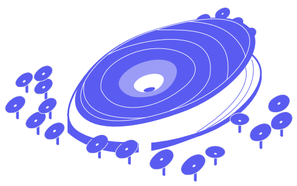
DUBAI EXPO 2020 SUSTAINABILITY PAVILION

GRIMSHAW

Location	Dubai, UAE
Completion	2020
Client	EXPO 2020 DUBAI UAE
Developer	Emaar Properties
Project Manager	T|ME (Turner Middle East)
Certifications	LEED Platinum (expected), LEED Zero – Energy and Water (expected)

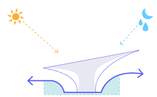
Project Partner/Lead Project team	Andrew Whalley/ Mark Rhoads Grimshaw, Rice Perry Ellis, ASGC, Buro Happold, Thinc Design, The Eden Project, Sherwood, Desert Inc., Cerami, Omnium, Emaar Properties, T|ME – Turner Construction Middle East



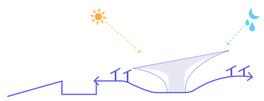
SUSTAINABILITY AND REGENERATIVE DESIGN CASE STUDY

Typical
Building above ground exposed to harsh environmental conditions

Buried accommodation
By submerging spaces, earth provides insulation reducing climate control loads



Canopy structure
Further shields building from sunlight



Landscape canopies
Additional shades provides pedestrian comfort, solar energy and atmospheric water generation

The sustainability drivers for the Sustainability Pavilion were net zero energy and water. The Pavilion is an opportunity for the U.A.E. to showcase innovations in energy generation and water management for the region and deliver an aspirational message about the natural world and technology to a global audience. Built for client Emaar Properties, this Pavilion is a permanent structure which will become a sustainability museum after Expo.

Sustainability was not just a discipline on the project, rather it was the basis of every engineering and architectural decision taken. The Pavilion explores the potential for buildings and their community of users to be both self-sustaining and regenerative - aiming to influence thousands of visitors, by empowering them to understand the environmental impacts, both positive and negative, of the choices they make daily.

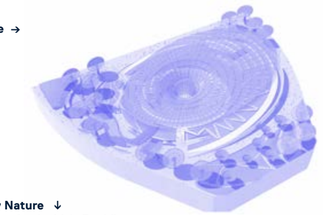
A regenerative approach shifts the focus of sustainable design from slowing down entropy, or doing less harm, to building the capacity of communities to evolve toward greater social, economic, and ecological value. Key to our design approach was developing a ranked matrix of project and place-based potential, leading the team to prioritize designs which will have the greatest potential to yield positive transformational change for our client and the communities in which the project is situated. For this project, we can point to both the combination of passive design strategies energy efficiency optimizations and on-site energy generation as well as the on-site water reuse, as the key prioritizations.

The Grimshaw sustainable and regenerative design process began with a rigorously defined performance framework composed of 11 performance areas. Within these performance areas, we defined goals and targets, building to strategies, systems, and eventually through detailed co-optimization analysis and simulation to integrated design solutions. Certain key design solutions are didactic in their prioritization of passive and low energy, low carbon systems, with an aspirational goal of becoming a net zero energy and water building.

For net zero energy, the major design challenges have been meeting the energy balance post Expo when in museum mode (also referred to as Legacy mode). This is due to the expected energy intensive program and the need to generate enough energy from the on-site PV to meet this demand. The major design challenges for net zero water were meeting the water balance in both Expo and Legacy, given the water intensive landscaping in the relatively dry environment and integrating on-site water reuse to meet the demand.

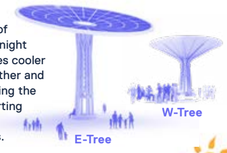
In terms of what we did differently for energy targets, we employed passive cooling by means of shading via 130m wide main roof canopy, and buried accommodation coupled with the use of high U-value materials for walls and roof, reduce cooling energy demand. This was perhaps the most significant first step in the energy reduction and optimization process. Specific to our water targets, no water from the Dubai potable water network will be consumed in operation. The Pavilion supplies 100% of its water use from on-site sources. A wide range of innovative strategies and technologies were integrated to achieve this target, including wastewater reuse and sewer mining, which have pushed code variance and approvals from the local authorities. Water usage in the region is exceptionally high and yet water is a scarce resource in the Middle East. This is a key message that the building aims to portray to visitors in attempt to improve practices in the region.

Overall Site →



Inspired by Nature ↓
The Inspiration for the Main Roof Canopy was the desert Ghaf Tree, a drought-tolerant tree, which can remain green even in harsh desert environments, essential for the survival of animal and plant species alike. The Socotra dragon tree, native to an archipelago in the Arabian Sea, is the inspiration for elements of the main canopy, the Energy Trees, and the Water Trees. Its dichotomous branching and umbrella canopy produce dense shade preventing evaporation – a critical adaptation to region's arid conditions.

Energy Trees and Water Trees ↓
The high levels of solar radiation or sunshine present a challenge and a resource for the project. The Energy Trees have been designed to produce energy and provide shade. They also have PV on the underside as reflected light hits them, maximizing the opportunity for energy generation. The Water Tree enables a passive method of dew harvesting (30 liters a day on average), taking advantage of the rapid change in temperature overnight where the inner cone surface becomes cooler to generate droplets of water that gather and run down to a collection point, irrigating the performative landscape below supporting their ecological services, including providing thermal comfort for visitors.



Key Sustainability Facts

PROJECT SITE
Greenfield - Native Desert

TRANSECT ZONE / CLIMATE ZONE
Campus zone / 1B

ECOREGION
Palearctic / The Arabian Desert and East Sahero-Arabian Xeric Shrublands

OPERATIONAL ENERGY/CARBON
- Aspirational net zero energy in Legacy mode
- pEUI: 226 kWh/m²/year or 71.6 kBTU/ft²/year (regulated loads). In order to meet the net zero energy aspirations, EUI needs to be reduced to further 180 kWh/m²/year or 57 kBTU/ft²/year.
- Reduction of pEUI from an equivalent new building: 42%
- Energy/fuel types annual energy demand carbon intensity: total site PV annual energy generation is 4.015 GWh, 100% renewable in Legacy mode.

EMBODIED CARBON
Reduction of GWP from an equivalent new building: 41%

WATER
- Aspirational net zero water in Expo and Legacy mode
- The Pavilion is a small-scale water treatment plant. It reuses water from various sources: near surface brackish surface, AC condensate reuse, grey water reuse and black water reuse. The black water reuse collects sewage from site and the external grid to be treated for irrigation.

Alignment with UN Sustainable Development Goals

SDG 6 CLEAN WATER AND SANITATION / SDG 9 INDUSTRY, INNOVATION & INFRASTRUCTURE
Net zero water design and small-scale water treatment plant introduce innovative infrastructure into the region and pilots new technologies for better landscape and architectural integration through an ecological approach to systems.

SDG 7 AFFORDABLE AND CLEAN ENERGY
Net zero energy design, canopy and E-Trees introduce an affordable integration of on-site energy generation with passive thermal comfort design for co-optimized design strategies.

SDG 12 RESPONSIBLE CONSUMPTION AND PRODUCTION / SDG 13 CLIMATE ACTION
The design team's focus on material and carbon reduction, from lightweight structures to innovative concrete reduction technologies, support responsible consumption and production goals.

Axonometric sectional diagram ↑

1. **Canopy –** The 135-metre wide canopy, which features more than 1,055 solar panels (8,000 m²), is multi-functional. Beyond harnessing solar energy and providing protection from the sun and rain, it collects rainwater, creates a micro-climate utilizing stack effect, and maintains an appropriate ambient light level in the courtyard.

2. **The Pavilion energy demand –** Generates its own power supply (a total of 4GWh of annual energy), which is partially made possible by energy saving techniques employed when designing the pavilion. High levels of air tightness and local demand-controlled ventilation provide excellent air quality whilst reducing energy consumption. Exhibition control system sensors react to occupancy, reducing energy consumption and also guiding visitors through the exhibition.

3. **Buried accommodation –** The Pavilion sits partially below ground, creating a thermal effect that means it is generally cooler than the ambient temperature. Energy is saved by burying much of the occupied spaces and providing thick, insulated walls with minimal glazing. The excavated waste was used in the landscaping around the building.

4. **Daylight –** Daylight is used where appropriate and a range of light pipe and fiber-optic systems are incorporated to provide daylight to deep spaces.

5. **Canopy shading –** The shading provided by the canopy reduces the energy consumption of the internal exhibition spaces through reducing the solar irradiation they receive.

6. **Water –** Rainwater is collected and percolated into the landscape to recharge the ground water that is then being extracted and treated for use as potable water within the building in line with net zero water aspiration. Throughout the exhibit experiences visitors will learn about the importance of ocean and coastal systems' health, access to healthy freshwater and drinking water, reduced snow melt and drought, the impact on farming and production systems, and increasing desertification. In response to these challenges, the Pavilion demonstrates technologies and approaches for efficient and sustainable water use captured through the message of this net zero water building. The Pavilion supplies 100% of its water use from on-site sources. It treats 100% of its wastewater, captures and infiltrates 100% of storm water, uses a district-scale strategy to mine wastewater from neighbors for treatment and reuse on-site and even uses water trees to capture water from the air.

7. **Ecology –** Integrated into this landscape of native and adapted species are new crops which provide food and biofuel. These food crops are being developed for arid climates that could contribute to the future food security in the region. The aesthetic planting provides stability for the fine soil, enabling the landscape to endure short, heavy periods of rainfall. Alongside the crops and aesthetic plantings lie constructed wetlands, reed beds processing the wastewater streams generated by the people and processes of the Pavilion.

8. **Energy Trees –** Eighteen E-Trees, which support a smaller axially rotating PV array dish on a long stem, provide an additional 4,000 m² of solar PV, approximately 2.6 GWh of power annually.

9. **Comfort –** Due to its high thermal mass the earth below ground is generally cooler than the ambient temperature during the occupied periods. The creation of sunken circulation routes improves thermal comfort by exposing occupants to this cooler sunken surface. As the day progresses the wind swings clockwise from south-easterly night breeze. The orientation of the riverbed area is designed to trap the cool air brought in overnight whilst the warm winds blow over the top so keeping riverbed temperatures below ambient into the day.

10. **Night cooling –** Low landscaping to the south-east of the site maximizes inflow of cool night air. This cools the thermal masses of the site and preconditions external spaces.

11. **Canopy materials –** The canopy is constructed from steel with 97% recycled content. To further lower the Pavilion's carbon footprint associated with the transport of materials, the steel elements were manufactured less than 15 minutes away. The primary steel of the canopy is topped by secondary steel catwalks that double as water collectors, at every other hoop, with photovoltaic panels sitting in between. The complexity of the design required the team to go beyond the common approach to collaboration, and apply complex computational methods, which included geometric algorithms that could coordinate and optimize both the architecture as well as the structural solution.

12. **Cement and embodied carbon reduction –** Strategies to reduce the use of cement included constructing approximately 10,900 m² of the upper floors with bubble decks, which uses approximately 25% less concrete and subsequently less steel compared to a solid concrete slab construction. These voided biaxial slabs, are a type of reinforced concrete slab which incorporates air-filled voids to reduce the volume of concrete required. These voids enable cheaper construction and less environmental impact.

13. **Education –** The design for each exhibit area encourages learning that can happen as part of school groups and other organized uses, particularly for Legacy. There are spaces to gather and talk with a leader or teacher. The whole experience, starting in the auditorium is designed to engage and educate visitors. Aspects in relation to the materials, systems, and resource use of the building. Resource use will be displayed throughout the museum connecting people with the current building demands and how these demands are being met.