of use, implementation, and in-depth sustainable solutions. Finally, Edge¹⁷ is a system focusing on cost-effective options for green design in the context of the local climate and is part of the International Finance Corporation (IFC) since 2013. (EDGE, 2023)

Considering there are different systems, there have been many types of research comparing and analyzing these systems. In their study, He, Kvan, Liu, and Li (2018) compare three certificates from America, Australia, and China that assess the buildings' sustainability. They compare Assessment Standard for Green Buildings (ASGB), Leadership in Energy and Environmental Design (LEED), and Green Star (GS) with a case study by analyzing the Melbourne School of Design building according to performance and design schemes to differentiate the *criteria-based* and *life cycle assessment* (LCA) ¹⁸ tools. They emphasize that green design and green building rating systems are interrelated and they categorize LEED and ASGB as design-guide schemes and GS as a performance-oriented certificate. (He et al., 2018)

These systems all assess green architecture and sustainability in their own criteria differing according to their political, geographical, and local inputs. Turkey has launched its own green building certification ÇEDBİK¹⁹ (Çevre Dostu Yeşil Binalar Derneği) in 2007. Although the association cooperates with systems such as BREEAM, LEED, EDGE, and DGNB, it has also worked to create its own system. It has listed its goals as reflecting environmental awareness and supporting conscious

¹⁷ EDGE offers three certification levels, *Level 1: EDGE Certified*, *Level 2: EDGE Advanced*, and *Level 3: Zero Carbon*, and applicable for various building types; *homes, hospitality, offices, hospitals, retail, warehouses, light industry, and education*. It focuses mainly on energy and water savings and material performances. (EDGE, n.d.)

¹⁸ *Life Cycle Assessment* (LCA) tools evaluate the whole life cycle of a building according to its environmental impacts. (Dhopade et al., 2023)

¹⁹ ÇEDBİKs certification B.E.S.T. aims to promote healthy, livable environments and communities with improved and efficient building standards. It is applicable only to new residential buildings. The evaluation has nine categories; *Integrated Green Project Management, Land Use, Water Efficiency, Energy Efficiency, Health and Well-being, Material and Resources, Residential Life, Operation and Maintenance*, and *Innovation*. Similar to LEED certification, it has four levels *certified, good, very good, and excellent*. (ÇEDBİK, 2019)

production while adapting existing certification systems to Turkey's local and regional forms of construction and design. (ÇEDBİK, n.d.) As a locally established system with regional specializations, ÇEDBİKs assessment certification B.E.S.T. (Ecological and Sustainable Design in Buildings) is inspired by other systems²⁰ but is mainly considered to be adapted from BREEAM. (Zarghami & Fatourehchi, 2020)

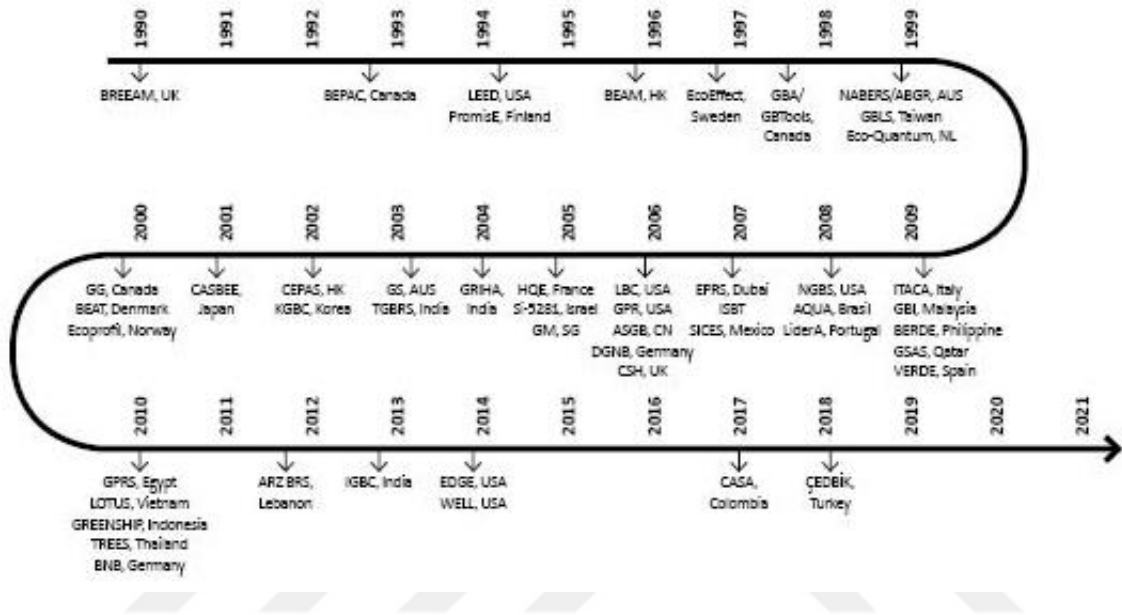


Figure 2.2. Green building rating systems and certifications timeline

In his book “Reinventing Green Building” Jerry Yudelson, the American author and environmentalist focused on the long-term impacts of urbanization on climate change and environment and showed the first 25 years of green building rating systems with an aim to raising awareness about the functioning of green building systems. (Yudelson, 2016) In the above graphic it is possible to see, many countries have attempted to assess buildings to reduce the damage caused by the built environment to nature and raise awareness over the years. However, the fact that they could not be united in a common denominator and polytheism raises different

²⁰ LEED, BREEAM, DGNB, and EDGE certifications

questions. It is normal to have different specialized criteria for each region and different requirements for each building culture. However, it is also possible that a unifying and more flexible, adaptive structure will create a more collective consciousness on this issue. Although there are many certification and assessment systems, the most popular, recognized, and widespread rating system in Turkey and the world is LEED Certification System. (Shad et al., 2017) Because it is the most common system, it sets standards in the industry and acts as an example for new systems. (Vosoughkhosravi et al., 2022) One of the most significant features distinguishing LEED from other systems is that it better identifies the inadequacies of criteria with examples that arise due to the variety of use and expands its scope by making continuous updates and revisions to prevent this and keep up with technological developments. Although it does not cover all building types that other systems do, LEED was established in the US, and the target audience and the market are other factors of widespread usage and credibility. (Bernardi et al., 2017) This popularity and recognition in the market has also caused it to be seen as a prestige by stakeholders, resulting in LEED certification coming to the forefront compared to other systems.

2.2.1.1 LEED (Leadership in Energy and Environmental Design) Certification and Its Application

LEED, or Leadership in Energy and Environmental Design, is a green building rating system with over 93,000 registered and certified projects from 160 countries for over 18 years, which takes up more than 1,7 billion square meters of space.²¹ It was established in 1998 by the non-profit organization US Green Building Council (USGBC). It aims to provide criteria to promote and encourage green building by all means and be updated throughout the years to ensure achievability and leadership

²¹ USGBCs' declaration, including all types of rating systems of LEED (LEED v4.1 BUILDING DESIGN AND CONSTRUCTION 2022)

measuring performance while expanding the sustainable design market. There are four main versions of LEED launched since its establishment, v1 in 1998, v2 in 2000, v3 in 2007 and v4 in 2016. The latest version, LEED v4.1, was updated on July 2022, aiming to be the most transparent and inclusive one up to date. (U.S. Green Building Council, 2023b)

After the prerequisites ensure eligibility for the certification, additional requirement credits are calculated according to performance in various categories. Four different levels can be achieved in the LEED rating system. These levels can be achieved from base to top; Certified, Silver, Gold, and Platinum. To earn these certifications, points are calculated according to detailed scorecards²² (*see Appendix B*). Each criterion equals a minimum of 1 point and varies according to specifications. The maximum possible total credit that can be earned is 110 points. (Wheeler, 2022) To receive the certification, “Certified” must be 40 to 49 points, “Silver” 50 to 59 points, “Gold” 60 to 69 points, and for “Platinum,” 80 to 110 points must be collected.



Figure 2.3. LEED Certification levels and points

LEED certification is a comprehensive rating system that can be applied to various types of construction projects, including new buildings, existing structures, and even large-scale urban developments. The criteria and evaluations create a framework for

²² usgbc.org. (n.d.). *LEED v4.1 BD+C scorecard*. U.S. Green Building Council.

different types and phases of buildings, from design to construction and maintenance. (Kubba, 2016) LEED v4.1 rating system claims to be compatible with all kinds of building types and phases, and to be applicable, there are six different categorizations, each with different criteria, reference guides, and scorecards. These categorizations are *Building Design and Construction (BD+C)*, *Interior Design and Construction (ID+C)*, *Operations and Maintenance (O+M)*, *Neighborhood Development (ND)*, *Residential*, and *Cities and Communities*. (U.S. Green Building Council, 2023) The categories and what types of buildings they apply are listed below;

Table 2.1 LEED v4.1 Certification categories and building types ²³

Certification Category	<i>Building Type</i>
Building Design and Construction – BD+C	<i>New Construction and Major Renovation</i> <i>Core and Shell Development</i> <i>Data Centers</i> <i>Healthcare</i> <i>Hospitality</i> <i>Retail</i> <i>Schools</i> <i>Warehouses and Distribution Centers</i>
Interior Design and Construction – ID+C	<i>Commercial Interiors</i> <i>Retail</i> <i>Hospitality</i>
Operations and Maintenance – O+M	<i>Existing Buildings</i> <i>Existing Interiors</i>
Neighborhood Development – ND	<i>Plan</i> <i>Built Project</i>

²³ (U.S. Green Building Council, 2022b)

Table 2.2 (continued).

Residential	<i>Multifamily</i>
	<i>Multifamily Core and Shell</i>
	<i>Single Family Homes</i>
Cities and Communities	<i>Cities</i>
	<i>Communities</i>

LEED v.14 Building Design and Construction (LEED v.14 BD+C) is for commercial and institutional buildings, both new and existing. In this thesis, LEED v4.1 BD+C will be referenced, based on, and discussed since it includes new design and construction on a building scale. As a design-guide schema, LEED v4.1 BD+C certificate criteria since July 2022 are listed below with the maximum possible points that can be gained in a project. (U.S. Green Building Council, 2022b)

Table 2.3 LEED v4 .1 BD+C New Construction Certificate Possible Points ²⁴

Credit Categories	Possible Points
Location and Transportation	16
Sustainable Sites	10
Water Efficiency	11
Energy and Atmosphere	33
Materials and resources	13
Indoor Environmental Quality	16
Innovation	6
Regional Priority	4
Integrative Process	1
<i>Total</i>	<i>110</i>

²⁴ From 110 points, a total of 30 points are related to context-based goals; from sustainable sites, location and transportation, and regional priority credits.

The categories consist of prerequisites and credits, each with assigned points in the scorecard. These categorizations help to evaluate the performance of the building in different areas of sustainability, each with different aims.

Integrative Process is the first category in the scorecard. It intends to support and maximize cost-effective and human-centered building design while promoting high-performance and innovative design outcomes. (U.S. Green Building Council, 2022a)

Location and Transportation category consists of 8 credit subcategories: Neighborhoods Development Location, Sensitive Land Production, High-Priority Site and Equitable Development, Surrounding Density and Diverse Uses, Access to Quality Transit, Bicycle Facilities, Reduced Parking Footprint, and Electric Vehicles. This category aims to emphasize the location of the building and prevent inappropriate and environmentally sensitive sites while reducing environmental impacts. It promotes the location to be accessible, close to public transportation, reduce vehicle distance and pollution, and open recreational spaces to encourage a healthier lifestyle and physical activity. Also, this category emphasizes the importance of low to no-carbon transportation, promotes bicycle use and infrastructure, and increases walkability. (Leading Green, 2021; U.S. Green Building Council, 2022b)

Sustainable Sites consist of two prerequisites; Construction Activity Pollution Prevention, Environmental Site Assessment, and eleven credits; Site Assessment, Protect or Restore Habitat, Open Space, Rainwater Management, Heat Island Reduction, Light Pollution Reduction, Site Master Plan, Tenant Design and Construction Guidelines, Places of Respite, Direct Exterior Access, and Joint Use Facilities. This category aims to reduce the site's harm, pollution, and contamination, protecting biodiversity, the environment, and habitat by considering the social, environmental, and cultural conditions. Also, the preservation and consideration of the existing natural environment and interaction with it have importance, as well as improving water quality, protecting wetlands, minimizing heat island effects, and

decreasing nighttime light pollution that effect night sky access. (U.S. Green Building Council, 2022a; Wheeler, 2022)

Water efficiency category has three prerequisite subcategories; Outdoor Water Use Reduction, Indoor Water Use Reduction, Building-Level Water Metering, and four credits; Outdoor Water Use Reduction, Indoor Water Use Reduction, Optimize Process Water Use, and Water Metering. Reduction of water usage and waste of the building and the building process is the primary aim of this category. Consumption, preservation, low-cost solutions, and water-efficient technologies and building elements, such as fixtures, are encouraged. (Leading Green, 2021; U.S. Green Building Council, 2022a)

Energy and Atmosphere category has the highest point return, with a possibility of 35 points, and has ten sub-criteria: four prerequisites and six credits. The prerequisites are Fundamental Commissioning and Verification, Minimum Energy Performance, Building-Level Energy Metering, and Fundamental Refrigerant Management. The credits are Enhanced Commissioning, Optimize Energy Performance, Advanced Energy Metering, Grid Harmonization, Renewable Energy, and Enhanced Refrigerant Management. Optimization of energy performance is the main aim of this category. This category aims to promote energy efficiency and optimize energy performance and management through the construction process and afterward. It also aims to minimize contribution to environmental harm and encourage renewable energy solutions. (Gurgun et al., 2016; Leading Green, 2021; U.S. Green Building Council, 2022a)

Materials and Resources category has two prerequisites; Storage and Collection of Recyclables and PBT Source Reduction – Mercury, and nine credits; Building Life-Cycle Impact Reduction, Building Product Disclosure and Optimization – Environmental Product Declarations (EPD), Building Product Disclosure and Optimization – Sourcing of Raw Materials, Building Product Disclosure, and Optimization – Material Ingredients, Persistent, Bioaccumulative, Toxic (PBT) Source Reduction – Mercury, PBT Source Reduction – Lead, Cadmium, and Copper,

Furniture and Medical Furnishings, Design for Flexibility, and Construction and Demolition Waste Management. This credit category aims to promote building materials having minimal to no negative impact on the environment and environmentally, economically, and socially preferable life cycles. Minimizing waste, reusing, and recycling is encouraged. (Leading Green, 2021; Linstroth, 2022; U.S. Green Building Council, 2022a)

Indoor Environmental Quality has three prerequisites; Minimum Indoor Air Quality Performance, Environmental Tobacco Smoke Control, and Minimum Acoustic Performance, and nine credits; Enhanced Indoor Air Quality Strategies, Low-Emitting Materials, Construction Indoor Air Quality Management Plan, Indoor Air Quality Assessment, Thermal Comfort, Interior Lighting, Daylight, Quality Views, and Acoustic Performance. The main aim of this category is to improve the comfort and health of the building occupants and installers in indoor spaces. Air quality and distribution, acoustic design, human health, comfort and productivity, thermal comfort, and smart, high-quality lighting solutions are priorities of the prerequisites in this category. (Linstroth, 2022; U.S. Green Building Council, 2022a; Wheeler, 2022)

Innovation category only consists of two credits: Innovation and LEED Accredited Professional. Promoting innovative design solutions, the aim of this category is to encourage innovative solutions throughout all stages and branches of construction of building design benefiting human and environmental health. (U.S. Green Building Council, 2022a)

The last category, Regional Priority, has one credit with the same name. The purpose is to encourage the attainment of credits that deal with environmental, social equity, and public health issues specific to a particular location. The adjacent sites and surrounding environment, accessibility and connectivity of the site, natural and alternative water resources feeding the environment, the project boundary, convenience for production -agriculture or food production-, the density of the built environment, vegetation, green infrastructure, on-site management of the natural

events, natural site hydrology, supporting and benefiting the renewable energy sources, benefiting from natural water and energy sources are some important fundamental concepts in this category. (Linstroth, 2022; U.S. Green Building Council, 2022a; Wheeler, 2022)



Table 2.4 LEED v4.1 BD+C Credit Categories and Aims

Category	Aim (in Keywords)
Integrative Process <i>Integrative Project Planning and Design (P)²⁵, Integrative Process</i>	cost-effective, human-centered design, high-performance, innovative design
Location and Transportation <i>LEED for Neighborhoods Development Location, Sensitive Land Production, High-Priority Site and Equitable Development, Surrounding Density and Diverse Uses, Access to Quality Transit, Bicycle Facilities, Reduced Parking Footprint, Electric Vehicles</i>	location, environmentally sensitive sites, accessibility, reduced pollution, open recreational spaces, low to no-carbon transportation, bicycle use, walkability
Sustainable Sites <i>Construction Activity Pollution Prevention (P), Environmental Site Assessment (P), Site Assessment, Protect or Restore Habitat, Open Space, Rainwater Management, Heat Island Reduction, Light Pollution Reduction, Site Master Plan, Tenant Design and Construction Guidelines, Places of Respite, Direct Exterior Access, Joint Use Facilities</i>	pollution reduction, biodiversity conservation, habitat preservation, natural environment and resources protection

²⁵ (P): Prerequisite

Table 2.5 (continued).

Water Efficiency <i>Outdoor Water Use Reduction (P), Indoor Water Use Reduction (P), Building-Level Water Metering (P), Outdoor Water Use Reduction, Indoor Water Use Reduction, Optimize Process Water Use, Water Metering</i>	water reduction, waste reduction, consumption, preservation, low-cost solutions, water efficiency
Energy and Atmosphere <i>Fundamental Commissioning and Verification (P), Minimum Energy Performance (P), Building-Level Energy Metering (P), Fundamental Refrigerant Management (P), Enhanced Commissioning, Optimize Energy Performance, Advanced Energy Metering, Grid Harmonization, Renewable Energy, Enhanced Refrigerant Management</i>	optimization, energy performance and efficiency, construction management, renewable energy
Materials and resources <i>Storage and Collection of Recyclables (P), PBT Source Reduction – Mercury (P), Building Life-Cycle Impact Reduction, Building Product Disclosure and Optimization – Environmental Product Declarations (EPD), Building Product Disclosure and Optimization – Sourcing of Raw Materials, Building Product Disclosure and Optimization – Material Ingredients, PBT Source Reduction – Mercury, PBT Source Reduction – Lead, Cadmium, and Copper, Furniture and Medical Furnishings, Design for Flexibility, Construction and Demolition Waste Management</i>	sustainable building materials, negative impact prevention, environmental and social life-cycle, economic, waste reduction, reuse, recycle

Table 2.6 (continued).

Indoor Environmental Quality	improving comfort and health, indoor air quality, acoustic design, human health, thermal comfort, lighting solutions
<i>Minimum Indoor Air Quality Performance (P), Environmental Tobacco Smoke Control (P), Minimum Acoustic Performance (P), Enhanced Indoor Air Quality Strategies, Low-Emitting Materials, Construction Indoor Air Quality Management Plan, Indoor Air Quality Assessment, Thermal Comfort, Interior Lighting, Daylight, Quality Views, Acoustic Performance</i>	
Innovation	innovative solutions, human health, environmental health
<i>Innovation, LEED Accredited Professional</i>	
Regional Priority	environmental and social equity, adjacent sites, accessibility of site, natural water and energy resources, production convenience, built environment density, green infrastructure, renewable energy sources
<i>Regional Priority</i>	



Figure 2.4. LEED v4.1 Credit Categories (U.S. Green Building Council, 2022b)

LEED certification uses various methods to evaluate the environmental performance of buildings, including energy modeling, commissioning, and life-cycle assessment. Energy modeling is used to evaluate the energy performance of a building by simulating the energy consumption and savings of different design options. Commissioning is used to verify that the building systems are installed and operating correctly to ensure energy efficiency and good indoor air quality. Life-cycle assessment is used to evaluate the environmental impact of the building materials and systems over the entire life-cycle of the building. (U.S. Green Building Council, 2023) LEED is constantly changing and evolving to stay current and keep up with technological improvements while also try to be more universal and inclusive towards more sustainable building design.

2.3 Evaluation of the Chapter: Discussion About the Limitations of the LEED Certification System

LEED Certification and its recognition aim to encourage improving environmental performance and market transformation towards more sustainable and innovative design. It can improve energy efficiency, reduce environmental impacts, and increase occupant comfort and health. (U.S. Green Building Council, 2023a)

Although there are many beneficial impacts towards a more sustainable view on the building industry, there are ongoing discussions about its benefits, particularly in terms of its effectiveness, ability to promote sustainable practices in the built environment, and its limitations as a tool for promoting sustainability. (Gurgun et al., 2016; Rakha et al., 2018; Suzer, 2015)

LEED certification can have a range of benefits in architecture and the built environment. USGBC promotes that LEED-certified buildings can use less energy and water -resulting in lower utility bills for building owners and operators-lower greenhouse gas emissions, produce less waste, and provide a healthier indoor environment for occupants compared to non-certified buildings. Moreover, LEED certification can provide financial benefits, such as higher rental rates or resale values, higher occupancy rates, and lower operating costs. (U.S. Green Building Council, 2023a)

A study examining the energy consumption and occupant comfort of a LEED-certified residential building compared to non-certified buildings on a university campus found that the LEED-certified building had higher energy consumption rates than non-certified buildings, which was attributed to its low score in the energy and atmosphere category. However, it had a higher satisfaction rating for overall comfort, which was attributed to its acceptable score in the indoor environmental quality category. The study concludes that LEED certification can lead to improved occupant satisfaction but may not always result in reduced energy consumption. (Vosoughkhosravi et al., 2022)

Another study reviews the impacts of LEED certification on construction costs by examining two buildings in Turkey that have achieved different levels of LEED certification and find that the unit cost of green elements for the platinum-certified building is higher than the gold-certified building with an additional construction cost. The study found that energy and water savings led to cost savings despite the increased cost. The study concludes that higher levels of certification result in higher costs but also lead to more significant savings from operating costs overall. (Uğur & Leblebici, 2018)

Since LEED was created in 1998, revisions and updates have been made to its criteria over time to reflect new technologies and materials, energy standards, and differences in building types. It caused a perception within the architecture, engineering, and construction industry that achieving higher certification levels has become more challenging, with each version becoming more strict. When the older versions' credit requirements were converted and compared with the new ones, the results showed that most projects decreased in certification levels. (Madson et al., 2022) Over time higher levels of certification became more challenging to obtain.

While LEED certification is often seen as a positive step towards sustainable building design, it is possible to identify potential disadvantages from another perspective, including the debates about the effectiveness of LEED certification in achieving sustainability goals. Although new versions try to achieve a more comprehensive approach, it is argued that the certification process is overly focused on superficial measures, seen as a simple checklist and does not go far enough to address larger issues such as social equity and climate change. (Rajkovich et al., 2013) The validity of LEED certification, citing concerns about self-reporting and lack of independent verification, are other disadvantages of the certification.

LEED certification and its process have flaws, such as a point system that encourages companies to see it as gaming the system without prioritizing the environment, the difficulty and expense of obtaining certification, an isolated evaluation of a building's design that ignores context and performance, and the potential loss of adaptability if it becomes a mandate. Additionally, some critics argue that the system allows certification seekers to achieve LEED status with actions that do not necessarily benefit the environment or comply with industry standards and that it does not consider the context of certification. As LEED certification becomes more mainstream, there is a concern that developers may blindly follow its requirements without truly questioning them. (Peterson & Ulferts, 2014)

Another major critique is its failure to account for geographic-specific characteristics. Additionally, some LEED credits are relatively easy to obtain and do not have significant environmental benefits but are given the same weight as credits

that are more difficult to achieve but have more significant benefits. As a result, building owners may prioritize more economic credits over those with greater environmental impact. These limitations are also present in other green building rating systems and are difficult to avoid due to the subjective nature of sustainability assessment. (Capuzzi & Beckman, 2010)

Architect Frank Gehry also criticized the LEED certification rating system for buildings in one of his interviews with Blair Kamin from the Chicago Tribune (2010), stating that a lot of the points awarded are for superficial add-ons (like *bike racks*²⁶) and that the costs of making a green building are enormous and do not pay back in the architect's lifetime. He sees the issue as a political one. (Singh, 2010) Although his perspective was criticized for being irresponsible regarding climate change, he stated a fact about the political and economic drives of the certification system and the limitations of the point system of LEED.

Most of the disadvantages of LEED certification have **context-based limitations**. Although the criteria are updated to be more inclusive, LEED was based on American climate zones and standards from the beginning, which may need to be revised for buildings in other regions with different climate conditions. This can lead to some credits or prerequisites that do not apply or do not reflect the specific environmental conditions of a building location, such as energy efficiency and water conservation. LEED certification requires compliance with specific regulations, which can create an additional administrative burden if not aligned with local building codes and standards. While focusing on energy, water efficiency, and sustainable materials, it may only partially reflect other aspects, such as social equity and biodiversity, leading to certifying buildings that are not truly sustainable. The LEED certification system is more inclusive and extensive in commercial and institutional buildings, leaving other building types secondary in criteria details. The

²⁶ Bicycle Facilities credit under the Location and Transportation category has recently been highly criticized by many as straightforward bike racks in terms of being an additional element and discarding the hierarchy of importance with other credit points.

certification process for existing buildings is complex and more complex. The process can be costly and time-consuming, making it difficult for smaller building projects or those with limited budgets to pursue certification.

Additionally, the system has been criticized for needing more transparency, particularly regarding how credits are awarded and the weighting of different categories, which can undermine its credibility. Furthermore, the certification process is based on self-reported data, which may need to reflect the proper environmental performance of a building accurately and can be biased. Despite these criticisms, LEED certification remains a valuable tool for promoting sustainable building practices and increasing awareness of environmental issues in the construction industry.

Overall, certain aspects of LEED certification are being criticized as being disadvantages like limitations in the rating system, lack of uniformity and consistency in interpretation, being expensive, slow, complicated, and skewed towards industrial solutions that are not appropriate or do not consider the location and context of the building. Additionally, the benefits of certain credits are not proportional to the effort required to achieve them, and the rating system does not consider geographic or demographic factors as much as it should. Furthermore, it is essential to note that it is only sometimes reflective of the actual environmental performance of a building. Disregarding the economic and political disadvantages, the most significant limitation in terms of design is the ignorance and subordination of context. It affects the effectiveness and applicability in different regions and types of buildings.

Table 2.7 Limitations of LEED Certification Summary

Limitations	Description
High energy consumption	LEED-certified buildings have higher energy consumption levels than non-certified buildings

Table 2.4 (continued).

High cost	Implementing credit features increases the construction cost, and higher levels of certification require additional costs
Effectiveness	The criteria evaluate the construction more than the performance of a building and focus on rather points solutions which do not always end up in sustainable outcomes
Limited scope	Some credit categories lack diversity and inclusivity more than others, and the difference between the detail and inclusivity of different building certification types creates imbalance
Point system focus	The system can lead to a focus on earning points rather than achieving sustainability, and the weight of the credit points does not reflect the difficulty and benefits of design outcomes and also questionable credibility
Challenging	Each version becomes more stringent and carries an administrative burden, which causes it to focus on more political and economic aspects rather than environmental and sustainable aims

Table 2.4 (continued).

Limited contextual consideration	The certification credits lack the flexibility and adaptability to be used in different regions and locations in the world and do not consider different environmental, social, cultural, and physical contexts
Involvement and Verification	Non-involvement of all relevant stakeholders and self-reporting, and lack of independent verification create a lack of validity

CHAPTER 3

BIOMIMICRY -IMITATION OF NATURAL PATTERNS- AS A METHODOLOGY FOR DESIGN

The concept of sustainability in architecture, green building evaluation systems, and LEED certification, in particular, have limitations and insufficiencies in achieving the desired results despite the positive objectives. Sustainability and its application in architecture have a linear structure and process, minimizing the damage inflicted. Sustainability and efforts in architecture can be taken to the next stage, that is, to a *regenerative* approach to eliminate the damage and contribute to nature positively. *Biomimicry* is a nature based regenerative design method that can be adopted instead of this approach in which green building certifications are used as a design tool.

3.1 Definitions: Conceptual Framework of Biomimicry

The term *biomimicry* translates literally as "*imitating life*"²⁷. While the term was first used in the scientific literature in the 60s, the essence of the concept - trying to understand nature and how it works - has older precedents and is still relevant today with new studies. (Pawlyn, 2016) The term became popularized in design and architecture in the 90s. Janine Benyus, who played an important role in this popularity, is one of the pioneers who defined and analyzed biomimicry in depth. Her ideas in her book "*Biomimicry: Innovation Inspired by Nature*" (Benyus, 1997) influenced many to focus and work on the topic. To further her work, in 2006, she co-founded the Biomimicry Institute with Bryony Schwan, where they defined biomimicry as "*...an approach to innovation that seeks sustainable solutions to*

²⁷ The word *biomimicry* was formed by combining the Latin terms *bios* (life) and *mimesis* (mimicking). (Pathak, 2019)

human challenges by emulating nature's time-tested patterns and strategies. The goal is to create products, processes, and policies—new ways of living—that are well-adapted to life on earth over the long haul." (Biomimicry Institute, n.d.-b) More simply, it is the idea of mimicking and imitating nature's patterns and strategies to obtain sustainable solutions. *"In other words, the natural world has characteristics that, if systematically studied and transferred, can help us move toward sustainability."* (Ilieva et al., 2022) Biomimicry is a multiscalar, function-based systematic approach and is applied in different fields from design to science and robotics. (Pawlyn, 2016) Due to its broad and multiscalar scope, there are variations in the interpretations and conceptualization of biomimicry in the literature. (Ilieva et al., 2022)

The fundamental and most accepted principle of biomimicry is that nature is the source of inspiration for the solutions generated. The aim of imitating nature comes from understanding nature and ecology as the oldest and most tested system on earth. (Pathak, 2019) It is a multidisciplinary field that observes nature's life cycles through time, examines ecology and biology's methods and systems, and seeks to find the solution by studying ecological systems and gathered knowledge. Ecology and the natural environment are based on a sustainable life and design model, and the natural lifespan on the earth is sustainable in itself. The lifecycles of these ecosystems, through time, alternate and evolve into more efficient systems and biomimicry aims to benefit from those efficiencies in nature. (Rao, 2014) There are many examples of learning and inspiration from nature throughout history. From one of the earliest examples, Leonardo DaVinci's designs on *flying machine*²⁸ created by examining and observing birds and how they fly, to another example Velcro²⁹ that has been used since its invention in 1948 inspired by the burdock burrs and their ability to stick

²⁸ *Flying machine* or *ornithopter* is Leonardo DaVinci's invention for flying. His drawings and notes portray his source of inspiration as bats, kites, and winged birds. (*Leonardo Da Vinci's Flying Machine Invention*, 2019)

²⁹ Georges de Mestral, a Swiss engineer, invented Velcro, a type of fastener with a hook and loop system, in 1948 after his experience in nature with the burdock burr plant. (AskNature, 2020)

only with their formal structure, and more recent and technological designs like the Daimler Chrysler³⁰ bionic concept car inspired by boxfish, can reveal some of the many variations and possibilities. (Pawlyn, 2016)

*“The aim of biomimicry is not to create an exact replica of a natural form, process, or ecosystem; instead, it is to derive design principles from biology and use those **principles as stimulus for ideation.**”³¹*

In other words, the strategy of biomimicry is to understand the linkages between biology and design while also understanding and focusing on the **reason** and **function** of living things. Biomimicry approach is based on function as the search for solutions from nature are functional. (Pawlyn, 2016) This understanding is the primary reason that differentiates biomimetic design from *bio-inspired*³² design like biophilic, biomorphic, or bioclimatic design. (Bennett, 2015)

In the Biomimicry framework, a function is how an organism **acts, adapts, behaves,** and **survives** in its natural environment, and it demonstrates a design strategy and solution in biomimetic design. (Biomimicry Toolbox, 2021) Observing and examining biology and identifying the right questions to search for are essential to identify and understanding the functions of living things. Asking how nature overcomes an obstacle, defines the function of nature, and can give different answers and solutions for design ideas and strategies.

³⁰ Daimler Chrysler’s concept Bionic Car was inspired by the form and performance of the yellow boxfish for its aerodynamic specialties. The aim was to create a fast, rigid car with a large volume and small wheels. (Abdel-Rahman, 2021)

³¹ (Kennedy et al., 2015)

³² *Bio-inspired* design refers to using biology as a source of inspiration when creating new ideas and designs and solving problems. Studying and mimicking the structure, behavior, or function of biological systems (organisms or ecosystems) can be involved in order to develop new technologies or products. (DeLuca, 2014) Fundamentally, bio-inspired design is a more comprehensive term containing Biomimicry and other strategies inspiring and learning from nature. Both bio-inspired design and Biomimicry are based on the idea that nature has already developed advanced and tested solutions to many of our challenges. By looking to nature for inspiration, it is possible to create more efficient, resilient, and sustainable designs.

3.1.1 Biomimetic Approaches to Architectural Design

The Biomimetic approach can be a design tool to sustain the existing conditions of a built environment and restore the environment in integration with the natural ecosystem. In their book *Cradel to Cradel: Remaking the Way We Make Things* McDonough and Braungart emphasized the importance of understanding and valuing nature and underlined the pleasure of using nature as a model; *“From my designer's perspective, I ask: Why can't I design a building like a tree? A building that makes oxygen, fixes nitrogen, sequesters carbon, distills water, builds soil, accrues solar energy as fuel, makes complex sugars and food, creates microclimates, changes colors with the seasons, and self-replicates. This is using nature as a model and a mentor, not as an inconvenience. It is a delightful prospect...”*. (Braungart & McDonough, 2008) Since humanity started to build its own, nature has been seen as a source of infinite materials and products, and people use these sources and generate waste and harm the harmony in nature. They strongly stressed the significance and need to understand human beings in the same position as other living things, or the consequences would be irreversible for our future and world. (Kekic et al., 2020)

The application of biomimicry as a design method in architectural practice is unrealized and perceived as an inconvenience as there is a limited number of built examples worldwide. Vincent et al. defend this as *“One barrier of particular note is the lack of a clearly defined approach to biomimicry that architectural designers can initially employ.”* (Vincent et al., 2006) Although research and ideas are developed on biomimicry, it is stated that the only built examples past the concept design are developed into products or materials due to the obstacles to employing the methodology. Because there are no distinguished and particular definitions in the biomimetic design approach and no strict borders, it can result in more innovative and different products with different perspectives and methodologies. However, this also leads to confusion, undefined and non-consecutive approaches in the literature, and a lack of application in practice. (Verbrugghe et al., 2023) The variations of approaches and definitions mainly adopt a common understanding in the core.

Different points can be seen when the critical and leading definitions in the literature are examined. The following table lists the definitions and approaches that have been accepted as critical in the literature and practice since the definition of Janine Benyus, first popularized definition of biomimicry in design and architecture.

Table 3.1 Different definitions and approaches on biomimicry.

Author	Year	Definition
Janine Benyus	1997	<i>imitation of nature's models as design inspiration to address human problems</i> ³³
Danya Baumeister	2005	<i>emulation of (the inherently sustainable) nature to design offers sustainable or less unsustainable products</i> ³⁴
Julian F.V Vincent	2006	<i>interpretation or translation from biology to design, addressing challenges in society</i> ³⁵
Maibrit Pedersen Zari	2007	<i>designers can mimic an organism, its behavior, or its ecosystem</i> ³⁶
Ille C. Gebeshuber	2009	<i>a transdisciplinary means (not an end) of mimicking nature</i> ³⁷

³³ (Benyus, 1997)

³⁴ (Reap et al., 2005)

³⁵ (Vincent et al., 2006)

³⁶ (Zari, 2007)

³⁷ (Gebeshuber et al., 2009)

Table 3.2 (continued).

Petra Gruber	2011	<i>a study addressing a theoretical framework instead of a practical solution</i> ³⁸
Michael Pawlyn	2011	<i>design that draws inspiration from the way functional challenges are tackled in biology</i> ³⁹
Lidia Badarnah	2017	<i>overcoming architectural challenges through environmentally friendly developments</i> ⁴⁰
Katharina Hecht & Maibrit Pedersen Zari	2020	<i>looking to nature to build sustainable urban environments to enhance ecosystem health and regeneration</i> ⁴¹
Biomimicry Institute	2022	<i>the practice of solving challenges by mimicking biological strategies in a regenerative way</i> ⁴²

Regardless the different interpretations and approaches, there are two phenomenons in biomimetic approaches to design; *from-nature-to-design* and *from-design-to-nature*. (Zari, 2007) These approaches have been also referred as *direct* and *indirect*

³⁸ (Gruber & Imhof, 2017)

³⁹ (Pawlyn, 2016)

⁴⁰ (Badarnah & Kadri, 2014)

⁴¹ (Zari & Hecht, 2020)

⁴² (Biomimicry Institute, n.d.-b)

in some literature. (Gamage & Hyde, 2012) The motivations behind these approaches are seeing biomimicry as a source for innovative solutions, increasing sustainability, and understanding ecosystems. The main difference between these two approaches is that one directly references biology, and the other is inspired by biology. In the first approach, *from-nature-to-design*, biology directly inspires the design from the initial design stage and designers look up to nature and identify similarities with how nature is systemized. (Verbrugghe et al., 2023) Solutions and optimizations for artificially human-manufactured designs are researched from nature and organisms according to design goals and design parameters. Although this approach solves critical design problems and initiates regenerative design solutions (Braungart & McDonough, 2008), it only addresses focused and isolated problems without regarding the urban and larger-scale effects of design. In the second approach, *from-design-to-nature*, biology - nature and biological solutions - still inspires the design. However, this approach does not investigate a specific design solution in the initial design stage, but biology influences the design. This approach's disadvantage can be the limitation of translation and understanding of biology and design simultaneously, and requires a knowledge and understanding of biology and ecosystems.

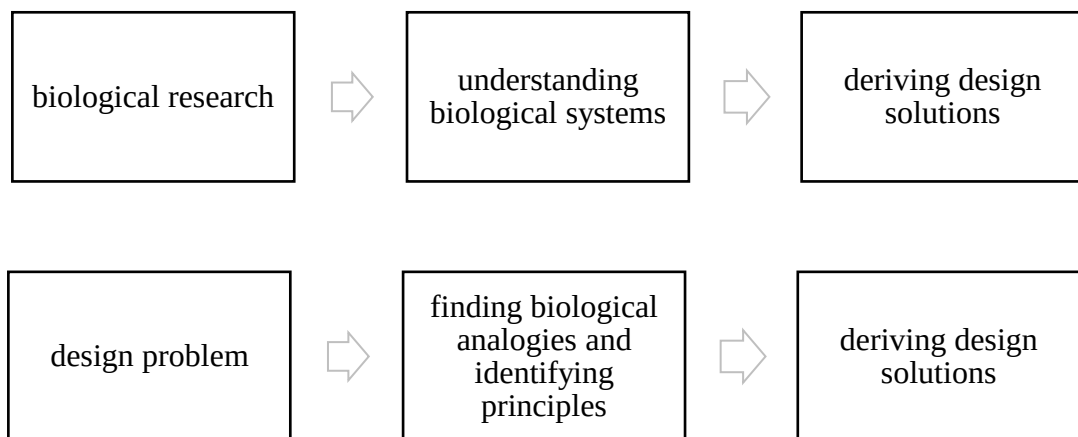


Figure 3.1. *From nature to design* and *from design to nature* approach stages

Given the different definitions and approaches in the literature, biomimicry has been associated with regeneration in more recent studies. Regeneration is mentioned in the works of Zari (2020) and Biomimicry Institute (2022), and different systems and frameworks are proposed to be used as a design method and strategy; Asknature's taxonomy tool, affiliated with the Biomimicry Institute, and Zari's application levels of biomimicry, the three-level framework of organism, behavior, and ecosystem.

3.1.1.1 Taxonomy: Function as a Tool of Categorizing

*Taxonomy*⁴³ is the study of the classification, primarily used in Biology for classifying and categorizing organisms and all living systems. Although it is crucial in biology, it can be used to describe any classification system. Biomimicry is directly related to ecology and biology, and as in biology, ideas and natural designs are classified under specific categories and functions in different scales in Biomimicry as well. This categorization enables a more systematic order while defining the solutions adapted from Biology. This multi-scalar approach, based on function, brings a hierarchical pattern to the definitions according to functions in the framework of Biomimicry, just like the categorization of organisms in Biology.

In her book *Biomimicry: Innovation Inspired by Nature* (Benyus, 1997) Janine Benyus, biologist and co-founder of Biomimicry Institute, underlined nature's principles and strategies in nine different chapters:

- *Nature runs on sunlight.*
- *Nature uses only the energy it needs.*
- *Nature fits form to function.*
- *Nature recycles everything.*

⁴³ According to Merriam-Webster, the dictionary definition of the word is “1: the study of the general principles of scientific classification: systematics, 2: classification, especially: orderly classification of plants and animals according to their presumed natural relationships.” (Merriam-Webster, n.d.-e)

- *Nature rewards cooperation.*
- *Nature banks on diversity.*
- *Nature demands local expertise.*
- *Nature curbs excesses from within.*
- *Nature taps the power of limits.*

Her categorization is differentiated according to principles, materials, lessons, mechanisms, and systems. Each further divided into subcategories into the chapters can be realized as roots of a taxonomy based on Biomimicry for design. *Biomimicry taxonomy* (Figure 3.3) is a classification system inspired by Benyus' works, developed by Biomimicry Institute⁴⁴ and AskNature,⁴⁵ categorizing nature and organisms' systems, behaviors, and functions. It is a guide for designers to use for inspiration, problem solutions, and communication. The primary idea behind this framework is categorizing functions as basic needs and actions. Instinctive acts and habits from nature are defined and simplified as keywords and organized accordingly. The diagram allows us to depict a more precise and function-based orientation for adapting solutions from nature, making the learning, and adapting process more accessible for architects and designers. It is a tool to "ask" nature "how" to solve a problem and find design solutions.

Identifying the design needs and the challenges that need to be overcome, Biomimicry Toolbox proposes a process to help designers. They propose a process called the biomimicry design spiral, detailing the approach from nature-to-design. Six sequential steps define the process using nature as a guide for designers. With each step, new information is gathered through the design solution. These steps are,

⁴⁴ *Biomimicry Institute*, formerly known as Biomimicry Guild, first founded in 1998, is a non-profit organization founded by Janine Benyus, Bryony Schwan, and Dayna Baumeister in 2006 in the United States. They aim to promote biomimicry culture through ideas, knowledge, and strategies learned from biology. (Biomimicry Institute, n.d.-a)

⁴⁵ *AskNature.org* is an online database and search engine about Biomimicry and was founded by the Biomimicry Institute in 2008. Since then, it has provided information and inspiration learned from nature to help spread nature-inspired design. (AskNature, n.d.-a)

respectively; **define**, the challenge or problem that needs to be solved, **biologize**, identifying functions and context of the problem, **discover**, finding strategies of natural models addressing the challenge, **abstract**, studying, and translating biological systems as design strategies, **emulate**, developing design concepts by compiling learnings from the strategies found, and **evaluate**, evaluating technical adequacy and feasibility of the design concepts, and assessing how well they solve the problem. Refine and revisit previous steps as needed to produce a viable solution. (Biomimicry Toolbox, 2017)

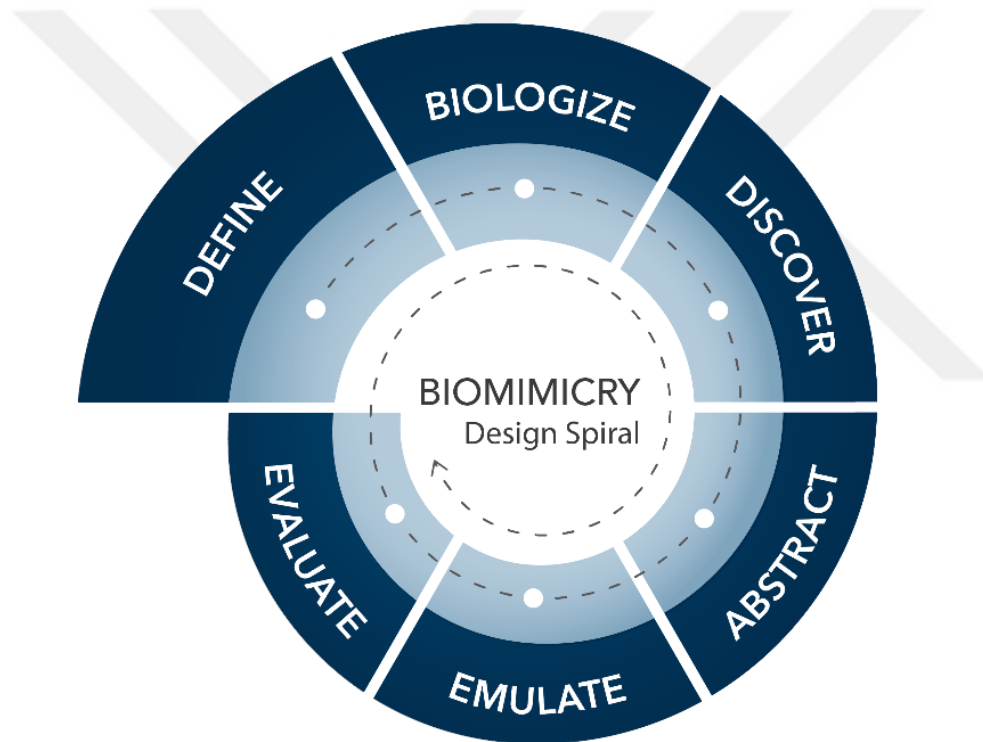


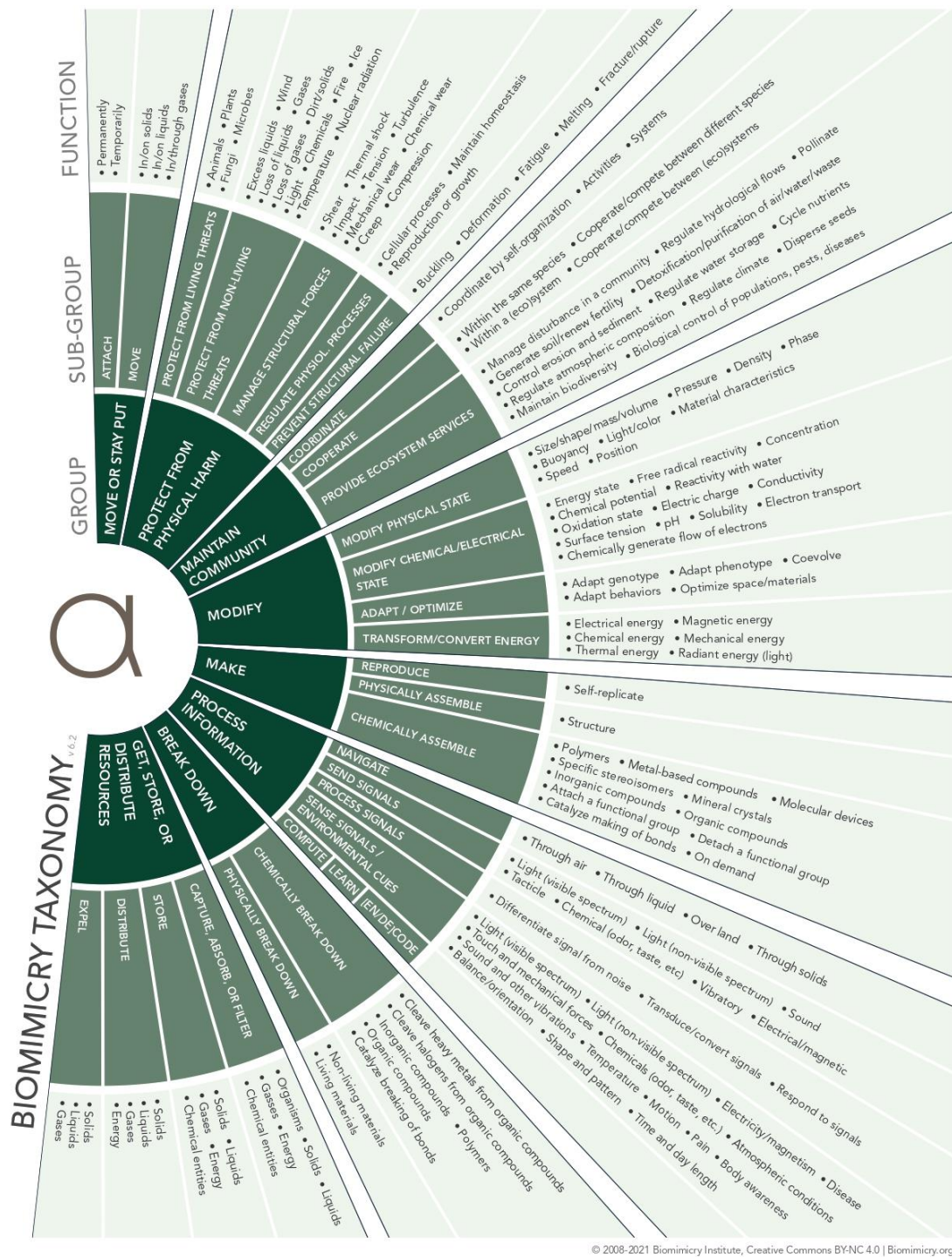
Figure 3.2. *The Biomimicry Design Process - Design Spiral* (Biomimicry Toolbox, 2017)

These definition of the process of design spiral is a guide for identifying the process of using biomimicry taxonomy and the database that Ask Nature provides. They

stress that this process is not the definitive way to biomimicry but a guide to understanding the concepts, principles, and methods to use as an initiator.

The Biomimicry Taxonomy diagram categorizes the organisms and living systems in nature into groups and sub-groups to gather strategies, also called biological analogies, of how they overcome challenges in nature based on function. Its focus on function allows it to gather solutions learned from nature to apply to challenges faced in life, both in natural and artificial productions. The diagram has eight groups, thirty sub-groups, and almost one hundred and sixty functions organized in hierarchical order. (AskNature, n.d.-b) The groups define general functions performed in nature, sub-groups are more specified functions, and finally, functions define detailed actions.

An example of using this tool is to find a strategy to achieve and define one of the eight groups that address the function wanted to meet. For example, if the "Move" group is selected, the tool will show the "Swim," "Fly," "Jump," and "Climb" sub-groups. Specific functions listed below a sub-group, for example, for the "Swim" sub-group, "Reduce Turbulence," "Use Undulatory Motion," and "Leverage Vortices" functions are listed. The tool shows examples of how these functions are used in nature and the related solutions learned and designed priorly from nature and organisms. It allows us to explore possibilities and strategies with questions about nature, like "How to prevent structural failure?" and shows examples of water lilies' ribbed underside structure supporting and enabling the leaf to float.



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Figure 3.3. The Biomimicry Taxonomy diagram created by AskNature shows the organization of the hierarchical structure of groups, sub-groups, and functions. (AskNature, n.d.-b)

3.1.1.2 Application of Design: Levels of Biomimicry

The main idea behind affecting and inspiring from the natural environment is because of the efficiency of natural systems and organisms, in terms of their use of materials, stability, complexity of forms, structures and processes. However, their complex structures and operations prevents the clear identification of these systems. The need for better definition and identification leads to different approaches and studies in Biomimicry to promote a more widespread use as a design methodology. Those studying this issue are working to create frameworks for better identification.

Maibritt Pedersen Zari is a New Zealander architect whose work focuses on redefining sustainable architecture with different approaches to the design and ecosystems. She especially focuses on biomimicry, ecology and natural system based developments. Her work embarks on the idea that Biomimicry is a source of possible innovation and it offers a way to create a more sustainable and even *regenerative* built environment. However, her work portrays that there have been numerous difficulties on adopting biomimicry as an architectural design method due to the inadequacy of definitions, that designers and architects can apply, of the different approaches to biomimicry. In her paper, *Biomimetic Approaches to Architectural Design for Increased Sustainability*, a comparative study on existing biomimetic technologies are made to understand different forms of biomimicry and design methodology. It is shown that different approaches have different outcomes regarding sustainability and regenerative potential. (Zari, 2007)

Zari and Storey emphasize the lack of hypothesis about Biomimicry and state a possibility of a regenerative habitat based on patterns of nature with identifications and reevaluations of the levels of Biomimicry. (Zari, 2007) In different disciplines that Biomimicry approach is well embraced as a method, it is implemented with clear and systematic definitions and rules. While implementing the rules and definitions of Biomimicry, different levels of Biomimicry are applied to the design. There are multiple studies done on biomimetic architecture and different models for sustainable design, learning from the examples of nature. Zari proposes a framework

in her book *Regenerative Urban Design and Ecosystem Biomimicry* with an understanding of three different forms and application levels: *organism*, *behavior*, and *ecosystem*. (Zari, 2018) In her example, what we think of as harming structures can help design them in the first place, like termite mounds. In this example, the relationship between the structures they create and what we design as architects reveal a relationship with the natural and built environments regarding the temperature and climate.

In this framework⁴⁶, 'level' refers to the mimicked biological characteristic. Each level sub divided into five 'dimensions' which refers to **scales of mimicking**; form, material, construction, process and function.

The first level implies the mimicking of a specific organism or its parts. *Organism level* disregards the organisms ecosystem and its contribution the larger context, it is the most specified level. *Behavior level* refers to mimicking the behavioral traits of organisms, like their survival coping mechanisms. The environmental challenges and conditions of organisms match humans; therefore, their behaviors are solutions to what humans face as challenges. The third level, the *ecosystem level*, mimics all of the principles, organisms, behaviors, and functions, which means the whole ecosystem itself. Studying a place's ecosystem, flora, and fauna and mimicking their characteristics and actions offers solutions and design strategies for the built environment. All of these levels and approaches in biomimicry require an in-depth understanding of biology and ecosystems and translation of this understanding to design.

⁴⁶ (Table 3.2) Zari's' framework for understanding the differences between each application level of Biomimicry, with the example of termites, how they live, how they act, and their ecosystem. (Zari, 2018)

Table 3.3 *A Framework for the Application Levels of Biomimicry (M. Pedersen Zari, 2018.)*

Level of Biomimicry	Dimension	Example – A building that mimics termite
Organism Level (Mimicry of a specific organism)	Form	The building looks like a termite.
	Material	The building is made from the same material as a termite; a material that mimics termite exoskeleton / skin for example.
	Construction	The building is made in the same way as a termite; it goes through various growth cycles for example.
	Process	The building works in the same way as an individual termite; it produces hydrogen efficiently through meta-genomics for example.
Behavior Level (Mimicry of how an organism behaves or relates to its larger context)	Function	The building functions like a termite in a larger context; it recycles cellulose waste and creates soil for example.
	Form	The building looks like it was made by a termite; a replica of a termite mound for example.
	Material	The building is made from the same materials that a termite builds with; using digested fine soil as the primary material for example.
	Construction	The building is made in the same way that a termite would build in; piling earth in certain places at certain times for example.

Table 3.2 (continued).

	Process	The building works in the same way as a termite mound would; by careful orientation, shape, materials selection and natural ventilation for example, or it mimics how termites work together.
	Function	The building functions in the same way that it would if made by termites; internal conditions are regulated to be optimal and thermally stable for example. It may also function in the same way that a termite mound does in a larger context.
	Form	The building looks like an ecosystem (a termite would live in).
	Material	The building is made from the same kind of materials that (a termite) ecosystem is made of; it uses naturally occurring common compounds, and water as the primary chemical medium for example.
Ecosystem Level (Mimicry of an ecosystem)	Construction	The building is assembled in the same way as a (termite) ecosystem; principles of succession and increasing complexity over time are used for example.
	Process	The building works in the same way as a (termite) ecosystem; it captures and converts energy from the sun, and stores water for example.

Table 3.2 (continued).

Function	The building is able to function in the same way that a (termite) ecosystem would and forms part of a complex system by utilizing the relationships between processes; it is able to participate in the hydrological, carbon, nitrogen cycles etc. in a similar way to an ecosystem for example.
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Zari's aim for this framework is to explore and comprehend various approaches to biomimicry and reveal its potential, how it can be applied to design, and what outcomes can be predicted in the end design. This approach does not only focus on the end product as an architectural design perspective, but it is also more general and inclusive in an urban scale. Due to its holistic design approach and limited definitions, biomimicry is a design tool that can provide unlimited results and possibilities. However, with unlimited possibilities and discoveries, it has the potential to be a disadvantage for the designer, as it is open to vague and misinterpreted ideas and is open-ended in addition to constantly presenting new, more innovative, and better design ideas. We need this framework and definitions to use biomimicry as a design methodology where we can improve our world and find solutions to our problems while at the same time not harming and respecting our environment and ecosystems.

3.1.2 Evaluating Biomimicry Approaches in Design

Both approaches of *Biomimicry Taxonomy* and *application levels of biomimicry* seek to find a method and strategy on a common ground to use nature's intelligence and systems and guide designers through the process of designing. While Ask Nature and Biomimicry Taxonomy is an online database accessible to everyone through

online resources and helps designers kickstart the initial process of incorporating biomimicry to design, there are limitations in the process. The tool's database is limited to the number provided as biological strategies, and there are many in nature yet to be discovered. Also, the design spiral process can be lacking in comprehending the multifunctional properties of organisms and solving multifunctional problems. (Kuru et al., 2020; Verbrugghe et al., 2023)

The need for an understanding of biological strategies and collaboration with experts is beneficial, and sometimes necessary, in both Ask Natures and Zaris approaches. However, the taxonomy toolbox is like an encyclopedia in some aspects and is more scientific and restrictive. Zaris's approach is more holistic and comprehensive as a design approach. Her framework has a broader scope with a larger scale of urban and ecosystem concerns and a categorization for translation to architectural design.

3.2 Biomimicry as a Regenerative Approach

Described as “sustainable,” current strategies for climate change in the built environment still result in adverse environmental impacts. (B. Reed, 2007) However, the goal should be to achieve neutral environmental impact and ultimately contribute more than it consumes to ecosystems while remediating past and current environmental damage. (Figure 3.4) Based on maintaining and operating, the anthropocentric traditional consuming state of mind stays on the opposite ends with the potential for improvement and regeneration. Sustainable design thinking -also promoted with net-zero movements- settled in a neutral zone between these opposite directions. Despite the intention of not harming the environment, the ultimate result is only minimizing the negative impacts of the built environment. Hence the totality of it still maintains in the negative impact zone when the already-built cities and buildings are considered. (Zari, 2018) Because of this, regenerative developments should consider their impact and the existing ones. As Jenkin and Zari emphasized, *“While aiming for neutral or reduced environmental impacts in terms of energy, carbon, waste or water are worthwhile targets, it is becoming clear that the built*

environment must go beyond this. It must have net positive environmental benefits for the living world.” (Jenkin & Zari, 2009) Achieving positive environmental impact⁴⁷ needs wholesome and integral thinking.

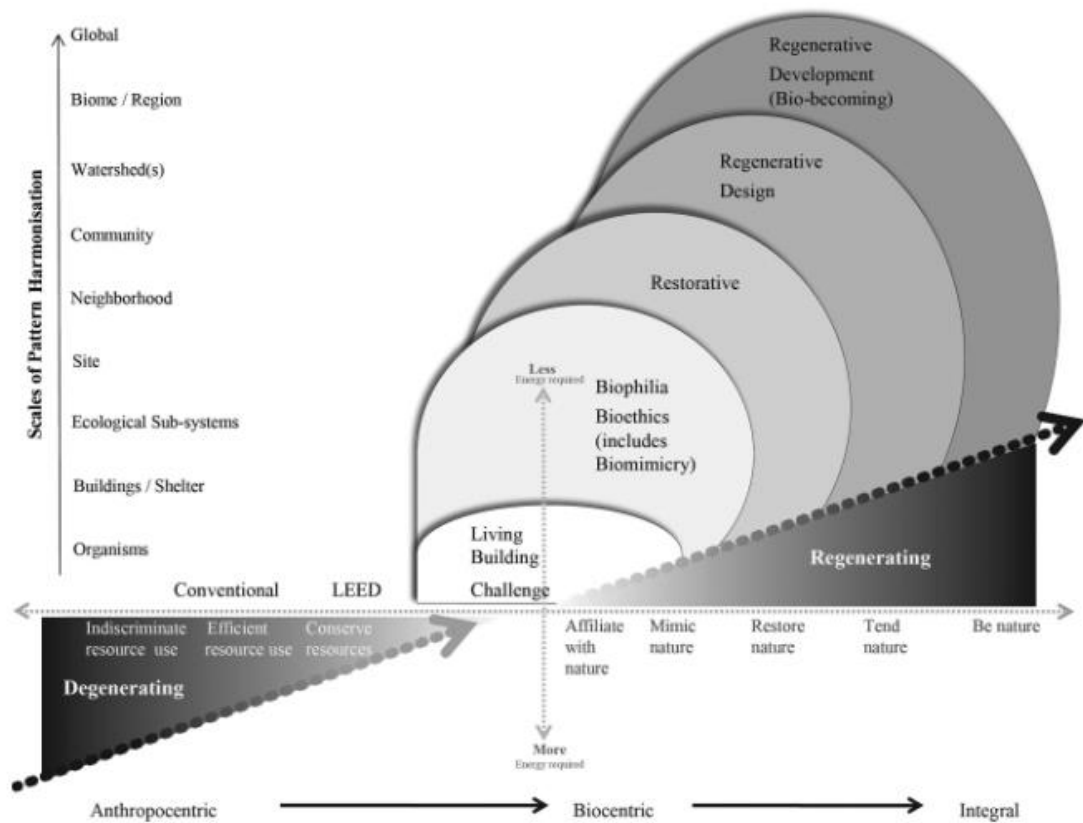


Figure 3.4. Trajectory of regenerative design (Zari, 2018)⁴⁸

Regenerative design aims to restore the health of ecosystems and promote the mutual benefit of human and non-human life by designing buildings as parts of larger

⁴⁷ It can also mean “net-positive impact or development,” aiming to create more than consumed (in terms of energy and any resources), contribute to restoring and regenerating, and support nature and life. Net-positive development “would meet or exceed established ESD (Ecologically Sustainable Development) criteria – but also reverse the impacts of current development systems, create eco-services, and increase the ecological base and public estate. (Public estate refers to the means of survival like food, land, air, water, soil, and eco-services accessible to the public.).” (Birkeland, 2007)

⁴⁸ Zaris’ interpretation on Reeds’ “Levels of Ecological Design” diagram (Mang & Reed, 2020)

systems and viewing buildings -or cities as independently functioning elements on a larger urban scale ⁴⁹ - as nodes in a system rather than individual objects. (Zari, 2018, Cp 1) Adopting a regenerative approach to design can lead to more effective and holistic projects, considering the social and ecological aspects of a design and the physical and psychological well-being of human inhabitants. Also, it can reduce the causes of climate change, increase ecosystem resilience, and potentially reduce some of the impacts of climate change. This paradigm shift in design thinking requires a fundamentally rethinking of architectural and urban design and changes in human behavior and consumption patterns.

Ecosystems that human interventions have not disrupted are practical models of life and organization. As Reed implies, understanding how they work can be an example for developing a regenerative design. (B. Reed, 2007) In contrast with the linear and exploiter industrialized building processes, ecosystems have cyclic, continuous, and opportunistic life cycles. As a result, it is helpful to use nature, ecosystems, and organisms as models and examples for design inspiration. Biomimicry integrates the accumulation of ecological and biological learning into humanity, including design, architecture, and engineering, so that it can be defined as a holistic and interdisciplinary approach. Biomimicry can be applied as a design strategy for a system change within the built environment to achieve a regenerative urban environment.

3.3 Architecture and Biomimicry: Context in Regenerative Design

In biology, context refers to the environment and other factors that impact the survival of an organism, while in design, context encompasses the conditions in which a design is used and by whom. Different strategies are used to accomplish the

⁴⁹ An approach that emphasizes, in an urban scale, cities should be considered as organisms with a system that functions in itself and can optimize and restore its existence. (Van Den Dobbelen et al., 2010)

same function depending on the context, and a strategy that works in one context may not work in another. Organisms and designs may need multiple strategies simultaneously to meet their functional needs. For example, a slow-growing tree may optimize photosynthesis using different-sized leaves. In contrast, a vine may use rapid growth to position leaves of the same size for photosynthesis. Because contexts are complex, achieving the same outcome may require different strategies. (Biomimicry Toolbox, 2021)

In Biomimicry, understanding ecological context of the mimicked component is crucial, either a single organism or whole ecosystem. Although, a singular and focused approach regarding the context in a larger scale may work as a solution, it is against the whole biomimicry idea as a holistic and regenerative approach. Armstrong criticizes this as not fulfilling sustainability potential and acting as additional singular solutions in architecture. (Armstrong, 2009)

The importance of context in regenerative design lies in its ability to inform holistic, site-specific, and sustainable solutions by understanding and embracing the context. Context serves as an input to establish a framework for understanding the systems and complexities of a particular site, considering the interconnectedness and interdependencies of ecological, social, and economic systems to continue to contribute to its environment. (B. Reed, 2007) It allows to create built environments that are deeply connected to the natural, cultural, and social systems, leading to regenerative outcomes that benefit both humans and the environment. Also, it provides valuable information about a place's climate, topography, biodiversity, and cultural aspects, to develop solutions that are adapted and resilient to the specific conditions and challenges of the environment. (Mang & Reed, 2020) Understanding and embracing context leads to regenerative outcomes that benefit humans and the environment. Therefore, understanding context and its importance as a design input should be further explored and investigated.

CHAPTER 4

DISCUSSION AND EVALUATION OF CONTEXT AS A DEFINITIVE INPUT VARIABLE: THE CASE STUDIES ON SUSTAINABLE AND REGENERATIVE DESIGN GOALS IN ARCHITECTURE

“Il n’ya pas de hors texte...”

“There is no outside-text.” (Derrida, Jacques)

As discussed in the previous two chapters, the interest and inclination toward sustainable design and solutions evolve swiftly. Different approaches that emerged from ecological thinking parallel each other and have common design inputs and sensitivities. When we look at green building certification systems, and LEED certification in particular, we see that while it positively impacts the sector, it is limited in various aspects and that biomimicry, a more comprehensive and holistic design approach, can be an alternative to this approach. Unlike sustainable design approaches, biomimicry, a regenerative design approach, aims to understand and learn from the ecosystem and the natural environment with a holistic and multi-scalar design approach and offers design solutions that are in harmony with our environment. When considering both approaches, the connection between the design and its *context* is crucial in distinguishing LEED and biomimicry. LEED has limitations in terms of inclusivity, while biomimicry embraces a more integrative approach. At this point, context gains decisive importance as a multi-scalar design input.

4.1 Realizing Context in Architecture

*Context*⁵⁰ is a comprehensive concept and a crucial factor in architecture. The consideration and exploration of context has been a crucial topic in discussions of the discourse surrounding vernacular architecture since the early settlements and the establishment of habitable spaces. This subject has been the focal point of numerous scholarly investigations, manifesting in diverse research methodologies and perspectives. (Cohen, 1974; Howard, 1965; Koetter & Rowe, 1979; Nesbitt, 2013; Rysiew, 2016; Schumacher, 1971)

The primary understanding of the context in architecture refers to the physical, social, and cultural environment of a building or a structure. Moreover, it is a design input that considers the surroundings of a design and responds accordingly. It can also be conceived as a framework in addition to being a design input. Its effects range from the social environment to the cultural, physical environment, and economy, including a site's natural environment, topology, climate, and cultural and historical background. Understanding context requires a broader approach to design rather than single-oriented design solutions. Learning and influencing from context and being in harmony with it is crucial. It is also essential for responsive, conscious, sustainable, functional, and culturally sensitive built environments. Realizing context needs a multidisciplinary approach and includes different fields, like engineers and urban planners, involved in the design process. The concept of context is a topic discussed previously in architecture. Many architects and theorists have done essential studies on this subject in the past and approached the understanding and concept of context differently—some at an urban level and some at a historical,

⁵⁰ The words' origins date back to the 15th century as "*contexere*" in Latin, meaning "*to weave or join together*," according to the Merriam-Webster dictionary. Through the years, the common usage and the meaning of the word "context" defined as "*1: the parts of a discourse that surround a word or passage and can throw light on its meaning, 2: the interrelated conditions in which something exists or occurs: ENVIRONMENT, SETTING*". (Merriam-Webster, n.d.-b)

social, and cultural level. Their work is showing its effects to this day, and many of them remain valid.

Christopher Alexander⁵¹ is one of the pioneers in architecture who explored the concept of context in his works. In his book “Notes on the Synthesis of Form” he examined the importance and scope of ‘context’ in relation to ‘form’ in historical precedents. (Alexander, 1964) He referred to ‘context’ as a factor affecting and defining the form as; “... *anything in the world that makes demands of the form is context.*”⁵² and its scope as a sum of all external factors in addition to the surrounding physical environment of a building. (Steadman, 2022) According to his idea, context shapes the form of our design and, as a result, our built environment.

Jane Jacobs⁵³ is another important name who believed that context plays an essential role in architecture. Her ideas on architectural, sociological, and economic aspects of planning and designing influenced architecture, city planning, and urban design. She approached the concept of context on a larger urban scale, specifically cities. In her book “*The Death and Life of Great American Cities*,” Jacobs explored and critiqued the ordinary and ongoing way of city planning and defended that livable cities must be planned and designed by observing social context, city life, and how people use it. (Wendth, 2009) She mentioned that the sociological and cultural aspects and daily habits of people living in the city should affect how we design the buildings and the cities. (Jacobs, 1961)

Urban planner and author Kevin Lynch’s works reflected the concept of the physical and urban context in architecture. His approach to cities and urban planning in his

⁵¹ Austrian architect Christopher Alexander worked on various design theorems and influenced many fields, from architecture to computer science. He has written about the context in many of his works. Some of his well-known works are “*Notes on the Synthesis of Form*” 1964, “*A City is Not a Tree*” 1965, “*A Pattern Language*” 1977, and “*The Timeless Way of Building*” 1979. (Christopher Alexander, 2008)

⁵² Alexander, C. (2002). 2 / Goodness of Fit. In *Notes on the Synthesis of Form* (pp. 19). Harvard Univ. Press.

⁵³ Jane Jacobs was a Canadian writer focused on urbanism and activism. She published seven books and influenced many about urban design, communities, and city planning. (Jane Jacobs, 2010)

book *“Image of the City”* focused on the perception, organization, and legibility of urban environments as a way of wayfinding through five elements in a city; nodes, paths, districts, landmarks, and edges. (Lynch, 1990) He defended that these five physical elements, their relationship with each other, and the images they reflect in users define the urban context of a city.

One of the best-known quotes of Jacques Derrida⁵⁴ is *“Il n’ya pas de hors texte...”* translated as *“There is no outside-text.”* in English. (Derrida, 1998) It has been interpreted in many studies with various comments in architecture. Besides sociological interpretations, his vision can be explained as ‘nothing happens outside of context.’ Similar to this idea, in his book *Event Cities* 3⁵⁵, Bernard Tschumi explored the relation between concept and context. According to him, it is impossible to think of a structure outside of its context. (Erman & Yilmaz, 2017) It is possible to see the traces of past environments in everything that evolves and changes. Nature stores past context traces in soil, evolution in our DNAs, and architecture in styles and elements. (Frankos, 2019) Physical and social context shapes and affects our lives and environments.

No building exists independently of its surroundings as if isolated in a void. It does not necessarily have to be a built environment like a city or a neighborhood. Nature and ecosystems also create a context and continue to coexist in a relationship whether we design it or not. No building we design and build exists independently of its context. The interaction of a structure, its surrounding context, and the users’ experience differ architecture from construction. Hart said, *“We are the context that gives a building meaning in the restless networks of our inner worlds.”* (Hart, 2021) The architecture and design process need to balance the innovation and introduction of a new structure and understanding the needs and history of the site and its natural,

⁵⁴ Jacques Derrida was an Algerian-born French philosopher. (Lawlor, 2021) Although he was not an architect, his works greatly affected architecture.

⁵⁵ Tschumi, B. (2005). *Event-cities 3: Concept vs. context vs. content*. MIT Press.

social, cultural, and economic environment. Context guides the design process as design input for responsive, functional, compatible, sustainable, and regenerative built environments.

4.1.1 Importance of Context in Sustainable and Regenerative Architecture

It is an absolute fact that context has an important place in architecture. However, context is even more critical when considering sustainable and regenerative architecture and design. Environmental impacts, the consequences of the built environment, and resource usage are some of the main concerns related to context in sustainable and regenerative architecture. The core idea and starting point for sustainable and regenerative architecture arise from climate change concerns in the early 80s. (Butt, 2022) The impacts of climate change affected the physical, social, and economic context of our built environment and the way we build it. (Zari, 2018) The fact that problems such as excessive energy consumption, climate change, the use and efficiency of natural resources, a one-sided consumption-oriented approach rather than mutual benefit, and the famine that this may cause were noticed in the world and started to show their effects caused by our habits and the built environment. Eventually, this revealed the idea of awareness of sustainable design. (Ergün & Aykal, 2022) While all these problems triggered by the built environment directly change, transform, and affect the social, cultural, physical, and natural contexts around them, their combination directly affects the context in which we live, namely our world. Therefore, it is not possible to consider sustainable design without context. In his book *“Sustainability in Architecture and Urban Design,”* Bovill mentions that the complexity and balance of the vast number of components in nature provide *“...the pattern for resilient sustainability”*. (Bovill, 2015) Nature is the origin of inspiration and the most inclusive context when considering sustainable design.

Understanding nature and the systems of an environment is also crucial in regenerative design. In his book *“Design With Nature,”* McHarg discusses how we occupy and change natural environments while designing and shaping landscapes. He used the notion of *“design with nature”* to emphasize the necessity to consider natural context as a design input and design regarding natural context. The best outcomes of harmony between built and natural context come accordingly. (Weller et al., n.d.) His ideas suggest that designing our cities and buildings according to and with respect to context -natural environments, ecologies, and natural forces- can lead the way to regenerative design and a regenerative future. (Doherty, 2022; McHarg, 1969) The ideas in his book are still valid; hence the effects of *“designing without nature”* surfaces, like climate change, famine, barren soil, and natural disaster, caused destruction.

Our built environments depend on and are nourished by their urban natural context. Regenerative design approaches design from different scales and considers context to integrate with the natural environment on an urban scale. Zari and Blanco emphasize regenerative designs aim to integrate and positively impact from this larger scale for mutually beneficial and contributing relationship between design and its context, as regenerative design *“...contributes to the possibility that the regenerative paradigm shift can ‘scale-jump’ to beyond the building scale to the urban scale”*. (Blanco et al., 2021)

4.1.1.1 Integrating Context with LEED Certification and Biomimicry

The importance of context is also reflected in sustainable and regenerative design tools and approach. It is possible to see references to social, cultural, economic, physical, and natural contexts in these design tools and methods and comprehend that context is a vital design input. Both LEED criteria and Biomimetic Architecture deliberate on context-based goals, especially natural context-based, LEED certification through its criteria and guidelines, and biomimicry through its design approaches and ecosystem understanding.

Environmental consciousness and sustainability principles are fundamental to LEED criteria, and many of these principles directly or indirectly affect the surrounding context. Context plays a significant role in determining a building's sustainability and environmental performance in LEED certification. Especially in some categories, the context is considered more relevant, significant, and directly related to design. According to the guidelines and scorecards, these categories are *location and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources*, and *regional priority*.⁵⁶ Listed categories contain several essential points and topics related to the local environment and surrounding context, and the LEED v4.1 BD+C guide lists required criteria and their implementation. (U.S. Green Building Council, 2022b) These criteria encourage designers to consider the environmental, social, and economic impacts of a building in its context and natural environment to promote sustainability and reduce negative environmental impacts of a building.

Context is also integral to the essence of biomimicry as it is directly related to biology as the study of examining nature and its systems. With a holistic understanding, it encourages considering wider ecological and social systems within a more comprehensive approach and challenges us to consider diverse scaled contexts in design. Biomimetic levels of design approach address context at different levels, from the organism to the ecosystem, while remaining in relationship with the natural context. Unlike LEED certification, in biomimicry, all design approaches directly related to context. In LEED certification, some specific categories and criteria are related to the context, while others can be considered entirely independent.

The following diagram analyzes the consideration and importance of context in LEED certifications criteria and application levels of biomimicry and their relation.

⁵⁶ Of all these categories, the energy and atmosphere category have the highest score weighting, with 33 possible points, followed by location and transportation, with 16 possible points. (U.S. Green Building Council, 2022b)

The relevance to context and its effect to design and design process is derived from the identifications and explanations of the criteria from the LEED BD+C v4.1 design guidebook and Zaris definitions of application levels of biomimicry.⁵⁷



⁵⁷ Chapter 2 for LEED certification criteria and Chapter 3 for biomimicry, respectively.

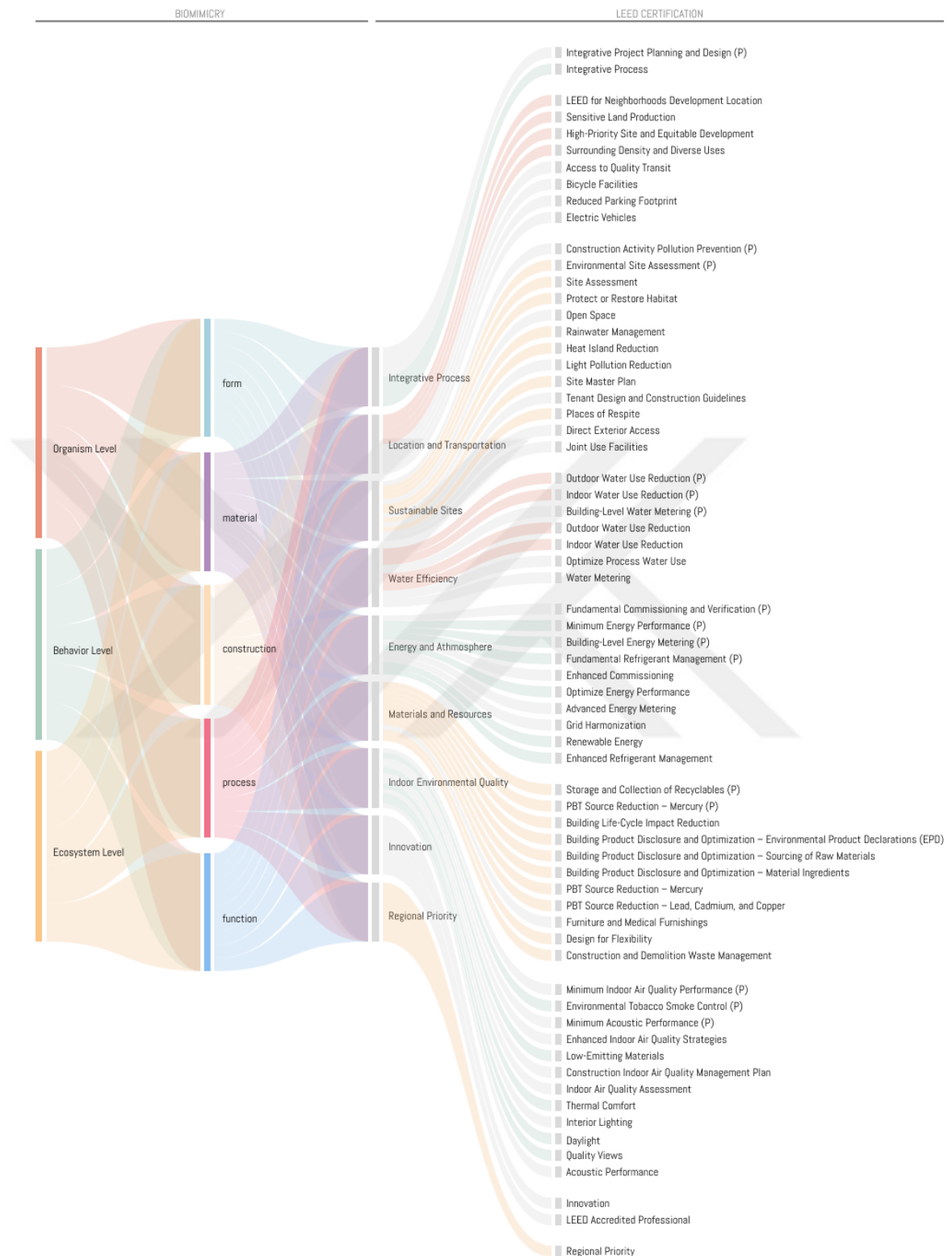


Figure 4.1. Context based LEED and Biomimicry relation diagram drawn by the author

The descriptions and guidelines of the LEED criteria affect the design and design process at different levels and fields of design. The diagram illustrates that biomimicry considers context across all application levels, including organism, behavior, and ecosystem. Each has different effects and scales in their application, from form, material, construction, and process to function. Their relation to LEED certification criteria based on context is depicted in colors. While some LEED certification criteria are point-focused and disregard contextual inputs, as grey shading indicates, its criteria that take context into account address context at limited scales and relate to different levels of biomimicry. Both design methods require interdisciplinary approaches, but as a regenerative design method, biomimicry incorporates and articulates contextual inputs at various scales and approaches design comprehensively. This **multi-scalar** approach and understanding of biomimicry stem from an understanding of ecology and natural systems and can be interpreted as from individual to whole. Like the classification of organisms in biology, categorizing and defining design ideas and elements based on their form, material, construction, process, and function reveals a multi-scalar understanding. This diagram will be used as an analytical method in the evaluation of the following case studies. Individual relations based on the case building will be depicted with highlighted relations to see singular design decisions and their impact scales.

4.1.2 Multi-scalar Understanding and Context

Climate change, resource depletion, and social and economic crises are global-scale impacts of the built environment. Regenerative design acknowledges these global, larger-scale impacts by embracing a multi-scalar understanding and recognizing connections and dependencies between living and non-living elements in different scales. Regenerative relationships between built and natural environments lead to more sustainable, integrated, and balanced living systems.

Biomimicry is rooted in ecological thinking and involves using natural systems, organisms, and biology as models for efficient working systems. This approach is

closely tied to regenerative design. (B. Reed, 2007) Understanding the function and relationships of organisms, as well as their hierarchy within natural systems, is crucial. Their natural living cycles create various relationships in different scales with unique effects, and the multi-scalar understanding biomimicry offers emanate from this. Comprehending natural living systems' principles, patterns, and strategies in biomimicry requires a deep understanding of various scales to apply them as design solutions. The framework of application levels of biomimicry represents this multi-perspective at organism, behavior, and ecosystem levels.

Interconnections and interdependencies in the ecology and the natural environment require recognition and understanding of different scaled systems and relations, which helps to understand the working systems and their hierarchies. From an architectural design perspective, regenerative design and biomimicry emphasize a spatial multi-scalar understanding. Reflecting on this, it is possible to categorize different scales for understanding and evaluating the architectural design and its relation with its context in different scales, from geographical to regional, urban, architectural, and living environment.



Figure 4.2. Scales and hierarchy of context in regenerative design drawn by the author

This multi-scalar approach to context allows a common ground for understanding and comparing different design strategies – LEED and biomimicry – and solutions and their environmental and sustainable impacts. The scope of the living environment encompasses the building's users and the natural environment, their daily activities, and their internal cycles from individual to whole. The architectural scale covers buildings and built elements, while the urban scale covers

neighborhoods and communities. Regional scale refers to cities, and geographical scale covers collective cities and built and natural environments on a larger scale.

The scale of the living environment is the smallest individual scale at which a space can be considered. The design elements and factors that shape a building, its identity, user habits, and its coexistence with its natural context can be considered at this scale. The form and morphology of a building, strategies and design ideas for efficient use of energy, materials and resources, indoor environments, innovative design solutions, and building management are examples of the architectural scale. Urban scale considers the relationships between built and natural environments, like buildings, transportation, infrastructure, natural environment, and social interactions. It considers the scale of a neighborhood and its community. Location, accessibility, green spaces, and balance of the urban fabric can be assessed in this scale. The regional scale considers a broader built and ecological context rather than individual neighborhoods and goes beyond the urban scale. Land use and urban planning, ecological conservation, development plans, and natural resource management are some issues addressed at the regional scale. Furthermore, finally, the geographical scale is the most general and comprehensive scale that includes and encompasses all previous scales and acknowledges global scale impacts of the built environment. Social, economic, and cultural factors, environmental impacts, and challenges like climate change and resource depletion can be considered as influencing inputs to design at this scale.

4.1.3 Incorporating LEED and Biomimicry with the Spatial Multi-scalar Framework of Context

Spatial multi-scalar understanding of the natural and built environments and their relationship to design and biomimicry provides a foundation and basis for understanding and evaluating the functional, efficient, sustainable, and responsible design of buildings and their environments.

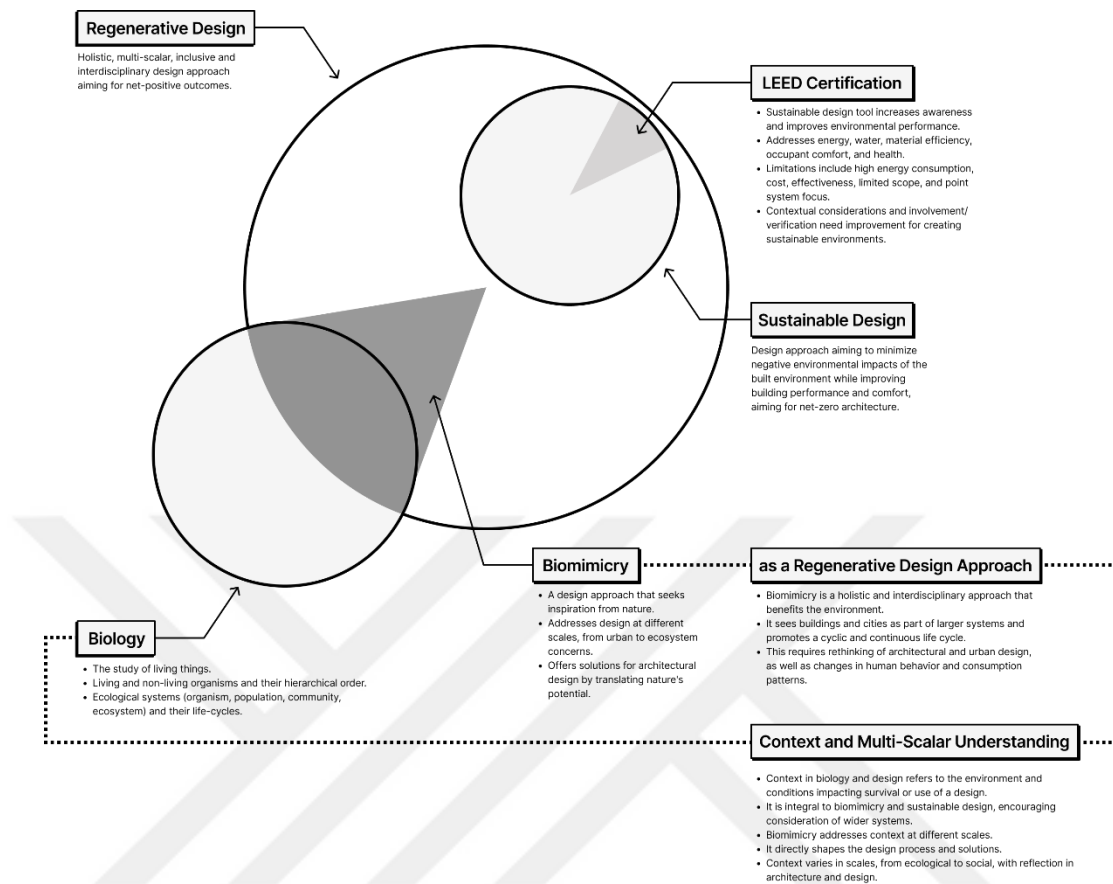


Figure 4.3. Relation diagram of sustainable and regenerative design concepts drawn by the author

Regenerative design is a comprehensive and interdisciplinary approach that aims for net-positive outcomes. When considering its relationship with sustainable design and its hierarchy, regenerative design is a larger-scale and inclusive approach incorporating sustainability. In the regenerative approach, a building is expected to contribute to its environment and its users in addition to sustaining its own existence. LEED certification is a smaller scale and specialized part of sustainable design in this hierarchy.

Biomimicry, on the other hand, is another design approach regenerative design incorporates, which intersects with another field of science, biology. Biomimetic architecture is an effective design method that draws inspiration from nature's various scales and adapts them to suit specific design challenges. This approach can

improve the built environment's performance, efficiency, and overall quality while fostering greater connection and harmony with the natural context. As a regenerative design approach, biomimicry is also holistic and multi-scalar approach. For this reason, it should be applied in architecture as a design method that can provide net-positive effects as an alternative to sustainable design approaches. It enables sustainable and regenerative designs to emerge without being result-oriented and requiring limited parameters.

Table 4.1 Discussions Summary

LEED Certification	It is a sustainable design tool that increases awareness, helps the improvement of environmental performance, energy, water and material efficiency, occupant comfort, and health, and leads market transformation toward more sustainable design. Its application and criteria have limitations like high energy consumption, high cost, effectiveness, limited scope, point system focus, challenging limited contextual considerations, and involvement and verification, which need to be improved in creating a sustainable environment.
Application Levels of Biomimicry	<i>Biomimicry</i> is a holistic, comprehensive, inclusive, and regenerative design approach addressing design in different scales.

Table 4.2 (continued).

	The framework has a broader scope with a larger scale of urban and ecosystem concerns and a categorization for translation to architectural design, revealing nature's potential and solutions as design solutions.
Biomimicry and Regenerative Design	Biomimicry offers a holistic, multi-scalar, and interdisciplinary method that can lead to progress while benefiting the environment with net-positive outcomes. It considers buildings as parts of larger systems and views buildings -or cities as independently functioning elements on a larger urban scale with the natural environment. It promotes a cyclic, continuous, and opportunistic life cycle for building processes with the mutual benefit of human and non-human life. Requires rethinking of architectural and urban design and changes in human behavior and consumption patterns.
Context and Multi-scalar Understanding	Context in biology refers to the environment and other factors that impact the survival of an organism.

Table 4.3 (continued).

Context in design encompasses the conditions in which a design is used and by whom.

Context is integral to the essence of biomimicry and sustainable design. It encourages considering wider ecological and social systems on different scales. Biomimetic levels of design approach address context at different scales, from the organism, behavior, and the ecosystem.

Context affects the design process and solutions directly in various scales and is a direct design input that shapes the design.

Context varies in different scales, from ecological to social, and has a spatial multi-scalar reflection in architecture and design.

4.2 Case Studies: Examples of LEED Certified and Biomimetic Architecture

In the face of global environmental challenges, architecture has begun recognizing and embracing sustainable and regenerative design principles. As architects, we are responsible for designing buildings that minimize their environmental impact, contribute to and are conscious of their surroundings, and foster a harmonious and cohesive relationship between the built and the natural environment. From a comprehensive perspective, it is possible to see the similarities and differences between sustainable and regenerative design approaches. Examining their

applications in architecture and analyzing case studies can provide a more precise and detailed view of these points. In this section, the applicability of biomimicry levels and LEED criteria through the selected designs and the results of the designs will be interpreted with a spatial multi-scalar collocation in seven main titles and in terms of LEED criteria and biomimicry and through the relationship diagram of application levels of biomimicry and LEED certification criteria.

The Eastgate Shopping Center in Zimbabwe, the Pixel building in Australia, and the Bullitt Center in the USA are chosen as case examples of biomimetic design and LEED-certified buildings. These buildings represent different approaches to sustainable and regenerative design, and were selected for their notable achievements. The Eastgate Shopping Center is one of the most well-known and precedent examples of biomimicry in architecture, the Pixel building is a LEED-certified building that achieved the highest score in its category up to date, and the Bullitt Center is a prime example that achieved the sustainability goals of LEED certification and used biomimicry in its design. Architectural drawings, plans, reports, and relevant documents related to the buildings will be used to examine the case studies.

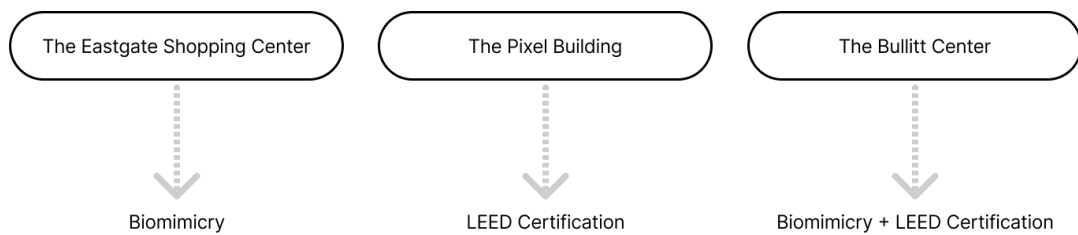


Figure 4.4. Case study Selected buildings for the case study

As mentioned in the previous sections, the criteria of the LEED certification system have specific groupings within itself and detailed criteria under these main

headings⁵⁸ based on building specifications and sustainability goals, which can limit the design process and its application. However, when we look at these main groupings, it is possible to evaluate them at the building scale and associate them with the biomimicry approach to achieve a more comprehensive understanding. Incorporating these standards into the biomimicry framework allows for a more inclusive, multi-scalar, and intentional approach to be attained. Looking at the framework of application levels of biomimicry, we can see that five larger scale and inclusive dimensions are used for grouping. These dimensions – form, material, construction, process, and function – indicate scale in a multi-scalar approach and are descriptive concepts corresponding to architecture and building specificity. Integrating these two approaches and their definitions, it is possible to relate them in terms of architectural concepts and terminologies, like site, morphology, tectonic, structure, operation and innovation. Perspective borrowed from application levels of biomimicry and LEED certification criteria, the case study analysis framework consists of six titles adapted from these *dimensions of scale*⁵⁹ for understanding and examining different elements and qualities of the selected buildings.

⁵⁸ Integrative Process, Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources, Indoor Environmental Quality, Innovation, and Regional Priority (see Chapter 2 for details) (Also Figure 4.4 middle column)

⁵⁹ Zari describes further categorization of application levels of biomimicry as “five possible ‘dimensions’ of scale of mimicry...form, material, construction, process, and function” in her work. (Zari, 2018)

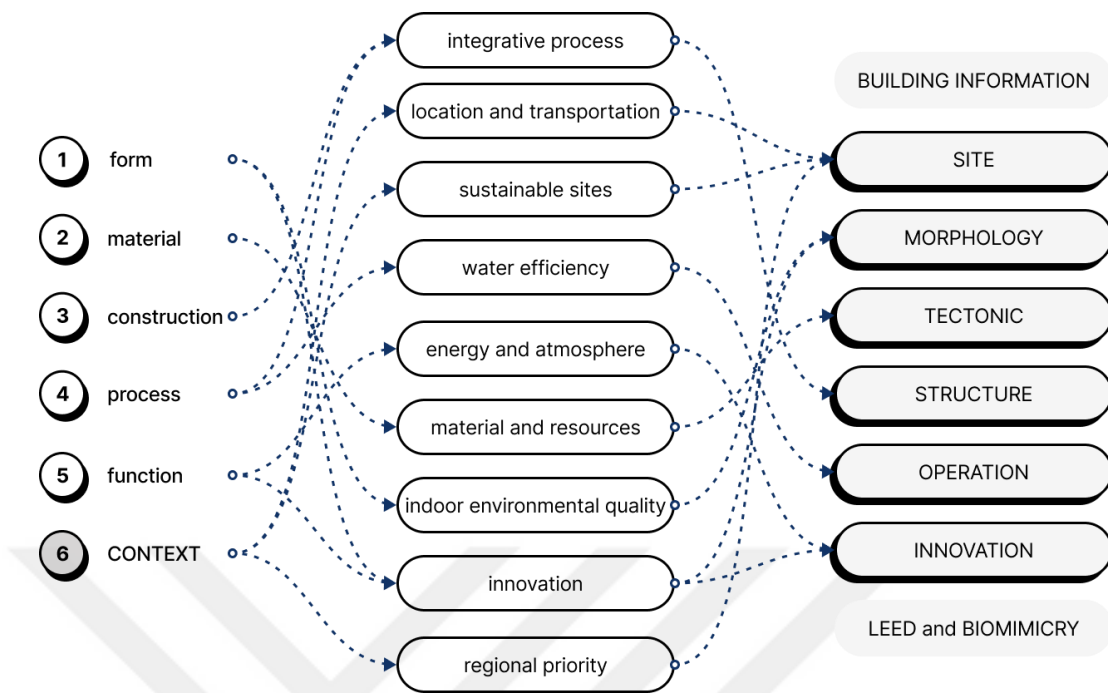


Figure 4.5. Integration of application levels of biomimicry dimensions and LEED certification criteria categories drawn by the author

While creating the framework for the case evaluation and analysis method, these five dimensions defined by Zari were taken as a basis for evaluating the building features that correspond to different scales, elements, and characteristics, and a perspective was created by adding architectural foundations from LEED certification criteria categories as well. Also, the concept of context discussed at the beginning of the chapter, which is of great importance in LEED certification and biomimicry approaches, will be evaluated in addition to these topics. The objective is to gain a comprehensive and progressive understanding of the design methods by analyzing the strategies and approaches used to achieve sustainability and regenerative design in each building, including LEED certification and biomimicry approaches. This analysis will reveal similarities and differences between the two approaches.

Case Analysis Framework

- | | | |
|---|--|--|
| 1 | Site and <u>Context</u> : | Site of the building, natural and built environment, context in different scales |
| 2 | Morphology and <u>Form</u> : | What the building looks like, its formal and design ideas |
| 3 | Tectonic and <u>Material</u> : | What the building is made out of, material selections and application |
| 4 | Structure and <u>Construction</u> : | How the building is made, structural design decisions and drives |
| 5 | Operation and <u>Process</u> : | How the building works, operational design and infrastructure |
| 6 | Innovation and <u>Function</u> : | What it is able to do, innovative design ideas |
| 7 | Evaluation in terms of LEED and Biomimicry | |

Figure 4.6. Case study analysis framework and details drawn by the author

Following this framework, the case examples will be examined and analyzed in these seven titles (Figure 4.6) after general building information⁶⁰ about the selected buildings provided. After the building information, by providing information about the *site and context*⁶¹, a foundation will be laid with the location and contextual characteristics of the building. The influence of context on the design, site characteristics including the urban, natural, and built environment, cultural and economic aspects, climate, and topography will be explored to understand contextual elements' effect on design and sustainability considerations.

⁶⁰ identity, designer, year, function

⁶¹ Location, geographical and contextual qualities, and specifications

Next, in the *morphology and form*⁶² section, buildings will be examined to understand their overall form, massing, and layout alongside the design ideas and schemas. Also, design inputs and inspirations that help to shape the design will be mentioned. *Tectonic and material*⁶³ detail of the selected buildings will be explained. Material selection of each building and evaluation of the sustainable and regenerative qualities of these materials and their contribution and support to the design will be detailed, considering their life cycle impacts and efficiency. Following *structure and construction*⁶⁴, structural systems, construction techniques, and inputs employed in the buildings will be explored, highlighting their contribution to the design for sustainability or regenerative principles. *Operation and process*⁶⁵ aspects of the buildings will be investigated to understand the life in the building and how it works. Systems and strategies applied in the buildings to improve and enhance efficiency, performance, management, and comfort will be addressed. Then in the *innovation and function*⁶⁶ section, innovative design strategies and technologies implemented in the buildings will be explored. Also, their function and contribution to functionality, inclusivity, and adaptability in terms of sustainable and regenerative design approaches will be explored. Finally, an evaluation of all these aspects regarding biomimicry and LEED certification criteria and goals will be delved into. Integration of design solutions, biomimicry principles, application levels, adaptation and compliance with LEED certification criteria, and further exploration of sustainable and regenerative design approaches and potentials will be emphasized.

In addition, the comparison and analysis of sustainable and regenerative design approaches will be conducted using the relation diagram to reveal how biomimicry and LEED criteria can complement each other will be discussed and evaluated in

⁶² Formal qualities and specifications, design ideas, and schemas that lead to that form

⁶³ Material and tectonic details, accessible, efficient, local material selection

⁶⁴ Structural and construction details, including construction methods and layouts

⁶⁵ Operational design and infrastructure detail

⁶⁶ Innovative design solutions, including new mechanical and electrical systems, heating and cooling systems, waste management

reference to the conceptual parameters of ecology, sustainability, regeneration, and biomimicry. This comprehensive analysis aims to gain insight into the application of LEED and biomimicry employed in these case buildings and reveal the correlation between these design approaches.

4.2.1 The Eastgate Shopping and Office Center in Zimbabwe

Designed by Mick Pearce and built in collaboration with Arup, the Eastgate Shopping Center in Harare, Zimbabwe, is one of the best-known examples of biomimicry in architecture. Since opening its doors, it has made the Eastgate Shopping Center a global landmark for innovative design. Completed in 1996, the structure has seven floors and is the country's largest retail and office building with 5600 m² of retail and 26000 m² of office space in addition to 450 parking spaces.



Figure 4.7. Eastgate Shopping Center (Brazier, 2008)

4.2.1.1 Site and Context

The building is located in Harare, Zimbabwe. Harare is the capital of Zimbabwe in Africa and stands out as the country's biggest and most heavily populated urban center. Hence the city is a critical center for the economy and industry and acts as a hub and distribution center with rail, road, and air transportation. (Britannica & T. Editors of Encyclopaedia, 2023) The city's economy relies on the distribution of agricultural products⁶⁷ and significant gold mines in the vicinity. The city is located in the northeastern part of the country and is 1490 meters above sea level. Harare has a subtropical highland climate⁶⁸, and the country has limited reserves. Therefore, air conditioning systems are crucial but must be imported at high costs. Because of the economic concerns, lack of skilled labor, and energy concerns, efficiency, and building performance are critical building factors in the city. The building is located on Robert Mugabe Avenue and Second Street and in a central business district easily accessible by public transportation.

⁶⁷ The most significant produce is the Virginia tobacco, followed by sugar, cotton, corn, and wheat. (Britannica & T. Editors of Encyclopaedia, 2023)

⁶⁸ The subtropical highland climate is distinct in regions with higher altitudes within the subtropics. It is characterized by mild summers, cool winters for eight months, and hot and humid four months, setting it apart from the lower altitude areas around it. (Geodiode, n.d.)

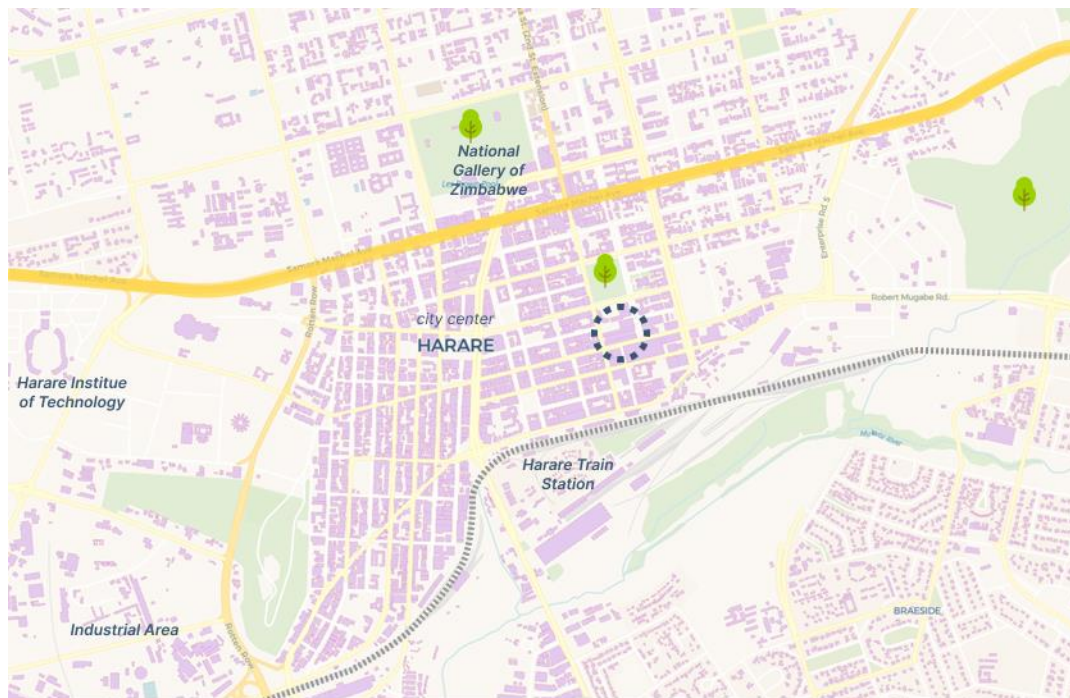


Figure 4.8. The Eastgate Shopping Center site plan

The building's investors asked Perace to design the country's largest office and retail building without having to pay for cooling systems, and Perace's challenge was: *"How do you design a building that cools itself?"* The challenge itself is directly related to the natural context of the building. Climate adaptation and site conditions are among the most important factors to consider when planning the design process. In this case, it has come to the forefront as a design input for comfortable interiors and use.

4.2.1.2 Morphology and Form

Pearce approached the design challenge, creating internal thermal comfort and cost-efficient energy consumption, inspired by nature, and used biomimicry to create natural cooling systems. He was inspired by the natural and complex structure of *Macrotermes michaelseni* and *Macrotermes subhyalinus* termite mounds and their self-cooling ventilation system. (Pawlyn, 2016) In nature, termites build and live inside tower-like mounds that can reach up to nine meters. These structures, home

to millions of termites, are filled with complex structures of tunnels and holes for airflow and ventilation, and thermoregulation that balances temperature throughout the day. The tunnels and openings carved by termites to control airflow catch the cool air inside as the wind blows, and warm air vents out from below levels through top and side openings.

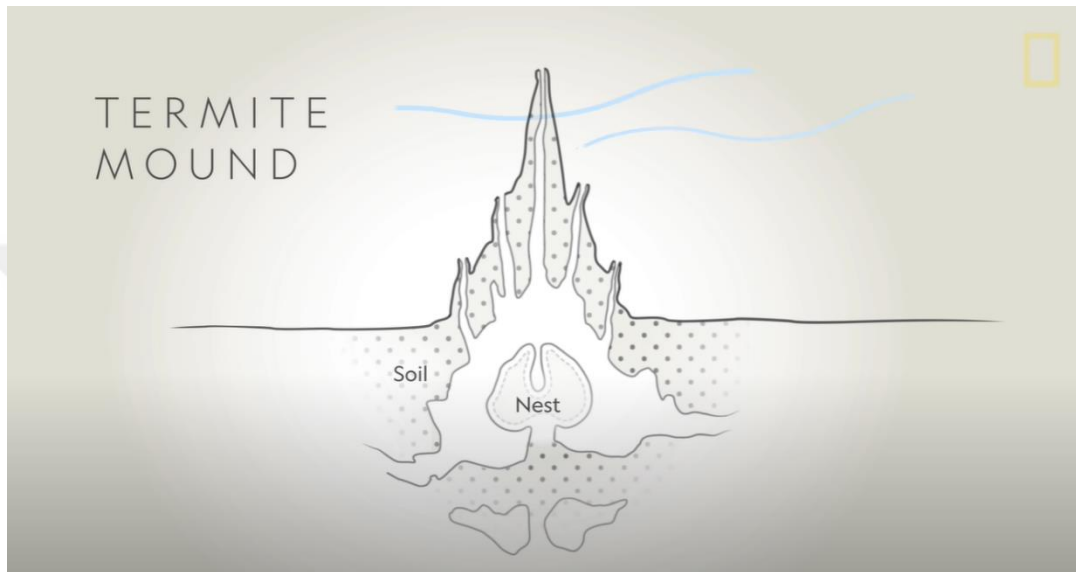


Figure 4.9. Inside of a termite mound (National Geographic, 2018)

The building is composed of two blocks connected by a glass roof. As circulation elements, steel bridges, and elevators provide the connection between these two blocks in the atrium and open up on the ground floor to connect with the streets and the city. (Pearce, 2016)

4.2.1.3 Tectonic and Material

The building is made from concrete slabs and brick. Like the soil inside a termite mound, these materials have a high thermal mass, meaning they can absorb much heat without changing temperature. To achieve the desired energy efficiency, thermal and interior comfort, direct sunlight in facades, window sizes, and lighting solutions material selections were carefully considered. (Arup, n.d.)



Figure 4.10. The Eastgate Shopping Center façade (Livin Spaces, 2018)

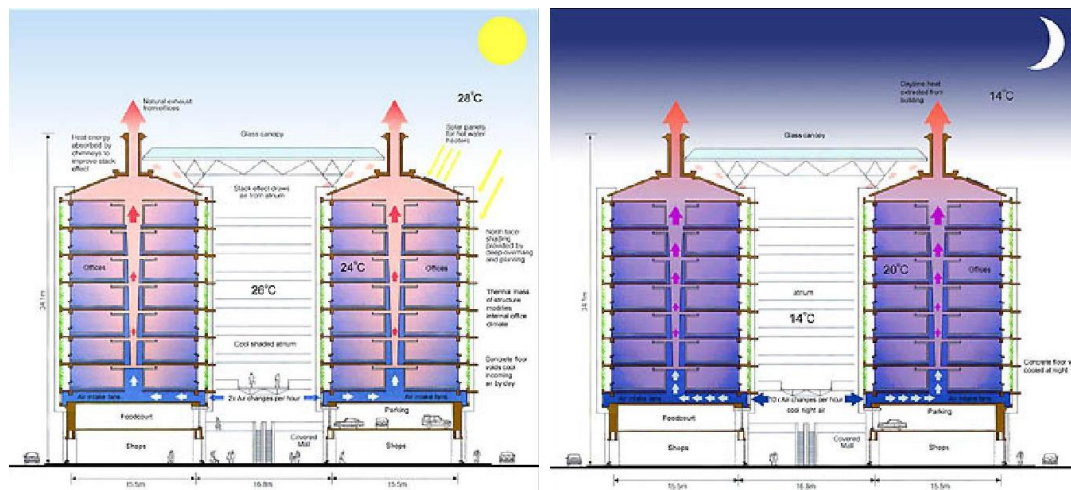
Furthermore, the material choice of concrete blocks absorbs the cold, insulating the building and cooling the circulating air. The concrete vaulted ceilings in the office space reflect the light of the luminaires from top to bottom and absorb their heat simultaneously. Façade elements block direct sunlight, and windows act as light and glare filters, controlling noise and providing security. (Pearce, 2016)



Figure 4.11. Facade detail (Tunguz, 2016)

4.2.1.4 Structure and Construction

The fractal construction of the building's façade, balconies, and shading structure is designed as an exterior envelope. It increases the surface area, which improves heat loss at night while reducing heat gain during the day. On the two concrete blocks, vents are connected from the façade to the core of the building on all levels and to the chimneys on the roof. The air shafts on the façade allow cool air inside the building, creating a stack effect, and chimneys on the roof level of the structure vent the warm air out of the seven floors from the core, supported by the fans in the lower levels. (Arup, n.d.; Pearce, 2016)



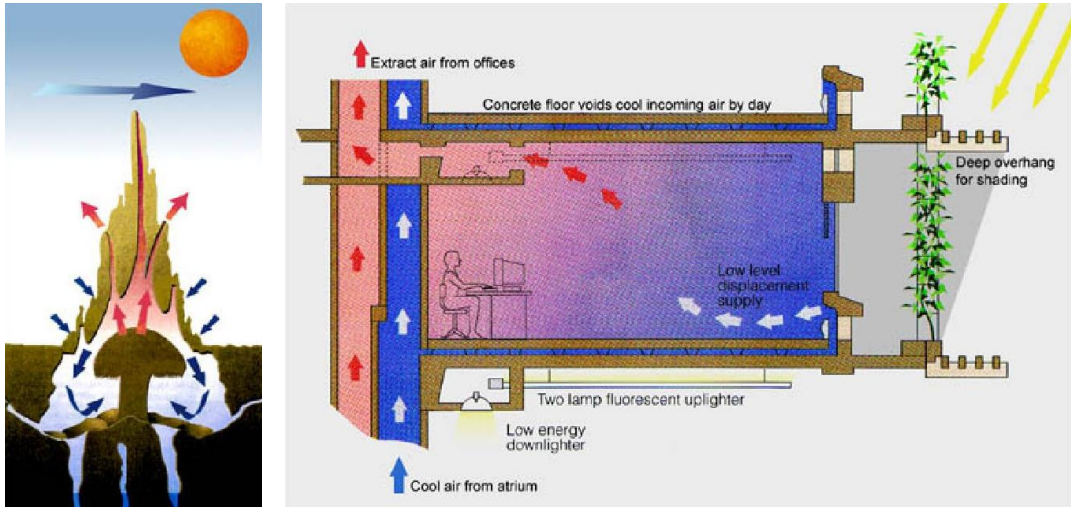


Figure 4.13. Energy efficient features (Pearce, 2016)

In addition to the natural ventilation system, other building features contribute to energy efficiency and production. Solar panels placed on the roof of the building provide energy to the building. The form of the façade elements and the greenery from planters control sunlight and heat gain and increase air quality and views while also inhabiting natural elements. (Pearce, 2016)



Figure 4.14. Facade balcony detail (Archnet, n.d.)

4.2.1.6 Innovation and Function

The building has several awards for its innovative design, including; the International Council of Shopping Centres (ICSC) Certificate of Merit in 1997 by the ICSC New York, the Fulton Award in 1997 by the Concrete Society of Southern Africa, and the Steel Construction Award in 1997 by Southern African Institute of Steel Construction.

The Eastgate Shopping Center exemplifies how nature can inspire sustainable design, emulating nature at the behavior level to create functional and innovative design solutions. Pearce did not only inspire by the form of nature but mainly by how termites behave and find a solution to survive in challenging contexts – extreme climate conditions – through design. (Hinkelman et al., 2021) Thermoregulation techniques, spatial organization, and material selections are observed in nature in similar contextual challenges. Zari stresses the importance of the application of biomimicry at the behavior level as “*requiring ethical decisions*” of the compatibility of natural solutions and human needs and gives examples of social behaviors and common acceptance of human rights and values. (Zari, 2018) Additionally, she suggests that mimicking whole systems instead of individual organisms, as in the Eastgate Shopping Center example, could be a better approach for enhancing the sustainability and regenerative capability of human-made environments. (Zari, 2018)



Figure 4.15. Longitudinal Section drawing showing cool and warm air ventilation (engineering for change, n.d.)

4.2.1.7 In Terms of LEED and Biomimicry

The Eastgate Shopping Center in Zimbabwe is an important example of how biomimicry can be used as a design approach in architecture and how it can ensure design solutions for our daily challenges. The fact that it has been in use for years and continues to be used with the same efficiency still today, the solutions it offers to its context and climate, and being one of the limited examples of biomimetic architecture, are among the features that make this building significant.

The application levels of biomimicry in this design to achieve thermally stable and comfortable interiors is in behavior level, which mimics the behaviors of termites and how they behave and adapt to extreme climate conditions to achieve comfortable living environments for themselves. The application of biomimicry at the behavior level can be seen in the design in all its five dimensions - form, material, construction, process, and function - with its different features derived from nature. (Zari, 2018) Though mainly focused on the context-based challenge of climate control and energy efficiency in this case, all dimensions refer to different scaled design solutions from formal design decisions to material selection, efficient performance-based operational systems, and functional, adaptable living environments while considering its urban, natural and built environment on larger scale context.

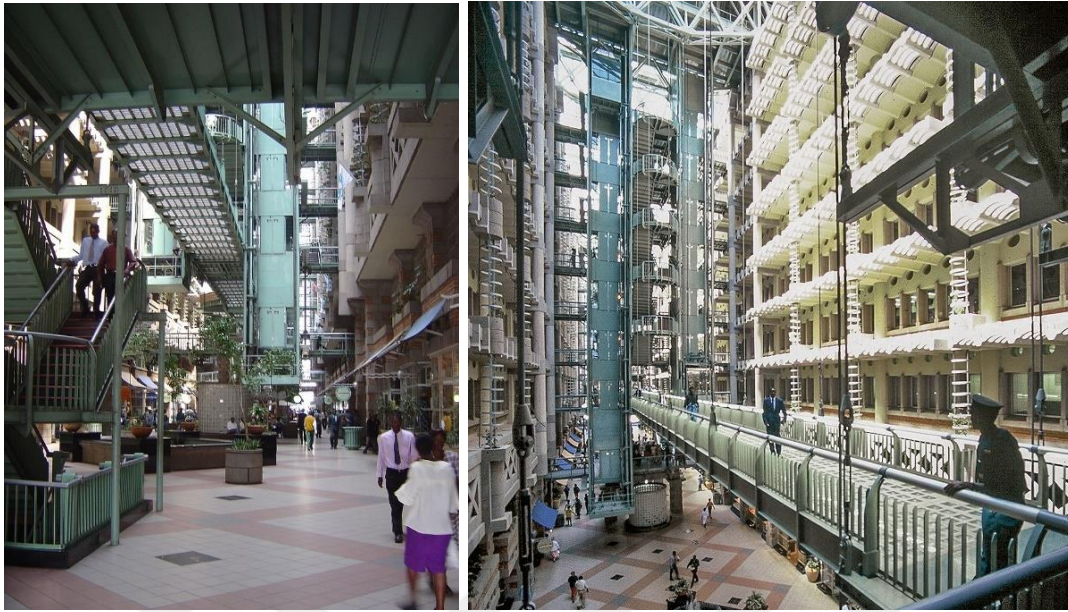


Figure 4.16. Interior of the Eastgate Shopping Center (Bembridge, 2003; Pearce, 2016)

As a multi-scalar and regenerative design method, biomimicry approaches design challenges and ideas with different dimensions. It allows the creation of integrated and different scaled and functional design solutions, as seen in this case. The challenge of designing a high-performance, efficient, and adaptable building inspired by nature and generating its own needs while contributing to its context reveals the regenerative features of the biomimetic design. The Eastgate Shopping Center acts as a living, breathing organism with its passive systems and design. The design of the building takes into account occupant health and interior comfort while also considering its environmental impacts and benefits and being environmentally responsible.

Table 4.4 Design correspondences of the application level of biomimicry of the Eastgate Shopping Center

Application Level	Dimension	Design
Behavior Level	<i>form</i>	the form of the structure is inspired by termite mounds
	<i>material</i>	the material selection is considered to be similar to soil and has a similar thermal mass
	<i>construction</i>	the construction of the building is inspired in the same way termites construct their mound
	<i>process</i>	the orientation and ventilation solutions are inspired by how termite mounds work
	<i>function</i>	the internal conditions and thermoregulation are inspired by the same way termite mound's function

The building is not LEED certified, though it is possible to relate design features to certification criteria following the guideline. Incorporating biomimicry and sustainable design solutions in different scales in the result aligns with the criteria of LEED certifications *integrative process, location and transportation, sustainable sites, energy and atmosphere, materials and resources, indoor environmental quality, innovation, and regional priority* credit categories. (Figure 4.17)

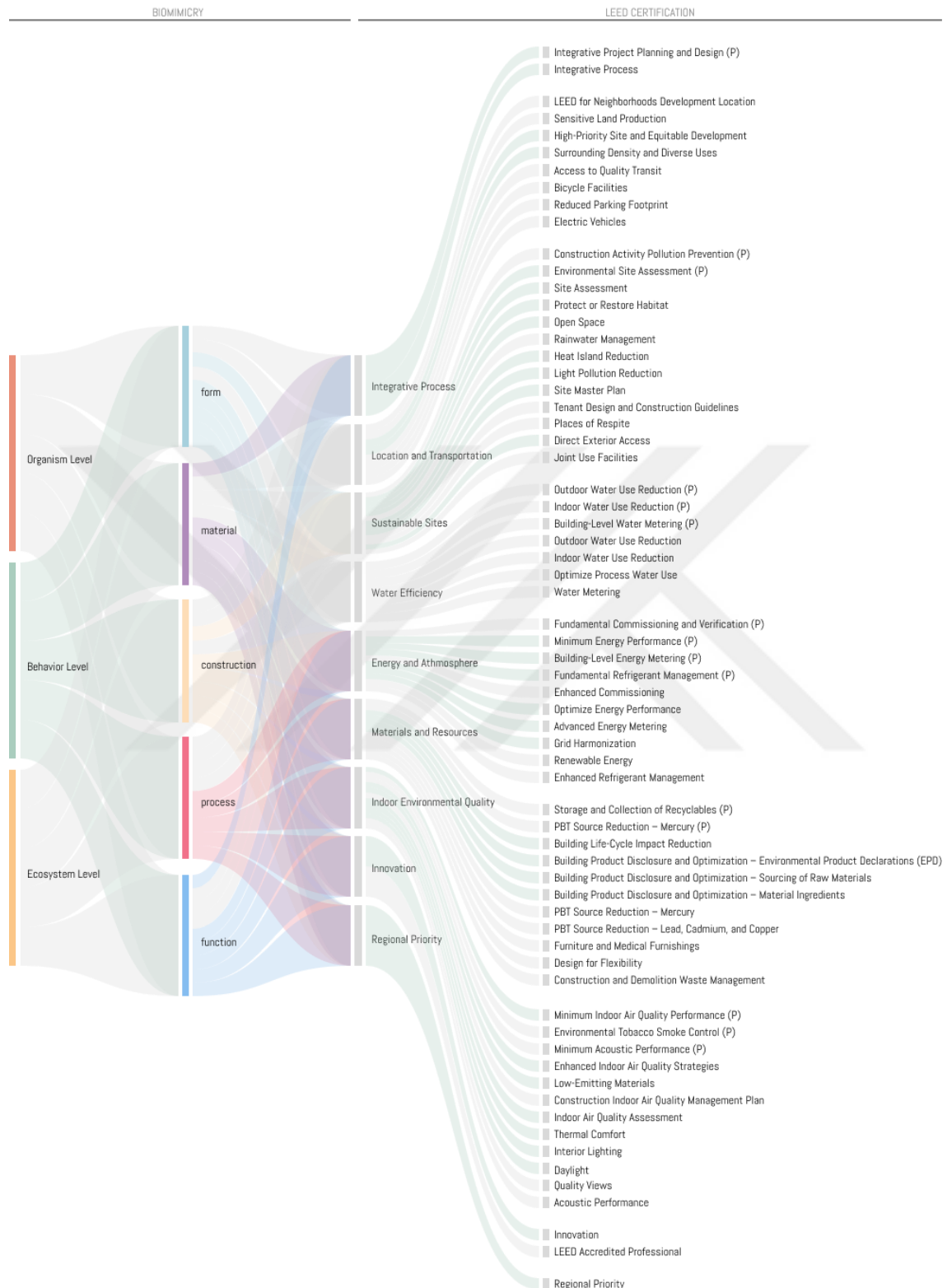


Figure 4.17. The Eastgate Shopping Center Biomimicry and LEED Certification Relation Diagram drawn by the author

Although focused on biomimicry, the solutions derived from nature and their application to building systems align with most LEED certification criteria. The most apparent design and related credit category is energy and atmosphere. Natural ventilation system design reduces energy consumption and, therefore, greenhouse gas emissions which the energy and atmosphere category promotes. Another design feature aligning with LEED criteria is the orientation and positioning of the structure and façade design to optimize light and solar heat to reduce artificial lighting and air conditioning systems, which can be related to materials and resources, energy and atmosphere, sustainable sites, and indoor environmental quality categories. A different feature is the selection of materials. Choosing locally sourced materials with high thermal capacity and incorporating local architectural forms into the design meets the criteria for sustainable sites, and materials and resources.

Table 4.5 Credit categories and design solutions that meet LEED criteria

<i>Credit Category</i>	<i>Design</i>
<i>Integrative Process</i>	cost-effective, high-performance design
<i>Location and Transportation</i>	central location and integration with pedestrian and public transport network
<i>Sustainable Sites</i>	water and pollution management, local design language, and integration with its site
<i>Energy and Atmosphere</i>	reduced energy consumption and greenhouse gas emissions with passive systems
<i>Materials and Resources</i>	locally sourced, low heat emitting, conscious material selections

Table 4.3 (continued).

<i>Indoor Environmental Quality</i>	thermally stable, comfortable, and livable indoors
<i>Innovation</i>	innovative design solutions and technologies
<i>Regional Priority</i>	adaptability to regional climate conditions

Overall, the Eastgate Shopping Center is one of the most well-known and acknowledged examples of biomimicry and how the imitation of natural solutions can be applied in architecture to create harmonious, efficient, innovative, resilient, and regenerative designs. Although the Eastgate Shopping Center is not LEED certified, it is an example of how a nature-based and nature-inspired design approach can be compatible with the sustainable design goals of the LEED certification criteria. Biomimicry and sustainable design can create innovative and environmentally friendly buildings that align with LEED certification criteria.

4.2.2 The Pixel in Australia

The Pixel building is located in Melbourne, Australia, and was designed by studio505⁶⁹ and completed in July 2010. The building is designed to be a 1136.4 m², six-story office and retail building in one of the important districts of north Melbourne. Designed with sustainability and technological advancement ambitions, the building is titled to be the first carbon-neutral office building in Australia.

⁶⁹ Architecture studio founded by Dylan Brady and Dirk Zimmermann

4.2.2.1 Site and Context

The Pixel building is located in Carlton, a suburb of Melbourne that boasts a prime location near universities and various amenities such as cafes, shops, museums, and parks within walking distance. The area is also known as the former site of the Carlton and United Brewery (CUB), which was actively used until 1987. Between 2009 and 2015, archeological studies were conducted on the site, revealing different layers of the area, which provided evidence of past residential and industrial use. (Stevenson, n.d.) Following the excavations and archeological studies, a new development plan was implemented for the area, which involved preserving some of the important buildings and street facades while introducing new development. (Dragomir, n.d.) The Pixel building is one of these new additions to the development area.

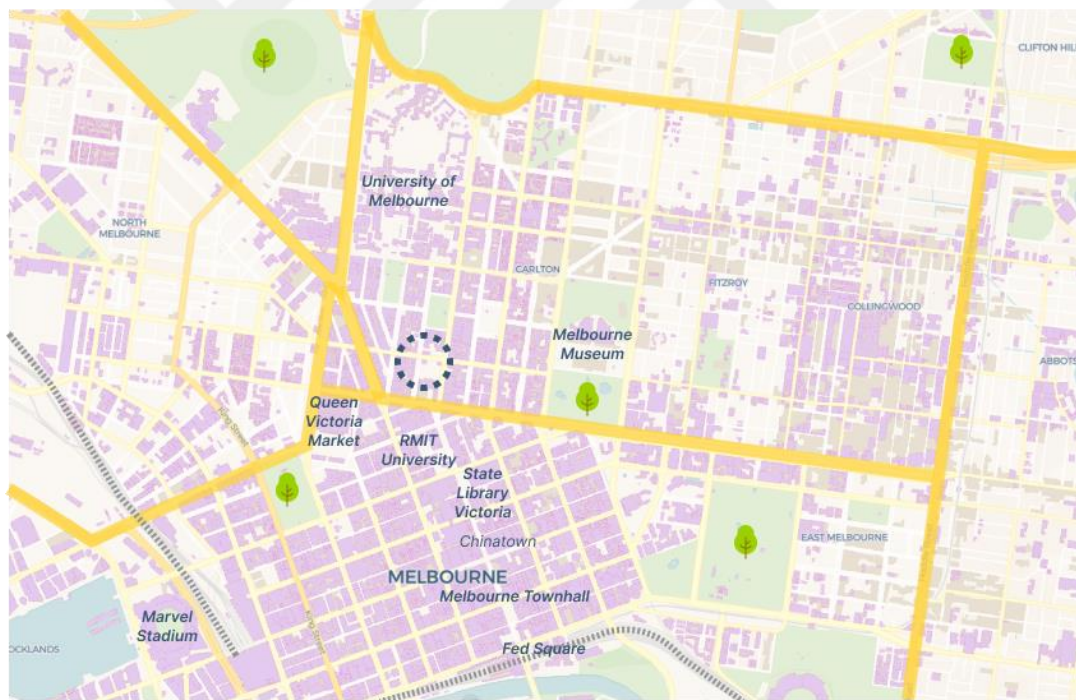


Figure 4.18. The Pixel Building site plan

4.2.2.2 Morphology and Form

The most striking feature of the building at first glance is the facade design, which also gives the building its name pixel. With this colorful, pixelated façade design, architects focused on various sustainable solutions and defined the building as a ‘future office prototype’; *“a prototype of the commercial buildings that will emerge when a carbon constrained environment demands a greater focus on energy efficiency. As a prototype, it enables an analysis of the ongoing implications of new technologies in the commercial building sector.”* (Studio 505, n.d.) A large team of designers, engineers, and consultants were involved, and analyses were made in the design and construction process of the building to generate detailed sustainable and technological solutions. (Architizer, 2014; Studio 505, n.d.)



Figure 4.19. Pixel building (Gollings, n.d.)

4.2.2.3 Tectonic and Material

The colorful façade materials are recycled to contribute to zero waste and assembled with steel tubes considering daylight, shading, and glare control. Supporting the panels, *Living Edge spandrels*⁷⁰ contribute to shading and water treatment and adds greenery to the building, acting like a continuation of the green roof. The building materials were also chosen consciously, considering the energy used for construction and materials. Double-glazed window walls, water-cooled ceiling slabs, and an insulating green roof contribute to the building's energy efficiency and carbon neutralization. (Bej, n.d.; Livin Spaces, 2017; Studio 505, n.d.)



Figure 4.20. Elevation drawings (Studio 505, n.d.)

⁷⁰ Living Edge spandrels, façade elements which can be seen in Figure 4.21, are angular-shaped elements with planters on them. While providing shading, it also helps with greywater treatment and water irrigation, acting like a passive greywater discharge system. In addition, it provides greenery and views of the building. (Brady & Zimmermann, n.d.)

Including façade elements and a specially developed concrete mix to reduce embodied carbon, recycled, sustainable, and sustainably sourced materials were used in the building. The specially developed kind of concrete used in the building is called *Pixelcrete*⁷¹. Pixelcrete is a low-carbon concrete mixture of recycled and reclaimed industrial materials, aggregate, and requires less cement. (Loh, n.d.) These material selections also contributed to minimizing waste during construction. (Livin Spaces, 2017; Morrison, n.d.)

4.2.2.4 Structure and Construction

The Pixel has a simple structure with special materials and systems. Apart from its specially designed pixelated façade, the building consists of concrete slabs and floor-to-ceiling insulated windows. This complex yet simple structural system is connected with environmental, efficient, and self-sustaining systems. (Porada, 2013) The most noticeable design element of the building, its façade, is designed to represent a pattern that *flows*, revealing the spaces behind and materials while also contributing to shading, water treatment, and ventilation systems.

The building incorporates natural ventilation, passive heating-cooling, and intelligent window technology to improve indoor air quality, reducing the need for mechanical cooling and heating systems and operating with fresh air. (Livin Spaces, 2017) These systems are integrated and interwoven in the structure with water-cooled ceiling slabs, directed water cycle on the floors, and structural façade elements. The building also features a green wall and rooftop garden that enhances air quality and offers a connection to nature for those who occupy the space. (Studio 505, n.d.)

⁷¹ A special concrete type designed by the company *Grocon*, an Australian construction company, specifically for the Pixel building (Loh, n.d.)

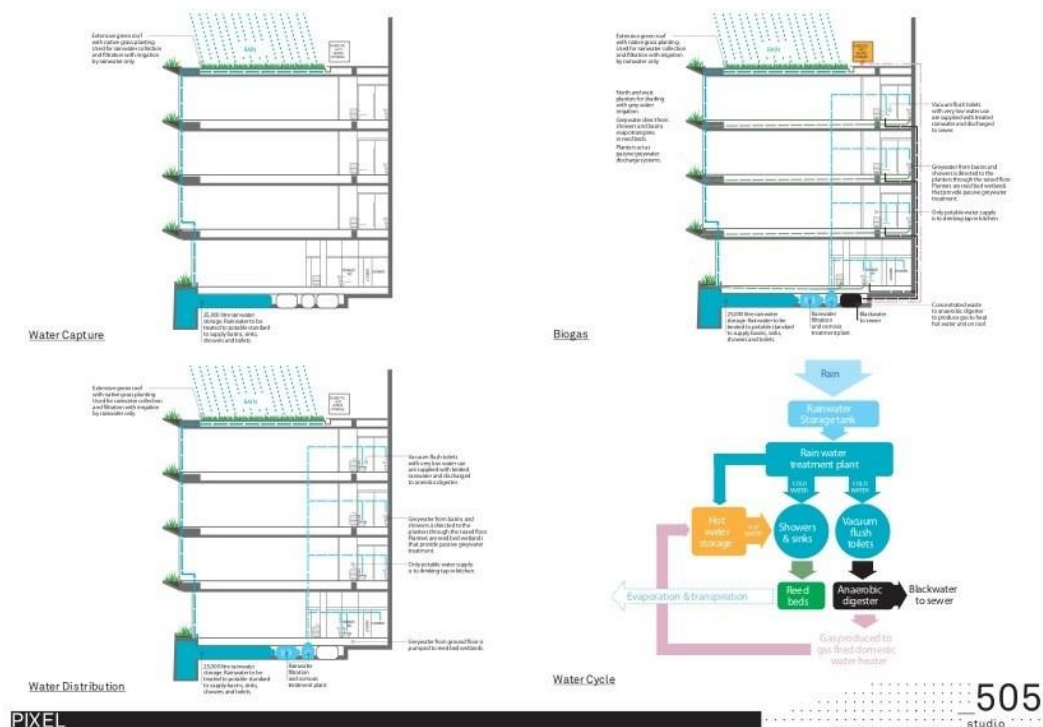


Figure 4.21. Water cycle and treatment system diagrams (Studio 505, n.d.)

4.2.2.5 Operation and Process

The Pixel is designed to be self-sufficient and mostly operate with passive or efficient, interconnected systems that work together. Water treatment and reuse is one of the main systems of the building, including an on-site water treatment and rainwater harvesting system that can reuse the collected water without connecting to main supplies of water and self-sustain itself. (Studio 505, n.d.) The green roof and planters on the façade help collect of rainwater and discharge greywater. Stored rainwater in the tanks is used as greywater in showers and sinks. Also, wastewater from these systems is reused again with a blackwater treatment system. (Livin Spaces, 2017; Morrison, n.d.)

The carbon-neutral energy system of the building uses photovoltaic panels, wind turbines, and biofuel generators and generates its electricity. The building uses passive heating and cooling systems and energy-efficient lighting solutions.

(Introba, n.d.) In addition, the green roof covered with native grass planting also contributes to insulation and reduces the heat island effect. (Calderon, 2019)



Figure 4.22. Green roof and solar panels (Studio 505, n.d.)

The building also manages waste on-site, including recycling and composting, with vacuum toilet technology and an anaerobic digester system that extracts waste and repurposes it in the building to reduce waste going to landfills. (Morrison, n.d.; Studio 505, n.d.)

4.2.2.6 Innovation and Function

The pixel building has been awarded for its innovative, technological, and sustainable design. The buildings' key features that helped to achieve this are carbon neutrality, waste management, energy efficiency, passive ventilation systems, and environmentally conscious and innovative design solutions. It generates its own power and water requirements on-site with wind turbines, biofuel generators and solar panel shading systems on the roof, and water balancing systems that do not

require to be connected to main supplies with rainwater harvesting, black water treatment system, and green roof. (Studio 505, n.d.)

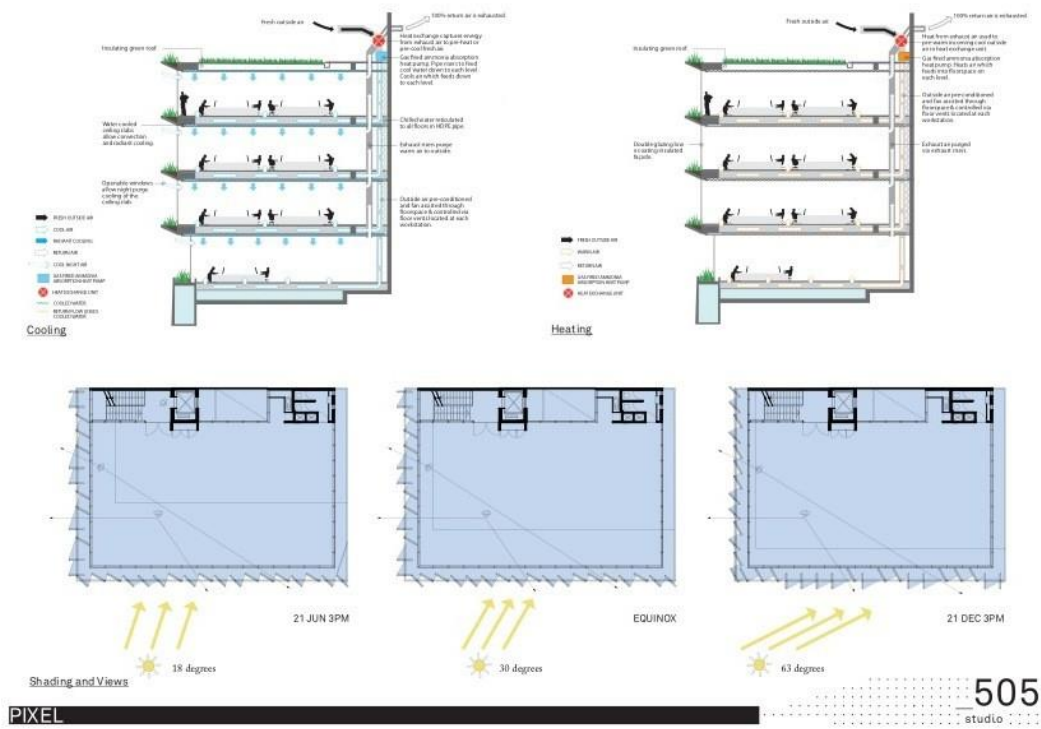


Figure 4.23. Heating and cooling system diagrams (Studio 505, n.d.)

The Pixel building is like a prototype to test new and innovative technologies for environmental, sustainable, and carbon-neutral constructions. The specially designed environmental concrete mixture, unique façade design with reused materials controlling light, and environmentally friendly heating and cooling systems to control carbon emissions using a *gas-fired absorption chiller*⁷² are innovative solutions that generate sustainable solutions in this building. (Calderon, 2019; Morrison, n.d.)

⁷² Gas-fired absorption chiller is an environmentally friendly HVAC system that uses water as a refrigerant. It provides energy efficiency using heat sources such as gas, hot water, and steam.

4.2.2.7 In Terms of LEED and Biomimicry

In 2012 the building achieved the LEED platinum certification in the v3 BD+C category with the highest score at the time in the world, and it is still among the highest-scored buildings in its category with 105 points out of 110. (U.S. Green Building Council, n.d.) Pixel gathered 105 total points from LEED BD+C: New Construction v3 - LEED 2009 rating system, only losing five points from the material and resources category. The points gathered from the categories are sustainable sites 26/26, water efficiency 10/10, energy and atmosphere 35/35, materials and resources 9/14, indoor environmental quality 15/15, innovation 6/6, and regional priority 4/4. The five points lost from the materials and resources category are from storage and collection of recyclables 0/0, building reuse - maintain existing walls, floors, and roof 0/3, building reuse - maintain interior nonstructural elements 0/1 and rapidly renewable materials 0/1 credits.⁷³ (U.S. Green Building Council, n.d.) Below is detailed information about sustainable design solutions for points scored in the LEED categories of the building.

Table 4.6 Credit categories and design solutions that meet LEED criteria

<i>Credit Category</i>	<i>Design</i>
<i>Sustainable Sites</i>	The location of the building is an easily accessible urban area well-connected to public transportation. (McDonald, n.d.)

⁷³ The complete scorecard can be found in Appendix D. USGBC evaluated the relevant criteria in the location and transportation category within the sustainable sites category for this building.

Table 4.4 (continued).

<i>Water Efficiency</i>	The building has an on-site water treatment and rainwater harvesting system. Rainwater is harvested after the irrigation on the roof; it is used as greywater and reduced in the building. In addition, wastewater is reused with a black water treatment system. (Livin Spaces, 2017; Morrison, n.d.)
<i>Energy and Atmosphere</i>	The carbon-neutral energy system of the building uses photovoltaic panels, wind turbines, and biofuel generators and generates its electricity. The building also uses passive heating and cooling systems and energy-efficient lighting solutions. The green roof covered with native grass planting also contributes to insulation and reduces the heat island effect. (Architizer, 2014; Morrison, n.d.; Studio 505, n.d.)
<i>Materials and Resources</i>	Including façade elements and a specially developed concrete mix to reduce embodied carbon, recycled and sustainable materials were used in the building. Waste was also minimized during construction, and over 95% of construction waste was diverted from landfills. (Livin Spaces, 2017; Morrison, n.d.)

Table 4.4 (continued).

<i>Indoor Environmental Quality</i>	The building incorporates natural ventilation and intelligent window technology to improve indoor air quality, reducing the need for mechanical cooling and heating systems and operating with fresh air. The building also features a green wall and rooftop garden that enhances air quality and offers a connection to nature for those who occupy the space. (Livin Spaces, 2017; Morrison, n.d.; Studio 505, n.d.)
<i>Innovation</i>	Environmental concrete development, façade design that controls daylight and glaring, and <i>gas-fired absorption chiller</i> to control carbon emissions are innovative solutions that generate sustainable solutions. (Livin Spaces, 2017; Morrison, n.d.; Studio 505, n.d.)
<i>Regional Priority</i>	The building manages waste on-site, including recycling and composting, with vacuum toilet technology and an anaerobic digester system that extracts waste and repurposes it in the building to reduce waste going to landfills. (Morrison, n.d.; Studio 505, n.d.)



Figure 4.24. Shading and glaring prevention seen from inside (Hosking, n.d.)

The Pixel Building in Melbourne demonstrates how sustainability can be integrated into every aspect of a design and construction to create a high-performing, environmentally friendly office building, meeting many of the LEED certification criteria. It is undeniable that Pixel is an innovative and highly sustainable building that utilizes advanced technologies. However, despite respecting its context, it will likely receive a LEED platinum award again if the building is relocated and built on another suitable site. Although LEED certification is an excellent way to encourage and recognize sustainable developments, it does not support context-specific design approaches and rewards point solutions.



Figure 4.25. The Pixel building, façade and wind turbines (Hosking, n.d.)

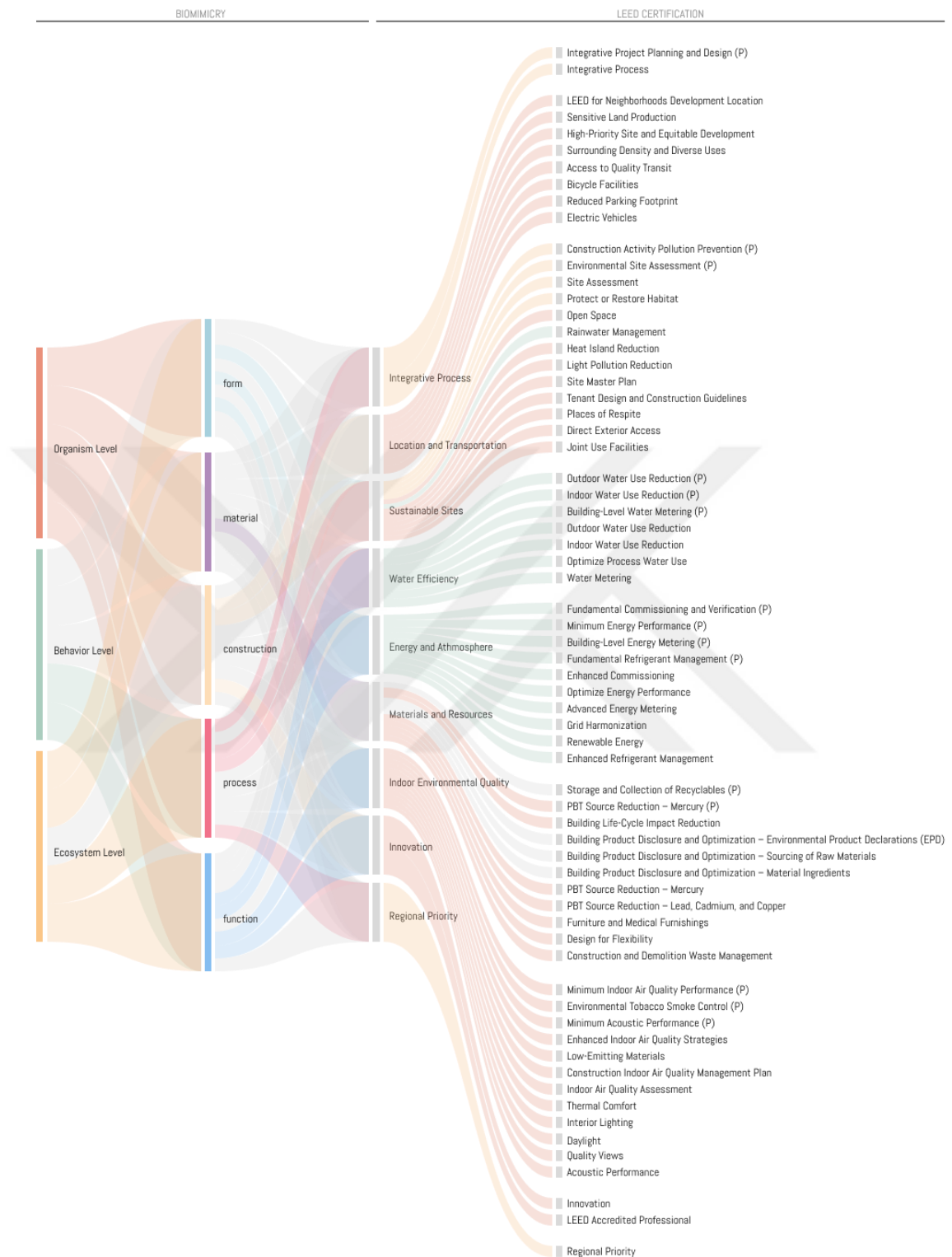


Figure 4.26. Pixel Biomimicry and LEED Certification Relation Diagram drawn by the author

Although the Pixel was not designed with a biomimicry approach, it may be possible to associate individual design decisions that meet the LEED criteria with applications to natural systems and incorporate application levels of biomimicry. However, these correlations will be generic and speculative. Each design aspect can be aligned with different dimensions of the application levels of biomimicry when compared with the LEED criteria. In this case, it is observed that all levels of biomimicry are utilized under generalizations.

Table 4.7 Design correspondences of the application level of biomimicry of the Pixel

Application Level	Dimension	Design
Organism Level	<i>form</i>	the form of the façade design can be found in the shapes in nature
	<i>material</i>	the green roof contributing to buildings cooling systems and supporting biodiversity
	<i>construction</i>	utilization of sunlight and air with façade elements
	<i>process</i>	passive ventilation systems, and water treatment systems can be found as counterparts of inspiration from nature
	<i>function</i>	principles of energy efficiency, waste management can be found in nature

Table 4.5 (continued).

Behavior Level	<i>process</i>	rainwater collection and reuse cycles mimic how organisms behave and respond to similar environmental changes and conditions
	<i>function</i>	adaptation to changing climate conditions with passive and natural ventilation systems to regulate temperature - how organisms regulate temperature
Ecosystem Level	<i>form</i>	the integration of the structure and its urban environment demonstrates the inspiration from natural ecosystems
	<i>material</i>	reusing materials inspired by the repurposing of resources in nature
	<i>process</i>	water treatment and harvesting systems positive effect on water resources inspired by natural efficiency
	<i>function</i>	environmental consciousness can be imitated from natural systems

Many design decisions and solutions can be found in nature as humans learned from nature and interpreted their systems throughout centuries. In this case, the interpretation of design elements to relate with nature, *from design to nature*, in different levels of application of biomimicry can be observed. Most of the design decisions can be matched at the organism level. The systems used in the design mimic how organisms breathe, how fluids circulate inside organisms, how organisms

utilize sunlight and air to sustain life, and how organisms regulate temperature. The form of the design can also be inspired by the shapes found in nature.

On the other hand, it is also possible to find examples that can be interpreted as behavior and ecosystem levels. Principles of energy efficiency, water treatment, waste management, and environmental consciousness can be imitated from natural systems and passive, natural ventilation systems adapting to changing climate conditions. Rainwater collection and reuse cycles mimic organisms' behavior and response to similar environmental changes and conditions. The integration of the structure and its urban environment demonstrates the inspiration from natural ecosystems. The green roof contributes to buildings cooling systems and supporting biodiversity, and rainwater harvesting systems have a positive effect on water resources inspired by natural efficiency and repurposing of natural resources in ecosystems.

Nature offers an infinite array of possibilities and systems that can serve as sources of inspiration. Sustainability solutions focusing solely on specific points can restrict opportunities for more comprehensive relationships with nature in building design. In buildings designed this way, it is only possible to establish generalized relationships with nature and design.

4.2.3 The Bullitt Center in USA

The Bullitt Center in Seattle, USA, is one of the prime examples of biomimetic architecture approaches that can achieve LEED certification without additional effort. Completed in 2013, the building was designed as a commercial office building by Miller Hull Partnership and owned by the Bullitt Foundation⁷⁴. The six-story, 4650m² buildings design features that distinguish it from other sustainable buildings,

⁷⁴ Bullitt Foundation is a non-profit organization founded by Dorothy Bullitt in 1952 to promote sustainable communities and environments. (The Bullitt Foundation, 2014)

with an ambition to create the *'World's Greenest Commercial' Building*⁷⁵. The president and CEO of the Bullitt Foundation Denis Hayes describes this ambition as *“There is not a single urban office building in the United States that is truly designed for today’s environment, much less for tomorrow’s, so we set out to build one: the greenest urban office building in the world.”* (Peña, 2014) A significant design and construction team with designers, engineers, and consultants worked together on the design with also contributions from public sector partners, including the Department of Planning and Development and the Washington State Department of Public Health, to identify barriers and building codes for innovative, integrated, and conscious design. (Bullitt Center, 2013)

4.2.3.1 Site and Context

The Bullitt Center is located in Seattle, USA, on Madison Street Pike/Pine neighborhood of Capitol Hill. It is a residential neighborhood known as a visiting destination for its social amenities and parks. The site is in a dense urban area, and next to the building, a small park provides greenery, shade, and views to the building while also benefiting from the resources the building provides.

The location is easily accessible for commuters with public transportation and is pedestrian friendly. Landmarks of Seattle can be accessed with bus or train transit, and downtown is within walking distance. The site of the building was chosen carefully in a central and easily accessible location with close facilities to promote walking, biking, and using public transportation, resulting in occupant health and reduced pollution.

⁷⁵ (Homchick Crowe, 2020)

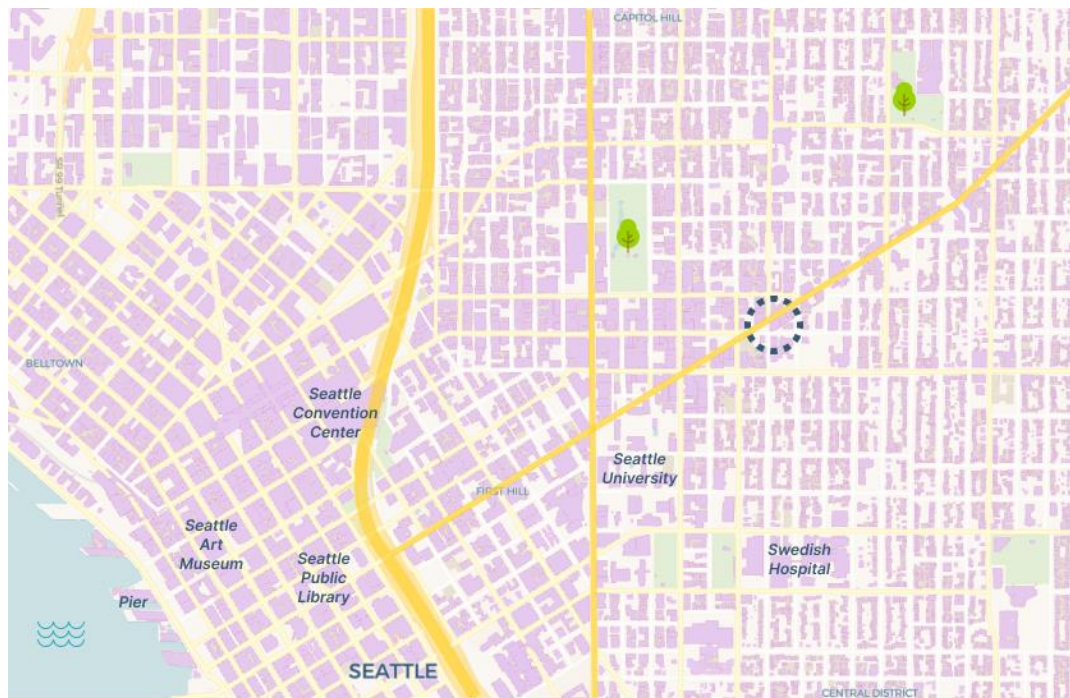


Figure 4.27. The Bullitt Center site plan

4.2.3.2 Morphology and Form

Although not initially intended for certification, it has become one of the most environmentally sustainable buildings globally. With this example, the *living proof* title proves that buildings designed with biomimicry are sustainable and regenerative structures and have qualifications beyond the criteria of LEED.

The Bullitt Centers' key features and achievements in terms of design are an extended building life cycle, net-zero water and energy systems, and occupant priority and wellness. To ensure these efficient systems, material selections, technological and operational advancements and innovations, and social and cultural assessments and analyses were prioritized in the design. The building generates on-site renewable energy with no environmental footprint, operates on a net-positive basis, and promises less maintenance and a comfortable user experience. Important key design features of the building are; radiant heating, ventilation system, energy

generation, water and waste management, and material selections. (Homchick Crowe, 2020)



Figure 4.28. The Bullitt Center (Stamets, 2013)

Since the early stages, a collaborative approach was taken to design a building emphasizing efficiency, performance, and environmental consciousness. This involved input from various professionals and sectors, resulting in a well-thought-out and carefully designed structure. Integration is crucial from the design phase to the building's operations, as a holistic approach was taken throughout the process for a regenerative architecture. Instead of focusing on individual sustainable design elements and singular efficiencies, the building is considered a living system. (Peña, 2014)

4.2.3.3 Tectonic and Material

Built to last 250 years, the materials used in the building are carefully selected and locally sourced. The building has a concrete base, steel reinforcing, and a heavy

timber framing structure. The timber structure offers aesthetics, low carbon footprint, regional compatibility, and renewable properties to the building, and the steel structure provides safety reinforcement. (Bullitt Center, 2021; Miller Hull, 2022) Façade elements are designed as a triple-layered system with different materials for thermal, air, and daylight control in collaboration with Schüco. The exterior Venetian blinds are automated to open and close according to sunshine for thermal control. Operable windows with insulated glazing help with air control, and interior blinds help with the glaring on the interiors. On the roof, 575 solar photovoltaic panels are placed inspired by the canopy of a tree. (Bullitt Center, 2021)



Figure 4.29. Roof solar array and city view (Kahn, n.d.)

4.2.3.4 Structure and Construction

The Bullitt Center is not only a net-zero energy building but it uses net-positive energy with overhanging photovoltaic panels on the roof of the structure producing more energy than consumed in the building in a year. There are 575 solar panels

situated on the roof which were inspired from the canopy of a tree. (Bullitt Center, 2021; Miller Hull, 2022)

The windows and shading design integrate triple control with automated exterior blinds, operable floor-to-ceiling windows, and interior blinds; thermal, air, and daylight control for a safe, naturally daylit, ventilated work environment. Exterior shades can be arranged according to the sun to control heat, windows can be opened for ventilation and fresh air, and the interior blinds help control the light and glare on the workspaces. (Bullitt Center, 2021; Miller Hull, 2022)

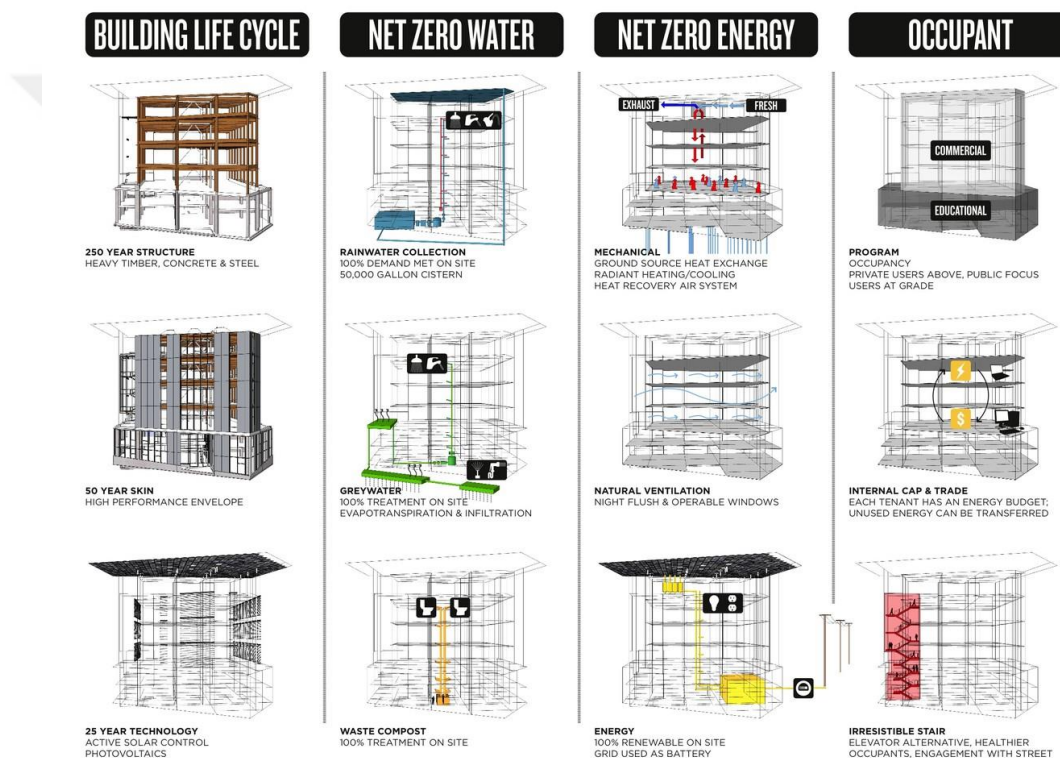


Figure 4.30. The Bullitt Center design features (Porada, 2013)

Instead of using elevators, the building promotes the stairs, called “*Irresistible Stairs*,” located on the front entrance of the building for visibility. Quality city and skyline views encourage occupants to use stairs instead of elevators to reduce electricity usage and enhance occupant health by promoting an active lifestyle. (Bullitt Center, 2021; Miller Hull, 2022) The building also provides a bike garage,

repair station, and each floor has showers for bikers and commuters to promote a healthy lifestyle. (Bullitt Center, 2021)



Figure 4.31. Irresistible staircase and bike garage (Kahn, n.d.)

4.2.3.5 Operation and Process

The building collects and reuses the rainwater to achieve net-zero water. All the water used in the building is collected from the roof, stored in the 56,000-gallon cistern in the basement, and treated for disinfection and purification to use as drinking, hygiene, and cleaning water. (Bullitt Center, 2021; Miller Hull, 2022) It also collects and reuses the structure's greywater from sinks, showers, and dishwashers. The water is collected, filtrated, disinfected, and reused to reduce wastewater. Excess water is treated in the rooftop wetland and returned to groundwater, supporting adjacent urban landscapes and biodiversity. (Bullitt Center, 2021; Miller Hull, 2022)

In addition, the building management systems, including passive and mechanical ventilation, water management system, heating and cooling system, and natural and artificial light management, operates to respond and interact with the environment of the structure and adapts accordingly with a combination of a passive and active system. (Bullitt Center, 2021) The building is heated with heat pumps and a radiant heat system. Geothermal well field located under the structure acts as a source for a

heat exchange system to warm a mix of water and glycol that runs up to the building and circulates in the floor to heat the interiors. The system can run in a reverse cycle in summer to reduce the heat on the interior floors. (Bullitt Center, 2021; Miller Hull, 2022) The ventilation system on the building provides fresh air all year long with a heat recovery ventilation system to keep the interiors in a comfortable thermal state without using much energy. The fresh air from outside is pulled into the building after filtration and exhausted outside with the help of a heat transfer wheel. (Bullitt Center, 2021; Miller Hull, 2022)

4.2.3.6 Innovation and Function

Upon analysis of the distinct characteristics that make this building unique, it can be observed that it is a living building that contributes to its surrounding environment and occupants. It utilizes advanced technology and sustainable solutions inspired by nature rather than solely relying on point-based, conventional sustainable practices to follow regenerative objectives and ambitions. (Quirós, 2019)

The Bullitt Centers' key features and achievements in terms of design are an extended building life cycle, net-zero water and energy systems, and occupant priority and wellness. To ensure these efficient systems, material selections, technological and operational advancements and innovations, and social and cultural assessments and analyses were prioritized in the design. The building generates on-site renewable energy with no environmental footprint, operates on a net-positive basis, and promises less maintenance and a comfortable user experience. Important key design features of the building are; radiant heating, ventilation system, energy generation, water and waste management, and material selections. (Homchick Crowe, 2020) Also, the innovative design of the elevators, designed by KONE, on the building regenerates energy from the movement of the elevator. It uses %60 less energy than regular elevators and collects excess generated energy to use in the building. (Bullitt Center, 2021)



Figure 4.32. The Bullitt Center and the interior office space (Kahn, n.d.)

The Bullitt Centers’ design elements and solutions aspiring a regenerative design approach from the knowledge and observation generated from nature while also respecting its natural environment exemplifies the success of integrated, regenerative, holistic design approach benefiting from biomimicry can achieve recognition and certifications.

4.2.3.7 In Terms of LEED and Biomimicry

The Bullitt Center is *“living proof that self-sustaining, net positive buildings are a realistic option and can be financially achievable, comfortable for tenants and a beautiful addition to the community with essentially no environmental footprint.”* (Urban Green Council, 2016) as stated by the U.S. Green Building Council. The building fulfilled and exceeded all the requirements for LEED platinum certification but did not strive to obtain the certification. Despite this, the building was recognized as a prime example by the USGBC for its sustainable and regenerative design.

The building fulfills the certification criteria by not only being self-sustaining and environmentally responsible but also producing more resources than the building and its occupants use in a year. In all credit categories, the building provides necessary design specifications, even specific criteria like bike racks, smart controls, passive cooling and heating systems, and waste management.

Table 4.8 Credit categories and design solutions that meet LEED criteria

<i>Credit Category</i>	<i>Design</i>
<i>Integrative Process</i>	collective design process, high-performance design
<i>Location and Transportation</i>	central and easily accessible location close to social amenities and open spaces, promoting walking and cycling for a healthier lifestyle, bike racks and garage
<i>Sustainable Sites</i>	water and pollution management, no environmental footprint, integration with its site and natural environment, waste management
<i>Energy and Atmosphere</i>	net-positive building life-cycle, energy regeneration, automated triple layer façade (glazing and shading)
<i>Materials and Resources</i>	durable, locally sourced, healthy, low carbon footprint, renewable building materials, and benefiting from and contributing to natural resources
<i>Indoor Environmental Quality</i>	fresh air all year long with heat recovery ventilation system, keeping the interiors in a comfortable thermal state, passive heating systems, occupant priority

Table 4.9 (continued).

<i>Innovation</i>	advanced technology and sustainable net-positive design solutions (elevator and façade design)
<i>Regional Priority</i>	in harmony with and providing for its environment

In all eight credit categories, the design elements of the building and its performance meet the criteria and qualify for the required points. Although the Bullitt Center complies with LEED criteria and is guaranteed to receive a certificate, the fact that it does not enter the certification process can be interpreted as not wanting to limit the design to these criteria. The reason for this can be shown as the fact that the building is not only a sustainable building that meets the criteria but also a building that benefits its owner, its occupants, and its environment, improving their health. It regenerates energy and resources and proves that designing regenerative self-sustaining, net-positive buildings is possible even in dense urban areas.

Viewing the Bullitt Center from a biomimicry framework, it can be seen that nature influences and inspires design at all application levels of biomimicry. The design of the building is inspired by Douglas fir⁷⁶ forests and their habitat. (Kapp, 2017) The key survival and adaptation characteristics of the trees, inspire different design features of the building from energy, water and solar efficiency, and materials.

⁷⁶ Douglas fir (*Pseudotsuga menziesii*) is an evergreen tree from the pine family. Its forests are located mainly in North America. (National Wildlife Federation, n.d.)

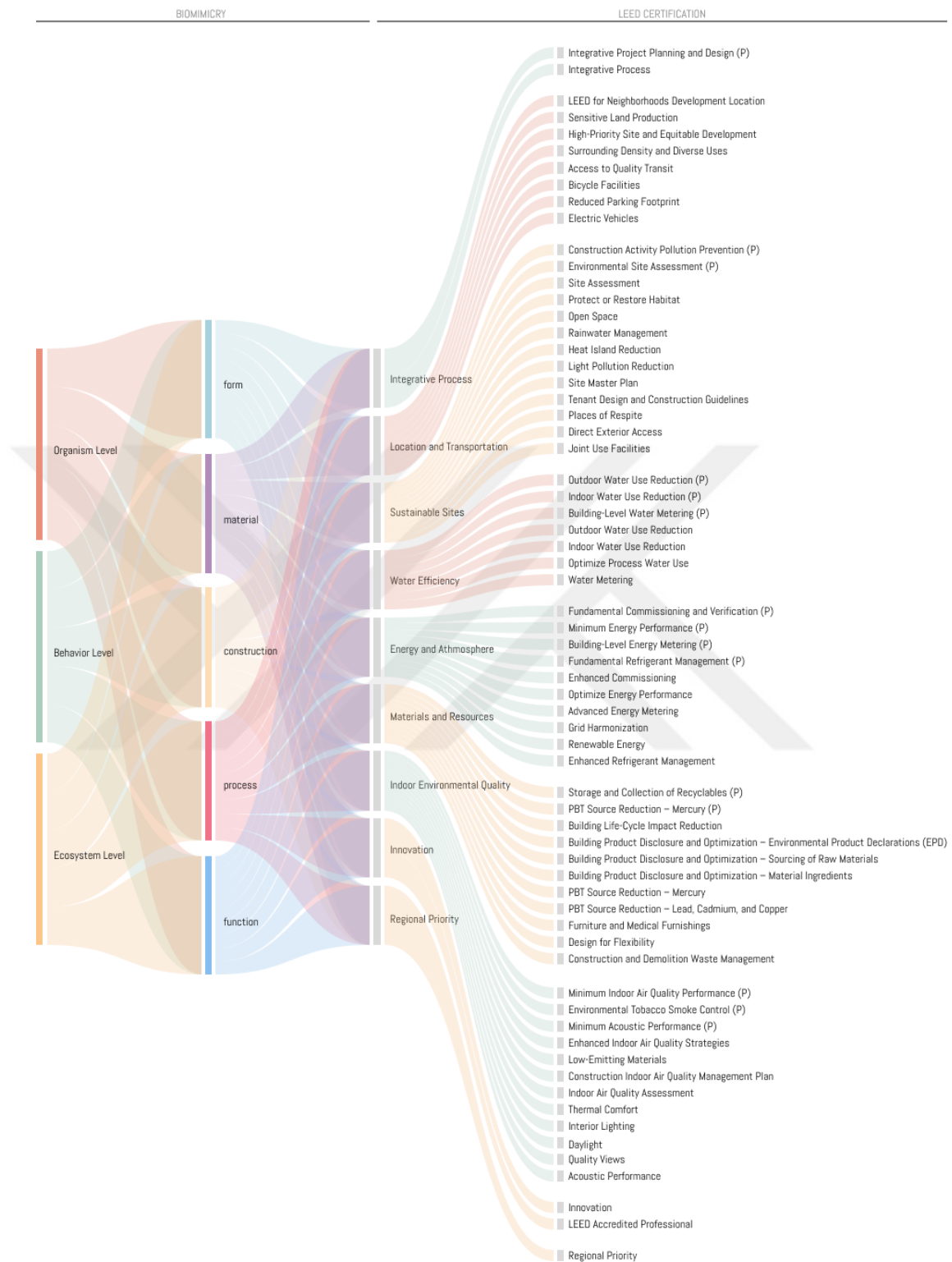


Figure 4.33. The Bullitt Center Biomimicry and LEED Certification Relation
Diagram drawn by the author

Table 4.10 Design correspondences of the application level of biomimicry of the Bullitt Center

Application Level	Dimension	Design
Organism Level	<i>form</i>	triple layered design of the façade inspired by the leaves of the trees to optimize daylighting and natural ventilation
	<i>material</i>	material selection of timber inspired by the forest for optimized solar heat gain
	<i>process</i>	the adaptation of trees to their local environment and climate to optimize daylight and natural ventilation for thermal comfort is mimicked as if the building breathes
Behavior Level	<i>construction</i>	the photovoltaic solar panels on the roof of the structure are mimicked and built like a tree canopy for capturing solar energy
	<i>process</i>	collection and treatment of water on-site before reusing is inspired by the natural reusing cycle of the soil and trees
	<i>function</i>	grey and wastewater management system is mimicked from the forest
Ecosystem Level	<i>process</i>	providing for local wildlife and reducing urban heat island effect

Table 4.7 (continued).

<i>function</i>	rainwater harvesting system and protection and contribution to nearby natural environments mimic the natural patterns of the forest
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The design decisions inspired by Douglas fir forests, each from one of the many elements in nature, have different function, effect, and benefit to the building in different levels and dimensions. The life-cycle patterns of the trees, their natural materials and material qualities, their formal qualities, survival, efficiency, optimization, and adaptation strategies to their environment inspire the design in this case.

The holistic and collaborative approach of the design process of this case, which was not designed with the aim of sustainability and achieving certification, has also manifested itself in the design. As a multi-scalar, regenerative design, it has become a living structure that not only contributes to its own existence and occupants but also benefits from and contributes to this environment as a harmonious part of the built and natural environment in which it is located.

4.3 Discussion and Evaluation: Sustainable and Regenerative Design Goals

Environmental consciousness and awareness of the natural and built environment in architectural design is accepted as a design norm in the world with the realization of climate change and our contribution to it. Seeking environmentally friendly, healthy, comfortable, conscious, zero or positive impacting, and sustainable built environments is the common ground in sustainable and regenerative design. With the examples of different design approaches to sustainability, LEED certification, and regenerative design, biomimicry, it is possible to distinguish the results of both approaches.

	 The Eastgate Shopping Center <i>Biomimicry</i> Harare, Zimbabwe Mick Pearce (+ Arup) 1996 retail and office building 5600 m² retail + 26000 m² office	 The Pixel Building <i>LEED Certification</i> Melbourne, Australia studio 505 2010 retail and office building 1136.4 m²	 The Bullitt Center <i>Biomimicry + LEED Certification</i> Seattle, USA Miller Hull Partnership 2013 office building 4650 m²
Site and Context	subtropical highland climate <i>(mild summers, cool winters)</i> industrially limited reserves <i>(need for importing from different countries)</i> located in a central busy district <i>(easily accessible and connection with main streets)</i>	former site of the Carlton and United Brewery <i>(key urban site with archaeological artifacts)</i> easily accessible <i>(connected to public transportation)</i> close amenities in walking distance <i>(shops, cafes, parks, museums, universities)</i>	a central key area in Seattle <i>(easily accessible for commuters and by walking)</i> close access to social amenities <i>(restaurants, cafes, parks, basic amenities)</i>
Morphology and Form	two blocks connected by a glass roof and steel bridges external envelope <i>(for thermal comfort)</i> a breathing building <i>(chimneys on the roof)</i>	colorful façade design <i>(giving identity to the building)</i> aiming for 'future office prototype' <i>(technological enhancements and high-performing, environmental design)</i>	'World's Greenest Commercial' Building <i>(designed to be with a holistic approach)</i> a living building <i>(self-sustaining and contributing to its environment and occupants)</i>
Tectonic and Material	low thermal emitting material selection <i>(concrete blocks and brick, concrete vaulted ceilings)</i> light and glare controlling glazing efficient lighting selections	recycled and reused materials <i>(facade panels)</i> locally sourced construction materials specially developed concrete mix <i>(low carbon footprint)</i> double-glazed window walls green roof	built to last <i>(locally sourced, durable, renewable and healthy material selection: concrete, steel, timber)</i> glazing for regional compatibility <i>(aesthetic, low carbon footprint, safety, thermal comfort and air quality)</i>
Structure and Construction	fractal construction of the external envelope <i>(facade and balconies to increase surface area)</i> air shafts, vents, chimneys <i>(for stack effect and air regulation)</i>	pixelated facade complex yet simple structure <i>(concrete slabs, floor to ceiling windows)</i>	active solar control photovoltaics <i>(overhanging photovoltaic panels on the roof)</i> high performance envelope <i>(triple layered glazing and shading)</i> heavy timber, concrete and steel structure irresistible stair <i>(healthier alternative, engagement with street)</i>
Operation and Process	natural passive ventilation system energy efficient mechanical and electrical systems <i>(for internal thermal comfort and cost-efficient energy consumption)</i>	self-sufficient passive systems <i>(water treatment and ventilation)</i> carbon neutrality and energy efficiency waste management	net-positive energy building <i>(radiant heating, natural ventilation, on-site energy generation)</i> water and waste management <i>(rainwater collection, on-site greywater treatment)</i> building management systems <i>(responding and adapting to its environment)</i>
Innovation and Function	thermoregulation in extreme climate conditions <i>(innovative regenerative systems and spatial organization)</i> generation and optimization of energy, heat and light	power generation <i>(from solar panels)</i> on-site technological treatment solutions innovative concrete mixture	living building <i>(generating resources and contributing to its environment)</i> elevator design by KONE <i>(regenerates energy from movement)</i>
In terms of LEED and biomimicry	Biomimicry – inspired from how termites live in extreme climate conditions, and adapt their living spaces	LEED Platinum Certified – achieved highest score in v3 BD+C category	Fulfilled and exceeded all the requirements for LEED platinum certification, Biomimicry – inspired from Douglas fir forests

Figure 4.34. Case study comparison matrix drawn by the author

The case analysis framework considering different scales of design, integrates a structured criteria based approach and a more holistic and inclusive design approach to reveal similarities and differences between the two approaches. It demonstrates that it is possible to evaluate both approaches in a shared framework to understand their design elements, performances, and impact on their context. Analysing these three projects with different design approaches and initiatives, it is possible to observe that both approaches, sustainable design – LEED certification – and regenerative design – biomimicry – generate technological and innovative design solutions to specific design problems considering performance and efficiency. They understand a need for a change to improve how we build and our built environments impacts. Figure 4.34 summarizes the projects' key aspects based on the comparison framework.

LEED certification is a promising initiator to raise awareness globally from designers to investors and occupants of buildings and improvement in the built environment. However, compared to the biomimicry approach and regenerative design, it lacks multi-scalar design outputs considering natural context, building life-cycle, and production contributing to its environment and nature. As can be observed from the case studies, the Bullitt Center, biomimetic architecture as a regenerative design approach can achieve LEED certification criteria without solely focusing on a single-oriented point-based design solution and contributes to its occupants and its environment.

The benefits and improvements of the building's performance and efficiency can be argued in terms of technological advancements, economical drives, and distinct design elements. However, considering a building in its larger urban scale, it is possible to understand that regenerative design – biomimicry – is a more holistic, multi-scalar, inclusive design method that leads designers to more sustainable design solutions in harmony with their environment. Regenerative design has a significantly broader scale than sustainable design, encompassing a more comprehensive and inclusive approach. Therefore, sustainable design can be considered a part of regenerative design.



CHAPTER 5

CONCLUSION

The world will not evolve past its current state of crisis by using the same thinking that created the situation.

- *Albert Einstein*

Sustainability and ecological thinking are essential aspects of our lives that cannot be ignored. The climate crisis and our consumption habits send warning signals through global and national crises. Recent earthquakes, climate changes, and resource crises are constant reminders that we need to become more aware of and improve our environment. The pandemic we have experienced has only highlighted the urgency of this matter. It is imperative that we take action now to address these issues before they become even more severe.

Especially in architecture, the rapid expansion and contribution to the built environment increase daily, and its consequences are apparent to such an extent that it is noticeable in our daily lives. Understanding our changing world and adapting to it is inevitable. Thus, how we think and construct our built environments and buildings needs a radical change embracing positive impacts rather than harming the natural environments and ecosystems.

The current approach to sustainability in the built environment primarily focuses on achieving efficiency to reduce the negative impacts caused by built environments and excessive resource use. Green building certification systems -LEED Certification- and incentive mechanisms promote commercial profits and recognition by only minimizing the negative impacts the buildings cause, disregarding their larger environmental impacts.

LEED certification promotes sustainable design and architecture with generalized and point-focused criteria. The approach and certification process lacks a holistic, integrated embracing of design process with its limitations and remains far from being a unifying and universal design approach. As a design incentive, the certification system achieves some sustainability goals; however, these goals do not go far from minimizing the negative impacts of the building itself.

To truly engage with the environment, it is crucial to base design on the health of ecological systems. It is imperative to shift from a point-focused approach to a holistic one that considers all living systems' relationships to comprehend their connections fully. An effective way to attain this understanding is through a context-based regenerative approach, which comprehensively integrates and understands each location's unique characteristics. The design process should prioritize creating mutually beneficial relationships within the system. This shift towards a more integrated approach to sustainability and sustainable architecture has the potential to exceed minimal negative impacts and environmental preservation to a regenerative and coherent natural and built environment.

The principle of biomimicry, involving the emulation and inspiration drawn from nature and its ecological processes, has been an intrinsic practice employed across generations, even before its formal designation. Throughout human history, the observant nature of humankind has naturally instigated a process of learning and development through the study of surrounding phenomena, subsequently integrating acquired knowledge into daily life practices and creative endeavors.

As a regenerative approach, biomimicry is observing, understanding, and examining natural systems and applying what is learned from nature to design. The design challenges faced in architecture can be solved with tested solutions in our natural environment. It is a holistic, multi-scalar, integrative design approach with context-based solutions. Thus, this approach focuses on more than just the end product to be efficient but also coherent with its environment and regenerative. The study of biomimetic design in architecture has yet to be widely established, but the

application levels of biomimicry in architecture offer a methodology and foundation in architectural design.

While LEED certification is a positive step and shares common goals with biomimetic and regenerative design towards a better, improved environment, it has limitations regarding inclusiveness, holism, and multi-scalar understanding. Its point criteria approach only considers the context on a small scale and needs a comprehensive understanding of the environment and design factors, including physical, social, and natural factors. On the other hand, biomimicry takes a more holistic and multi-scalar approach to design and understand the environment. The application levels of the biomimicry framework consider context as a design input and factor that directly impacts design. This approach addresses design problems at the organism, behavior, and ecosystem levels, leading to a more direct relationship with context and its multi-scalar approach.

By analyzing case studies with different design methods and aims, both approaches may have common grounds for building scale applications; however, they differ in multi-scalar understanding and integration of context as a definitive design input. This suggests that the regenerative design approach encompasses a sustainable design approach on a larger scale.

The case studies demonstrated in the thesis suggest that while LEED certification has more systematic and directive criteria but can be restrictive, biomimicry provides a framework for guidance and problem-solving on a broader scale with a holistic approach to design. As a design method, it can create positive impacts and products without being result-oriented. Buildings designed with this method are also very likely to meet certification criteria.

Sustainable design tries to protect existing resources while showing more passive goodwill. Nevertheless, this approach must be revised considering today's population growth and rapid resource demand. Conservation and self-sustaining are not enough considering direct and indirect damage and consumption of the resources; we need

to go beyond that and contribute to our environment, and regenerative design is a promising approach toward a significant and lasting impact.

Although many examples of LEED-certified buildings exist, biomimicry in architecture has yet to become widespread and adopted. On top of this, the number of buildings designed with biomimicry and aiming to achieve LEED certification simultaneously is quite limited. In order to better understand the implications of these results, biomimicry as a regenerative design approach and its framework of application levels need to become more widespread and more widely accepted as a guiding method in design. At the same time, design should be approached from a multi-disciplinary and multi-scalar perspective, and the context in all scales should be integrated into the design process.

It is important to note that the application levels of the biomimicry framework should not be considered definitive design solutions. A comprehensive understanding of different fields is required to effectively analyze and extract design solutions from nature. To better understand the implications of these results, future analysis with more examples of these approaches and, if possible, both approaches together would provide a better understanding of detailed application methods.

While this study provides an insight into sustainable and regenerative design with research on LEED certification criteria and application levels of biomimicry through case studies, further understanding and integration of concepts to the design practice can advance knowledge and awareness in this field to improve the way we design our built environments. Incorporating regenerative design and biomimicry into architectural design education can open a new door in the design perspective and contribute to the production of more exemplary designs by creating a foundation in this field while at the same time helping to develop and adopt this approach.

In the current landscape of architectural practice, regenerative design approaches and projects have attained growing prominence due to their emphasis on environmental sustainability and ecosystem restoration. In this context, biomimicry emerges as a compelling and transformative methodological paradigm that can serve as a seminal

guide for crafting built environments that embrace regenerative principles and harmoniously integrate with and draw inspiration from nature's innate wisdom. By embracing biomimicry's ethos of learning from and emulating nature's time-tested strategies, architects can create ecologically resilient and harmonious architectural solutions that contribute positively to the broader ecological system.

In the future, when it is foreseen that the climate crisis and change are design challenges that cannot be ignored, deepening research on regenerative design and biomimicry will enable the development of a vision in education, building information, and practice. Additionally, researching the role of interdisciplinary collaborations between architects, biologists, engineers, and other relevant disciplines in fostering biomimetic design would help develop collaborative models and frameworks. Understanding the challenges and opportunities in implementing biomimicry in architectural practice, such as the need for specialized knowledge, access to relevant resources, and integration within existing design processes, would also be beneficial.

Furthermore, investigating the role of emerging technologies, such as computational design tools and digital fabrication, in supporting biomimetic design processes and exploring their potential for scalable implementation in architectural practice would contribute to advancing the field. Lastly, studying the awareness, attitudes, and perceptions of architecture professionals and educators towards biomimicry and the barriers and enablers for its adoption in practice and education would help identify strategies to promote greater acceptance and integration of biomimicry principles. Addressing these research areas can foster a more comprehensive understanding of biomimicry in architecture education and practice, facilitating its broader adoption and impact.

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APPENDICES

A. Appendix A

No.	Standard	Time Issued	Country	Leading Organization
1	BREEAM	1990	United Kingdom	Building Research Establishment Ltd. (BRE)
2	BEPAC	1993	Canada	The University of British Columbia
3	EcoEffect	1997	Sweden	The Royal Institute of Technology, Stockholm and the University of Gavle
4	LEED	1998	United States	U.S. Green Building Council (USGBC)
5	GBA/GBTool	1998	Canada	International Initiative for a Sustainable Built Environment
6	NABERS/ABGR	1999	Australia	The Office of Environment and Heritage (OEH)
7	EEWH	1999	China	National Council for Sustainable Development under the Ministry of the Interior (MOI)
8	Eco-Quantum	1999	Netherlands	IVAM
9	GG	2000	Canada	ECD Energy and Environment Canada
10	BEAT	2000	Denmark	Danish Building Research Institute (SBI)
11	Ecoprofil	2000	Norway	Norwegian Building Research Institute (SINTEF Byggforsk)
12	CASBEE	2001	Japan	Japan Sustainable Building Consortium (JSBC)
13	CEPAS	2002	Hong Kong	Building Department of Hong Kong Special Administrative Region of the People's Republic of China
14	PromisE	2002	Finland	VTT Technical Research Station
15	KGBC	2001	Korea	Korea Green Building Council
16	GreenStar	2003	Australia	Green Building Council Australia
17	TGBRS	2003	India	The Energy and Resources Institute (TERI)
18	GRIHA	2004	India	The Energy and Resources Institute (TERI)
19	HQE	2005	France	Cerway
20	Si-5281	2005	Israel	Standard Institute of Israel
21	GM	2005	Singapore	Building and Construction Authority (BCA)
22	LBC	2006	United States	International Living Future Institute
23	GPR	2006	United States	Built It Green
24	ASGB	2006	China	Ministry of Housing and Urban-Rural Development of People's Republic of China
25	DGNB	2006	Germany	The German Sustainable Building Council (Non-profit organization)

26	CSH	2006	United Kingdom	Department for Communities and Local Government
27	EPRS	2007	Abu Dhabi	Abu Dhabi Urban Planning Council GBI
28	SICES	2007	Mexico	The Mexico Green Building Council (MGBC)
29	NGBS	2008	United States	National Association of Home Builders (NAHB)
30	AQUA-HQE	2008	Brasil	Vanzolini Foundation at the Polytechnic University of Sao Paulo
31	LiderA	2008	Portugal	Manuel Duarte Pinheiro, Ph.D.
32	ITACA Protocol	2009	Italy	Institute for Innovation, Procurement Transparency and Compatibility Environmental-National Association of Regions and Autonomous Provinces (ITACA)
33	GBI	2009	Malaysia	Architectural Association of Malaysia (PAM)
34	BERDE	2009	Philippine	Philippine Green Building Council (PHILGBC)
35	GSAS	2009	Qatar	Gulf Organization for Research & Development
36	VERDE	2009	Spain	Green Building Council España (GBCE)
37	GPRS	2010	Egypt	Egypt Green Building Council
38	LOTUS	2010	Vietnam	Vietnam Green Building Council (VGBC)
39	GREENSHIP	2010	Indonesia	Green Building Council Indonesia
40	BEAM Plus	2010	Hong Kong	Hong Kong Green Building Council and the BEAM Society Limited
41	TREES	2010	Thailand	Thai Green Building Institute
42	BNB	2010	Germany	the Federal Ministry of the Interior, Building and Community
43	ARZ BRS	2012	Lebanon	Lebanon Green Building Council (LGBC)
44	IGBC	2013	India	Indian Green Building Council
45	EDGE	2014	United States	International Finance Corporation –World bank group Green
46	WELL	2014	United States	The International WELL Building Institute (IWBI)
47	SITES	2015	United States	The Sustainable Sites Initiative
48	CASA Colombia	2017	Colombia	Consejo Colombiano de Construccion Sostenible (CCCS)
49	CEDBIK	2018	Turkey	Turkey Green Building Council
50	DGBC Woonmerk	2018	Netherlands	Dutch Green Building Council
51	B.E.S.T.	2019	Turkey	Turkey Green Building Council

B. Appendix B – LEED v4.1 for Building Design and Construction Checklist



LEED v4.1 BD+C: Healthcare

Project Checklist

Project Name:

Date:

Y ? N

	Y			Prereq	Integrative Project Planning and Design	Required
				Credit	Integrative Process	1

	0	0	0	Location and Transportation		9
				Credit	LEED for Neighborhood Development Location	9
				Credit	Sensitive Land Protection	1
				Credit	High Priority Site and Equitable Development	2
				Credit	Surrounding Density and Diverse Uses	1
				Credit	Access to Quality Transit	2
				Credit	Bicycle Facilities	1
				Credit	Reduced Parking Footprint	1
				Credit	Electric Vehicles	1

	0	0	0	Sustainable Sites		9
	Y			Prereq	Construction Activity Pollution Prevention	Required
	Y			Prereq	Environmental Site Assessment	Required
				Credit	Site Assessment	1
				Credit	Protect or Restore Habitat	1
				Credit	Open Space	1
				Credit	Rainwater Management	2
				Credit	Heat Island Reduction	1
				Credit	Light Pollution Reduction	1
				Credit	Places of Respite	1
				Credit	Direct Exterior Access	1

	0	0	0	Water Efficiency		11
	Y			Prereq	Outdoor Water Use Reduction	Required
	Y			Prereq	Indoor Water Use Reduction	Required
	Y			Prereq	Building-Level Water Metering	Required
				Credit	Outdoor Water Use Reduction	1
				Credit	Indoor Water Use Reduction	7
				Credit	Optimize Process Water Use	2
				Credit	Water Metering	1

	0	0	0	Energy and Atmosphere	35
	Y			Prereq Fundamental Commissioning and Verification	Required
	Y			Prereq Minimum Energy Performance	Required
	Y			Prereq Building-Level Energy Metering	Required
	Y			Prereq Fundamental Refrigerant Management	Required
				Credit Enhanced Commissioning	6
				Credit Optimize Energy Performance	20
				Credit Advanced Energy Metering	1
				Credit Grid Harmonization	2
				Credit Renewable Energy	5
				Credit Enhanced Refrigerant Management	1

	0	0	0	Materials and Resources	19
	Y			Prereq Storage and Collection of Recyclables	Required
	Y			Prereq PBT Source Reduction- Mercury	Required
				Credit Building Life-Cycle Impact Reduction	5
				Credit Environmental Product Declarations	2
				Credit Sourcing of Raw Materials	2
				Credit Material Ingredients	2
				Credit PBT Source Reduction- Mercury	1
				Credit PBT Source Reduction- Lead, Cadmium, and Copper	2
				Credit Furniture and Medical Furnishings	2
				Credit Design for Flexibility	1
				Credit Construction and Demolition Waste Management	2

	0	0	0	Indoor Environmental Quality	16
	Y			Prereq Minimum Indoor Air Quality Performance	Required
	Y			Prereq Environmental Tobacco Smoke Control	Required
				Credit Enhanced Indoor Air Quality Strategies	2
				Credit Low-Emitting Materials	3
				Credit Construction Indoor Air Quality Management Plan	1
				Credit Indoor Air Quality Assessment	2
				Credit Thermal Comfort	1
				Credit Interior Lighting	1
				Credit Daylight	2
				Credit Quality Views	2
				Credit Acoustic Performance	2

	0	0	0	Innovation	6
				Credit Innovation	5
				Credit LEED Accredited Professional	1

	0	0	0	Regional Priority	4
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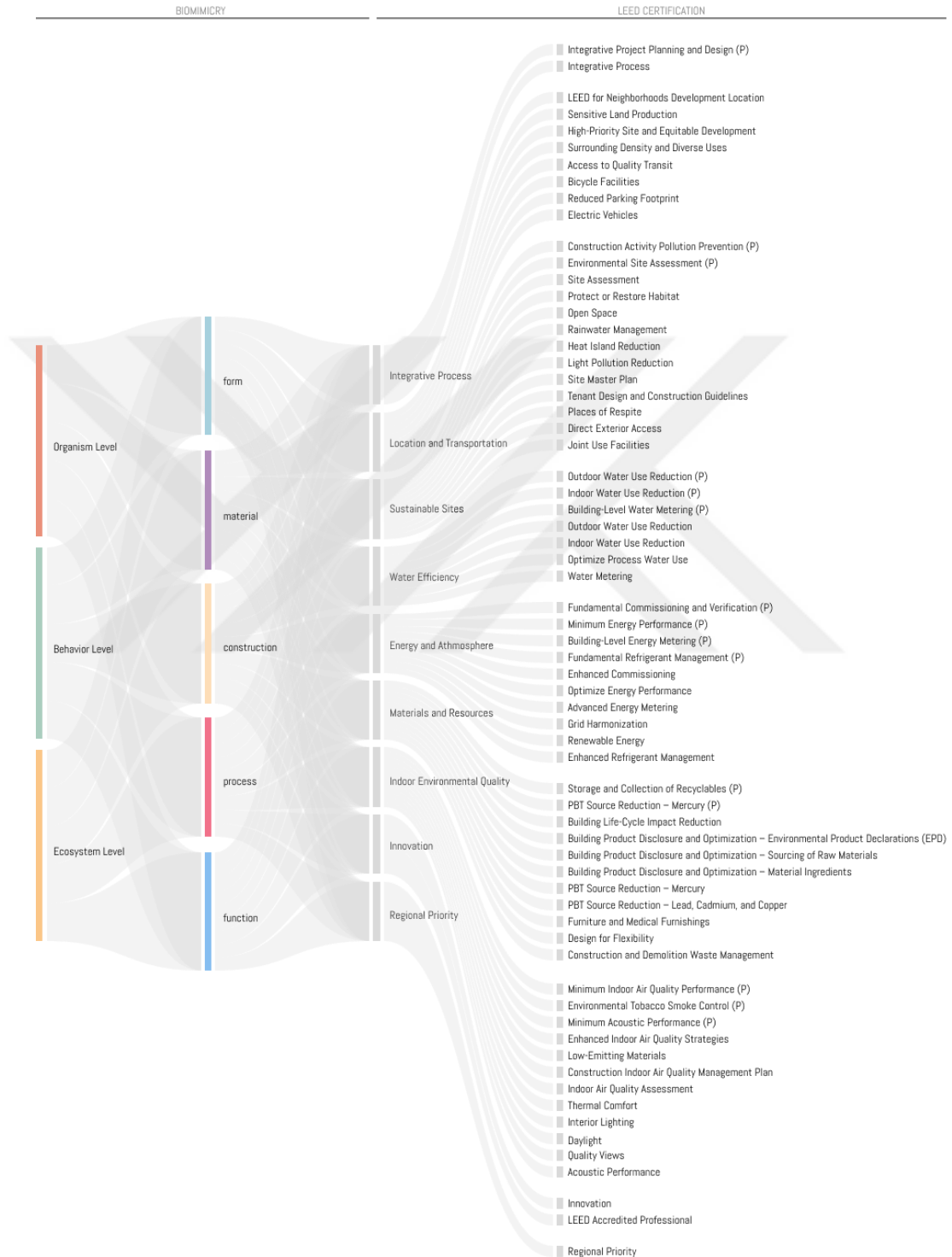
				Credit	Regional Priority: Specific Credit	1
				Credit	Regional Priority: Specific Credit	1
				Credit	Regional Priority: Specific Credit	1
				Credit	Regional Priority: Specific Credit	1

	0	0	0	TOTALS	Possible Points:	110
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Certified: 40 to 49 points, **Silver:** 50 to 59 points,
Gold: 60 to 79 points, **Platinum:** 80 to 110



C. Appendix C – Biomimicry and LEED Criteria Relation Diagram



D. Appendix D – Pixel by studio505 LEED Certification Scorecard

1000002829, Carlton, Victoria		Pixel		LEED BD+C: New Construction (v2009)		PLATINUM, AWARDED FEB 2012	
		SUSTAINABLE SITES		AWARDED: 26 / 26			
SSp1	Construction activity pollution prevention	REQUIRED				MATERIAL & RESOURCES	
SSc1	Site selection	1/1				CONTINUED	
SSc2	Development density and community connectivity	5/5				MRC5	Regional materials
SSc3	Brownfield redevelopment	1/1				MRC6	Rapidly renewable materials
SSc4.1	Alternative transportation - public transportation access	6/6				MRC7	Certified wood
SSc4.2	Alternative transportation - bicycle storage and changing rooms	1/1					
SSc4.3	Alternative transportation - low-emitting and fuel-efficient vehicles	3/3				INDOOR ENVIRONMENTAL QUALITY	
SSc4.4	Alternative transportation - parking capacity	2/2				AWARDED: 15 / 15	
SSc5.1	Site development - protect or restore habitat	1/1				EQp1	Minimum IAQ performance
SSc5.2	Site development - maximize open space	1/1				EQp2	Environmental Tobacco Smoke (ETS) control
SSc6.1	Stormwater design - quantity control	1/1				EQc1	Outdoor air delivery monitoring
SSc6.2	Stormwater design - quality control	1/1				EQc2	Increased ventilation
SSc7.1	Heat island effect - nonroof	1/1				EQc3.1	Construction IAQ Mgmt plan - during construction
SSc7.2	Heat island effect - roof	1/1				EQc3.2	Construction IAQ Mgmt plan - before occupancy
SSc8	Light pollution reduction	1/1				EQc4.1	Low-emitting materials - adhesives and sealants
		WATER EFFICIENCY		AWARDED: 10 / 10		EQc4.2	Low-emitting materials - paints and coatings
WEp1	Water use reduction	REQUIRED				EQc4.3	Low-emitting materials - flooring systems
WEC1	Water efficient landscaping	4/4				EQc4.4	Low-emitting materials - composite wood and agri-fiber products
WEC2	Innovative wastewater technologies	2/2				EQc5	Indoor chemical and pollutant source control
WEC3	Water use reduction	4/4				EQc6.1	Controllability of systems - lighting
		ENERGY & ATMOSPHERE		AWARDED: 35 / 35		EQc6.2	Controllability of systems - thermal comfort
EAp1	Fundamental commissioning of building energy systems	REQUIRED				EQc7.1	Thermal comfort - design
EAp2	Minimum energy performance	REQUIRED				EQc7.2	Thermal comfort - verification
EAp3	Fundamental refrigerant Mgmt	REQUIRED				EQc8.1	Daylight and views - daylight
EAc1	Optimize energy performance	19/19				EQc8.2	Daylight and views - views
EAc2	On-site renewable energy	7/7					
EAc3	Enhanced commissioning	2/2				INNOVATION	
EAc4	Enhanced refrigerant Mgmt	2/2				AWARDED: 6 / 6	
EAc5	Measurement and verification	3/3				IDc1	Innovation in design
EAc6	Green power	2/2				IDc2	LEED Accredited Professional
		MATERIAL & RESOURCES		AWARDED: 9 / 14			
MRp1	Storage and collection of recyclables	REQUIRED				REGIONAL PRIORITY CREDITS	
MRC1.1	Building reuse - maintain existing walls, floors and roof	0/3				AWARDED: 4 / 4	
MRC1.2	Building reuse - maintain interior nonstructural elements	0/1				EAc2	On-site renewable energy
MRC2	Construction waste Mgmt	2/2				SSc2	Development density and community connectivity
MRC3	Materials reuse	2/2				SSc3	Brownfield redevelopment
MRC4	Recycled content	2/2				SSc6.2	Stormwater design - quality control
						WEC2	Innovative wastewater technologies
						TOTAL	
						105 / 110	
						40-49 Points CERTIFIED	
						50-59 Points SILVER	
						60-79 Points GOLD	
						80+ Points PLATINUM	