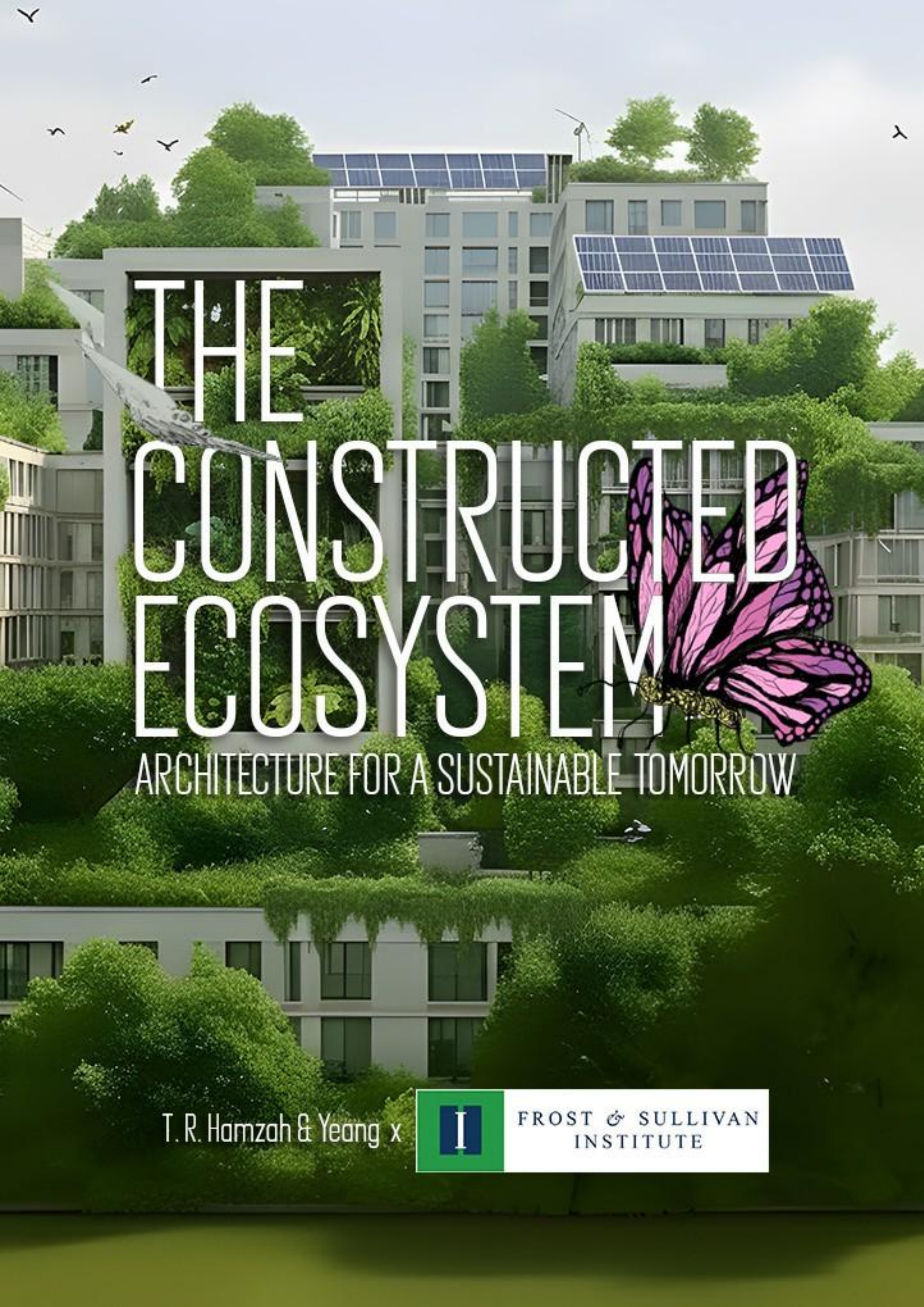


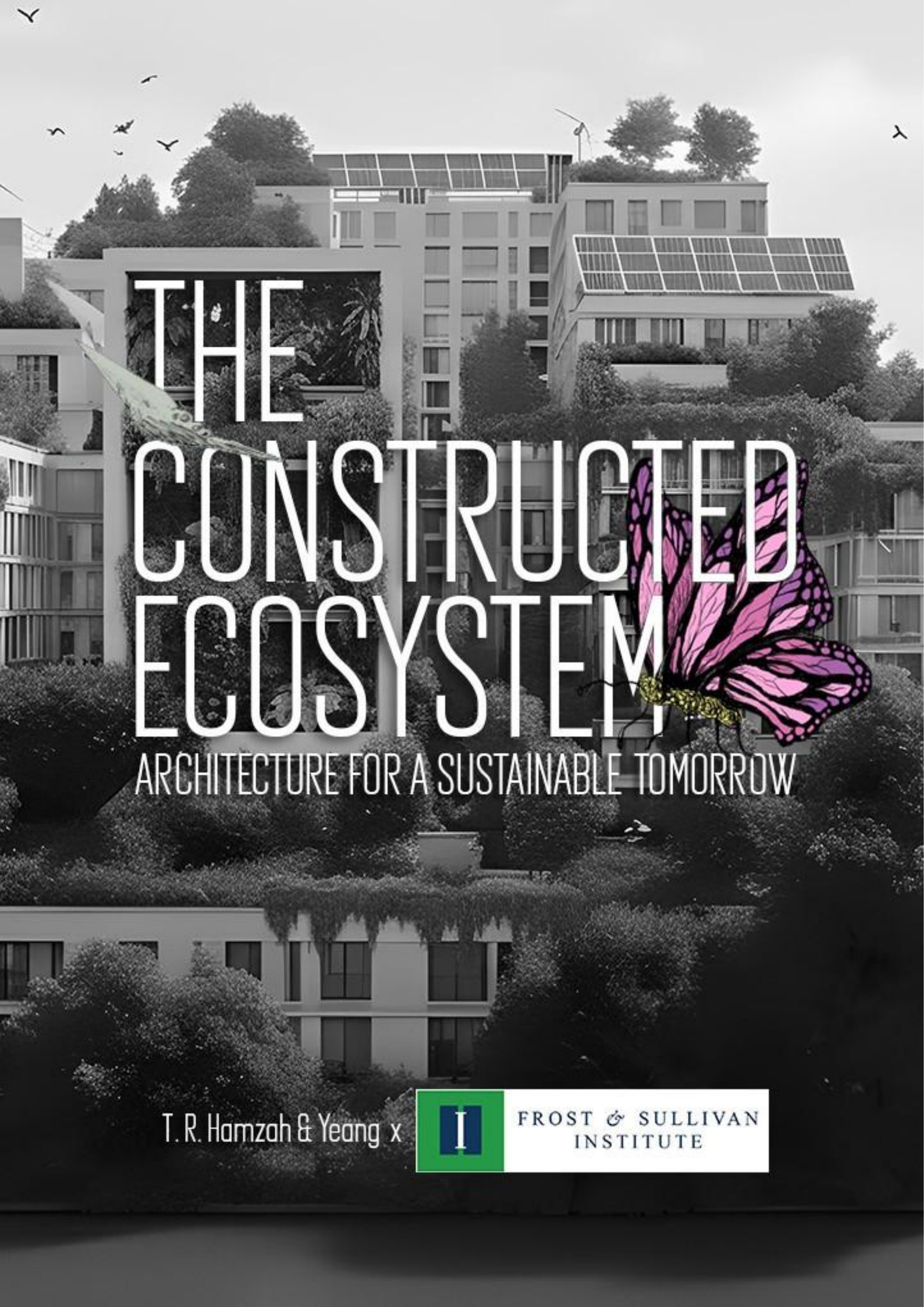
THE CONSTRUCTED ECOSYSTEM

ARCHITECTURE FOR A SUSTAINABLE TOMORROW

T. R. Hamzah & Yeang x FROST & SULLIVAN INSTITUTE

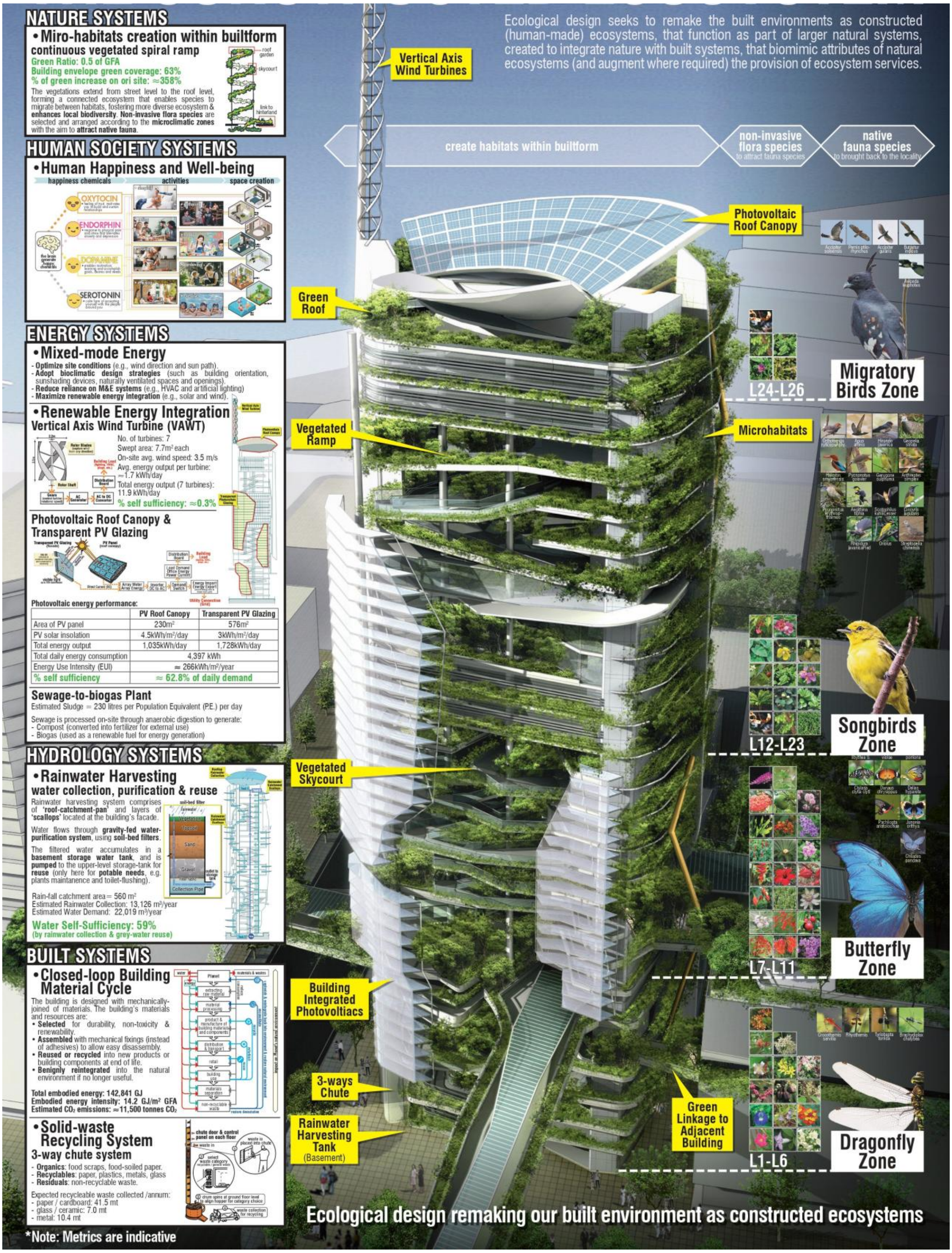
THE CONSTRUCTED ECOSYSTEM

ARCHITECTURE FOR A SUSTAINABLE TOMORROW



T. R. Hamzah & Yeang x FROST & SULLIVAN INSTITUTE

Designing Constructed Ecosystem



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Foreword 1

Frost & Sullivan Institute

The Frost & Sullivan Institute (FSI) stands at the forefront of transformative change, where business innovation meets global responsibility. Founded on Executive Director David Frigstad's mission to address critical global challenges, FSI champions its "Innovation to Zero" framework—targeting the elimination of poverty, hunger, illiteracy, and environmental degradation. By combining Frost & Sullivan Inc.'s analytical expertise with a network of global visionaries, FSI recognizes and promotes leaders who demonstrate that business excellence and sustainable development are inseparable partners in creating meaningful change. Long before sustainability became a global imperative, Dr. Yeang articulated a vision rooted in ecological integration, systems thinking, and long-term responsibility. His work transcends architecture; it challenges how cities grow, how resources are respected, and how innovation can serve both people and the planet.

At the Frost & Sullivan Institute, our mission is to identify, celebrate, and amplify leaders whose work advances a more secure, equitable, and prosperous future. We believe that lasting progress is driven by individuals who build ecosystems of change, leaders who inspire collaboration, accelerate implementation, and create impact that extends far beyond their immediate sphere. This collaboration offers a window into a mind that has consistently looked beyond convention and toward possibility. It is our hope that these pages will inspire reflection, spark dialogue, and encourage others to pursue innovation with purpose.

On behalf of the Frost & Sullivan Institute and Frost & Sullivan, I extend my heartfelt congratulations to Dr. Ken Yeang. May his vision continue to inspire those who believe that design, when guided by responsibility and foresight, can truly help shape a better world.

Frost & Sullivan Institute

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Architect: Ken Yeang

Ken Yeang is a renowned architect, ecologist, and sustainability advocate recognized for his pioneering work in eco-architecture and bioclimatic design (since 1971). With a career focused on integrating nature within the urban landscape, Dr. Yeang's projects emphasize ecological harmony, energy efficiency, and the responsible use of materials. His approach promotes designs that adapt to natural ecosystems, creating architecture that is both sustainable and resilient. Dr. Yeang's work has set a benchmark for sustainable urban design, inspiring future architects to integrate environmental responsibility into their projects.

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Dr. Ken Yeang

2 Our Current Condition

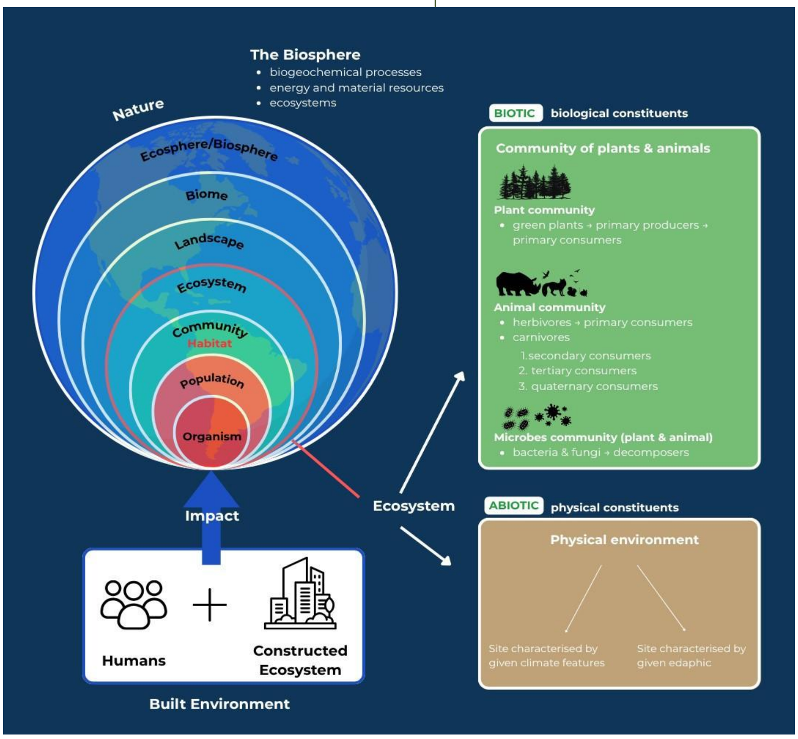
how does ecological design offer a path towards planetary salvation?

Our society is likened to a crowded, leaking boat (our urban environment) adrift in a turbulent sea (the environmental crisis), facing the imminent threat of planetary apocalypse. To survive, we need the knowledge of ecology to mend the leak and guidance to navigate to safety, all while time rapidly diminishes. Ecological design, fundamentally based on the science of ecology and biomimicry of nature's ecosystems, offers this crucial knowledge and guiding directive. Our tools are regenerative "constructed ecosystems" that work with nature, not against it. This approach is the bedrock of ecological design, providing solutions for designers to help save the planet.

SOURCE: FROST & SULLIVAN INSTITUTE AND T. R. HAMZAH & YEANG

In what profound ways must we redefine our relationship with nature, and how does ecology serve as the indispensable foundation for design in addressing the environmental crisis?

The purpose of ecological design is to reverse the degradation caused by our built environment, which has alienated much of Earth from its natural state. Our current destructive practices in designing society's-built environment and technological systems are unsustainable. While past efforts focused on minimizing negative impacts, the extensive damage inflicted by humans now demands ecological design to be a "race and rescue mission" to repair and regenerate the planet's systems. Human society bears the responsibility to address this crisis for the benefit of all life, not just our own species. Even if humanity imperils itself, nature will eventually recover through adaptive responses and succession. This necessitates a fundamental shift in our thinking about nature.



source: T. R. Hamzah & Yeang Sdn. Bhd.

Addressing the environmental crisis requires more than just changes in how we design, build, operate, and use the built environment. We must profoundly rethink, repurpose, and reinvent design to prevent further harm and actively repair damaged natural environments, considering materials throughout their entire lifecycle. This transformation also demands changes in human society's socio-economic-political and institutional structures. Embracing ecological design represents a redefined social contract between humans and nature.

The current environmental crisis is humanity's most complex existential challenge, making it the paramount task for all designers today. Ecology, as the branch of biology studying the relationships between organisms and their surroundings, provides the scientific basis for this undertaking. The ecological health of the planet forms the baseline for assessing all human activities impacting the biosphere. Ecology matters because the healthy state of the planet's ecosystems, biogeochemical cycles, and their constituents are vital for the continued viability of all life on Earth.

3 Innovation

Ecological design

The general principles, goals and design tactics that define ecological design as the framework for creating built systems that work in synergy with nature as Constructed Ecosystem.

1. Ecological design harmonizes built system with nature

Principle: Address the current environmental crisis and avert further impairments to the Planet, the built environment (its structures, components, systems and processes, production and products), together with any impacting human activities must function systemically, physically, benignly and seamlessly with nature. Functioning benignly means not negatively disrupting the biosphere's systems, its constituents and processes. Seamlessly means being biointegrated without any negative dislocation in structure and processes in nature.

Goal: To avert the impairments caused by the existing built environment, and to design, regenerate and restore any legacy degradation of nature.

Design: Design the built environment (its production, operation and disposal over its entire life-cycle) to foster ecologically positive and mutually beneficial (symbiotic) relationships with nature. The approach being ecology-based is different from what is currently being practiced.

2. Ecological design creates built environments as living systems

Principle: The built environment must be nature-like and be designed, constructed and operated as a living system and not as inert objects, harmful technological systems and resource- depleting structures.

Goal: To ensure that the built environment adapts, evolves and interacts dynamically with its ecological contexts, contributing to regeneration and resilience of ecosystems.

Design: Design to integrate self-regulating, adaptive and responsive systems that draw from natural living processes, so that built systems' inputs, outputs, internal processes and external interactions function as active living participants in the Planet's ecological cycles.

3. Ecological design is based on the science-of-ecology as Applied Ecology

Principle: Ecological design must be guided by the principles of ecology as “applied ecology”, adopting systems ecology as the scientific foundation for making the built environment.

Goal: To ground design in ecological knowledge so that every intervention contributes to maintaining, restoring, or enhancing ecological processes.

Design: Design to employ the science of ecology as (applied ecology) in the design, through integrating with ecological flows, relationships and cycles in the biosphere as models for planning, constructing and operating the built environment.

4. Ecological design ensures no harm to nature, repairs past impacts and regenerates nature

Principle: The built environment over its entire life-cycle and with all its related human activities must do no irreversible unregenerable harm to nature and at the same time repair past environmental damage (such as by sequestering legacy contaminating emissions).

Goal: To minimise and avert ecological harm, to sustain existing ecosystems processes and regenerate degraded ecosystems to contribute positively to ecosystems.

Design: Design starts with responding to the locality’s ecology before action is imposed on it to avoid undesirable disruptions and irreversible damage to the ecological systems and the biosphere (atmosphere, geosphere and hydrosphere). Design must integrate the built environment’s systems, components and functions with the ecosystems’ structure and processes, while simultaneously repairing and regenerating degraded ecosystems from past impairments. Design must eliminate discharging harmful emissions and wastes into the ecosystem and biosphere.

5. Ecological design protects species biodiversity and natural processes

Principle: Ecological design safeguards and enhances the Planet's biodiversity in its biomes and ecosystems locally, regionally and globally.
Goal: Preserve the integrity and resilience of ecosystems, their biodiversity and processes at all scales.

Goal: Preserve the integrity and resilience of ecosystems, their biodiversity and processes at all scales.

Design: Design to conserve, restore and enhance biodiversity and ecosystems processes at all scales by embedding and biointegrating habitats within human-made systems and built environments to create the built environment as constructed ecosystems. Design must avert fragmentation of ecosystems, retain existing ecological continuity and create new designed linkages, such as by connecting ecological patches and corridors (both vertically and horizontally in builtforms) and by nature-based design solutions that support thriving species, their movements across landscapes and ecosystems. At the same time, design must avert disrupting the ecosystems processes, such as photosynthesis processes, the production of nutrients, the hydrology of the ecosystem, the microbial life such in the soils, the disrupting of species interactions and other ecosystem functions and processes.

6. Ecological design remakes and reinvents our built environment (our urban structures and cities) as constructed ecosystems

Principle: All urban realms (including cities) must be remake and regenerated as constructed ecosystems and hybrid cultural systems composed of both natural and human-made constituents that are seamlessly biointegrated into a whole system.

Goal: To transform urban environments from being ecologically-destructive systems into regenerative systems that restore biodiversity, enhance resilience, and sustain human and planetary well-being.

Design: Design systems based on biomimicry that adopt ecosystem principles from systems ecology, transforming the built environment into bioengineered "constructed ecosystems." By emulating and enhancing natural ecosystem structures and processes, the built environment becomes a nature-based system that engages with nature in a mutually beneficial, nature- to-nature relationship. This replaces the harmful technology-to- nature approach that has contributed to the environmental crisis. Future design, construction, and operation of the built environment must be guided by ecological science.

7. Ecological design biointegrates our built environment with nature at all scales

Principle: Ecological design must integrate across multiple layouts and scales, from the material and component level to buildings, to infrastructures, to cities, to regional landscapes and to the level of the biosphere.

Goal: To ensure coherence and synergy between design action at different scales.

Design: Design to employ nested, hierarchical, and networked design strategies that connect from the micro-scale (materials, components) to the meso-scale (buildings, communities), to the macro-scale (regions and biomes) and to the mega scale (biosphere) as a continuous set of relationships system inasmuch as achievable.

8. Ecological design responds to the climate of its locality as bioclimatic design

Principle: The built environment must be first designed as a passive low energy system that harmonizes with the climate and microclimate of its locality, minimizing and eliminating fossil- fuel energy demand while maximizing comfort through natural means.

Goal: To reduce & eliminate dependence on fossil-fuel energy by bioclimate design for enhancing human comfort & natural responsiveness prior to using mechanical systems.

Design: Design to employ passive design strategies (built form orientation, natural ventilation, solar shading, thermal buffering, natural daylighting), integration with landscape elements to create built environments that adapt to their specific climatic and seasonal context.

9. Ecological design optimises resource efficiency and circularity

Principle: Use natural resources prudently without wastage and prevent depletion of 'non-renewable' (by human time scales) resources and ensure that the biosphere's cycles and processes are not disrupted by wastes, emissions or human activities.

Goal: Create built systems where material and energy resources are efficiently used, continually cycled, safely reintegrated into the natural environment, eliminating wastes and regenerating natural capital to ensure a sustainable future.

Design: Design to prioritize renewable inputs with efficiency, to eliminate waste outputs. To adopt circular material use systems as processes of use and reuse to conserve both physical and biological resources, to optimise material and energy consumption, to avoid wastes, to avoid depletion of not easily renewable resources, to design and make built systems that facilitate reuse and endless recycling before their benign reintegration into the biosphere at the end of useful life (as against passive accumulation on the planet).

10. Ecological design prevents pollution of the natural environment

Principle: Avoid non-regeneratable contaminating of the natural environment, its systems & processes (land, waterways, aerial environments).

Goal: Stop degradation of ecosystems, their structure, processes and functioning caused by contaminating emissions.

Design: Design must stop producing and releasing persistent or harmful substances (solid, liquid, particulate, biological material) into the biosphere. Eliminate toxic substances through design choices in production. Employ clean technologies and actively sequester past emitted pollutants.

11. Ecological design innovates for sustainability

Principle: Pursue constant innovation, improvements and advancing of solutions that enable a sustainable future for all life on the Planet.

Goal: Enable human society to thrive within Earth's limits by adoption of innovative solutions.

Design: Design to continuously develop and invent solutions, processes and strategies that ensure and advance human society's ability to co-exist benignly with nature and that further improve the resilience of the Planet.

12. Ecological design enhances human health, happiness, comfort & well-being

Principle: Ecological design and action must not be detrimental to human health and must enhancing happiness and well-being, while improving living conditions that support a higher quality of life.

Goal: Design to ensure and promote human health, happiness, well-being and comfort.

Design: Design to incorporate biophilic design solutions to create healthy environments that support physical and mental well-being of human society through its physical and eco- psychological (biophilic) effects.

13. Ecological design inspires society's stewardship of nature

Principle: Foster ecological ethics and the environmental responsibility towards the Planet in human society.

Goal: Embed sustainable environmental values & justice in human society through education.

Design: Design to engender ecological ethics, equity and cultural meaning in all human endeavours to cultivate enlightened global environmental stewardship for a sustainable human civilization.

14. Ecological design makes nature visible in its designed systems

Principle: Enable human society to appreciate, understand and visually expensive ecological design. Aesthetically reveal the beauty of nature's structure and processes in the designed systems.

Goal: Increase human visual awareness and enjoyment of the beauty in nature's forms, processes and in its interdependencies.

Design: Design to make the outcomes of ecological design be visually evident in the built systems by translating natural processes, ecological services and ecosystem functions into tangible, evidently perceivable aspects of built elements through the designed forms and components so that their aesthetics, presence, and functioning are directly experienced and appreciated by human society.

Skylon

The Ecological building: Challenging Conventions in High-Rise Design

Ken Yeang's work and designs defy traditional architectural norms, incorporating sustainability-focused features like Editt Towers constructed ecosystem.

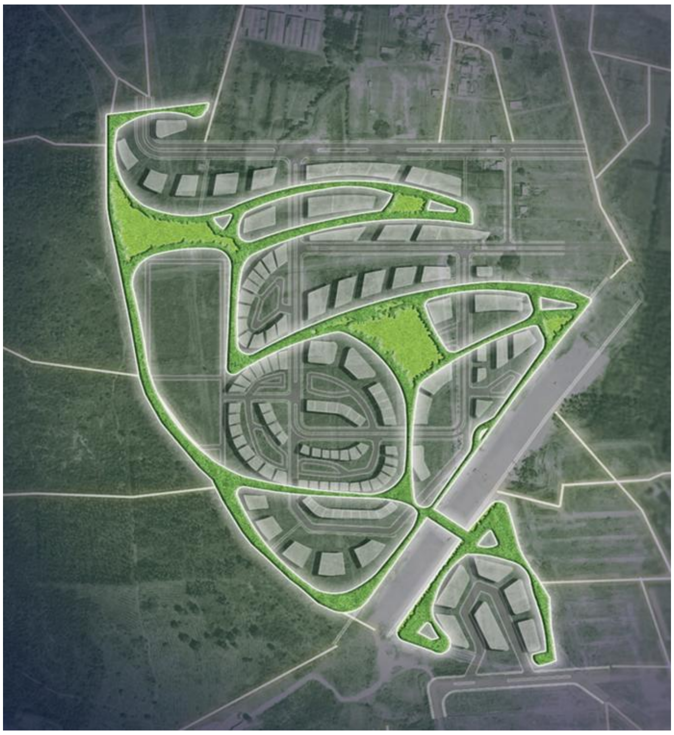
▶ EDITT Tower

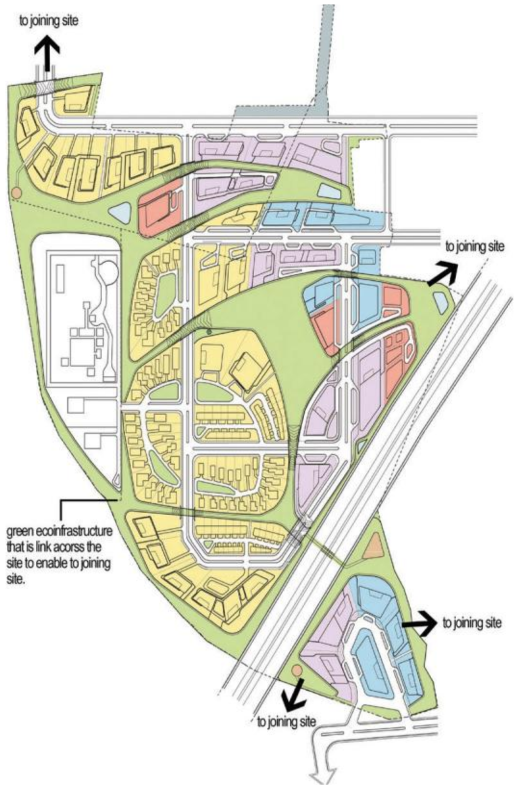
EDITT


Vertical Axis Wind Turbines
Photovoltaic Roof Canopy
Green Roof
Vegetated Ramp
Microhabitats
Vegetated Skycourt
Green Linkage to Adjacent Building
Rainwater Harvesting Tank (Basement)

SOMA Masterplan

4 | Eco Masterplanning



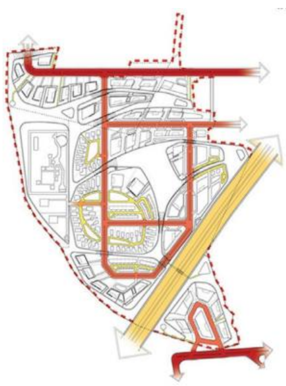


The development is designed around the green spaces to create continuity and a pleasurable lifestyle. Green technology incorporating environmentally friendly and recyclable material, maximum openings for natural lighting and ventilation, roof gardens and green terraces, rainwater harvesting and low energy building designs is used.

Green Infrastructure

Red Infrastructure

Blue Infrastructure



Grey Infrastructure

Integrating nature into his architectural designs is a core tenet of Ken Yeang's philosophy. His designs incorporate biodiverse ecosystems—through vertical gardens, sky courts, and green facades—that reduce pollution, foster biodiversity, and create sustainable living spaces. Projects such as the SOMA Masterplan in Bangalore exemplify how urban areas can be designed to include natural ecosystems, supporting healthier urban environments in alignment with global sustainability goals.

Model for Ecoloogical Design 5

How does ecological design fundamentally redefine the relationship between the built environment and nature?

Ecological design is a nature-based approach that views the built environment as applied ecology, aiming to avert degradation and regenerate naatural systems. It transforms human-made elements into "nature-like, ecology-based systems". The current "technology-to-nature" interface, which causes environmental crisis, is replaced by a seamless "nature-to-nature" biointegration where the built environment functions harmoniously with natural systems. This approach mandates design based on nature's structures and processes, especially ecosystems. Society's activities and built environments must engage symbiotically with nature, moving beyond mere nature-based design to be truly ecology-based, using the science of ecology to inform the form, content, functions, and life cycles of built systems through "ecomimicry". The goal is to "re-nature and re-wild" urban environments into ecologically balanced systems, prioritizing nature over technological or anthropocentric approaches. Ultimately, ecological design is rooted in the biomimicry of ecosystems.

• nature
(ecosystems & biogeochemical cycles)

- ecomimicry
- biogeochemical cycles
- abiotic constituents
- biotic constituents
- habitats
- species
- biodiversity
- ecosystem conservation & regeneration
- biomes
- biosphere
- habitats repair

NPEI
(Net Positive Ecological Impact)

• human society
(well-being & happiness)

design to engender release of chemicals in brain

- social
- economic
- political
- institutional
- cultural
- biophilic
- ecologically-responsible behavior
- ecologically-responsible diet
- green spaces for human health, well-being & happiness

NWHHS
(Net Well-being, Healthy & Happy Society)

• built systems & infrastructures
(zero wastes and emissions)

- infrastructures
- artefacts
- buildings (zero carbon materials)
- design for recycling & reuse
- carbon capture systems
- smart systems
- smart grids
- large-scale electricity storage
- hydrogen production (without emitting carbon)
- low embodied energy & carbon neutral construction operations
- sustainable production systems (incl. food)
- society's technological systems

NZW/E
(Net Zero Waste / Emissions)

• energy systems
(clean renewable energy/carbon neutral design)

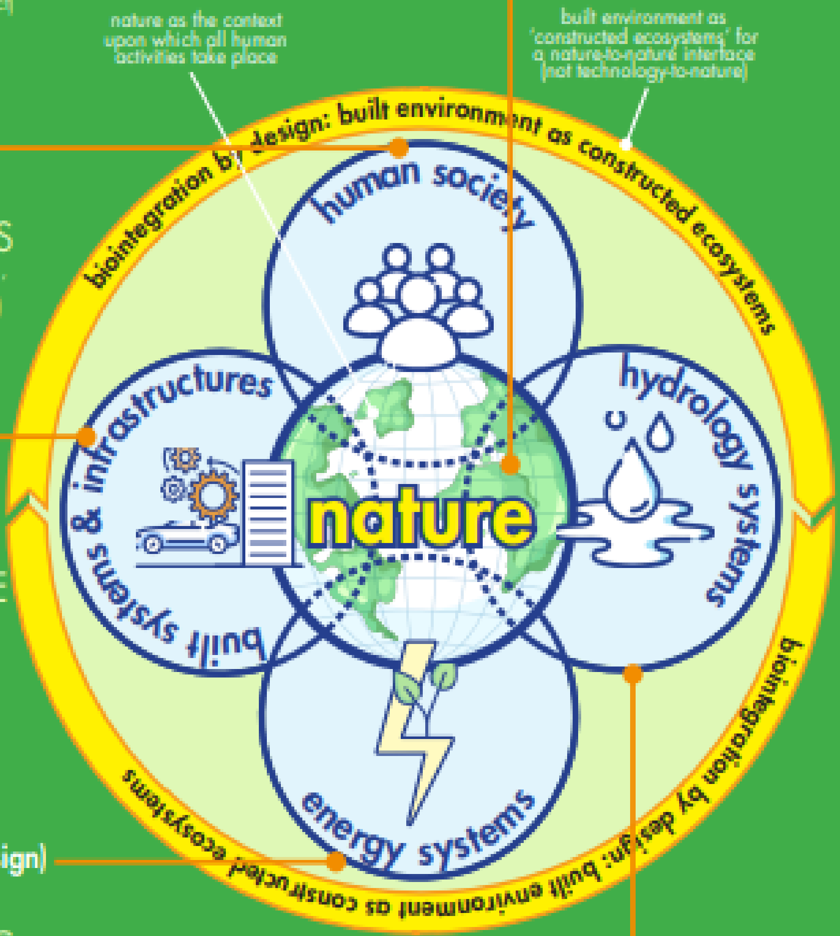
- renewable sources: ambient & on-site energy (solar, wind, water, geothermal)
- passive-mode systems
- mixed-mode systems
- smart full-mode systems
- productive-mode systems
- surplus energy storage systems
- biofuels
- battery & storage systems
- hydrogen production

NSE&ZC
(Net Surplus Energy & Zero Carbon)

• hydrology systems
(water management & conservation)

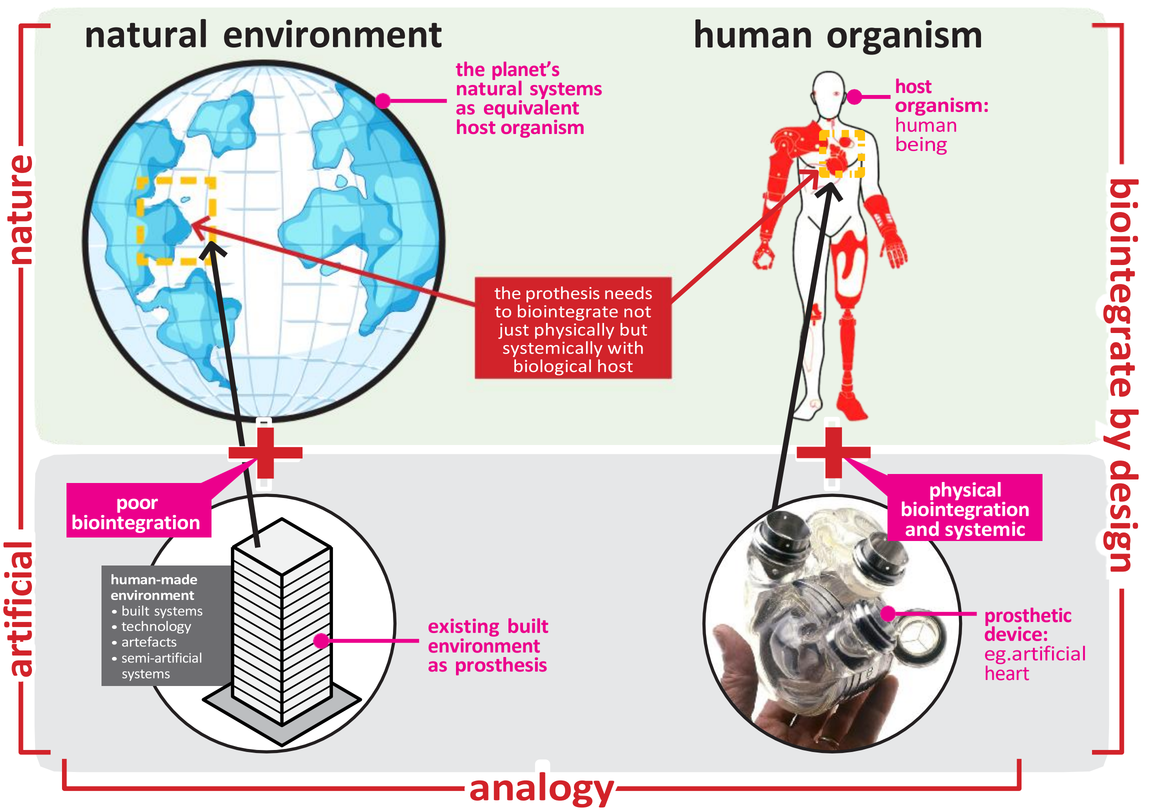
- rainwater harvesting (rainfall, dew, snow)
- ground water recharging
- waterways (seas, lakes, rivers)
- water reuse & recycling
- desalination
- water conservation
- bioswales
- sustainable drainage
- 'sponge-city' concept

NZW
(Net Zero Water)



What does it mean to design through biomimicry, and how does the concept of an 'ecosystem' serve as the blueprint for creating constructed environments?

Biomimicry in design involves closely imitating the physical and systemic aspects of biological systems to create new systems beneficial to humans and benign to the planet. The process identifies a biological system to be mimicked, with the 'ecosystem' being the chosen model for ecological design. An ecosystem is an abstract concept from Systems Ecology, representing a community of organisms and their physical environment interacting. Its living and non-living components are interconnected through nutrient cycles and energy flows, maintaining a balanced state. The objective of ecomimicry design is to transform the built environment into "constructed ecosystems". This involves emulating, replicating, augmenting, and enhancing ecosystem properties, including the provision of 'ecosystem services'—nature's ecologically beneficial functions. Applying biomimicry of ecosystem attributes to all human-made systems (structures, infrastructures, artifacts, and technological systems) is the fundamental basis and comprehensive goal of ecological design.



source: T. R. Hamzah & Yeang Sdn. Bhd.

6 Impact

Environmental Leadership in Architecture

Yeang's eco-architecture has set a new standard in environmental leadership within the architectural community. By consistently implementing sustainable practices, he demonstrates the practical feasibility of green building principles at scale. His approach, which prioritizes environmental stewardship, inspires a shift towards eco-friendly design, driving the industry closer to the "Innovating Environmental Challenges to Zero" objective by proving that sustainable buildings can be functional, aesthetically appealing, and environmentally responsible.

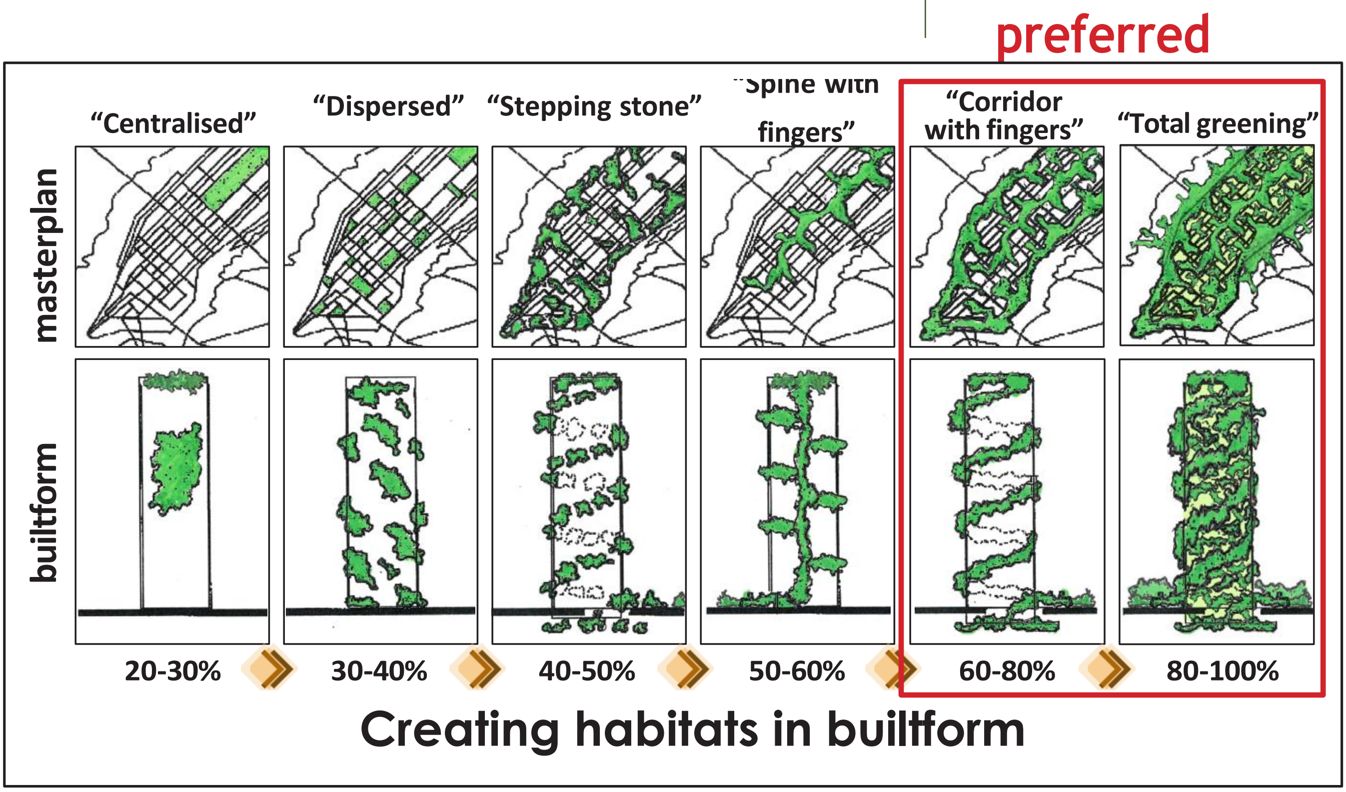
Inspiring a Global Shift Towards Sustainable Building Practices

Yeang's work dispels myths around sustainable architecture's costs, practicality, and aesthetic value. His projects illustrate that sustainable practices can be integrated effectively, without excessive cost or resource use. Dr. Yeang's real-world implementations challenge the misconceptions that green design is impractical or financially prohibitive, highlighting its viability as a cost-effective, sustainable model for cities worldwide.

Positive Influence on Urban Communities

Yeang's buildings enhance the livability of urban environments. His designs create healthier spaces for residents, with features like natural lighting, improved air quality, and access to green areas. The National Library in Singapore and the Kowloon Waterfront Masterplan serve as prime examples, transforming urban spaces into environments that foster well-being and sustainability. His projects not only benefit individual residents but also contribute to broader environmental health, showcasing how visionary architecture aligns with both community needs and environmental priorities.

Creating habitats in builtform 7



source: T. R. Hamzah & Yeang Sdn. Bhd.

As global priorities shift towards infrastructure and environmental resilience; there's an increasing need for sustainable architectural practices that address urban expansion challenges while safeguarding natural ecosystems. Yeang's work with bioclimatic and eco-architecture exemplifies this strategic imperative. His approach supports both global sustainability goals and the Frost & Sullivan Institute's vision of "Innovating Environmental Challenges to Zero". By embedding ecological design into urban planning, Yeang's architecture promotes environmental harmony, driving change within an industry often constrained by conventional, resource-heavy practices.As global priorities shift towards infrastructure and environmental resilience; there's an increasing need for sustainable architectural practices that address urban expansion challenges while safeguarding natural ecosystems. Yeang's work with bioclimatic and eco-architecture exemplifies this strategic imperative. His approach supports both global sustainability goals and the Frost & Sullivan Institute's vision of "Innovating Environmental Challenges to Zero". By embedding ecological design into urban planning, Yeang's architecture promotes environmental harmony, driving change within an industry often constrained by conventional, resource-heavy practices.

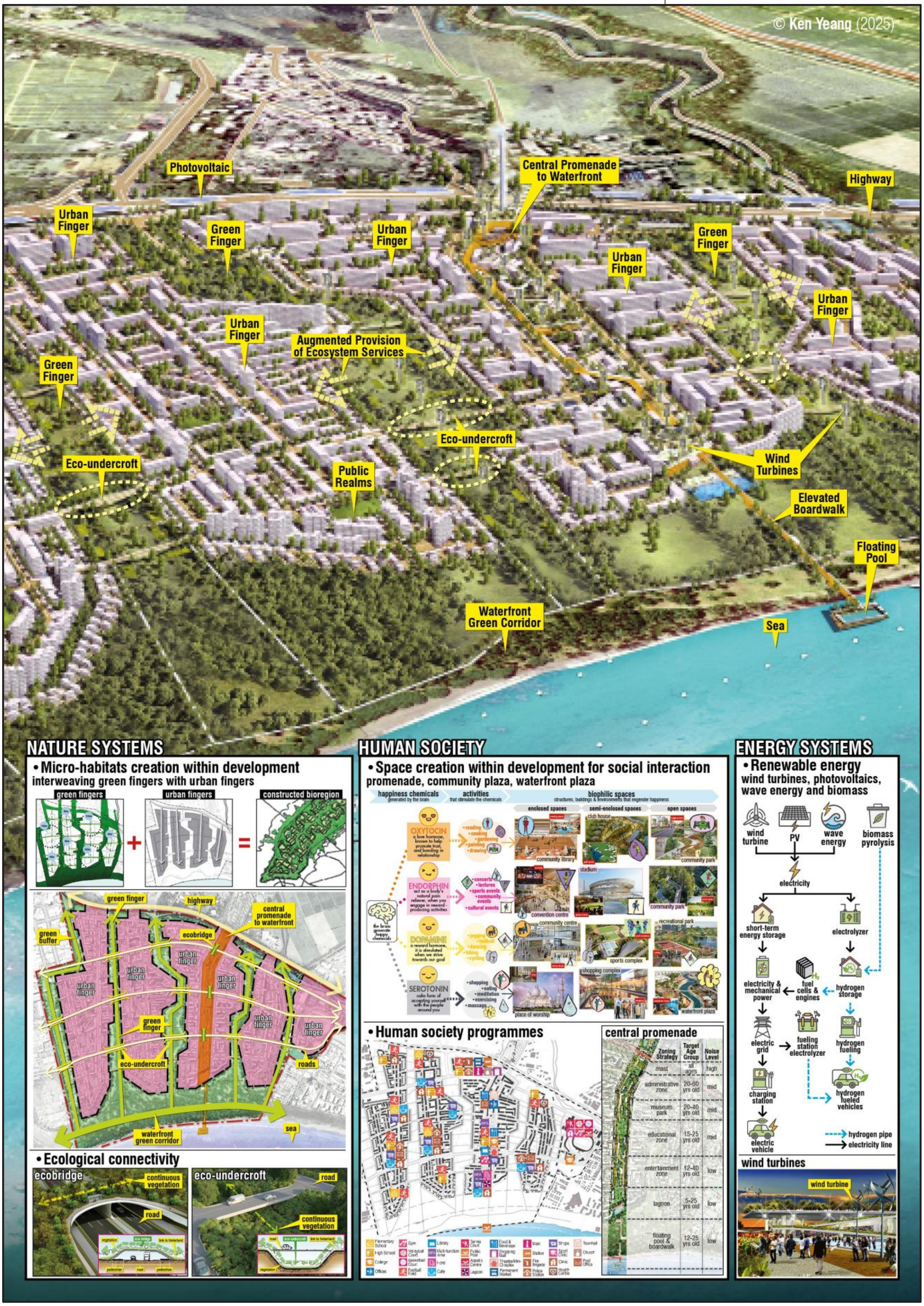
▶ Solaris Singapore

Beyond mitigating harm, what transformative ecological outcomes can we anticipate from embracing ecological design?

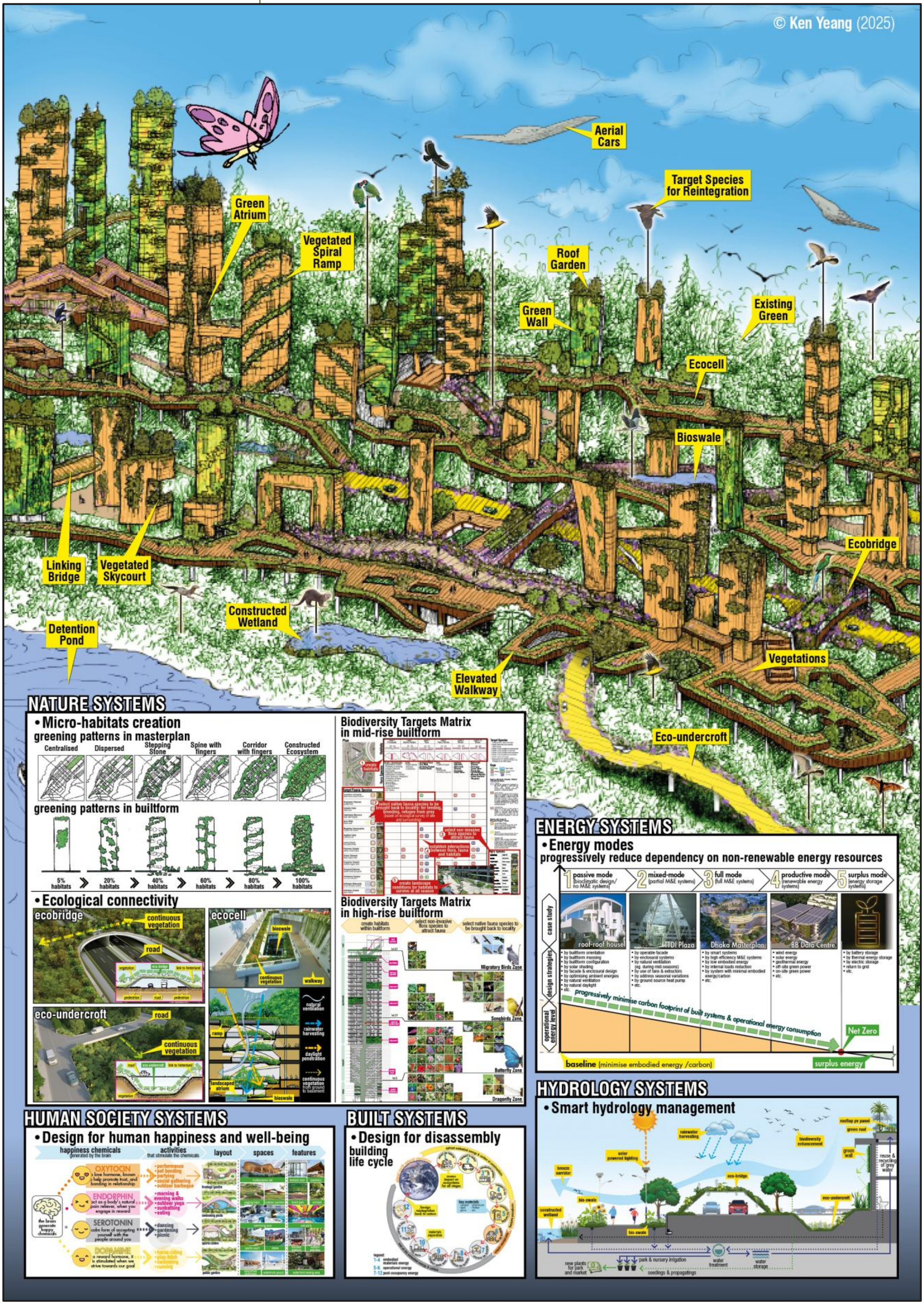
Ecological design must ensure that throughout a built system's life cycle, negative impacts are eliminated, and positive ecological outcomes are achieved, alongside creating healing, healthy, biophilic, comfortable, and aesthetically fulfilling human environments. Beneficial outcomes include restoring and regenerating damaged ecology. Positive outcomes also involve preventing further ecosystem degradation (e.g., averting deforestation), conserving water (e.g., recharging groundwater, treating blackwater, harvesting, recycling water), and restoring soil health (e.g., averting erosion). It also addresses aerial pollutants (eliminating toxic emissions), ocean acidification, and manages waste within the built environment (conserving and reusing materials). Furthermore, it promotes adopting renewable on-site energy systems, including transitioning from a fossil fuel-based economy to a renewable energy one, and averting other negative impacts on the natural environment.

Designing must go beyond simply conserving the planet's natural environment and resources. Human society's system of resource use must change, closing the cycle of non-renewable material throughput. Ecological design requires built systems to be designed from the outset for future materials reuse and recycling, enabling adaptive reuse of buildings, material reconstitution, and benign reintegration into the natural environment. Achieving these comprehensive goals regionally and globally is a complex and extensive endeavor, demanding coordinated waste-materials management systems to avoid passive accumulation or harmful discharges into the biosphere.

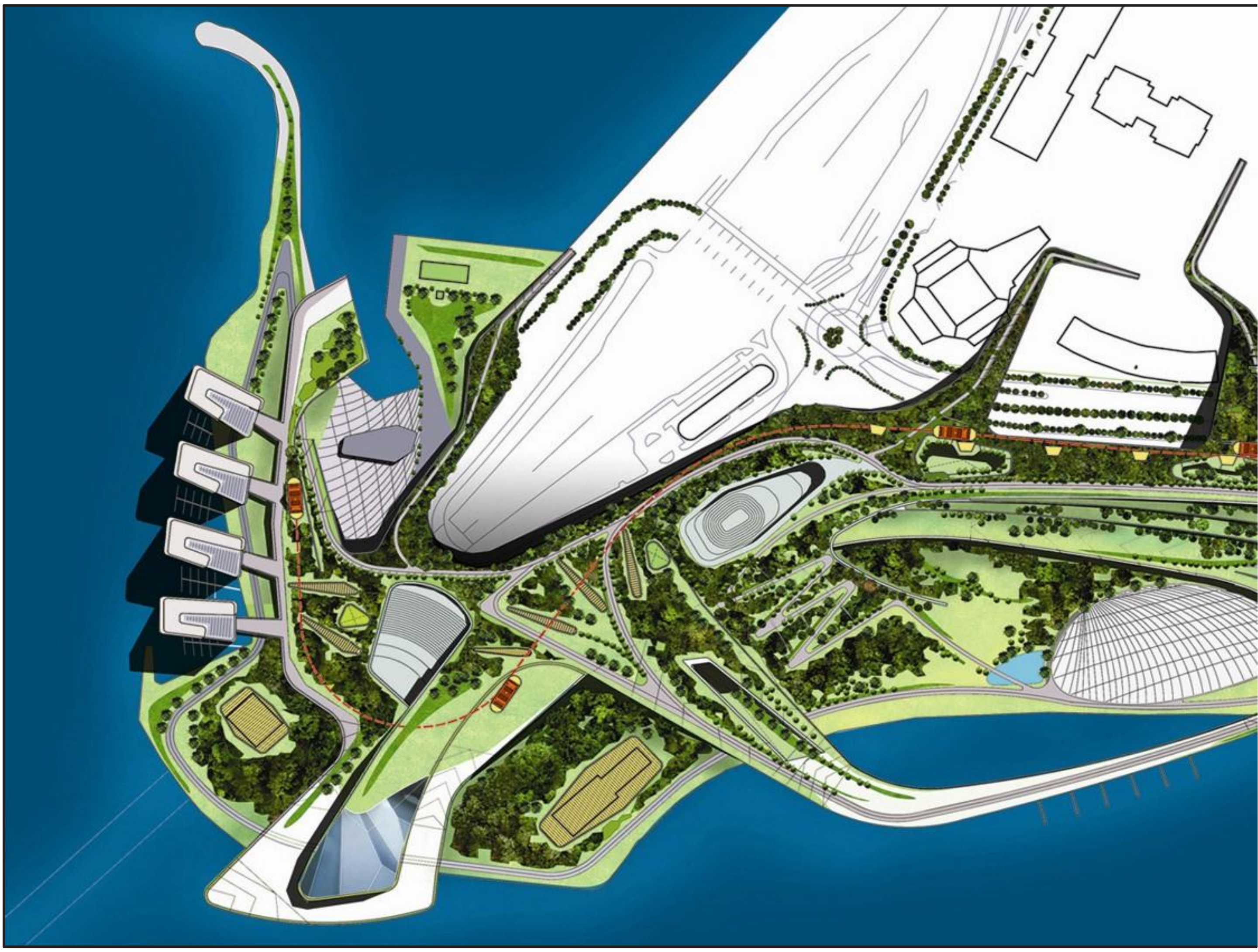
The Constructed Bioregion 8



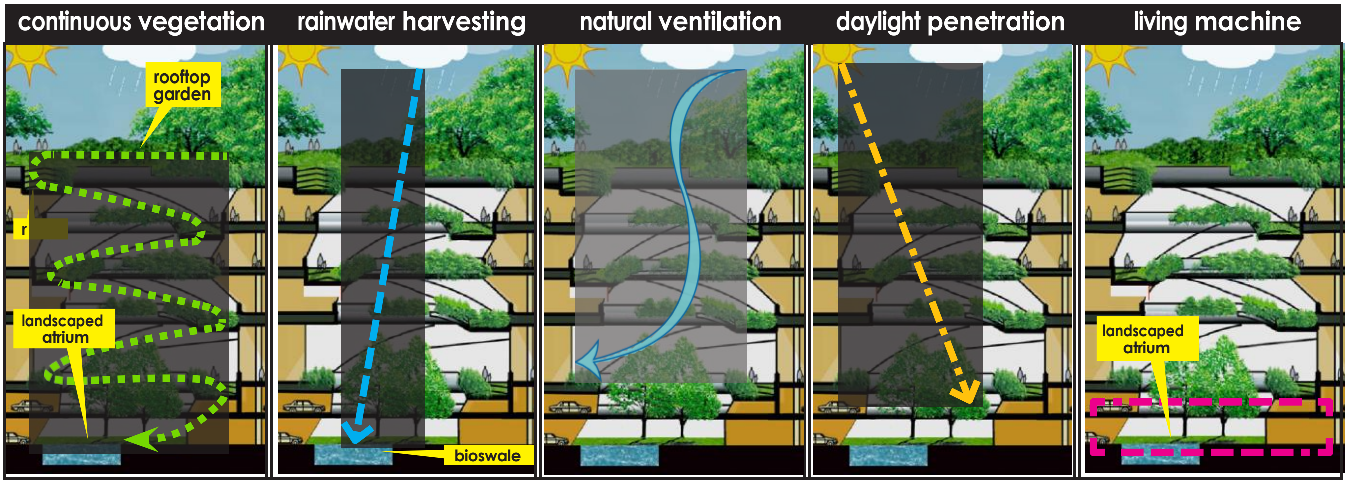
9 The Constructed Ecocity



The Green Masterplan 10



•the eco-cell



source: T. R. Hamzah & Yeang Sdn. Bhd.

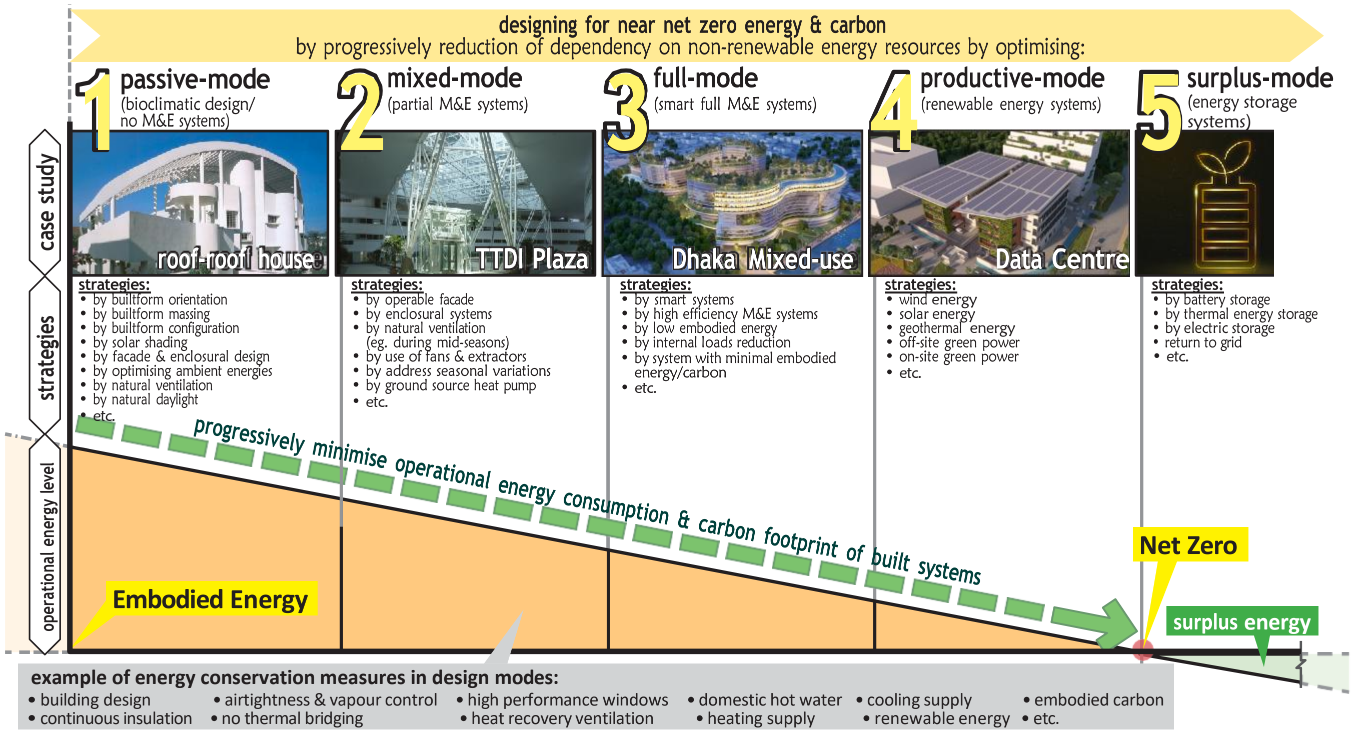
▶ West Kawloon Waterfront

- **The Green Masterplan: Green Infrastructure in Urban Development**

The masterplan showcases green infrastructure, addressing urban sustainability and livability by incorporating ecological systems within a dense urban setting. This plan has influenced similar developments, aligning with Frost & Sullivan's goal of reducing environmental impacts through innovative, green urban infrastructure.

Designing for Surplus Energy 11

In what critical ways does ecological design diverge from conventional green building certification systems, and what implications does this have for achieving true planetary health?



source: T. R. Hamzah & Yeang Sdn. Bhd.

Ecological design fundamentally differs from prescriptive green accreditation systems (like LEED, BREEAM, CASBI). These systems often prioritize technological engineering aspects, such as net-zero energy and water management or decarbonization, making ecological considerations secondary. For example, the 'Passivhaus' approach focuses on energy efficiency but may not adequately consider local ecology. In contrast, ecological design is performance-based, not prescriptive. While it incorporates benign technological aspects like energy and water systems, these are always secondary to ecology. Bioclimatic design, which responds to local climate for low-energy systems, is considered a subset of ecological design, as ecological design extends beyond climate to consider the broader natural environment and its ecology.

12 Why we do, what we do?

While human societies face many pressing and interconnected issues, such as poverty, inequality, poor public health, food insufficiency, and inadequate habitation, addressing these becomes easier with a clean environment. Current societal action on the environmental crisis is inadequate and fragmented, necessitating the scaling up of ecology-based design. Success requires collective action and political leadership from society as a whole, rather than isolated efforts by individuals, groups, or nations, without which "business-as-usual" will persist. Furthermore, ecologically responsive design must involve not only the current generation of designers, who need to be re-educated to be "ecoliterate," but also future generations. Architectural pedagogy must be reframed to equip future generations with a deep understanding of the ecological impacts of buildings and an ecology-based approach. Ultimately, the solution to the environmental crisis is not solely ecological design or changes in built systems but addressing its root cause: people. The solution begins with people acting as good stewards of the planet.

SOURCE: FROST & SULLIVAN INSTITUTE AND T. R. HAMZAH & YEANG