Designing for a Resilient Planet

Ken Yeang
Executive Director, T.R. Hamzah & Yeang Sdn Bhd

Our architecture, besides fulfilling their design functions, can be regarded as life-size experiments in our endeavours to seek solutions that address the current environmental crisis. The work is nature-based and founded on the science of ecology. Why ecology? The reason being the future viability of life for all species (including humans) on the planet is linked to sustaining the resilient ecological health of the planet.

In earlier years, our work sought to make minimal negative impacts on nature, but today with humanity's extensive deleterious acts on the planet's ecology, our design has to become a race and rescue mission.

Each project for us seeks to further advance and provide guidance for addressing aspects of the current environmental crisis, such as loss of biodiversity, ways to avoid reduction of fragmentation of the natural landscape and to enhance ecological nexus, delivering net zero to surplus energy solutions and others.

Underlying the work is an ongoing research framework. The culmination is the fostering of further research enabling our design work to progress and advance the field of endeavour.

Ecological design is the bio-integration of a set of five key factors into built form, being: nature, human society, built systems, energy systems and water systems. Ecological design seeks to synergistically bio-integrate these factors with the aim to achieve positive ecological outcomes and avert irreversible negative impacts.

Firstly, design starts with nature—that is the originating context and baseline upon which all the other factors must benignly and synergistically integrate and upon which all human acts, activities and its built environment take place.

The planet earth is surrounded by a thin film that is the biosphere. It is approximately 20 kilometres high and within this biosphere are units in nature—ecosystems—that comprise of both biotic and abiotic constituents acting together to form unified wholes interacting with the planet's biogeochemical cycles.

The key factor to bio-integrate with nature is our human society and its social, economic, political and institutional systems. Humanity's acts and activities have extensively impacted nat ure. Human societies determine what and where its built systems are constructed. Designing for people must engender well-being and create a happy and healthy society and a healing environment.

Another crucial component for bio-integration is human society's built environment with its structures, infrastructures, its mobility systems, its various production systems (including products of energy and food), its water reticulation and management systems, and other technological aspects including its cyber networks and the production of the multitude of artefacts that humans make, where design must strive for net zero waste and net zero emissions (gases, solids, particulates and liquids).

A further key factor to be bio-integrated is the production of energy that powers human society's activities, its built environment, its mobility and other systems. The energy needs to be renewable to achieve net zero emissions surplus energy, zero carbon and with built systems that have low embodied carbon.

The final factor for biointegration is the built environment's water management systems that require integrating with the planet's hydrological cycles to achieve net zero water, maximising reuse, recycling and conservation. Design needs to regard potable and clean water as a resource to be conserved.

Ecological design requires all these multifaceted and diverse factors to be comprehensively and seamlessly brought together into a designed system, while eliminating any adverse impacts on the natural environment. Successfully achieving this bio-integration both physically and systematically is, of course, easier said than done. This then is the challenge inherent in ecological design.

Humans—just one of the species in the planet—are the most powerful of all species. Humans possess the ability to radically alter landscapes and change waterways, impact and simplify the planet's biomes, reduce its biodiversity with species loss, cause extreme global climate conditions and effect a multitude of other callous environmental impacts.

Humans make large volumes of artefacts. In effect, humans make more artefacts than any other species in nature. But after a brief period of use, humans throw these artifacts away. The biosphere being a closed systems has no 'away', and the used and unwanted items clutter up and contaminate the planet. Ecological design must ensure that all built structures and artefacts avert this end outcome and are made for long life or for reuse or continuous recycling.

The planet's current environmental crisis can be viewed as caused by the discrepancy in the interface between human-made items with nature. The interface is where the synthetic human-made items and built environment impact nature's biological and physical systems, where the material, physical and operational discrepancy in this interface is the cause of the current environmental crisis. The current built environment is mostly abiotic, inorganic and physical, whereas nature consists of biological systems (with biotic and abiotic constituents). It is this ineffectual interface of content and functions between the built environment's components, processes and emissions with nature and its processes that is the cause of the current environmental crisis.

The proposition in ecological design to redesign and to remake our built environment to become nature-based systems as hybrid biological entities, as 'human-made ecosystems'- Being nature-like can effectively interface and bio-integrate with nature in a 'nature-to-nature' basis, enabling a seamless and benign relationship of the built systems with nature in as much as achievable. This then is the fundamental underlying principle for ecological design, requiring the repurposing and the remaking of the existent built environment into hybrid ecosystems. This is achieved by the biomimicry of the 'ecosystem' (as a concept from Systems Ecology) and its properties.

The process of biomimicry requires designing to replicate (reproduce), or to emulate (copy) or augment (collaborate) the built environment with ecosystem attributes.

This design process starts with identifying the key ecosystem properties for biomimicry. The crucial immediate ecosystem attribute to replicate by the existing built environment is the biological structure of ecosystems. The biological structure of the ecosystem consists of both biotic and abiotic constituents acting together to form a whole system. It is then evident that the existing biological structure of the built environment consists of mostly inorganic elements. Ecological design needs then to physically and systemically integrate biotic constituents as habitats into the existing or in new built environment.

We can identify the key patterns for integration of biotic constituents as habitats within the built form as centralised, dispersed, stepping-stone, spine and spiral pattern.

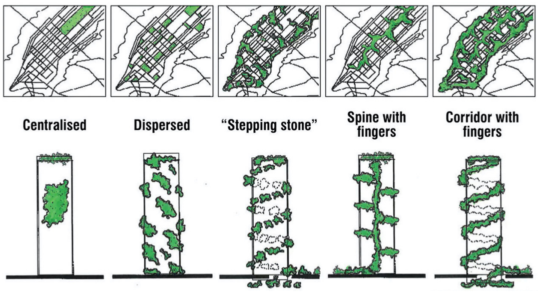

Figure 01. Five biological patterns developed to emulate, replicate and augment ecosystems in our built environment

Figure 02. Menara Boustead tower, Kuala Lumpur, Malaysia, 1986

The centralised pattern is the consolidating of all biotic elements in a centralised location. This is not preferred as the habitat is not linked to the ground plane and has little or no opportunity to be connected to other green built systems and neither can it be linked to its green hinterland.

Another pattern is the spotty pattern with dispersed relationships. Again, the habitats are not linked with each other or to the ground plane with few opportunities for species movement and interaction between the habitats, and there is no opportunity to be connected to other hybrid-built systems and to its green hinterland. An earlier design attempt in putting vegetation in buildings is the use of the dispersed pattern combined with skycourts in Menara Boustead.

There is the stepping stone pattern, enabling better opportunities for certain species to move between the habitats in the built form. Another pattern is a vertical spine with fingers extending to the green pods or sky courts.

The ecologically preferred pattern is the spiral intertwining configuration. The habitats being interconnected, transform the vegetation into a single large, interconnected habitat that has a greater pool of natural resources to be shared among the species within the habitats, which engenders a more biodiverse population and, consequently, a more stable habitat.

A further crucial ecosystem attribute to emulate is the ability of ecosystems to provide ecosystem services. Ecosystem services are functions that ecosystems perform for the planet without human intervention. Ecosystem services include photosynthesis, the internal recycling of materials, the purification of water, the sequesting of aerial pollutants, symbiosis (between species), production of food, undergoing succession and others. These are some of the ecosystem attributes that design should strive to replicate to transform the built environment into human-made ecosystems.

Humans, in their acts on the planet, fragment ecosystems, dissect and partition the natural environment with such structures as fences, roads, drains, impervious surfaces and other structures. These inhibit species movement and interaction across the urban landscape. Ecological design needs then to restore and repair the fragmented ecosystems with greater connectivity, to enable species interaction extending across the ground plane with a seamless connection, to further connect up the built form with the links that could extend horizontally to its green hinterland.

In a scheme, we explored the idea of the vegetated ramp as a habitat that is like a vertical linear 'park-in-the-sky'. The concept envisioned a vegetation ramp circulating around the building's periphery, extending from the ground plane to the top of the building linked to other green built systems. The aspiration was for the building

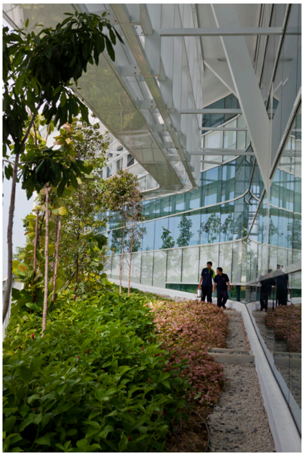

Figure 03. Figure 04. Solaris building, One-north, Singapore, 2010. Left: The spiral, vegetated ramp on the exterior of the building

to serve as a catalyst for urban greening, facilitating the greening of the city, where as the vegetation spiral reaches the roof level of an adjacent buildings, it bridges across to the adjoining roof which is then greened. The building becomes then a device for progressively greening the city.

Connectivity is a crucial attribute in designing for ecological nexus. This enables design to repair fragmented habitats and ecosystems that humans have chopped up. We must exercise caution on how we lay out built systems on the landscape to not cut up the ecology of the land. Urban development contributes to significant destruction of ecosystems and habitats and to repair this we must reconnect fragmented ecosystems as much as possible.

We sought to further develop the vegetated ramp concept to have adjoining walkways placed at the façade, providing access by the walkway for maintenance of the habitats without traversing through the internal user spaces. This device was materialised in the Solaris building that features a spiral, vegetated ramp leading to a mid-level garden and further to a garden at the top of the building, with mini-plazas located at the corners, facilitating communal activities within the floors. If we are to stretch out, the ramp would be 1.3 kilometres long, probably the longest vertical linear park in the world. The built form comprises two blocks wrapped by the facade. Bridges connect the two blocks, and between them is a mixed-mode atrium with an operable glass-roof, allowing mixed-mode cooling (non-air conditioned) on non-inclement days. Sensors automatically close the glass louvers in inclement weather.

Another experimental feature is the 'diagonal light shaft', which is a shaft cut-out diagonally across the floors allowing visual connection from the street level to the upper parts of the building.

The 'eco-cell' is another experiment in the building. It is a device facilitating the extension of vegetation from the ground floor to the basements. At the base of the eco-cell is a 'bioswale', but ideally a 'living machine' (the type by John Todd) that functions as a biological wastewater treatment plant.

Ecological design as an approach seeks to create habitats within buildings that can be green roofs, vertical green walls, green sky courts, green atriums, green patches and patches at ground level and other adjoining green areas. To assist in designing for biodiversity, we prepare a 'biodiversity matrix' to select appropriate flora species to attract selected fauna species to enhance the building's biodiversity. Once the locations of the habitats are established in the built form, we populate them with flora species that attract selected non-invasive indigenous fauna species to specific targeted habitats. We then examine the interaction between the species at the various habitats in the built form. This provides the foundation for designing the conditions in the habitats to transform the entire building into a 'living system' as a constructed ecosystem. This, in turn, contributes to the biodiversity of the locality.

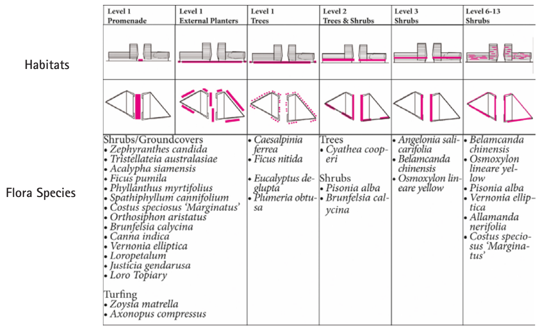

Figure 05. Example of a Biodiversity Matrix, created to identify species and habitats within development to enhance local biodiversity, 2023

Suasana PjH is project that demonstrates these principles is a scheme comprising of two mixed-use blocks that are nearly symmetrical chevron-shaped blocks, with a promenade that runs between the two blocks in an axis to the waterfront. The decision to split rather than join the two blocks into a single large complex was to preserve this axis from the plaza to the waterfront. Departing from the appearance of a Modernist building, we shaped and faceted the built form's facade using the metaphor of a 'gem'. A 'songket' pattern, (derived from a Malay fabric) was incorporated to signify the cultural identity of the locality. The facade is a series of fritted-glass panels with an air gap in-between each panel that function as a double-skin. This outer skin is faceted while the inner skin is vertical in order to not affect the internal office space layouts. Approximately 50% of the outer skin is clear, allowing ample natural light and serving as an experimental

Figure 06. Suasana PjH building, Putrajaya, Malaysia, 2017

sunshade. The west side, exposed to the warm sun, is angled to protect the facade from excessive solar insolation.

The building's energy intensity is measured at 136.18 kw.hr/sqm/annum, a significant reduction compared to the average office building at 2.90° latitude, which is approximately 210.52 kw.hr/sqm/annum. The project is an experiment exploring an alternative to the conventional horizontal louver sun-shading through the use of fritted-glass. This works in reducing the energy intensity of the building by at least 40%.

The eco-cells in this structure further extend vegetation from the habitats at the third floor continuously down to the basement. The eco-cells promote better integration of greenery, facilitate rainwater harvesting, enhance natural ventilation into the building's inner areas and provide opportunities for daylight penetration.

This project served as an experiment for addressing biodiversity enhancement in a medium-rise built form, but what about in a high-rise built form? In a project (currently under construction), we employ the 'tree with fingers' habitat pattern. Habitats are strategically created considering the surrounding local ecology to determine which non-invasive flora species will attract selected fauna species (invertebrates and birds). The lower floors house a green wall zone for invertebrates (dragonflies), followed by the butterfly zone, then the songbird zone, and finally the migratory bird zone at the upper parts. The biodiversity matrix is used to identify the targeted bird species and the flora species that will attract them.

Figure 07. Skylon building, Kuala Lumpur, Malaysia, under construction

For example, a green index (in Singapore) quantifies the amount of vegetation in a building over its footprint on the land area.

Figure 08. La Reunion Masterplan, La Reunion, France, 2013

The minimum requirement is a score of 6, but this building achieves an index of 12.2, being twice the minimum required by the local green rating system. As an overall design strategy, we should always strive to surpass the green rating system's criteria.

One of the properties of ecosystems to be emulated and replicated is the provision of ecosystem services. Ecosystem services is a term coined by ecologists (around 2000), to encompass the functions that nature performs for the planet without human intervention. Increasing the biotic content of our buildings for phytoremediation is one aspect (as seen in the Solaris building) where the design extends the vegetation ramp from the ground floor to the roof level.
In this design, although the extended vegetation is beneficial, it is not entirely satisfactory.

While it is technically feasible to technologically emulate the way nature produces oxygen and sequests pollutants and other ecosystem services, it is technically problematic to perform these at the scale that nature achieves it. Instead of replication, the design solution can juxtapose the biotic constituents as 'green fingers', adjoining the urban realms and weaving nature within the built environment as a series of green strips to augment the provision of ecosystem services into the urban realms (such as in the La Reunion Island project, east of Madagascar). The masterplan design starts with collecting the species at the existing green spine along the waterfront and interweaving the green fingers extending from the linear vegetated spine at the seafront towards the hinterland. To maintain continuity in the green strips, we introduce 'eco undercrofts,' where the greenery goes underneath the roads. Augmentation is one method to provide ecosystem services by the collaboration of greenery in close proximately to the urban realms.

Figure 09. Soma Masterplan, Bangalore, India, 2008-ongoing

Another key ecosystem service to bio-mimic is how nature cleans and provides pure water. In a masterplan project (in Bangalore, India), we created a mixed residential and commercial development located next to a forest reserve. We introduced a vegetated spine adjoining the forest reserve to collect the species then extend vegetated fingers across the site. These reconnect the forest reserve habitats and

Figure 10. The EDITT tower, Singapore, 1998

species to the green areas in adjacent sites and reinforce the locality's ecological nexus. The water distribution system incorporates detention ponds to manage surface water and adopts constructed wetlands to treat black water (that progress through a series of polishing ponds from settling ponds, wet woodlands, treatment marshes and a final pond). By the time the water reaches the last pond, it is nearly clean, demonstrating a natural method of waste-water treatment that does not rely on external energy sources. In addition, 'ecobridges' (a reverse of the earlier eco-undercoat) were implemented in the masterplan allowing vegetation to traverse over roads without bifurcation.

Nature harnesses solar energy to sustain ecosystems but, in contrast, the existing built environment is dependent mostly on the use of fossil fuels. Acknowledging the need to reduce fossil fuel usage and to achieve net-zero to surplus energy and net-zero carbon environments, we advocate an approach for design as a progression series of design steps. Starting firstly with optimising passive-mode design through to optimising mixed-mode design options, through smart full-mode design to productive-mode design. Productive mode involves producing non-grid energy.

Designing for passive-mode low-energy requires adopting bioclimatic design principles, incorporating strategies like appropriate orientation, building configuration, facade design, optimising ambient energies, natural ventilation optimisations and others. This is followed by mixed-mode using partial mechanical systems (such as ceiling and side-throw fans) to enhance comfort conditions. Full mode (mechanical) systems must be smart and highly efficient with low embodied carbon content. Productive mode entails producing one's own energy leading to surplus-energy and decarbonisation.

We can illustrate how this could be implemented in a tower project, as was the case for the EDITT Tower in Singapore, in which we show how the core position of the building can contribute towards a lower energy building. We locate the core on the east and west sides to reduce its energy consumption as the ideal configuration for the high-rise building form at the Equator.

Another example is the use of the 'umbrella' concept, that is strategically positioned to shield it from solar insolation and inclement weather. The Roof-roof House (1985) further illustrates a passive-mode approach as an experiment using a louver-umbrella, resulting in lower energy consumption compared to the traditional residential building.

The 'umbrella' is an effective 'cybernetic' concept because if the sun comes from another side, the umbrella can move to that direction. My go-to challenge is then to design a building which has an umbrella canopy that automatically shifts and adjusts depending on the climate conditions and the direction of the sun, wind rain and snow at any given time of the day.

Figure 11. Great Ormond Street Hospital for Children NHS Trust extension project, London, United Kingdom, 2012

Figure 12. The Roof Roof House, Kuala Lumpur, Malaysia, 1984–85

In a mixed-mode design approach in the temperate climatic zone, the aim is to extend the comfortable mid-seasons (spring and autumn) into the winter and summer periods through natural ventilation, reducing the need for cooling in summer and heating in winter. In the Great Ormond Street Hospital Extension project, London, the design has a glass-flue placed on the building's facade that controls the air circulation in the lower floors by regulating valves at the top and at the bottom of the flue.

Productive mode energy systems mean that we generate our own energy. In a current project (PV Roof for Net Zero Design), under construction), we put photo-voltaics on the roof in an extended overhead panel to enable the building's common areas to be energy independent by acquiring enough solar energy. The building has a double-skin brickwork, and a green facade on the south side.

Figure 13. PV Roof for Net Zero Design, Malaysia, ongoing

We designed a building that becomes entirely a power-station that generates and supplies energy not just to itself but to others in its locality. The idea is where the entire building is covered with embedded photo-voltaics glass to produce its own energy.

We need to further design for net zero waste and zero emissions and to reuse and recycle materials to emulate one of the properties of the ecosystem. The built environment produces waste outputs of heat, solids, gases and liquids. We must design to ensure these outputs are reused, recycled, reconstituted and eventually reintegrated benignly back into the biosphere.

To be effective, designing for recycling has must be done at a citywide scale. We designed a scheme using recycled materials (in Berlin) in a building where it's waste materials from its facade and

Figure 14. BSR Building, Berlin, Germany, in design stage

structure go back to the city's Recycling Centre that accumulates recycled materials from the city for reuse and recycling.

In an ideal situation, we must design our built environment and its system to perform self-corrective action to monitor and regenerate any deleterious impacts on the planet. To achieve this, we need to use intelligent systems and sensors to globally monitor the planet's natural systems so that we can take immediate corrective action to repair and regenerate the affected areas that are in danger of being impaired.

In summary, the principles presented here are twofold. The first is eco-centricity, which is designing based on the science of ecology and the second is eco-mimicry, which is designing to remake the built environment as human-made ecosystems by replicating, emulating and augmenting ecosystem attributes to interface with nature on a nature to-nature base.

Our human society, encompassing its social, economic, political and institutional systems, further poses a crucial challenge for ecological design. To be truly effective, our ecological design endeavours require not only our designing and remaking the built environment, but also instigating behavioural changes in human society to adequately address the impacts of human acts and activities and the built environment on the natural environment. This necessitates a collective commitment by all of humanity to sustainable practices. This then is part of the challenge for us to fully address the impacts of human acts and activities and that of its built environment on the natural environment for a sustainable and resilient future for all life on the planet.