ORA House: An Ecosystemic Approach to Design of a Net-Zero House for the Middle East

SHAMEEL MUHAMMED
Heriot Watt University

A net-zero residential unit for a harsh climate condition as that of the middle east is a challenging goal. With temperatures rising to 50-degree celsius during peak summer, in addition to occasional dust storms and high humidity levels, achieving a desirable indoor comfort condition require architects and engineers to break away from the conventional design strategies and look for innovations in spatial planning, materials and building technology. In hot arid climate regions, there is a heavy reliance on efficient air-conditioning to achieve optimum indoor comfort condition. When it comes to achieving energy efficiency in building performance in the middle east, strategies to reduce the cooling load is a crucial factor the dictates design decisions.

ORA house is a net-zero residential project that was designed and build for the first-ever Solar Decathlon Middle East 2018 (SDME). The international competition open to universities was organized by Dubai Electricity and Water Authority (DEWA) of the United Arab Emirates in collaboration with the Department of Energy - United States of America. The rules of the competition were adapted from the previous versions of solar decathlon held in U.S and Europe. An essential requirement set by SDME 2018 was to design highly efficient, sustainable, grid-connected solar-powered houses that can sustain in the extreme Middle East climate. The ORA House project was led by a multidisciplinary team of students and faculty of Heriot Watt University, Dubai. The project was developed over one and a half years in collaboration with key industry partners.

Figure 1. ORA House - South Elevation. Image credit : Shreya Sathyanadhan

Figure 2 ORA House - Wesr Elevation. Image credit : Shreya Sathyanadhan.

Many projects showcased in various Solar Decathlon competitions have addressed integrated design and its relevance to the design of a sustainable house (Zhang et al. 2014; Wang et al. .2013; Peng et al. 2013; Battista et al. 2015). In most cases, the focus is on the effective integration of particular technology, especially solar photovoltaic panels, to the architectural and spatial design. ORA house, too, to a large extent, has achieved this in its design proposal. Amongst many novel aspects, the overall approach to the integrated design and team functioning is worth highlighting.

A key design strategy for the ORA House was the conception of its name. Inspired by the model of a natural ecosystem such as a desert oasis, 'ORA' is an acronym of 'Organic', 'Resilient' and 'Adaptive' that represents three separate ecologies. These ecologies come together, forming a synergy whereby the independent systems are designed to operate in a symbiotic relationship with each other. While the 'Organic' ecology comprises of all the passive design strategies, 'Resilient' ecosystems addresses the active design systems employed in the ORA House. 'Adaptive' ecosystems recognize and facilitate the requirements of a multi-cultural and diverse population of UAE while adapting to changing weather conditions.

The design approach significantly improved the building performance and efficiency in comparison to the previous design iterations put forward by the team. Simultaneously the adoption of an eco-systemic design approach gave the young multidisciplinary team of undergraduate students a successful modus operandi. The team was able to establish an effective communication platform whereby both the part –individual and discipline as well as the whole –team and house, could co-exist with each other. This eco-systemic design approach helped the team to investigate the independent and overall impact of individual systems. Conventionally, what we witness in practice is a linear process, whereby the lead designer or engineer would have to adapt/modify following the other. The eco-systemic design approach has helped explicitly in defining the overall team strategy and has facilitated innovative approach to key challenges of the project, such as the lowering of the cooling load of the ORA house

The 'Hybrid Barjeel' an adaptation of the vernacular wind catchers from desert architecture is one of many components that has resulted out of the eco-systemic design approach. The prevailing hot air from the north-west or south-west channels into the west-facing Hybrid Barjeel with the help of Ghaf and Olive trees placed on the west side of the building site.

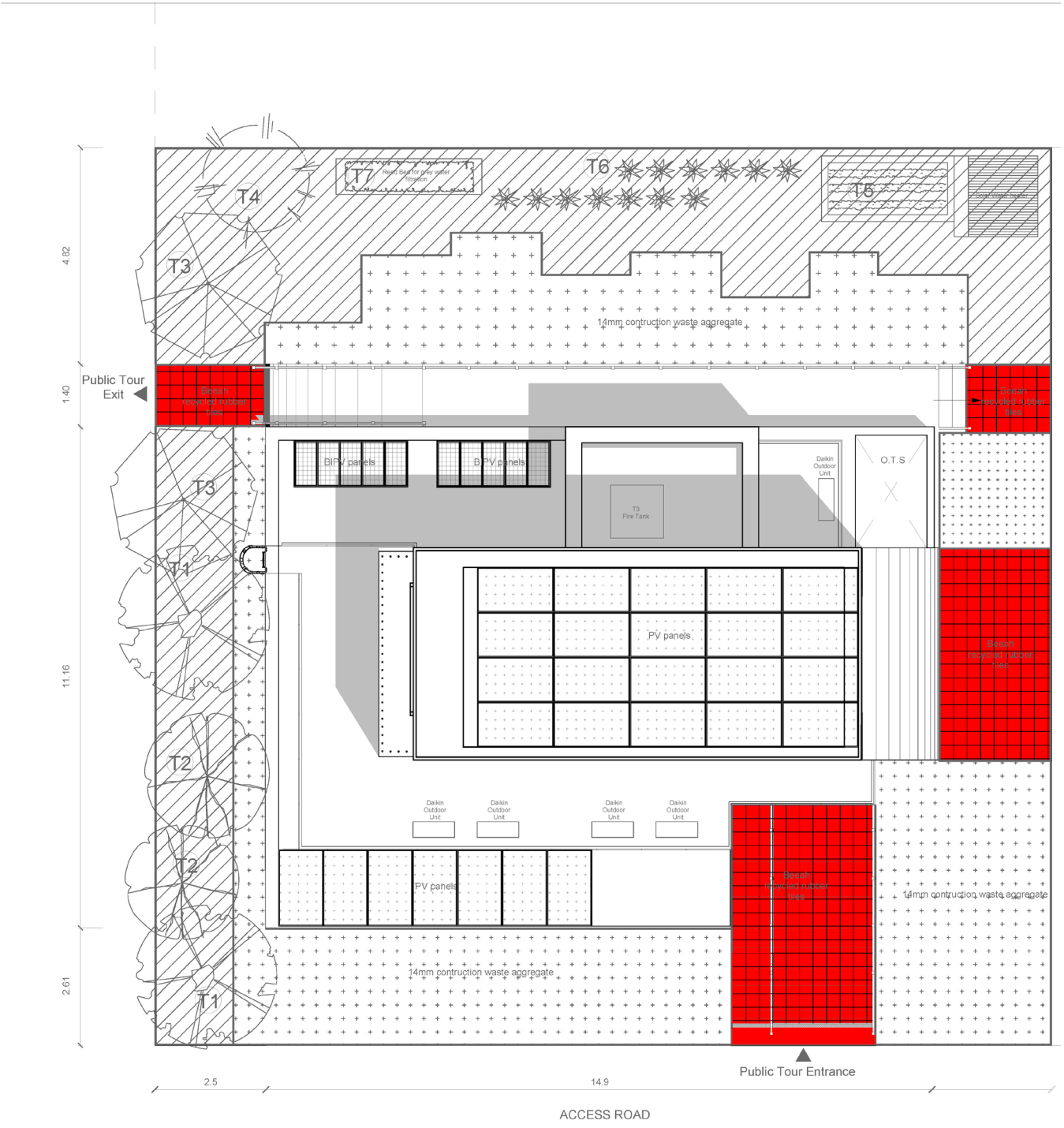

Figure 3. ORA House Site plan

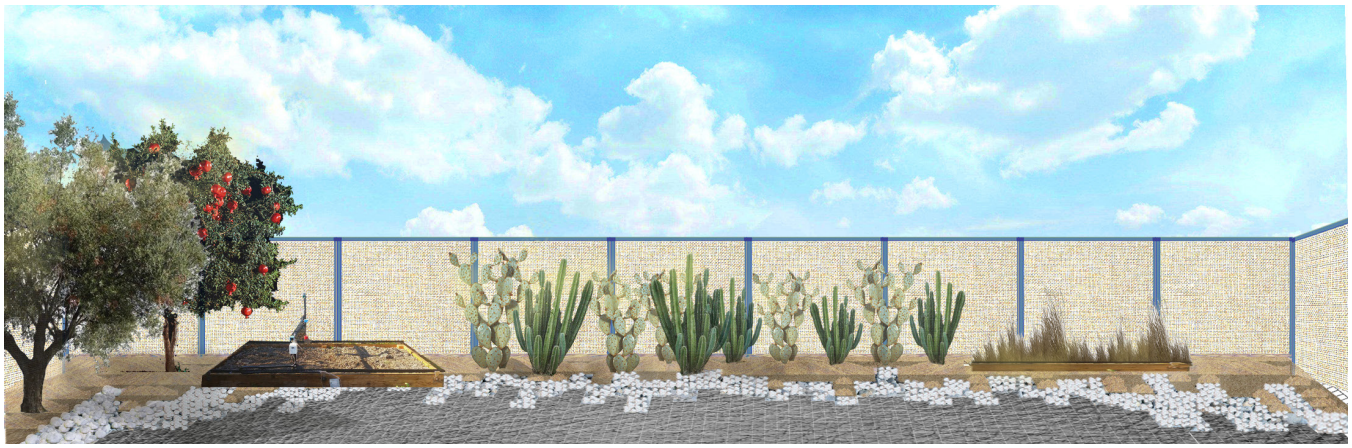

Figure 4. Landscape Design - Organic Ecosystem

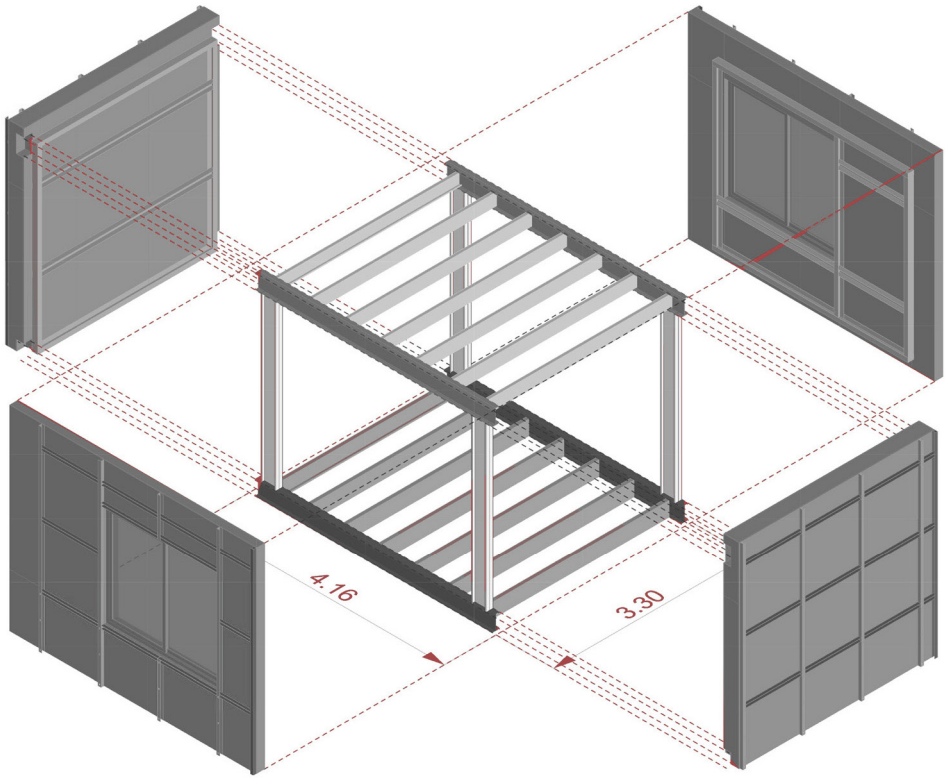

Figure 5. Spatial and Structural Module - Adaptive Ecosystem

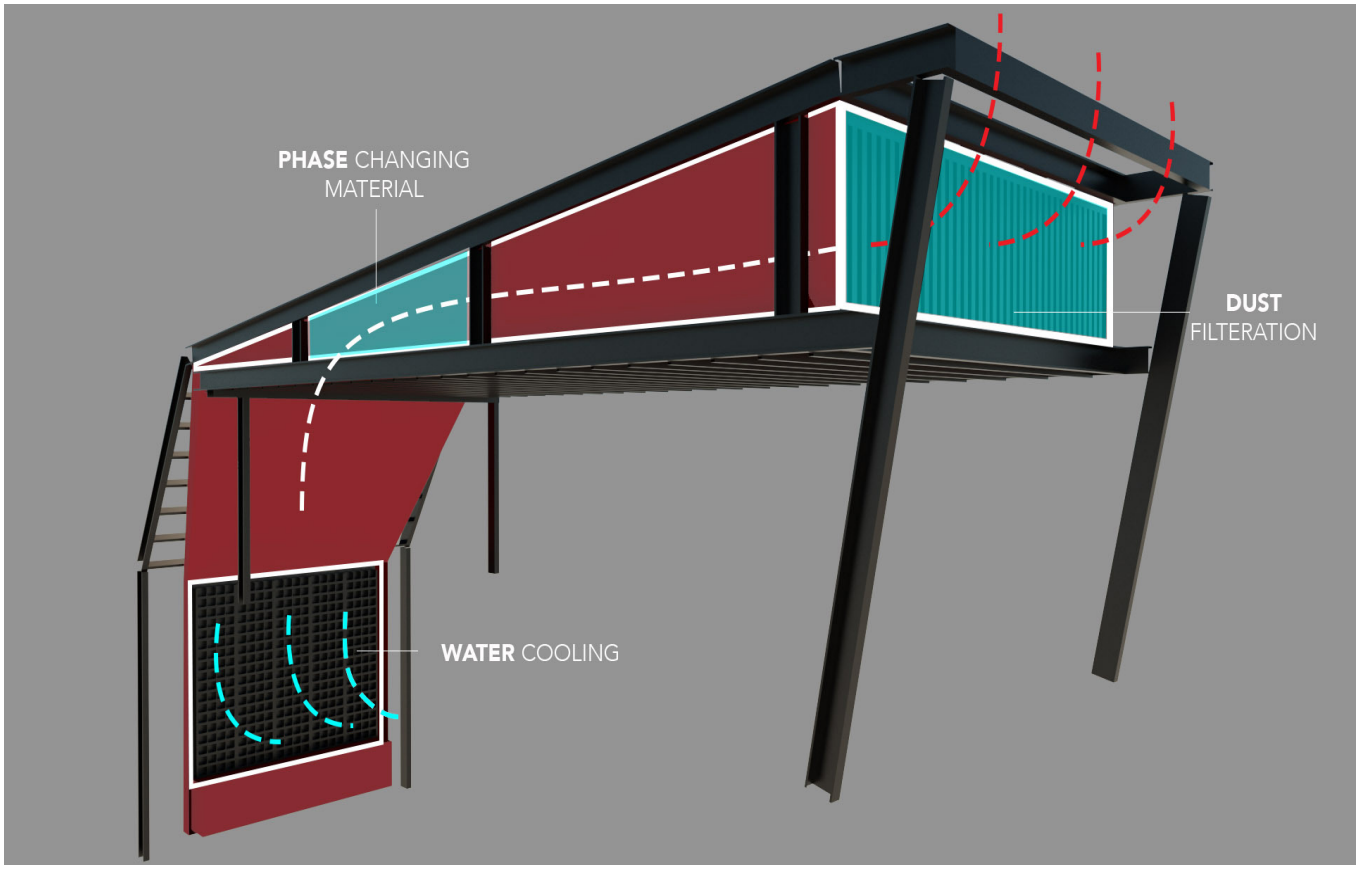

Figure 9. Hybrid Barjeel. Organic and Resilient Ecosystems

The landscape design, as part of the passive system (Organic), facilitates in dust filtration and cooling of the incident wind. The dust filter installed at the mouth of the Hybrid Barjeel tackles harsher conditions such as a sand storm. The overall horizontal geometry of the barjeel is designed to give a funnelling effect, thereby increasing the incident velocity of the prevailing wind. The air channel then passes through a chamber of phase-changing material that can absorb the heat due to its chemical property. The incident wind, therefore, cools down before reaching the roots of an interior hydroponic green wall with NASA graded plants which aid in improving indoor air quality by absorbing carbon dioxide and other toxins. The pre-cooled air then enters a vestibule from where the resilient and highly efficient HVAC system takes the air for heat exchange and circulation. Along the section of the barjeel, sensors inform the intelligent BMS system to adapt and optimize the HVAC system according to user needs and performance targets. The organic cooling of the incident air by an ecosystem of passive systems, the resilient HVAC design, along with an adaptive BMS system, effectively lowered the overall cooling load requirement of the ORA House.

Along with many other design components, the adapted version of the barjeel in ORA house is a promising design concept for the Middle East. The actual evaluation of its impact on cooling load and energy efficiency is yet to be determined. Further studies would require extensive data collection, which in turn could also lead to design improvements for better efficiency and performance.

ORA house did well in SDME 2018 contest by taking fourth place in the 'Sustainability', fourth place in 'Innovation in Architecture' and fourth place in 'Innovation in Engineering and Construction'.

ACKNOWLEDGEMENTS:

The author would like to acknowledge the Project Student Team: Sarah Asif, Amro Mansy, Leander Joseph, Asidha Siddik, Muskan Mardia, Noor ul-Ain, Shreya Sathyanadhan, Antony Vighin, Karim Fahmy, Devasri Jaganathan, Faisal Razzak, Rinku David, Akshaya Sankaran, Lue Xiong, and Harikrishnan Thangamani.

ENDNOTES

1. Gabriele Battista et al., "Energy Performance And Thermal Comfort Of A High Efficiency House: Rhome For Dencity, Winner Of Solar Decathlon Europe 2014," Sustainability 7, no. 7 (2015): 9681-9695. DOI: 10.3390/su7079681
2. Changhai Peng et al., "Design and practical application of an innovative net-zero energy house with integrated photovoltaics: a case study from Solar Decathlon China 2013," Architectural Science Review 58, no. 2(February 2015): 144-161. DOI: 10.1080/00038628.2015.1011075
3. Hong Zhang et al., "Integration of Sustainability in Net-zero House: Experiences in Solar Decathlon China," in Energy Procedia Volume 57, ed. Alvaro Lentz, David Renné (Amsterdam: Elsevier, 2014), Pages 1931-1940. DOI: 10.1016/j.egypro.2014.10.057
4. Shaosen Wang et al., "The Passive Design Strategies and Energy Performance of a Zero-energy Solar House: Sunny Inside in Solar Decathlon China 2013," Journal of Asian Architecture and Building Engineering 15, no.3(2016) : 543-548. DOI: 10.3130/jaabe.15.543

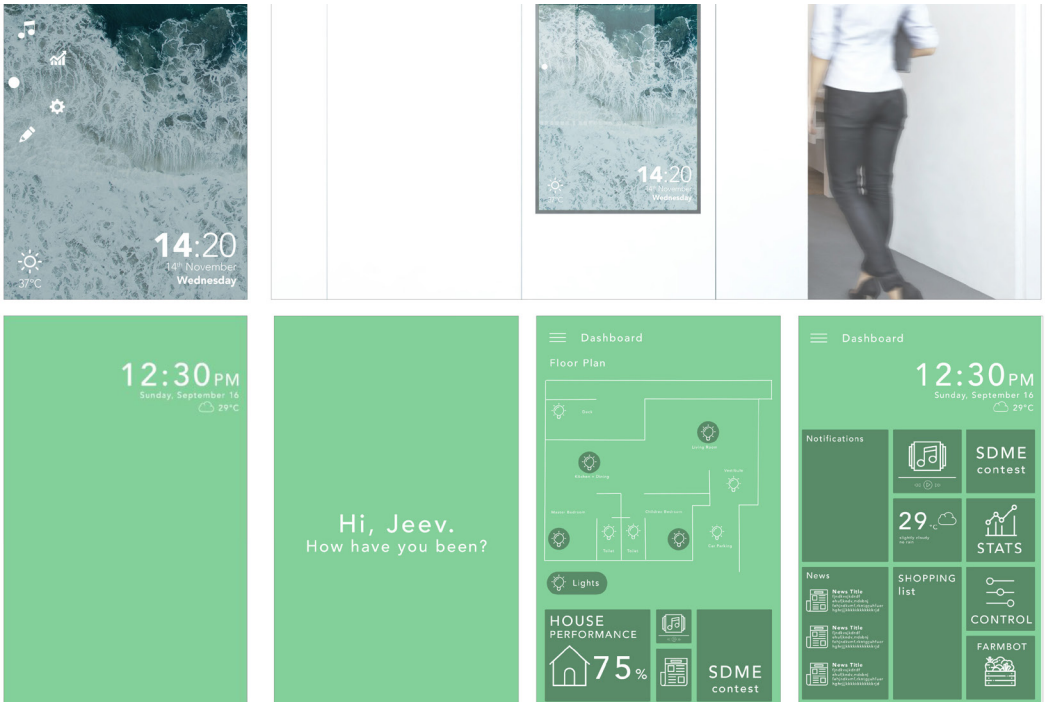

Figure 9. ORA UI. Adaptive Ecosystem

Figure 10. Vestibule area - ORA House - Precooled zone. Image credit Faisal Razzak.