Sustainable Architecture: A Critique of LEED and the Potential of Biomimicry

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I. Abstract

This project explores the potential of biomimicry to be used as a sustainable design tool within the framework established by the Leadership in Energy and Environmental Design (LEED) certification process. The study aims to answer the following research questions: What are designers' perceptions of LEED and its contributions to the field of sustainable design? What work is being done to realize biomimicry in Los Angeles? Is biomimicry a realistic design approach, or should it exist as a theoretical framework? Can biomimicry theory be utilized to reconfigure the checklist-based approach to achieve LEED certification? From conducting interviews, this study found: a gap in design-based policy and its contribution to the field of sustainable design, the barriers that exist to realize biomimicry in architecture, and the importance of design experimentation in the expanding the field of architecture. This study concludes by recommending that the United Green Building Council redesigns the LEED certification process and allocate resources to further develop biomimicry theory.

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III. Introduction

The world is facing many environmental challenges that can be attributed to the rapid development of the built environment and urban areas. Today, urban areas use between 67 and 76 percent of global energy and consist of buildings with short life cycles designed with unsustainable materials (Ness and Xing, 2017, Booth, 2014). As people gain awareness of environmental issues, they have created movements and policies geared towards increasing the sustainability of the built environment.

In 1993, the U.S. Green Building Council (USGBC) developed the Leadership in Energy and Environment Design (LEED). This certificate program aims to make sustainable building initiatives accessible to architects and developers, as well as creating a means to measure and document sustainable buildings. With nearly 100,000 certified buildings in over 150 countries, LEED has become the global standard for sustainable design. LEED certification has four possible certification levels with six categories. LEED is essentially a checklist, where points are ascribed to projects that implement different initiatives from each category, the more points a project receives, the higher the overall rating is. See **appendix A** for LEED certification checklist.

LEED has proven incredibly successful in advancing the green building movement, however many architects are critical of the checklist-based approach and its impact on the field of sustainable design. These arguments stem from the fact that the checklist does not allow for the transformative and innovative design necessary to radically redirect the field of architecture. A multidisciplinary approach that includes architects, politicians, scientists, and planners is necessary to create and maintain a sustainable city.

Biomimicry provides a multidisciplinary approach to sustainability by combining methods found in science and design as it is a largely theoretical design process that takes inspiration from nature. Architects can utilize biomimicry theory to address the shortcomings present in the LEED certification process and transform the built environment. Theoretically, biomimicry is a perfect approach to sustainable design, but little of its theory is present contemporary design, much less realized in the built environment.

The goal of my research is to expand on the existing literature of approaches to sustainable design. My research questions include: What are designers perceptions of LEED and its contributions to the field of sustainable design? What work is being done to realize biomimicry in Los Angeles? Is biomimicry a realistic design approach, or should it exist as a theoretical framework? Can biomimicry theory be utilized to reconfigure the checklist-based approach to achieve LEED certification? From interviewing professionals whose work pertains to sustainable design, biomimicry, urban planning, and design consultancy, I found a gap in design-based policy and its contributions to the design field, the barriers that exist to realize biomimicry in architecture, and the need for design experimentation to expand the field of sustainable architecture.

IV. Personal Motivation

Last spring, I spent the semester in Berlin, Germany studying sustainable development. My three teachers were all architects who advocate for the advancement of sustainable design and application of biomimicry theory; they all integrate biomimicry theory in their work. They are responsible for introducing me to this growing paradigm. Germany is one of the most environmentally progressive and sustainable countries in the world, and I had the opportunity to see biomimicry theory realized in the built environment firsthand. It made sense to me and seemed to be the most logical answer to questions about sustainability; take inspiration from the most sustainable system in existence—nature! Upon my arrival to the states, I wanted to explore the ways biomimicry was being implemented in the United States—more specifically Los Angeles. That led me to this research project and I hope I have done justice to the field of sustainable design, biomimicry, and architecture.

V. Literature Review

The Problem of Design

The Industrial Revolution of the eighteenth and nineteenth centuries created the incentive and possibility for mass production and rapid development of goods and services. Firms and corporations extracted and processed nutrients and resources for industrial growth, making them unfit for recycling (van Dijk et al, 2013). Fossil fuels catalyzed the development of urban areas and simultaneously increased the emission of dangerous pollutants. This proved to be unsustainable because of the strain placed on the Earth's natural resources. Benyus (2002) also notes, "The economy put no price tag on resource drawdowns or on pollution, it gave no incentive to extract sustainably, process cleanly, or optimize use." Lack of incentives propagated unsustainable urban development. Today urban areas use around 67 and 76 percent of global energy and generates three quarters of the world's carbon emissions. The building and construction industries generate, "33% of emissions, 40% of material consumption, and 40% of all waste" (Ness and Xing, 2017). This unsustainable model has created urban areas that emit large amounts of carbon and use excessive energy—a problem that is exacerbated by architectural design.

The incorporation of unsustainable materials in the construction of buildings is problematic. By definition, unsustainable materials are unusable after a building's life cycle, use excessive materials and energy in their production, and otherwise burden the environment (Booth, 2014). Many building materials have short lifespans and their values decrease with time in a process called down cycling (Bollinger et al, 2006). There is little financial incentive for the construction and manufacturing industries to use and create sustainable materials. Using unsustainable materials in architectural design results in buildings with short life cycles. This phenomenon is present in mid-century modernist designs. Buildings of this era have poor energy performance and are in constant states of disrepair because they incorporate non-replaceable materials (Brandt, 2017).

Architects who produce poor design contribute to the environmental crisis by constructing an unsustainable built environment. “The built environment’s role in both contributing and mitigating global warming needs to be better understood by architects, and urban designers, given their role in the creation of the [built] environment (Hagan, 2013). In order to successfully mitigate the impacts of global warming, architects must be active stakeholders and feel a deeper responsibility to involve sustainability in their work and educate their clients (Hagan, 2013).

What is Sustainable Architecture?

Sustainability has many definitions and applications. Generally, sustainability can be defined as meeting “the needs of the present without compromising the ability of future generations to meet their own [needs]” (Grierson and Moultrie, 2011). When applied to sustainable design and sustainable architecture it “gathers a wide and heterogeneous series of principles and concepts from a variety of disciplines. It cannot be recognized as a coherent field. It is not clear yet what is implied by terms such as sustainable design” (Cucuzzella, 2015). The lack of a clear definition for sustainable design highlights the importance of collaboration with other fields. Sustainability “is a field of discourse and practices that straddles multiple disciplines including architecture, engineering, urban planning, ecology and climatology” (Owen and Kim, 2008). Again, these working definitions imply that in order for sustainable design to be successful it must be approached through multiple disciplines.

Sustainable architectural design is a growing field. While researchers find it difficult to define sustainable architecture, terms such as green buildings, zero waste, closed-loop systems, sustainable design, ecological design, green design, ecologically sustainable design, etc., are commonly used to describe the application of sustainability to building practices. Despite the prevalent use of these terms, their application to the built environment is rare or nonexistent. Many structures fail to move away from traditional construction and design models; they merely serve as an improvement within an unsustainable paradigm (Kibert, 2016).

LEED as the Sustainable Architecture Standard

In 1993, the USGBC formed the LEED to make sustainable building initiatives accessible to all developers and architects, as well as to develop a means to measure and document sustainable initiatives. LEED has created momentum in the sustainable design field; it is the most widely used green building rating system in the world and has been applied to more than 92,000 projects in over 165 countries (Matisoff et al, 2014). LEED is a comprehensive point system that allows developers and architects to identity and implement sustainable strategies to their project (Choi et al, 2015).

There are six LEED certification categories: sustainable sites, water efficiency, energy and atmosphere, materials and sources, indoor environmental quality, and innovation in design. Points are awarded based on the number of sustainable solutions applied to the project. The more points a design receives, the higher the overall rating. There are four possible levels of certification based on the number of points achieved: Certified (40-49), Silver (50-59), Gold (60-79), and Platinum (80+) (USGBC, 2018). See **appendix A** for LEED certification checklist.

LEED strives to provide a metric of understanding and measuring green buildings (Kauffman, 2016). The LEED standards are flexible in terms of what it means to be green and how a project can achieve that definition. LEED does not have performance-based goals and it instead aims to reduce a project's overall impact on the built environment. Thus, the way sustainability is approached is at the discretion of the patrons of the project (Cidell, 2009). The USGBC provides resources to understand the LEED rating system but lets the patrons determine the methodology used to achieve sustainable design and become LEED certified (Opoku et al, 2015). With this flexible framework, LEED creates space for interdisciplinary design teams to be successful (Kauffman, 2016).

LEED Certification and Energy Usage

It is important to acknowledge the importance and success of LEED certification, but also to be critical of its process and impact on constructing the approach to sustainable design. While LEED currently represents the standard for producing green and environmentally friendly buildings, does this system achieve its goals? Newsham et al, 2009, conducted a study to assess the post-occupancy evaluation to measure how well LEED certified buildings perform in relation to non-certified buildings and LEED buildings with different certification levels. The study found that 28 to 35 percent of LEED certified buildings used more energy per floor area than non-certified buildings. Furthermore, they did not find a statistically significant relationship between LEED certification levels and energy performance. For example, a LEED gold building did not exhibit better energy performances than a LEED silver building, nor did a LEED platinum building outperform the other levels. This disproves the precedent that high scoring LEED buildings are more sustainable than buildings with a lower rating or non-LEED certified buildings. The study notes that its data collection was limited to the first year of the LEED building, so perhaps the performance of the studied buildings improved with time (Newsham and Birt, 2009).

Nevertheless, Newsham et al. highlight a major flaw in LEED certification: the checklist does not set measurable performance goals. LEED certification requires energy consumption to be modeled during the design process, but it does not require buildings to prove that they have met their goals post-construction. This process does not account for how people will interact and use the building post-construction, or that predicted energy use can be greatly underestimated (Auer et al, 2012). This calls the efficacy of LEED certification and what it means for a building to be LEED certified into question.

The Shortcomings of a Checklist

The LEED checklist does not cultivate innovative design solutions. A checklist-based approach to sustainable design is dangerous because it encourages a standard and formulaic approach. An *USA Today* review of 7,000 LEED certified commercial buildings proved that designers targeted the easiest and cheapest green points to achieve their scores. For example, a building can include bike racks and will earn points towards LEED certification (Peterson et al, 2014). The LEED checklist encourages designers to greenwash their projects, meaning: implementing green roofs, vertical gardens, solar panels, wind turbines, etc. (Auer et al, 2012). These are short-term solutions that do not represent a deep commitment to sustainability nor do they adequately address the field of architecture's shortcomings. Green features cannot exist simply as a design add on; instead, an emphasis on long-term design solutions will allow for a critical re-conception of the relationship between sustainability, the built environment, and architecture.

The LEED certification checklist does not encourage sustainable solutions that are specific to the surrounding environment. LEED solutions appear to be applicable and generalizable to any climate. With this approach, designers can obtain points without thinking about the environmental impact of their project (Kauffman, 2006, Cucuzzella, 2015). Architects cannot continue to design with "universally applicable blueprints to bring about sustainability"

(Wahl and Baxer, 2008). They should approach design in a holistic and integrative way that acknowledges how the building will interact within the existing local urban and environmental systems (Fecheyr-Lippens and Bhiwapurkar, 2017, Auer et al, 2012). Architects that ignore the larger environmental and urban context during their process produce buildings that are unconnected and insensitive to its surrounding environment. (Auer et al, 2012) Thus, LEED's approach to sustainable design is inadequate to shift the design paradigm (Cucuzzella, 2012). While LEED is successful in providing guidance to architects in achieving sustainable design, it fails to encourage innovative sustainable solutions. In order for architecture to be sustainable, a massive innovation is required (Auer, 2012).

A Multidisciplinary Approach is Necessary to Design Sustainably

Long-term sustainable design solutions require a multidisciplinary approach. A successful sustainable design solution "will require collaboration of urban planners, architects, engineers, politicians and academics" (Ali, 2008). Architects of the built environment must extend their gaze beyond conventional approaches and apply solutions found in science, technology, and policy (Farmer, 2013). LEED certification has provided an approach to sustainable design, but this approach exists within an untenable system that does not produce transformative results. The architect cannot accomplish sustainability alone. It is necessary for a multitude of professionals to develop a long-term transformative strategy that moves beyond simply alleviating problems associated with environmentalism (Dijk, 2014). Biomimicry has the potential to provide a comprehensive solution to the standardized—and largely ineffective LEED certification—approach to sustainable design.

Biomimicry Theory

Janine Benyus created the theoretical framework of biomimicry. She defines the field as "a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems" (2002). Benyus identifies the potential for nature to be used as a model, a measure, and a mentor for all fields. For the purpose of this study, I will address biomimicry's application to the fields of architecture and design. Nature can be used as a model that designers take inspiration from and apply to their design process. Nature is the most efficient model in existence and can be used to measure the effectiveness of a design. Lastly, nature can provide designers with a new way of visually interpreting the world (Benyus, 2002).

Biomimicry as the Multidisciplinary Approach to Sustainable Design

Biomimicry has the potential to be the multidisciplinary approach that the LEED certification process fails to cultivate. Biomimicry exists as a multidisciplinary framework that "stresses the interconnectedness of systems to solve complex problems; similarly, the integration of varied disciplines yield fertile ground for comprehensive designs to address an array of environmental issues in which buildings are constructed and operated" (Mazzoleni and Price, 2013). Biomimicry has the potential to reconstruct the way sustainable architecture is thought about and present an alternative approach that challenges the current sustainability paradigm. LEED certification encourages designers to reduce impact on the environment, whereas biomimicry attempts to create structures that have a positive impact on the environment (Buck, 2017).

Biomimicry Design Process

Biology-to-design and design-to-biology are two identified approaches to biomimicry. The biology-to-design begins with an understanding of a biological phenomenon and applies it to an architectural design challenge. On the other hand, design-to-biology begins with a design challenge, understands its typology, and then attempts to find a relevant biological solution (Rinaldi, 2007). Architecture can either mimic natures forms for aesthetics or to provide additionally functionality (Fecheyr-Lippens and Bhiwapurkar, 2017). Given the variety of local environmental conditions, architects must assess the site and its surrounding environment to have a better context to apply a biological concept. This allows for the biological strategy to be abstracted into a sustainable and applicable design principle that directly engages with its surrounding environment (Fecheyr-Lippens and Bhiwapurkar, 2017). Biomimicry can challenge the designer to think about the local context, a shortcoming noted in LEED certification.

Biomimicry Realized

Mick Pearce, a Zimbabwe based architect, has integrated biomimicry in his work. Pearce utilized the biology-to design approach by mimicking termite mounds to design the Eastgate Center (1996) in Harare, Zimbabwe – the largest office and shopping center in the area (Yomotov, 2014). Reference **appendix B** for photos. Temperatures in Zimbabwe fluctuate from 54° F at night to 95° F during the day and termites must maintain a temperature between 86 to 88° F to survive. The mounds have structural features that help regulate heat—during the day termites dig vents at the bottom of the mounds to bring cool air in and send hot air up to be released. Termites are constantly building new tunnels and blocking others to maintain the desired temperature within the mound (Yomotov, 2014).

Pearce was inspired by the mound's ability to control temperature and utilized the termites cooling methods for his Eastgate Center design. Pearce designed the building to have passive cooling system. Passive cooling is a design methodology where a building can regulate its temperature without a traditional heating, ventilation, and air conditioning system (HVAC). (Yomotov, 2014). During the day, the concrete building absorbs heat for later use to prepare the occupants for the cool temperatures at night. Fans, at the bottom of the building are used to draw the stored heat out of the concrete walls and sent it up to be released. This is an example of passive cooling as the building naturally regulates it temperature. This method was significantly cheaper than installing a traditional HVAC system. In the five years after completion, the Eastgate Center saved more than $3.5 million in energy costs. (Yomotov, 2014).

Biomimicry as a Regenerative Design Tool for the Built Environment

Instead of focusing on a singular project, designers can apply biomimicry to the built environment at large. Utilizing a biomimicry-based sustainable design process, "The built environment can function more like a system than a set of individual unrelated object-like buildings" (Pederson-Zari, 2011). Biomimicry has the potential to push the boundaries of sustainable design and create large-scale solutions. If design were to truly mimic nature, cities would function as complex, interactive, and high functioning ecosystem.

Critiques of Biomimicry and the Role of Theory in Architecture

The main critique of biomimicry is that it is too theoretical of a solution to achieve sustainable design. Although many of biomimicry's principles have not been realized in the built environment, theory contributes to the progression of architecture and sustainable design. Biomimicry may not currently be a feasible design solution, however:

> Theory uncovers aspects of the architecture practice that, while not useful or even correct for building now, may become a resource for future architectures. The theoretical

> text seeks out for us what we cannot otherwise imagine, but it does not do so by presenting us with a concrete representation, or even a guide to one, but rather by exposing the gaps and holes in our discipline and our discourse that are our own inability to see beyond the present and its ideological closure (Krista and Hays, 2009)

Even if biomimicry is proven to be an unrealistic design solution, the research supporting it is still relevant to the field of architecture. The research sheds light into the current shortcomings of sustainable architecture and presents new possibilities for architecture evolve into a more multidisciplinary field. Architectural theory, and design-based policy like LEED, "must continually be interrogated, evaluated, and revised" (Sykes and Hays, 2010) to progress. As research continues and the field of biomimicry expands, the likelihood of its theory being realized increases.

Helms et al, Cohen-Helfman and Reich suggest that biomimicry should remain a theoretical and inspirational approach instead of an applicable solution. Due to the lack of resources, architects could oversimplify and/or falsify a biological concept that could yield inapplicable designs (Helms et al, 2009). Another argument is that biology is replicable in theory but difficult to realize due to limitations in scale, material constraints, manufacturing constraints, and design ability. It can be difficult for architects to move micro and nano-scaled biological concepts into macro scaled architecture. Sometimes there is no artificial substitute for a biological material. Architects can utilize biomimicry as inspiration to assist design instead of utilizing it as a holistic design process (Cohen-Helfman and Reich, 2016).

Bensaude-Vincent et al, Fecheyr-Lippens, et al, and Fecheyr-Lippens and Bhiwapurkar, do not see the potential of biomimicry as a feasible design solution. Biomimicry currently exists as a new way of thinking and acting ecologically, but "the concept itself and its implications are philosophically undeveloped" (Blok, 2016). Some chemists believe that:

> Not all chemists have renounced the ambition to emulate, or even surpass, the limits of nature and therefore, 'biomimicry is no guarantee of success. Nature can only be used as a structural model… biomaterials are too complex and, in many cases, too temperamental for industrial production, we cannot simply transfer a solution found in nature to a technological problem' (Bensaude-Vincent et al, 2002).

A team could envision a biomimicry solution but find no appropriate manufacturing techniques to realize the project in a sustainable manner (Fecheyr-Lippens, et al, 2015). Current manufacturing techniques do not yield many affordable building materials that function as well as they do in nature, which ultimately limits usage of reusable building materials (Fecheyr-Lippens and Bhiwapurkar, 2017).

A misconception of biomimicry is that it guarantees sustainable results. The relationship between biomimicry and sustainability is still in question due to lack of implementation. A design might mimic nature but may incorporate toxic materials or require large amounts of energy. Projects could structurally mimic one aspect of nature but still use very unsustainable materials (Cohen-Helfman & Reich, 2016). Therefore, it is important to recognize that incorporating biomimicry as a sustainable design tool requires careful analysis.

VI. Methodology

Research Questions

This study contributed to the existing literature of biomimicry as an emerging field and its application to architecture and design. My research questions were: What are designers perceptions of LEED and its contributions to the field of sustainable design? What work is being done to realize biomimicry in Los Angeles? Is biomimicry a realistic design approach, or should it exist as a theoretical framework? Can biomimicry theory be utilized to reconfigure the checklist-based approach to LEED certification?

Design and Procedure

This was a qualitative study and I conducted semi-structured interviews. Interviews were conducted to gain expert opinion on LEED, sustainable design, and biomimicry. On average, these interviews lasted about 40 minutes. My interviews examined sustainable design, LEED certification process, the potential of architecture to become a more multidisciplinary field, and the application of biomimicry theory. Some interview questions specifically addressed the research or field of the participant. The questions aimed to provide insight into the experts' understanding of biomimicry principles and how their work contributes to the overall field of sustainably and biomimicry. Together, these interviews reveal a multidisciplinary narrative of sustainability in Los Angeles as it relates to planning, policy, biomimicry, and design.

Participants

Participants in this study were Los Angeles based professionals from the fields of sustainable design, architecture, LEED consultancy, and urban planning. Professionals from multiple disciplines were selected to gain a holistic and multidisciplinary understanding of approaches to sustainable design and biomimicry application.

Seven experts participated in this study. Colin Mangham, an entrepreneur and the founder and director of BiomimicryLA, architects and researchers, Illaria Mazzoleni and Berenika Boberska, landscape designer and researcher, Claire Latane, Stephanie Pincetl, professor and Environment and Sustainability director of the California Center for Sustainable Communities at UCLA, Urban Planner, L. DeKoven Ashley, and Drew Shula, LEED consultant. I also attended Mayor Garcetti's hour long keynote address on sustainable development to see if he addressed the relevance of architecture in sustainable development.

Reference **Appendix B** for the complete list of interview questions, and reference **Appendix C** for a complete list of names and corresponding job titles of the participants.

VII. Findings and Analysis

Overview

Several overarching topics emerged from the participants responses. These topics include: positon on the LEED certification process, architecture as a multidisciplinary field, the role of the planner in the creation of sustainable cities, the relevance of designed-based policy, and thoughts of biomimicry and its applicability to sustainable design.

Table 1: *Reoccurring topics from the interviews organized by last name of the participant.*

	Expert							
		Mazzoleni	Latane	Boberska	Ashley	Shula	Mangham	Pincetl
Topics	Critical of the LEED certification	**X**	**X**	**X**	**X**			
	LEED does what it intended to do					**X**	**X**	**X**
	Sustainable design requires a multidisciplinary approach	**X**	**X**	**X**	**X**	**X**	**X**	**X**
	I have worked with experts in fields outside of my own	**X**	**X**	**X**	**X**	**X**	**X**	**X**
	The planner is most responsible creating sustainable cities	**X**	**X**	**X**			**X**	
	Progressive designers do not need sustainable policy	**X**	**X**	**X**				
	"Biomimicry" is not well understood or marketable	**X**	**X**	**X**	**X**	**X**	**X**	**X**
	Research about biomimicry needs to be better developed	**X**	**X**	**X**	**X**	**X**	**X**	**X**
	Biomimicry is not a feasible design solution	**X**	**X**	**X**	**X**	**X**	**X**	**X**
	Biomimicry should not be included in policy	**X**	**X**	**X**	**X**	**X**	**X**	**X**

* In his one hour long global and local sustainable development keynote address, Mayor Eric Garcetti did not mention sustainable architecture or design.

All participants acknowledged the importance of LEED serving as measurement for sustainable design. Participants were divided on the overall success of the certification process, three participants completely supported LEED, and four were critical of the checklist-based approach.

Non-Design Based Professionals Support LEED

Three participants actively supported LEED and believed the program achieves its intended goals. Shula, Pincetl, and Mangham all point to LEED's global success and its progress in the field of sustainable design. As mentioned previously, the biggest critique of the LEED certification process is its check-list based approach to design. Shula, Pincetl, and Mangham did not mention the checklist in their review of the program. None of these participants have a background in design which could impact their perception of the success of the certification process. This highlights a disconnect between the perceptions of the success of LEED certification by designers and non-designers.

LEED Critiques and the Potential of Policy to Hinder Design

The architects and urban planning participants were appreciative of LEED but very critical of the checklist-based process and its subsequent outcomes. Mazzoleni, Latane, and Boberska argue that the USGBC has been successful in pushing sustainability into policy and building code, which has translated to the rise of green buildings. Latane said, "I think LEED has become successful in changing the conversation. It used to be that you had to convince people to use green systems [in projects]. Cities did not have a way to quantify or mandate green development." It is important to highlight that the architects do not take issue with sustainable policy and LEED certification—the program is a useful tool to document sustainable building initiatives. However, architects take issue with the overall process of LEED certification because the checklist is not design orientated.

The architects take issue with the LEED certification process because the checklist is an insufficient means of encouraging innovative sustainable design solutions and cultivating an integrative and transformative design approach. Boberska notes shortcuts designers take while going through LEED certification which impacts the overall quality of their design. "You can go through this entire checklist of things, and even if you do all of them, the result is awful, and not necessarily sustainable" (Boberska, personal interview). Latane expressed a similar viewpoint that expands on Boberska's argument and said, "designers do whatever they can to get the minimum amount of points, and it is not about the process as much, nor does it encourage an integrated design process" (Latane, personal interview). While LEED has been successful in starting the conversation about sustainable design, it is important to acknowledge that many architects take issue with the process it cultivates. It seems to a note a mechanical process—one that not only ignores the surrounding environment, but also the building post-occupancy.

All of the architects argued that policy is not inherently necessary to achieve sustainable design. Mazzoleni argues that progressive and radical designers do not need policy to design sustainably. Boberska expressed a similar perspective to Mazzoleni and finds design-based policy, like LEED, problematic and unsuccessful because it encourages designers to design within limitations by using a prescribed checklist. As stated previously, sustainability is a system that should be approached through multiple disciplines and integrated throughout the entirety of the design process. Sustainable architecture cannot be achieved through a checklist of add-ons. These critiques highlight the need for the LEED certification checklist to be restructured to be more design oriented and conducive to an integrative approach to sustainable design.

The Necessity of a Multidisciplinary Design Approach

The architects believe a multidisciplinary approach to sustainable design will produce the best results. None of the architects think that successful sustainable design can be achieved from utilizing approaches only found in architecture. All of the architects collaborate with experts from biology, ecology, and chemistry to find inspiration to influence their design process. They all note the importance of working with other experts at the early stages of their design process to ensure that they are actively integrating other strategies instead of simply adding on other perspectives. Their approach differs from the LEED certification process because they find solutions from other fields and attempt to best integrate these strategies into their process.

Sustainable Cities and the Role of the Planner

The three architects I interviewed disagreed with the claim that architects should lead and facilitate the movement towards creating sustainable cities. All architects argued that the planner has disappeared from the discussion about sustainability and that has led to a lack of large scale sustainable initiatives. Latane argues:

> I would disagree with architects leading the conversation. If you look at the bigger picture, at a regional scale, it really comes down to land-use planning, where you are placings things, and how you are planning your communities, how you plan to lay things out in a city. It is more complex than creating a single building. (Latane, personal interview)

Boberska has similar views as Latane and argues that the planner is necessary in connecting fields together to have an impact on the built environment as a whole. These points further highlight the importance of a multidisciplinary approach to sustainability that includes policy directives that target the role of the planner. This approach cannot be limited to connecting architects and scientists but must connect the architect to planners and policy makers to address sustainability on larger scales.

In his interview, Ashley responded to the critiques of the role of the planner. Ashley agrees overall with the architects' argument about the failed planner. He believes planners fail because they are restricted to the agenda of the public sector. Most planners work in the public sector and must first address the needs of the community; sustainability is never seen as a top priority, and therefore explains why sustainable practices appear on small scales, in singular projects, but do not appear at the community level or on a larger scale.

These critiques of the public-sector planner raise issues of awareness and accessibility of sustainable practices to the general population. Perhaps public-sector planning has failed to address sustainability because it is not a priority to the general public.

No Biomimicry Related Projects in Los Angeles

None of the participants knew of biomimicry related work happening in Los Angeles. BiomimicryLA is inactive. None of the participating architects are currently commissioned, nor have they recently been commissioned for a project related to biomimicry. Instead, they are expanding upon existing biomimicry theory and continuing to research its applicability to architecture. Ashley has "lost faith in biomimicry" and does not wish to involve his current work with it. Shula has never had a client interested in biomimicry nor has he successfully marketed it to a client.

Biomimicry is Not a Feasible

All participants argue that the existing biomimicry theory is not yet applicable to design or design-based policy. Four reasons were presented in the interviews: the name "biomimicry" is confusing and misleading, it is too expensive and unmarketable, and more research needs to be conducted to increase the likelihood of its application to architecture.

"Biomimicry" is Misleading

All participants believe that the title biomimicry is misleading. All participants have had an experience where a client found the title "biomimicry" troublesome and lost interest. Mangham suggested that the name biomimicry makes the field sound trivial, "that one can simply go in nature and learn how to design" (Mangham, personal interview). Mazzeloni stated that she "prefers 'bio-inspired' to 'biomimicry'" because it makes the field seem less rigid. This name implies design is copying nature, which is not how biomimicry aims to be applied. The confusion over the name "biomimicry" contributes to the second reason for why it is not more widely implemented: it is not marketable.

Biomimicry is Unmarketable

Biomimicry has very high upfront costs. All participants expressed concern regarding the cost of sustainable materials and investing in experimental ideas. Mangham, Shula, and Ashley argue that biomimicry is not realized because of the high cost. Shula expressed difficulty marketing biomimicry to his clients. He argued that for the expense, there is little dollar value for the client. Ashley expressed similar experiences with attempting to market biomimicry to his clients and has never had a client interested in the work, nor could he market biomimicry in a way to inspire a client to incorporate it into their project. Ashley argues biomimicry is only accessible to developers and clients who have a lot of money to experiment with design, but it is not accessible or of interest to the average client.

Biomimicry Should Not be Incorporated in Policy

All participants believe that biomimicry should not be incorporated into policy. No participant could figure out how biomimicry could be incorporated into the LEED certification process, nor could they think of ways to create a new policy that incorporates biomimicry into design. Boberska argues that biomimicry is not meant to be formal and incorporating it to policy could result in a process similar to LEED certification.

Future Research is Necessary to Realize Biomimicry

All participants believe biomimicry should continue to be researched and further developed. Shula argues that biomimicry best serves as an inspirational and problem-solving design tool. Further, that biomimicry should be taught in architecture school as a design tool that will inspire future designers of the field. Ashley argues that he sees potential for biomimicry to be applied to architecture and the built environment more broadly, but he did not express a strategy or next steps for implementation. Mazzoleni sees value in gradual steps to incorporate biomimicry into architecture and policy and is hesitant to force its application because it can lead to an oversimplification of its theory. All of these responses suggest that biomimicry continue to be researched. However, Mazzoleni expresses the difficulty of conducting independent research and seeks a more institutional form of researching biomimicry.

VIII. Discussion

The critiques of LEED are relevant to understanding the contemporary failure in creating a transformative sustainable design solution. The checklist process does not advocate for experimentation, a process that must occur if biomimicry were to be realized. I began my research with the intention of proving that biomimicry is the future of sustainable design. This is something I still believe, but I had to take a step back to understand why biomimicry has not been applied. It is not because the process is too abstract or theoretical; rather biomimicry cannot be realized within the existing paradigm of sustainable design because it does not fit in the LEED certification process which has set the standard and process for sustainable design. Biomimicry has the potential to become a practical design strategy if design experimentation is encouraged and actively pursued in the design field.

All of the architects critiqued the checklist-based approach of LEED which highlights a gap in design-based policy and its contributions to the design field. These critiques raise the question: who creates design-based policy? According to the USGBC, none of the three founders of LEED have a background in design. Out of the 43 employees currently listed in the executive staff, board of directors, and advisory council, there is one architect, one biomimicry expert, and one urban planner (USGBC, 2018). It becomes apparent that LEED is not design oriented because designers and planners do not play an active role in the creation and maintenance of the LEED certification process. Perhaps if designers were included in the creation and maintenance of LEED, it could spark a shift from a utilize a checklist-based approach. Instead, LEED would be more design oriented and encouraging of multidisciplinary and innovative solutions.

IX. Recommendations

This research highlights designers' critiques of the LEED certification process, as well as the lack of involvement architects have in the formation and implementation of design-based policy. From these critiques, it becomes apparent that biomimicry is not fit to solve the shortcomings in the existing LEED paradigm. Thus, I recommend that the LEED certification process be redesigned.

Redesign the LEED Certification

This section supports a general restructuring of the LEED certification process, namely by moving away from the checklist format. All of the participating architects argued that design-based policy is often formulaic and prescribed. As noted, there are few design experts working on and maintaining the LEED certification process. The LEED team should be more inclusive of designers. It should have them consult and assist in shifting the LEED certification process towards something designers no longer see as formulaic or prescribed. Architects have the most insight into the design process, and therefore, non-design experts should not have the most authority in the approach to sustainable design. If the LEED certification process reflects a designers' process it has the potential to be more intuitive and encourage an approach that is not prescribed or restricting.

LEED should have a database of sustainable solutions that architects, and developers can access. These solutions should be place-based and address the environmental concerns of a local community instead of them being prescribed solutions that can work anywhere. This change will instigate design that is more contextual to the location it exists in. Projects should be assessed in relation to buildings in their local environment, instead of suggesting that there is a universal definition of sustainability.

Projects should be assessed on their effectiveness and sustainable success, instead of how many green add-ons are present in the design. The certification process should focus more on outcomes of sustainable design and implement a reward system for how well the building performs. Buildings must undergo performance assessments. This will discourage green add-ons and hopefully incentivize solutions that efficiently reduce impact.

USGBC Should Support Biomimicry

While biomimicry is not currently a feasible design solution, that does not mean that its theory should not be experimented or further researched. All participants in the study believe that there is potential for biomimicry principles to be relevant to architecture and implemented. However, none of them have noted space for this experimentation. The USGBC should support and institutionalize biomimicry research relevant to building design. My recommendation is that the USGBC actively supports developing biomimicry theory and encourage design experimentation. The USGBC should create a pilot program that incentivizes designers to experiment with biomimicry principles and approaches. For example, in the LEED certification process, architects can be awarded for employing either of the two approaches to biomimicry application: design-to-biology, or biology-to-design. The USGBC supporting research experimentation creates the potential for LEED to be constantly evolving and employing new methods to achieve sustainable design.

X. Conclusion

This study has challenged the current standard for sustainable design—LEED certification. I have highlighted the disconnect between the LEED certification process and architects' perceptions of the overall success of the program. I have explored the potential for biomimicry theory to be applied to architecture and potentially present a new approach toward sustainable design. While the theory is not currently applicable, this study has highlighted the importance of the expansion of biomimicry theory and encouraged experimentation of its methods. Ultimately, this research has led me to recommend a paradigm shift of approaches towards sustainable design and a reconstructing of LEED certification to ultimately transform the field of architecture. My hope is that this study has provided reason for biomimicry theory to continue to be researched and experimented by architects to create a more sustainable built environment.

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XII. Appendices

Appendix A: LEED Certification Checklist

Below are the checklists presented on the USGBC website for those seeking LEED certification.

LEED for New Construction and Major Renovations (v4)

		POSSIBLE: 1
Credit	Integrative process	1

	LOCATION & TRANSPORTATION	POSSIBLE: 16
Credit	LEED for Neighborhood Development location	16
Credit	Sensitive land protection	1
Credit	High priority site	2
Credit	Surrounding density and diverse uses	5
Credit	Access to quality transit	5
Credit	Bicycle facilities	1
Credit	Reduced parking footprint	1
Credit	Green vehicles	1

	SUSTAINABLE SITES	POSSIBLE: 10
Prereq	Construction activity pollution prevention	REQUIRED
Credit	Site assessment	1
Credit	Site development - protect or restore habitat	2
Credit	Open space	1
Credit	Rainwater management	3
Credit	Heat island reduction	2
Credit	Light pollution reduction	1

	WATER EFFICIENCY	POSSIBLE: 11
Prereq	Outdoor water use reduction	REQUIRED
Prereq	Indoor water use reduction	REQUIRED
Prereq	Building-level water metering	REQUIRED
Credit	Outdoor water use reduction	2
Credit	Indoor water use reduction	6
Credit	Cooling tower water use	2
Credit	Water metering	1

	ENERGY & ATMOSPHERE	POSSIBLE: 33
Prereq	Fundamental commissioning and verification	REQUIRED
Prereq	Minimum energy performance	REQUIRED
Prereq	Building-level energy metering	REQUIRED
Prereq	Fundamental refrigerant management	REQUIRED
Credit	Enhanced commissioning	6
Credit	Optimize energy performance	18
Credit	Advanced energy metering	1
Credit	Demand response	2
Credit	Renewable energy production	3
Credit	Enhanced refrigerant management	1
Credit	Green power and carbon offsets	2

	MATERIAL & RESOURCES	POSSIBLE: 13
Prereq	Storage and collection of recyclables	REQUIRED
Prereq	Construction and demolition waste management planning	REQUIRED
Credit	Building life-cycle impact reduction	5
Credit	Building product disclosure and optimization - environmental product declarations	2
Credit	Building product disclosure and optimization - sourcing of raw materials	2
Credit	Building product disclosure and optimization - material ingredients	2
Credit	Construction and demolition waste management	2

	INDOOR ENVIRONMENTAL QUALITY	POSSIBLE: 16
Prereq	Minimum IAQ performance	REQUIRED
Prereq	Environmental tobacco smoke control	REQUIRED
Credit	Enhanced IAQ strategies	2
Credit	Low-emitting materials	3
Credit	Construction IAQ management plan	1
Credit	IAQ assessment	2
Credit	Thermal comfort	1
Credit	Interior lighting	2
Credit	Daylight	3
Credit	Quality views	1
Credit	Acoustic performance	1

	INNOVATION	POSSIBLE: 6
Credit	Innovation	5
Credit	LEED Accredited Professional	1

	REGIONAL PRIORITY	POSSIBLE: 4
Credit	Regional priority	4
TOTAL		110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

Yes	?	No	Materials & Resources		13 Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
			Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roc	1
			Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Eleme	1
			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
			Credit 3.1	**Materials Reuse**, 5%	1
			Credit 3.2	**Materials Reuse**,10%	1
			Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
			Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufacture	1
			Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufacture	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes	?	No	Indoor Environmental Quality		15 Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
			Credit 1	**Outdoor Air Delivery Monitoring**	1
			Credit 2	**Increased Ventilation**	1
			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
			Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
			Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems**, Lighting	1
			Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
			Credit 7.1	**Thermal Comfort**, Design	1
			Credit 7.2	**Thermal Comfort**, Verification	1
			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No	Innovation & Design Process		5 Points
			Credit 1.1	**Innovation in Design**: Provide Specific Title	1
			Credit 1.2	**Innovation in Design**: Provide Specific Title	1
			Credit 1.3	**Innovation in Design**: Provide Specific Title	1
			Credit 1.4	**Innovation in Design**: Provide Specific Title	1
			Credit 2	**LEED® Accredited Professional**	1

Yes	?	No	Materials & Resources		13 Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
			Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roc	1
			Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Eleme	1
			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
			Credit 3.1	**Materials Reuse**, 5%	1
			Credit 3.2	**Materials Reuse**,10%	1
			Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
			Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufacture	1
			Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufacture	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes	?	No	Indoor Environmental Quality		15 Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
			Credit 1	**Outdoor Air Delivery Monitoring**	1
			Credit 2	**Increased Ventilation**	1
			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
			Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
			Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems**, Lighting	1
			Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
			Credit 7.1	**Thermal Comfort**, Design	1
			Credit 7.2	**Thermal Comfort**, Verification	1
			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No	Innovation & Design Process		5 Points
			Credit 1.1	**Innovation in Design**: Provide Specific Title	1
			Credit 1.2	**Innovation in Design**: Provide Specific Title	1
			Credit 1.3	**Innovation in Design**: Provide Specific Title	1
			Credit 1.4	**Innovation in Design**: Provide Specific Title	1
			Credit 2	**LEED® Accredited Professional**	1

LEED Checklist. USGBC website.

Appendix B: Interview Questions

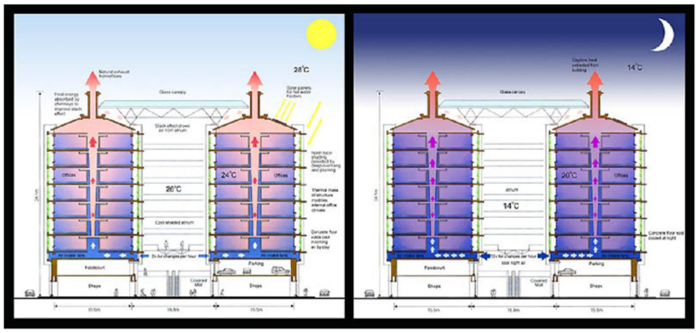
- Do you think architecture as a field is becoming more sustainable? If yes, how? If no, why?
- Do you actively pursue sustainability in your projects? Do you find your clients being interested in sustainability? What is that relationship like?
- What are your thoughts on the LEED certification process?
- Whose job is it to make cities more sustainable? The designer or the planner? Why?
- Do you see value in architecture as a field becoming more multidisciplinary? Have you worked with experts from other fields on a project?
- Do you think sustainable policy produces more sustainable design? Is it necessary to achieve sustainable design?
- How did you get introduced to/involved with biomimicry?
- What work have you done with biomimicry?
- Do you see potential for biomimicry to become a practical design strategy?
- Why do you think biomimicry is not more widely practiced?
- Is the name "biomimicry" limiting?
- Do you think its valuable for more research to go into biomimicry and its application?
- Do you think if biomimicry were included in sustainable policy it would encourage application to design?
- Are there any final statements you would like to say about anything we spoke about before we end the interview?

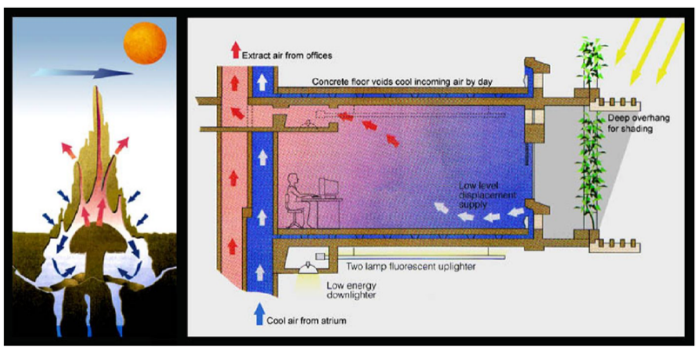
Appendix C: Complete List of Participants and Their Corresponding Job Title

- **Colin Mangham:** Entrepreneur, Founder and Director of BiomimicryLA
- **Illaria Mazzoleni:** Architect, Founder of IM-Studio, Researcher
- **Berenika Boberska:** Architect, Researcher, Professor at Woodbury College
- **Stephanie Pincetl:** Researcher**,** Professor-in-Residence at the UCLA Institute of the Environment and Sustainability, Director of the California Center for Sustainable Communities at UCLA, researcher
- **L. DeKoven Ashley:** Urban Planner, Previous member of BiomimicryLA, Founder and Director of ThrdPlace
- **Drew Shula:** Green Building and LEED Consultant, Founder and Director of Verdical Group
- **Claire Latane:** Landscape designer, Senior Associate at Studio-MLA

Appendix D: Mick Pearce's EastGate Center

These are photos of Mick Pearce's Eastgate Center that showcase the biological principles found in the termite den.





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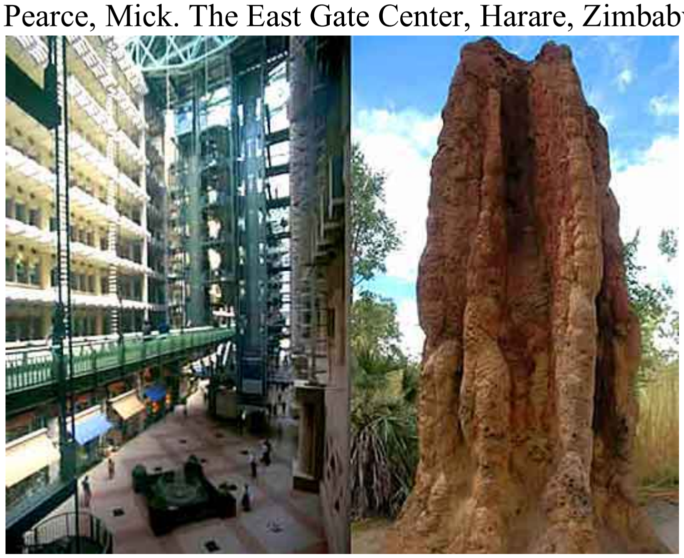

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