Innovations in Green Building:

Why Sustainable Construction Should Include Localized Knowledge

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Abstract

The need for improved sustainability in the built environment is paramount in all areas of the world. This paper examines how western notions of green buildings perform poorly as a one-size-fits-all solution. Through a review of current literature and case studies, this paper suggests that utilizing traditional building practices and local resources could benefit communities, the environment, and global knowledge systems as a whole. Following a universal view of what qualifies as “green” reduces sustainability, marginalizes local knowledge, and impedes innovation. Sustainable construction must consider location as a critical factor in design. While this paper focuses on sustainable construction, it is informed by and may be applicable to wherever indigenous and western knowledge relate.

1. Introduction

The issue of sustainability is relevant for all built environments, both rural and urban, in western and non-western countries. While sustainable construction has progressed significantly, the popularization of delocalized or universal frameworks has mobilized a dependence on expensive technology, specific materials, and a disregard for local knowledge (Boschmann & Gabriel, 2013; Tarimo, 2019). Thus universal sustainable construction standards are often inapplicable to diverse regions, where material availability, climate extremes, budget restrictions, or historical practices may be different enough to render such standards irrelevant (Newman, 2013; Castro-Lacouture et al., 2009). As a result, some sustainable construction projects actually work against their good intentions and further reinforce the need for holistic sustainability (Cavada et al., 2014; Cugurullo, 2016; Wan & Ng, 2016). Overall, from restrictive construction standards to the limited scope of assessment tools, attempting to universalize and homogenize sustainable construction restricts motivation for true innovation (Morel et al., 2001; Boschmann & Gabriel, 2013). Despite the far-reaching influence of western sustainability frameworks, alternative ideas may be more applicable by region and may also prove useful even for the western world (Gurun et al., 2015; Neama, 2012; Peters, 2011). The popularity of sustainable construction is largely positive, but insisting on western perspectives overlooks ingenuity from other groups and stymies much-needed innovation on the local and global scale.

This paper aims to discuss the merits of innovating sustainable construction, which is currently dominated by specific western knowledge, by introducing localized or indigenous knowledge. Research of both peer-reviewed literature as well as less formal accounts are important for this topic due to the unavoidable perspective prevalent in scholastic works inspired or supported by the western world. First, it is important to understand how indigenous and western knowledge systems tend to interact. Then, sustainable construction and its complications are discussed. Finally, the possibility and benefits of hybrid knowledge systems - ones that draw from western and non-western knowledge - is considered.

2. Indigenous Knowledge Systems

Indigenous, or local, knowledge refers to “all knowledge pertaining to a particular people and its territory”, and largely still remains unacknowledged by western knowledge systems (Battiste, 2005; Agrawal, 1995; Kraak, 1999). Indigenous knowledge systems refer to “local knowledge that is unique to a given culture or society” (Mapara, 2009; Raymond et al., 2010). Mostly, indigenous knowledge has been pushed out of urban and even sometimes rural life, where more western practices and values tend to reign (Raymond et al., 2010; Garutsa & Nekhwevha, 2019). In this section, we will discuss the western representation of indigenous knowledge, the trends away from indigenous knowledge, and suggest education and architecture as examples of the perceived superiority of western knowledge even today.

Indigenous people and their knowledge have a lengthy history of being marginalized by the western world (Garutsa & Nekhwevha, 2019; Battiste, 2005). Unfortunately, the trend during western colonialism - whether into the Americas, Asia, Africa, Australia, the Middle East, or even neighboring regions of Europe - was to view a different group of people as inferior (Kraak, 1999; Eglash, 2002). Instead of studying and understanding the lifestyle and ingenuity of another group, western colonizers seemed quick to classify the differences in cultures and practices as ignorance of the other people, for example marginalizing true scientific innovation as art (Kraak, 1999; Battiste, 2005). Instead of appreciating the wonders of diversity, Europeans assumed a hierarchy in which they were on top (Smallacombe, 2000). The western perspective on indigenous knowledge is clear through language that was once commonly used to describe other groups of people: uncivilized, savage, primitive, backwards, etc (Verran, 2001; Battiste, 2005). Even today, the language used to describe non-western or pre-colonial ways of life paints a similar picture but perhaps less clearly: close to nature, “vanishing native”, ancient practices, etc. (Eglash, 2002).

It is clear that there is a discouraging misunderstanding between the western and indigenous worlds that has lasted for centuries. In a way, any evidence of indigenous knowledge systems prevailing for so long under such conditions is somewhat of a miracle (Battiste, 2005). Under colonization, indigenous people were “alienated from their cultures”, displaced from their heritage lands, forced into monoculture farming, taught European languages and history in place of their own, evangelized from their traditional spirituality, and treated brutally under the justification that they were inferior and ignorant (Mapara, 2009; Battiste, 2005). Along these lines, in his 2009 article, Jacob Mapara offers a complementary definition to indigenous knowledge systems as “knowledge forms that have failed to die despite the racial and colonial onslaught that they have suffered at the hands of Western imperialism and arrogance” (Mapara, 2009). Although citizens, developers, and scholars have begun to call for acknowledgement of indigenous knowledge, mostly in the past half century (Agrawal, 1995; Davis & Wagner, 2003), there is a “gradual waning of indigenous knowledge systems” in both urban and rural areas (Garutsa & Nekhwevha, 2019).

In many post-colonial nations, western systems are implemented in lieu of indigenous systems, perhaps as a result of colonization or as an effort to modernize and model local development from a global influence (Garutsa & Nekhwevha, 2019). Indeed, indigenous knowledge has become an “obsolete artifact, useful only for historical display” and has been almost entirely replaced by western knowledge systems (Kraak, 1999). However, in many cases, these post-colonial nations have not experienced immediate benefits from attempting to build their countries after western knowledge; instead “poverty, ecological destruction, and the displacement and museumization of traditional technologies” abound in these regions despite foreign interference and influence under the promise of improvement and development (Kraak, 1999). Without acknowledging indigenous knowledge for its ingenuity or advantages, many countries shaped by colonization attempt to develop under an ill-fitting western framework, as seen through examples of education and construction.

“The marginalization of Indigenous knowledge in educational institutions” is unfortunately relevant worldwide, including for industrialized countries (Battiste, 2005); this example, however, will primarily focus on African education systems. Many African schools still prescribe to the colonial curriculum even decades after gaining independence (Nyamnjoh, 2012). Thus African children may learn “A for apple” even if they have never seen an apple, they learn that Africa had no valuable history before the Europeans arrived, they learn that mathematics and science are inherently western and absent from pre-colonial civilizations (Adichie, 2009; Badawi, 2017; Mavhunga, 2017; Eglash & Odumosu, 2005). Especially for higher education, students leaving their home continent in pursuit of a quality education is not uncommon or even inherently problematic; however, acknowledging only western knowledge often leaves these graduates with the choice to stay in the western world where they see their knowledge in action or return home and attempt to rebuild the western world back into their home country (Moyo, 2019; Anderton, 2009). Dr. Nkosana Moyo, an intellectual and politician, puts the danger of celebrating only western education and knowledge in Africa into powerful terms; he argues that by sending young Africans away to learn “inadvertently we are actually colonizing our own children…. Because the imperception that we’ve created in their minds is the world we run is not worth belonging to” (Moyo, 2019). To eliminate the modern colonialism or “cognitive imperialism” of an education system that continues to marginalize indigenous knowledge is to “find a respectful way to compare Eurocentric [or, western] and Indigenous ways of knowing and include both into contemporary modern education” (Battiste, 2005).

Thus improving education in Africa may require that the continent - and certainly the world - broaden the definition of what knowledge means so that it may include other forms of knowledge. Is knowledge only gained through formal education in a schoolhouse with young children wearing uniforms, through science in stationary and sparkling clean laboratories, through social studies and history classes framed by a certain perspective, through standardized tests applied across a state, nation, or globe? “The extension of the view that knowledge is science often contradicts the thinking in most non-Western societies that knowledge is culture” (Chirikure, 2017). A singular narrative of what constitutes education and knowledge abounds in the global sphere, and knowledge gathered through cultural, local, and traditional means fades into irrelevance (Garutsa & Nekhwevha, 2019).

Similarly to education systems, construction in post-colonial nations has gradually shifted to reflect more western and less indigenous influences, with serious consequences. Especially in urban areas, western materials and building styles are imported in a quest to modernize and develop respectably (Raymond et al., 2010; Twumasi-Ampofo & Oppong, 2016; Wilson & Tolkin, 2010). Building styles and how they change over time provides a fascinating approach to studying the dynamic qualities of a nation’s identity and culture. Buildings “are filled with cultural symbolism, their architecture can tell stories of local history, and they help create a sense of place” (Boschmann & Gabriel, 2013). “Construction has often been seen as a local industry” because it relied on local climate, resources, and knowledge, but it is increasingly being brought to a larger scale and made uniform through "professional standards, building codes," and of course a desire to conform to what is modern and respectable (Seadan & Manseau, 2001). Even in a nation seeking to rebuild a lost identity, the built environment is informed or inspired by the dominance of the western world. The irony of the situation is painful: people with a heritage of rich knowledge look to their old colonizers who systematically marginalized that knowledge.

The western world found success and has developed amazing science and technology. But that doesn't mean it's the only knowledge or way of life worth pursuing. Practices or values curated from one location, culture, or group mindset are not often directly translatable to other areas. For post-colonial or developing nations, drawing inspiration solely from western knowledge often causes complex problems which shows that the western world does not have a one-size-fits-all application. Unfortunately, from colonization, to post-colonial development and modernization, to technology and globalization today, the western world still reigns.

3. Sustainable Construction

The term 'sustainable construction' was initially defined in 1994 as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles" (Du Plessis, 2005). Through various early definitions, the movement of sustainable, or green, construction strongly focused on the environmental impacts of the built world (Du Plessis, 2005). 'Green buildings' were popularized as a part of sustainable construction, as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's lifecycle" (Chan et al., 2018). Over the next decade, they grew quickly to become a household term and an official guideline for industries, institutes, governments, and residents (Hirokawa, 2009).

Many industrialized countries have developed their own standards of distinguishing and qualifying green buildings: "Building Research Establishment Environmental Assessment Method (BREEAM) …, Green Star from Australia, the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) from Japan, the Building and Environmental Performance Assessment Criteria (BEPAC) from Canada, and the Leadership in Energy and

Environmental Design (LEED) from the United States", to name a few (Castro-Lacouture et al., 2009). Despite the other sustainable construction standards in existence and use, "LEED has established strong credibility among the experts" and is now considered by some as the primary reference system for green buildings around the globe (Castro-Lacouture et al., 2009; Boschmann & Gabriel, 2013; Gurun et al., 2015). Therefore, the discussion of sustainable construction and green buildings in this paper and the section below is ultimately in reference and comparison to the LEED standards, as opposed to an alternative sustainability standard.

LEED is the pinnacle of green building guidelines in the United States, and is increasingly influencing sustainable construction projects throughout the world (Castro-Lacouture et al., 2009). Even in 2005, when the program was still young, LEED certification was already a requirement for new buildings in 41 cities or counties in the United States (Suttell, 2005). Today, LEED projects account for nearly half of all construction projects in the nation (Salmonsen, 2017). More than 45,000 residential projects are listed publicly on the LEED directory, approximately 85.7% of which are in the United States (USGBC, 2020). As it has "been applied to more than 30 countries" (Gou & Xie, 2017) and has even influenced other nations' certification standards, the LEED certification system "is the mostly recognized system in the world" (Gurun et al., 2015; Castro-Lacouture et al., 2009).

Certification that a building is sustainable throughout its life-cycle is obtained through intentionally achieving certain objectives during the entire process of design, construction, and maintenance (LEED, 2020; BREEAM, 2016; Du Plessis, 2005; Chan et al., 2018). A large focus of LEED certification standards (and others, such as BREEAM) is on energy and water efficiency (see Appendix A); as such, most certifiably sustainable buildings boast that they host clean energy generators such as wind turbines or solar panels, and feature responsible water usage such as in-house water treatment or water-free urinals (Frangoul, 2014). While aspiring to have a reduced carbon footprint is admirable, there are perhaps other dimensions of construction that may deserve more attention, such as materials used. In fact, in a CNBC report of the top 10 most sustainable buildings in the world, only two examples reference the materials used, one for "energy saving glass" and the other for a bamboo interior (Frangoul, 2014).

LEED standards were designed to be a universal sustainability certification tool (Boschmann & Gabriel, 2013); however, there exist legitimate arguments that "the vision of the

LEED rating system is severely limited" and as such ill-fitted to be used as a one-size-fits-all approach to sustainable construction (Newman, 2013). This section below discusses some of the major criticisms of or shortcomings in the LEED sustainability certification standard. First, a general cost-benefit of attaining a LEED certification is suggested. Then, the section puts forth the importance of materials in sustainable construction. Finally, the benefits of considering local environments for construction is mentioned as well as the importance of encouraging true innovation in the field of sustainable construction.

3.1 The High Cost of LEED's Technology Focus

The additional cost required for green building certification "is the most recognized barrier to green building adoption in both developed and developing markets" (Chan et al., 2018). Therefore, there must be a substantial benefit "in spite of cost being a common reason for the bankruptcy of many [green building] projects" (Castro-Lacouture et al., 2009). A plaque touting LEED certification can increase rent rates and higher resale value, and on the surface it shows that this building is trying to lessen human impact on the world (Newsham et al., 2009). However, studies comparing LEED buildings to conventional buildings have been mathematically inconclusive and left up to interpretation on whether or not the certification actually correlates to saving in energy (Newsham et al., 2009; Scofield, 2009). So if LEED-certified buildings do not always radically benefit the environment, what are the positives that offset the higher price tag? Arguably, LEED has become such a popular certification tool because it is "market-driven" and "allows for a convenient business-as-usual approach to the use and design of buildings" (Boschmann & Gabriel, 2013). In other words, many industrialized areas are quick to promote technological solutions for environmental problems instead of more systematic or behavior-changing solutions - and LEED tends to reward this (Boschmann & Gabriel, 2013). If the goal is to be certified more than it is to be sustainable, there may exist a "tendency to encourage point-grabbing and earning certification through low-hanging fruit credits", thus attaining the positive public perception and higher rent rates by adding "bicycle facilities" or "interior lighting" without needing to consider designs that would truly promote behavioral change for the sake of the environment (Boschmann & Gabriel, 2013; LEED, 2020).

For more rural or developing areas, high-technology LEED objectives are not as relevant or financially possible. Especially in these areas, "the budget can determine the success of the green building projects, many of which are abandoned due to insufficient funds" (Castro-Lacouture et al., 2009). In projects with a more restricted budget or where certain aspects of the LEED scorecard are less relevant, the point-grabbing method is likely not as realistic or beneficial; in fact, a case study in Columbia showed that "as more points are awarded, it is more expensive to add a marginal point" (Castro-Lacouture et al., 2009). Even in the United States, rural areas often use sustainability criteria such as LEED objectives to inspire sustainable construction, but certification is not always pursued due to cost, lack of access, spatial or population density focuses, or infrastructure capacity restrictions (Bowen, 2005; Affordable Housing Council, 2007; Boschmann & Gabriel, 2013). For example, LEED tends to reward high-technology replacements for more sustainable natural systems, such as automated mechanical heating and cooling in preference of passive thermal control like construction material, operable windows, or cross-ventilation systems (Boschmann & Gabriel, 2013; LEED, 2020). From a study in Colorado, between "six case study buildings only 15 LEED credit points (out of 241) were earned directly or indirectly … from vernacular architecture [i.e., historical regional design] or efficient qualities of adaptive reuse [i.e., repurposing a historic building for modern use]" (Boschmann & Gabriel, 2013). For small-scale or rural development projects obtaining a certification is a prohibitive expense, and raises the question of whether regionally sustainable buildings are ignored in the universal LEED lens.

The higher cost of attaining a LEED certification can be attributed to a number of various elements, including perhaps hiring a LEED-accredited professional or opting for high-technology ticket items such as renewable energy or water-free urinals (LEED, 2020; Frangoul, 2014). However, materials and resources represent a large sum of any construction project's budget and can "reach up to 20-30% of the total buildings cost" (Castro-Lacouture et al., 2009). In any case, materials are not allotted much space or many points on the LEED scorecard despite the critical importance of materials in construction projects (LEED, 2020).

3.2 Importance of Materials in Construction Projects

“Selecting inappropriate materials can be expensive, but more importantly, it may preclude the achievement of the desired environmental goals (Castro-Lacouture et al., 2009; Chan, et al., 2018). For example, LEED may award points for “low-emitting materials”, recycled or reused materials, or certified wood, all of which may be difficult or expensive for a certain region to acquire (LEED, 2020; Castro-Lacouture et al., 2009). And if these LEED-promoted materials are more expensive than local materials which may not be rewarded by the scorecard, the true sustainability of the project or the certification is put into question. Certain natural materials have been found to perform equivalently or even better than common commercial materials for certain building purposes; in fact, cement blocks have been found to be stronger when fortified with coconut fibers but would not necessarily be accepted by U.S. building standards (Ganiron, et al., 2017; Kanna & Dhanalakshmi, 2018). Additionally, recycled materials do not necessarily perform better when compared to a similar item made with all new material; for example recycled steel studs would be factored into the score despite a higher embodied energy due to the steel recycling process and even if wood studs would perform better (Bowyer et al., 2006). More so, sourcing construction materials locally (for example timber from a nearby tree instead of the single LEED-promoted organization to provide certified wood) tends to improve social justice situations as well as the environment by supporting the local rather than global economy, potentially reducing embodied energy due to transportation, and avoiding questionable worker’s or indigenous people’s rights protections from more global distributors (Bowyer et al., 2006; LEED, 2020; Morel et al., 2001). The focus placed on materials and resources in LEED criteria is brief and may overlook certain critical information such as embodied energy or local availability of LEED-promoted construction materials (Bowyer et al., 2006; Castro-Lacouture et al., 2009).

Despite construction materials being a somewhat secondary focus of LEED criteria, there is a pressing need to reevaluate the materials that are used in new construction projects, especially in developing countries. As mentioned above, local availability of LEED-scoring materials is commonly a barrier for rural or developing construction projects. Additionally, due to materials representing a significant portion of the overall cost of the building, some regions have created their own certification systems that would better reflect the importance of materials.

For example, India has created their own assessment criteria called LEED India which is designed to be more specific and relevant to their regional needs (Gurun et al., 2015). While LEED awards only around 12% of the available points to materials and resources, LEED India reserves 19% for that section (Gurun et al., 2015). For regions in which "local conditions are not reflected" in LEED standards and certification is thus difficult to attain, it is critical to adapt the criteria to fit their own local needs instead of attempting to utilize LEED as the one-size-fits-all application for which it was designed (Gurun et al., 2015; Boschmann & Gabriel, 2013).

3.3 Need for Localization and Innovation of Sustainable Construction

Buildings designed and constructed with "local materials and traditional technology" score poorly when evaluated with sustainability tools such as LEED, even if higher-scoring alternatives would create various hardships and higher energy usage for the community at hand (Wan & Ng, 2016). For example, material manufacturer information, including for certified wood, was insufficient for LEED standards for the case of Bogota, Columbia and thus would require importing wood or materials at high expense or potentially forfeiting LEED certification (Castro-Lacouture et al., 2009). In a Colorado case study, points were not highly awarded for reusing the traditional materials from a historic building or "natural systems for heating, ventilation, and illumination – the largest energy sinks of most modern buildings" (Boschmann & Gabriel, 2013).

Attempting to apply one sustainability criteria to another country or to a more rural environment can be problematic because it is less likely to take into consideration the area-specific desires and capabilities. "For example, LEED, originated from the U.S. had been applied to more than 30 countries. Arguably, importing these tools from one nation to others caused problematic consequences especially on economic and social sustainability" because they are often specific to the desires and capabilities of their origins (Gou & Xie, 2017). Bicycle racks may be relevant for the United States, but less necessary in hotter climates such as the Middle East (Neama, 2012). Similarly, LEED's focus on water efficiency may not be sufficient for areas that have much higher drought potential such as Egypt (Neama, 2012). With more diverse regions influenced by or attempting LEED standards, the downsides of a one-size-fits-all sustainability approach become unignorable.

LEED-accredited architect Charles Newman states that “the vision of the LEED rating system is severely limited” and suggests that sustainable building in (especially rural) Africa should follow other guidelines (Newman, 2013). Newman claimed that up to 45% of the LEED scoreboard “are simply irrelevant or financially irresponsible” for rural Africa because “some of the LEED credits are geared towards urban ‘first world’ problems” (Newman, 2013). Examples of irrelevant points include designs that electric vehicle stations, third-party supervision of mechanical systems, and a contract to at least partially rely on renewable energy - all of which imply that vehicles, mechanical systems (such as HVAC), or electricity should be present in these buildings even if it is not entirely applicable to sites outside of the urban United States (Newman, 2013). Newman stated that “LEED doesn’t work here in rural Africa” (Newman, 2013) and “suggested considering more social and economic factors when assessing building sustainability in Africa” instead of simply focusing on architecture (Wan & Ng, 2016). Therefore, work must be done to further assess community-specific sustainable construction guidelines instead of simply following a framework that might work well in American cities.

Gradually, developing countries are beginning to adapt existing sustainable construction standards or create their own to better fit their own regional needs. Independent systems include those from industrial countries mentioned at the opening of this section (BREEAM, CASBEE, etc.), as well as Egypt’s Green Pyramid (Neama, 2012) or Abu Dhabi’s Pearl Rating System for Estidama (Gurun et al., 2015). “Adaptations of the LEED system have been applied or are in the process of implementation in Brazil and Mexico, two of the largest developing economies in the Western hemisphere”, as well as LEED “being proposed as a reference framework for countries in which there is no current” assessment system such as Columbia (Castro-Lacouture et al., 2009). As mentioned before, LEED India was created as a more regional modification to the world-recognized system (Gurun et al., 2015). This type of regional adaptation and localized development of standards is crucial because LEED itself tends to be more focused on rewarding “technology and green gadgetry” and a “triumph over nature” than “design that is simple, invisible, and non-reliant on complex technologies” and “limits more transformative paradigm-shifting advances in sustainability” (Boschmann & Gabriel, 2013). In other words, relying on technology to overcome local environmental needs and globalize rather than localize construction reduces the acknowledgement of revolutionary or innovative design and diminishes the importance of "cultural values of a place and people" (Boschmann & Gabriel, 2013; Neama, 2012; Newman, 2013).

4. Investigating Hybrid Knowledge

Drawing from various sources of knowledge - thus creating a hybrid knowledge system - is one way to overcome tensions of technological innovation and sustainability. Hybridizing knowledge systems, instead of preferring one to another, is an important conceptual approach because it reduces the divisions inherent to hierarchy. Especially in the era of modernization, technology, and globalization, there is so much knowledge out there in the world - focusing only on one form or origin is foolish and incomplete. Instead, it is essential that we focus on studying and appreciating the diversity of global knowledge in order to better inform our development and improve our interactions with other people and our environment. This section will show through brief examples that hybrid knowledge systems based on indigenous knowledge or natural systems may have holistic benefits as well as various complications. Later, case studies specific to sustainable construction and its relationship to hybrid knowledge are considered in depth.

4.1 Benefits and Complications of Hybrid Knowledge

Enriching modern knowledge with traditional forms of science and ingenuity has the potential to bring about a host of positive consequences other than simply modernizing a fading cultural practice. In the 1980s, mathematician Ron Eglash studied fractals in Africa after noticing that rural African villages were laid out in large-scale and complex fractals (see Appendix B). Fractals, in which a shape is comprised only of that same shape such as a rectangles within other rectangles, were not "invented until the 1970s" by the western world (Eglash, 2007). However, African indigenous groups preceded the western world in understanding and using fractals. While this is a phenomenal discovery and studying indigenous knowledge as distinct from western knowledge is important to do, there are benefits that go beyond the interests of academia. As mentioned before, many Africans learn that indigenous African people and knowledge is less valuable than western knowledge. As Eglash puts it, "it's really very successful teaching children that they have a heritage that's about mathematics, that it's not just about singing and dancing" (Eglash, 2007). Studying and teaching young Africans about the ingenuity of their heritage and its relevance today helps build a well-deserved respect for African knowledge and can reframe western knowledge to live in an African lens instead of the other way around.

In the realm of construction, applying indigenous knowledge in a modern framework can improve sustainability and society as well. By building her home with natural materials, traditional methods, and a local workforce, Laura Tarimo of Tanzania challenged the notion that "building with mud is becoming a fading practice [because] the idea that using cement represents progress and modernity while building with earth represents backwardness and a time in the past we no longer wish to remember" (Tarimo, 2019). In order to build her house in the modern age using traditional methods, she studied both popular western and local indigenous knowledge forms, thus creating a hybrid knowledge system in which one could complement the other and create something new. And aside from being more environmentally-friendly, and locally-economical, Tarimo saw another benefit of returning to traditional methods: community engagement. During the design process, she worked closely with her local community; during construction, passersby stopped in order to watch, learn, and even participate; and even after the house was built, she persists that it feels more collaborative than in domination with the natural world (Tarimo, 2019). Thus blending western and indigenous knowledge offered holistic benefits by creating a successful residential structure and also engaging the local community and bridging a cultural gap that forces traditional knowledge and practices to seem irrelevant in the modern world.

Innovations based on the natural world and not indigenous knowledge could also be considered hybrid knowledge systems. Biomimicry defines an approach to sustainable design in which designers view plants, animals, natural processes as a product of long-term research and therefore aim to mimic natural occurrences (Nkandu & Alibaba, 2018). Drawing upon natural cycles or practices can improve the interaction of man-made structures with the world, such as through increasing aerodynamic effects, eliminating the need for energy-intensive temperature control systems, optimize functions provided by certain design characteristics, or even bring new life to materials once considered waste (Nkandu & Alibaba, 2018; Peters, 2011; Boschmann & Gabriel, 2013). Biomimicry "where resources are reused and kept in a loop of production and usage", in other words a circular life-cycle of materials, represents a hybrid system of knowledge that is desirable in popular systems such as LEED (Urbinati, Chiaroni, & Chiesa, 2017; LEED, 2020). Brief examples of buildings designed with biomimicry (see Appendix C) may include Zimbabwe's Eastgate Building which modeled its cooling system from naturally temperature-controlled termite mounds or England's Eden Project in which "soap bubbles and pollen grains" inspired the construction of domes in which "the final superstructure weighs less than the air it contains" (Singh & Nayyar, 2015; Nkandu & Alibaba, 2018). Biomimicry as an innovative solution to modern problems is challenging, location-specific, yet perhaps slower than following the status quo, but very much worth it, if successful (Peters, 2011).

However, in certain cases, there are serious restrictions in place that prevent the transfer of non-western knowledge and the creation of hybrid knowledge systems. For example, in a 2001 study, a small complex of homes was built using only local materials and a local workforce in an effort "to drastically reduce the environmental impact of construction" (Morel et al., 2001). While the homes were successful, innovative, and much more sustainable than with more contemporary construction using industrialized materials and processes, the existence of strict standards, policies, or governing bodies presented a serious obstacle to the efforts to innovate sustainable construction. Towards the end of the publication, the paper mentions that "as the houses do not follow any French standards, and since they are not traditional either, it was necessary to obtain a special agreement from the state; cost US$10,000" (Morel et al., 2001). While implementing building standards and insurance policy requirements are undoubtedly necessary to protect human lives and the environment, they are in many ways a barrier to innovation and building upon multiple forms of knowledge. This poses a great dilemma in the quest to hybridize knowledge systems or even to find innovative solutions within one in particular: how can the western world learn from indigenous knowledge while pre-set standards uphold solely western knowledge? How can a hybrid system of knowledge realistically exist at such a phenomenal cost to bring a new idea to the table?

Certainly, there exist a plethora of modern examples of the benefits and complications of cross-cultural collaboration. Often, the ability for mutual learning and drawing from various knowledge systems determines the success of these important projects. While brief examples are helpful for general take-aways, more in-depth case studies are crucial for understanding the intricacies of hybrid knowledge systems in relation to sustainable construction efforts across the world.

4.2 The Case of Rural China

From a 2016 study regarding rural development in Southwest China, three villages are identified that represent how blending knowledge systems can be beneficial or not (see Appendix D). These villages have similar climate and mountainous terrain, but each offered a different lens on sharing knowledge and engaging the community. The first example, Liudou, remains largely insulated from the influence of outside development and still features local materials and practices, for better or for worse. Jiulong, the second village, experienced post-earthquake "reconstruction [which] followed the modernization model that emphasizes rapid reconstruction, using industrialized building materials and construction methods, and aiming at concentrated use of space to create a greater number of apartments on little land" (Wan & Ng, 2016). Despite the good intentions for this framework, the village is a perfect example of unsustainable and inappropriate knowledge transfer; this reconstruction was expensive, foreign, and performed poorly in terms of energy efficiency and environmental effects compared to what existed before in the village. However, in the final village, Nuomi, the award-winning post-earthquake reconstruction featured "innovations based on local traditional building technology" that ultimately improved the quality, durability, and sustainability of the village structures and also empowered the local people through cooperation (Wan & Ng, 2016). Overall, these case studies represent how attempting to introduce external knowledge into new areas is difficult to do sustainably and appropriately, but drawing from both local and foreign knowledge can amount to a tremendous success.

4.3 The Case of Masdar City, Abu Dabi

The example of Masdar City as one that, despite some critiques, is largely celebrated by much of the western world also provides an interesting question regarding the influence of the western world on the global perspectives of development. While reflecting some elements of Islamic and Middle Eastern culture, there are substantial differences between the identities of modern and traditional Arab cities (see Appendix E). In a 2016 article comparing Masdar City to Medieval Cairo, the influence of the western world is emphasized through harsh western critiques of Islamic and Arab cities throughout the 20th century (Hassan et al., 2016). Thus, many architects abandoned traditional elements of Arab cities and instead adopted western elements such as gridlike streets instead of winding, taller buildings instead of mostly laying below an outer gate, and western technology or styles instead of passive or traditional technologies; however, Masdar City did align numerous aspects of its design with traditional Islamic city-planning styles, including square shape, direction of major streets, and mixed-use buildings (Hassan et al., 2016). Therefore, Masdar City seems to have attempted to blend traditional styles with modern styles, Arab and Islamic culture with western technology and sustainability goals. Certainly, Masdar City is very different from traditional Islamic cities - but it is also different from many western cities. The (largely successful) efforts of Masdar City at representing the values and knowledge of both traditional and modern standards is a noteworthy outcome of this case study.

Sustainability frameworks have been found to be problematic if applied to other countries or areas than its design (Gou & Xie, 2017; Wan & Ng, 2016). The inability for a universal sustainability code is further illustrated from the language and meaning of sustainable goals and capabilities being inconsistent between or even within countries. While Masdar City in Abu Dabi is generally considered to be “the world’s most sustainable eco-city”, the lack of a universal definition or agreement on what constitutes a ‘smart city’ raises questions on how successful sustainable cities truly are and how to encourage sustainable development across the globe (Cavada et al., 2014). Due to a lack of universal or consistent governmental policy on sustainable development, “what is meant to solve environmental problems (technological development) reinforces the same dynamics that caused them in the first place” (Cugurullo, 2016). With the example of Masdar City, a well-publicized focus on renewable energy production and economic value in the current eco-city market overshadows the city’s impacts on its surrounding environment and distribution of social benefits (Cugurullo, 2016). From the necessity of considering location-specific requirements and capabilities that prevent the global application of sustainability frameworks, to the lack of concise definition and analysis of sustainability initiatives, there exists a large gap between the current state of development and a potential for global sustainable development.

4.4 The Case of Ghana

Ghana is host to numerous styles of buildings and homes, undoubtedly due to permanent effects of colonization from numerous European powers for centuries. Traditionally, houses in Ghana were laid out in a communal way, and featured earth walls and thatched roofs. In Northern regions, where the climate tends to be drier and hotter, the buildings were often round with a main door and sometimes a small number of windows to aid in circulation (see Appendix F) (Omondi, 2019). These round houses would stand close together in a community of similar buildings. In Southern regions, which often experience more humidity and rainfall, the buildings tend to be steep and narrow with an open square courtyard at the center and point to the Ashanti Kingdom which reigned over most of Ghana (see Appendix F) (Omondi, 2019; "Asante Traditional Buildings", 2018). However, the above descriptions are generalizations; variety in traditionally styled homes depends greatly on the resources in the exact area, weather at the time of building, and the people who were involved in building ('Marihellum', 2012).

When European powers invaded the nation, many traditional homes and villages were destroyed, and architecture quickly began to reflect western influences. Construction materials quickly changed to depend on unrenewable or imported materials such as cement and corrugated tin. Port cities were transformed and developed in accordance with the face of western architecture (see Appendix G) (Countries and their Cultures, 2020; Twumasi-Ampofo & Oppong, 2016). After centuries of colonization, Ghana gained independence from Britain and began to reimagine the national identity and culture to represent modern life and the traditions that had been lost. Much like many other areas, developed or developing, the distinction between modernization and gentrification is unclear, and finding ways to be innovative in cities often pushes certain voices, especially local or traditional ones, out of the conversation (Wilson & Tolkin, 2010). Many new buildings in Ghana's cities showcase the lasting effects of colonialism, even decades after independence; One Airport Square (see Appendix G) received great publicity for being "Ghana's first green building", and was largely celebrated as a huge achievement for the nation even before construction was completed ('Marihellum', 2012). However, some critics of the building wonder where a Ghanaian identity hides in this beautiful, but very western-inspired, building.

Recently there has been an increased focus on sustainable buildings, especially in the western world. In fact, many international conferences on sustainable construction initially did not include representatives from developing countries such as Ghana (Du Plessis, 2005). The idea of sustainable, or green, buildings has emerged in developing countries as almost a way to prove that the nation is growing in a positive direction ('Marihellum', 2012; Twumasi-Ampofo & Oppong, 2016). For example, Ghanaian architect Joe Osae-Addo studied and lived abroad before eventually returning to build a home for his family. The goal of the "Inno-native" home was to meld Ghanaian tradition and modern style. It features locally-sourced wood and traditional inspiration beside IKEA fixtures and western appliances (see Appendix H). The home is heralded as a beautiful example of modern Ghanaian-inspired architecture – and it even attempts to be sustainable, for example by using natural circulation instead of an air conditioner (Anderton, 2009).

Another successful example of sustainable Ghanaian construction is the Zaina Lodge (see Appendix H). As "West Africa's first luxury safari lodge", this beautiful modern Ghanaian building can be appreciated by travelers from various origins (Zaina Lodge, 2018). The lodge features traditional Ghanian architecture in its building materials and process, external facade, and roofing structures, but also includes various western touches such as televisions and air conditioning. While not necessarily a certified "green" building, it is considered an ecolodge - but that title could have more to do with its location around nature than its construction or operation (Ghana Tourism Authority, 2018). In any case, this building serves to show how valuable showcasing local tradition and practices can be, even if just to make a hotel breathtaking and unique.

However, not all buildings designed to be sustainable, modern, and Ghanaian have been successful. The "Hope City Project" was designed to be six large, technologically advanced buildings standing together around a central courtyard as a way to blend Ghanaian tradition with modernization (see Appendix H). Unfortunately, despite a large amount of publicity for the project, it was never started and has been largely forgotten in the more than decade since it was proposed ('Marihellum', 2012; Kuuire, 2017). Finding a way to design and build a modern sustainable building is already challenging, but to do so while also calling upon Ghanaian tradition or identity is a phenomenal feat if done successfully.

5. Discussion

As discussed previously, western standards for sustainable construction perform poorly as universal solutions for reasons such as but not limited to material availability, appropriateness of goals, over-reliance on technology, high cost, and inadaptability to local knowledge. As shown before (through the example of Tarimo's mud house, the Colorado case studies, and villages in rural China), sustainable buildings that use local materials, passive heating or cooling technology, and community involvement may be poorly assessed if viewed purely through a lens of western frameworks like LEED (Tarimo, 2019; Boschmann & Gabriel, 2013; Wan & Ng, 2016). For construction that aims to align or compete with western standards (such as the French housing complex, the Ghanian Inno-native home design, the Columbian office building, and Masdar City), innovation comes at a high cost due to permits and insurance, imported materials and complex technology, or certification investments (Morel et al., 2001; Anderton, 2009; Castro-Lacouture et al., 2009; Hassan et al, 2016). Often, sustainable construction based on external knowledge systems fail to take into account critical elements such as community culture, surrounding environments, and social justice, which can be seen through the examples of Jiulong, colonial Ghana, and Masdar City (Wan & Ng, 2016; Twumasi-Ampofo & Oppong, 2016; Wilson & Tolkin, 2010; Cugurullo, 2016). Even within the western world, sustainable construction standards are not universally applicable from urban to rural landscapes or for historic versus new construction (Bowen, 2005; Affordable Housing Council, 2007; Boschmann & Gabriel, 2013). Through these diverse examples, it is clear that what is sustainable in one location is not necessarily sustainable in another. Thus, sustainable construction requires localization not generalization, foreign standards should be indirect inspiration not direct adoption, and innovation in the field must be encouraged.

This paper has shown that western sustainability frameworks are not one-size-fits-all, and that indigenous or local knowledge can have holistic benefits when applied to the field of sustainable construction. Introducing indigenous knowledge into the conversation of sustainable construction has the potential to revolutionize the field on a global scale by encouraging localized innovation, but must also overcome certain obstacles including marginalization and additional cost to compete with the status quo. The most difficult aspect to overcome marginalization is that the separation of different forms of knowledge for the sake of comparison may be further destructive (Agrawal, 1995). Thus it is difficult to gather unbiased evidence if research is dominated by one perspective, and the likelihood for misunderstanding is high, especially when some voices are often left out (DuPlessis, 2005). Perhaps “focusing on the similarities between the two systems of knowledge rather than on their differences may be a more useful place to start” (Battiste, 2005). In order to truly innovate the field of sustainable construction, it is required that all forms of knowledge be regarded as valuable and the notion of sustainability be understood as an overarching goal, not a strictly defined quality. In any field, innovation is never achieved by following prescribed pathways to an end; instead, breaching a status quo and challenging one’s knowledge is a necessity for innovation (Verran, 2001; Boschmann & Gabriel, 2013).

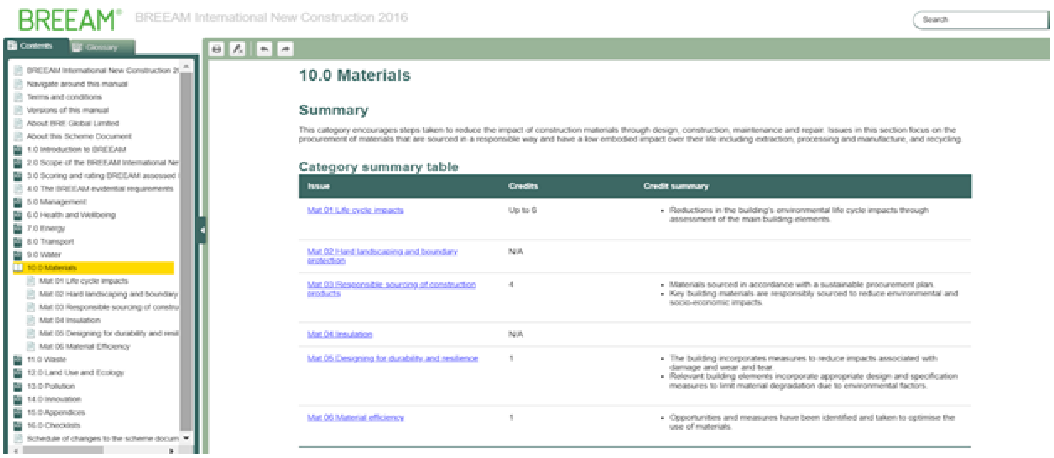
6. Conclusion

Sustainability frameworks are not universally applicable. While it has been reported that criteria such as LEED are not designed for and do not perform as well when applied to rural rather than urban areas or international rather than American projects, these criteria nevertheless continue to inform projects in developing countries (Wan & Ng, 2016; DuPleiss, 2005). Attempting to import western standards or western innovation into non-western areas creates inconsistent and eventually destructive policies, communities, identities, and ethics (Verharen et al., 2014; Twumasi-Ampofo & Oppong, 2016; Nyamnjoh, 2012). The challenge is to find a way to foster home-grown innovation, especially in a community where experts are educated overseas and traditional innovation has been somewhat forgotten or paused for another focus; perhaps the best possible outcome would be a blend of western and non-western innovation such as with the “Inno-native” home by western-educated Ghanian architect Joe Osae-Addo (Anderton, 2009).

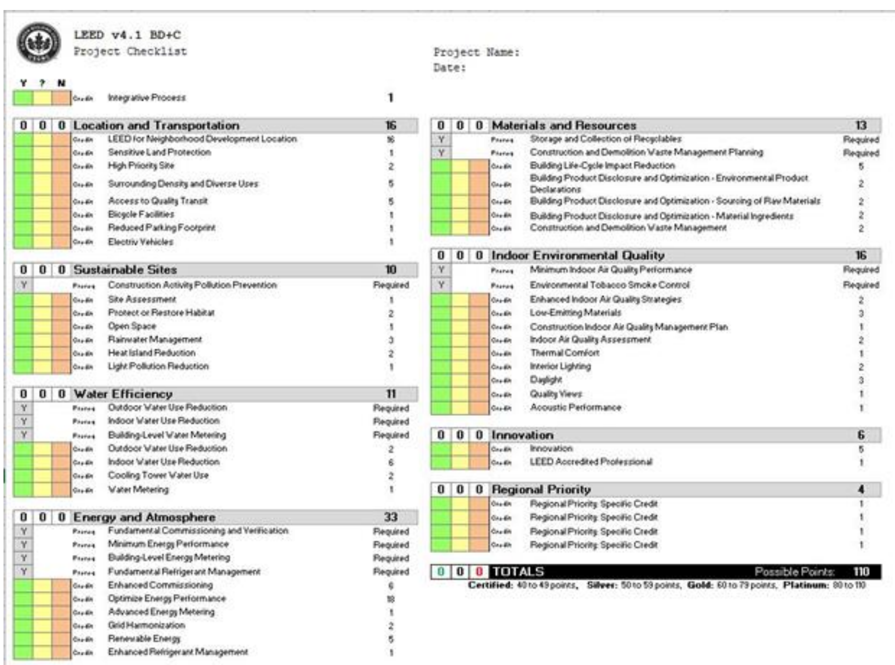
Investigating indigenous African knowledge would benefit not only African countries but also the world at large, including the western part of it. For centuries, the western world has been used as the ultimate metric for defining progress and knowledge. Disregarding indigenous knowledge was a pattern of colonization; continuing to deepen social, cultural, and educational divides at a time of globalization where collaboration is so critical and true innovation so necessary. Right now there is no one-size-fits-all solution to sustainable construction, and there are real downsides to pretending there is. Revitalizing and investigating the merits of non-western knowledge and innovation, in this case regarding sustainable construction but applicable to other examples, would likely prove beneficial. We don't know what the outcome would be, but without introducing more voices and more ideas to the conversation, we will be squandering one of our most important resources: human ingenuity.

Appendix

Appendix A. BREEAM and LEED scorecards



BREEAM International New Construction 2016 Materials Credit Scorecard. Materials typically account for less than 10% of the available score (BREEAM, 2016).



LEED v4.1 Scorecard. Here, materials and resources account for less than 12% of the available score (LEED, 2020).

Appendix B. Fractals in Africa

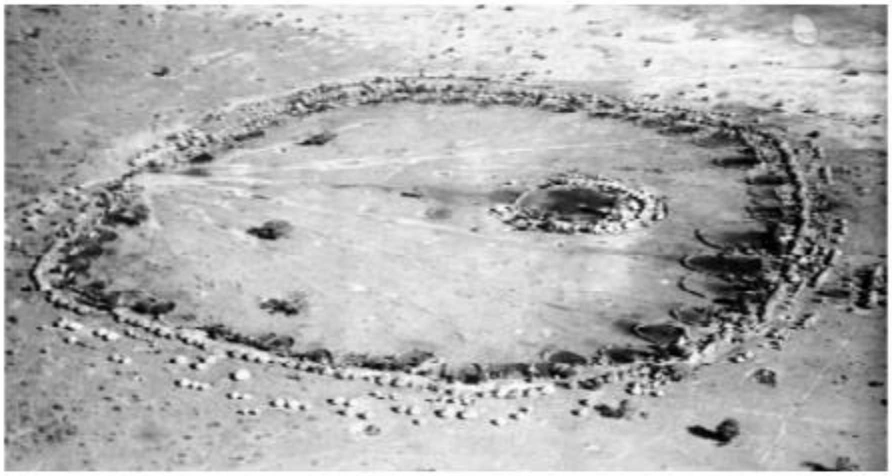
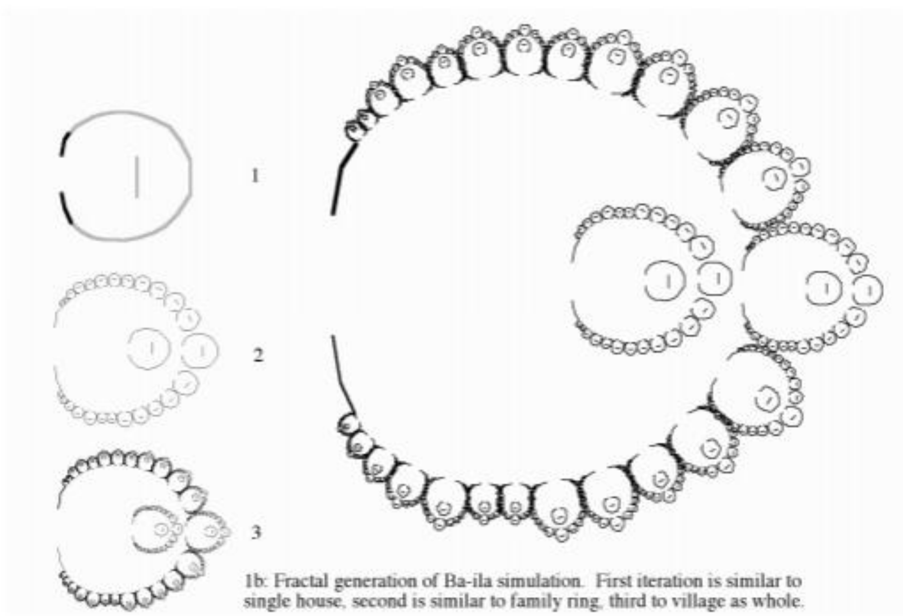


Figure 1a. Aerial view of a Ba-ila settlement in southern Zambia.



1b: Fractal generation of Ba-ila simulation. First iteration is similar to single house, second is similar to family ring, third to village as whole.

Figure 1b. Fractal pattern in Ba-ila settlement.

All above figures from "Fractals, Complexity, and Connectivity in Africa" (Eglash & Odumosu, 2005).

Appendix C. Biomimicry in Architecture

The EastGate Centre in Zimbabwe (right), inspired by termite mounds (left) for natural ventilation and temperature control. (Nkandu & Alibaba, 2018; Singh & Nayyar, 2015).

Geodesic domes of the Eden Project in Cornwall, England, inspired by “soap bubbles and pollen grains”, that maximize surface area versus weight (Singh & Nayyar, 2015).

Sea sponge (left) and London's Gherkin Tower (right) which is energy efficient due to its open vent shafts in lieu of columns. (Nkandu & Alibaba, 2018; Singh & Nayyar, 2015).

Appendix D. Liudou, Jiulong, and Nuomi Villages in Rural China

FIGURE 2

Liudou Village. (Photos by Xinan Chi)

FIGURE 3

Jiulong Village. (Photos by Li Wan)

FIGURE 4

Nuomi Village. (Photos by Li Wan)

All above figures from "Assessing the Sustainability of the Built Evnironment in Mountainous Rural Villages in Southwest China" (Wan & Ng, 2016).

Appendix E. Masdar City

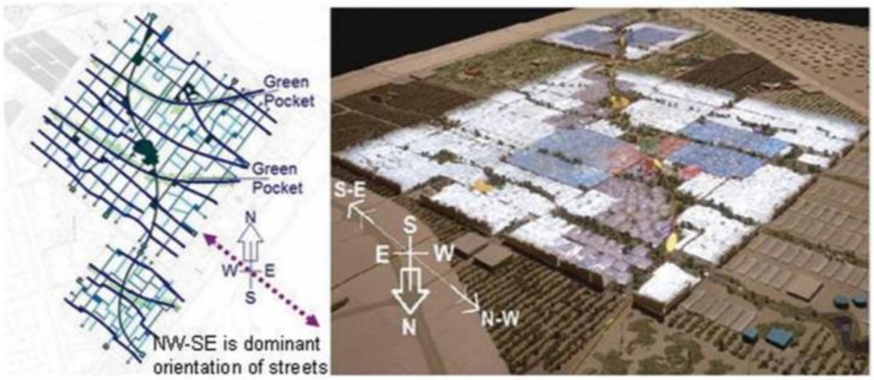


Figure 5. Masdar City consists of two squares. The first is big and the second is small. The dominant orientation of the streets lies on a southeast–northwest axis.

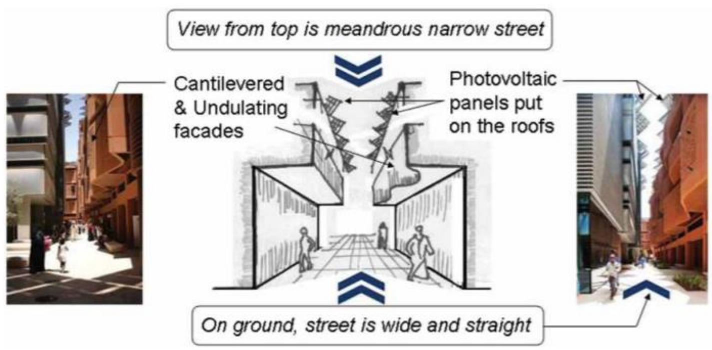


Figure 7. The streets have been designed as wide and straight on the ground. If we look from a bird's eye view towards the streets, we would find them twisting and narrow due to prominent cantilevers, undulating facades and photovoltaic panels fixed on the roofs. The Masdar planners achieved shaded areas without compromising the movement of pedestrians or light motorized vehicles.

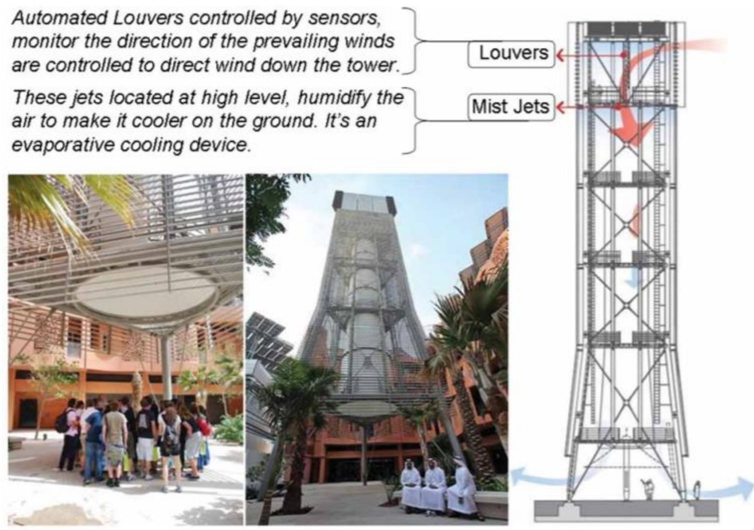


Figure 9. The windcatcher in Masdar City involves complex technology to control the orientation of the wind and the quality of the air. Windcatchers are used in public spaces alongside buildings.

Figure 11. Courtyards are an important element in Masdar City's urban fabric. Most buildings include them. The urban syntax is also based on the courtyards' configuration.

All above figures from "From Medieval Cairo to Modern Masdar City" (Hassan, et al, 2016).

Appendix F. Traditional Ghana Buildings

Round mud house, presumably from the North of Ghana (MeQasa, 2018).

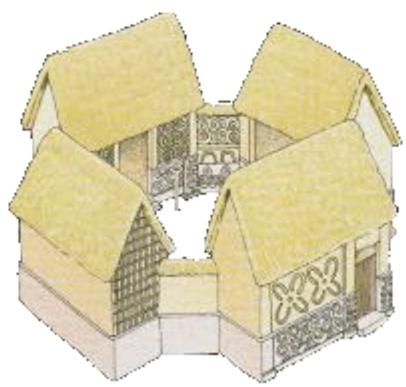


Diagram of traditional Southern buildings, with a central courtyard (Saxon, Jr., 2015).

Alternative view of Southern Ashanti style building ('Marihellum', 2012).

Larabanga Mosque in Northern Ghana, likely from 1421 (Adam, 2017).

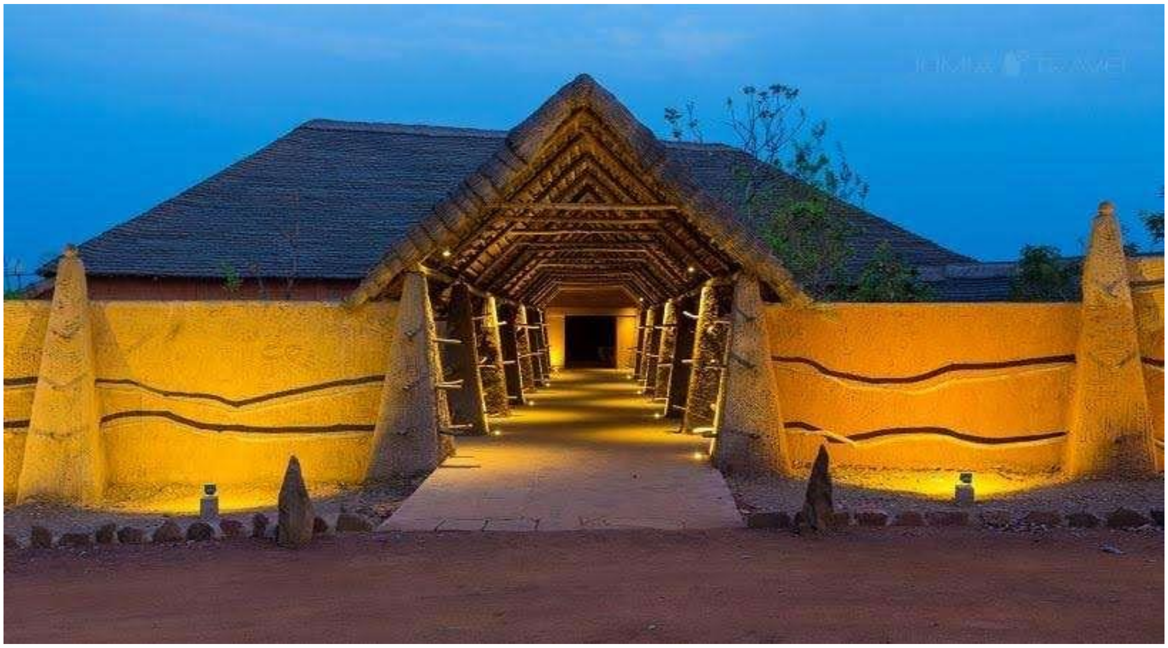
Appendix G. Westernized Buildings in Ghana

One Airport Square, “Ghana’s first green building” (‘Marihellum’, 2012).

Ramseyer Memorial Presbyterian Church, built in the early 1900s (Twumasi-Ampofo & Oppong, 2016).

Appendix H. Hybrid Ghana Buildings

“Inno-native” home design in Accra by Joe Osae-Addo (Anderton, 2009).



Entryway to Zaina Lodge, noticeable for its Ghanaian architecture (compare to the Larabanga Mosque from Appendix D; Ghana Tourism Authority, 2018).

Zaina Lodge lounge (Zaina Lodge, 2018).

Artist’s rendering of Hope City, a failed plan from 2013 for a smart city in Ghana (Kuuire, 2017).

References

Adam, H. (2017, January 20). The Beauty of Ghanaian Architecture In Four Buildings. Retrieved from https://theculturetrip.com/africa/ghana/articles/the-beauty-of-ghanaian-architecture-in-four-buildings/

Adichie, C. N. (2009). The Danger of a Single Story [Video file]. Retrieved from https://www.youtube.com/watch?v=D9Ihs241zeg.

Affordable Housing Council (2007). Affordable green building in rural communities. Washington, DC.

Agrawal, A. (1995). Dismantling the divide between indigenous and scientific knowledge. Development and change, 26(3), 413-439.

Anderton, F. (2009, January 16). An Inno-native Approach. Retrieved from https://www.dwell.com/article/an-inno-native-approach-adefecc6

Asante Traditional Buildings - Ghana. (2018). Retrieved from https://www.africanworldheritagesites.org/cultural-places/ancient-sub-saharan-civilisations/asante-buildings.html

Badawi, Z. (2017). Using African History as a Tool For Change [Video file]. Retrieved from https://www.youtube.com/watch?v=IsdwybV07e8.

Battiste, M. (2005). Indigenous knowledge: Foundations for first nations. WINHEC: International Journal of Indigenous Education Scholarship, (1), 1-17.

Boschmann, E. E., & Gabriel, J. N. (2013). Urban sustainability and the LEED rating system: case studies on the role of regional characteristics and adaptive reuse in green building in Denver and Boulder, Colorado. The Geographical Journal, 179(3), 221-233.

Bowen, T. S. (2005). Constructive criticism. Retrieved July, 7, 2008.

Bowyer, D., Howe, D. J., Fernholz, K., & Lindburg, A. (2006). Designation of Environmentally Preferable Building Materials Fundamental Change Needed within LEED. Dovetail Partner Report.

BREEAM International New Construction 2016. (2016). Retrieved from https://www.breeam.com/BREEAMInt2016SchemeDocument/

Castro-Lacouture, D., Sefair, J. A., Flórez, L., & Medaglia, A. L. (2009). Optimization model for the selection of materials using a LEED-based green building rating system in Colombia. Building and environment, 44(6), 1162-1170.

Cavada, M., Hunt, D. V., & Rogers, C. D. (2014, November). Smart cities: Contradicting definitions and unclear measures. In World Sustainability Forum (pp. 1-12). MDPI AG.

Chan, A. P. C., Darko, A., Olanipekun, A. O., & Ameyaw, E. E. (2018). Critical Barriers to Green Building Technologies Adoption in Developing Countries: The Case of Ghana. Journal of Cleaner Production, 172, 1067–1079. doi: 10.1016/j.jclepro.2017.10.235

Chirikure, S. (2017). What Do Science, Technology, and Innovation Mean from Africa?. MIT Press. Mavhunga, C. C. (Ed.).

Countries and their Cultures: Ghana. (2020). Retrieved from https://www.everyculture.com/Ge-It/Ghana.html

Cugurullo, F. (2016). Urban eco-modernisation and the policy context of new eco-city projects: Where Masdar City fails and why. Urban Studies, 53(11), 2417-2433.

Davis, A., & Wagner, J. R. (2003). Who knows? On the importance of identifying “experts” when researching local ecological knowledge. Human ecology, 31(3), 463-489.

Du Plessis, C. 2005. Action for Sustainability: preparing an African plan for sustainable building and construction. Building Research & Information, 33(5) 1-11.

Eglash, R. & Odumosu, T. B. (2005) Fractals, Complexity, and Connectivity in Africa. What Mathematics from Africa? Sica, G. (Ed.).

Eglash, R. (2002) Computation, Complexity and Coding in Native American Knowledge Systems. Changing the Faces of Mathematics: Perspectives on Indigenous People of North America.

Eglash, R. (2007). The Fractals at the Heart of African Designs [Video file]. Retrieved from https://www.youtube.com/watch?v=7n36qV4Lk94.

Frangoul, A.. (2014, August 11). Ten of the World's Most Sustainable Buildings. Retrieved from https://www.cnbc.com/2014/08/11/ten-of-the-worlds-most-sustainable-buildings.html

Ganiron Jr, T. & Ucol-Ganiron, N. & Ganiron III, T. (2017). Recycling of Waste Coconut Shells as Substitute for Aggregates in Mix Proportioning of Concrete Hollow Blocks. The Scientific World Journal. 77. 107-123. Retrieved from https://www.researchgate.net/publication/257099368_Recycling_of_Waste_Coconut_Shells_as_Substitute_for_Aggregates_in_Mix_Proportioning_of_Concrete_Hollow_Blocks

Garutsa, T. C., & Nekhwevha, F. (2019). Decreasing reliance of indigenous knowledge systems in rural households-the case of Khambashe, Eastern Cape, South Africa [Abstract]. Africa Insight, 49(1), 17-36.

Ghana Tourism Authority. (2018) Ghana Tourism Authority Facebook Page. Retrieved from https://www.facebook.com/ghanatourismauthority/posts/zaina-lodge-is-the-first-luxury-ecolodge-of-its-kind-in-west-africa-explore-eco-/2479487462067806/

Gou, Z., & Xie, X. (2017). Evolving green building: Triple bottom line or regenerative design? doi:https://doi.org/10.1016/j.jclepro.2016.02.077

Gurgun, A. P., Komurlu, R., & Arditi, D. (2015). Review of the LEED category in materials and resources for developing countries. Procedia engineering, 118, 1145-1152.

Hassan, A. M., Lee, H., & Yoo, U. (2016). From medieval Cairo to modern Masdar City: lessons learned through a comparative study. Architectural Science Review, 59(1), 39-52.

Hirokawa, K. H. (2009). At home with nature: Early reflections on green building laws and the transformation of the built environment. Envtl.L., 39, 507.

Kanna, G. V., & Dhanalakshmi, G. (2018). Experimental Investigations on Bricks with the replacement of Coconut Fibre.

Kraak, A. (1999). Western science, power and the marginalisation of indigenous modes of knowledge production. Interpretative minutes of the discussion held on'Debates about Knowledge: Developing Country Perspectives.

Kuuire, J. (2017). What Happened to Hope City? Retrieved from https://technovagh.com/2017/03/18/what-happened-to-hope-city/.

LEED. (2020). LEED v4.1. Retrieved from https://www.usgbc.org/leed/v41#bdc

'Marihellum'. (2013, February 18). A short brief about architecture in Ghana. Retrieved from https://kickoffghana.wordpress.com/2012/12/23/a-short-brief-about-architecture-in-ghana

Mapara, J. (2009). Indigenous knowledge systems in Zimbabwe: Juxtaposing postcolonial theory. Journal of Pan African Studies, 3(1).

Mavhunga, C. C. (2017). What Do Science, Technology, and Innovation Mean from Africa?. MIT Press.

MeQasa. (2018, June 26). The Evolution of Ghanaian Houses. Retrieved from https://meqasa.com/blog/evolution-ghanaian-houses/

Morel, J.C. &Mesbah, M.A. & Oggero, M & Walker, P. (2001). Building houses with local materials: Means to drastically reduce the environmental impact of construction. Building and Environment. 1119-1126.10.1016/S0360-1323(00)00054-8.

Moyo, N. (2019). Modern Self Enslavement by Africans [Video file]. Retrieved from https://www.youtube.com/watch?v=1fVB-r4qTig.

Neama, W. A. S. A. (2012). Protect the planet through sustainability rating systems with local environmental criteria-LEED in the Middle East. Procedia-Social and Behavioral Sciences, 68, 752-766.

Newman, C. (2013, April 12). Why LEED Doesn't Work in Rural Africa and What Will. InterCon. Retrieved from https://intercongreen.com/2013/04/12/why-leed-doesnt-work-in-rural-africa-and-what-will/

Newsham, G. R., Mancini, S., & Birt, B. J. (2009). Do LEED-certified buildings save energy? yes, but…. Energy and Buildings, 41(8), 897-905.

Nkandu, M. I., & Alibaba, H. Z. (2018). Biomimicry as an alternative approach to sustainability. Architecture Research, 8(1), 1-11.

Nyamnjoh, F. B. (2012). ‘Potted plants in greenhouses’: A critical reflection on the resilience of colonial education in Africa. Journal of Asian and African Studies, 47(2), 129-154.

Omondi, S. (2019, May 8). What Type Of Climate Does Ghana Have? Retrieved from https://www.worldatlas.com/articles/what-type-of-climate-does-ghana-have.html

Peters, T. (2011). Nature as measure: The biomimicry guild. Architectural Design, 81(6), 44-47.

Raymond, C. M., Fazey, I., Reed, M. S., Stringer, L. C., Robinson, G. M., & Evely, A. C. (2010). Integrating local and scientific knowledge for environmental management. Journal of environmental management, 91(8), 1766-1777.

Salmonsen, M. (2017). The top U.S. cities for LEED-certified construction. Retrieved from https://www.builderonline.com/building/safety-healthfulness/the-top-us-cities-for-leed-certified-construction_o

Saxon, Jr., R. (2015, November 10). From the Detroit Bungalow to the Ashanti Traditional Home. Retireved from http://detroitarchitectjournal.blogspot.com/2012/04/from-detroit-bungalow-to-ashanti.html.

Scofield, J. H. (2009). Do LEED-certified buildings save energy? Not really…. Energy and Buildings, 41(12), 1386-1390.

Seaden, G. & Manseau, A. (2001) Public policy and construction innovation, Building Research & Information, 29:3, 182-196, DOI: 10.1080/09613210010027701

Singh, A., & Nayyar, N. (2015). Biomimicry-an alternative solution to sustainable buildings. Journal of Civil and Environmental Technology, 2(14), 96-101.

Smallacombe, S. (2000). On display for its aesthetic beauty; How western institutions fabricate knowledge about aboriginal cultural heritage. Political theory and the rights of indigenous peoples, 152-162.

Suttell, R. (2005). America's cities 'LEED' the way. Retrieved from https://www.buildings.com/article-details/articleid/2475/title/america-s-cities-leed-the-way

Tarimo, L. (2019). Why I Live in a House Made of Mud [Video file]. Retrieved from https://www.youtube.com/watch?v=wSdZ9AX8H5M.

Twumasi-Ampofo, K. & Oppong, R. (2016). Traditional Architecture and Gentrification in Kumasi Revisited. African Journal of Applied Research (AJAR), 297-109. Retrieved from www.ajaronline.com.

Urbinati, A., Chiaroni, D., & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. Journal of Cleaner Production, 168, 487-498.

USGBC. (2020). USGBC - LEED project directory. Retrieved from https://www.usgbc.org/projects?Rating+System=%5B%22LEED+BD%2BC%3A+Homes%22%5D

Verharen, C., Gutema, B., Tharakan, J., Bugarin, F., Fortunak, J., Kadoda, G., ... & Middendorf, G. (2014). African philosophy: A key to African innovation and development. African Journal of Science, Technology, Innovation and Development, 6(1), 3-12.

Verran, H. (2001). Science and an African logic [Reviews]. University of Chicago Press.

Wan, L., & Ng, E. (2016). Assessing the sustainability of the built environment in mountainous rural villages in southwest china. Mountain Research and Development, 36(1), 4-14. doi:10.1659/MRD-JOURNAL-D-14-00067.1

Wilson, M. O., & Tolkin, P. (2010, September 1). Listening There: Scenes from Ghana. Retrieved from https://placesjournal.org/article/listening-there-scenes-from-ghana/?cn-reloaded=1

Zaina Lodge. (2018). https://zainalodge-ghana.com/gallery