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Ecoskyscrapers and Ecomimesis: New tall building typologies

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Biography

Ken Yeang is an architect-planner, and one of the foremost ecodesigners, theoreticians, and thinkers in the field of green design. After having studied architecture at the Architectural Association in London, his work on the green agenda started in the 70s with his doctoral dissertation for the University of Cambridge on ecological design and planning. Yeang is the author of several books on ecological design, including The Skyscraper, Bioclimatically Considered: A Design Primer (1996) published by Wiley-Academy, and The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings (1999) published by Prestel (Germany). He is the distinguished Plym Professor at the University of Illinois and Adjunct Professor at the University of Malaya and University of Hawaii (at Manoa) and recently received a D.Lit. (Hon) from the University of Sheffield. He is an Honorary FAIA and has served on the RIBA Council. A principal of Llewelyn Davies Yeang (UK) and its sister firm, Hamzah & Yeang (Malaysia), Ken Yeang is well known for designing signature green high-performance buildings and master plans, and for his pursuit of an ecological aesthetic in his designs.

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Abstract
Designing the ecoskyscraper involves configuring its built form and operational systems so that they integrate with nature in a benign and seamless way over its lifecycle, by imitating the structure, processes and properties of ecosystems, an approach referred to here as ecomimesis.
By biologically integrating compatibly all aspects and processes of our built environment with the natural environment, we enhance our human-made ecosystems' abilities to sustain life in the biosphere.

Part 1 discusses the theory and premises for the ecoskyscraper. Part 2 discusses exemplary projects from Ken Yeang's offices.

Keywords: Skyscraper, Ecosystems, Environment, Exemplary Projects

Part 1. Theory and Premises

'The Skyscraper is not an ecological building type'

At the outset, we should be clear that the skyscraper is not an ecological building type. In fact it is one of the most un-ecological of all building types. The tall building over and above other built typologies uses a third more (and in some instances much more) energy and material resources to build, to operate and eventually, to demolish. It is regarded here as a building type that if inevitable, needs to be made ecological inasmuch as possible.

Its unecologicalness is largely due to its tallness which requires greater material content in its structural system to withstand the higher bending moments caused by the forces of the high wind speeds at the upper reaches of its built form, greater energy demands to transport and pump materials and services up the building's floors working against gravity, additional energy consumption for the mechanized movement of people up and down its elevators, and other aspects arising from its excessive verticality.

What is the rationale for the skyscraper typology and why make it green? The argument is simply that the tall building is a building type that will just not go away overnight and until we have an economically viable alternative built form, the skyscraper as a building type will continue to be built prolifically, particularly to meet the demands of urban and city growth and increasing rural-to-urban migration.

The fact is that the skyscraper can never be a truly green building, certainly not in totality. If we accept this premise, then green designers instead of negating it, should seek to mitigate its negative environmental impacts and to make it as humane and pleasurably habitable for its inhabitants as possible.

There might be conditions where its built form would be justifiable, for instance to urgently meet intensive accommodation requirements and where it is built over or near a transportation hub to reduce transportation energy consumption, and where by virtue of its smaller footprint it will have considerably lesser impact on sensitive vegetated greenfield sites or on productive agricultural land.

Designing ecologically

Saving our environment is the most vital issue that humankind must address today; thus designing ecologically is crucial. Within this context it is clear that the building of green and ecological buildings is just one part of the entire environmental equation that we must address. We must ultimately change our cities into green ecocities in entirety as well as change all of our industries and manufacturing, all of our forms of transportation and all of the myriad human activities. In making these green we must integrate them seamlessly with the natural environment.

Addressing the current state of environmental impairment has to be carried out at all levels of our human world - globally, regionally, locally and individually. Changes must be made at the physical level of our built environment, but also at the political level by devising and implementing green legislation and at the social level in redefining the way we live our lives, all with ecologically benign strategies. We need new social, economic and political models with non-polluting manufacturing and industrial production processes, using green systems and materials, that are carbon neutral and with zero-waste as is the case with ecosystems in nature.

Environmental bio-integration – Ecomimesis

The ecological approach to design is about environmental bio-integration. If we are able to integrate everything we do and make in our built environment (which by definition consists of our buildings, facilities, infrastructure, products, refrigerators, toys, etc.) with the natural environment, then there will be no environmental problems whatsoever.

Successfully achieving this is our challenge. Simply stated, ecodesign is designing for bio-integration. This can be achieved at three levels: physically, systemically and temporally.

We start by looking at nature. Nature without humans exists in stasis. To achieve a similar state of stasis in our human built environment, our built forms and systems need to imitate nature's processes, structure, and functions, as in its ecosystems. How can we design our built systems to be like ecosystems? For instance, ecosystems have no waste. Everything is recycled within the system.

By imitating this function, our built environment will produce no wastes. All its emissions and products will be continuously reused, recycled within the system and when emitted be reintegrated with the natural environment. In tandem with this is an increasing efficient uses of non-renewable energy and material resources.

The process of designing to imitate ecosystems is ecomimesis. This is the fundamental premise for ecodesign. Our built environment must imitate ecosystems in all respects. This is what our tall building built form must do.

What is Eco Design?

Nature regards humans as one of its many species. What differentiates humans is their capability to inflict devastating changes on the environment. Such changes are often the consequences of manufacturing, construction and other human activities (e.g. recreation and transportation). Our built forms are essentially enclosures erected to protect us from the inclement external weather, enabling some activity (whether residential, office, manufacturing, warehousing, etc.) to take place.

In this regard, the tall building is an intensification and extrusion of an enclosural system within a comparatively small site footprint. On occasions such small footprints can contribute to ecologically preserve the land within the site for productive uses and in other conditions can contribute positively to preserving and enhancing local biodiversity.

Ecologically, a building is a high concentration of materials on a location (often using non-renewable energy resources) extracted and manufactured from some place distant in the biosphere, transported to that location and fabricated into a built form or an infrastructure (e.g. roads and drains), whose subsequent operations bear further environmental consequences and whose eventual after-life must be accommodated.

There is much misperception about what is ecological design. We must not be misled and seduced by technology. There is a popular perception that if we assemble in one single building enough eco-gadgetry such as solar collectors, photo-voltaics, biological recycling systems, building automation systems and double-skin façades, we will instantaneously have an ecological architecture.

The other common misperception is that if our building gets a high notch in a green-rating system, then all is well. Nothing could be further from the truth. Worse, self-complacency sets in whereupon nothing further is done to improve environmental degradation. Although these technological systems are relevant experiments towards an ecologically responsive built environment, their assembly into one single building does not make it automatically ecological.

In a nutshell, ecodesign is designing the built environment as a system integrated within the natural environment. The system's existence has ecological consequences and its sets of interactions, being its inputs and outputs as well as all its other aspects (such as transportation, etc.) over its entire life cycle, must be benignly accommodated with the natural environment.

Ecosystems in the biosphere are definable units containing both biotic and abiotic constituents acting together as a whole. From this concept, our businesses and built environment should be designed analogously to the ecosystem's physical content, composition and processes. Besides regarding architecture as just art objects or as serviced enclosures, we should regard it as artifacts that need to be operationally integrated with nature.

Balancing the built environment

It is self-evident that the material composition of our built environment is almost entirely inorganic, whereas ecosystems contain a complement of both biotic and abiotic constituents, or of inorganic and organic components.

Our myriad construction, manufacturing and other activities are, in effect, making the biosphere more and more inorganic, artificial and increasingly biologically simplified. To continue without balancing the biotic content means simply adding to the biosphere's artificiality, thereby making it increasingly more and more inorganic. Exacerbating this are other environmentally destructive acts such as deforestation and pollution. This results in the biological simplification of the biosphere and the reduction of its complexity and diversity.

We must reverse this trend and balance our built environment with greater levels of biomass, ameliorating biodiversity and ecological connectivity in the built forms and complementing their inorganic content with appropriate biomass.

In the case of the skyscraper, which by virtue of its dense built form is already a high intensification of inorganic mass, the integration of the biotic component in an ecological nexus is crucial to the skyscraper's built form.

Ecological Linkages

We should improve the ecological linkages between our designs and the surrounding landscape, both horizontally and vertically. Achieving these linkages ensures a wider level of species connectivity, interaction, mobility and sharing of resources across boundaries. Such real improvements in connectivity enhance biodiversity and further increase habitat resilience and species survival. Providing ecological corridors and linkages in regional planning is crucial in making urban patterns more biologically viable.

Besides improving connectivity and nexus horizontally in our built environment, this linkage must be extended vertically within the skyscraper, with organic connectivity stretching upwards within the built form to its roofscape, as a form of vertical landscaping.

More than enhancing ecological linkages, we must biologically integrate the inorganic aspects and processes of our built environment with the landscape so that they mutually become ecosystemic. This is the creation of human-made ecosystems compatible with the ecosystems in nature. By doing so, we enhance human-made ecosystems' abilities to sustain life in the biosphere.

The Ecology of the site

Ecodesign is also about discernment of the ecology of the site. This is the first consideration in designing the ecoskyscraper. Any activity from our design takes place with the objective to physically merge with the ecosystems and the ecology of the locality.

Particularly in site planning, we must first understand the properties of the locality's ecosystem before imposing any human activity upon it. Every site has an ecology with a limiting capacity to withstand stresses imposed upon it, which if stressed beyond this capacity, becomes irrevocably damaged. Consequences can range from minimal localized impact (such as the clearing of a small land area for access), to the total devastation of the entire land area (such as the clearing of all trees and vegetation, leveling the topography, diversion of existing waterways, etc.).

In most instances, skyscrapers are built on zero-culture land, or land whose ecology has already been cleared or built over and extensively modified. The ecological benefit of the skyscraper built form is its small footprint which has lesser impact on the site's ecology, and if the site remains vegetated (and not entirely paved) it provides greater land area for surface water percolation back into the earth.

To identify all aspects of the carrying capacity of a site, we need to carry out an analysis of the site's ecology. We must ascertain its ecosystem's structure and energy flow, its species diversity and other ecological properties. Then we must identify which parts of the site (if any) have different types of structures and activities, and which parts are particularly sensitive. Finally, we must consider the likely impacts of the intended construction and use.

This is a major undertaking. It needs to be done diurnally over the year and in some instances over years. To reduce this lengthy effort, landscape architects developed the sieve-mapping technique. This enables the designer to map the landscape as a series of layers in a simplified way to study its ecology.

As we map the layers, we overlay them, assign points, evaluate the interactions in relation to our proposed land use and patterns of use and produce a composite map to guide our planning (e.g. the disposition of the access roads, water management, drainage patterns and shaping of the built form(s), etc.).

Designing operational systems

Designing the ecoskyscraper also involves configuring its built form and operational systems so that they are not dependant (in totality or inasmuch as possible) on non-renewable sources of energy. Ecomimicry tells us that like ecosystems its only source of energy has to be from the sun. Designing for temporal integration is about designing for the long-term sustainable use of the biosphere's renewable and non-renewable resources.

In addressing this, we need to utilise low energy design to create internal comfort conditions within the tall building built form. There are essentially five modes: Passive Mode (or bioclimatic design), Mixed Mode, Full Mode, Productive Mode and Composite Mode, the latter being a composite of all the preceding.

Designing for low energy means looking first at Passive Mode strategies first, then Mixed Mode, Full

Mode, Productive Mode and, finally, Composite Mode, all the while adopting progressive strategies to improve comfort conditions relative to external conditions while minimizing demands on non-renewable sources of energy.

Passive Mode design is bioclimatic design, or designing to optimise on the ambient energies of the locality by designing with its local climate and seasonal variations. A quick indicator of the locality's climatic conditions is its latitude although even within a given latitude there are wide climatic variations, dependant for instance on whether it is an inland site or by the waterfront or its altitude above sea level.

Meeting contemporary expectations for comfort conditions cannot be achieved by Passive Mode or by Mixed Mode alone. The internal environment often needs to be supplemented by using external sources of energy, as in Full Mode. Full Mode uses electro-mechanical systems or M&E (mechanical and electrical) systems to improve the internal conditions of comfort, often using external energy sources (whether from fossil-fuel derived sources or from local ambient sources).

Ecodesign of buildings and businesses must minimize the use of non-renewable sources of energy. In this regard, low-energy design is an important objective.

Passive Mode

Passive Mode is designing for improved comfort conditions over external conditions without the use of any electro-mechanical systems. Examples of Passive Mode strategies include adopting appropriate building configurations and orientation in relation to the locality's climate, appropriate façade design (e.g. solid-to-glazed area ratio and suitable thermal insulation levels, use of natural ventilation, use of vegetation, etc.).

The design strategy for the built form must start with Passive Mode or bioclimatic design. This can significantly influence the configuration of the built form and its enclosural form. This must be the first level of design consideration in the process, following which we can adopt other modes to further enhance the energy efficiency.

Passive Mode requires an understanding of the climatic conditions of the locality, then designing not just to synchronize the built form's design with the meteorological conditions, but to optimize the ambient energy of the locality into a design with improved internal comfort conditions. Otherwise, if we adopt a particular approach without previously optimizing the Passive Mode options in the built form, we may well have made non-energy-efficient design decisions that we will have to correct with supplementary Full Mode systems. This would make nonsense of designing for low-energy.

Furthermore if the design optimizes its Passive Modes, it remains at an improved level of comfort during any electrical power failure. If we have not optimized Passive Modes in the built form, then when there is no electricity or external energy source, the building may be intolerable to occupants.

The location of the elevator core, vertical circulation and service ducts in the configuring of the skyscraper's built form can contribute to its low energy performance by serving as a thermal buffer between the inside of the internal spaces with the external environment.

Mixed Mode and Full Mode

Mixed Mode is where some electro-mechanical (M&E) systems are used. Examples include ceiling fans, flue atriums and evaporative cooling.

Full Mode is the full use of electro-mechanical systems, as in any conventional building. If users insist on having consistent comfort conditions throughout the year, the designed system heads towards a Full Mode design.

It is clear that low-energy design is essentially a user-driven condition and a life-style issue. Passive Mode and Mixed Mode design can never compete with the comfort levels of the high-energy, Full Mode conditions.

Productive Mode and Composite Mode

Productive Mode is where the built system generates its own energy (e.g. solar energy using photo-voltaic systems, or wind energy).

Ecosystems use solar energy, which is transformed into chemical energy by the photosynthesis of green plants and drives the ecological cycle. If ecodesign is to be ecomimetic, we should seek to do the same. At the moment the use of solar energy is limited to various solar collector devices and photovoltaic systems.

In the case of Productive Modes (e.g. solar collectors, photovoltaics and wind energy), these systems require sophisticated technological systems. They subsequently increase the inorganic content of the built form, its embodied energy content and its use of material resources, with increased attendant impacts on the environment. Ideally as in ecosystems, we should use energy-generation systems that imitate photosynthesis (e.g. photo voltaic systems using dye-cells).

Composite Mode is a composite of all the above modes and is a system that varies over the seasons of the year.

Green Materials and Components

Ecodesign requires the designer to use green materials and components that facilitate reuse, recycling and reintegration for temporal integration with the ecological systems.

We need to be ecomimetic in our use of materials in the built environment. In ecosystems, all living organisms feed on continual flows of matter and energy from their environment to stay alive, and all living organisms continually produce wastes. An ecosystem generates no waste; one species' waste being another species' food. Thus matter cycles continually through the web of life. It is this closing of the loop in reuse and recycling that our human-made environment must imitate.

We should unceremoniously regard everything produced by humans as eventual garbage or waste material. The question is what do we do with the waste material? If these are readily biodegradable, they can return into the environment through decomposition, whereas the other generally inert wastes need to be deposited somewhere, currently as landfill or pollutants.

Ecomimetically, we need to think about how the skyscraper's components and its outputs can be reused and recycled at the outset in design. This determines the processes, the materials selected and the way in which these are fabricated, connected to each other and used in the skyscraper built form.

For instance, to facilitate reuse, the connection between components in the skyscraper's built form needs to be mechanically joined for ease of demountability. The connection should be modular to facilitate reuse in an acceptable condition.

Systemic Integration

Another major design issue is the systemic integration of our built forms and its operational systems and internal processes with the ecosystems in nature.

This integration is crucial because if our built systems and processes do not integrate with natural systems then they will remain disparate, artificial items and potential pollutants. Their eventual integration after their manufacture and use is only through biodegradation. Often, this requires a long-term natural process of decomposition.

While designing for recycling and reuse within the human-made environment relieves the problem of deposition of waste, we should integrate not just the organic waste (e.g. sewage, rainwater runoff, wastewater, food wastes etc.) but also the inorganic ones as well.

Here we might draw an analogy between ecodesign and prosthetics in surgery. Ecodesign is essentially design that integrates our artificial systems both mechanically and organically, with its host system namely the ecosystems. Similarly, a medical prosthetic device has to integrate with its organic host being - the human body. Failure to integrate well will result in dislocation in both.

By analogy, this is what ecodesign in our built environment and in our businesses should achieve: a total physical, systemic and temporal integration of our human-made, built environment with our organic host in a benign and positive way. The remainder of this paper illustrates five examples of Ecoskyscraper design selected from recent works by our practice.

Part 2. Exemplary Projects

The EDITT Tower: Singapore

The design for the EDITT Tower, on an urban corner site in Singapore, is a hybrid form that fulfils the client's requirements for an Expo Tower. The overall programme of uses is initially defined by the nature of an Expo event and includes retail areas, exhibition spaces and auditorium uses as well as more conventional open office spaces on the upper level, but its design allows future transformation to offices or apartments.

The 26-storey tower advances ideas for a civilized vertical urbanism – the continuous extension of street life into the elevated levels of the skyscraper. But perhaps more important in the context of this paper, the project explores and demonstrates an ecological approach to tower design. The design and its inherent plan geometry display an organic composition – related both to public space and circulation – advancing towards a new ecological aesthetic. (See Figure 1)

Figure 1: The Editt Tower, Singapore

The design displays an organic composition advancing towards a new ecological aesthetic.

The plan organization incorporates several features that have come to be recognized as the signature hallmark of our designs. These include vertical landscaping, skycourts, atrial spaces and sky-plazas; and very heavy solar-shielding of the eastern face, with a unified ‘wall’ of stair towers, lifts and restroom accommodation.

The two central propositions of place making and public circulation, coupled with an extended ecological agenda both take their place as major forces and expressive elements within the design. They are the root and content of the whole architectural form and substantiate our contention that the design of energy-efficient enclosures has the potential to transform architectural design from being an uncertain, seemingly whimsical craft, into a confident science.

One issue in the design of skyscrapers is the poor spatial continuity that usually occurs between street-level activities and those spaces at the upper-floors. This is due to the fact that conventional towers are based on repetitious, physical compartmentalization of floors within an inherently sealed envelope. Urban design involves ‘place making’ and in the Editt Tower in creating ‘vertical places’, our design brings ‘street-life’ to the building’s upper-parts through wide landscaped-ramps upwards from street-level. Ramps are lined with street activities: stalls, shops, cafes, performance spaces and viewing decks, up to the first six floors. Ramps create a continuous spatial flow from public to less public, as a vertical extension of the street, thereby eliminating the problematic stratification of floors inherent in the tall buildings typology.

Aside from the abundant, spiraling landscape of indigenous vegetation, which assists ambient cooling of the façade, two further elements were foremost in the form-giving process. These are the curvilinear rooftop rainwater collector, and the attendant rainwater façade collector scallops, which form the rainwater collection and recycling system. Equally the extensive incorporation of photovoltaic panels on the east façade, add another level of formal detail towards reduced energy consumption.

The ecological response began with an extensive analysis of the site’s ecology. This exhaustive analysis of ecosystem hierarchy, determined that the site had a city centre ‘zero culture’, which is a devastated urban ecosystem with none of its original topsoil, flora & fauna remaining. This focused the design approach towards the restoration of organic mass, which would enable ecological succession to replace the inorganic nature of the site.

The design response biologically rehabilitates the site’s almost entirely inorganic character with a well-planted façade with garden terraces in the form of a continuous ‘landscaped ramp’ that weaves its way upwards from the ground plane to the summit of the tower. The continuous vegetated areas occupy a surface area of biomass that equals approximately half the gross area of the entire tower, in an exceptionally high ratio of abiotic to biotic components in this human-made ecosystem. A survey of indigenous planting within a 1.5 km radius identified species that would be appropriate for the site. The planting contributes to the ambient cooling of the façades through evapo-transpiration and the landscaped ramp coupled with the continuously shifting organic plan results in a built form that is literally a vertical landscape. (See Figure 2)

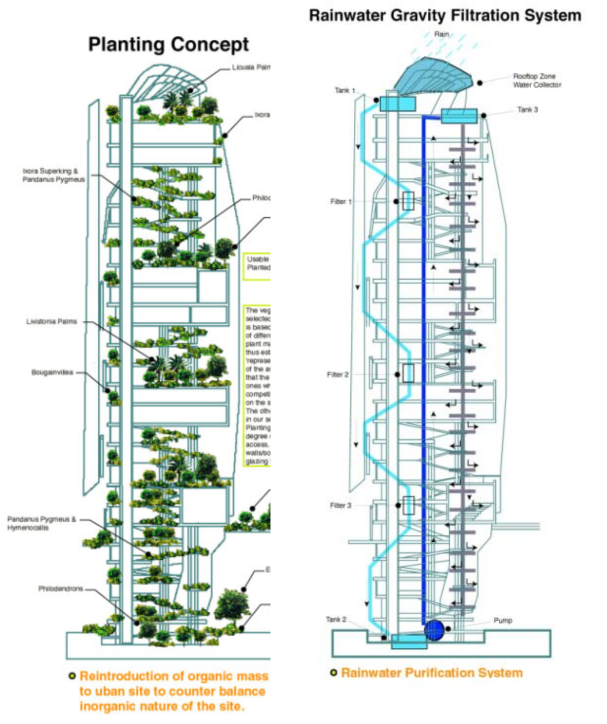

Figure 2: Editt Tower, Singapore

The reintroduction of organic mass to an urban site. Rain water purification system

The ecological design process includes a ‘loose-fit’ philosophy, which will enable the building to absorb change and retrofitting over its life span. This involves removable partitions and floors, reuse of skycourts, and mechanical jointing, which enables future recovery of materials.

A series of systems further underscores the ecological design of the tower. As well as water recycling and purification associated with rainwater and grey-water reuse, the project includes sewage recycling, solar energy use, building material’s recycling and reuse, together with natural ventilation and ‘mixed-mode’ servicing. The latter optimizes the use of mechanical air-conditioning and artificial lighting systems are reduced, relative to the locality's bioclimatic responses. Ceiling fans with demisters are used for low-energy comfort cooling. Wind is also used to create internal comfort conditions by the introduction of 'wind-walls', which are placed parallel to the prevailing wind to direct airflow to internal spaces and skycourts to assist natural cooling.

The whole material fabric and structure of the tower were subjected to an embodied energy and CO^2 emission assessment, in order to understand the environment impact of the project, and to define a balance between embodied and operational energy content. While these methods are neither unique nor overly new in themselves, this signals our ecological attitude to design, and provides the basis for development in future projects.

Chong Qing Tower: China

The Chong Qing Tower is designed to accommodate the headquarters of the Jian She Industry Corporation Ltd in Chong Qing. China. The tower springs from a podium containing a large exhibition hall. A number of Eco-Cells designed as vertical cellular slots are integrated into the podium with a spiral vegetated ramp that starts from the basement and climbs to the roof of the podium to bring biomass, vegetation, daylight, rainwater and natural ventilation into the inner depths of the floors (See Figure 3). Other features incorporated in the exhibition hall podium are a bio-swale (pond) to collect rainwater, solar thermal collectors, and photovoltaic panels.

Figure 3: Chong Qing Tower, China

Landscape is continuous from street level to the summit of the tower.

The site edge is planted with hardy trees and plant species indigenous to Chong Qing with the landscaping continuous from street level to the base of the office tower, which is conceived as a vertical extension of the roof garden above the exhibition hall. A spiral planter system encircles the tower bringing vegetation to the summit. Sky courts at the edges of the tower are located next to the structural lift core as pocket parks-in-the-sky. These also serve as interstitial zones between the internal areas and external areas. Recessed balconies with full-height glazed doors open out from the offices. These serve as areas for planting and landscaping. At the summit of the tower are four wind turbines.

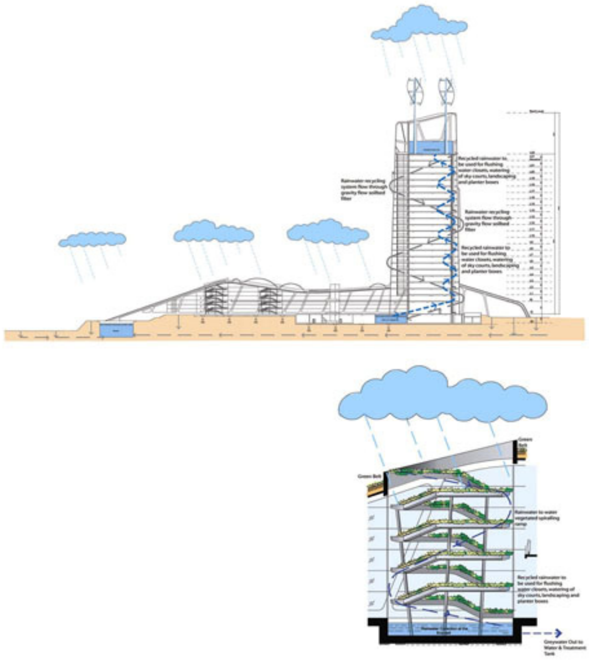

Figure 4: Chong Qing Tower, China

Rain water recycling and collection. Recycling through soil bed filters to eco-cells.

Recycled rainwater is used for flushing water closets, watering of sky courts, landscaping and planter boxes. The rainwater flows through gravity flow soilbed filters and is collected at the base of the eco-cells. The design also experiments with waterless sewage systems (See Figure 4).

BIDV Tower: Vietnam

The Bank of Investment and Development Vietnam Tower is located on Nguyen Boulevard an important artery of Ho Chi Minh City. Conceptually the design seeks to incorporate and integrate the boulevard into the building both socially and physically. The boulevard leads seamlessly into the building and rises up the tower, infusing each floor with greenery before descending back down to merge with the city streets (See Figure 5).

The 40-storey tower serves three different functions. Ground level to Level 4 are for the use of BIVD. Levels 5 and 6 are for international and national conferences and seminars while Levels 7 to 39 are for lettable offices. Recreational and dining areas and a roof garden top the building.

Wind funnels ensure that all lift lobbies, toilets and fire stairs are naturally ventilated as well as channeling wind to cross-ventilate the office workspaces. Eco-cells are a passive method of bringing sunlight and fresh air into the basement. Sky-courts allow the occupants to enjoy greenery as well as being an effective method of passively cooling the ambient temperature. All result in a state-of-the-art tower.

Figure 5: BIDV Tower, Vietnam

The boulevard is extended upwards infusing the tower with greenery.

K Tower: Kuwait City

The 65-storey, 260-metre high K Tower is an iconic building that is intended to be an iconic landmark on the Kuwait City skyline. The tower is divided into four main areas. At basement level are four floors of car parking, above this is a six-storey podium and rising from the podium a 59-storey office tower surmounted by a 36-metre high 'cupola' beneath which is a an observation deck and lush rooftop garden.

Given that for four months of the year Kuwait is too hot for outdoor activity, we have proposed a building that is adaptable to a range of local climatic conditions, consisting of passively cooled triple-volume sky-courts 'snaking' up to the summit of the tower.

The precedent for the design is a desert flower called 'cynarium'. This is intended to be symbolic of progress in the harsh desert environment. The concept is developed from the shape of three petals of the cynarium plant and spirals through 180 degrees to the top of the building. The three strands weave upwards and form a 'vertical necklace of gardens' (See Figure 6). The intertwining form emerges from the ground and appears to 'grow' out of the site.

The vegetation works its way up from the eco-pods in the basement via the landscaped ramps. The vegetation then fans out into a large podium rooftop garden providing space for public social activity. The necklace of greenery continues up the tower via skycourts and atriums to the summit, culminating in a viewing deck that overlooks the ocean, Kuwait City and the desert.

Figure 6: K Tower, Kuwait City

Greenery spirals upwards and forms a 'necklace of gardens'.

The tower responds bioclimatically to the solar path and wind-rose as a passive-mode of design to address the hot arid climate of the locality. Intermediate sky-courts create a cool microclimate assisted by the spillage of air from the internal floors.

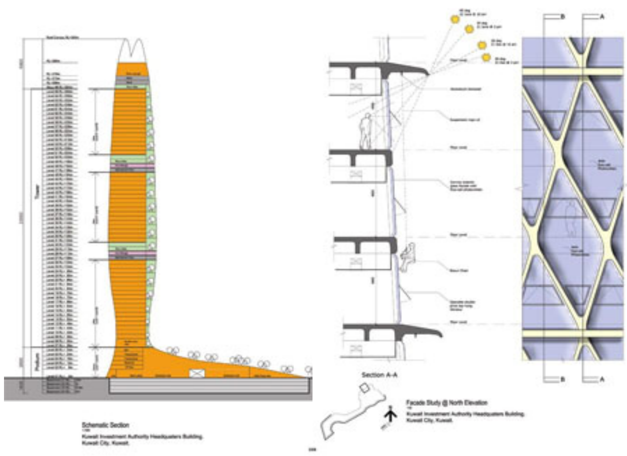

Figure 7: K Tower, Kuwait City

Schematic section indicating vertical gardens and façade study.

Rainwater is collected from the roof garden at the summit of the office tower and the landscaped roof of the podium for recycling. The water is first stored in collection tanks, and then transferred to a treatment tank. The 'grey' water is subsequently used for water closets, and watering of landscape areas.

An important design feature is the eco-skeletal structure supporting the continuous organic content of the building, which is expressed on the façade (See Figure 7). Sun-shading devices are an integral part of the cladding system. The twisting form of the building is intended to create a delicate balance of modern technology and nature symbolising Kuwait's cultural, social and economic development.

Eco Bay Complex: Abu Dhabi UAE

Our proposal for Eco-Bay is based on the idea of a 'green oasis of ecological living'. This oasis is conceived as a network of passively-cooled gardens and public spaces beginning with a large plaza at ground level, which then winds its way up to the sky as a series of pocket gardens floating within each of the five towers (See Figure 8).

Given that for many months of the year Abu Dhabi is, like Kuwait, too hot for prolonged outdoor activity, we have proposed an environment, which is adaptable to the range of local climatic conditions. Whereas most local mixed-use development are based on two standard typologies – either that of storefronts accessed directly from the street, or of enclosed climate-controlled shopping malls – we have created a third option suitable for the climatic and urban conditions of Abu Dhabi, consisting of a semi-enclosed and passively-cooled pedestrian street and courtyard/atrium around which the various programmes and buildings are organised.

The eco-court is conceived as a five-storey atrium space facing out towards the Loop Road. A low-energy evaporative cooling system obviates the need for air-conditioning and provides a year-round public courtyard inspired by traditional souks, suitable for hosting informal markets as well as public events. During cooler months, operable windows could open up the entire atrium to create a truly outdoor plaza.

Figure 8: Eco Bay Complex: Abu Dhabi UAE

Eco Bay is conceived as a 'Green Oasis' with a network of passively coded gardens.

An eco-street is designed as a sweeping pedestrian arcade which allows shoppers and residents to traverse the site from one end to the other in a shaded, enclosed and evaporatively-cooled environment. The eco-street ramps up two storeys to cross over a central feeder road and in the process connect with a future elevated train station thereby integrating the site's interior circulation system with the larger system of public transportation.

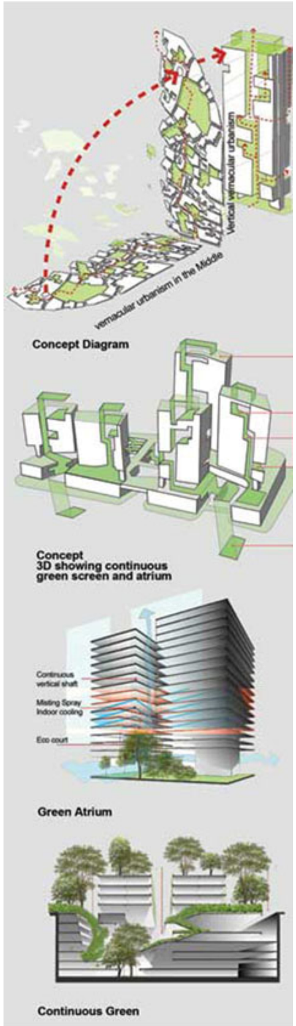

Figure 9: Eco Bay Complex: Abu Dhabi UAE

The concept expressed diagrammatically.

Inspired by traditional local typologies of public space our design translates the concept of horizontal streets and public courts into a vertical system beginning at ground level and ascending to the lower rooftops. Starting at basement level these voids allow light, air and vegetation into underground parking areas. The vegetation then progresses up the ramps, which connect at the podium level, transforming the ramps into an indoor network of tree-lined streets. At the level of the podium roof these elements of vegetation fan out into rooftop gardens partially shaded by a canopy. Finally, this ‘garland of greenery’ traces its way up a continuous vertical shaft along the southern façade of each tower, projecting out into scalloped pocket gardens and atriums as it works its way up towards the rooftop, culminating in rooftop gardens and restaurants which look towards the ocean and the skyline (See Figure 9).

The ecological aims of this proposal were firstly to create lifecycle energy savings but secondly to create a strong visual symbol of the healthy and holistic lifestyle, which is the identity of Eco-Bay. The resulting bio-climatic design focuses on low energy systems of passive cooling and also on the literal ‘greening’ of the site in the form of vertical gardens.

Bio-climatic features include our proposal to passively cool the building through a combined system of natural ventilation, evaporation and shading systems. A misting system is implemented in the indoor garden and at the atrium spaces, serving to both cool them and to water the plants. Small ‘notches’ in the façade of the indoor atriums force wind inside (in effect acting as a wind wall) which contributes to evaporation subsequently reducing the indoor air temperature. This system implemented in other projects implemented by our office is proven to be more energy efficient than other forms of air-conditioning.

The south, east and west facades of the building are clad with deep sun-shading louvres to block direct sunlight during the hot months of the year, while permitting indirect natural daylight to illuminate the interiors. All roofs are covered in vegetation to prevent roof top solar heat gain. The floor plates of the towers are long and narrow and orientated towards prevailing winds to create optimal conditions for natural ventilation.

While serving mainly as a system for cooling the building, the network of vertical shafts and pocket gardens also provides abundant flora and the associated benefits of freshly oxygenated air. The evaporative-cooling system eliminates the unhealthy quality associated with artificial air-conditioning while the system of greenery absorbs CO2 emissions, filters toxins and produces fresh oxygen.

Although an urban site, vegetation is integrated in much of the built-up area. This allows for a diversity of species to flourish.

Our design weaves together various social, urban and ecological concerns into a single integrated system that doubles as a visual icon for sustainable living. This system – namely the network of vertical gardens - combines the ecological requirements for natural ventilation, evaporative cooling and air purification with the social requirements to provide spaces for leisure and interaction. Most important the ‘garland of gardens’ is legible and the first impression is of a suspended oasis of healthy and holistic living creating a brand image for Abu Dhabi.

Conclusion

The key principles and means to design the skyscaper as a human-made ecological system are illustrated in the five towers. The evolving principles and ideas on ecomimesis while discussed with regard to the tall building typology are however applicable to the wider role of redesigning our human built environment and its eco-physical, eco-social, eco-political, eco-economic systems to enable the survival of our human species.