Revista Hábitat Sustentable Vol. 13, N°. 2. ISSN 0719 - 0700 / Págs. 22 -35
https://doi.org/10.22320/07190700.2023.13.02.02

EXPLORING SUSTAINABLE APPROACHES AT DUBAI EXPO 2020: A BLEND OF BIOPHILIC AND BIOMIMICRY DESIGNS

Recibido 12/10/2023
Aceptado 28/11/2023

EXPLORACIÓN DE ENFOQUES SUSTENTABLES EN LA EXPO DE DUBÁI DE 2020: UNA MEZCLA DE DISEÑOS BIOFÍLICOS Y BIOMÍMESIS

EXPLORANDO ABORDAGENS SUSTENTÁVEIS NA DUBAI EXPO 2020: UMA MISTURA DE DESIGNS BIOFÍLICOS E BIOMIMÉTICOS

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ABSTRACT

Dubai Expo 2020 provides an international platform for advancing innovation through meticulously curated exhibits with themes such as sustainability and cultural exchange displayed in pavilions dedicated to individual countries. This research study uses biophilic or biomimetic design strategies to assess the sustainability practices employed in a group of pavilions at the Dubai Expo 2020 that employ biophilic and/or biomimetic design strategies. Biophilic philosophy emphasizes nature-based concepts to foster positive relationships between humans and living organisms, whereas biomimicry imitates natural processes/systems for building practices. Incorporating biophilic and/or biomimetic techniques into pavilion design provides visitors with a one-of-a-kind experience while displaying explicit sustainability principles that go beyond the event's existing architectural framework guidelines. The research evaluation process includes architectural structure designs, materials used during production/creation periods, energy efficiency measurements implemented, and sustainable water management plans based on natural ecological systems. It will also evaluate the adherence of each pavilion chosen to genuine sustainability values by analyzing the incorporation of nature-based concepts into its overall design for potential future reference applications. These techniques have significant potential to improve human health, reduce environmental impact, and encourage global resiliency when implemented beyond Dubai Expo 2020. In conclusion, the research aims to inspire sustainable designs well beyond the Dubai Expo 2020 by demonstrating how biophilic or biomimetic practices are crucial facilitators in constructing spaces that maximize human welfare without endangering the environment. It is also a foundational resource for architects and urban planners committed to advancing sustainable architectural practices through future development projects prioritizing human welfare and environmental protection.

Palabras clave
Expo Dubai 2020, sustainability, biophilic, biomimicry, nature-based

RESUMEN

La Expo de Dubái 2020 es una plataforma internacional para el avance de la innovación a través de exposiciones meticulosamente seleccionadas, con temas como la sostenibilidad y el intercambio cultural expuestos en pabellones dedicados a países individuales. Esta investigación usa estrategias de diseño biofílico o biomimético para evaluar las prácticas de sustentabilidad usadas en un grupo de pabellones en la Expo de Dubái de 2020, que usan estrategias de diseño biofílico y/o biomimético. La filosofía biofílica hace hincapié en conceptos basados en la naturaleza, con el objetivo de fomentar relaciones positivas entre los seres humanos y los organismos vivos, mientras que la biomímesis imita los procesos/sistemas naturales para las prácticas de construcción. La incorporación de técnicas biofílicas y/o biomiméticas en el diseño de los pabellones proporciona a los visitantes una experiencia única, al tiempo que muestra principios de sostenibilidad explícitos que van más allá de las directrices del marco arquitectónico del evento. El proceso de evaluación de la investigación incluye diseños de estructuras arquitectónicas, los materiales utilizados durante los periodos de producción/creación, las medidas de eficiencia energética aplicadas y los planes de gestión sostenible del agua basados en sistemas ecológicos naturales. También se evaluará la adhesión de cada pabellón seleccionado a auténticos valores de sostenibilidad analizando la incorporación de conceptos basados en la naturaleza en su diseño general para posibles aplicaciones futuras de referencia. Estas técnicas tienen un potencial significativo para mejorar la salud humana, reducir el impacto ambiental y fomentar la resiliencia global cuando se lleven más allá de la Expo de Dubái de 2020. En conclusión, la investigación apunta a inspirar diseños sostenibles mucho más allá de la Expo de Dubái de 2020, al demostrar cómo las prácticas biofílicas o biomiméticas sirven de facilitadores clave en la construcción de espacios que maximizan el bienestar humano, sin poner en peligro al medio ambiente. También sirve como recurso fundamental para arquitectos y urbanistas comprometidos con el avance de las prácticas arquitectónicas sostenibles a través de futuros proyectos de desarrollo, que den prioridad tanto al bienestar humano como a la protección del medio ambiente.

Keywords
Expo de Dubái 2020, sustentabilidad, biofílica, biomímesis, basada en la naturaleza

RESUMO

A Dubai Expo 2020 oferece uma plataforma internacional para o avanço da inovação por meio de exposições meticulosamente selecionadas com temas como sustentabilidade e intercâmbio cultural exibidos em pavilhões dedicados a países individuais. Este estudo de pesquisa utiliza estratégias de design biofílico ou biomimético para avaliar as práticas de sustentabilidade adotadas em um grupo de pavilhões da Dubai Expo 2020 que empregam estratégias de design biofílico e/ou biomimético.A filosofia biofílica enfatiza conceitos baseados na natureza para promover relações positivas entre humanos e organismos vivos, ao passo que a biomimética imita processos/sistemas naturais para práticas de construção. A incorporação de técnicas biofílicas e/ou biomiméticas no projeto do pavilhão proporciona aos visitantes uma experiência única, ao mesmo tempo em que exibe princípios explícitos de sustentabilidade que vão além das diretrizes de estrutura arquitetônica propostas para o evento. O processo de avaliação da pesquisa inclui projetos de estruturas arquitetônicas, materiais utilizados durante os períodos de produção/criação, medidas de eficiência energética implementadas e planos de gerenciamento sustentável da água com base em sistemas ecológicos naturais. Ele também avaliará a adesão de cada pavilhão escolhido aos valores genuínos de sustentabilidade, analisando a incorporação de conceitos baseados na natureza em seu projeto geral para possíveis aplicações futuras de referência. Essas técnicas possuem um potencial significativo para melhorar a saúde humana, reduzir o impacto ambiental e incentivar a resiliência global se forem implementadas após a Dubai Expo 2020. Por fim, a pesquisa tem como objetivo inspirar projetos sustentáveis muito além da Dubai Expo 2020, demonstrando como as práticas biofílicas ou biomiméticas são facilitadoras cruciais na construção de espaços que maximizam o bem-estar humano sem colocar em risco o meio ambiente. É também um recurso fundamental para arquitetos e planejadores urbanos comprometidos com o avanço das práticas arquitetônicas sustentáveis por meio de futuros projetos de desenvolvimento que priorizem o bem-estar humano e a proteção ambiental.

Palavras-chave:
Expo Dubai 2020, sustentabilidade, biofílico, biomimética, baseado na natureza.

INTRODUCTION

Emulating life's creativity is crucial for human survival and a sustainable future. Nature serves as a source of design inspiration for the built world, as it understands sustainable construction. Sustainability is a significant factor in design, and understanding the value of nature and its influence on design is essential. Nature's natural cycles, such as providing food for insects and fruits for variety, have been challenging for humans to complete since humanity's inception (Green, K, 2005; Karabetça, A.R., 2015).

Nature is critical to reaching the worldwide goal of net zero emissions by 2050. However, according to United Nations Secretary-General Antonio Guterres, nature needs assistance. We can escape climate catastrophe and restore our world by defeating the COVID-19 pandemic (Aboulnaga & Helmy, 2022). Biophilia, bioengineering, bionics, and biomimicry are biological terms that describe the laws of nature that have governed 30 million species for 3.85 billion years (Isle & Leitch, 2023). Bio-concepts, such as biophilia and biomimicry, are used to integrate nature into human activities, focusing on Janine Benyus' principles for sustainability. This study explores these concepts in architecture.

BIOPHILIC DESIGN

The creation of biophilic design has taken many steps in history. As shown in Figure 1, it has involved considering guidelines in the design phase, incorporating natural characteristics into built environments, and representing shapes like botanical, animal, and shell motifs through arches, vaults, and domes, varying sensory experiences through time, change, transitions, and complementary contrasts (Terrapin Bright Green, 2014). This type of design evokes historical, cultural, geographic, spiritual, and ecological significance, transforming humans and creating nature-like environments (Biancardi & Cascini, 2023; Al-Rhodesly, 2019). Biophilic Design focuses on reconnecting with nature, transforming human awareness, and fostering a new ethic of duty for caring for the world (Van der Ryn & Cowan, 2013; Thampanichwat et al., 2013). Mass and volume are linked to biophilic design, with material, object, light, landscape, and viewpoint referencing natural elements, without examining color or sound details.

BIOMIMICRY

From the Greek words bios-life and *mimesis*-mimic, imitate, biomimicry translates to "the imitation of life." Engineering, product design, and architecture all use biomimicry, which takes inspiration from nature's mechanisms and applies them to the shortcomings humans face (Thampanichwat et al., 2013; Taylor Buck, 2017). Biomimicry in design can promote climate action, build green, sustainable cities, achieve sustainable development, and comply with the United Nation's SDGs. Incorporating natural elements into a design can inspire sustainability and protect ecosystems in the face of climate change and COVID-19 while combining architectural features with nature and technology can overcome city resilience challenges (Aboulnaga & Helmy, 2022).

Designers are increasingly aware of the natural opportunities to enhance human and system functionality. This has increased interest in biomimicry for built environments and sustainability (Oguntona & Aigbavboa, 2023; Jamei & Vrcelj, 2021). Architecture that uses biomimicry takes cues from the methods, tools, and ideas employed by other organisms to suit their needs and secure their existence on Earth. J. Benyus proposes two key methods for using biomimicry (Jamei & Vrcelj, 2021; Aamer et al., 2020). Biology-to-design aims to solve design challenges by identifying basic functions and analyzing natural principles. This approach enables advanced, sustainable buildings with aesthetical, physical, and mechanical aspects. Designers can create this technique by collaborating with nature, existing practices, or experimental design-science (Fahmy, 2018). The parallels between nature and architecture in this context have motivated numerous researchers to use biological systems to manage environmental variables (Varshabi, Arslan Selçuk, & Mutlu Avinç, 2022; Perricone et al., 2021). As a result, biomimicry-based design has arisen as a transdisciplinary, groundbreaking architectural movement (Faragalla & Asadi, 2022).

Sustainable pavilions at expos typically focus on environmentally friendly practices, energy efficiency, and the use of renewable resources. These pavilions often incorporate green building technologies, sustainable materials, and innovative designs that minimize their environmental impact. These pavilions may showcase advancements in renewable energy, waste reduction, water conservation, and sustainable living practices.

Features of sustainable pavilions are achieved within biophilic and biomimicry design frameworks and may include:

- Solar panels for energy generation.
- Rainwater harvesting systems.
- Sustainable and recyclable construction materials.
- Smart technologies for energy management.

OBJECTIVES AND METHODS

The objective is to inspect and analyze biophilic and biomimicry features applied in Dubai expo's pavilions

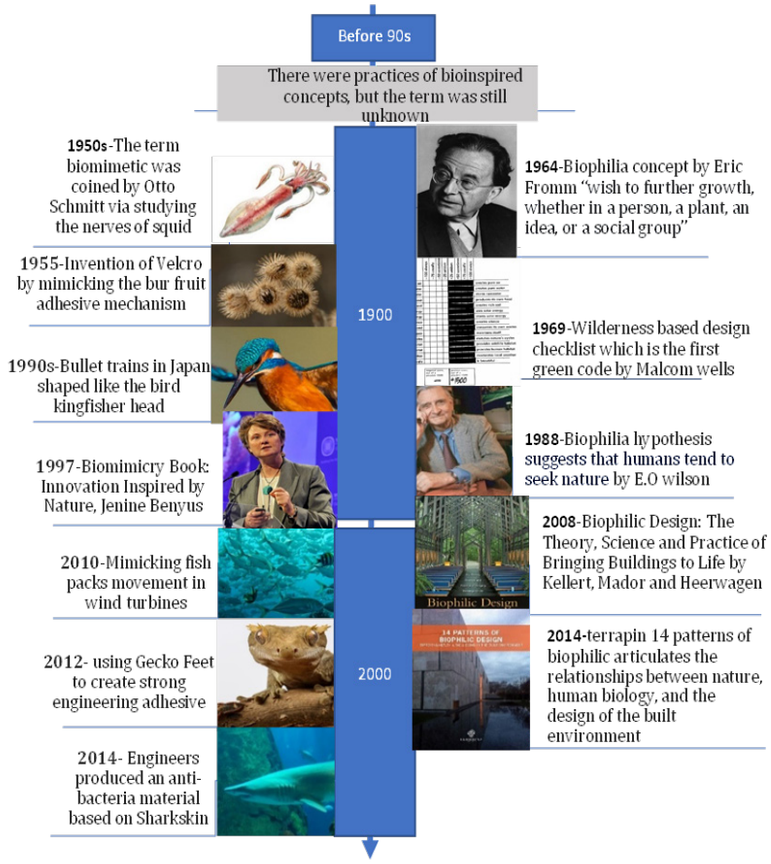


Figure 1. Summarized history of Biophilic and Biomimicry design. Source: Schreiner, (2018); University of Minnesota, (2023); Zare et al., (2021).

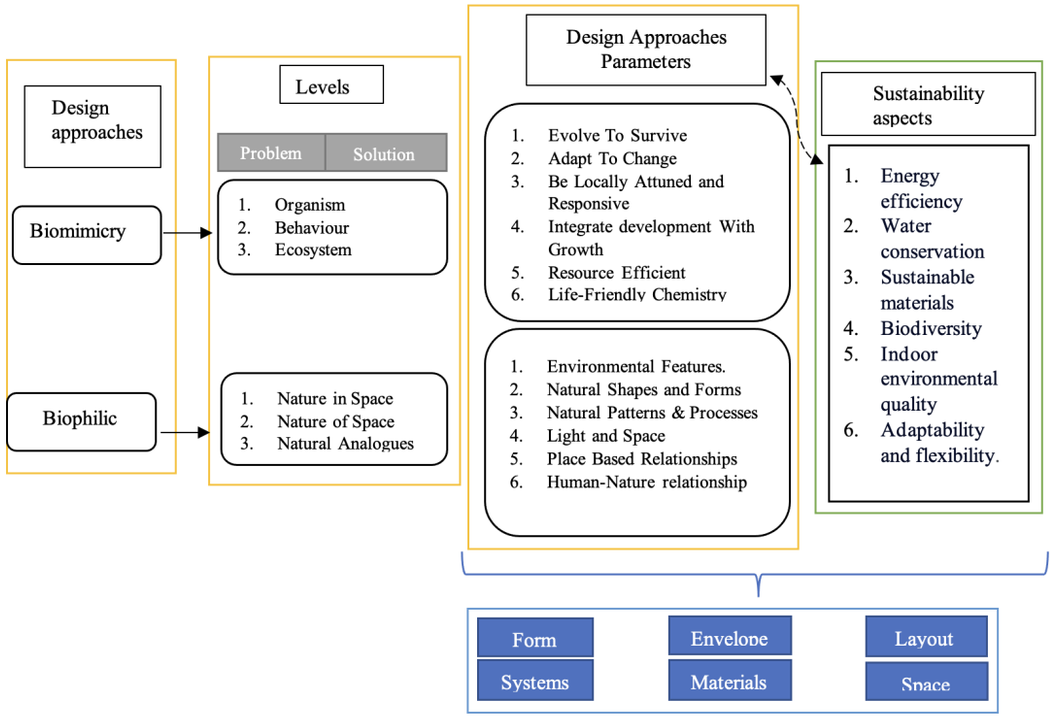


Figure 2. Flow chart of the study analysis framework. Source: The authors.

through their architecture and relationship with sustainability approaches.

1. Evaluate the integration of biophilic and biomimetic concepts in pavilion architecture.
2. Examine how these strategies enhance explicit sustainability principles.
3. Analyze architectural elements, materials, and their compatibility with these strategies.
4. Measure reduced environmental impact and potential energy efficiency gains.
5. Validate the long-term applicability of these techniques beyond the Expo.

The methodology evaluates the biophilic and biomimicry features in terms of sustainability:

1. Establishing a biophilic and biomimicry identification and categorization guide
2. Referencing biophilic design to green designs and biomimicry as science to learn strategies from nature.
3. Identifying sustainability criteria and goals
4. Analyzing each biophilic and biomimicry feature in terms of sustainable design principles / biophilic design principles

ANALYSIS FRAMEWORK

The identification and categorization guide for the five pavilions at the Dubai Expo focuses on biomimicry and biophilia concepts. It involves collecting and recognizing building elements, such as ventilation systems and architectural design, and classifying them using a checklist (Figure 2). Successful elements are considered under the study concepts, and the number of parameters added measures the strength of the concept's implementation.

There are some characteristics shown in Table 1 that aid in recognizing whether a building element responds to a particular parameter. Realistically, the building elements are identified from data that can be analyzed in different ways depending on the purpose of the

Table 1. Biomimicry and Biophilic design characteristics. Source: Kellert, 2008

Biomimicry parameter	Characteristics	Biophilic parameter	Characteristics
Evolve to survive	Replicate strategies Embody information Redo successful approaches Create new options	Environmental Features.	Air, Water, Plants Animals, Materials
Adapt to change	Respond to dynamic contexts Incorporate diversity Self-renewal Embody resilience Meet a functional need	Natural Shapes and Forms	Botanical Motifs Shells and spirals Curves and arches Fluid forms Abstraction of nature
Be locally attuned and responsive	Use available resources Integrate within the surrounding	Natural Patterns and Processes	Sensory richness Area of emphasis Patterned wholes Bounded spaces Linked series and chains
Integrate development with growth	Self-organize Start from simple to complex. Allow interactions	Light and Space	Composition Communication Preference Engagement Pragmatics Daylight Filtered light Reflected light
Resource efficient	Recycle all materials Fit form to function Multi-functional design One solution for multi-needs Low energy Processes	Place-based Relationships	Geographic connection Historic connection Ecological connection Cultural connection
Life-Friendly Chemistry	Use water as solvent. Small subset of elements. Support life processes.	Human-Nature relationship	Prospect/refuge Order/complexity Curiosity/enticement Attraction/attachment Exploration/discovery

analysis. Nevertheless, the characteristics are examples of what a biophilic and/or biomimetic element can be like, but not necessarily all that it can be. Understanding the parameters as fundamental for making judgments is key to the identification process; the guide is just there to guide, not to determine facts.

DUBAI EXPO 2020 PAVILIONS ANALYSIS

This study will focus on five pavilions of Belgium, Netherlands, Singapore, Sustainability, and UAE, spread all over the Dubai expo area. It is important to point out that all these pavilions are high-tech structures. They represent countries with high per capita income and vast resources to support them. Each pavilion will be introduced in general and analyzed by element; each building element (form, materials, layout, space, systems, and envelope) that possesses biophilic or biomimicry parameters will be represented here; the parameters are coded in reference to Table 2. These parameters define a vital part of the analysis framework (Figure 2); once the building element is recognized, the author can relate it to biophilic or biomimicry concepts (Kellert, 2008).

Table 2. Reference codes for biophilic and biomimicry parameters. Source: The authors.

Biophilic design	Code
Environmental Features.	P1
Natural Shapes and Forms	P2
Natural Patterns and Processes	P3
Light and Space	P4
Place-Based Relationships	P5
Human-Nature relationship	P6
Biomimicry	**Code**
Evolve to Survive	M1
Adapt to Change	M2
Be Locally Attuned and Responsive	M3
Integrate development with Growth	M4
Resource Efficient	M5
Life-Friendly Chemistry	M6

BELGIUM PAVILION

The Belgium Pavilion information is shown in Table 3. It was inspired by the notion of a "Green Arch" and forms a massive four-story rectangular structure wrapped in luxuriant vegetation. It comprises 500m² of exhibitions offering a glimpse into the future of Belgium's mobility technologies and innovations. A brasserie and takeaway kiosk for your fix of Belgium specialties in a luxurious yet cozy setting. A rooftop terrace with a lounge area for you to enjoy the sunset and the view. Almost 100 vertical strips of blonde wood line the pavilion's longest façades, rising skyward to resemble the ribs of a vast ship.

Table 3. Belgium Pavilion information. Source: Expo, 2020; Expo, 2021.

Architect	Assar / Vincent Callebaut
Theme	Diversity in harmony
Area	3,500 m²
Location	Mobility District

SOLAR CANOPY

The slender bridge-building shown in Figure 3 is a dynamic monolith dedicated to renewable energies, covered with a large photovoltaic and thermal solar canopy. This building element uses renewable natural resources such as sunlight to produce electricity and domestic hot water for the pavilion's self-consumption. Easing the pressure of limited natural resources and using what is abundant in the surroundings is one of the most natural behaviors of decomposers, using the dead tissues available everywhere in nature as a food source. (M5)

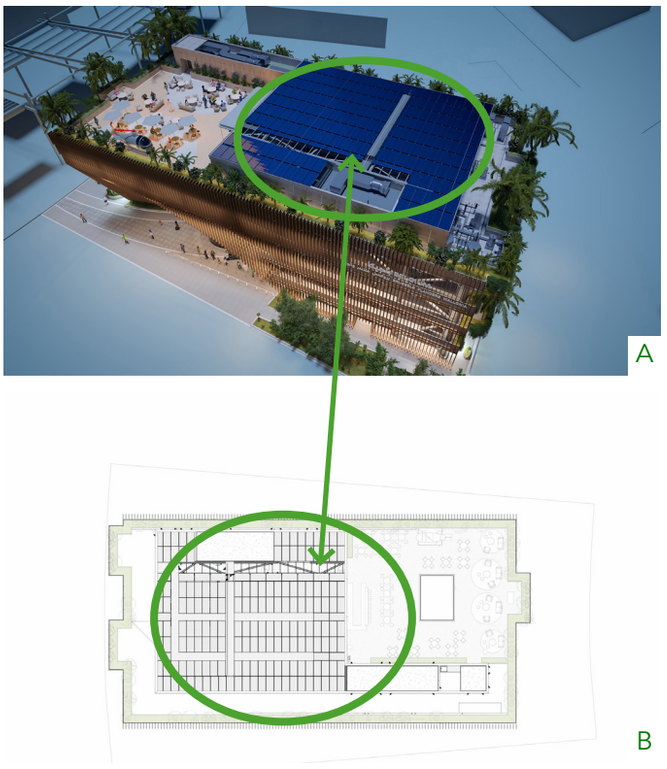


Figure 3. (A) Belgium pavilion's perspective and (B) roof plan indicating solar canopy. Source: Assar, 2020; Dey, 2021.

THE PARABOLOID

The paraboloid shown in Figure 4 is built with more than 5.5 linear kilometers of spruce louvers, generating a giant wooden Mashrabiya. It is considered a significant cultural connection to the United Arab Emirates as part of heritage building design elements. (P5) The Mashrabiya, built in CLT, features a 180-degree rotating element for solar protection, energy efficiency, and natural ventilation. This contributes to (P1) because it is the integration of natural materials but highly contradicts (M3). The wood used in the building is not native and is likely imported, potentially reducing energy savings. The wrapping technique creates mystery and surprise in the building's shape and form. (P6) The element significantly impacts the building layout, emphasizing the main axis and creating a fluid shape, connecting urban surroundings and outdoor spaces (P1) (P5). The surface exposure to the outside is increased thanks to the curvature shape, allowing more daylight into the building, contributing to saving energy and better indoor environment quality (M5) (P6).

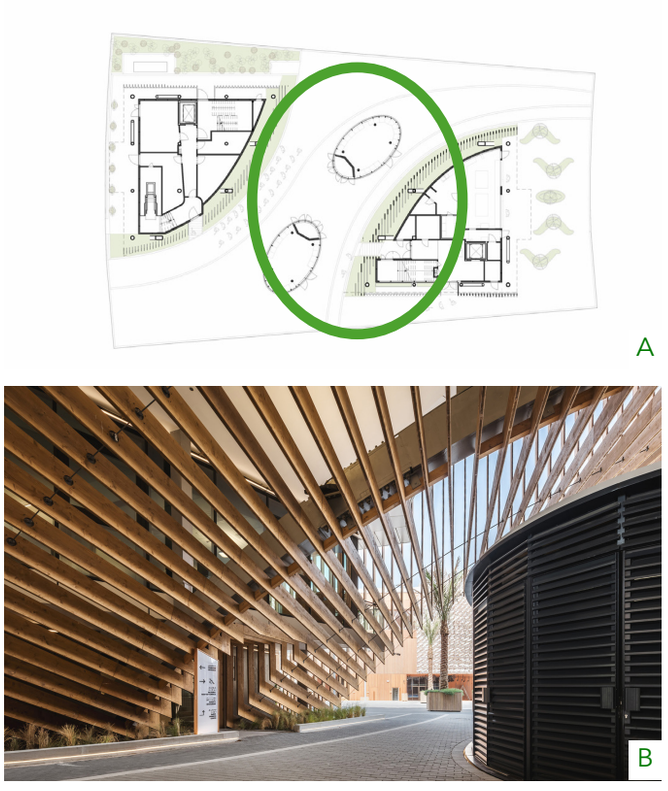


Figure 4. (A) Belguim pavilion's paraboloid indications on the ground floor and (B) a close-up with spruce louvers representing the Mashrabiya concept . Source: Assar, 2020; ArchDaily, 2021.

GREEN FAÇADE

The green arch features balconies and a rooftop with over 2,500 plants, shrubs, and trees. Drip-watered façades refresh outdoor terraces, promoting sustainable water delivery and resource preservation. Greenery aligned on different levels helps the building's cooling and energy savings (Figure 5) (M5). The approach involves using living organisms to solve problems, connecting the building's natural identity and form to nature, and enhancing its performance (P1).

Figure 5. (A) Belgium pavilion's green façade and (B) its indications on the plan. Source: Assar, 2020.

THE ESCALATOR

The futuristic escalator shown and indicated in Figure 6, designed as a space-time tunnel, propels visitors toward the 2050 Odyssey. This area induces sensory enrichment due to its interior design, which is unique from the rest of the building (P3). Making this design for a multiple-level system creates an experience involving mystery in the discovery at the end of the ride, primarily because this is an event-based building that is not regularly found in similar residential or commercial buildings (P6).

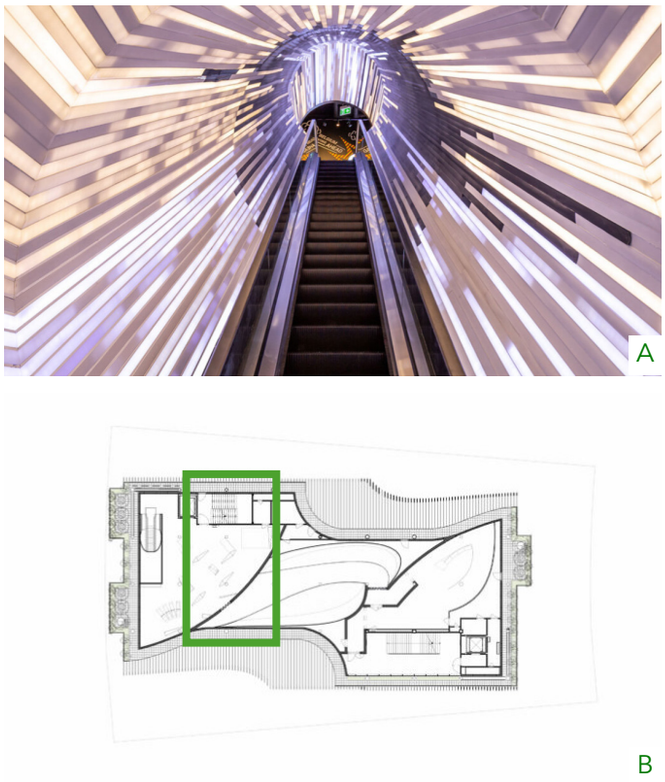


Figure 6. (A) Belguim pavilion space-time tunnel escalator and (B) its location on the plan. Source: Assar, 2020; ArchDaily, 2021.

NETHERLANDS' PAVILION

As the Netherlands' contribution to Expo 2020 Dubai, V8 (Table 4) Architects designed a pavilion with its own contained water, electricity, and food system, as well as a leave-no-trace mentality. The Dutch Biotope pavilion includes, in addition to the main exhibition space, an auditorium, VIP lounge, restaurant, store, and back offices on a total floor area of 3,727 square meters.

Table 4. Netherlands Pavilion information. Source: The National UAE, (2020).

Architect	V8 Architects
Theme	Sustainable solutions through out-of-the-box creativity
Area	3,727 m²
Location	Sustainability District

Biotope

Inside the pavilion, a large cone is the main element of the exhibit- a vertical farm covered in edible plants on the outside and mushrooms on the inside, as shown in Figure 7. Providing indoor natural elements that are also useful is a core in integrating development with growth (P5) (P1) and creating a solid ecological connection where the element is positioned and designed as a core part of the pavilion (M4). The chimney-like structure regulates temperature and moisture, harvesting water from air humidity for plant irrigation. Powering renewable energy from lightweight, transparent solar cells, the pavilion uses the sun's abundant sun and scarce water to feed 9,300 plants (M3). The result of creating such a significant natural element is the ability to minimize active system usage and energy use by relying on the natural process to regulate temperature (M5). The condensation process leaves high levels of CO2, making the cone the ideal place to grow other kinds of food. The space is humid, dark, and cold; these are the perfect conditions for edible oyster mushrooms. You can smell them here as they grow inside the cone, creating a sensory-rich experience (P3).

Figure 7. Netherlands Pavilion Biotope exhibiting vertical farm as a core. Source: Aouf, 2020.

Entrance

Visitors descend into the pavilion on a ramp, as shown in Figure 7, and start experiencing the shift in temperature, creating a sense of exploration and discovery right at the beginning of the experience. The contrast of order and complexity reinforces the machine metaphor in the control room that leads inside the central cone, where the pavilion's technical innovations can be projected onto white umbrellas (P6).

Materials

The Netherlands Pavilion uses reclaimed iron, biopolymers, and bio-mass tiles for an eco-friendly exterior, promoting circular economy principles (M5) (M6). V8 Architects built the pavilion primarily from steel hired from locally based companies. Sand excavated from the site is used for filling the double sheet piling and as a temporary insulation material and will be used to fill the plot back in again after the Expo (M3). The walls shown in Figure 8 are made from steel sheet piling, and the roof is made from steel tubes, while concrete was avoided in the pavilion foundations to avoid harsh chemicals (M6). Amsterdam-based Buro Belén's biodegradable canopy and biopolymer maize curtain in the space enhance environmental connection and human-made construction elements (P1).

Figure 8. (A) Netherlands Pavilion 3D section showing materials, levels, and movement axis and (B) entrance gateway with a horizontal projection and leveling. Source: Aouf, 2021; The National UAE, 2020.

SINGAPORE PAVILION

The Singapore Pavilion at Expo 2020 Dubai exemplifies the city's desire for a sustainable future that integrates architecture, nature, technology, and culture (Table 5). The pavilion was developed by WOHA Architects and landscape design firm Salad Dressing to present a sample of Singapore's urban environment that exemplifies the city-state's City in Nature goal. Through the marriage of technology and nature, the multi-layered green space generates a self-sufficient ecosystem that highlights notions of sustainability and resilience.

Table 5. Singapore Pavilion information. Source: Expo 2020 – Singapore Pavilion, 2023.

Architect	WOHA
Theme	Nature. Nurture. Future.
Area	1,500 m²
Location	Sustainability District

The ground gardens

Singapore's multi-layered green space (Figure 9) showcases sustainability and resilience by integrating technology and nature. With over 170 plant species,

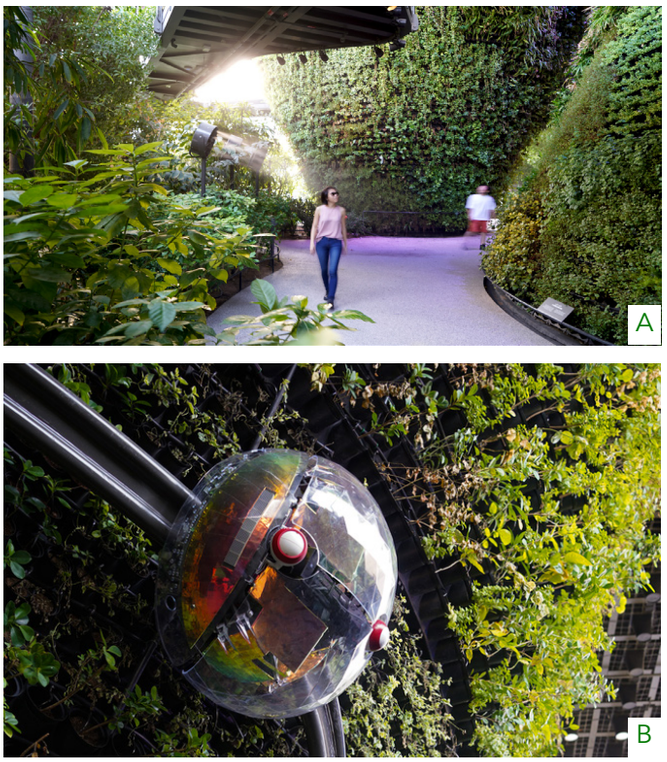


Figure 9. Singapore pavilion ground floor vertical garden and (B) climbing robots that act as a maintenance system. Source: Transsolar Klima Engineering, 2021.

visitors can experience tropical rainforests, mangrove areas, and forest streams, creating a rich bio environment (M4) (P3) (P1) (P6). Housing 80,000 plants from more than 170 plant varieties and an integrated system of greenery, energy, and water management within an efficiently designed 1,500-square-meter site is creating a new self-sufficient environment that mimics the sufficiency of nature as a system (M1).

Oceania Robotics developed three prototype climbing robots for vertical and skyrise gardens, utilizing communication systems reminiscent of living organisms to maintain greenery and monitor plant health (M4).

Thematic cones

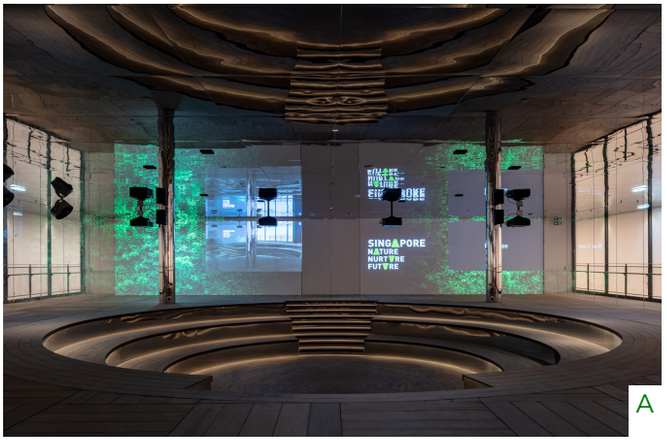
The pavilion's biophilic design and architecture showcase nature as an urban solution, surrounded by 3 modular cones, vertical greenery, and a hanging garden. It features tropical trees, shrubs, orchids, and ethnobotanical plants. Innovative solutions like dry misting and solar pipes enable tropical plants to thrive, creating a sensory heaven (P1) (M4). The shape of the cone can be more thoughtful because nature is messy and not perfectly curved and geometrical (P2).

Experience an experiential journey through the Pavilion, featuring Ground Garden, Garden Cones, and Hanging Garden, showcasing Singapore's natural heritage, innovative urban solutions, and orchid species (P3).

Singapore pavilion offers comfortable, enjoyable walks with shading, vegetation cooling, and fine mist fans, saving resources and the cooling load in the desert (M5).

Sky market

Although the sky market in Figure 10A is isolated from the very dense greenery on the first two floors, it represents a great element of prospect, mystery, and discovery. On the other hand, the exterior in Figure 10 B clearly defines it as an endpoint for the nature journey by creating a completely opposite environment with plain walls, clean edges, and a central destination (P6).



A

B

Figure 10. (A) Singapore pavilion's exotic interior sky market and (B) its emphasis on the exterior. Source: form Transsolar Klima Engineering, 2021.

Solar canopy

The pavilion, powered by 517 solar panels, provides 161 MWh of power during the expo. It is self-sustaining in the harsh desert environment, using local resources and irrigation for the extensive greenery. The pavilion's design mimics nature's power, reducing the ambient temperature by 6-10°C (M5) (M3).

SUSTAINABILITY PAVILION

Grimshaw's (Table 6) pavilion is one of three flagship structures at Expo 2020 Dubai, which opened earlier this month, a year later than planned due to the pandemic. It contains 6,000 square meters of exhibition space and sits at the heart of the Expo's Sustainability District. It promises to show visitors "how we can change our everyday choices to reduce our carbon footprint and environmental impact."

Table 6. Sustainability Pavilion information. Source: Expo 2020 - Terra 2023.

Architect	Grimshaw Architects
Theme	Nature. Nurture. Future.
Area	1,500 m²
Location	Sustainability District

Energy and water system

The pavilion's design combines natural processes like photosynthesis, optimizing sunlight, and humidity harvesting, with a 130-meter roof, photovoltaic panels, and 18 "Energy Trees" for shade (M1). The pavilion's water management system uses condensation, filtered and disinfected, mixed with desalinated water, and generates power through rooftop photovoltaic panels. It

generates clean water through wastewater, condensation, and brackish surface water—the combined usage of many sustainable resources achieves many of the region's sustainable goals (M5).

Materials

Sustainability Pavilion at Expo 2020 Dubai for having an embodied carbon footprint of almost 18,000 tons – a figure that is double the recommended level for a building of its size. Its spectacular steel canopy, shown in Figure 11, is responsible for significant, unnecessary, and harmful emissions that contribute to global warming and pollute nature (M6).

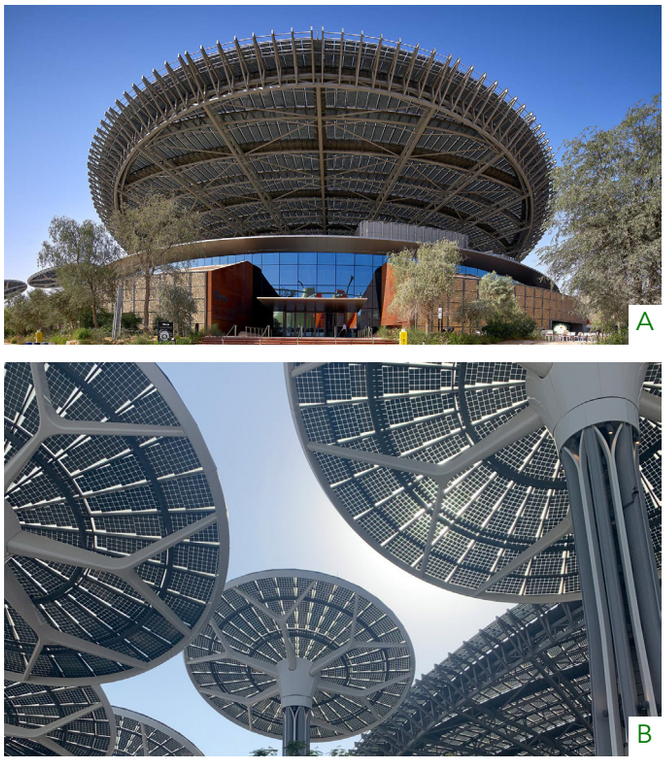


Figure 11. Sustainability pavilion exterior canopy made of steel and (B) photovoltaic trees that are nature-based in form and function. Source: Fairs, 2021; Prisco, 2021.

Form

The funnel shape shown in Figure 12 stimulates natural ventilation and brings daylight inside the pavilion. The curvature shape is a biophilic pattern, and its contribution to ventilation helps minimize cooling loads and save energy. Daylight acts as a natural element inside the pavilion and contributes to energy savings by reducing the need for artificial lighting (M5) (M4) (P2).

UAE PAVILION

The design of the UAE Pavilion evokes a falcon in flight, referencing the Emirates' traditional art of falconry. The main building resembles a titanic oval, with a grand, four-story entrance set into the tip. More than 25 feather-like panels are arranged at the dome of the pavilion, each curving down toward the structure's entrance (Table 7).

Table 7. UAE Pavilion information. Source: Expo 2022 – UAE Pavilion, 2023.

Architect	Santiago Calatrava
Theme	Introducing the UAE's rich culture and bright future
Area	15,000 m2
Location	Opportunity District

Roof design

The four-story pavilion was informed "by a falcon in flight" and is topped by a series of "wings," creating a natural shape and form for the entire building. To bring the pavilion's central theme of "falcon in flight" to life, the roof is designed in the shape of wings that portrays the flow of movement (P2). The sloped geometry of the roof and the floating wings create visual and outward connections that welcome visitors approaching the UAE pavilion from all directions, enhancing its accessibility (P5).

There are 28 wings made of carbon fiber and covered in PV panels, as shown in Figure 12. Hydraulic actuators fuel the wings' movement (M5). The entire roof can be opened in three minutes by spreading the wings, which gives the ability to adapt to change and create new options (M1) (M2). The structure protects panels from rain and sandstorms, while local sourcing and cold-forming processes minimize environmental impacts, conserving resources and enhancing local employment opportunities (M3) (M5).

Figure 12. UAE pavilion wing-like form. Source: Ravenscroft, 2021.

Spherical Center

At the center of the 15,000-square-meter pavilion is a sphere-shaped void, as shown in Figure 13, that serves as an auditorium. It is surrounded by a multi-level gathering space, with a circular skylight incorporating the Expo 2020 logo. (P2) The platform, which supports the seating, can move and transport the audience between different floors, which creates a sense of dynamic discovery while meeting functional needs (M2) (P6). The Oculus skylight is designed like the Expo 2020 logo and is located at 27.8 meters. It provides daylight inside the pavilion space, reducing the need for artificial lighting by using a sustainable light source (P4).

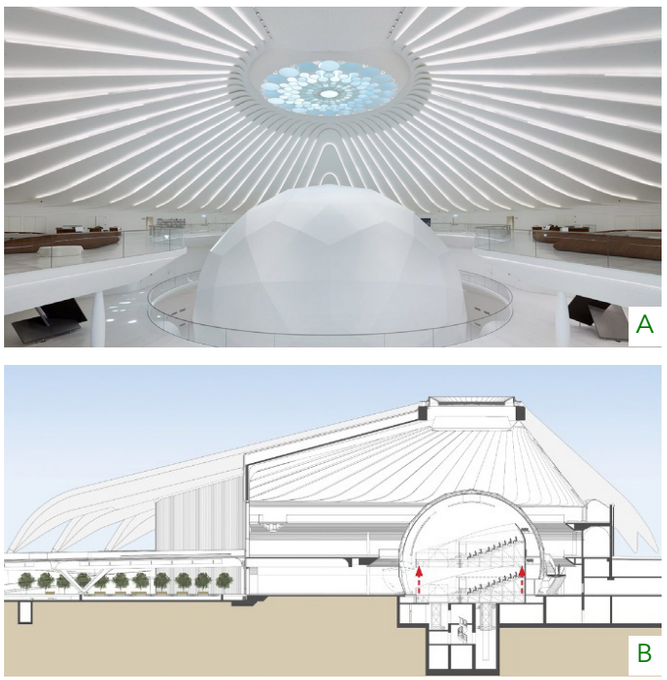


Figure 13. (A) UAE pavilion spherical core and (B) its section. Source: Ravenscroft, 2021.

Landscape

Moreover, the surrounding landscape shown in Figure 13 contains 80 trees and over 5,600 plants to ensure a biophilic environment is maintained and enhance biodiversity (P1). The design incorporates plant species not commonly used in public spaces, juxtaposing them with the falaj, an ancient irrigation system in the UAE. This geographically, culturally, and ecologically sustainable approach highlights the innovative falaj's cultural significance. (P5)

Passive cooling, ventilation, and shading strategies reduce the building's energy consumption, creating comfortable outdoor environments with shaded gardens and large pools (M3). Shaded arcades, protected by the sheltering form of the floating wings, allow for outdoor environments that are host to native and regionally adapted tree and plant species, highly functional and responsive to the region's hot climate. These passive strategies reduce energy use, especially for the prevailing cooling needs (P5).

DISCUSSION

Biophilic and biomimicry features can serve the sustainable agenda; the five cases discussed contain 60 features, each achieving 1-2 sustainable aspect(s), as shown in Table 8. This shows how integrating nature into the human-built environment can benefit the occupants and the natural environment. Future applications can attempt to cover more aspects in a strategy to promote the benefits of bio-inspired design strategies in buildings. This can be achieved by dedicated research into integrating nature's needs with human necessities. We can benefit the world and the human species by further understanding nature and how it works.

Table 8. Summary of patterns and their sustainability aspects. Source: The authors

Biophilic design	Code	No. of applications	Sustainability aspects addresses
Environmental Features.	P1	8	Energy efficiency Indoor environmental quality
Natural Shapes and Forms	P2	4	Energy efficiency Adaptability and flexibility
Natural Patterns and Processes	P3	4	Biodiversity Indoor environmental quality
Light and Space	P4	1	Energy efficiency
Place-Based Relationships	P5	6	Biodiversity Indoor environmental quality
Human-Nature relationship	P6	7	Indoor environmental quality Adaptability and flexibility
Biomimicry	**Code**	**No. of applications**	**Sustainability aspects addresses**
Evolve to Survive	M1	3	Biodiversity
Adapt to Change	M2	2	Adaptability and flexibility
Be Locally Attuned and Responsive	M3	6	Energy efficiency Water conservation
Integrate development with Growth	M4	5	Energy efficiency Biodiversity
Resource Efficient	M5	11	Energy efficiency Indoor environmental quality
Life-Friendly Chemistry	M6	3	Sustainable materials

CONCLUSION

The combination of biophilia and biomimicry in design represents a paradigm shift to peacefully integrate human and natural ecosystems. The reverence for life reveals itself in biophilic design, which smoothly incorporates nature into the structural composition of numerous buildings. Integrating sustainability concepts from the start of a project shows a commitment to harmonious relationships between built surroundings and ecological systems. This dedication supports sustainability.

Dubai Expo 2020 pavilions feature nature-inspired designs that promote sustainability and harmony with nature's beauty. Biomimetic design addresses interdisciplinary sustainability issues, promoting energy conservation and a deep connection with the natural world. Biomimicry demonstrates economic and environmental sustainability, showcasing the wisdom of nature and human inventiveness in interacting with nature.

The study examined the Dubai Expo 2020 pavilions' biomimetic application. These examples showed how these techniques may transform design through sustainability. These pavilions offered physical places and immersive experiences that reflected nature's dynamic and harmony by incorporating natural concepts and ideas.

Nature, biophilia, and biomimicry are fundamental concepts that create harmony in structures. As architects, creativity encompasses human connections, environmental sustainability, and a future where architecture becomes part of life's symphony rather than just shelter.

Authors' contribution: Conceptualization, I.I. and B.A.; Data curation, B.A. and I.I. ; Formal analysis B.A. ; Investigation, B.A. , Funding acquisition, I.I. ; Research, I.I. and B.A ; Methodology, B.A. and I.I.; Project Management, I.I.; Resources; Software; Supervision I.I. ; Validation, I.I. ; Visualization I.I. ; Writing - original draft, B.A.; Writing - review and editing I.I.e architecture becomes part of life's symphony rather than just shelter.

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