Audrey Allen

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The Relationship between Vernacular Architecture and Embodied Energy

ABSTRACT

A rapidly changing climate has forced society to analyze and adjust every anthropogenic system to work with the environment and not against it. One significant area of sustainable development is architecture. The buildings humans interact with daily contribute to energy demand. With a growing population and an increasing need for expanding development, this energy use must be optimized through sustainable architecture initiatives. At the core of these initiatives exits low embodied energy. This concept suggests the importance of reducing emissions in architectural development by implementing low-energy materials through low-energy mechanisms. This ensures the holistic sustainability of a building, so materials are not exploited for the sake of other sustainable design features. Consequently, vernacular architecture maintains similar principles, as it involves locally sourced materials. Therefore, exploring a relationship between vernacular architecture and embodied energy could produce an optimized method of achieving sustainable architecture. This paper serves as an investigation of this concept to determine a potential benefit to maintaining vernacular architecture when pursuing low embodied energy. A case study of the Frick Environmental Center (FEC) in Pittsburgh, Pennsylvania is analyzed throughout this review to explore the addressed topics in an applied context (i.e. Pittsburgh Parks Conservancy, 2021). This building possesses numerous sustainable design features, achieving both LEED Platinum and Living Building Challenge certifications, serving as a useful example of low embodied energy and vernacular architecture implementation (i.e. International Living Future Institute, 2022; USGBC). Exploration of this case study involves analysis of its sustainable design features related to embodied energy and vernacular architecture using the 3 E's and Ten Shades of Green sustainability frameworks (i.e. Buchanan, 2005). A precedent, the Cope Environmental Center, is also reviewed to address the historical context of the case study and how it showcases the sustainable development progression through low embodied energy and vernacular architecture (i.e. Cope Environmental Center). Through the analysis of the FEC, an informative relationship between vernacular architecture and low embodied energy is apparent, as the use of both concepts in tandem promotes optimal environmental design and the increased value of a building. Further investigation of this relationship could inspire new mechanisms for achieving sustainable architecture, propelling the movement toward environmentally-conscious design.

1.0 INTRODUCTION

1.1 Sustainable Building Design - Embodied Energy

As climate change persists, people become increasingly aware of their environmental impact. A popular calculator for determining one's energy use is the Footprint Calculator designed by the Global Footprint Network. This platform allows users to answer a series of questions to calculate their carbon footprint, represented by how many Earths they would need to sustain their energy use. Of these seventeen questions, seven pertain to the energy efficiency of the user's dwelling. A detail that is often overlooked by homeowners is highlighted as a significant energy drain in this questionnaire. This is attributed to the complexity of homes

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and other buildings as they include energy-reliant components: construction, materials resourcing, heating, cooling, water, electricity, and much more. This circumstance has not only been recognized by the Global Footprint Network but also by those perpetuating the sustainable architecture movement. The EPA describes green building, *or sustainable architecture*, as an effort to reduce the emissions of a building throughout its lifecycle (i.e. EPA, 2016). This involves several aspects of design and implementation, including the structure's embodied energy. The measurement of embodied energy pertains to the materials used to construct a building and is a sum of the energy required to extract, manufacture, transport, use, and discard the materials. **Figure 1** showcases the relationship between materials production and the structure utilizing such materials in the context of embodied energy (i.e. Australian Government, 2020). This relationship is important, as it informs the meaning of sustainability. In other words, sustainable technology is imperative to sustainable architecture, but it must also exemplify low embodied energy in its design for true energy efficiency. As the ideas surrounding embodied energy develop, architectural researchers must look at the interdependence of this concept and how it can expand to maximize value and efficiency.

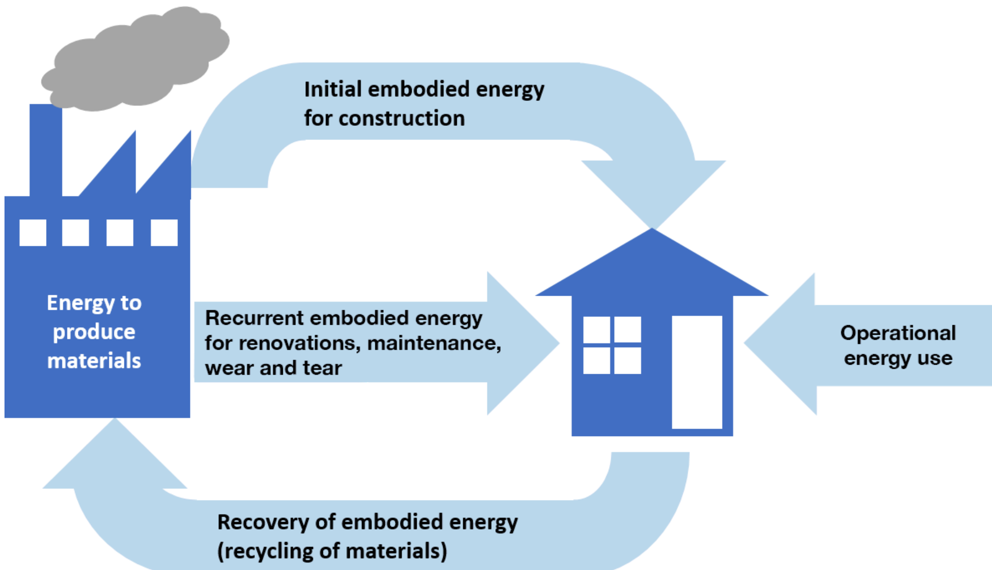

Figure 1. ***Australian Government, 2020***
Depiction of the lifecycle of materials from production, to implementation, to use, to recycling in terms of embodied energy.

1.2 Sustainable Building Design - Vernacular Architecture

Vernacular architecture is commonly seen as a method of preserving the culture of a region by using local and native resources in a building's design. Such structures are important to the identity of its region, but the benefits extend beyond existence value. Vernacular architecture plays a role in sustainable architecture by consequently promoting the use of low embodied energy. Because these resources are produced natively and acquired locally, they require less transportation and manufacturing emissions (i.e. Fernandes, Mateus, & Bragança, 2014). Furthermore, they often consist of natural components, promoting biodegradability. Examples of such vernacular building materials and their relative energy efficiency are shown in **Table 1.** Therefore, low embodied energy and vernacular are interdependent concepts, and studying them in tandem can promote the optimization and development of both, achieving increased sustainability. However, there are disadvantages surrounding vernacular architecture. For instance, some natural materials, like those depicted in **Table 1**, have low insulation abilities or need frequent repair and replacement compared to conventional building materials (i.e. Fernandes, Mateus, & Bragança, 2014). Therefore, a question regarding the benefits of vernacular architecture in achieving low embodied energy compared to conventional design is posed.

Table 1. *Fernandes, Mateus, & Bragança, 2014*
A comparison of the embodied energy and global warming potential of vernacular building materials (*) versus conventional building materials.

Material	Embodied energy (MJ eq./m^3)	Global Warming Potencial (kg CO_2 eq./m^3)
Granite*	1300	26
Timber*(1)	1058.88	57.7
Rammed earth*	942.5	37.7
Straw*	65	0.65
Concrete	1449.63	264
Steel (sections)	182286	2035800
Brick, perforated	4245	357
Ceramic tiles	22185	1167
Roof tiles	5865	535.5
Polystyrene XPS	3271.13	341.25

Sources: Bragança & Mateus 2011; *Berge 2009. Notes: (1) Sawn timber, air dried, including planning processes.

1.2 Case Study: Frick Environmental Center

To explore the benefits, or lack thereof, of vernacular architecture in achieving low embodied energy, an example of a building exemplifying these features must be analyzed, such as the Frick Environmental Center (FEC). Located at Frick Park in Pittsburgh, Pennsylvania, the FEC exists as a community building that hosts educational events to promote the conservation of the surrounding environment. The community gained access to the building when its owners, the Pittsburgh Parks Conservancy and the City of Pittsburgh opened its doors on September 10, 2016. The building was designed with sustainability in mind by architect Bohlin Cywinski Jackson, engineers RAM-TECH Engineers, P.C., H.F. Lenz Company, and Barber & Hoffman, and construction manager P.J. Dick Incorporated (i.e. International Living Future Institute, 2022). As seen in **Figure 2**, these stakeholders worked to include energy monitoring, life-cycle carbon neutrality, passive design, and additional sustainable design factors. A key part of this design was achieving low embodied energy and vernacular architecture to maintain a connection to the surrounding native green space on the 644 acres of Frick Park. To understand the exploration of these ideas, an idea of the frameworks of analysis must be established. One significant framework, the 3 E's framework, establishes the need to achieve environmental, equitable, and economical features in sustainable architecture. A second framework, the Ten Shades of Green, was established by Peter Buchanan in the 2005 book *Ten Shades of Green: Architecture and the Natural World*. The shade most relevant to this analysis is the fourth: Embodied Energy (i.e. Buchanan, 2005). The climate of Pittsburgh must also be understood to grasp the embodied energy and vernacular design features of the FEC. Pittsburgh exists in the cool and humid continental climate (Zone 5) with predominant winds from the west (**Figure 3 -** 270°) and high heat and humidity during the summer months of May through August (**Figure 4**) (i.e. CBE Clima Tool). Considering these climate conditions informs the influence of vernacular architecture on embodied energy for this case study.

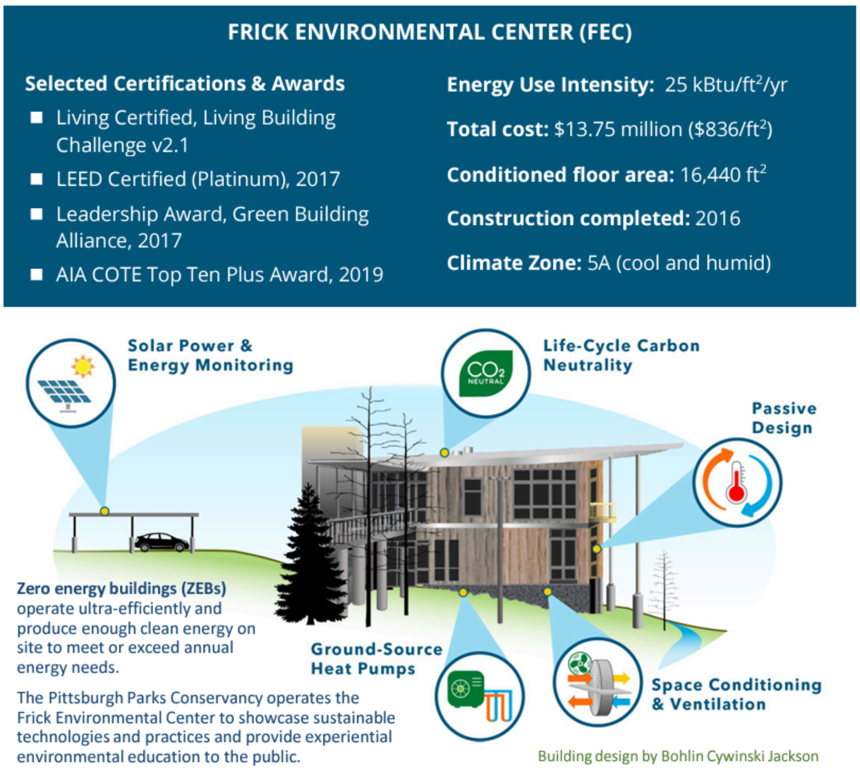

Figure 2. ***Office, U.S.D. of E.B.T., 2022***
An overview of the sustainable design features of the Frick Environmental Center.

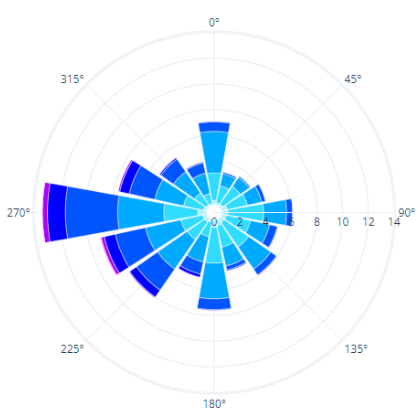

Figure 3. ***CBE Clima Tool***
Predominant wind directions of Pittsburgh, Pennsylvania.

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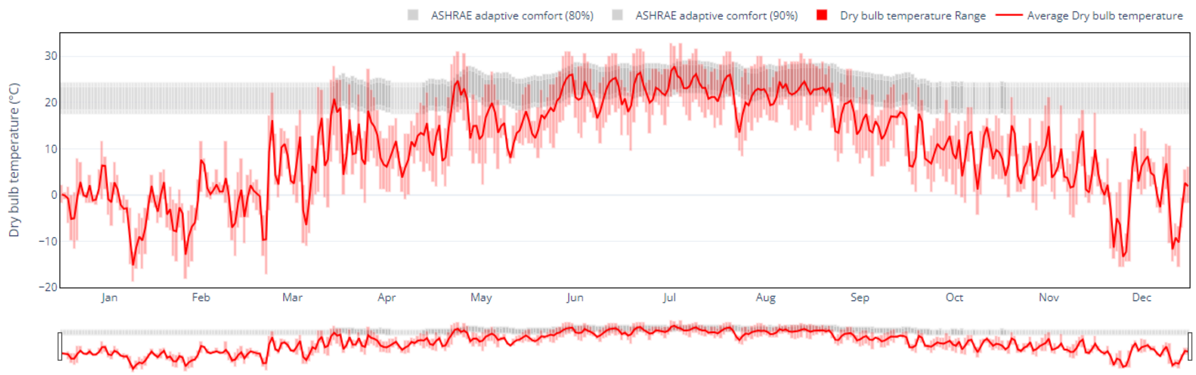

Figure 4. ***CBE Clima Tool***
Yearly temperature and humidity of Pittsburgh, Pennsylvania.

2.0 CONTEXT ANALYSIS

2.1 Historical Context

The FEC was established with two primary requirements at the forefront of design: achieve a zero-energy building and promote community involvement through sustainability. To achieve these goals, the stakeholders behind the design of the FEC followed Leadership in Energy and Environmental Design (LEED) Platinum standards and the Living Building Challenge (LBC) standards (i.e. Pittsburgh Parks Conservancy, 2021). The U.S. Green Building Council (USGBC) established LEED in 1998 to propose specified measures for determining a certified green building (i.e. USGBC). Since its establishment, it has undergone several revisions and now includes ratings for Building Design and Construction (BD+C), Interior Design and Construction (ID+C), and Building Operations and Maintenance (O+M) for various building types and scales (i.e. USGBC). In 2017, the FEC achieved Platinum LEED certification by accomplishing the sustainability areas depicted in their LEED scorecard in **Figure 5** (USGBC, 2017). Just one year later, in 2018, the FEC went on to earn the LBC Certification, becoming the first municipally owned and free public building in the U.S. to become a Living Building (i.e. Pittsburgh Parks Conservancy, 2018). The LBC had been established twelve years before this, in 2006, by the International Living Future Institute to asses the following seven 'petals' or areas of sustainability: place, water, energy, health and happiness, materials, equity, and beauty (i.e. International Living Future Institute, 2022). One major contributor to the ability of the FEC to achieve such prestigious standards was the increasing accessibility to sustainable technology at the time of its construction. **Figure 6** highlights these developments in areas of passive design, solar power and energy modeling, space conditioning and ventilation, ground-source heat pumps, and life-cycle carbon neutrality (i.e. Office, U.S.D. of E.B.T., 2022). Most of the technology mentioned here was established around the early to mid-2000s (ex. 600 275-W solar panels, automated ventilation windows, etc.), providing an optimal time for the commencement of the FEC construction in 2014. However, the construction of the FEC was still hindered by the timeline of sustainable development, for the materials transparency concept was not fully established at the time of construction (i.e. Office, U.S.D. of E.B.T., 2022). Therefore, those designing the building went to great lengths to achieve low embodied energy, which involved slow processes of individually assessing the embodied energy of each building material chosen (i.e. Office, U.S.D. of E.B.T., 2022). Despite these novel achievements in sustainable design, the FEC invited some areas of concern among the community members it wanted to serve.

1000027431, Pittsburgh, Pennsylvania

Frick Park Environmental Center

LEED BD+C: New Construction (v2009) — **PLATINUM, AWARDED DEC 2017**

SUSTAINABLE SITES		AWARDED: 19 / 26
SSp1	Construction activity pollution prevention	REQUIRED
SSc1	Site selection	1 / 1
SSc2	Development density and community connectivity	0 / 5
SSc3	Brownfield redevelopment	0 / 1
SSc4.1	Alternative transportation - public transportation access	6 / 6
SSc4.2	Alternative transportation - bicycle storage and changing rooms	1 / 1
SSc4.3	Alternative transportation - low-emitting and fuel-efficient vehicles	3 / 3
SSc4.4	Alternative transportation - parking capacity	2 / 2
SSc5.1	Site development - protect or restore habitat	1 / 1
SSc5.2	Site development - maximize open space	1 / 1
SSc6.1	Stormwater design - quantity control	1 / 1
SSc6.2	Stormwater design - quality control	1 / 1
SSc7.1	Heat island effect - nonroof	1 / 1
SSc7.2	Heat island effect - roof	1 / 1
SSc8	Light pollution reduction	0 / 1

WATER EFFICIENCY		AWARDED: 10 / 10
WEp1	Water use reduction	REQUIRED
WEc1	Water efficient landscaping	4 / 4
WEc2	Innovative wastewater technologies	2 / 2
WEc3	Water use reduction	4 / 4

ENERGY & ATMOSPHERE		AWARDED: 33 / 35
EAp1	Fundamental commissioning of building energy systems	REQUIRED
EAp2	Minimum energy performance	REQUIRED
EAp3	Fundamental refrigerant Mgmt	REQUIRED
EAc1	Optimize energy performance	19 / 19
EAc2	On-site renewable energy	7 / 7
EAc3	Enhanced commissioning	2 / 2
EAc4	Enhanced refrigerant Mgmt	2 / 2
EAc5	Measurement and verification	3 / 3
EAc6	Green power	0 / 2

MATERIAL & RESOURCES		AWARDED: 6 / 14
MRp1	Storage and collection of recyclables	REQUIRED
MRc1.1	Building reuse - maintain existing walls, floors and roof	0 / 3
MRc1.2	Building reuse - maintain interior nonstructural elements	0 / 1
MRc2	Construction waste Mgmt	2 / 2
MRc3	Materials reuse	0 / 2
MRc4	Recycled content	2 / 2

MATERIAL & RESOURCES		CONTINUED
MRc5	Regional materials	2 / 2
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 9 / 15
EQp1	Minimum IAQ performance	REQUIRED
EQp2	Environmental Tobacco Smoke (ETS) control	REQUIRED
EQc1	Outdoor air delivery monitoring	1 / 1
EQc2	Increased ventilation	0 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	0 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - flooring systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and agrifiber products	1 / 1
EQc5	Indoor chemical and pollutant source control	0 / 1
EQc6.1	Controllability of systems - lighting	0 / 1
EQc6.2	Controllability of systems - thermal comfort	1 / 1
EQc7.1	Thermal comfort - design	1 / 1
EQc7.2	Thermal comfort - verification	1 / 1
EQc8.1	Daylight and views - daylight	0 / 1
EQc8.2	Daylight and views - views	0 / 1

INNOVATION		AWARDED: 5 / 6
IDc1	Innovation in design	0 / 1
IDc2	LEED Accredited Professional	0 / 1

REGIONAL PRIORITY CREDITS		AWARDED: 4 / 4
EAc2	On-site renewable energy	1 / 1
SSc6.1	Stormwater design - quantity control	1 / 1
SSc6.2	Stormwater design - quality control	1 / 1
SSc7.2	Heat island effect - roof	1 / 1

TOTAL	86 / 110

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

Figure 5. ***U.S. Green Building Council, 2017***

The LEED scorecard for the FEC, showcasing the areas in which Platinum certification was achieved.

Passive Design	Solar Power and Energy Monitoring	Space Conditioning and Ventilation	Ground-Source Heat Pumps	Life-Cycle Carbon Neutrality
Technical Highlights **Building envelope:** Features well-insulated slab (R-10), walls (R 19 to 22), and continuously insulated roof (R-48). **Window-to-wall (WWR) ratio:** The relatively modest WWR of 0.37 helps provide better overall insulation. **Window overhang**: Overhangs are positioned to block peak summer rays yet let in warming winter sun (at lower angle). **Strategic planting:** Trees filter late-day summer sun and permit winter daylighting. **Massing**: Setting the north side of the building into the existing hillside takes advantage of the natural thermal regulation provided by the ground mass. **Natural ventilation**: Mechanized windows open and close automatically, and manual windows are sequenced via a light notification system for occupants. **Daylighting**: When sufficient daylight can be harvested, artificial lighting is dimmed automatically. **Building orientation:** Orientation takes advantage of prevailing wind directions.	**Technical Highlights** **PV panels:** The 600 275-W solar panels and racking system help shade the parking area. **Micro-inverters:** Eight of these plug-and-play devices convert direct current from the solar panels to alternating current for use in the building. **Enterprise electrical monitoring:** System enables remote sub-system monitoring of detailed data and dashboards in real time.	**Technical Highlights** **Fenestration:** Operable and mechanized windows and operable interior transoms harness natural ventilation to expel heat overnight in warm weather. **Indicator panels:** Six zone sensors alert occupants to open or close windows based on temperature and humidity. **Indoor air quality:** Zone-level CO_2 sensors activate mechanical assistance or switch to mechanical ventilation. **Dedicated outside air handler:** A 3,500 cubic ft. per minute (CFM) unit with energy recovery enthalpy wheel and 12 variable-air-volume (VAV) boxes regulate the volume of air flow.	**Technical Highlights** **Well field:** Eighteen vertical GHX loops (1¼" poly-ethylene pipes) circulate glycol/water medium to 520-ft. depth. **Ground-source heat pumps:** Five 8-ton water-to-water ground-source heat pumps (GSHPs) and two 1.5-ton water-to-air GSHPs provide space conditioning. The water-to-water GSHPs have a rated coefficient of performance (COP) of 4.3 for heating and an energy efficiency ratio (EER) of 17.8 for cooling. The water-to-air GSHPs have a rated EER of 17.9. Heat pumps use a reversible expansion valve to run the refrigeration cycle forward or in reverse—enabling highly energy-efficient heat absorption *or* heat rejection, as appropriate to the season. **Hydronic piping:** The in-floor zoned hydronic piping system circulates heated water to warm interior spaces.	**Technical Highlights** • **Life-cycle analysis:** The team assessed the embodied carbon of all materials and the carbon impacts of building operations. • **Materials sourcing:** An upper limit was placed on the distance from which construction materials could be transported. • **Transport and delivery**. A four-day work week was instituted during construction. • **Carbon offsets.** Construction-related CO_2 emissions were quantified and offset by purchased credits.

Figure 6. ***Office, U.S.D. of E.B.T., 2022***
Technical highlights summarizing the technology and innovation behind the sustainable design of the FEC.

2.2 Challenges

The mission of the FEC was to support the longevity of the Pittsburgh environment by providing environmentally educational opportunities to the community. Although these efforts were forged to better the community and surrounding ecosystem, some individuals expressed their concerns for environmental preservation. These community members felt the land conversion needed to implement the FEC contradicted its sustainability (i.e. Chen, 2014; Nuttall, 2014). Opposing arguments suggest that the sustainable development involved, including runoff mitigation and native habitat restoration, negates this land conversion. Furthermore, the educational opportunities work to propel sustainable initiatives to help in society's climate restoration initiatives and, therefore, the establishment of the FEC is necessary. Other disagreements relate to the design of the FEC. Such arguments support there is not enough vegetation surrounding the FEC, glass facades have impacted the bird population, and some components are disorganized, likely a result of achieving more LEED aspects (i.e. Payne, 2020). Another significant challenge in constructing the FEC relates to the acquisition of LEED Platinum and LBC standards. Because the FEC is a free, public facility estimating the number of visitors a day can be difficult. This impacts the capacity at which energy systems can operate, and if they go beyond capacity, LEED and LBC recognition would be lost (i.e. Prosoco, 2018). Nevertheless, the FEC and the stakeholders involved in its construction were able to persist through these challenges and critiques, and today, the FEC successfully operates.

3.0 FRAMEWORK ANALYSIS

3.1 The Sustainability of Low Embodied Energy

The FEC showcases numerous examples of climate themes and sustainable strategies, but this review focuses on exploring the relationship between vernacular architecture and embodied energy. To understand these aspects relative to the FEC, they must be explained through the lens of sustainability. The 3 E's framework can be used to inform the concept of sustainability, which suggests a balance between environmental, ethical, and economic considerations, as depicted in **Figure 7**. Materials with low embodied energy support these three components. Oppositely, materials with high embodied energy degrade the environment, harm humanity, and sacrifice financial longevity. When removing natural resources from their native landscape for transportation over great distances (from the Global South to the Global North), biodiversity is lost to deforestation and erosion, negatively impacting the health of the ecosystem (i.e. Fernandez, 2012). At the same time, indigenous land is compromised for the citizens of the Global South being exploited for resources by the Global North (i.e. Fernandez, 2012). The extent of this phenomenon is showcased in **Figure 8**, using deforestation as an example (i.e. Fernandez, 2012). Finally, as resources are irresponsibly obtained, they cannot regenerate at a sufficient rate to maintain economic growth, limiting intragenerational prosperity. To mitigate these circumstances, materials with low embodied energy must be introduced. These include resources such as bio-based materials, like bioplastics, biodegradable materials, recyclable materials, and energy-generating materials, like photovoltaic cells for solar energy (i.e. Peters, 2011). Such materials have low embodied energy as they either require less energy to obtain, produce, and use, or they generate energy, promoting the 3 E's framework. These ideas are further explored in Buchanan's Ten Shades of Green with an explanation of embodied energy. Buchanan emphasizes the need to maintain low embodied energy as sustainable technology develops because certain modern materials have higher embodied energy, like aluminum (i.e. Buchanan, 2005). Therefore, although the other nine Shades are imperative to sustainable architecture, they must not be pursued at the expense of embodied energy. This concept showcases the interdependence of embodied energy in several aspects of sustainable architecture.

Figure 7. ***State Sustainability Index, 2016***
Visual depiction of the 3 E's framework of sustainability.

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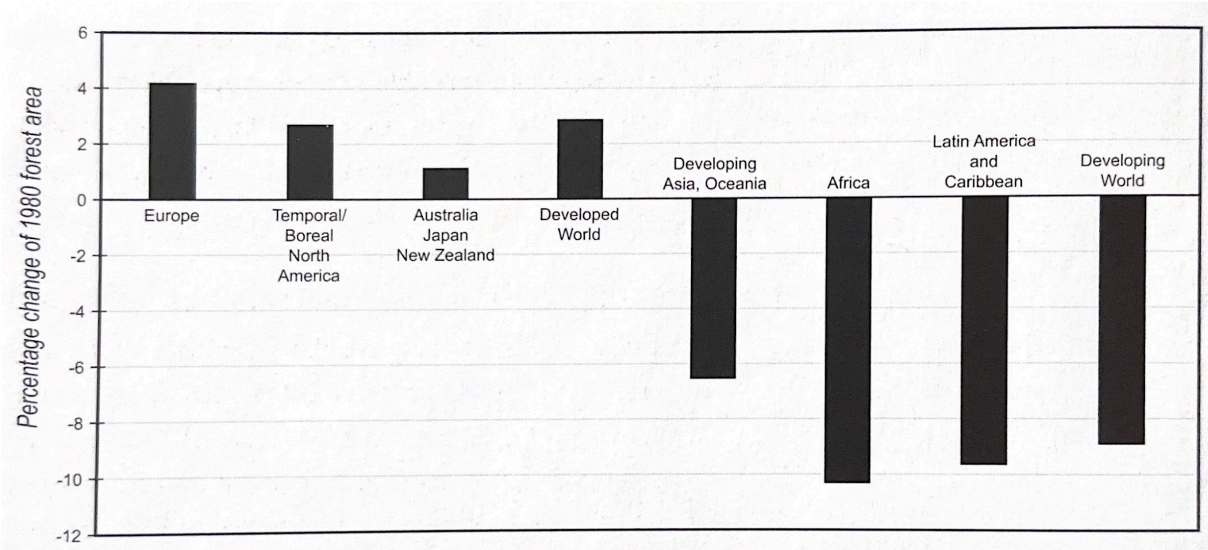

Figure 8. ***Fernandez, 2012***
The differential impact of deforestation affecting the Global South (developing) versus the Global North (developed).

3.1 The Sustainability of Vernacular Architecture

Vernacular architecture promotes sustainability as described by the 3 E's and Ten Shades of Green frameworks through similar mechanisms as low embodied energy. A large focus on equity, from the 3 E's framework, is supported by vernacular architecture. This is due to the importance of culture for those promoting vernacular designs (i.e. Nguyen et al., 2019). The environmental component of vernacular architecture exists within the proximity and accessibility of the native materials used in development (i.e. Fernandes, Mateus, & Bragança, 2014). More specifically, less energy is used for the transportation and production of materials because they are adapted for the environment in which they are used (i.e. Fernandes, Mateus, & Bragança, 2014). Furthermore, less processing is required as vernacular materials are often used in their natural state (i.e. Fernandes, Mateus, & Bragança, 2014). These factors contribute to the economical components of vernacular architecture, as it is cheaper to carry out these acquisition and implementation processes compared to those used for conventional structures. In Buchanan's explanation of the Embodied Energy Shade, he explains that more raw and organic materials have lower embodied energy (i.e. Buchanan, 2005). This applies to materials used for vernacular architecture, including timber, rammed earth, and straw (**Table 1**). These details showcase similarities in the sustainability of vernacular architecture and low embodied energy. Reviewing how these components play a role in the FEC will reveal how vernacular architecture can influence embodied energy.

4.0 FOCUS STRATEGY

4.1 Embodied Energy of the Frick Environmental Center

Because the developers of the FEC were designing the building with LEED Platinum and LBC standards in mind, the FEC showcases numerous components of sustainability (**Figure 9**). These initiatives involved the development of a life-cycle assessment system to determine which materials would possess the lowest embodied energy in compliance with the LBC Red List standards for unacceptable materials (i.e. International Living Future Institute, 2022). These materials included locally sourced wood, stone, and concrete aggregate seen in **Figure 10** (i.e. Prosoco, 2018). Furthermore, work weeks were limited to four days to prevent the amount of emissions released when acquiring, transporting, and implementing materials (i.e. Office, U.S.D. of E.B.T., 2022). Additionally, the use of diesel-fueled equipment was limited, and all businesses associated with the construction had to meet the Tier 4 vehicle and machinery emission requirements set by the U.S. EPA (i.e. Office, U.S.D. of E.B.T., 2022). These carbon-limiting practices were used throughout the construction of the FEC, impacting the implementation of additional sustainable features; however, the materials required to construct the technology in the FEC, including those shown in **Figure 9**, have not specifically been recorded as locally sourced, possessing low embodied energy. All of these measures combined to limit the embodied energy of the FEC; however, **Figure 5** indicates low LEED scores for building and materials resources. This is likely due to the original public facility at Frick Park having burned down in 2002, resulting in the need for an entirely new build. The use of low embodied energy does not directly impact an individual's experience at the FEC, except for the locally acquired components related to vernacular design.

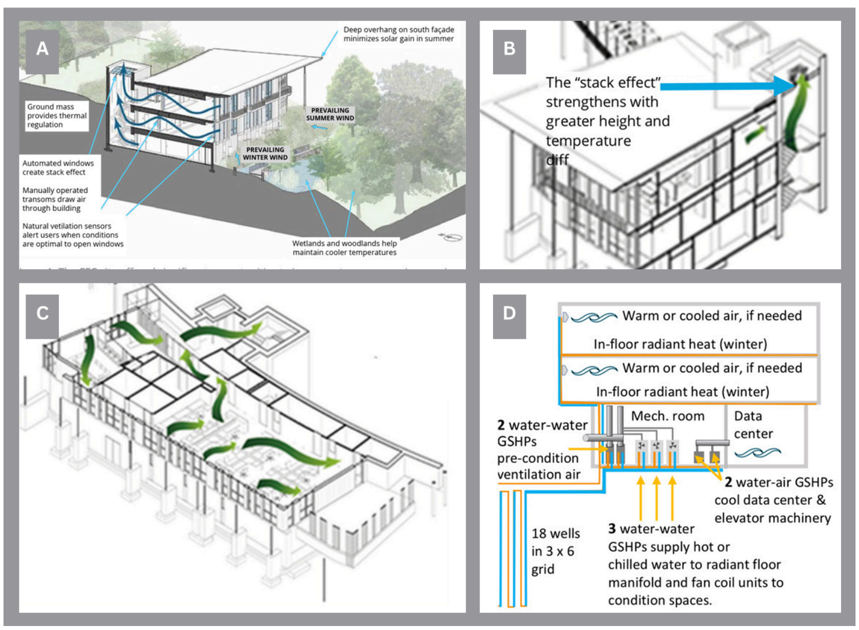

Figure 9. ***Office, U.S.D. of E.B.T., 2022***
Sustainable design features of the FEC: **A)** Energy-saving passive design features **B)** Automated windows to allow rising warm/stale air to exit for ventilation **C)** Automated and occupant-operated windows and transoms for ventilation **D)** Ground-source heat pumps (GSHPs) provide efficient heating and cooling

Figure 10. ***Office, U.S.D. of E.B.T., 2022***
Construction of the FEC showcasing the materials used for framing.

4.2 Vernacular Features of the Frick Environmental Center

In achieving sustainability standards, the developers of the FEC looked to vernacular design. This also contributed to their mission of promoting community involvement, by including local cultural features. The main commitment to vernacular architecture was the use of black locust siding, seen in **Figure 11**, a material traditionally used by Pennsylvania farmers for barns and fencing, owing to its weathering resistance (i.e. International Living Future Institute, 2022). Furthermore, the interior of the FEC showcases vernacular design, with the recycling of excess timber from native tree species used in building the furniture (i.e. Pittsburgh Parks Conservancy, 2021). An example of this can be seen in **Figure 12.** Traditional design was also maintained by salvaging features from the previous environmental center at Frick Park, including gatehouses and a fountain (i.e. International Living Future Institute, 2022). The use of vernacular architecture in the development of the FEC achieved the mission of the project, exemplifying both sustainable design and community connection.

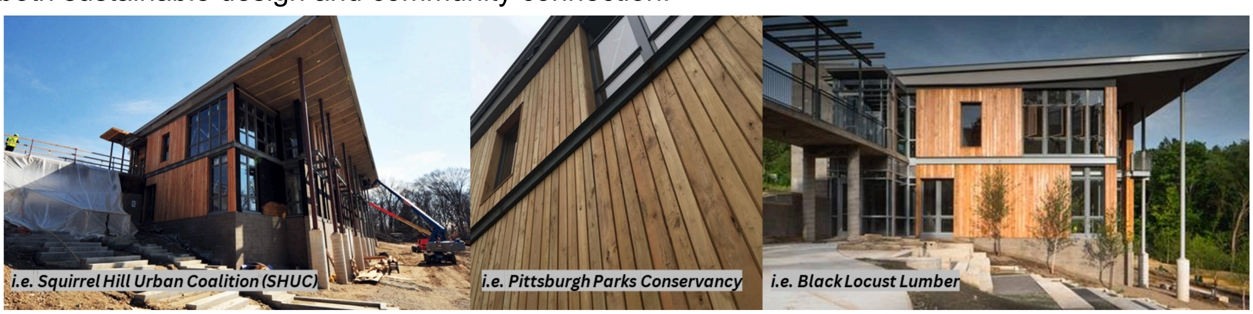

Figure 11. ***SHUC, Pittsburgh Parks Conservancy, and Black Locust Lumber***
Images exemplifying the use of black locust siding for the FEC.

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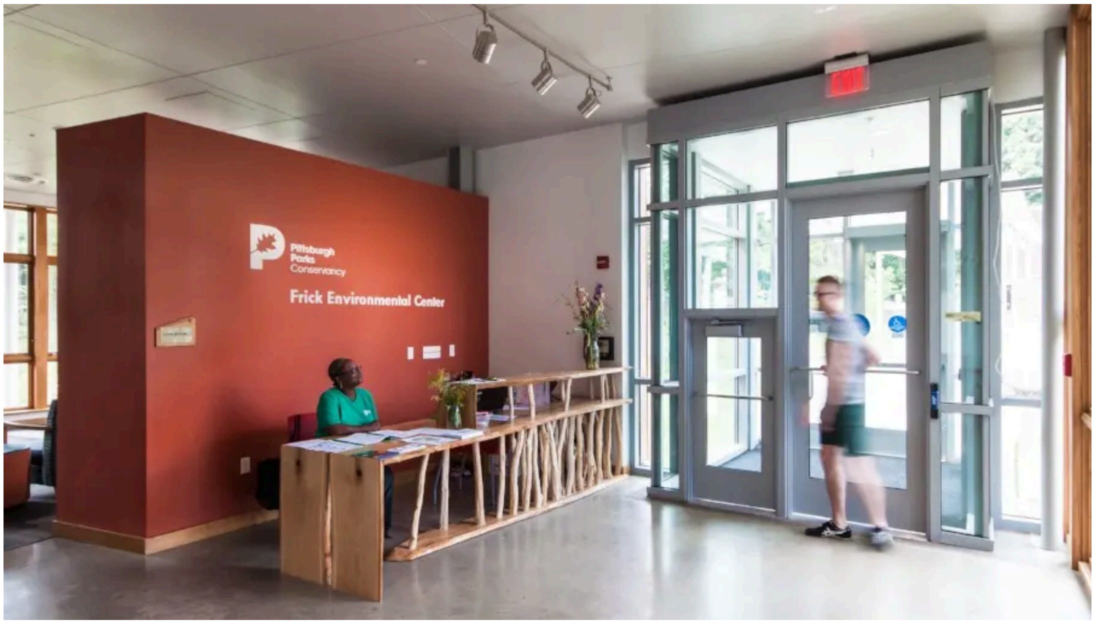

Figure 12. ***Pittsburgh Parks Conservancy, 2021***
The entrance of the FEC showcases a desk made of salvaged native wood.

4.3 Impact of Vernacular Architecture on Embodied Energy at the Frick Environmental Center

The FEC attained a sustainable design by complying with LEED Platinum and LBC standards, which require low embodied energy. One method used in constructing the FEC to acquire low embodied energy was incorporating vernacular design. Building with native materials, like black locust (**Figure 11**), allowed the FEC to decrease resource emissions while promoting Pittsburgh's cultural history. Furthermore, this design aspect aided in the FEC achieving its mission: “The Frick Environmental Center provides families, students, and learners of all ages with a state-of-the-art space for hands-on, experiential environmental education” (i.e. Pittsburgh Parks Conservancy, 2021). Utilizing vernacular architecture throughout the FEC contributes to the environmental education goal of the FEC, by providing an example of how a building can achieve sustainability. The vernacular design further contributes to the community component of the FEC’s mission by supporting the region's tradition and allowing local visitors to celebrate themselves and their history. Therefore, to achieve both its low embodied energy and community goals, the FEC had to incorporate vernacular architecture. Understanding this design strategy and how it has developed throughout the history of sustainability is important in understanding its potential.

5.0 PRECEDENT AND INFLUENCE ANALYSIS

5.1 Cope Environmental Center

Twenty-four years before the completion of the FEC, the Cope Environmental Center (CEC) opened in Centerville, Indiana in 1992. This environmental education center has a similar mission to the FEC: “We promote the sustainable use of the Earth’s resources through education, demonstration, and research” (i.e. Cope Environmental Center). This building was a product of architect LWC, Incorporated and engineers Heapy Engineering, Coor Consulting and Land Services, and JPS Consulting Engineers (i.e. International Living Future Institute, 2022). Some of the strategies used by the FEC to achieve both vernacular architecture and low embodied energy reflect those incorporated into the CEC design. For instance, the wood used for the CEC, includes Indiana-native species, promoting both decreased acquisition emissions and appreciation for local trees (i.e. International Living Future Institute, 2022). Furthermore, insect-derived impurities in the wood, which can be seen in **Figure 13**, were celebrated instead of rejected (i.e. International Living Future Institute, 2022). Handmade cabinets were also sourced locally, using native materials, and community members donated additional artistic design pieces, which can be seen throughout **Video 1** (i.e. Cope Environmental Center). Although the construction of the CEC commenced before the FEC, their histories coincide, as the CEC did not achieve its Living Building title until 2021, with the LBC design implementation beginning in 2014 (i.e. Cope Environmental Center). Therefore, the CEC served as an inspiration to pursue environmental education for the longevity of one's community, while the FEC was a trailblazer in earning LBC standards. As a result, both centers successfully implemented both low embodied energy and vernacular architecture to achieve sustainability.

Figure 13. ***Cope Environmental Center***
An indoor view of the CEC showcases the display of imperfect wood grain, as seen toward the bottom left.

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6.0 DISCUSSION

In reviewing the FEC, it is clear that vernacular architecture played a key role in achieving LEED Platinum and LBC standards. Vernacular design elements largely contributed to the low embodied energy of the FEC, as acquiring and implementing local materials allowed for decreased emissions. Celebration of local history also assisted the FEC in achieving its goals of engaging the community to promote environmental education. The use of vernacular design does, however, come at a cost. Although incorporating native species (**Figure 11**) into construction lowers embodied energy and exemplifies tradition, it also involves the removal of plants vital to an ecosystem. Therefore, while lowering resource emissions, it is also imperative to gauge the impact of doing so and determine mitigation strategies to protect native habitats. For instance, replanting the removed trees. Nevertheless, the sustainability efforts used in the FEC have proven beneficial in achieving its goals. Moving forward, the FEC or initiatives inspired by its design can look to incorporate vernacular and low embodied energy into all design elements. This means using local resources to construct technology like solar panels, heating systems, and water filtration systems. Regardless, the FEC stands as a great example of the interconnectedness of vernacular architecture and low embodied energy. To achieve one is to achieve the other, and this must be considered in future projects. According to **Figure 14**, this idea has begun to take off, with a recent increase in literature correlating vernacular architecture and sustainability. As these ideas undergo further research, the optimization of sustainable design will be enhanced, aiding in the fight against climate change.

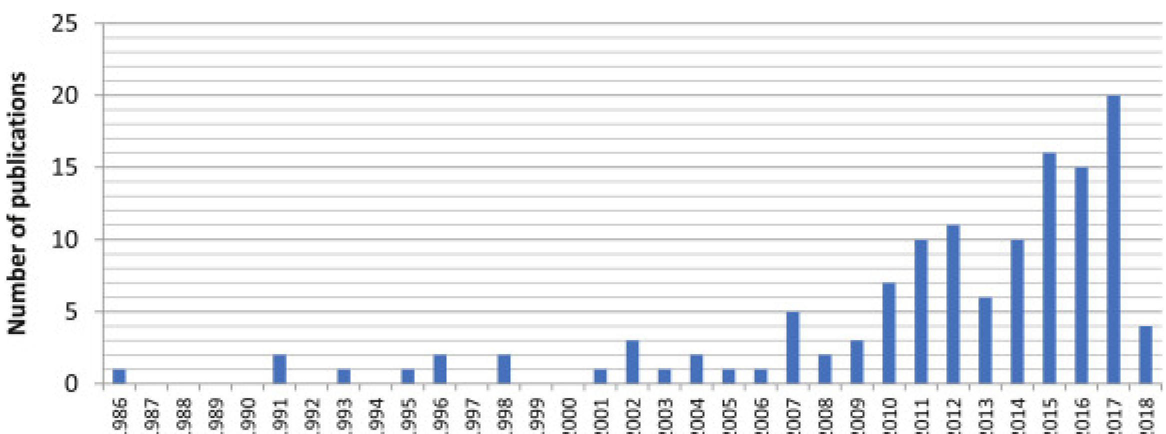

Figure 14. *Nguyen et al., 2019*
A graph depicting the number of publications of literature correlating vernacular architecture and sustainability.

7.0 CONCLUSION

Since the initiation of the Environmental Movement with the 1970 Earth Day, society has learned more about their impact on Earth's climate. As a result, architecture has taken on a new form in the shape of sustainability. By reviewing the Frick Environmental Center through sustainability frameworks, including The 3 E's and The Ten Shades of Green, and how it fits into the timeline of environmentalism, a new understanding of sustainable design has been established. These findings explored the relationship between low embodied energy and

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vernacular architecture, ultimately determining a positive correlation. With goals of achieving sustainability through low embodied energy, a building must also incorporate vernacular design. This promotes the use of local materials to decrease emissions and celebrate a region's history. By incorporating traditional elements, structures like the FEC, achieve further community support, propelling the spread of environmental education. Emphasizing this idea moving forward will inspire innovative strategies to maximize the sustainability of architecture.

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