Evaluating Material Criteria in LEED, BREEAM and PRS
for Sustainable Buildings in the UAE Context

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Evaluating Material Criteria in LEED, BREEAM, and PRS for Sustainable Buildings in the UAE Context

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ABSTRACT

To understand the sustainability of the built environment in the United Arab Emirates, this thesis examines not only the environmental dimension of construction but also the preservation of cultural identity in contemporary architecture. The research explores how materials used in traditional Emirati architecture are represented in modern buildings and how sustainability rating systems address these materials within the UAE context.

The main aim of this study is to identify which sustainability rating system, among LEED, BREEAM, and the Pearl Rating System (PRS), is the most suitable for application in the UAE. The thesis investigates how each system treats the material category, how sustainability of building materials is measured, and why a local system such as PRS was developed. It further assesses whether PRS adequately reflects the specific environmental and contextual challenges of the country.

To achieve these objectives, two types of analysis were conducted. The first was a comparative analysis of the material criteria of the three rating systems, applied to the same case study building. The second was a sensitivity analysis, which introduced a revised list of locally produced and environmentally friendly materials. The comparative analysis was then repeated using this new list to evaluate how the material changes influenced the rating outcomes. In addition to these analyses, the research was supported by an extensive literature review and the examination of alternative data sources.

The findings reveal that, compared to internationally recognized systems, PRS remains less developed and does not fully address the UAE's environmental challenges. However, despite these limitations, PRS achieved the highest score among the three systems when applied to the local case study. This suggests that the UAE's local system is better suited for evaluating material-related sustainability criteria in residential projects than LEED or BREEAM. Furthermore, the study highlights that the UAE's current material industry demonstrates strong potential for sustainable development. A wide range of factories now produce both modern materials and contemporary adaptations of traditional ones.

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List of Abbreviations

UAE - United Arab Emirates
LEED - Leadership in Energy and Environmental Design
BREEAM - Building Research Establishment Environmental Assessment Method
PRS - Pearl Rating System
LCA - Life Cycle Assessment
PM - Particulate Matter
GHG - Greenhouse Gas
PSB - Palm Strand Board
ISO - International Organization for Standardization
EMSTEEL - Emirates Steel Industries
EMCON - Emirates Concrete Industries
CFP - Carbon Footprint of a Product
EPD - Environmental Product Declaration
USGBC - U.S. Green Building Council
UK - United Kingdom
BRE - Building Research Establishment
BOQ - Bill of Quantities
KFUMP - King Fahd University of Petroleum and Minerals
HVAC - Heating, Ventilation, and Air Conditioning
CMU - Concrete Masonry Unit
EPiC - Embodied Carbon in Construction Calculator
AED - Arab Emirates Dirham
PVC - Polyvinyl Chloride
GWP - Global Warming Potential
ICE - Inventory of Carbon and Energy
ODP - Ozone Depletion Potential
CPE - Chlorinated Polyethylene
CPVC - Chlorinated Polyvinyl Chloride
CSPE - Chlorosulfonated Polyethylene
SCS - Scientific Certification Systems
C2C - Cradle to Cradle
TSCT - The Structural Carbon Tool
K-12 - Kindergarten through 12th Grade Education
IMPACT - Integrated Material Profile and Costing Tool
U.S. - United States
EUR - Euro
USD - United States Dollar
RAK - Ras Al Khaimah
CO_2 - Carbon Dioxide

Figure 1.1
Source: Unsplash, photo by Shane Rounce.

Figure 1.2
Source: Pexels, photo by Mahmoud Alaydi

Chapter 1

1.1 Importance of Sustainable Buildings

What does sustainability mean in the context of architecture, and when did it become a critical concern? The concept gained significant attention during the 1970s, a period marked by rising energy costs and growing environmental awareness [Pacific Northwest National Laboratory, n.d.]. Building design began to be reconsided to use fewer resources, leading to the emergence of terms such as low energy, solar design, and passive architecture. This shift marked a fundamental change in architectural priorities by creating buildings that are functionally formed in response to the climate [Flynn, 2024].

Sustainability in architecture is not a single, isolated concept. Rather, it encompasses a network of interrelated strategies aimed at creating buildings that are environmentally responsible, culturally relevant, and economically viable. A widely accepted model for understanding sustainable development is the "triple bottom line" [Janjua et al., 2020], which addresses three interconnected dimensions:

- Environmental strategies involve reducing reliance on non-renewable energy, incorporating renewable energy sources, minimizing water use, reducing waste, using recycled or locally sourced materials, and improving indoor and outdoor environmental quality.

- Sociocultural strategies aim to integrate local materials that reflect cultural identity, engage communities in the design process, preserve architectural heritage, and ensure accessibility and inclusivity.

- Economic strategies focus on selecting long-lasting, low-maintenance materials, promoting adaptable or modular building designs, and lowering operational costs over the building's lifetime.

More broadly, they help reduce the negative contributions of architecture to CO_2 emissions, pollution, climate change, and resource depletion.

Globally, buildings and construction account for nearly 40% of energy use and 36% of CO_2 emissions, making the built environment a key sector in climate action [United Nations Environment Programme [UNEP], 2020].

As Sim Van der Ryn argues, "Sustainability is not about building green buildings. It's about making whole systems work" [Van der Ryn & Cowan, 1996]. This highlights the importance of integrated thinking in sustainable design, moving beyond isolated building technologies toward holistic approaches that respond to environmental, social, and economic systems.

In the context of the United Arab Emirates, applying sustainable strategies is not simply a recommendation, it is a necessity. The United Arab Emirates faces extreme climatic conditions, limited freshwater resources, and rapid urbanization, all of which are discussed in the following sections.

38% of the UAE's total CO_2 emissions come from the construction sector, largely due to the use of carbon-intensive materials such as concrete, steel, and aluminum. [MOCCAE, 2023; IEA, 2022]

But how can the sustainability of a building be measured? Since the 1990s, various green building rating systems have emerged to provide standardized methods for evaluating environmental performance. A core tool used in these systems is the Life Cycle Assessment (LCA), which assesses a building's total environmental impact, from raw material extraction and production, to transportation, construction, use, and eventual demolition.

Among the internationally recognized sustainability rating systems are LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method). Although these systems share similar objectives, they differ in their areas of emphasis and certification criteria. In addition to these international systems, many regions have developed their own localized sustainability rating systems tailored to specific environmental, social, and cultural conditions. One such example is the Pearl Rating System, developed specifically for Abu Dhabi, which addresses the challenges of building design in hot and arid climates.

While many studies analyze green building systems, few evaluate their material criteria within the Gulf's environmental and cultural context. In addition, there is a lack of research that applies these systems to real case studies to assess how many points buildings achieve and how effectively the systems reflect local construction practices. A more detailed discussion of these aspects is provided in the next chapters.

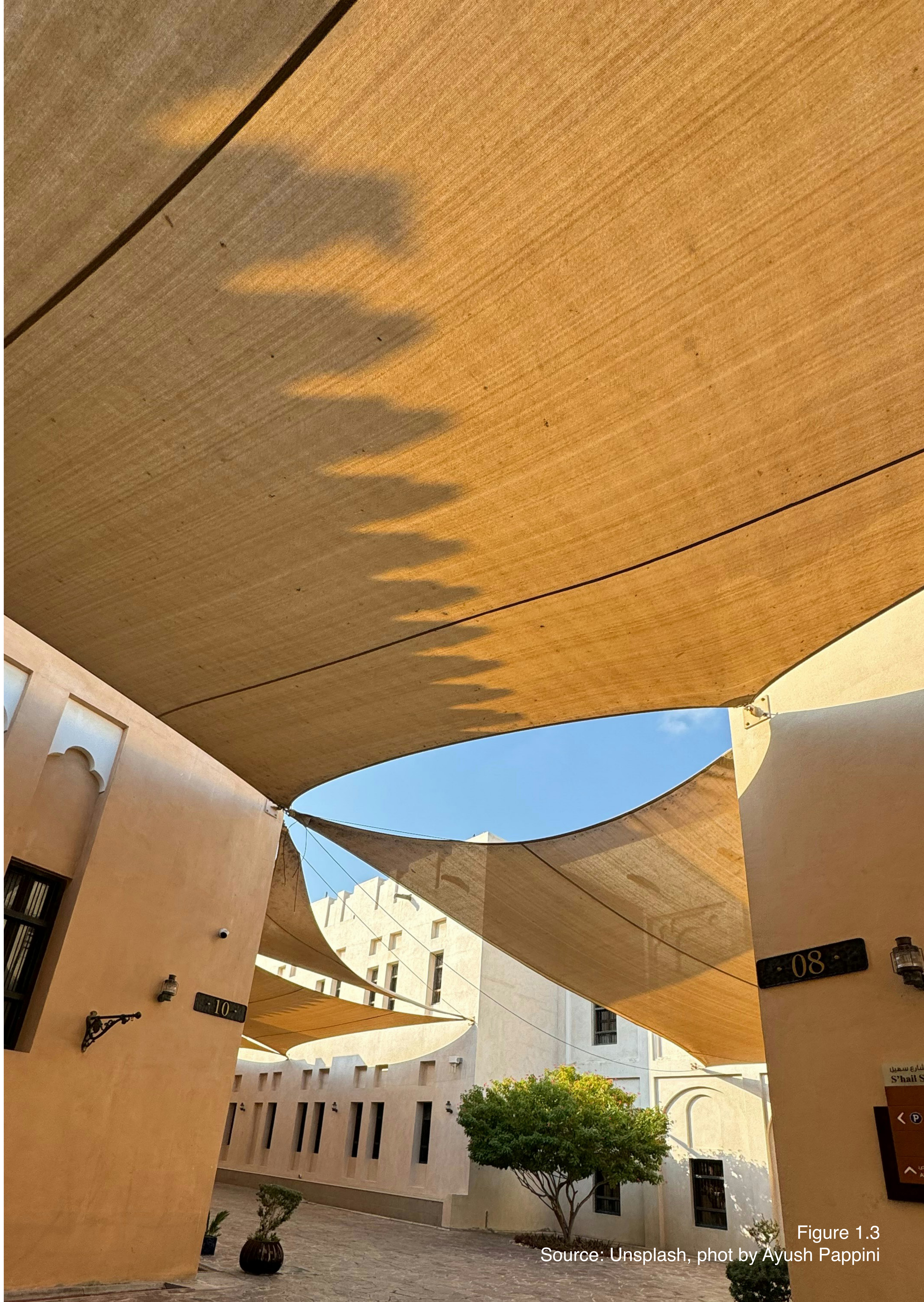


Figure 1.3
Source: Unsplash, phot by Ayush Pappini

Materials are a fundamental component of any building and play a critical role in determining its overall performance. In the context of sustainability, the selection of building materials directly influences how much energy and water a building will consume throughout its life cycle [Usta & Zengin, 2021].

Beyond environmental considerations, building materials also affect indoor environmental quality, including air quality, humidity control. For healthier indoor environments, it is important to choose materials that are breathable, non-toxic, and capable of naturally regulating heat and moisture [Prucnal-Ogunsote et al., 2023].

Another essential factor is climatic suitability. Materials should be chosen based on their responsiveness to local weather conditions. In the case of the UAE, which experiences high temperatures, materials that resist heat gain, reflect solar radiation, and support passive cooling are particularly valuable in improving energy efficiency and thermal comfort.

Historically, before the widespread availability of industrial materials such as steel, concrete, and glass, people relied on locally sourced materials that were easy to find, extract, and use. In the UAE these materials, adobe, coral stone, limestone, palm wood, gypsum, animal hair, etc. formed the foundation of vernacular architecture [Ragette, 2003]. They were not only climatically appropriate but also culturally embedded. Traditional homes were naturally cooler in summer, warmer in winter, and required minimal mechanical energy input.

Together, concrete and steel account for approximately 15% of global carbon dioxide emissions, largely due to their energy-intensive production processes [International Energy Agency [IEA, 2022]

However, with rapid urban growth and the rise of modern construction methods, industrial materials became the new standard, particularly for high-rise and commercial development. While they enabled new architectural possibilities and faster construction timelines, they also introduced significantly higher embodied energy and environmental degradation. This marked a shift from building with nature to building against it.

The UAE imports over 80% of its construction materials, significantly increasing embodied carbon through transport and production emissions. [Circle Economy, 2021]


Figure 1.4
Source: Unsplash, photo by Alex Block.

Figure 1.5
Source: Unsplash, photo by Stanislav Rozhkov

1.3 Environmental Challenges in the UAE

It is important to address the environmental issues of the region to better understand the conditions in which buildings are constructed, as different climates require different design approaches. This section discusses the main environmental challenges faced by the United Arab Emirates.

Environmental issues can be grouped into different categories such as climate-related challenges, water scarcity, air pollution, land degradation, and waste management.

One of the most important environmental challenges in the UAE is related to the climate. The country has a hot desert climate, which means extremely high temperatures, and strong solar radiation. From June to September, during the summer season, temperatures can rise up to 50 °C, while humidity can reach 80–90%. Even at night, the temperature rarely drops below 30 °C. In the cooler months, from November to April, the weather becomes more bearable, with average daytime temperatures around 25 °C and lower humidity levels. Nights can be cooler, especially in desert areas, where temperatures can fall below 10 °C. [Salam, 2015]

As Victor Olgyay said, “Climate has long been recognized as a primary determinant of architectural form” [Olgyay, 2015]. In the UAE’s case, to achieve indoor comfort, one either needs to rely on mechanical air conditioning or use materials that naturally help regulate temperature.

Materials with high thermal mass are particularly useful in this climate. They absorb heat during the day and release it at night when outdoor temperatures are lower, helping to keep indoor spaces more balanced. Another helpful feature in hot climates is the use of light-colored or reflective materials. This reduces heat absorption, keeps interiors cooler, and helps lower the surface heat gain of the building.

Low rainfall and water scarcity are two critical environmental challenges faced by the United Arab Emirates. As a desert country, it receives very limited annual precipitation, typically between 100 to 150 mm, mostly confined to the winter months. Compounding this issue, the country has no permanent rivers or lakes, and its underground freshwater reserves are both limited and often saline. As a result, the UAE relies heavily on desalination to meet its water needs. While effective, desalination is an energy-intensive process that significantly contributes to carbon emissions, thereby adding further pressure on the environment.

“Desalination accounts for nearly 20% of electricity consumption in the UAE.” [international Renewable Energy Agency [IRENA], 2020]

At the same time, water is also needed in large quantities for the construction sector, especially for materials like concrete and cement. For the production and application of just one cubic meter of concrete, around 300 to 400 liters of water are required. This is nearly equal to the daily water use of one person in the UAE. [Goethe-Institut, n.d.] So, if we look at a mid-sized building, the total water needed for concrete can be equal to the daily water needs of around 500 people.

This comparison helps to highlight how resource-intensive modern construction can be. By replacing water-heavy materials like concrete with alternatives can significantly reduce both water and energy consumption and help to create buildings that are more in harmony with the environment.

Final environmental issue that will be discussed in this section is dry northwestern winds, known as the Shamal, which bring dust from the desert into the cities and cause dust storms. These storms reduce visibility, damage building surfaces, and create health problems, especially respiratory issues for people. Dust storms also contribute to poor air quality by increasing the amount of particulate matter (PM) in the air. In addition to dust, there are other major sources of air pollution in cities, such as vehicle emissions, construction site dust, and industrial activities. [Jung & Abdelaziz Mahmoud, 2023]

These conditions highlight why globally standardized systems such as LEED and BREEAM may fail to capture the material realities of arid environments, as they often overlook specific regional challenges that are crucial for achieving a truly sustainable built environment.

1.4 Aims and Objectives of the Research

The aim of this thesis is to evaluate how sustainability rating systems, such as LEED, BREEAM, and the Pearl Rating System, assess material sustainability in the UAE context, and to explore the impact of substituting high-emission materials on the scoring outcomes in each system. Furthermore, the research examines the continuity between traditional and contemporary construction practices to determine the extent to which modern material use aligns with vernacular architectural principles.

By analyzing a single case study building, the research investigates the results obtained from each rating system and identifies the differences in how material-related credits are awarded.

A sensitivity analysis is then conducted to identify and substitute the most environmentally impactful materials with alternative options, including both internationally recognized and locally produced Emirati materials. This phase of the study assesses how material changes influence the building's embodied greenhouse gas (GHG) emissions and examines whether these substitutions affect the project's performance under each rating system.

Following the sensitivity analysis, a comparative re-evaluation is carried out to determine whether the reduction in embodied emissions leads to improved results in LEED, BREEAM, and PRS.

The overall objective of the research is to highlight how material selection strategies can influence sustainability certification performance and to identify opportunities for better integration between international and regional sustainability assessment approaches.

This research addresses the following questions:

1. How do these systems address material sustainability?

2. Which system aligns best with UAE's environmental priorities?

3. How can the use of local materials influence rating outcomes?

4. In what ways can the Pearl Rating System be improved?

Having identified the environmental and construction challenges of the UAE, the next chapter explores how traditional building materials responded to these challenges and how their sustainable principles can guide modern practice.

Figure 2.1
Source: Pexels, photo by Reyyan

Chapter 2

2.1 Material Culture and Sustainability in the UAE Contex

As the environmental issues of the UAE were already discussed in the previous chapter, it is crucial to understand how architecture can use this knowledge to design sustainable buildings. It is essential to reflect on the country's climatic conditions and the availability of local resources in order to create buildings that perform better within their context.

By examining the UAE's traditional and vernacular architecture, it is possible to identify a group of building materials that were widely used in different types of structures. These materials, such as adobe, palm tree, gypsum, lime, and coral stone were locally available and sourced from the coastal, desert, and mountainous areas of the Emirates. However, they were not used only because they were easy to find, but also because of their natural properties, which provided thermal comfort, supported natural ventilation, and offered protection from intense heat. These qualities, combined with architectural elements designed for comfort, made traditional buildings well adapted to the local climate.

Through their properties, these materials became a defining feature of architecture in the UAE and an important part of its cultural identity.

It is interesting to observe how materials used in vernacular architecture are now evolving and becoming relevant for contemporary construction. The methods of manufacturing and construction techniques are changing, allowing these materials to be reinterpreted for modern use.

2.2 The Evolution of Building Materials in the UAE

If we compare the current situation of locally produced materials with those traditionally used in buildings in the United Arab Emirates, it becomes evident that many of the same materials are still used today, although their production methods and applications have evolved. The following section discusses several examples of these materials and how their characteristics and environmental impacts have changed over time.

As previously mentioned, the materials that shaped vernacular and traditional architecture in the UAE included adobe bricks, palm tree components, coral stone, limestone, gypsum, and others.

The first material to be discussed is,

Adobe, one of the oldest traditional building materials in the UAE. Historically, adobe was used in exterior walls, including those of wind towers and other vernacular buildings. It was widely used in inland and oasis regions where stone was scarce. Adobe was typically made from a mixture of clay, sand, and water, which was placed into rectangular molds and left to air-dry, first in the shade and then in the sun to minimize shrinkage. It was valued for its ability to regulate indoor temperature, keeping interiors cool in summer and warm in winter. Adobe could also be reused and recycled [Ragette, 2003; Costa, Cerqueira, Rocha, & Velosa, 2019].

Today, similar materials are still produced locally. For example, the Red Clay Brick Factory manufactures a range of clay-based products, including solid and perforated bricks. They are commonly used for non-structural walls, pavements, and fire- and sound-resistant elements. However, unlike traditional adobe, which was sun-dried, modern production involves kiln-firing at 900-1200°C [Diyar Home, n.d.]. This process significantly increases greenhouse gas emissions compared to traditional methods, which had no carbon emissions.

The evolution of adobe from a low-impact, sun-dried material to kiln-fired clay bricks illustrates how technological advancement has improved durability but increased environmental impact.

Palm wood is another important material, which remains relevant for sustainable building practices. Each part of it was used in construction. The trunks were used as beams and vertical supports, the fronds were woven into wall panels, roofing, and shading devices, and the fibers were used to make ropes and cords that bound building elements together [Jonoobi et al., 2019]. From a sustainability perspective, the date palm is a fully renewable material with low embodied energy.

In contemporary construction practice, from the palm fronds are manufactured Palm Strand Board (PSB®). These boards are commonly used for façade and wall cladding, flooring, furniture, and decorative applications [DesertBoard LTD, 2023].

Over time, the palm tree has shifted from being used in structural elements to applications like wall cladding and flooring, maintaining its environmental performance and acting as a carbon sink [DesertBoard LTD, 2023].

Limestone is the next material historically used in vernacular Emirati architecture. Traditionally, it was used both structurally and for exterior wall finishes, like whitewash due to its reflective white color, which reduced heat gain and made it suitable for hot climates [Ragette, 2003]. It is naturally abundant in the country, found in both mountainous and coastal regions. Limestone is composed of organic remains such as shells and coral, formed through sedimentary processes. It can be easily recycled and has the unique ability to reabsorb CO_2 from the atmosphere during its lifespan [Manoharan & Umarani, 2022].

In modern construction, limestone is often added to cement and concrete as a partial replacement for clinker, helping to reduce embodied carbon. Thus, its function has transformed from a primary structural material to a component that improves the environmental performance of composite materials.

The evolution of limestone from a natural structural material to an additive in industrial composites demonstrates how traditional resources can continue to contribute to sustainability when integrated into modern production methods.

Gypsum is the final material discussed. In traditional Emirati buildings, gypsum was widely used for wall plastering and interior finishes. It was preferred for its smooth texture, light color, and fast-setting time. Gypsum is a breathable material with low thermal conductivity, contributing to passive cooling and comfort in hot climates. It also offers soundproofing properties and can be easily recycled due to its low processing energy. In modern construction, the use of gypsum has remained similar to traditional applications, retaining its practical and environmental advantages.

Figure 2.2 illustrates the transformation of building materials from their vernacular use to their current forms of industrial production.

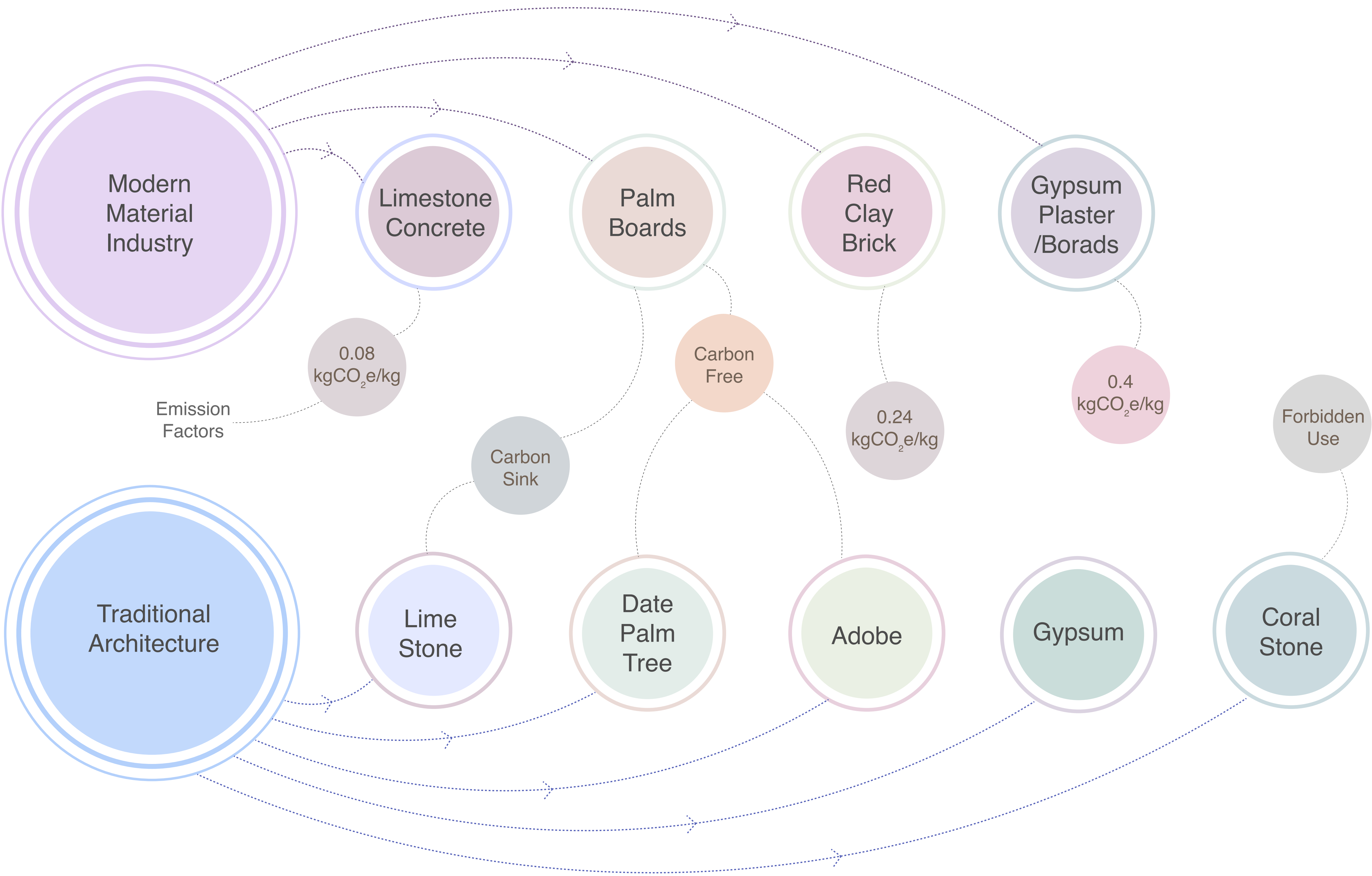


Figure 2.2 — Transformation of Traditional Materials into Contemporary Manufacturing Products

Made by author

2.3 Locally Manufactured Materials in Contemporary Practice

The idea of what defines local materials in architecture is not always straightforward. It raises questions such as whether local materials are those that hold cultural and historical significance in traditional construction and cannot easily be replaced, or simply those that are geographically available within a region. In the case of the United Arab Emirates, local materials were historically those that could be found in the surrounding environment and were therefore used extensively in building practices.

However, similar materials were also used across the Gulf region. Neighboring countries shared comparable climatic conditions and resource availability, which led to the development of similar architectural features such as wind towers and mashrabiyas. Therefore, these materials cannot be considered exclusive to the UAE, but rather characteristic of the broader Gulf context, differing mainly in their specific applications or construction techniques.

Today, locally produced materials may include those that were not naturally available in the past but are now manufactured within the country, such as concrete or steel. Despite technological advancements, the essence of local materials remains tied to the idea of origin, memory, and connection to the place.

When discussing materials and their origin, environmental performance, mechanical properties, and functional development over time, it is also essential to consider their production context, where and how they are made. This section focuses on factories that represent the current building material industry in the UAE, showing how traditional practices and modern industrial methods coexist in today's construction sector. These factories are key contributors to the country's material supply chain and play a central role in supporting both residential and commercial construction. Their size and distribution across the UAE reflect the national effort to achieve greater self-sufficiency in the production of essential building materials. In addition to serving the local market, many of these factories export their products to neighboring and international markets, demonstrating the regional and global competitiveness of the UAE's building material industry.

As shown in figure 2.3, the factories producing building materials are mainly located along the northeastern coast of the UAE, near the country's largest cities. These materials are further examined in later sections of this research in relation to sustainability performance.

The first identified factory is RAK Ceramics, located in the Ras Al Khaimah Emirate, which produces ceramic and porcelain tiles, sanitaryware, and tableware [RAK Ceramics, 2025].

The second is Al Diyar – The Red Clay Brick Factory, situated near Ajman. Originally founded in Saudi Arabia, it later established a branch in the UAE and now manufactures a range of clay products, including solid and perforated bricks, tiles, and cladding elements, all certified under ISO quality standards [Al Diyar, 2025].

The Emirates Beton factory, located in Dubai, produces ready-mix concrete and related concrete products, also certified under ISO standards (Emirates Beton, 2025). In the same emirate, two additional factories were identified: Emirates Steel Industries, which manufactures steel products, cement blocks, and pipes [EMSTEEL, 2025], and EMCON, which also specializes in concrete production [EMCON, 2025].

Further south, in Abu Dhabi, several important factories are located. DesertBoard produces Palm Strand Board (PSB®) using date palm, offering products certified with EPD, LCA, and Carbon Footprint (CFP) labels [DesertBoard, 2025].

Dubai Plaster, also based in Abu Dhabi, manufactures cement, lime, and gypsum-based dry-mix mortars, plasters, and renders [Dubai Plaster, 2025]. The Emirates Lime Factory, likewise, in Abu Dhabi, produces quicklime, hydrated lime, and dololime [Emirates Lime Factory, 2025].

Finally, Henkel Polybit Industries, a German-origin company with a UAE branch, manufactures waterproofing materials [Henkel Polybit Industries Ltd, 2025].

As illustrated in the accompanying map, the highest concentration of manufacturing facilities is located in Abu Dhabi and Dubai, the two largest and most industrially developed emirates. Considering that more than 65% of the UAE's population lives in Abu Dhabi, Dubai, and Sharjah, these regions also represent the country's main construction zones [Worldometer, 2025]. This spatial relationship between population density and industrial activity highlights how material production is closely aligned with areas of active urban growth and building development.

Figure 2.4 presents the annual revenues of each factory and their approximate shares within the UAE construction materials market. The UAE construction materials market was valued at USD 16.2 billion (EUR 14 billion) in 2024 and is projected to reach around USD 20 billion by 2030 [PS Market Research, 2024]. By knowing the revenues for all the factories, the relative share of each can be estimated, showing clear differences in production scale, ranging from approximately 40% to 0.03%. EMSTEEL stands out as the dominant producer among the selected factories, followed by RAK Ceramics with an estimated 5% share. The remaining factories represent smaller portions of the market but play a crucial role in supplying materials that are modern equivalents of traditional, locally sourced resources. Their contribution enhances the diversity of the UAE's construction material market while promoting more sustainable and environmentally conscious building practices.

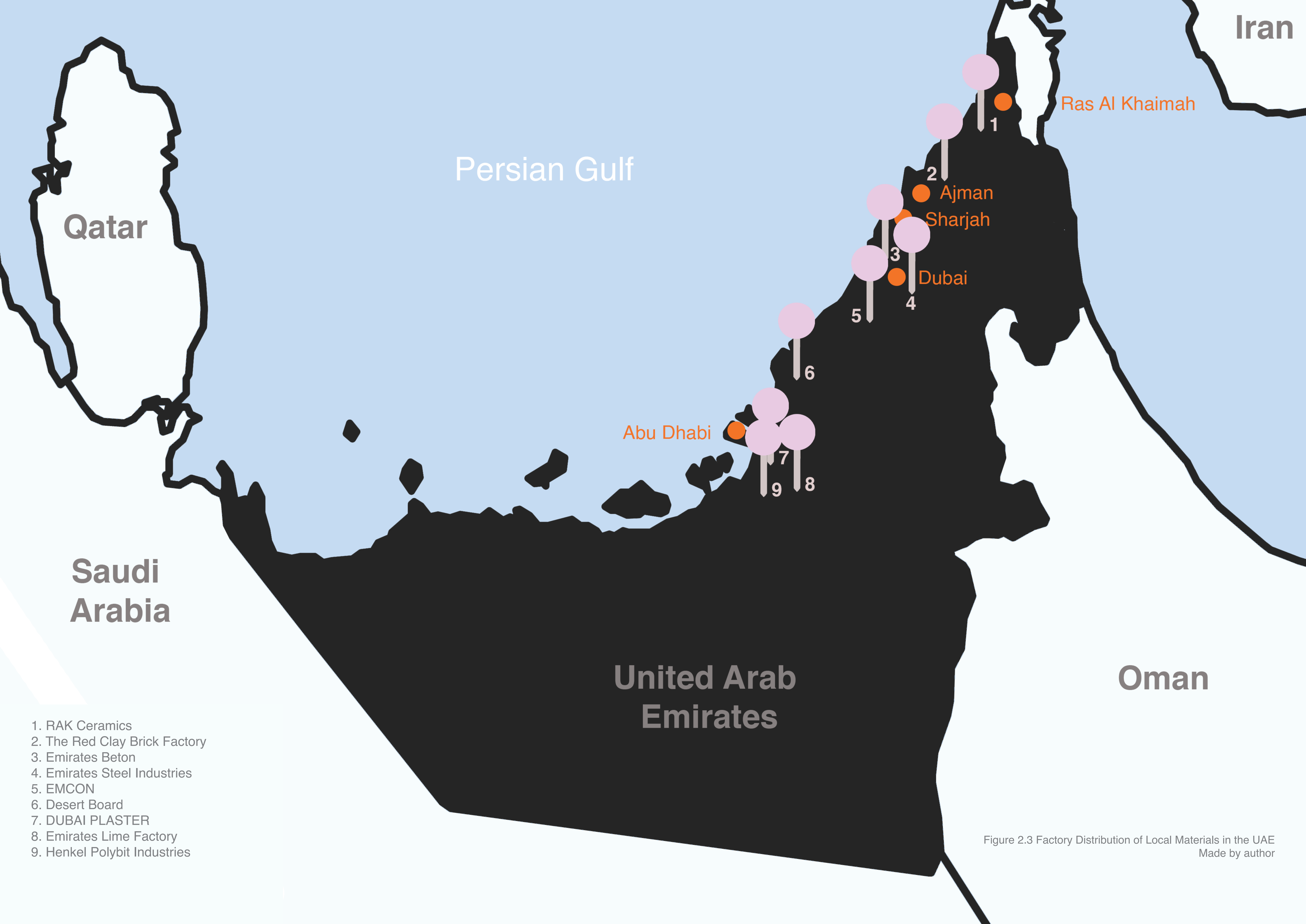


Figure 2.3 Factory Distribution of Local Materials in the UAE
Made by author

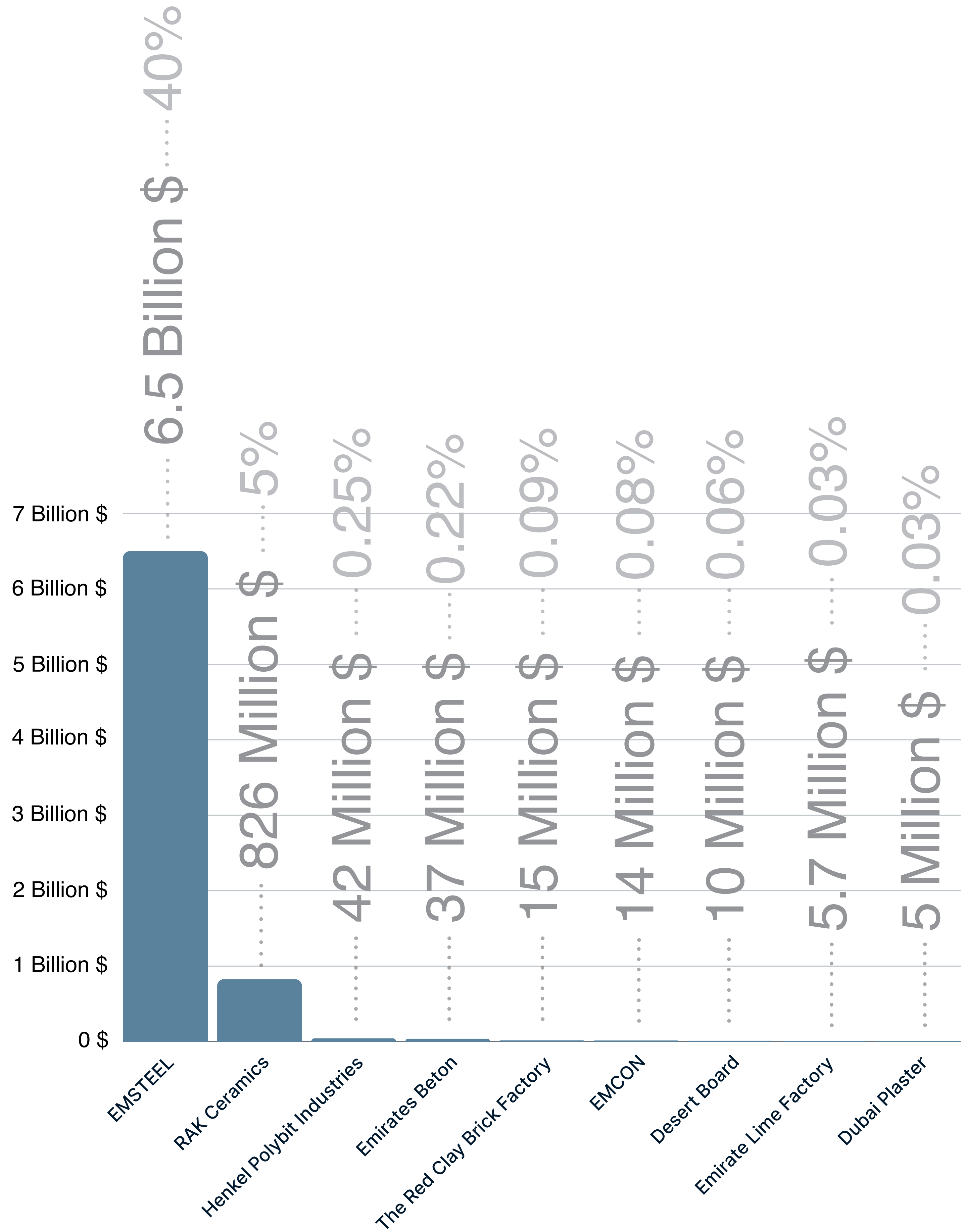


Figure 2.4 — Annual Revenues and Approximate Market Share of Selected UAE Building Material Factories

Made by author by using data from Emirates Steel Arkan (2025), ZoomInfo (n.d.), RAK Ceramics (2025), RocketReach, n.d. and PS Market Research (2024)

Overall, the analysis of the selected factories highlights the dual nature of the UAE's material industry. The balance between large-scale industrial production and smaller, innovative activity that support sustainability and local identity. Together, they demonstrate how traditional material practices have evolved into modern industrial systems capable of meeting both local and international demand.

This local production base forms the foundation for the following chapters, which assess how these materials perform within sustainability rating systems and their influence on overall building performance.

Chapter 3

3.1 Estidama and The Pearl Rating System in Abu Dhabi

Estidama, meaning “sustainability” in Arabic, is an initiative launched in 2008 by Abu Dhabi’s Urban Planning Council. Unlike other rating systems, Estidama is not certification tool, but a broader initiative aligned with the Abu Dhabi Vision 2030. It encompasses social, cultural, environmental, and economic sustainability under one system, aiming to support the development of sustainable cities across the UAE and the region [Abu Dhabi Urban Planning Council, 2016].

At the core of Estidama lies the Pearl Rating System, a structured certification mechanism. The PRS provides requirements and credits to guide the sustainable design, construction, and operation of buildings and communities. Its creation was a response to the limitations of existing systems in addressing the climatic, cultural, and environmental priorities of the Gulf region [Ramani & García de Soto, 2021].

International systems like LEED and BREEAM were useful references, but they were developed for different regions and could not fully address the local challenges of the UAE. Therefore, a system was needed for projects to use more easily, while still following international sustainability principles.

Another important reason for the differences between the rating systems is that each has its own scope and purpose, which can vary depending on the type of project. For example, in the UAE, around half of all construction projects are residential villas [Digital Dubai, 2024, Dubai Data & Statistics Establishment, 2024]. The Pearl Rating System includes specific documentation dedicated to different project types, one of which is the Pearl Villa Rating System [Abu Dhabi Urban Planning Council, 2016]. Because of this structure, PRS can often be a more suitable and practical system for assessing residential villas than LEED or BREEAM, which were primarily developed for larger commercial or institutional buildings.

These are the 4 types of documentations of the PRS:

- Pearl Community Rating System
- Public Realm Rating System
- Pearl Building Rating System
- Pearl Villa Rating System

The answer to how effective PRS is compared to international systems becomes clearer through the comparative analysis conducted in this research.

3.2 Materials in PRS

Pearl Certification System Overview

The Pearl Rating System, awards projects between one and five Pearls based on their overall sustainability performance. In Abu Dhabi, all new developments are required to achieve a minimum of 1 Pearl with fulfilling all mandatory credits, while government-led projects must attain at least 2 Pearls that require accumulating optional credits, with threshold set as represented in the table 3.1.

The PRS is built upon seven major categories, each weighted to reflect the local context (Table 3.2, pg 40).

A total of 177 points are available for buildings from all the 7 categories included in the system, though the exact number varies depending on the project type, whether a villa, building, or community [Abu Dhabi Urban Planning Council, 2016].

As an example, the “Resourceful Energy” category, which aims to reduce energy demand and promote the use of renewable resources, includes three mandatory and seven optional credits.

For instance, optional credits of Energy category collectively offer up to 44 points, so the maximum points a project can get from this category is 44 out of 177. Resourceful Energy and Precious Water are prioritized categories due to their high impact on sustainability outcomes [Abu Dhabi Urban Planning Council, 2016, Raveendran, Hassan, & Tabet Aoul, 2020].

Stewarding Materials

Another essential category in PRS is “Stewarding Materials,” which emphasizes responsible material selection and waste management across all phases of construction. In the Pearl Building Rating System this category contains 3 mandatory and 15 optional credits (Table 3.3, pg 41).

These requirements promote material reuse, reduction of construction waste, elimination of hazardous components, and incorporation of certified and durable materials, ultimately lowering the long-term environmental im pact of buildings. If fully achieved, this category can contribute up to 28 points, which is weighted 16% in the whole rating system [Abu Dhabi Urban Planning Council, 2016].

The primary aim of this credit is to support the local economies, reinforce cultural and environmental appropriateness, and reduce the carbon footprint associated with long-distance transportation. Local materials tend to be climatically suited, easier to obtain, and less energy-intensive to deliver, aligning well with the sustainability principles of Estidama [Abu Dhabi Urban Planning Council, 2016].

3.3 Comparison with LEED and BREEAM

Overview of LEED

LEED was developed in the 1990s for the U.S. market but has since been adopted globally. Some countries have customized it, such as LEED Italy, to better suit local regulations and building traditions. LEED evaluates buildings through seven categories (Table 3.4, pg 42) [Hamweyah, 2018, Rezaallah et al., 2012].

In terms of materials, the “Materials and Resources” category includes two mandatory and five optional credits, with additional credits specifically applicable to the healthcare sector (Table 3.5). LEED promotes principles of transparency and circular economy by encouraging the disclosure of material composition and production processes. The system places emphasis on third-party verification, such as Environmental Product Declarations (EPDs), and the chemical content of materials, particularly for healthcare-related projects. LEED focuses on how materials are produced, their components, and the manufacturers behind them. The total points project can get from this category is 14, which is weighting 13.5% in a whole rating system.

To ensure that a material is environmentally and human health–friendly, several forms of verification are accepted. Manufacturers are required to submit documentation through recognized standards and certifications, including GreenScreen, Cradle to Cradle Certification, International Alternative Compliance Path, and approval through the U.S. Green Building Council (USGBC). These tools provide a clear and verifiable overview of a material’s ingredients and environmental impact [USGBC, 2019].

Overview of BREEAM and BREEAM Gulf

BREEAM was the first established sustainability rating system, introduced in 1990 in the United Kingdom. It was initially developed as a national system for offices and residential buildings but has since expanded into various sectors globally [Rezaallah et al., 2012]. Its main categories and weightings are in table 3.6 (pg 38).

To adapt to different regional contexts, BREEAM International and BREEAM Gulf were developed. BREEAM Gulf targeted countries such as the UAE, Qatar, Oman, and Bahrain [BRE Global, 2012]. Its intent was to respond to regional challenges like water scarcity and extreme heat, [World Bank, n.d] and therefore adjusted its category weightings accordingly (Table 3.7).

Although well-intentioned, BREEAM Gulf was discontinued after two years, reportedly due to limited stakeholder adoption and implementation challenges [Architects' Journal, 2014].

The "Materials" category of BREEAM is primarily focused on minimizing the environmental impact of materials used throughout the entire life cycle of a building (Table 3.8). It has maximum 13 points to reward projects and it weights 13.5% out of all the points available in the system.

The main objectives of this category include promoting sustainable performance, encouraging life cycle assessment (LCA), and ensuring the durability of construction materials. BREEAM supports the use of LCA tools, Green Guide Ratings, EPDs, and BREEAM Mat IMPACT-compliant tools, through which projects can earn points under various credits. The system also emphasizes the importance of responsible sourcing, requiring that materials be produced from certified suppliers.

An additional concern within BREEAM is ensuring that materials are protected from environmental degradation, with the aim of reducing the need for replacements and extending the service life of materials used in construction [BRE Global, 2016].

Comparative Analysis: LEED vs. BREEAM vs. PRS

Based on the brief comparative analysis, the following points summarize the main focus areas of each sustainability rating system.

- BREEAM focuses on management and process efficiency, and is closely aligned with the legal and environmental standards of the UK and Europe.

- LEED is structured to be flexible and international, with a strong focus on energy performance and product transparency.

- PRS, developed specifically for the United Arab Emirates, places greater emphasis on water and energy efficiency.

When comparing LEED, BREEAM, and PRS, it becomes clear that each system reflects the priorities and conditions of its own regulatory context. Their structures and evaluation methods differ, making each system more suitable for specific building types or project scales. For example, LEED includes several credits that apply exclusively to healthcare facilities, such as those related to medical ventilation systems or specialized waste management. Therefore, if a hospital were evaluated under all three systems, it would likely achieve higher results in LEED.

Another difference among the three rating systems lies in the weighting of the materials category within the overall sustainability system. LEED and BREEAM have similar weighting, accounting for approximately 12–14 points (13.5% each), while PRS assigns a slightly higher weight of 16%, distributed across 28 credits. This variation reflects how each system defines the relative importance of materials in achieving overall building sustainability.

When examining the most prioritized categories in each system, clear distinctions emerge. In BREEAM, the highest weighting is given to Energy and Health/Well-being (15% each). LEED assigns the greatest importance to Energy (33%) and Sustainable Sites (24.5%), while PRS prioritizes Energy (25%) and Water (24%).

In all three systems, the energy category remains the most significant, which is understandable as energy performance is a global concern rather than a regional one (Table 3.9, pg 44). However, the second most weighted category differs between systems, reflecting the specific priorities and environmental challenges of the regions where they are applied. For instance, water scarcity is one of the major environmental challenges in the UAE, as mentioned in Section 1.3.

However, a significant difference lies in the requirements and implementation mechanisms. PRS does not mandate third-party certifications and does not clearly outline what specific documentation needs to be provided to achieve credits. In contrast, both LEED and BREEAM offer well-defined criteria, supported by structured requirements and detailed descriptions of necessary documentation and tools. Although PRS includes credits with objectives similar to those in LEED and BREEAM, it lacks clarity in explaining how these credits are to be met and verified.

The following chapter tests these systems using a representative residential case study to evaluate their practical outcomes.

System Overview

Table 3.1 — Minimum Required Points

Pearl Rating Level	Minimum Required Points
1 Pearls	All Mandatory
2 Pearls	All Mandatory + 60 Optional Credits
3 Pearls	All Mandatory + 85 Optional Credits
4 Pearls	All Mandatory + 115 Optional Credits
5 Pearls	All Mandatory + 140 Optional Credits

Made by Author using Urban Planning Council (2010). Estidama Pearl Rating System:

Table 3.2 — Categories Weighting Distribution

Category	Weighting %	Points
Resourceful Energy	25	44
Precious Water	24	43
Livable Buildings	21	37
Stewarding Materials	**16**	**28**
Integrated Development Process	7	13
Natural Systems	7	12
Innovating Practice (Bonus)	1	3

Made by Author using Department of Urban Planning and Municipalities. (2010). The Pearl Rating System for Estidama: Design & Construction - Version 1.0. Abu Dhabi Urban Planning Council

Material Category Credits

Table 3.3 — Material Category Credits and Points Allocation

Credit Type	Credits	Points
Mandatory	Hazardous Materials Elimination	R
	Basic Construction Waste Management	
	Basic Operational Waste Management	
Optional	Non polluting Materials	3
	Design for Materials Reduction	1
	Design for Flexibility & Adaptability	1
	Design for Disassembly	1
	Modular Flooring Systems	1
	Design for Durability	1
	Building Reuse	2
	Material Reuse	1
	Regional Materials	2
	Recycled Materials	6
	Rapidly Renewable Materials	1
	Reused or Certified Timber	2
	Improved Construction Waste Management	2
	Improved Operational Waste Management	2
	Organic Waste Management	2

- Waste Management
- Design Efficiency and Adaptability
- Material Sourcing and Composition

Made by Author using Urban Planning Council (2010). Estidama Pearl Rating System: Design & Construction Guide for Buildings.

LEED

Table 3.4 — Categories Weighting Distribution

Category	Weighting (%)
Energy and Atmosphere	33
Sustainable Sites	24.5
Indoor Environment Quality	14
Materials and Resources	**13.5**
Innovation & Design	6.5
Water Efficiency	5.5
Regional Priority	4

Made by Author using U.S. Green Building Council (2023). LEED v4 for Building Design and Construction – Credit Categories and Point Allocation.

BREEAM

Table 3.6 — Categories Weighting Distribution of BREEAM

Category	Weighting (%)
Health and Well-being	15
Energy	15
Materials	**13.5**
Management	12
Land Use and Ecology	10
Pollution	10
Innovation	10

Made by Author using BRE Global (2016). BREEAM UK New Construction, Technical Manual. Building Research Establishment (BRE).

BREEAM Gulf

Table 3.7 — Categories Weighting Distribution of BREEAM Gulf

Category	Weighting (%)
Water	30
Health and Well-being	15
Energy	14
Materials	**9**
Management	8
Land Use and Ecology	7
Pollution	7
Transport	5
Waste	5

Made by Author using Emirates Green Building Council & BRE Global (2012). Memorandum of Understanding – BREEAM Gulf Initiative.

LEED

Table 3.5 — Material Category Credits and Points Allocation

Credit Type	Credit	Points
Mandatory	● Storage and Collection of Recyclables	R
	● Construction and Demolition Waste Management	
Optional	● Building Life-Cycle Impact Reduction	2-6.
	● Environmental Product Declarations	1-2.
	● Sourcing of Raw Materials	1-2.
	● Material Ingredients	1-2.
	● Construction and Demolition Waste Management	1-2.

- Waste Management (green)
- Life-Cycle and Impact Assessment (dark blue)
- Material Sourcing and Composition (light blue)

Made by Author using U.S. Green Building Council. (2019). LEED v4 for Building Design and Construction

BREEAM

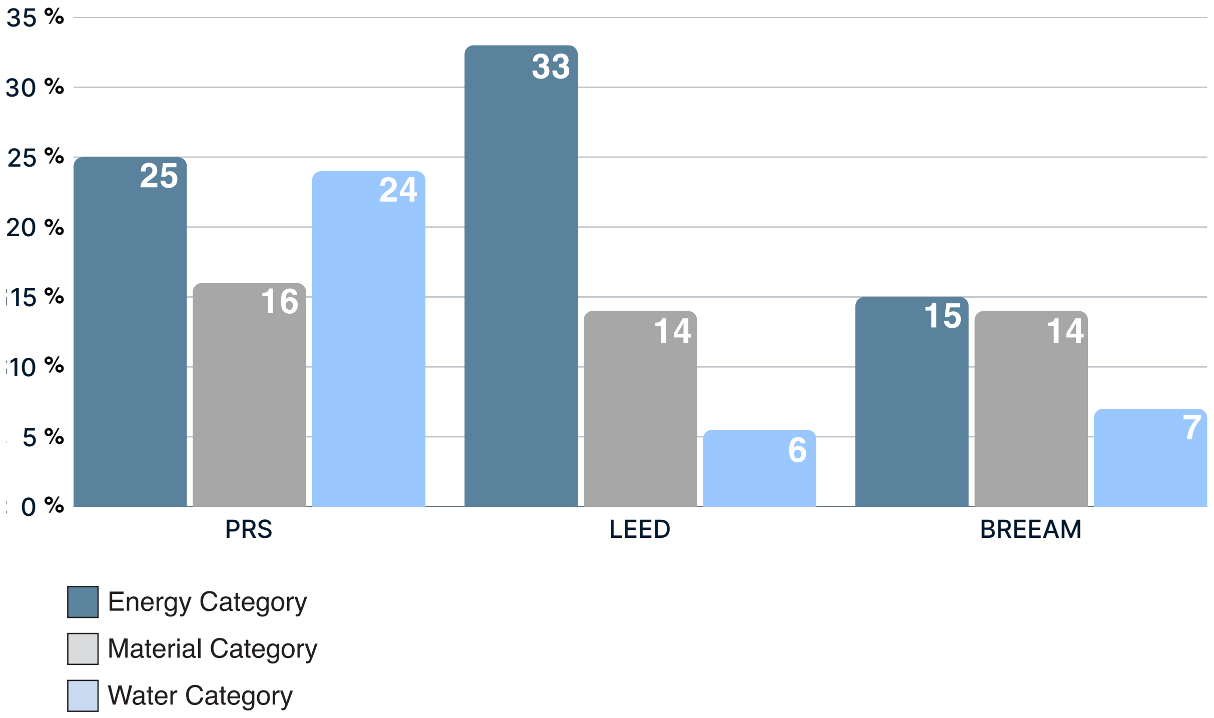
Table 3.8 — Material Category Credits and Points Allocation

Credit Type	Credit	Points
Optional	● Life Cycle Impacts	1-6.
Mandatory for Timber	● Responsible Sourcing	4
Optional	● Environmental Product Declarations	1
	● Design for Durability and Resilience	1
	● Material Efficiency	1

- Life-Cycle and Impact Assessment (dark blue)
- Design Efficiency and Adaptability (orange)
- Material Sourcing and Composition (light blue)

Made by Author using BRE Global. (2016). BREEAM International New Construction 2016: Technical Manual SD233 2.0. BRE Group.

Table 3.9 — Comparison of Category Weightings



Made by Author using Urban Planning Council (2010), BRE Global. (2016) and U.S. Green Building Council

Figure 4.1
Made by author

Chapter 4

4.1 Introduction

This chapter presents a comparative analysis of how the same building performs under three different sustainability rating systems mentioned before. As the central focus of this thesis is on materials, only the material category of each system is evaluated. However, a complete assessment of materials also requires consideration of greenhouse gas emissions and cost, as these factors directly influence the environmental and economic performance of a building. Including these dimensions provides a clearer understanding of how each system rewards sustainable material use.

To conduct the comparative analysis, it was first necessary to identify a reference building with complete and reliable data. However, due to the limited availability of detailed material-related information for UAE buildings, a comparable alternative was selected. The case study building is located in Saudi Arabia, 350 km north from the United Arab Emirates (Figure 4.1/4.2). Given the climatic, cultural, and construction similarities between Saudi Arabia and the UAE, this case provides a valid proxy for regional material performance.

The aim of this analysis is to assess how each system evaluates materials in practice, and to identify differences in how deeply materials are addressed in their respective certification processes. This comparison also serves as a foundation for suggesting improvements to the Pearl Rating System.

Table 4.2 — Case Study Project Information

	Dhahran, Saudi Arabia	2013	
	2 Floor Villa	Desert Climate	
m²	377	8	

Made by Author using Asif et al., 2017. “Life cycle assessment of a three-bedroom house in Saudi Arabia”.

The comparative analysis began by selecting a building project that already included a detailed Bill of Quantities (BOQ). This document served as the foundation for extracting data on all the materials used in the building. Based on this material inventory, further calculations were carried out by the author to estimate both the greenhouse gas emissions and costs. This was done by assigning standard unit emission factors and unit cost values to each material, and then calculating the total impact for each material type.

The case study building represents a typical residential house commonly found in Saudi Arabia and the United Arab Emirates. It was chosen, because it reflects the most ordinary form of housing construction in the region. Ordinary residential buildings make up most of the built environment in the Gulf and are responsible for the largest share of material use and environmental impact in the construction sector. By focusing on an ordinary instead of an exceptional or iconic building, this study aims to look at the real challenges found in today's construction practices. Studying a common type of house helps to better understand how sustainability rating systems work in everyday situations, where buildings are built repeatedly, using standard materials and simple designs. This approach gives a clearer view of how effective these systems are in improving the environmental performance of the majority of buildings, rather than only exceptional cases.

The second step involved collecting certifications for all materials used in the project, (e.g., Environmental Product Declarations, Verified Health Product Declaration) (Table 4.9, pg 68, A1-A30, pg 98). Based on these certifications, the specific information required by each rating system was identified to evaluate the materials category. Using the official manuals and guidelines of LEED, BREEAM, and PRS, a data checklist was developed by the author (Table 4.7, pg 66). This checklist included key indicators such as material origin, recyclability, certification status, chemical composition, and environmental declarations.

The final step consisted of the point calculation process. Each credit within the materials category of the three systems was evaluated based on the collected data. Requirements from each rating system were carefully read and cross-checked with the actual documentation available for the building materials. Points were awarded where the building met the criteria.

The outcome of this process is expressed in table 4.13 (pg 71), indicating the extent to which the building fulfilled the material-related requirements in each rating system. This allows for a clear, side-by-side comparison of how the same building performs under LEED, BREEAM, and PRS when evaluated solely on material sustainability.

The information about the selected building is taken from the article “Life Cycle Assessment of a Three-Bedroom House in Saudi Arabia” [Asif et al., 2017]. The case study building is located in the Eastern Province of Saudi Arabia, a coastal area with climatic conditions closely comparable to those of the United Arab Emirates. The house is situated within the King Fahd University of Petroleum and Minerals (KFUPM) campus and serves as accommodation for university staff or students. It consists of two floors, with total floor are of 377 m^2. The ground floor accommodates a reception area, study room, technical spaces, kitchen with laundry, and dining area, while the first floor contains two master bedrooms with private bathrooms and closets, two additional bedrooms with a shared bathroom, and a maid's room (Figure 4.3).

The article provides detailed information about the building's structural and envelope components, including the floor, wall, roof, window, and HVAC system configurations. The structure is made of reinforced concrete, while the external walls consist of two layers of concrete blocks, thermal insulation and are finished with plaster. The internal walls are made of concrete masonry units, thermal insulation and are also finished with plaster. The windows are double-glazed (4-12-4 mm) with an air gap and aluminum frame.

The publication lists all the materials used in the project along with their application, quantity, density, weight and embodied energy values. All the provided information is forming the basis for the environmental impact of the building materilas and comparative assessment carried out in this research.

The chosen building represents a form of mass-produced housing that relies on standardized building materials, modular design, and minimal architectural variation, making it clearly different from high-profile commercial buildings. This example helps to understand the material and environmental performance of ordinary housing in the UAE. If the chosen case study was an extraordinary building with advanced architectural design (Figure 4.4), the results of the analysis would likely differ, as such projects often use specialized materials, modern technologies, and larger budgets. However, by focusing on an ordinary construction type, this thesis aims to highlight the real challenges and current level of sustainability within the UAE's residential sector.

4.4 Material Impact Assessment

A total of 20 building materials were analyzed in this study (Table 4.6, pg 56). The materials with the highest quantities used in the case study were concrete, plaster, steel rebars, and cement, which significantly contributed to both the cost and environmental impact of the building (Table 4.5, pg 54).

To support the analysis, data was gathered from multiple sources. Material information was extracted from the aforementioned project's Bill of Quantities (BOQ). Embodied GHG emissions were calculated by the author using emission factors from the EPiC database [Stephan, & Prideaux, 2019], which provides standardized values for embodied energy, water, and GHG emissions per unit of material. In the summary tables 4.5 and 4.6, data sourced from case study is highlighted in green, while calculated values from secondary sources made by the author are marked in blue for clarity.

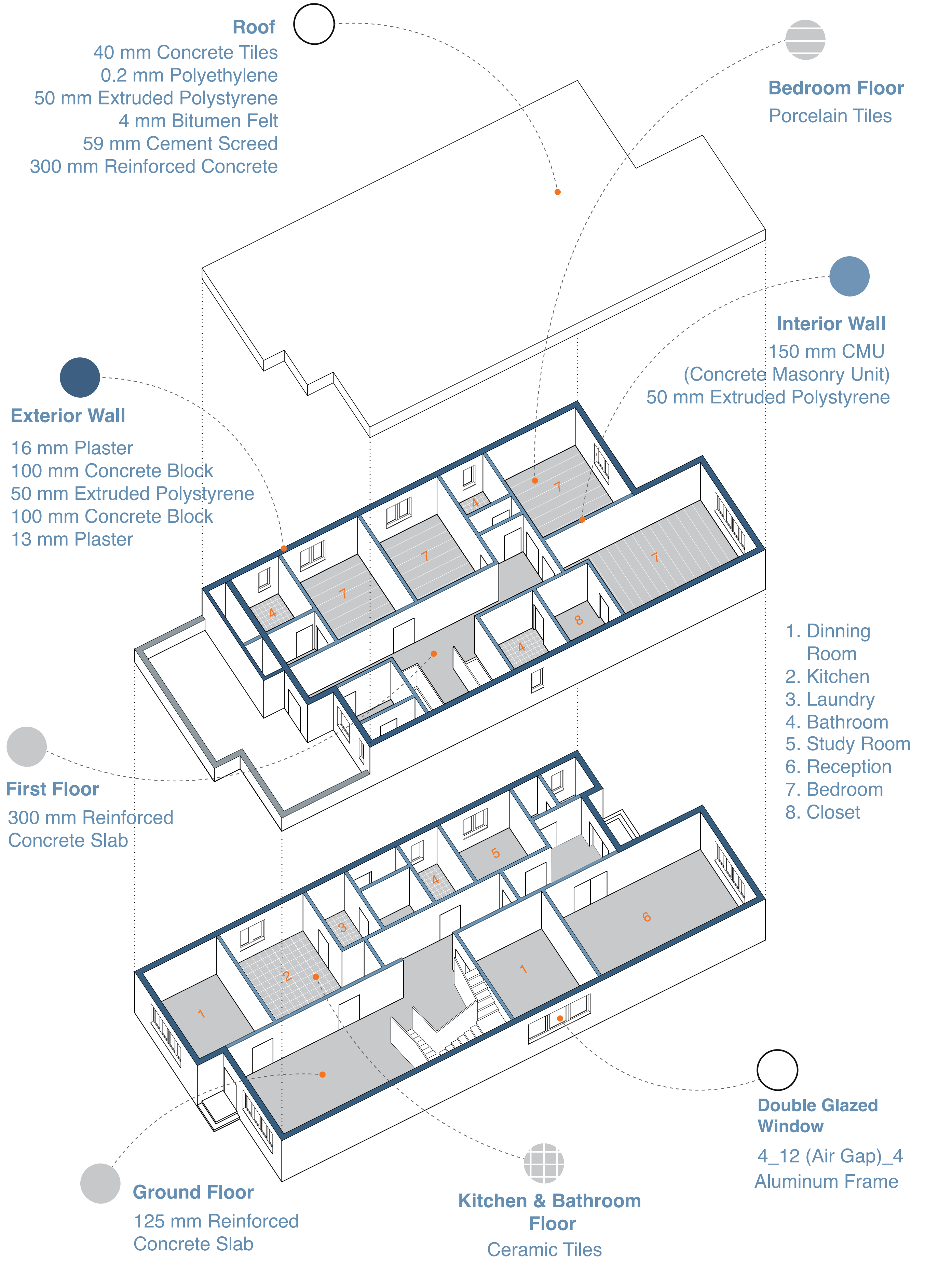
Cost estimation was based on market data from the United Arab Emirates, primarily using price indices provided by the Emirate of Ras Al Khaimah Statistics Center [Department of Economic Development, Ras Al Khaimah, 2024, Dubai Statistics Center, 2019]. This sources offers annual pricing for a wide range of construction materials. All costs presented in Table 4.5 are expressed in Emirati Dirhams (AED), where 1 AED equals approximately to 0.23 EUR. Based on these values, material costs were calculated and grouped into categories required for the assessment of the materials-related credits in the three rating systems (Table 4.9, pg 66).

As shown in Table 4.4, the materials with the highest GHG emissions are also generally the most expensive. For example, concrete alone contributes to 35.5% of the total GHG emissions from building materials, and accounts for 20.5% of the total material cost. However, some materials do not follow this trend. Polystyrene, for instance, contributes only 2.4% of GHG emissions but represents 7.7% of the cost. A similar pattern is observed for polyvinyl chloride (PVC).

This discrepancy can be explained by the nature of these materials. Polystyrene is a high-performance thermal insulator that is often imported, derived from petrochemical sources, and required to comply with technical standards such as fire resistance. Likewise, PVC is also produced from oil-based raw materials and typically needs to meet certification requirements for fire safety, chemical resistance, and durability [Dulet, n.d.].

Based on the total GHG calculations, the embodied GHG emission per square meter of the analyzed building is 1169 $kgCO_2e/m^2$. This value will later be compared with a baseline building, and further evaluated through sensitivity analysis to understand how changes in material selection can influence the overall environmental impact.

Figure 4.3 — Exploded Axonometric Diagram Showing Material Composition and Layering of the Case Study Building



Made by Author using Asif et al., 2017. "Life cycle assessment of a three-bedroom house in Saudi Arabia".

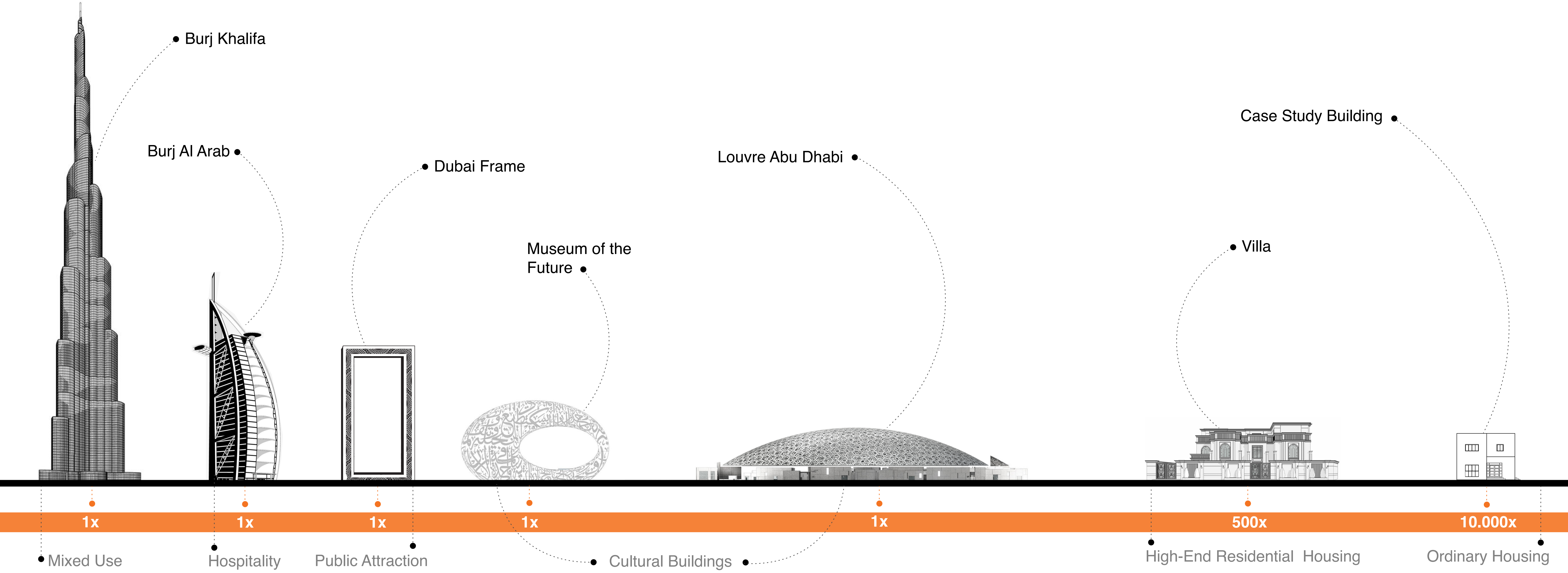
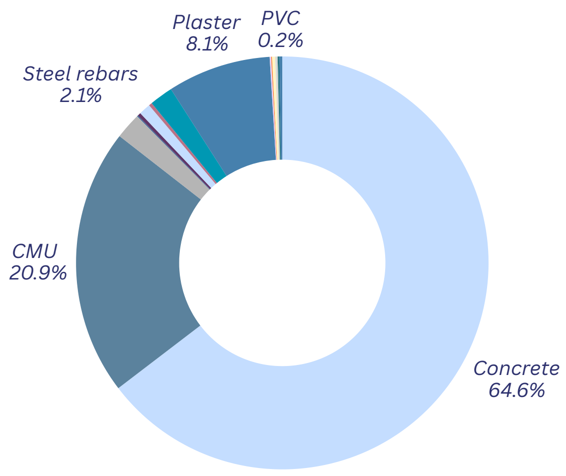


Figure 4.4 — Spectrum of Building Typologies in the UAE: From Extraordinary Landmarks to Ordinary Housing

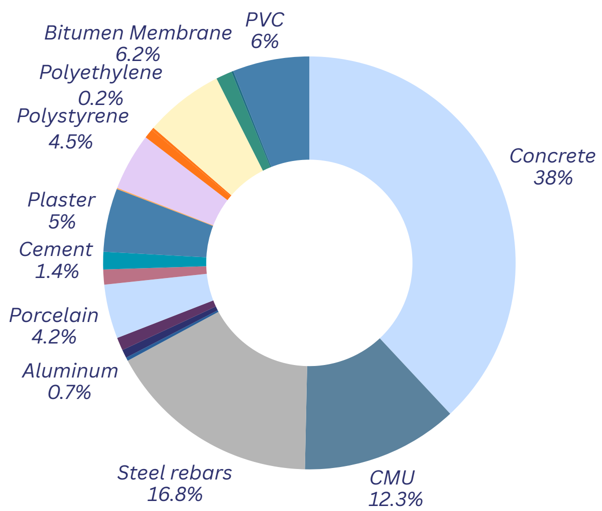
Made by Author

Case Study Material Breakdown

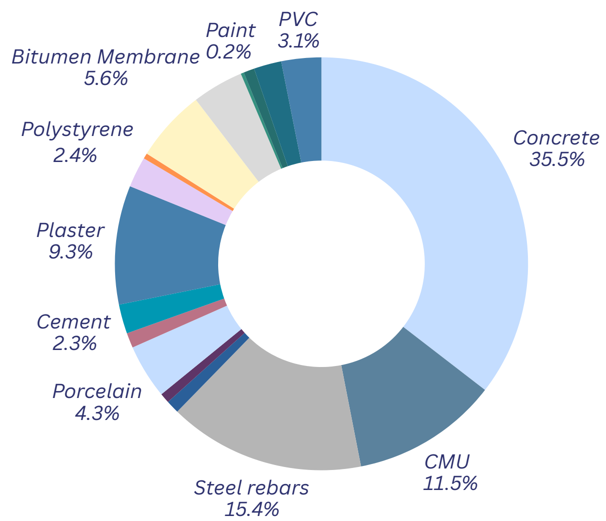
Table 4.5 — Distribution of Case Study Materials by Weight, Energy, Emissions, and Cost



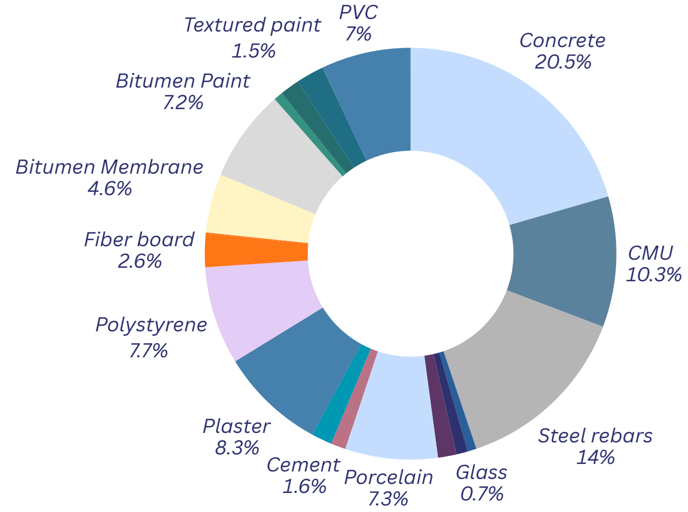
Weight Distribution



Embodied Energy Distribution



Greenhouse Gas Emission Distribution



Cost Distribution

Made by Author using:
GHG Emission Factors
Crawford, R. H., Stephan, A., & Prideaux, F. (2019). EPiC Database – Embodied Carbon and Energy Database, University of Melbourne.
Material Costs
Department of Economic Development – Ras Al Khaimah. (2024). Building Materials Prices Statistics.
Embodied Energy and Weight
Asif, M., Dehwah, A. H. A., Ashraf, F., Khan, H. S., Shaukat, M. M., & Hassan, M. T. (2017). Life cycle assessment of a three-bedroom house in Saudi Arabia. Environments, 4(3), 52.

Material Data of the Case Study Building

Table 4.6 — Material Inventory with Embodied GHG Emissions and Cost Breakdown for the Case Study Building

N	Material	Use	Unit	Quantity	Weight (kg)	Density (kg/m^3)	Embodied Energy (MJ)	Embodies GHG Emission (kgCO$_2$e)	Total GHG Emissions (kgCO$_2$e)	Cost (AED)	Total Cost (AED)
1	Concrete	Roof, columns, beams, footings, stairs	m^3	413.2	1,012,340	2450	1,692,805	155,900	440,897	105370	477484
2	Concrete masonry units (CMU)	Exterior and interior walls	PCs	26,350	327,450	12.4 kg/block		50,427		52700	
3	Steel re-bars	Reinforcement (structural elements)	m^3	-	32,173	-	747,732	67,563		72154	
4	Glass	Windows	m^3	0.36	900	2500	11,804	4,545		3600	
5	Aluminum	Framing	m^3	0.13	361	2700	29,164	642		4584	
6	Wood	Doors and cabinets	m^3	4.91	3928	800	45,135	3,418		7469	
7	Porcelain	Room tiles	m^2	575	14,375	25 kg/m^2	240,081	18,688		37375	
8	Ceramic	Bathroom and kitchen tiles	m^2	331	3972	12 kg/m^2		5,164		5958	
9	Cement	Rooftop tiles	m^3	12	28,800	2400	60,971	10,080		8415	
10	Plaster	Exterior and interior walls	m^3	70.5	126,900	1800	221,039	40,890		42638	
11	Gypsum	Wall and ceiling	m^3	3.74	46	12.3	4233	20		18	
12	Polystyrene (EPS)	Thermal insulation	m^3	58.9	1885	32	199,495	10,564		39589	
13	Fiber board	Ducting	m^3	17.8	854	48	33,185	1,879		13197	
14	Polyethylene	Vapor barrier (foundation and roof)	m^3	0.1	95.5	955	9054	600		662	
15	Bitumen Membrane	Water proofing (envelop)	m^2	825	3878	4.7 kg/m^2	276,677	24,819		23762	
16	Bitumen Paint	Water proofing (foundation)	L	-	2800	-		17,640		37229	
17	Paint (White)	Interior	m^2	1577.8	160	-	56,022	1,088		3692	
18	Textured paint	Exterior	m^2	620.54	591	-		3,723		7858	
19	Galvanized iron sheets	Duct work	m^2	279	1728	6.2 kg/m^2	6818	9,504		11214	
20	Polyvinyl chloride (PVC) – plumbing	Sewer pipe, potable and hot water system, gas piping system	m	3809	3308	-	267,668	13,743		36195	

Data Extracted from the Case Study Article

Data Calculated by the Author

Made by Author using:

Material Quantities

Asif, M., Dehwah, A. H. A., Ashraf, F., Khan, H. S., Shaukat, M. M., & Hassan, M. T. (2017). Life Cycle Assessment of a Three-Bedroom House in Saudi Arabia. Environments, 4(3), 52. https://doi.org/10.3390/environments4030052

GHG Emission Factors

Crawford, R. H., Stephan, A., & Prideaux, F. (2019). EPiC Database – Embodied Carbon and Energy Database, University of Melbourne.

Material Costs

Department of Economic Development – Ras Al Khaimah. (n.d.). Building Materials Prices Statistics.

Material Data of the Baseline Building

Table 4.7 — Baseline Building GHG Emissions by Material

N	Material	Use	Unit	Quantity	Weight (kg)	Density (kg/m^3)	Embodied Energy (MJ)	Embodies GHG Emission ($kgCO_2e$)	Total GHG Emissions ($kgCO_2e$)
1	Concrete	roof, columns, beams, footings, stairs	m^3	413.2	1,012,340	2450	1,692,805	86,353	304,286
2	Concrete masonry units (CMU)	Exterior and interior walls	PCs	26,350	327,450	12.4 kg/block		27,931	
3	Steel re-bars	Reinforcement (structural elements)	m^3	-	32,173	-	747,732	55,338	
4	Glass	Windows	m^3	0.36	900	2500	11,804	1,467	
5	Aluminum	Framing	m^3	0.13	361	2700	29,164	2,408	
6	Wood	Doors and cabinets	m^3	4.91	3928	800	45,135	2,608	
7	Porcelain	Room tiles	m^2	575	14,375	25 kg/m^2	240,081	11,443	
8	Ceramic	Bathroom and kitchen tiles	m^2	331	3972	12 kg/m^2		3,162	
9	Cement	Rooftop tiles		12	28,800	2400	60,971	23,328	
10	Plaster	Exterior and interior walls	m^3	70.5	126,900	1800	221,039	30,202	
11	Gypsum	Wall and ceiling	m^3	3.74	46	12.3	4233	8	
12	Polystyrene (EPS)	Thermal insulation	m^3	58.9	1885	32	199,495	6,956	
13	Fiber board	Ducting	m^3	17.8	854	48	33,185	-734	
14	Polyethylene	Vapor barrier (foundation and roof)	m^3	0.1	95.5	955	9054	243	
15	Bitumen Membrane	Water proofing (envelop)	m^2	825	3878	4.7 kg/m^2	276,677	24,819	
16	Bitumen Paint	Water proofing (foundation)	L	-	2800	-		10,528	
17	Paint (White)	Interior	m^2	1577.8	160	-	56,022	344	
18	Textured paint	Exterior	m^2	620.54	591	-		2,222	
19	Galvanized iron sheets	Duct work	m^2	279	1728	6.2 kg/m^2	6818	4,977	
20	Polyvinyl chloride (PVC) – plumbing	Sewer pipe, potable and hot water system, gas piping system	m	3809	3308	-	267,668	10,685	

Data Extracted from the Case Study Article

Data Calculated by the Author

Made by Author using:
Material Quantities
Asif, M., Dehwah, A. H. A., Ashraf, F., Khan, H. S., Shaukat, M. M., & Hassan, M. T. (2017). Life Cycle Assessment of a Three-Bedroom House in Saudi Arabia. Environments, 4(3), 52.
GHG Emission Factors
ICE Database Educational V4.0 – Dec 2024

4.5 Certification Results Comparison

LEED

This section presents a step-by-step evaluation of how each credit under the LEED rating system's Material and Resources category was assessed in the selected case study.

The analysis begins with the list of LEED credits (Table 4.11, pg 70). The first two, Storage and Collection of Recyclables and Construction and Demolition Waste Management Planning, are mandatory prerequisites, meaning they are required but do not award points.

The first prerequisite requires the project to allocate dedicated space for the collection and storage of recyclable materials such as mixed paper, cardboard, glass, plastics, and metals. The second prerequisite involves preparing a waste management plan, describing how construction waste will be diverted and specifying recycling facilities for each material

These two prerequisites do not directly address the use of materials or their sustainability certifications. For this reason, they were considered as fulfilled by default.

The third credit is Building Life-Cycle Impact Reduction, offers four compliance options, which are

1. Historic Building Reuse
2. Renovation of Abandoned or Blighted Building
3. Building and Material Reuse
4. Whole-Building Life-Cycle Assessment.

In this case, option 4 was selected as the most applicable. It requires demonstrating a 10% reduction in at least three out of six environmental impact categories and one of them must be GWP. The impact categories include:

- global warming potential (GWP)
- depletion of the stratospheric ozone layer
- acidification of land and water sources
- eutrophication
- formation of tropospheric ozone
- depletion of nonrenewable energy resources

To assess this, a baseline building was modeled using the same quantities as in Table 4.6, but with embodied carbon data from the ICE database [Circular Ecology, 2024]. This database was selected due to its standardized and internationally recognized emission factors for typical construction materials. The analysis revealed that the baseline building performed approximately 30% better (Table 4.7, pg 58) than the project building in terms of global warming potential.And the reduced 807 $kgCO_2e/m^2$ GHG emission for each square meter of the building.

As this impact category is mandatory for earning the credit, no points were achieved.

The fourth credit, Environmental Product Declarations, includes two options, each awarding 1 point:

1. Requires at least 20 different materials from 5 manufacturers, each with:

- Product-specific declaration
- Environmental Product Declarations
- USGBC approved program

2. Requires that at least 50% (by cost) of all materials used are verified through EPDs or similar certifications demonstrating impact reductions in at least three of the six categories mentioned earlier.

For Option 1, the project included 20 materials, 6 of which had EPDs. An additional 6 had SCS certifications, with 4 certified for recycled content and 2 with third-party certification (Table 4.10, pg 68), some of which are recognized by USGBC (e.g., recycled content certificates). Thus, a total of 12 materials met the requirements, insufficient to meet the 20-material threshold. For Option 2, only 33% of the total material cost met the criteria, which also falls short of the 50% requirement. As a result, no points were awarded under this credit.

The fifth credit, Sourcing of Raw Materials, also includes two options, each awarding 1 point:

1. Use at least 20 materials from 5 manufacturers that provide transparent reporting on raw material sourcing and extraction practices.
2. Ensure that at least 25% of the total material cost is attributed to materials that meet responsible sourcing criteria (e.g., recycled content, third-party verified reports).

The project was able to meet Option 2 by using materials with recycled content covering 33% of total cost, thereby earning 1 point.

The sixth credit, Building Product Disclosure and Optimization – Material Ingredients, has three compliance paths. All require detailed disclosure of chemical ingredients:

1. Requires 20 products with chemical inventory (e.g., Health Product Declaration, Cradle to Cradle, etc.)
2/3. Require 25% (by cost) of all materials to come from manufacturers with deeper transparency and third-party verified supply chain optimization programs.

The project could only document 2 materials with valid certification, accounting for 9% of the material cost, which is insufficient to meet any of the thresholds. Therefore, no points were achieved from this credit.

The final credit, Construction and Demolition Waste Management, offers two options:

1. Divert 50–75% of construction waste into 3 or 4 different material streams
2. Keep total construction waste generation below 12.2 kg/m² of the building floor area.

In this case, the credit do not specifically evaluate the sustainability or certification of materials used. Therefore, they were assumed to be satisfied by default for the purpose of this analysis.

Out of a total of 14 possible points in the LEED Materials and Resources category, the project earned 3 points, resulting in a 21% achievement rate. This outcome reflects the challenges of meeting LEED requirements when limited certifications or material transparency data are available.

BREEAM

BREEAM provides fewer credits in the materials category compared to LEED (Table 4.12). The first credit is Life Cycle Impact, which requires the use of the Mat 01 International Calculator. This tool calculates the percentage improvement in environmental performance of the building materials based on life cycle impact categories. Depending on the percentage achieved, the project can earn up to 5 points.

There is also a separate requirement under the same credit that rewards 1 additional point if the project uses at least five materials with EPDs. In this case study, six materials had valid EPDs (Table 4.10), which satisfies the condition and earns 1 point from this option.

The second credit is Responsible Sourcing of Construction Products. It has two components.

1. Development of a Sustainable Procurement Plan, which must be prepared by the concept design stage. It should be a documented and enforceable policy that ensures materials are responsibly sourced and encourages the use of certified products.
2. Requires the use of the Mat 03 tool to calculate the percentage of materials that are responsibly sourced. Based on the result, the project can earn up to 3 points.

As there was no access to the Mat 01 and Mat 03 calculators at the time of this analysis, the final estimation of these credits could not be completed.

The third credit is Designing for Durability and Resilience, which offers 1 point. It requires the building to include protective design features that reduce the risk of damage or deterioration in areas exposed to frequent use or environmental conditions. These include components such as external walls, staircases, doors, and windows, and environmental risks such as wind, solar radiation, or pests.

The final credit is Material Efficiency, with a maximum of 1 point. To achieve it, the project must identify and implement strategies that improve efficiency in material use throughout the design and construction phases.

The last two credits do not directly evaluate the materials used or their certifications. Therefore, for this analysis, they were considered as fulfilled by default. Overall, the project is estimated to achieve 4 points, representing approximately 33% of the total available credits in the materials category.

PRS

Analysis of the Pearl Villa Rating System reveals several differences from the Pearl Building Rating System, that was presented in the chapter 3 (Table 3.3, pg 41), particularly in the number of available credits and the nature of certain criteria. The first three credits in the Stewarding Materials category are mandatory (Table 4.13, pg 70). The first one, Hazardous Materials Elimination, requires confirmation that no materials containing asbestos or chromated copper arsenate-treated timber are used in the project. In cases where any portion of the building is reused, documentation must verify that it is also free of ACMs. Compliance with this credit must be supported by purchase records or other documentation confirming the exclusion of such materials.

The second mandatory credit, Basic Construction Waste Management, requires the development of a Construction and Demolition Waste Management Plan prior to any construction activities. This plan must specify whether the construction waste will be sorted on-site or mixed, and it must also demonstrate that at least 30% of the waste, by weight or volume, will be recycled or salvaged.

The third required credit, Storage and Collection of Waste and Recyclables, involves providing a designated storage area equipped to accommodate bins for recycled waste. The credit specifies the required color-coding for different waste types and provides guidance on design considerations for the storage space, such as the selection of interior finishes for walls and flooring. Furthermore, the credit mandates the inclusion of small bins with at least three compartments within kitchen areas. Reference images of compliant bins are also included in the source material. All three of these required credits were considered automatically achieved, as the materials used in the case study did not include any asbestos, and the other two credits are

The fourth credit, Non-Polluting Materials, consists of two options, each worth one point.

1. Requires that all thermal insulation materials used in the project have an Ozone Depleting Potential (ODP) of zero and a Global Warming Potential of less than five.
2. Focuses on the substitution of chlorine-based materials, such as PVC, CPE, CPVC, and CSPE, with more environmentally sustainable alternatives.

The credit also provides guidance on which building elements could be substituted, such as floor and wall coverings, piping systems, and window frames. To comply with this credit, a summary list of all insulation products used in the project must be provided, along with documentation confirming that they meet the ODP and GWP requirements. In this case study, the first option was met through the use of appropriate thermal insulation, while the second option was not satisfied due to the use of PVC in plumbing systems. Consequently, the project earned one point from this credit.

The fifth credit, Design for Durability, requires the development of a comprehensive durability plan for the building. This plan must include estimated life spans for key building elements such as the foundation, walls, and roofing systems. For components with shorter life expectancies, the plan should detail strategies for their eventual replacement. The credit also outlines design strategies to enhance durability and service life, including features such as façade access and systems for condensate capture.

The sixth credit, Building Reuse, presents two options:

1. One point is rewarded if at least 20% of the structural system is reused
2. Two points are rewarded if 40% is reused.

The project must also include a narrative explaining how reuse targets will be achieved, accompanied by a demolition plan. Both the fifth and sixth credits were automatically considered achieved, as they do not depend directly on the materials assessed in the case study.

The seventh credit, Regional Materials, is structured into two options.

1. One point is awarded if 5% of the total material cost is attributed to materials extracted and manufactured within 500 kilometers of the project site
2. Two points are awarded if this threshold is increased to 10%.

The documentation must include the cost of materials, extraction locations, transport distances, and transportation methods. In the case study, four out of twenty materials were identified as regional (Table 4.8), accounting for approximately 25% of the total material cost. As a result, the project earned two points from this credit.

The eighth credit, Recycled Materials, includes three options.

1. Pertains to recycled steel and awards one point if either 50% of all structural steel or 80% of the reinforcement steel in concrete is derived from recycled sources.
2. Involves cement replacement and evaluates concrete mixes based on their GHG emissions. A reference table outlines the thresholds for awarding one or two points based on the performance of the concrete mix.
3. Pertains to recycled aggregates, granting one point if 15% of the total aggregate volume is recycled, and two points if 100% recycled aggregates are used in the base, subbase, or backfill.

In the present case study, none of these criteria were met. The concrete mix exceeded the allowed GHG limits, the steel used contained only 10% recycled content, and no recycled aggregates were included in the project material list. As a result, no points were awarded from this credit.

The ninth credit, Reused or Certified Timber, offers one or two points depending on whether 50% or 70% of the timber used in the project is either reused or certified. Acceptable certifications include Forest Stewardship Council, Programme for the Endorsement of Forest Certification, Canadian Standards Association, Sustainable Forestry Initiative, or Malaysian Timber Certification Scheme. In the case study, the particleboard used was neither reused nor certified by any of the accepted standards, resulting in zero points for this credit.

The final two credits in the Stewarding Materials category are Improved Construction Waste Management and Composting. The former offers one point for diverting 40% of construction or demolition waste, and two points for achieving a 50% diversion rate. This credit requires the provision of separate bins for organic waste in kitchens, gardens, and centralized storage areas, or alternatively, evidence of an on-site composting plan. Both of these credits were assumed to be achieved, as they are not tied directly to material characteristics or certifications.

In conclusion, the case study achieved 10 out of a possible 18 points within the Stewarding Materials category of the Pearl Villa Rating System. This represents a fulfillment rate of approximately 55%.

The final outcomes of the three rating systems are summarized in Table 4.14, which highlights the differences in their approaches to materials and certification requirements. Among the three systems, the highest percentage of achievable points was recorded under the Pearl Rating System. This result may be influenced by the fact that the case study building is located in Saudi Arabia, which could have supported the use of regional materials.

The comparative analysis highlights differences among rating systems but does not yet account for the influence of material selection. The following chapter introduces a sensitivity analysis using both international and local

Supporting Tables for Analysis

Table 4.8 — Sustainability Attributes of Construction Materials Extracted from the Certificates

Feature \ Material Name	Cement	Concrete	Concrete masonry units (CMU)	Steel rebars	Glass	Aluminum	Wood	Porcelain	Ceramic	Polyethylene	Plaster	Gypsum	Polystyrene (EPS)	Fiber board	Bitumen Membrane	Bitumen Paint	Paint	Textured paint	Galvanized iron sheets	Polyvinyl chloride (PVC)
regionally extracted/manufactured	No	No	No	Yes	No	Yes	No	Yes	Yes	No	No	Yes	No	No	No	No	No	No	No	No
reused	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
recycled	No	Yes	No	Yes	No	No	No	Yes	No	Yes	No	No	Yes	No	No	No	No	No	Yes	No
recycled content	-	-	-	10%	-	-	-	100%	-	95%	-	-	20%	-	-	-	-	-	11%	-
renewable	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
biodegradable	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
certified	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
material ingredient disclosure	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No	No
hazardous/toxic materials	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes

Local Materilas used in the Case Study Building

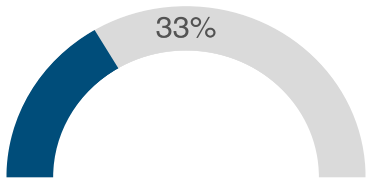
Made by Author using material certification data extracted from manufacturer documentation provided in the submitted PDFs [A1-A19, pg.98].

Table 4.9 — Material Cost Percentages for Credit Compliance

Material Group: Certified Recycled Materials

Value: 160.994 AED

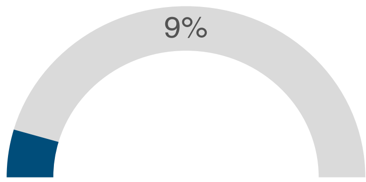
Applicable Credit: LEED Credit 4 & 5



Material Group: Material Ingredient Optimization

Value: 43.189 AED

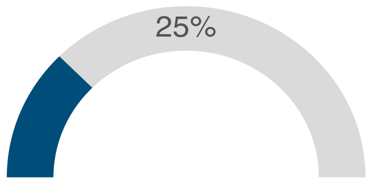
Applicable Credit: LEED Credit 6



Material Group: Regional Materials

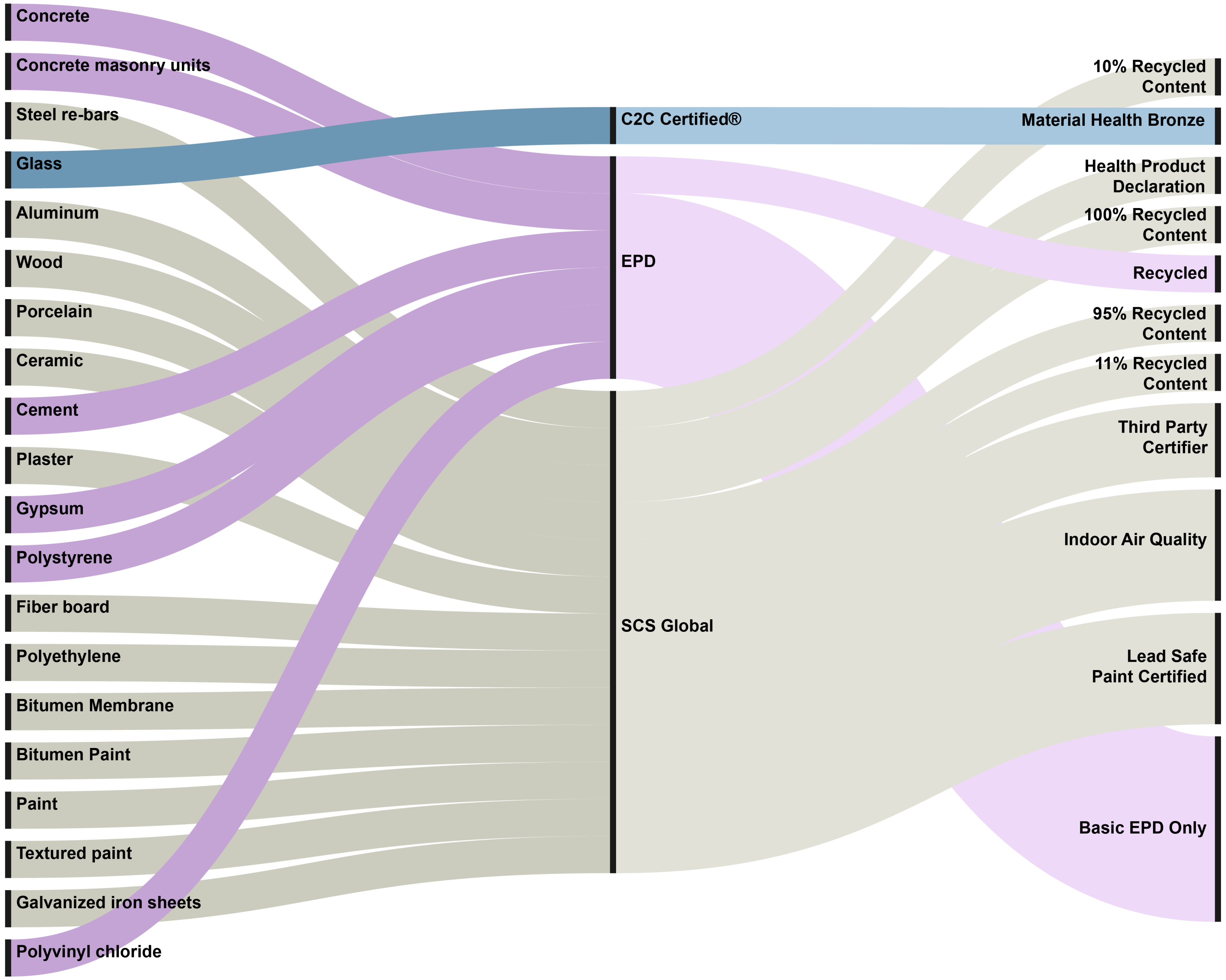
Value: 120.089 AED

Applicable Credit: PRS Credit 7



Made by Author using data from Table 3.3.

Table 4.10 — Certifications of Materials Used in the Case Study Project



Made by Author using material certification data extracted from manufacturer documentation provided in the submitted PDFs. [A1-A19, pg 98]

Breakdown of Material Credits and Achievements of the Systems

LEED

Table 4.11

Credit	Maximum Credit Points	Points Earned
Storage and Collection of Recyclables	R	achieved
Construction and Demolition Waste Management		achieved
Building Life-Cycle Impact Reduction	2-6.	-
Environmental Product Declarations	1-2.	-
Sourcing of Raw Materials	1-2.	1
Material Ingredients	1-2.	-
Construction and Demolition Waste Management	1-2.	2
Total	14	3
Total percentage(%)	13.5	**21%**

Made by Author using LEED v4.1 BD+C credit structure and project-specific evaluation and project case study data.

BREEAM

Table 4.12

Credit	Maximum Credit Points	Points Earned
Life Cycle Impacts	1-6.	1
Responsible Sourcing	4	1
Design for Durability and Resilience	1	1
Material Efficiency	1	1
Total	12	4
Total Percentage(%)	13.5	**33%**

Made by Author using BREEAM International New Construction 2016 criteria and project case study data.

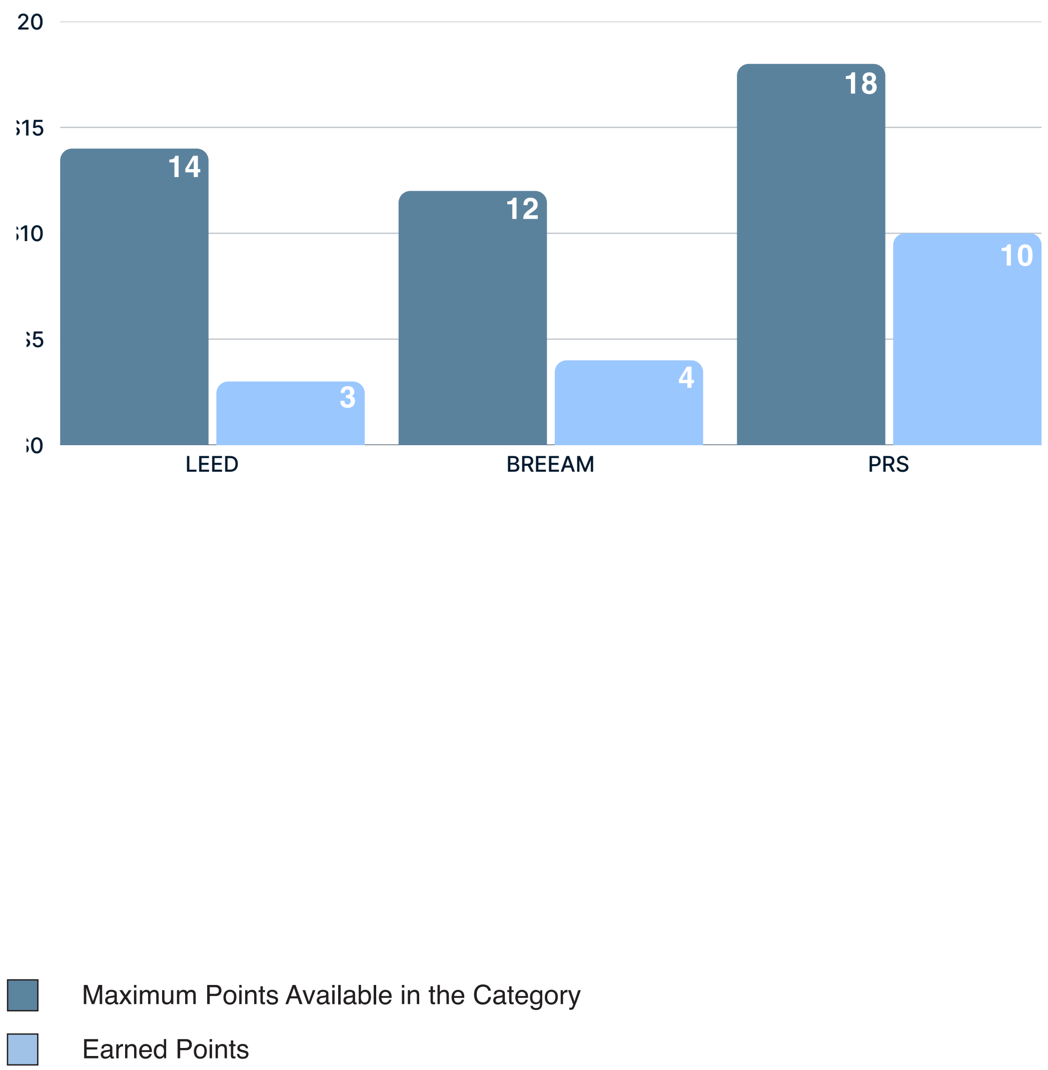
PRS

Table 4.13

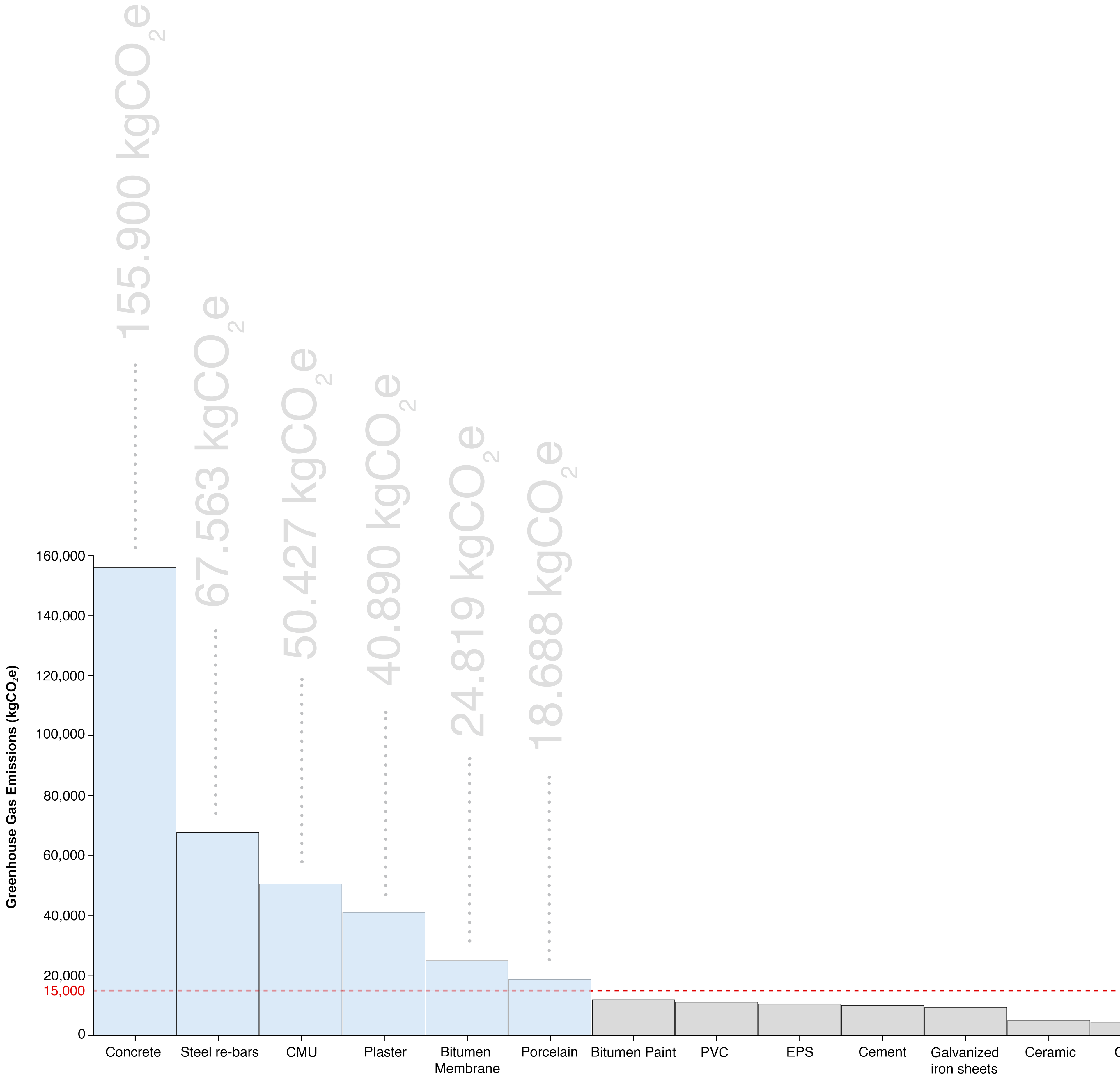
Credits	Maximum Credit Points	Points Earned
Hazardous Materials Elimination	R	achieved
Basic Construction Waste Management		achieved
Storage and Collection of Waste Mnagement		achieved
Non polluting Materials	2	1
Design for Durability	1	1
Building Reuse	2	2
Regional Materials	2	2
Recycled Materials	5	-
Reused or Certified Timber	2	-
Improved Construction Waste Management	2	2
Composting	2	2
Total	18	10
Total Percentage(%)	16%	**55%**

Made by Author using Pearl Villa Rating System: Design & Construction, Version 1.0, April 2010 and project case study data.

Table 4.14 — Summary of Material Points Achieved Across Rating Systems



Made by Author using case study building achievements in LEED, BREEAM, and PRS system's material category.



Chapter 5

5.1 Introduction and Methodology

The purpose of this chapter is to identify the materials that have the greatest influence on the building's sustainability performance and to replace them with alternative options that have lower environmental impacts. Afterwords, to evaluate whether these substitutions can improve the results within the materials category of the three sustainability rating systems. In another words, sensitivity analysis are conducted to assess how the material changes affect the points achieved in each system. This analysis is based on the case study data presented in Table 4.6.

The first step was to identify which materials have the highest impact on the building's overall GHG emissions. Table 5.1 shows how much each building material contributes to the total emissions of the case study. The top six materials, concrete, steel rebars, CMU, plaster, bitumen membrane, and porcelain, account for approximately 81% of the building's total GHG emissions. Therefore, the sensitivity analysis focuses on these six materials out of the total twenty. This targeted approach allows for meaningful reductions to be evaluated while maintaining focus on the most significant contributors to embodied carbon.

Another important point is that the GHG emission factors used in this analysis include only the A1–A3 stages of the material life cycle, which cover raw material extraction, transport to the manufacturer, and the manufacturing processes. These stages are typically used in early-stage carbon assessments and provide a consistent and reliable basis for comparing different materials.

Table 5.1 — Contribution of Materials to Total GHG Emissions

Materials Selected for Sensitivity Analysis (GHG > 15,000 $kgCO_2e$)

Other Case Study Building Materials

GHG Emission Threshold

Made by Author using data from Table 4.6

The methodology involved two main phases:

Phase 1 – International Substitution: Each of the six materials was substituted with lower-impact alternatives sourced from international databases such as the ICE (Inventory of Carbon and Energy) [Institution of Civil Engineers, 2024] and the Structural Carbon Tool (TSCT) [The Structural Carbon Tool Team, 2024]. The goal was to estimate the potential GHG reductions that could be achieved in general, regardless of local availability.

Phase 2 – Local Substitution: The same materials were then replaced with alternatives that are manufactured in the UAE. This step evaluates how regional differences in material sourcing and production, influence emissions and explores the role of local materials in sustainable design strategies.

After conducting the sensitivity analysis, the materials identified in Phase 2 were added to the rest of the materials used in the project, and the comparative analysis described in Chapter 4 was repeated.

5.2 Sensitivity Analysis

Table 5.2 presents the results of the first phase of the analysis. For each of the six selected materials, alternative options were identified using the databases indicated in the table. The alternatives could either be different types of the same material or different materials used for the same purpose, chosen based on their availability in the selected data sources.

The weight and current GHG emissions of each material were taken from Table 4.5 and are highlighted in green, following the same approach as in that table. The new GHG emission factors were then collected from the referenced sources (Table 5.2, "Revised GHG Emissions per kg"), and the total emissions for each material were recalculated by the author (T. 5.2, "Revised GHG Emissions"). The total GHG emissions of the entire building, using the new materials in place of the original ones, are presented in the next column (T. 5.2, "Revised Total GHG Emissions").

The next step involved calculating the reduction in emissions compared to the baseline analysis for each material individually (T. 5.2, "Reduction in GHG Emissions"). After evaluating all six materials, the combination of alternatives with the lowest GHG emissions was selected, and the overall reduction for the entire building was calculated (T. 5.2, "Revised Combined Total GHG Emissions"). The lowest GHG values chosen for each material are highlighted in Table 5.2.

The results indicate a 52% decrease in total GHG emissions for the case study building when only six materials were changed.

The most significant improvement came from replacing conventional concrete with a mix containing 70% blast furnace slag, resulting in a 20.7% reduction. Substitutions for steel and CMUs followed, with a combined reduction of 19.5%.

These findings highlight that structural materials such as concrete and steel offer the greatest opportunity for emissions reduction, due to their high quantities and carbon intensity. However, non-structural elements like plaster and bitumen membranes also contribute to the overall impact and should not be overlooked when making sustainable material choices.

Table 5.3 presents the second phase of the sensitivity analysis, which evaluates the impact of using materials manufactured within the United Arab Emirates. The GHG emission factors for these materials were derived by author from EPD, specific to UAE-based manufacturers [A20-A25, A27-29, pg 108]. Based on these emission factors, the revised GHG emissions were calculated for each material.

In this phase, the scope of material substitution is narrower compared to the first phase, primarily due to the limited availability of local data and EPDs. Nonetheless, the results indicate that replacing conventional materials with locally produced alternatives can lead to significant improvements in environmental performance.

The most notable reductions were again observed in structural materials. Concrete and steel rebars showed the highest individual improvements, each achieving a 13% reduction in GHG emissions. This highlights the importance of targeting high-impact structural components when seeking to reduce a building's carbon footprint.

An unexpected outcome of this analysis is the higher GHG emissions associated with adobe bricks when compared to concrete blocks. Despite adobe being a traditional and widely used material in the vernacular architecture of the UAE, its production process specifically kiln-firing at temperatures ranging from 900°C to 1200°C results in elevated emissions. This finding is based on production data provided by The Red Clay Brick Factory [Diyar Home. (n.d.), A26].

Overall, the implementation of locally manufactured materials led to a 34% reduction in total GHG emissions. This demonstrates the potential environmental benefits of regional sourcing.

Although the emission reduction was lower compared to the international scenario, a 34% improvement was still achieved. This demonstrates that while locally manufactured materials may not always offer the lowest GHG emissions globally, they still present substantial environmental benefits especially when considering additional factors such as regional availability, reduced transportation emissions.

Table 5.2 — International Substitution - GHG Emissions of Alternative Construction Materials

Made by Author using ICE v3.0 and TSCT.

Current Material	New Material	Source	Weight (kg)	Current GHG Emission ($kgCO_2e$)	Revised GHG Emissions per kg ($kgCO_2e/kg$)	Revised GHG Emissions ($kgCO_2e$)	Revised Total GHG Emissions ($kgCO_2e$)	Reduction in GHG Emissions (%)	Revised Combined Total GHG Emissions ($kgCO_2e$)	Overall Reduction in GHG Emissions (%)
Concrete	Concrete with CEM 1, RC 32/40	ICE	1,012,340	155,900	0.138	139703	424,700	3.7	212,073	52
	Portland Limestone Concrete (14% Limstone)	ICE			0.078	78963	363,960	17.5		
	Concrete with 35% Natural Pozzolanic ash	ICE			0.108	109333	394,330	10.6		
	Concrete with 40% of cement is replainced with fly ash	ICE			0.101	102246	387,243	12.2		
	Concrete with 70% of cement is replaced with Blast Furnace Slag	ICE			0.064	64790	349,787	20.7		
CMU	High density solid Concrete blocks	ICE	327,450	50427	0.085	27833.25	418303	5.1		
	Hollowcore Concrete Blocks	ICE			0.0852	27899	418369	5.1		
	Cellular Concrete Blocks	ICE			0.0854	27964	418434	5.1		
	Compressed stabilised earth block - 5% cement	TSCT			0.043	14080	404550	8.2		
	Rammed earth, Cement stabilised - 5%	TSCT			0.068	22267	412737	6.4		
	Rammed earth,Lime stabilised 2%	TSCT			0.028	9169	399639	9.4		
	Brickwork - Unfired clay brick	TSCT			0.076	24886	415356	5.8		
Steel Rebars	Steel Rebars	ICE	32,173	67563	1.72	55338	428672	2.8		
		TSCT			0.72	23165	396499	10.1		
		ICE			1.61	51799	425133	3.6		
Plaster	Plaster, Gypsum	ICE	126,900	40890	0.164	20812	420819	4.6		
	Plasterboard	ICE			0.238	30202	430209	2.4		
		ICE			0.322	40862	440869	0.0		
					0.278	35278	435285	1.3		
Bitumen Membrane	High-Density Polyethylene	ICE	3878	24819	1.93	7485	423563	3.9		
	Bitumen Membrane	ICE			0.163	632	416710	5.5		
Porcelain	Porcelain	ICE	14,375	18688	0.758	10896	433105	1.8		

- Data Extracted from the Case Study Article
- Data Calculated by the Author
- Chosen Alternative Material for Analysis
- Percentage of Impact Reduction After Choosing Alternative Materilas

Table 5.3 — Local Substitution - GHG Emissions of Alternative Construction Materials

Current Material	New Material	Manufacturer	Weight (kg)	Current GHG Emission ($kgCO_2e$)	Revised GHG Emissions per kg ($kgCO_2e/kg$)	Revised GHG Emissions ($kgCO_2e$)	Revised Total GHG Emissions ($kgCO_2e$)	Reduction in GHG Emissions (%)	Revised Combined Total GHG Emissions ($kgCO_2e$)	Overall Reduction in GHG Emissions (%)
Concrete	Concrete	Emirates Beton	1,012,340	155,900	0.098	99209	384,206	12.9	290,507	34
CMU	Adobe	The Red Clay Brick Factory	327,450	50427	0.24	78588	469058	-6.4		
	Concrete Hollow Block	EMCON			0.125	40931	431401.25	2.2		
Steel Rebars	Rebar	Emirates Steel Industries	32,173	67563	0.551	17727	391061	11.3		
					0.315	10134	383468	13.0		
Plaster	Plaster	DUBAI PLASTER	126,900	40890	0.237	30075	430082	2.5		
Bitumen Membrane	Bitumen Membrane	Polybit UAE	3878	24819	0.229	888	416966	5.4		
	Polycoat				0.789	3060	419138	4.9		
Porcelain	Porcelain	RAK Ceramics	14375	18688	0.555	7971	430180	2.4		

Made by Author using EPDs of UAE-based manufacturers [A20-A25, A27-29 pg.108]

5.3 Re-Evaluation of Rating Results

LEED

For the comparison of rating systems with the new range of substituted materials, Table 5.3 (Local Substitution) is used, as the materials used in it have all the necessary certifications for evaluating credit requirements. The analysis begins again with the LEED rating system. Table 5.4 summarizes all the certification-related information that supports the re-evaluation of point allocation, while the materials that were changed are highlighted. Table 5.7 identifies the specific credits within the material category that could potentially be affected by these changes (highlighted in blue), therefore, only these credits are discussed in this section.

In this scenario, first credit that will be dicsussed is the Building Life-Cycle Impact Reduction, that showed improved potential for achievement. It requires a mandatory of 10% reduction from the baseline building in 3 impact categories from this list,

- global warming potential (greenhouse gases), in kg CO_2e
- depletion of the stratospheric ozone layer, in kg CFC-11
- acidification of land and water sources, in moles H^+ or kg SO_2
- eutrophication, in kg nitrogen or kg phosphate
- formation of tropospheric ozone, in kg NO_x, kg O_3 eq, or kg ethene
- depletion of nonrenewable energy resources, in MJ.

Based on the updated building GHG emissions presented in Table 5.3, a 5% reduction was achieved. Which was not enought to fullfill the requirments of the credit. So, the credit could not be attained.

The Environmental Product Declarations credit also showed improved potential for achievement. Under Option 2, the project earned one point. The total cost of the nine materials with lower GHG emissions compared to the baseline building accounted for 50% of the total material cost, which meets the exact requirement for this option. These materials, plaster, steel, bitumen membrane, aluminum, cement, and porcelain, performed better than those in the baseline scenario and other 3 materials met 3rd requirements under Option 2, which include using products certified through USGBC-approved programs.

The Sourcing of Raw Materials credit remained unchanged, maintaining 1 point due to the continued use of materials with recycled content representing at least 25% of total cost. Although the list of materials with recycled content has changed, their combined cost still meets the 25%

representing at least 25% of total cost. Although the list of materials with recycled content has changed, their combined cost still meets the 25%
threshold (Table 5.5), and no additional improvements were possible for this credit.

Finally, for the Material Ingredients credit, the available material certifications were not compatible with Options 1 and 2. The only applicable path was Option 3, which requires at least 25% (by cost) of materials to come from manufacturers with transparent, third-party-verified programs ensuring safe and environmentally responsible chemical management throughout the supply chain. The provided certifications did not include this type of information; therefore, this credit was not achieved.

In conclusion, after introducing new materials with improved environmental performance, the project earned one additional point in the LEED materials category. As a result, the project now achieves a total of four points, corresponding to 28% of the total available points in this category. Although some credit thresholds were only partially met, the analysis indicates a clear improvement in sustainability performance compared to the first scenario.

BREEAM

In the case of BREEAM, two credits were identified as potentially affected by the material substitutions, as highlighted in Table 5.8.

The first is the Life Cycle Impact credit, which evaluates the environmental performance of the building using the Mat 01 calculator. However, this tool was not accessible for this study, and therefore the exact score could not be determined. In the updated scenario, the total GHG emissions were reduced by 34%, indicating a lower overall environmental impact compared to the previous case. Consequently, it can be assumed that if the Mat 01 calculator had been available, the project would have achieved a higher score for this credit.

The second credit is Responsible Sourcing, which also requires a specific assessment tool that was not available for this analysis. As a result, no change could be recorded in the achieved points for this credit.

The BREEAM material category results remained the same after substituting the six most impactful materials, even though environmental performance improved in quantitative terms.

Supporting Tables for Analysis

Table 5.4 — Sustainability Attributes of Construction Materials Extracted from the Certificates

Feature \ Material Name	Cement	Concrete	Concrete masonry units (CMU)	Steel rebars	Glass	Aluminum	Wood	Porcelain	Ceramic	Polyethylene	Plaster	Gypsum	Polystyrene (EPS)	Fiber board	Bitumen Membrane	Bitumen Paint	Paint	Textured paint	Galvanized iron sheets	Polyvinyl chloride (PVC)
regionally extracted/manufactured	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No	Yes	No	No	No	No	No
reused	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
recycled	No	No	No	Yes	No	No	No	No	No	Yes	No	No	Yes	No	No	No	No	No	Yes	No
recycled content	-	-	-	3%	-	-	-	-	-	95%	-	-	20%	-	-	-	-	-	11%	-
renewable	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
biodegradable	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
certified	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
material ingredient disclosure	Yes	No	No	Yes	No	Yes	No	Yes	No	No	Yes	No	No	No	Yes	No	No	No	No	No
hazardous/toxic materials	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes

Local Materials Used in the Initial Analysis

New Local Materials Introduced in the Re-Evaluation

Local Materials Replaced Between Analyses

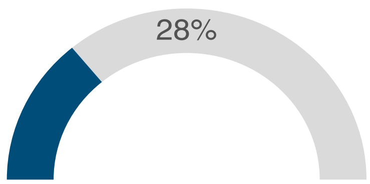
Made by Author using material certification data extracted from manufacturer documentation provided in the submitted PDFs [A20-A30, pg.108].

Table 5.5 — Material Cost Percentages for Credit Compliance

Material Group: Certified Recycled Materials

Value: 123.169 AED

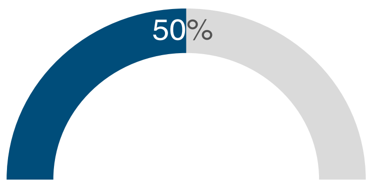
Applicable Credit: LEED Credit 4 & 5



Material Group: Reduced Impact Materials

Value: 240.393 AED

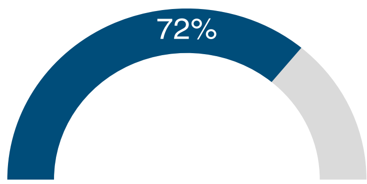
Applicable Credit: LEED Credit 5



Material Group: Regional Materials

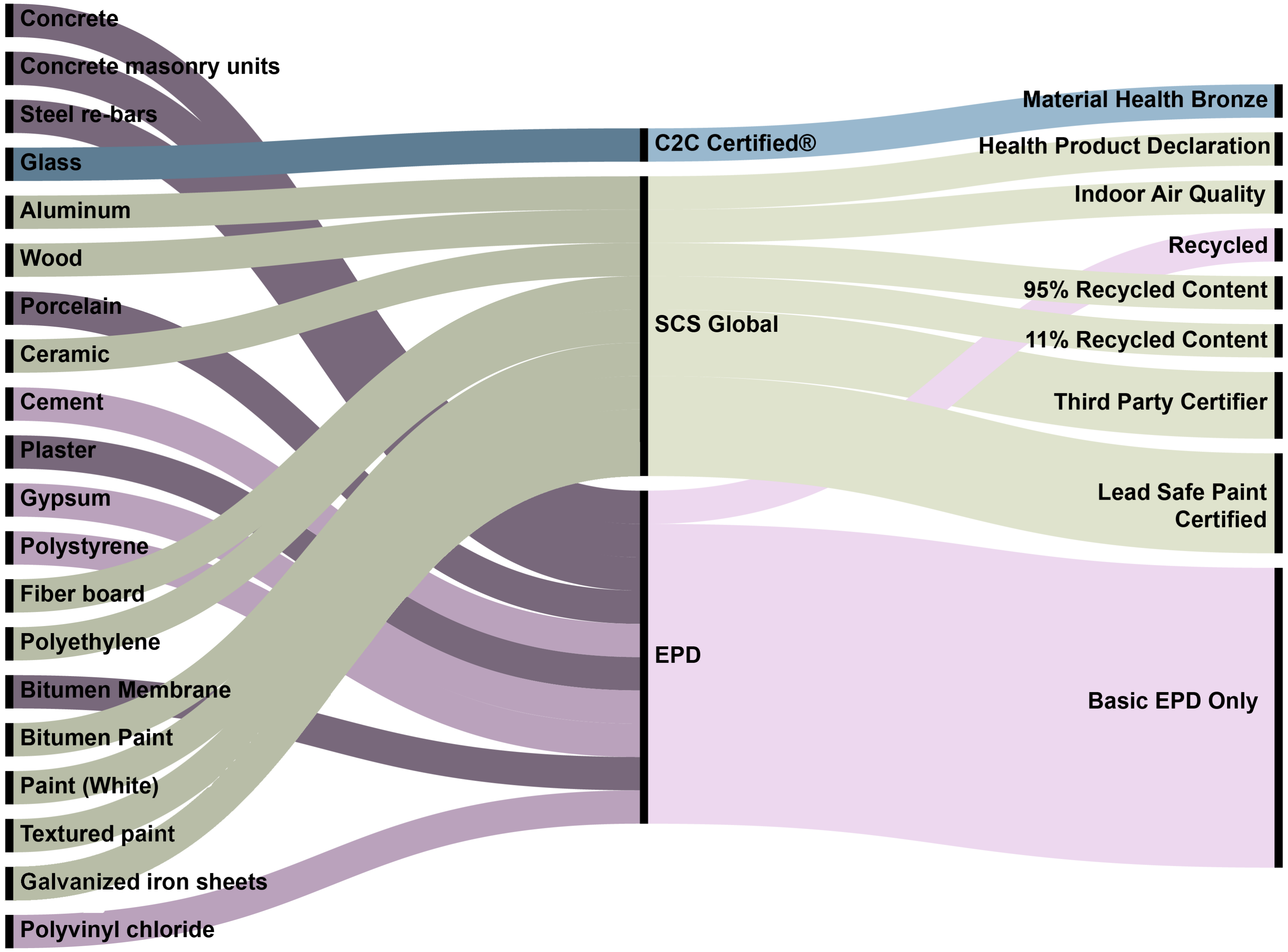
Value: 344.559 AED

Applicable Credit: PRS Credit 7



Made by Author using data from Table 4.6

Table 5.6 — Certifications of Materials Used in the Re-evaluation of the Case Study



Made by Author using material certification data extracted from manufacturer documentation provided in the submitted PDFs. [A1-A30, pg.98]

System Outcomes After Re-evaluation

Re-Evaluation of Material Credits and Achievements of the Sytems

LEED

Table 5.7

Credit	Maximum Credit Points	Points Earned
Storage and Collection of Recyclables	R	achieved
Construction and Demolition Waste Management		achieved
Building Life-Cycle Impact Reduction	2-6.	-
Environmental Product Declarations	1-2.	1
Sourcing of Raw Materials	1-2.	1
Material Ingredients	1-2.	-
Construction and Demolition Waste Management	1-2.	2
Total	14	4
Total percentage(%)	13.5	**28%**

Credits identified as candidates for revision during re-evaluation

Credits modified during re-evaluation

Made by Author using LEED v4.1 BD+C credit structure and project-specific evaluation.

BREEAM

Table 5.8

Credit	Maximum Credit Points	Points Earned
Life Cycle Impacts	1-6.	1
Responsible Sourcing	4	1
Design for Durability and Resilience	1	1
Material Efficiency	1	1
Total	12	4
Total Percentage(%)	13.5	33%

Made by Author using BREEAM International New Construction 2016 criteria and project case study data.

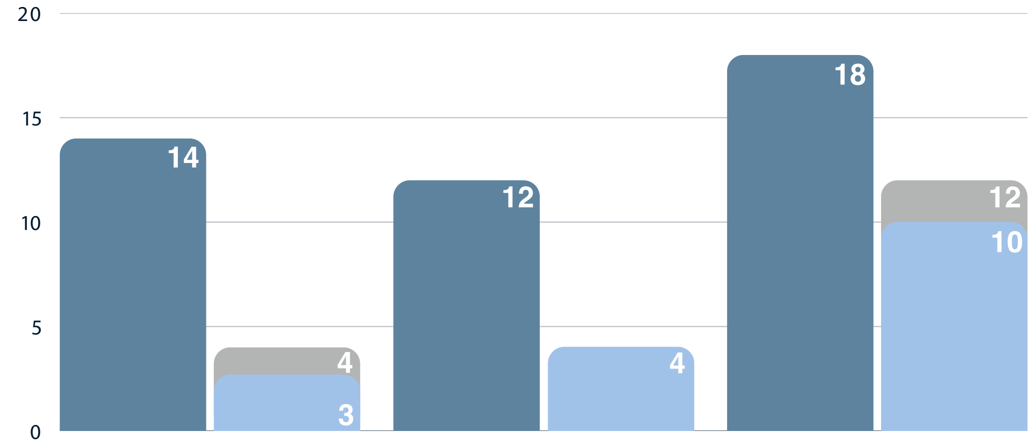
PRS

Table 5.9

Credits	Maximum Credit Points	Points Earned
Hazardous Materials Elimination	R	achieved
Basic Construction Waste Management		achieved
Storage and Collection of Waste Mnagement		achieved
Non polluting Materials	2	1
Design for Durability	1	1
Building Reuse	2	2
Regional Materials	2	2
Recycled Materials	5	2
Reused or Certified Timber	2	-
Improved Construction Waste Management	2	2
Composting	2	2
Total	18	12
Total Percentage(%)	16%	**66%**

Made by Author using Pearl Villa Rating System: Design & Construction, Version 1.0, April 2010.

Table 5.10 — Summary of Material Points Achieved Across Rating Systems



Maximum Points Available in the Category

Earned Points in the Initial Analysis

Earned Points After Re-evaluation

Made by Author using case study building achievements in LEED, BREEAM, and PRS system's material category.

PRS

Proceeding to the PRS, Table 5.9 highlights in blue the credits that could potentially be affected by the material substitutions.

The first credit, Hazardous Materials Elimination, remains satisfied as in the previous scenario, with no change in compliance.

The second credit, Non-Polluting Materials, also remains unchanged, as no thermal insulation materials were modified during the sensitivity analysis.

The third credit, Regional Materials, shows a significant improvement. In the initial scenario, it had already achieved the maximum available points with 25% of the total material cost sourced regionally. After the sensitivity analysis, this percentage increased to approximately 72% (Tbale 5.5) of the total material cost, further reinforcing the project's compliance with this credit. The Recycled Materials credit, which previously did not earn any points, now achieves 2 point under Option 2. This option requires that the GHG emissions of the concrete fall within the range specified in the PRS manual, which promotes the use of cement containing supplementary materials such as fly ash, ground granulated blast furnace slag, or silica fumes, as well as the increased use of aggregates or admixtures. The new concrete used in the sensitivity analysis is meeting the required GHG emission range for both cast-in-place and precast concrete.

The final credit, Reused and Certified Timber, remains unchanged, as the particleboard used in the previous scenario was not modified.

Overall, the PRS evaluation shows an improvement of two additional points, bringing the total achievement in the material category to 66%.

5.4 Summary and Discussion of Findings

Among the three systems, two showed changes after the introduction of new materials. The local UAE rating system and LEED demonstrated a slight improvement, while the BREEAM assessment could not be fully completed due to missing data required for a comprehensive evaluation.

The difference in the number of points achieved among the systems can be explained by the scope of their material-related credits. Both LEED and PRS include credits related to construction waste management, which, although relevant to sustainability, do not directly assess the environmental performance of materials. In this case, LEED earned 2 points and PRS earned 4 points for waste management alone, meaning that around 14–22% of total material points were linked to waste practices rather than material selection. Another difference lies in how the systems address durability. Both BREEAM and PRS allocate one point for this credit, but their approaches differ. BREEAM focuses on preventing damage and material degradation, an important aspect in the UAE context, while PRS evaluates durability through expected service life and maintenance planning.

In PRS, the materials category is divided into more specific credits, such as recycled, regional, reused, and non-polluting materials, while LEED and BREEAM combine these aspects under broader criteria. This structure allows PRS to achieve a higher number of individual credits compared to LEED and BREEAM. Conversely, LEED and BREEAM include separate credits for life-cycle impact assessment, which carry higher point values and significantly influence the final score. PRS, however, does not include a distinct life-cycle or GWP assessment credit, referring to global warming potential only indirectly in specific material categories.

For example, looking more closely to the statistics of the types of projects using each system, LEED certification in 2020 was mainly achieved by office, healthcare, higher education, and K-12 buildings, which together represented over 60% of all certified projects [U.S. Green Building Council [USGBC], 2021, March]. However, by 2022, the distribution had changed: approximately 50% of certifications were for residential buildings, 27% for offices, 13% for retail, and 4% for higher education [U.S. Green Building Council [USGBC], 2021, June]. This shows a noticeable shift, with residential projects increasing and becoming comparable in number to commercial buildings.

For BREEAM, the distribution is relatively similar. Between 1990 and 2012, about 52% of certified buildings were domestic, while 42% were non-domestic or commercial (BRE Global, 2014). This again shows that roughly half of all certified buildings under BREEAM serve a domestic function.

From these observations, it can be concluded that both LEED and BREEAM are applied across a wide range of building types, but residential projects represent a significant portion of all certifications. This suggests that sustainability considerations are integrated, not only in large commercial or institutional projects but also in residential developments, which make up a major part of new construction worldwide.

CONCLUSION

This thesis examined three sustainability rating systems, LEED, BREEAM, and the PRS to understand how each evaluates material sustainability within the context of the United Arab Emirates. The research aimed to determine which of these systems is most appropriate for assessing ordinary residential buildings constructed in the country.

To achieve this aim, two types of analysis were conducted. The first was a comparative analysis of the material categories of the three rating systems, applied to an existing case study building. The second was a sensitivity analysis, which involved replacing high-impact materials with locally available, lower-impact alternatives. The comparative analysis was then repeated using the modified material list to assess how the inclusion of local materials affected the results. These analyses made it possible to understand how materials are treated in each system through a real example that reflects the practical challenges faced by the built environment in the UAE.

The results revealed that, although PRS is not as technically developed as LEED or BREEAM, it achieved the highest score when evaluating the material sustainability of the case study building. This indicates that the UAE's local sustainability rating system is the most suitable for assessing material performance in the country's construction context. The sensitivity analysis further showed that while local material substitutions did not result in the greatest overall reduction in emissions, as it could, however, PRS again obtained the highest score. This outcome demonstrates that locally manufactured building materials can contribute effectively to sustainable construction and can help projects perform better under PRS. Therefore, the relationship between local building material production, the national sustainability rating system, and sustainable building practices in the UAE are complementing each other.

These findings highlight that sustainability rating systems designed for specific regional conditions can lead to more accurate and effective environmental outcomes. Systems tailored for countries sharing similar climatic and material challenges can better address local environmental issues and provide clearer pathways toward sustainable development. The comparative analysis confirmed that international systems such as LEED and BREEAM, which are not designed for the Gulf's environmental conditions or material practices, achieved lower results. Their structures and evaluation methods differ, reflecting global targets rather than regional priorities.

Future research could focus on improving the material category of the Pearl Rating System by incorporating local life-cycle data and promoting the use of Environmental Product Declarations among building material manufacturers in the UAE. In addition, PRS could be further enhanced by placing greater emphasis on the specific environmental challenges of the country and integration of cultural continuity, which could help strengthen the link between contemporary architecture and its traditional roots and make the system more effective and contextually relevant.

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ANNEX

Material Certifications

A1

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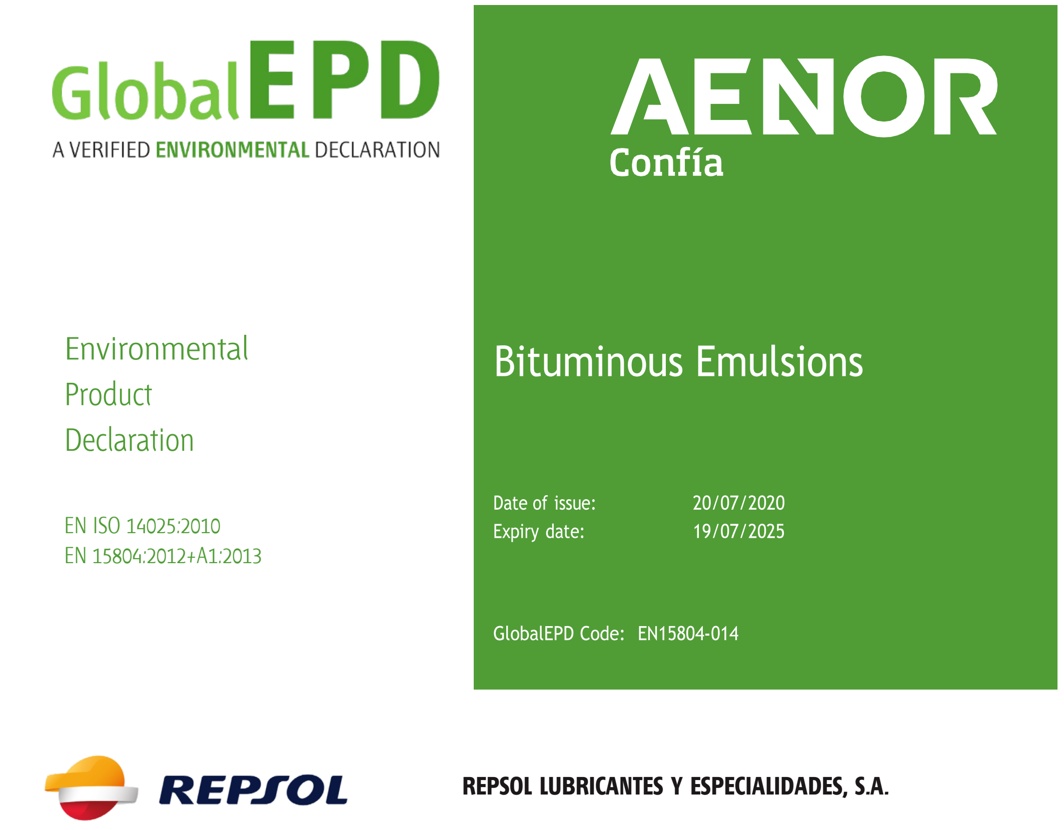
A2



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A3

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A4

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A5

Environmental Product Declaration

EPD® THE INTERNATIONAL EPD® SYSTEM

ECO PLATFORM EPD VERIFIED

In accordance with ISO 14025:2006 and EN 15804:2012+A2:2019/AC:2021 for:

Concrete blocks

from

CITY STONE DESIGN s.r.o.

EPD of multiple sites, based on average results

CITYSTONEDESIGN®

Programme:	The International EPD® System, www.environdec.com
Programme operator:	EPD International AB
EPD registration number:	S-P-13340
Publication date:	2024-04-12
Valid until:	2029-04-11

An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com

City Stone Design s.r.o. (2024). Environmental Product Declaration – Concrete blocks (S-P-13340). The International EPD® System. https://www.environdec.com

A6

Environmental Product Declaration

Paros

Programme The International EPD® System
Programme operator EPD International AB
EPD registration number S-P-04984
Publication date 2021-12-06
Revision date 2023-03-03
Valid until 2026-12-05

C16/20 - 16mm	C16/20 - 31.5mm	C20/25 - 16mm
C20/25 - 31.5mm	C25/30 - 16mm	C25/30 - 31.5mm
C25/30 - 31.5mm SEASIDE	C25/30 - 31.5mm WATERPROOF	C30/37 - 16mm
C30/37 - 31.5mm	C30/37 - 31.5mm WATERPROOF	C35/45 - 31.5mm
C35/45 - 31.5mm		

in accordance with ISO 14025 and EN 15804:2012+A2:2019

EPD® THE INTERNATIONAL EPD® SYSTEM

ECO PLATFORM EPD VERIFIED

LAFARGE

HERACLES Group (Lafarge). (2021). Environmental Product Declaration – Ready mix concrete, Paros (S-P-04984). The International EPD® System. https://www.environdec.com

Owens Corning. (2025). Environmental Product Declaration – FOAMULAR® NGX® XPS Insulation (SCS-EPD-09753). SCS Global Services. https://www.scsglobalservices.com/certified-green-products-guide

A7

Environmental Product Declaration | Owens Corning | FOAMULAR® NGX® XPS Insulation

OWENS CORNING® | VERIFIED by SCS Global Services ENVIRONMENTAL PRODUCT DECLARATION BASED ON LCA

Declaration Owner
Owens Corning
One Owens Corning Parkway, Toledo, OH, USA
1-800-GET-PINK (1-800-438-7465)
www.owenscorning.com

Products
FOAMULAR® NGX® XPS Insulation

Functional Unit
1 m² of insulation with a thickness required for an average thermal resistance RSI = 1 m²K/W maintained for 75 years

EPD Number and Period of Validity
SCS-EPD-09753
EPD Valid January 10, 2024 through January 9, 2029
Version Date: July 1, 2025

Product Category Rule
PCR Guidance for Building-Related Products and Services Part A: Life Cycle Assessment Calculation Rules and Report Requirements. Version 4.0. Mar. 2022

PCR Guidance for Building-Related Products and Services Part B: Building Envelope Thermal Insulation EPD Requirements. Version 3.0. April 2023

Program Operator
SCS Global Services
2000 Powell Street, Ste. 600, Emeryville, CA 94608
+1.510.452.8000 | www.SCSglobalServices.com

SCSglobal SERVICES

Shandong Xingang Group. (2025). CARB Phase 2 certification – Medium Density Fiberboard (MDF, 8.1–18 mm). SCS Global Services. https://www.scsglobalservices.com/certified-green-products-guide

A8

SCS Global Services does hereby certify that an independent evaluation has been conducted on behalf of:

Shandong Xingang Group

Yitang Town, Lanshan District, Linyi City, Shandong 276000, China
Mill Number: SCS-09-0093

For the following Product and Thickness range:

Medium Density Fiberboard (MDF): 8.1 - 18 mm

In compliance with the CARB Composite Wood ATCM, California Code of Regulations, Sections 93120-93120.12, Title 17, products at the specified site meet the necessary qualifications to be certified for the following claim.
Third Party Certifier: TPC-09

CERTIFIED CARB ATCM 93120 SCS GLOBAL SERVICES – CalCompliant Medium Density Fiberboard

calCOMPliant™- Phase 2

Valid From: January 04, 2025 to January 04, 2026
Certificate # SCS-CARB-001004

SCS Global Services is a California Air Resources Board approved Third Party Certifier for compliance with the Composite Wood ATCM, California Code of Regulations, Sections 93120-93120.12, Title 17. Please verify the source and validity of this certificate by visiting the SCS Green Products Guide, http://www.scsglobalservices.com/certified-green-products-guide.

SCSglobal SERVICES

Diana Kirsanova Phillips, Chief Assurance Officer, SCS Global Services

A9

material health

CERTIFIED cradle to cradle c2ccertified.org

Sisecam Flat Glass Italy SRL

VIA J. LINUSSIO, 2, SAN GIORGIO DI NOGARO, Italy

has successfully achieved

C2C Certified® Material Health Bronze

for the product(s) under the name:

Float glass & Laminated glass

Certification Number
11799

Standard Version
4.1

Achievement Level
Bronze

Effective Date
26 May 2025

Expiration Date
25 May 2028

Lead Assessment Body
EPEA GmbH - Part of Drees & Sommer

Products Covered
Please see the List of Certified Products (available on the Cradle to Cradle Certified Product Registry) for all products included in this certification

Elwyn Grainger-Jones
Executive Director
Cradle to Cradle Products Innovation Institute

Phases and Processes considered in the Chemical Toxicity Assessment
Manufacturing; Professional use; Use; Intended end of use: recycling; Unintended end of use: landfilling.

PRODUCT OPTIMIZATION SUMMARY

- [x] Compliant with Leading Chemical Regulations
- [x] Organohalogen substances of special concern and functionally-related non-halogenated classes of equivalent concern are below allowable thresholds (exemptions apply)
- [ ] No exposure to EU CLP Category 1 & 2 Carcinogens, Mutagens and Reproductive toxicants or Substances of Very High Concern; Carbon-bonded halogens are <1% of each material (exemptions apply)
- [ ] Meets VOC emissions testing requirements
- [ ] Meets VOC content requirements
- [ ] Product is optimized for material health (no grey or x-assessed chemicals)
- [ ] Process chemicals have been identified and none are grey or x-assessed
- [ ] Actions taken to reduce and eliminate emissions of hazardous chemicals in the product's supply chain

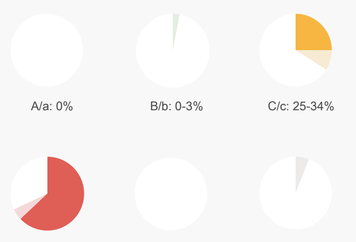
PERCENTAGE ASSESSED

94-100%

Method:
Weighted average of fully and partially assessed materials by weight

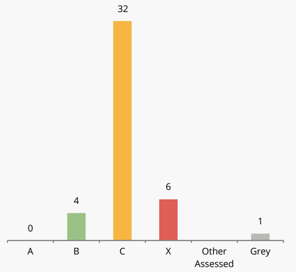
Inventory threshold for chemicals in each material = 100 ppm

ASSESSMENT RATINGS



% HOMOGENEOUS MATERIALS

PRODUCT OPTIMIZATION



43 HOMOGENEOUS MATERIALS

Note: Other assessed includes recycled content that has passed the required analytical tests, Externally Managed Components (EMCs) and/or C2C Certified inputs.

See the Cradle to Cradle Certified Product Registry at www.c2ccertified.org for additional details.
Use of the certification marks is subject to the terms and conditions of the C2CPII Certification Agreement and Trademark Use Guidelines.

Amsterdam, The Netherlands | San Francisco, California, USA
Cradle to Cradle Certified is a registered trademark of the Cradle to Cradle Products Innovation Institute.

cradle to cradle products innovation INSTITUTE

Şişecam Flat Glass Italy SRL. (2025). C2C Certified® Material Health – Float glass & laminated glass (Certification No. 11799). Cradle to Cradle Products Innovation Institute. https://www.c2ccertified.org

A10

ENVIRONMENTAL PRODUCT DECLARATION

USG ME GYPSUM BOARD

SKYROCK & SHEETROCK GYPSUM BOARD REGULAR
FACTORY OF USG MIDDLE EAST

Regular Gypsum Board has a noncombustible core suitable for use on interior walls and ceilings.

USG

Sustainable practices have naturally been an inherent part of our business at Factory of USG Middle East. They help shape the innovative products that become the homes where we live, the buildings where we work and the arenas where we play.

From the product formulations we choose, to the processes we employ, Factory of USG Middle East is committed to designing, manufacturing, and distributing products that minimize overall environmental impacts and contribute toward a healthier living space.

We believe that transparency of product information is essential to our stakeholders and EPDs are the next step toward an even more transparent Factory of USG Middle East.

USG ME's gypsum boards listed in this UL Environment Certified Document provides Life Cycle Assessment (LCA), LCA Impact Measures, Product Composition, Material Definitions, Manufacturing Process, Product Performance Attributes and Product Application.

USG Middle East Ltd. (2022). Environmental Product Declaration – Skyrock & Sheetrock Gypsum Board Regular (Declaration No. 4789313705.107.1). UL Environment. https://spot.ul.com

A11

CERTIFICATE OF ACHIEVEMENT

CERTIFIED RECYCLED CONTENT® SCS GLOBAL SERVICES

MINIMUM 11% RECYCLED CONTENT
POST-CONSUMER
PRE-CONSUMER

SCS Global Services does hereby attest that an independent assessment was conducted on behalf of:

Baosteel Zhanjiang Iron & Steel Co., Ltd.

No.18, Daodong Avenue, Dongjian Street Office, Zhanjiang Economic and Technological Development Zone, Zhanjiang, Guangdong, China

For the following Products:
Metals: **Hot galvanized steel strip-DS11**

Certified by SCS Global Services qualifying for the following claim:
Minimum 11% Recycled Steel Content, a mix of Post-Consumer and Pre-Consumer Recycled Material

Conforms to SCS Recycled Content Standard V8-0. The material quantification and mass balance calculations are completed on a dry weight basis.

SCSglobal SERVICES
SCS Global Services, 2000 Powell Street, Suite 600
Emeryville, CA 94608 USA

Certificate Number: **SCS-RC-08521**
Valid From: **December 19, 2024**
Valid To: **December 18, 2025**

Diana Kirsanova Phillips, Chief Assurance Officer,
SCS Global Services

Baosteel Zhanjiang Iron & Steel Co., Ltd. (2024). Recycled Content Certification – Hot Galvanized Steel Strip (SCS-RC-08521). SCS Global Services. https://www.scsglobalservices.com/certified-green-products-guide

A12

SCS Global Services does hereby certify that an independent assessment has been conducted on behalf of:

MAPEI Corp.

1144 E. Newport Center Drive, Deerfield Beach, Florida 33442, United States

For the following product(s):

See Addendum

The product(s) meet(s) all of the necessary qualifications to be certified for the following claim(s):

Indoor Advantage™ Gold

Indoor Air Quality Certified to SCS-105 v4.2-2023

Conforms to the CDPH/EHLB Standard Method (CA 01350) v1.2-2017 for the private office, school classroom, and single-family residence parameters[1].

[1] Modeled as Flooring

Measured Concentration of Total Volatile Organic Compounds (TVOC): Less than/equal to 0.5 mg/m3 (in compliance with CDPH/EHLB Standard Method v1.2-2107)

INDOOR ADVANTAGE GOLD BUILDING MATERIALS

ANSI National Accreditation Board ACCREDITED ISO/IEC 17065 PRODUCT CERTIFICATION BODY

Registration # SCS-IAQ-06774
Valid from: March 23, 2025 to March 22, 2026

Diana Kirsanova Phillips, Chief Assurance Officer, SCS Global Services

MAPEI Corp. (2025). Indoor Advantage™ Gold Certification – Mapeheat and Mapeguard Systems (SCS-IAQ-06774). SCS Global Services. https://www.scsglobalservices.com/certified-green-products-guide

A13

SCS Global Services does hereby certify that an independent assessment has been conducted on behalf of:

Asian Coatings Phils., Inc.

48 Amang Rodriguez Brgy Santolan, Pasig City, Philippines

For the following product(s):

Paints and Coating Brands:
Welcoat

The product(s) meet(s) all of the necessary qualifications to be certified for the following claim(s):

LEAD SAFE PAINT CERTIFIED

Conforms to the Lead Safe Paint Certification Standard, version 2.0, March 2016 and Lead Safe Paint Certification Requirements, Version 2.0, March 2015. The concentration of lead is less than 90 ppm on a dry weight basis.

www.leadsafepaint.org

Registration # SCS-LSP-09659
Valid from: December 13, 2023 to December 13, 2026

Nicole Munoz, Vice President
SCS Global Services
2000 Powell Street, Ste. 600, Emeryville, CA 94608 USA

Asian Coatings Phils., Inc. (2023). Lead Safe Paint® Certification – Welcoat Paints (SCS-LSP-09659). SCS Global Services. https://www.scsglobalservices.com/certified-green-products-guide

Designtex. (2024). Indoor Advantage™ Gold Certification – Wallcovering and Plaster Finishes (SCS-IAQ-03697). SCS Global Services. https://www.scsglobalservices.com/certified-green-products-guide

A14

SCS Global Services does hereby certify that an independent assessment has been conducted on behalf of:

Designtex

14 Industrial Way, Portland, Maine 04103, United States

For the following product(s):

See Addendum

The product(s) meet(s) all of the necessary qualifications to be certified for the following claim(s):

Indoor Advantage™ Gold - Building Materials

Indoor Air Quality Certified to SCS-105 v4.2-2023

Conforms to CDPH/EHLB Standard Method (CA 01350) v1.2-2017 (effective January 2017) for the school classroom[1] and private office[1], and single-family residence scenarios.

[1] Modeled as Wallcovering

Measured Concentration of Total Volatile Organic Compounds (TVOC): Less than/equal to 0.5 mg/m3 (in compliance with CDPH/EHLB Standard Method v1.2-2017)

INDOOR ADVANTAGE GOLD BUILDING MATERIALS

ANSI National Accreditation Board ACCREDITED ISO/IEC 17065 PRODUCT CERTIFICATION BODY

Registration # SCS-IAQ-03697
Valid from: October 09, 2024 to October 08, 2025

Diana Kirsanova Phillips,
Chief of Staff to the CEO/Chief Assurance Officer

Novolex. (2024). Recycled Content Certification – Polyethylene Mailer Bags (SCS-RC-20305). SCS Global Services. https://www.scsglobalservices.com/certified-green-products-guide

A15

CERTIFICATE OF ACHIEVEMENT

SCS Global Services does hereby attest that an independent assessment was conducted on behalf of:

Novolex

1009 Rock Avenue Yakima, Washington 98902 United States

For the following Products:
Plastics - Bags and Liners: **95% recycled content polyethylene mailer bags**

Certified by SCS Global Services qualifying for the following claim:
Minimum of 95% Recycled Content with at least 50% Post-Consumer and Balance 45% Pre-Consumer Polyethylene Content.

Conforms to SCS Recycled Content Standard V7-0. The material quantification and mass-balance calculations are completed on a dry-weight basis.

MINIMUM 95% RECYCLED CONTENT
50% POST-CONSUMER
45% PRE-CONSUMER

SCS Global Services, 2000 Powell Street, Suite 600 Emeryville, CA 94608 USA

Certificate Number: **SCS-RC-20305**
Valid From: **December 23, 2024**
Valid To: **September 11, 2025**

Diana Kirsanova Phillips, Chief Assurance Officer,
SCS Global Services

A16

CERTIFICATE OF ACHIEVEMENT

SCS Global Services does hereby attest that an independent assessment was conducted on behalf of:

RAK Ceramics PJSC

P.O. Box 4714, Al Jazirah Al Hamra, Ras Al Khaimah , United Arab Emirates

For the following Products:

Tile: **Porcelain Tile - Reuse Minerals**

Certified by SCS Global Services qualifying for the following claim:

100% Pre-Consumer Recycled Porcelain Content

Conforms to SCS Recycled Content Standard V8-0. The material quantification and mass-balance calculations are completed on a dry-weight basis.

CERTIFIED RECYCLED CONTENT SCS GLOBAL SERVICES

100% RECYCLED CONTENT
PRE-CONSUMER
PORCELAIN TILE

SCSglobal SERVICES

SCS Global Services, 2000 Powell Street, Suite 600 Emeryville, CA 94608 USA

Certificate Number: **SCS-RC-20079**
Valid From: **June 16, 2025**
Valid To: **April 04, 2026**

Diana Kirsanova Phillips, Chief Assurance Officer, SCS Global Services

RAK Ceramics PJSC. (2025). Recycled Content Certification – Porcelain Tile (SCS-RC-20079). SCS Global Services. https://www.scsglobalservices.com/certified-green-products-guide

Emirates Steel Industries Co. PJSC. (2024). Recycled Content Certification – Carbon Steel Reinforcing Bar (SCS-RC-06311). SCS Global Services. https://www.scsglobalservices.com/certi-

A18

CERTIFICATE OF ACHIEVEMENT

SCS Global Services does hereby attest that an independent assessment was conducted on behalf of:

Emirates Steel Industries Co. PJSC (Emirates Steel)

Industrial City of Abu Dhabi (ICAD-1), Musaffah, Abu Dhabi United Arab Emirates

For the following Products:

Metals - Steel: **Carbon Steel Reinforcing Bar (Hot Rolled Steel Rebar in Straight Length & Coil), Hot Rolled Plain Round Steel Wire Rod in Coil, Hot Rolled Structural Steel Sections (Non-Alloy Structural Steel Sections - Beams, Columns, Channels and Sheet Piles)**

Certified by SCS Global Services qualifying for the following claim:

Average 10% Recycled Metal Content with at least 5% Post-Consumer and Balance 5% Pre-Consumer Recycled Material (plant-wide weighted average)

Conforms to SCS Recycled Content Standard V7-0.The material quantification and mass-balance calculations are competed on a dry-weight basis.

CERTIFIED RECYCLED CONTENT SCS GLOBAL SERVICES

AVERAGE 10% RECYCLED CONTENT
5% POST-CONSUMER
5% PRE-CONSUMER

SCSglobal SERVICES

SCS Global Services, 2000 Powell Street, Suite 600 Emeryville, CA 94608 USA

Certificate Number: **SCS-RC-06311**
Valid From: **August 27, 2024**
Valid To: **November 26, 2025**

Diana Kirsanova Phillips, Chief Assurance Officer, SCS Global Services

A17

ENVIRONMENTAL PRODUCT DECLARATION

PVC Pipes / Gutters / Downpipes

In accordance with ISO 14025 and EN 15804:2012+A2:2019

Programme:	EPD Australasia Limited www.epd-australasia.com
Programme operator:	EPD Australasia
EPD registration number:	S-P-05501
Publication date:	2022-11-25
Valid until:	2027-11-25

An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com

AUSTRALASIA EPD® ENVIRONMENTAL PRODUCT DECLARATION

ECO PLATFORM EPD VERIFIED

MARLEY by aliaxis

Marley New Zealand. (2022). Environmental Product Declaration – PVC Pipes, Gutters, and Downpipes (S-P-05501). EPD Australasia Limited. https://www.epd-australasia.com

Panjin Jijia Ecological Board Industry Co., Ltd. (2024). SCS Global Certification – Particle Board (8–25 mm) No-Added Formaldehyde (SCS-CARB-000794). SCS Global Services. https://www.scsglobalservices.com/certified-green-products-guide

A19

SCS Global Services does hereby certify that an independent evaluation has been conducted on behalf of:

Panjin Jijia Ecological Board Industry Co., Ltd.

Daqing Village, Qingshui Town, Dawa County, Panjin, Liaoning 124208, China
Mill Number: SCS-09-0273

For the following Product and Thickness range:

Particle Board (PB): 8-25 mm

In compliance with the US EPA 40 CFR Part 770, Title VI, Formaldehyde Emission Standards for Composite Wood products, products at the specified site meet the necessary qualifications to be certified for the following claim.

Third Party Certifier: TPC-09

CERTIFIED CARB ATCM 93120 SCS GLOBAL SERVICES
CalCompliant-NAF Particle Board

calCOMPliant™- NAF Exemption

No-Added Formaldehyde
Exemption Granted From: October 07, 2024 to October 07, 2026
Certificate # SCS-CARB-000794

SCS Global Services is a California Air Resources Board approved Third Party Certifier for compliance with the 40 CFR Part 770, Title VI, Formaldehyde Emission Standards for Composite Wood products. Please verify the source and validity of this certificate by visiting the SCS Green Products Guide, http://www.scsglobalservices.com/certified-green-products-guide.

SCSglobal SERVICES

Nicole Munoz, Vice President, ECS
SCS Global Services
2000 Powell Street, Ste. 600, Emeryville, CA 94608 USA

A20

Environmental Product Declaration

EPD® THE INTERNATIONAL EPD® SYSTEM

ECO PLATFORM EPD VERIFIED

In accordance with EN 15804:2012+A2:2019/AC:2021, ISO 14025 and ISO 21930:2017 for:

BITUSTICK R 400 - UAE

From

Polybit Henkel

Programme:	The International EPD® System, www.environdec.com
Programme operator:	EPD International AB
EPD registration number:	EPD-IES-0017673
Publication date:	2024-12-18
Valid until:	2029-12-16
	An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com

Henkel AG & Co. KGaA. (2024). Environmental Product Declaration – BITUSTICK R 400 (EPD-IES-0017673). The International EPD® System. https://www.environdec.com

A21

Environmental Product Declaration

EPD® THE INTERNATIONAL EPD® SYSTEM

ECO PLATFORM EPD VERIFIED

In accordance with EN 15804:2012+A2:2019/AC:2021, ISO 14025 and ISO 21930:2017 for:

POLYCOAT RBE 10 - UAE

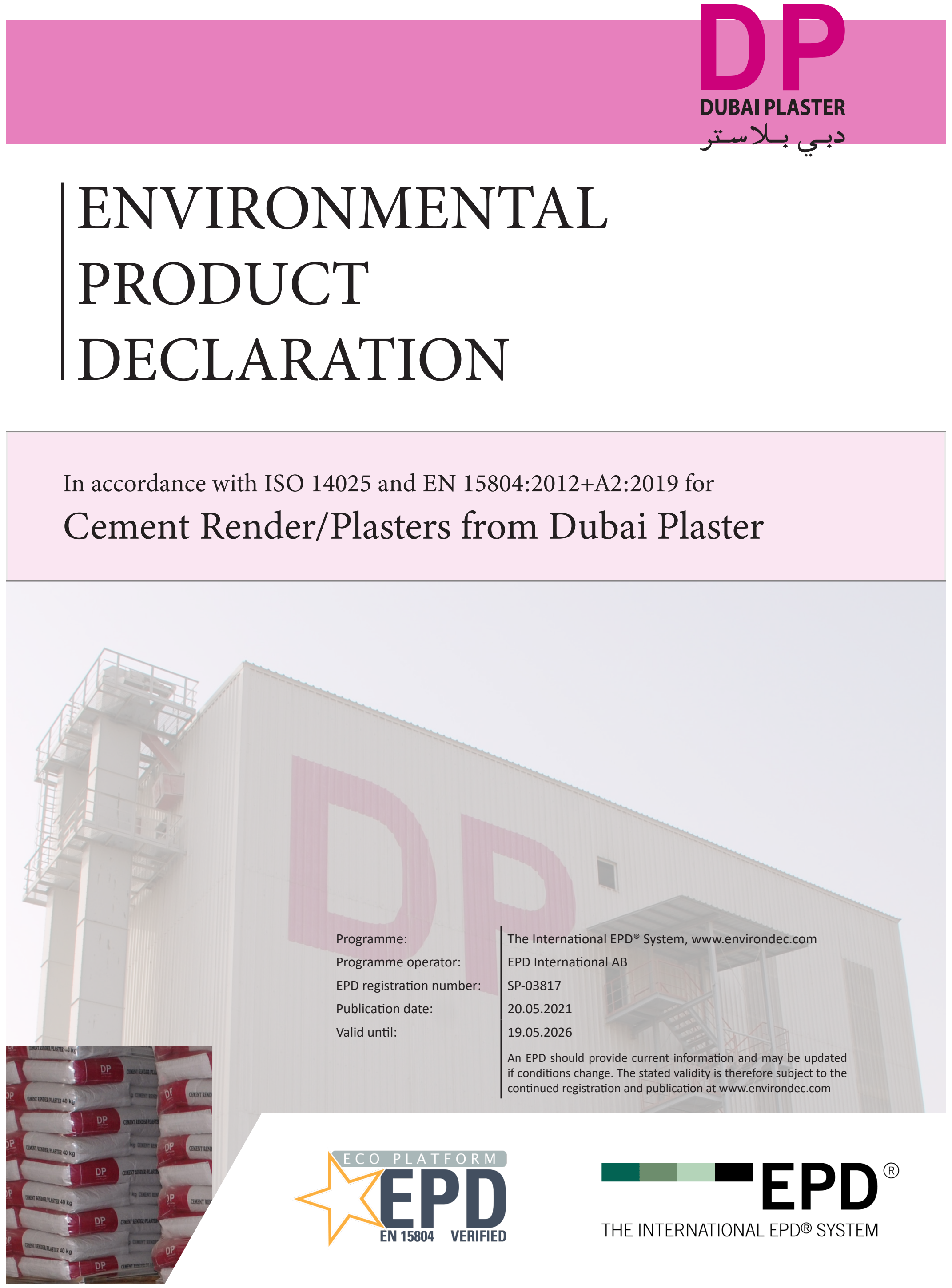
From

Polybit Henkel

Programme:	The International EPD® System, www.environdec.com
Programme operator:	EPD International AB
EPD registration number:	EPD-IES-0018276
Publication date:	2025-01-24
Valid until:	2030-01-21
	An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com

Henkel AG & Co. KGaA. (2025). Environmental Product Declaration – Polycoat RBE 10 (EPD-IES-0018276). The International EPD® System. https://www.environdec.com

A22


DP DUBAI PLASTER دبي بلاستر

ENVIRONMENTAL PRODUCT DECLARATION

In accordance with ISO 14025 and EN 15804:2012+A2:2019 for

Cement Render/Plasters from Dubai Plaster

Programme:	The International EPD® System, www.environdec.com
Programme operator:	EPD International AB
EPD registration number:	SP-03817
Publication date:	20.05.2021
Valid until:	19.05.2026
	An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com

ECO PLATFORM EPD EN 15804 VERIFIED

EPD® THE INTERNATIONAL EPD® SYSTEM

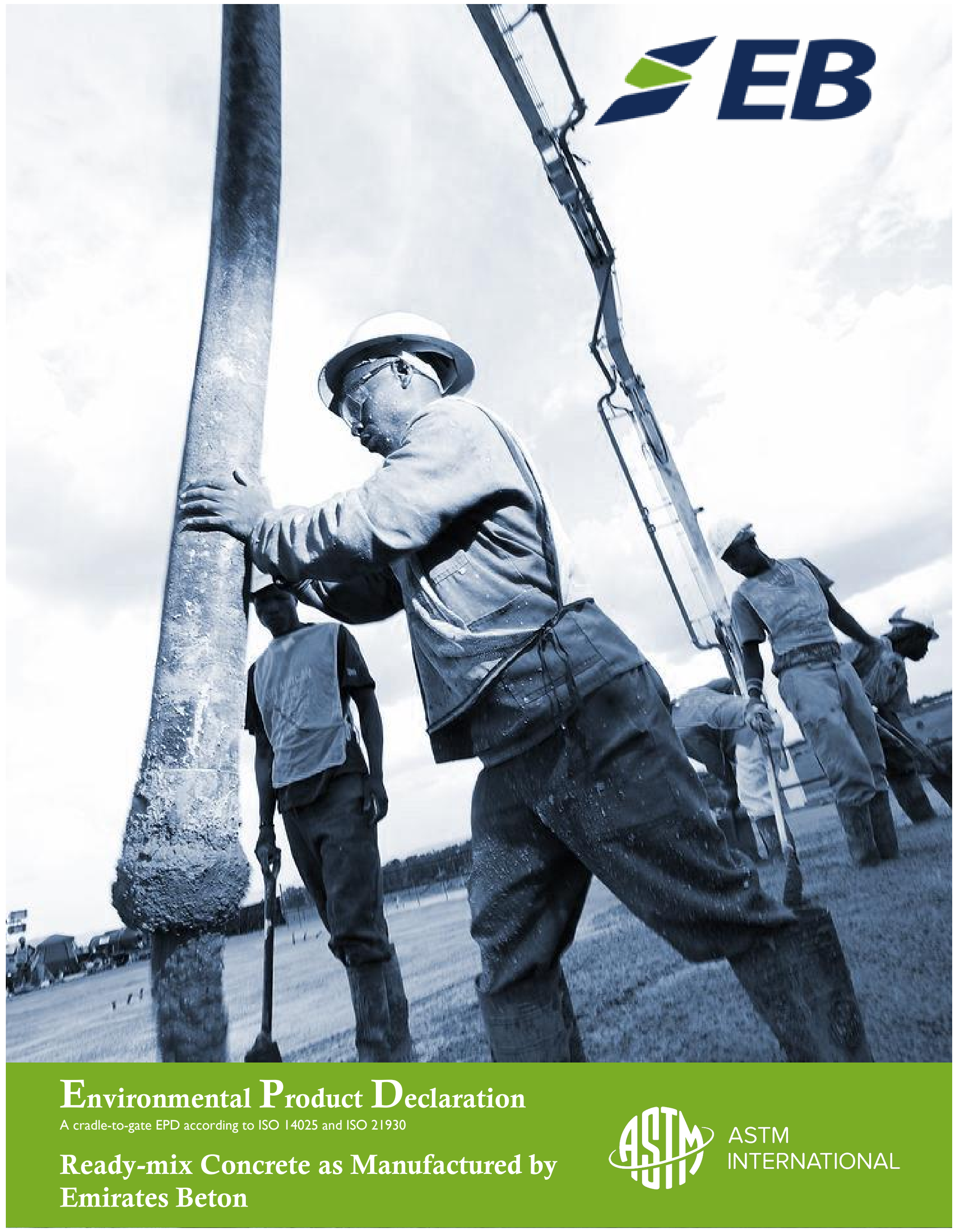
Dubai Plaster Drymix L.L.C. (2021). Environmental Product Declaration – Cement Render/Plasters (SP-03817). The International EPD® System. https://www.environdec.com

A23

EMCON LLC. (2019). Environmental Product Declaration – Concrete masonry products (EPD-110). ASTM International. https://www.astm.org

Emirates Beton Ready Mix LLC. (2018). Environmental Product Declaration – Ready-mix concrete (EPD-083). ASTM International. https://www.astm.org

A24



Environmental
Product
Declaration

RAK CERAMICS 1990-2020 30TH MOVING FORWARD

Ceramic & Porcelain Tiles

RAK Ceramics PJSC. (2021). Environmental Product Declaration – Ceramic & Porcelain Tiles (EPD-165). ASTM International. https://www.astm.org

A26

Environmental
Product
Declaration

EPD® ECO PLATFORM EPD VERIFIED

In accordance with ISO 14025:2006 and EN 15804:2012+A2:2019/AC:2021 for:

Palm Strand Board (PSB)

EPD of multiple product: thickness range 10-45 mm, all products included

from

DesertBoard LTD

DesertBoard. By Al Talah Board Manufacturing Co. LTD

Programme:	The International EPD® System, www.environdec.com
Programme operator:	EPD International AB
EPD registration number:	S-P-12052
Publication date:	2023-12-21
Valid until:	2028-11-16

An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com

DesertBoard LTD. (2023). Environmental Product Declaration – Palm Strand Board (PSB) (S-P-12052). The International EPD® System. https://www.environdec.com

Emirates Steel Industries Co. PJSC. (2025). Environmental Product Declaration – TrueGreen Steel Reinforcement Bars (EPD-IES-0019774:004). The International EPD® System. https://www.environdec.com

A27

Environmental
Product
Declaration

EPD® THE INTERNATIONAL EPD® SYSTEM
ECO PLATFORM EPD VERIFIED

In accordance with ISO 14025:2006 and EN 15804:2012+A2:2019/AC:2021 for:

True:Green

TRUEGREEN STEEL REINFORCEMENT BARS IN STRAIGHT FORM (SMP3)

from

Emirates Steel Industries Co. PJSC

حديد الإمارات
EMIRATES STEEL
PART OF EMSTEEL GROUP

Programme:	The International EPD® System, www.environdec.com
Programme operator:	EPD International AB
EPD registration number:	EPD-IES-0019774:004
Publication date:	2025-04-21
Updated Version Date	2025-09-24
Valid until:	2030-04-21

An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com

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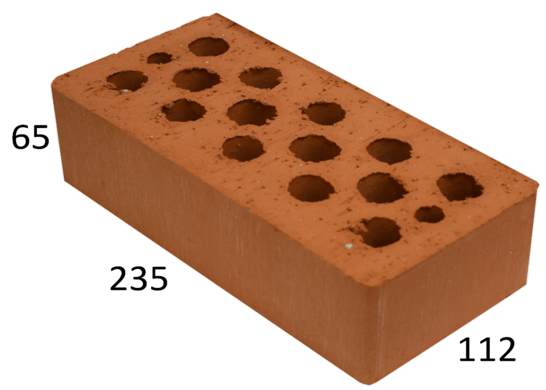
الديار
ALDIYAR

Product Name	Perforated 1	
Code	F1N	
Texture	Smooth	
Color	Red Terracotta	
Dimension (mm)	≈65 x 112 x 235	
Weight (kg)	≈2.5	
Temperature of Firing	900~1,200°C	
Water Absorption	≈10%	
Compressive Strength	≈40 N/mm²	
Reaction to fire	Class A1 (Highest Resistance)	
Package Net Size (m)	0.95 x 0.83 x 1.02	
Wooden Pallet	Yes	
Plastic Strap	Yes	
Plastic Sheet Cover	Yes	
Quantity of bricks per pallet	360	
Pallet Weight (kg)	900	
Truck size	25 ton	30 ton
Quantity of pallet per truck	28	32
Quantity of bricks per truck	10,080	11,520
Products is free of Asbestos		



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www.diyarhome.ae
sales@sdsholding.net
@aldiyarhome

Diyar Home. (n.d.). Perforated 1 F1N brick – product data sheet. SDS Holding. https://www.diyarhome.ae bre

Statement of Verification

BREG EN EPD No.: 000132 Issue 05
ECO EPD Ref. No. 000426
This is to verify that the

Environmental Product Declaration

provided by:

Emirates Steel Industries Co. PJSC (member of UK CARES)

BRE Global Verified EPD

is in accordance with the requirements of:

EN 15804:2012+A2:2019

and

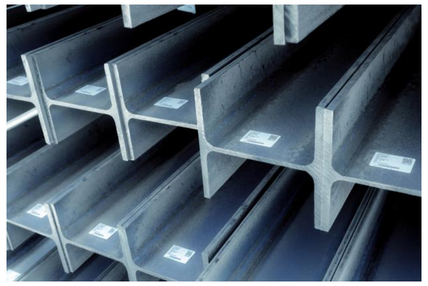
BRE Global Scheme Document SD207

This declaration is for:

Non-alloy structural steel (Direct Reduced Iron Production Route)

Company Address

PO Box 9022, Abu Dhabi Industrial City (ICAD-1)
Musaffah
Abu Dhabi
UAE



emirates steel حديد الإمارات
a SENAAT company إحدى شركات صناعات

18 May 2018	Emma Baker Operator	21 April 2023 Date of this Issue
18 May 2018 Date of First Issue		20 April 2026 Expiry Date

BRE Global Verified EPD

This Statement of Verification is issued subject to terms and conditions (for details visit www.greenbooklive.com/terms.

To check the validity of this statement of verification please, visit www.greenbooklive.com/check or contact us.

BRE Global Ltd., Garston, Watford WD25 9XX.
T: +44 (0)333 321 8811 F: +44 (0)1923 664603 E: Enquiries@breglobal.com

ECO PLATFORM EPD VERIFIED

BF1805-C-ECOP Rev 0.3 Page 1 of 18 © BRE Global Ltd, 2022

Emirates Steel Industries Co. PJSC. (2022). Environmental Product Declaration – Non-alloy structural steel (BRE Global, PN 514 Rev 3.0). BRE Global. https://www.greenbooklive.com

IMQ S.p.A. (2024). Product Carbon Footprint Verification Statement for Palm Strand Board (PSB), Desert Board Division (Certificate No. A090.2023). IMQ S.p.A. https://www.imq.it

N° A090.2023

IMQ

PRODUCT CARBON FOOTPRINT VERIFICATION STATEMENT

Standard **ISO 14067:2018**

Company Name:	**TALAH BOARD MANUFACTURING COMPANY LTD DESERT BOARD DIVISION**
Registered Office/Production Site:	ABU DHABI KHALIFA INDUSTRIAL ZONE - KP04 - KIZAD - UNITED ARAB EMIRATES

In compliance with the principles and requirements of ISO 14067:2018, as described in the Study:

«LCA study of palm strand boards (PSB)» Rev. 3 of 2023/11/15

it is declared that the CFP value of:

Product:	**PSB – Palm Strand Board**
PCR or CFP-PCR (if applicable):	**2019:14 Construction products v. 1.2.5**
Functional Unit (FU):	**N.A.**
Declared Unit (DU), if applicable	**1 m3 of PSB (density is 800 kg/m3 on average thickness range 10-45 mm)**
Complete CFP (including all phases)	**NO**
System boundary (for partial CFP):	**Cradle to gate with option (C1-C4 + D)**
Phases excluded from system boundaries, if applicable:	**Distribution and use (A4; A5; B1-B7)**
Assessment period:	**2022**

is 1,07E+03 kg CO2e / 1 m³ palm strand boards (PSB)

This value is splitted as follows:

A1-A3 Supply of raw materials Transportation, Manufacturing	**- 4,01E+02 kg CO_2e**
C1-C4 - End of life	**1,47E+03 kg CO2e**
Level of assurance:	**reasonable**

Mod. 4785A-EN/7

21 | 12 | 2023 First Issue Date	26 | 01 | 2024 Current Issue Date	Flavio Ornago *Business Unit Management Systems Director*

THIS CERTIFICATE IS SUBJECT TO COMPLIANCE WITH THE CFP REGULATION

ACCREDIA L'ENTE ITALIANO DI ACCREDITAMENTO
GHG N° 0016GHG
Membro degli Accordi di Mutuo Riconoscimento EA, IAF e ILAC
Signatory of EA, IAF and ILAC Mutual Recognition Agreements

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di Torino

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Mari Amirjanyan

2025