# **Eco-mimesis in Bio-Climatic Skyscrapers**: What's *Doable* v/s What's *Done*…

**ACRECONF India 2012**
**"Reviving Mother Earth through Better Building Design"**
*12-13th January, 2012- India Habitat Centre, New Delhi*

**Vibhor Mukul Singh**
B. Arch., M. S. *(Arch & Urban Design)*
Ph. D. (XXVI° Cycle Research - A.U.D.C.H.L.)
*Politecnico di Milano (Milan, Italy)*
**Urbanism Planning Architecture (Italia) S.r.l.**

## *Key Words:*

*Skyscrapers, High-Rise, Tall Buildings, Sustainability, Green-Architecture, Bio-Climatic Design, Eco-mimesis, Eco-Cells, Eco-Linkages, Sub-Tropical Climate, Comfort*

## *The Abstract:*

The Indian mega cities have been growing at an amazingly fast pace, and the phenomenon has been catalysed by several factors especially in the last decade. Considering the extent and speed of the urban sprawl of these cities, skyscrapers are becoming a *"necessary evil"* of our society. As an architect and urban planner, we need to acknowledge this fact, and mitigate their negative environmental impacts to make them as humane and pleasurably habitable for its inhabitants as possible. This paper primarily first underlines the necessity and feasibility of Tall Buildings in India and then focuses on three important parts: *critical analysis of the various methods being adopted (in India) to make them Green & Sustainable*, *the lapses being experienced between the theory and practice of Green & Sustainable High-Rise Architecture, and a comparative study (along with some relevant examples) of what is being practiced* by the experts & researchers in European & Scandinavian countries, to *enlist what is "Doable" based on the principles of* ***Eco-mimesis***. We shall also discuss various popular misperceptions surrounding *ecological design.*

## *The Objective:*

This paper seeks to find alternative design approaches for tall buildings that are inspired by both the urban and environmental aspects, with long-term sustainability at the core of our thinking. It further discusses what is ***Eco-mimesis***, ***Energy Eco-Cells***, ***Eco-linkages*** and few other similar theories that are being applied by various architects and researchers across the globe. We shall look into the various active & passive methods of designing a Bio-climatic skyscraper and *highlight some very handy software and tools currently being used* by various architects & researchers to establish the ground rules for designing a Bio-climatic skyscraper.

Further, we shall take up a few examples of important theories that are being put into practice in a number of European & Scandinavian countries to underline the gap between the theories and practices in India. Various active & passive design strategies that are being implemented, various considerations that are undertaken while locating & planning high rise buildings in an urban fabric.

## *The Approach*

- An analysis of the bioclimatic theories by various architects and Ken Yeang in particular
- Case studies analysed through simulation and post occupancy studies
- An analysis of selected key bioclimatic features as forwarded in the theories
- An analysis of bioclimatic high-rise forms and its climatic performance under the Sub-Tropical climate
- Link theory & performance of the high-rises and identify any underlying conflicts between the two
- Attempt to reconcile theory and performance under its climatic and cultural context

**Identify the key bioclimatic features**

↓

**Select appropriate case studies**

↓

**Evaluate the energy performances of selected 'bioclimatic' features**

↓

**Evaluate the overall performance of the 'bioclimatic envelopes'**
***(energy use, interaction with daylight and heat gain and occupant assessment of internal environments under the Tropical climate)***

↓

**Compare with performances of the 'generic' models**

↓

**Comparison and discussion**

## *Methodology – The simulation process*

| | | | | | | |
|---|---|---|---|---|---|---|
| Building model | | APACHE | | Shadow analysis | | APACHE |
| Weather data | → | Heat Gain | → | | → | Simulation Dynamic |
| Construction data | | | | | | Thermal Simulation |
| Operating schedules | | | | | | |

## *Introduction*

Tall buildings often become symbols of the city in which they are located. As highly visible beacons, they present an incredible opportunity to promote more sustainable ways of living. As hubs of economic development, tall buildings serve an important purpose. Innovations that occur in their development can trickle down to sustainable models for the rest of the city; fireproofing and elevators are great historic examples of this. Tall buildings have great potential of creating sustainable built environments by their own nature. They provide denser usable spaces using less land. Therefore, more land can be saved for environmentally friendly green spaces. A tall building has less area of the exposed surface directly contacting harsh outdoor environment. Thus, energy usage for environmental control can be less. Power can be served with shorter length of distribution lines. Hence, electricity can be delivered more efficiently in tall buildings. There are many other inherent sustainable features tall buildings can provide, which come from their compactness and higher density.

The best thing we can do as architects is to make super tall buildings as sustainable as possible, and approach them as opportunities to test new ideas and technologies. We can also re-invent how they are used. The way that we conceive tall buildings is an important part of contributing to urban vitality and reducing sprawl. In addition, right now—facing an urgent need to reduce the way buildings affect the environment—we need them as catalysts for change. We are trying to get to a better place with regard to our impact on the environment, to reduce the carbon footprint of our buildings and our cities. Recognizing tall buildings as a natural architectural phenomenon due to their efficient urban land use as well as their inherent symbolic power, and appreciating sustainable design as zeitgeist, this paper presents various design strategies to produce sustainable tall buildings.

## *Background*

### *Why Tall...?*

Skyscrapers are one typology of buildings that has always been thought to have more cons than pros. Yet they have been very much a part of our urban fabric, and more so with a high sense of pride attached to them as symbols of modernity, development and futurism. In many cases, they came out from a necessity, be it scarcity of land or any other, but then, coupled with tremendous technological development in the last century and the growing aspirations of the architects and planners, started to be the identity bearers of leading mega cities of the world.

Building skyscrapers in the first place is a very sensitive issue. *To handle issues like homogeneous urban densities, shrinking city centres, urban sprawl and sustainable future growth, they will very much have to be a part of our cities.* This inference is a direct implication from the optimum utilization of resources based on the urban population density. In today's times, with increasing population and consumption, loosing space per capita and resources depleting, and at the same time more and more urbanizing, tall buildings are regarded as a possible solution for housing people and activities in a sustainable way.

The root cause of the above proposition can be understood at a level further as follows. The process of shrinkage of an urban centre is paralleled by a subsequent urban sprawl. The two processes are very symbiotic in nature. Moreover, in case of India, this relation between shrinkage and urban sprawl is currently maintaining a very delicate balance. On one hand when there's a flux of the service sector population (especially the young and professionally educated) moving towards the outer limits of the city, there is also a flux of the rural population moving into the urban limits of the city, in search of work and better lifestyle. These urban sprawls also face the problem of resource allocation, as the local municipality of urban limits does not have its jurisdiction over such places. As a result many scholars have termed such areas as *'areas with leap-frog development'*, marked with lack of proper planning, low density population, inhabited mainly by rich and influential population, good connectivity with the city, etc. The phenomena of urban sprawl can be witnessed in the peripheral villages of New Delhi. The urban expansion of Delhi has led to engulfment of surrounding village lands for the urban development process.

Densities allow for faster movement of goods, people and ideas. *Tall buildings could play a substantial role in this.* Sustainable building is an evolutionary process. It involves many little insights, inventions, initiatives and policies that make buildings gradually more energy friendly, more durable, and so on. Solutions are aimed towards reducing the use of energy, transportation costs and creation costs; and increasingly towards the creation of energy, carbon neutral development, and the like. Therefore, the presence of skyscrapers in our cities cannot be totally refuted or ignored.

### *Why Green & Sustainable...?*

Urbanization is a key global mega trend presenting one of the biggest challenges to sustainable development. Understanding and learning to guide our shifting urban patterns of living has become the priority for many planners and decision makers, something that can lead to solutions such as *Ecocities*. And since buildings account for 40 % of energy usage worldwide, many believe that focusing on the design and energy efficiency of buildings themselves will make a significant contribution to reducing carbon emissions.

*Conventional Skyscrapers* are, as most of us would agree, not very ecological in their behaviour. The anti-ecological character of skyscrapers can be attributed primarily to their 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. *(Ken Yeang)* A number of surveys and interviews have been conducted in the past that very much establish the fact that human response to skyscrapers is, in most cases, contra.

What is then, 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 city growth, and increasing rural-to-urban migration. *(Ken Yeang)*

Skyscraper can never be a truly green building. And so we should seek to mitigate its negative environmental impacts and to make it as humane and pleasurably habitable for its inhabitants as possible.

Tall buildings have a crucial role to play in this debate on the urban future. Itself the historical epitome of energy and consumption excess, the typology has the opportunity to reinvent itself as a model for denser, more sustainable cities; concentrated centres of work and life activity. Additionally, the financial and professional investment in each tall building project gives the typology an opportunity to push the agenda for sustainable design, experimental technologies and the real need for post-occupancy monitoring, for the benefit of the built realm as a whole.

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 less impact on sensitive vegetated green field sites or on productive agricultural land. This leads us to the next level of inferences:

## *How to make them green and sustainable...?*

Aiming for energy efficiency and optimal density in building always means looking at both inputs and outputs. The design of the structure has to balance the performance of the building and the needs of the client with the demands of the location within the urban and geographical context, the need for low ecological impacts and the financial considerations. Technological innovations and guidelines help, but the peculiarities of local conditions and the need for a holistic approach considering the urban infrastructure complicate the process. It takes a thorough planning to ensure typical urban functions do not get in each other's way and create unpleasant environments because of it.

Many experts expect to see increasing use of bio-mimicry techniques in architecture to more closely reflect the local environment. In this kind of design, certain ecological characteristics can be used to the building's advantage, such as wind current and sun paths. This is part of an ecological design process, in which one tries to incorporate existing flows into the design of the building, so they become an integral part of it.

Environmental architecture is only now beginning to being embraced by the mainstream. The question is what exactly is sustainable, and in how far can tall buildings provide this, or in other words, How Tall is still sustainable? Designing a Bio-climatic skyscraper involves configuring its built form and operational systems so that they integrate with nature in a benign and seamless way over its life cycle, by imitating the structure, processes and properties of ecosystems, an approach referred to here as ***Eco-mimesis***, and introduced by the architect *Ken Yeang*. As we go further with the paper, we shall discuss more about Eco-mimesis in detail.

## ***What is Bio-Climatic...?***

By adapting the philosophy of Bio-climatic design, we tend to make our high-rise buildings environmentally more responsible and resource efficient throughout their life cycle, from design to construction, operation, maintenance, renovation and demolition. The concept expands the conventional/classical concerns of economics, utility, durability and comfort. The process is intended to reduce the overall impact of the built environment on the natural environment primarily by maintaining an ecological approach and carrying out a much-needed environmental bio-integration at every possible level. Bio-climatic approach acknowledges the visual impact and alteration it creates in nature; an architecture that is concerned by the pollution it generates, be it solid, liquid or gaseous. It tries to reconcile the energy saving issue with the quality of the environment inside the buildings and reduce the environmental impact.

Although it is a relatively new term, but the phenomenon is ages old. For centuries, planners and designers have thoroughly banked upon the concepts of climatology and passive building comfort measures to obtain a suitable internal environment for all types of buildings. Entire cities were built on these principles, which extensively used the ideas like natural daylight and ventilation for maximum part of the day, solar heat gains, water conservation, etc. More recently, in the last century, Olgyay brothers coined the term “Bioclimatic architecture” and used psychometric bases to develop the bioclimatic charts, to relate climate to strategies to be used to get thermal comfort. Even today, most studies on bioclimatic architecture still use the bioclimatic charts.

The concept of bio-climatic design and embracing the nature and environment is as old as civilization, but the recent rise in ‘biophilia’ has enabled design to explore different ways in which nature can be integrated with the buildings.

*A Bio-Climatic Skyscraper*

Bioclimatic skyscrapers are ones that use environmentally and climatically sensitive forms and means of construction. The points vital to bioclimatic skyscraper design are:

- variability in facade and building performance in response to climate and location
- alignment of building along the solar path
- flexibility to adjust to different climatic needs throughout the year
- use of entirely passive means of lighting and ventilation whenever possible
- material selection based on ecologically sound principles

Given that a location's climate is a relatively durable feature, it is a legitimate starting point for expression in relation to place. Bioclimatology, in architectural terms, is the relation between the form of a structure, and its environmental performance in relation to its external climate. Although such an approach has higher start-up costs, it produces lower life-cycle energy costs, as well as providing a healthier and more human environment within the structure. Other issues that we can consider vital to bioclimatic consideration are those of place-making, preserving vistas, creating public realms, civic zones, physical and conceptual linkages, and the proper massing of built forms. A bioclimatic skyscraper should be its own little environmentally interactive community as well as interacting with the surrounding community.

Bioclimatic skyscrapers are intended to address the wants and needs of its inhabitants. They attempt to provide greater individual control of the internal environment, recreation on the ground plane as well as other provisions for recreation and relaxation, a view out, accessibility and access to transitional spaces, a sense of awareness of place and more space per person.

Approaches to bioclimatic design also include and increased organic mass in the urban setting through landscaping of greenery as part of the entire building facade. Such greenery also provides some shade, air-filtration, an improved microclimate on the facade of the building, photosynthetic absorption of pollutants, windbreaks, and improved aesthetics. Ventilation is achieved through a simple chimney effect coupled with wind channelling.

The bioclimatic approach is an excellent way to rethink skyscrapers in terms of greater environmental integrity and in terms of occupant health and well-being.

## *Ken Yeang and his approach*

Ken Yeang, a Malaysian architect and expert in ecological design, has worked extensively on bioclimatic skyscrapers and brought about tremendous paradigm shift in green design. Each project he undertakes, gives him an opportunity to evolve on his previous ideas. He maintains that a bioclimatic approach is the best initial design strategy. The design responds in a number of ways to the local climate. These factors configure and shape the built form and the orientation of the buildings. These climatically oriented design strategies optimize the ambient energies of specific locations.

He also suggests that bioclimatic design is not green design in its entirety but simply one of the aspects of it. Although it is one of the pivotal factors and provides an excellent starting point for design, which is why it is superior to others as it lets the building function in the event of a power failure. It also provides a scaffold for subsequent energy saving techniques. In his statement about “The Bioclimatic City”, Ken Yeang wrote, “The bioclimatic city reacts like the human body to changes in its environment. As the body maintains its organic stability, for example by cooling via its extremities and by its homeostatic systems, so can the tropical city employ cooling layers and use the principles of homeostasis to maintain levels of comfort.”

For Yeang one of the terms for this re-orientation is the term ‘green’ in various combinations such as ‘*green skyscraper’ or ‘sky courts’ or ‘vertical gardens’*, a direct reference to the reality of nature. Yeang gives a clear analogy: “Biologically, the leaf is an efficient solar collector. In summer, the leaves take advantage of solar radiation, permitting air to circulate between the plant and the building. It cools by means of a ‘chimney effect’ and through transpiration. In winter, the overlapping leaves form an insulating layer of stationary air around the building. Even in regions too cold for evergreen to grow, summer cooling may still be an important factor, lending an energy saving and biological validity to planting.”

Yeang believes a building should function as an ecosystem. We should try to make a building into a living system. Balancing the organic components with the inorganic is crucial. This marks the next stage of development. The practical advantages of planting in a large building range from passive cooling- whereby plants naturally add moisture to the air, which helps to cool it- to insulation. However, there are psychological benefits as well. Greenery improves the sense of wellbeing of the occupants. Researchers have shown that patients who can see trees through their hospital windows recover faster than those who cannot. Nevertheless, making a truly green building presents multiple challenges, from drainage to irrigation and picking the right species of trees and plants to be grown and providing them with sufficient daylight.

The green lungs in the city should not be just the open green areas for bringing the natural green environment into the cities, but rather they should contribute ecologically. Ideally, green lungs would function as 'enhancements for biodiversity, as greenery for the sequestering of $CO_2$, and as an integral part of the eco-infrastructure of the city with ecological corridors and fingers that must be relinked and reconnected to the landscape in the hinterland' using eco-bridges eco-under crofts.

"Geometrically," says Yeang in his book *Bioclimatic Skyscrapers*, "the skyscraper can be regarded primarily as an intensification of built space over a small site area. The tall building type permits more useable floor-space to go higher, to make more cash from the land, and put more goods, more people and more rents in one place. The environmental justification is that the high-rise's concentration of commercial activities in an urbanised location enables the reduction of energy consumption in transportation. Designing with the climate in mind comes with a functional aesthetic dimension in his skyscrapers that is rarely found in conventional high-rise buildings.

## *Maintaining an Ecological Approach*

As the whole world looks to the problem of climatic change and depleting natural resources, clubbed with issue related to saving our environment, it becomes inevitable for us designers to adopt an ecological approach. From this point of view, building green becomes an important part of the strategy as well. Making the cities green does not necessarily mean planting greens, but integrating them with the natural environment. Unit by unit, the cities and communities need to be turned into eco-cities, if not entirely then mostly, by changing all the equations of habitation, movement and behaviour.

We must look at the issues at every level- micro and macro, local and global, physical and socio-psychological. This is crucial to reach to the root cause of the damages being done to the environment. Here, it is needless to say that, the pivotal catalyst for redefining the way we live our urban lives is a strong socio-political will and intervention. A total paradigm shift is required, a change in outlook- socially, politically and economically. Equally important is the use of eco-friendly production techniques, practices and materials, leading to lowering in carbon emissions and minimal waste production.

## *Ecomimesis or Environment Bio-Integration: The key*

Maintaining an eco-friendly approach is all about the environmental bio-integration. From gadgets to people, from buildings to contextual surrounding elements, everything bears a relationship with each other and with the immediate natural environment; and all these elements, organic and inorganic, must be integrated with the later for the good. In general, this approach of integrating the built environment with the natural environment can be termed as eco-design and bio-integration.

***Today's question and the challenge is, "How to do this?"***

If we look at the functioning of our natural environment, it is not hard to observe that it maintains a crucial equilibrium amongst all its constituents- flora, fauna, terrain and atmosphere. Not only is there equilibrium, but a symbiotic relationship amongst each other as well. Our goal must be to achieve similar equilibrium and reciprocal relationship in the built environment- trying to learn from the nature's processes, functions and structures, so that the built environment behaves like an eco-system in itself.

A good example is not to consider waste as waste, but an entity that is recyclable and reusable, something that is by-produced by one process and becomes the input or fodder for another, so on and so forth. In this way, almost everything can be recycled and re-used within the system, and when re-emitted, can be re-integrated in to the environment system. This practically reduces the load and demand of non-renewable sources of materials and energy.

***In the nutshell, this process of imitating the phenomenon of the environment, as stated by Yeang, can be termed as Eco-mimesis.*** It is a fundamental premise in eco-design. Our built environment must be a sensitive imitation and intelligent representation of the natural environment and so should be tall buildings in particular.

## *Equations & Guidelines of Ecomimesis*

We can consider our buildings to be a collection of one or several activities in a single place, which can be results of various human functions. Having said this, we can understand Tall Buildings as nothing but a high degree of concentration of these activities in that place due to increased habitants and their functions. Usually with a smaller footprint, they are forced to grow vertically above each other, owing to a variety of reasons. From one point of view, this can be considered a blessing in disguise, as it helps preserve land and thereby the local bio-diversity. Further, a skyscraper is also a high concentration of materials on a particular site, which in most cases, is brought there from far-off locations, and often at high costs of manufacture and transportation, using non-renewable sources and un-ecological techniques. We must bear in mind the eventual consequences of this approach and consider the possibilities of accommodation of their after-life.

For quite some time now, there have been lots of debates and perceptions as to what is “green-architecture” or “sustainable development” or “eco-friendly design”. It is high time that we look at the issue with a more neutral mind and outlook. Most designers today, unfortunately, think that merely planting trees at various levels in a building or creating a living wall or use of photovoltaic cells and solar panels, etc, are the key and almost conclusively the core of eco-design. Some even talk of installing recycling units and systems or skin facade treatments, thinking this will instantaneously and incessantly produce an eco-friendly solution for sky-scrapper architecture. To some extent, it is true that it helps, but does it really form the core of the solution that can be called eco-friendly? All these solutions, as I would call it, form the second level of the solutions. Practically not even solutions, but remedies. Before application of these technologies and gadgetries, we have to adopt a passive bio-climatic approach, failing which, all our efforts involving use of active modes will tend to be inefficient. What good will a solar installation be, if we don’t pay attention to the solar orientation and the resulting internal layout of our buildings and its influence on the load and power requirements as well as the internal habitable environment conditions.

We must understand that none of the approaches can be generalized, as each project is specific to its location and many other factors including physical, socio-cultural, economical, to name a few. One strategy that may work for one project, might not work for another in some other location. Hence, we need to develop our approach on a project-to-project basis and not by generalised guidelines.

Eco-design is all about integration of the built and the natural, the biotic and the abiotic. The existence of a system bears a consequence on the natural environment with its own sets of inputs and outputs. All the natural factors must be considered along with issues like transportation, conservation of resources, accommodation of by-products, recycling of waste and re-use after life. Eco-systems in biosphere are definable units. Hence, our built environment should be designed analogously to the physical contents of an ecosystem.

In addition, ***it is high time we pay attention in this context and try to first freeze, then to reverse the trends; thereby bringing about the mush needed balance between the biotic and the abiotic components of the environment.*** This is the key to preserving the natural biodiversity and its balance. As we know that building, a skyscraper means accumulation of a huge mass of material composition in one place, which is largely, inorganic in nature. The construction activity, simply adds on to the inorganic component of the environment. The more we build, the more we increase the inorganic component, depleting the natural complexity and diversity of the nature and environment. This results in simplification of the biosphere. The processes are being further catalysed by pollution, deforestation and increased consumption of natural resources due to increase in population, and are deteriorating the situation and making the natural environment more and more depleted and inorganic.

***Establishing linkages between the built and natural environment is also very important.*** This links are required at all possible levels- horizontally, physically, psychologically, metaphorically. These linkages are crucial to ensure a wider level of experience of mobility, interaction and connectivity with the idea of sharing resources across the boundary. These kinds of linkages are crucial for the functioning and maintenance of the bio-diversity of the natural environment, and further increase the habitat resilience. They make the urban patterns more biologically viable. Since skyscrapers have a vertical character, these linkages acquire significance in the vertical direction as well. Activities, spaces and movements along with the building elements and movements, along with the building elements must extend their relationship not only to the ones at their level, but also to the ones above and below them. This can be done in several ways, the most obvious being a unified vertical landscape scheme.

But due attention must be given to what kind of spaces and ecosystems these schemes generate. They must relate to the assigned functions in the building, and at the same time the environment outside the building. It has to be incessant and continuous and look a lieu or else, the whole system will fail to even work.

The natural and the synthetic should embrace each other. That is what is meant by establishing an Eco-Link, a phenomenon very much a part of the Eco-mimesis approach.

The process of Eco-design starts from the basics- the site itself. Every project, as I mentioned earlier, is site and location specific, and so should be our approach. It is all about reading and judgement of the site and its conditions- the location, the climate, the surroundings, the connectivity and so forth. That is how only we can think of relating and merging with the ecology. It is important to pay attention to the local conditions, their pros and cons, their scopes and limitations, before arriving at any conclusion regarding the allocation of any sort of human activity to it.

Every site is like a living organism with its own capacity to handle the imposed pressure and stresses and to be resilient. If these limits are pushed hard, they cause irreversible damage to the available resources causing the inevitable. This calls for not just a careful study of the land use pattern, but also comprehension of the future trends of development. Here is where a holistic approach towards sustainable development comes in. Questions should be asked as to what is the type and level of infrastructure available, what are the on and off-site features, what resources are available locally, what is the context, what kind of activity is being anticipated, what is the local flora and fauna, the type of terrain, so and so forth. All these issues frame the basic strategy that would eventually form eco-friendly design. 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, 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 forms).

In case of skyscrapers, there is an advantage that they have a comparatively “smaller” footprint, thereby reducing the possible impacts on the ecology of the site and providing more options to establish eco-linkages in an urban environment. Lesser footprint implies more possibility of water percolation and recharging of ground water resources. They have a climatically interactive building design, which integrates the scope to use the location and the regulatory systems inherent in Architecture, through the choice of orientation, form, fabric and use of natural resources of energy to achieve indoor comfort conditions to reduce the load on the non-renewable sources of energy.

Using green building materials and products also promotes conservation of dwindling non-renewable resources. In addition, integrating green building materials into building projects can help reduce the environmental impacts associated with the extraction, transport, processing, fabrication, installation, reuse, recycling, and disposal of these building industry source materials. Green building materials are composed of renewable, rather than non-renewable resources. Green materials are environmentally responsible because impacts are considered over the life of the product. Depending upon project-specific goals, an assessment of green materials may involve an evaluation of one or more of the criteria.

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. Ecomimetically, we need to think about how the skyscraper’s components and its outputs can be reused and recycled at the outset in design.

*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) but also the inorganic ones.

All these guidelines are the vital points that govern the process of ecomimesis and considerably enhance the environmentally responsive behaviour of our skyscrapers. We shall now look at some of the tools that can be used, some schemes that can be implemented and certain methods that can be adopted as a part of the phenomenon of ecomimesis.

## *Principles & Strategies of Ecomimesis*

There are essentially 5 modes of low-energy design to create internal comfort conditions:

### *Passive Mode (or Bioclimatic Design)*

Passive design is the key to sustainable building. It responds to local climate and site conditions to maximize building users' comfort and health while minimizing energy use.

It achieves this by using free, renewable sources of energy such as sun and wind to provide household heating, cooling, ventilation and lighting, appropriate façade design and adopting appropriate building configurations and orientation, thereby removing the need for mechanical heating or cooling. Using passive design can reduce temperature fluctuations, improve indoor air quality and make a home drier and more enjoyable to live in. It can also reduce energy use and environmental impacts such as greenhouse gas emissions. The key elements of passive design are, building location and orientation on the site; building layout; window design; insulation (including window insulation); thermal mass; shading; and ventilation. Each of these elements works with others to achieve comfortable temperatures and good indoor air quality.

The first step is to achieve the right amount of solar access – enough to provide warmth during cooler months but prevent overheating in summer. This is done through a combination of location and orientation, room layout, window design and shading. Insulation and thermal mass help to maintain even temperatures, while ventilation provides passive cooling as well as improves indoor air quality.

All of these elements work alongside each other and therefore should be considered holistically. For example, large windows that admit high levels of natural light might also result in excessive heat gain, especially if they cast light on an area of thermal mass. Similarly, opening windows that provide ventilation will also let in noise.

### *Mixed & Full Mode*

Mixed mode is where some electromechanical systems are used. Examples include ceiling fans, flue atriums and evaporative cooling. Full mode is the full use of electromechanical 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 lifestyle 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 photovoltaic 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 eco-design is to be ecomimetic, we should seek to do the same. Now 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, photovoltaic 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., photovoltaic 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.

It is extremely important to follow these modes in the same sequence in order to achieve the best result and maximum efficiency from each of them. If done so, they can considerably reduce the load on each of the following mode, thereby effectively reducing the overall energy requirement of the building. Designing under Eco-mimesis means looking first at passive mode strategies.

To carry out bioclimatic constructions, it is important to carry out a preliminary analysis of the climate of the area where the building is to be located. This includes a study, as complete as possible, of the climatic factors: temperature, radiation, humidity & precipitation, and wind speed & direction. *Meteonorm and Weather Tool software* are some of the programs that we designers use in order to create climatic charts and psychometric diagrams.

The applied bioclimatic strategies form an integral part of architectural design in a passive way. Once studied the climatic conditions of the environment, we compare them with the thermal comfort needs, setting the comfort area in a range of temperatures between 20º and 26º C, and varying the humidity between 20% and 80%.

Below is a series of stepwise strategies for a passive bioclimatic design approach:

*a) Integration to the existing urban fabric*
It is extremely important to understand the prevailing set of conditions of the site, with respect to its location, the off-site features and the infrastructure available around it. This is crucial to understand the possibilities of making efficient use of the city's service facilities like connecting roads and other modes of transportation, electricity, water supply, sewage disposal, etc., avoiding over-burdening or underutilization of them while preventing duplication of the some. In addition, in our case (of eco-friendly design), it is important for working out the possibilities of treating them as subsequent levels of service feeders (considering what type and how much of energy can be generated on-site) and of reverse feeding them with excess energy, if generated.

Keeping in mind that our approach has to be eco-friendly, and considering that most of our design strategies will be based on bio-climatic design, we would be incorporating a number of active and passive eco-design parameters and ecomimesis principles. This would take off a considerable amount of burden from the city's infrastructure. However, how and to what extent is the question. Moreover, the answer to this question leads us to the type of relationship that will be established with the city's infrastructure. We must create new connections while strengthening the existing ones. The building shell (epidermis) regulates its contact with the environment, the view and the climatic elements, sun and wind.

*b) Location of the building.*
The building location is the first that should be decided in the sequence of choice of strategies. A bad location could provoke that the rest of strategies have less influence than they should. While contemplating the above mentioned determinants, some of the bases for a good election of the location could be:

- -Avoiding close geographical features that would obstruct the radiation and/or wind circulation.
- -Placing the building next to water layers (lakes, fountains) or green surfaces, since they reduce thermal oscillations.

*c) Shape and orientation of the building.*
The orientation of the building is also an important strategy, because it is influenced by the development of the urban framework where the building is located and in turn influences the internal building environment. Regarding this matter, in our latitudes it is recommended, as far as possible, a NE-SW orientation as shown, because it is on this façade that the building gets a bigger amount of solar radiation in summer than the radiation on East or West façades. This situation happens in the Northern hemisphere due to the sun trajectory.

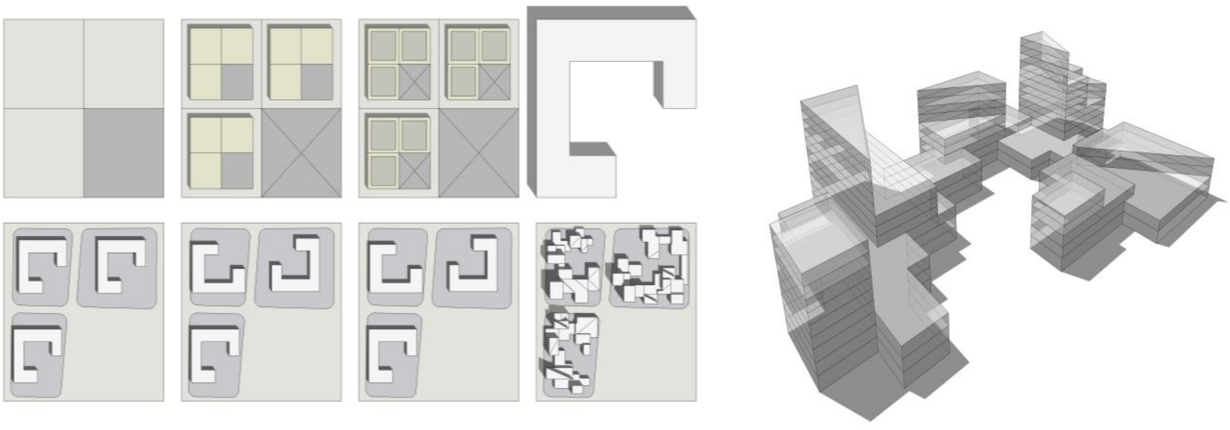
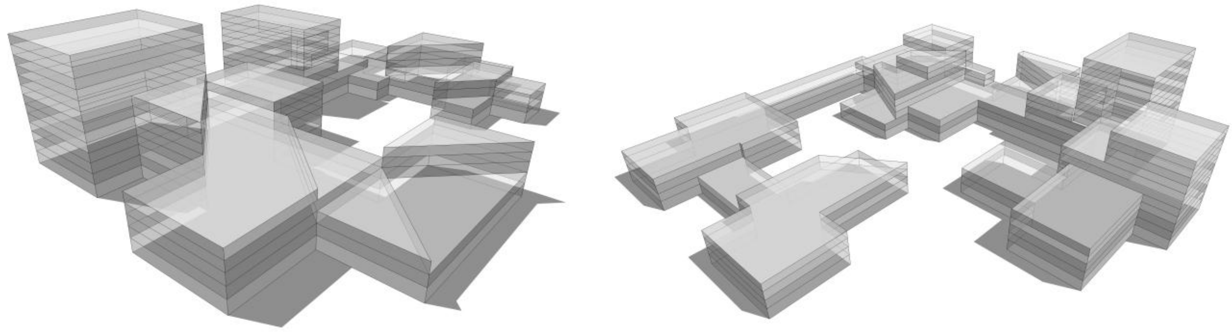


*Illustration showing the orientation, volumetric and climatic study process for a mixed use development in Shanghai.*



*Several options for volumetric configurations were studied to make most judicious use of natural lighting and ventilation.*

The shape of the building has an influence on the building's surface exposed outdoors. So, compact forms result in a smaller surface exposed to the exterior. For this reason, the shape of the building depends on what goals we want to achieve:

-In dry, warm areas, the day solar radiation is huge and we need a minimum contact with exterior. Therefore, compact forms are used.

-In humid, warm areas, the biggest issue that must be avoided is environmental humidity. Therefore, a bigger surface exposed helps to the elimination of this humidity by allowing the ventilation. For that reason, there is a tendency to look for more open forms.

-In cold areas, the situation is similar to dry and warm areas. The outdoors is so unfavourable that we need to isolate from it. To do so, compact forms are used (An extreme case of this situation is the Eskimo igloo).

-In warm areas we look for a balance between both situations depending on the goals to be accomplished.

*d) Solar protection (Cooling Period: Summer)*

This is another particularly interesting system. Moreover, its design is usually simple and logical. It is about designing mechanisms or devices that reduce the intensity of solar radiation to avoid its negative effect both on energy and light at certain points during the year. There are fixed and mobile solar protection elements, horizontal and vertical, interior and exterior:

-Horizontal elements: eaves, portico or arcade, corbels, venetian blinds, pergola, canopy and shield roof.

-Vertical elements: screen, sun breakers, vertical blind, double wall, and lattice.

-Combinations: recessing of windows, change of orientation in windows, shutters, new glazing, curtains and interior blinds, vegetation and colour of the envelope.

Most of solar protection strategies require a good use, so it is important that the user is well-informed and involved in getting the comfort in the interior of the building.

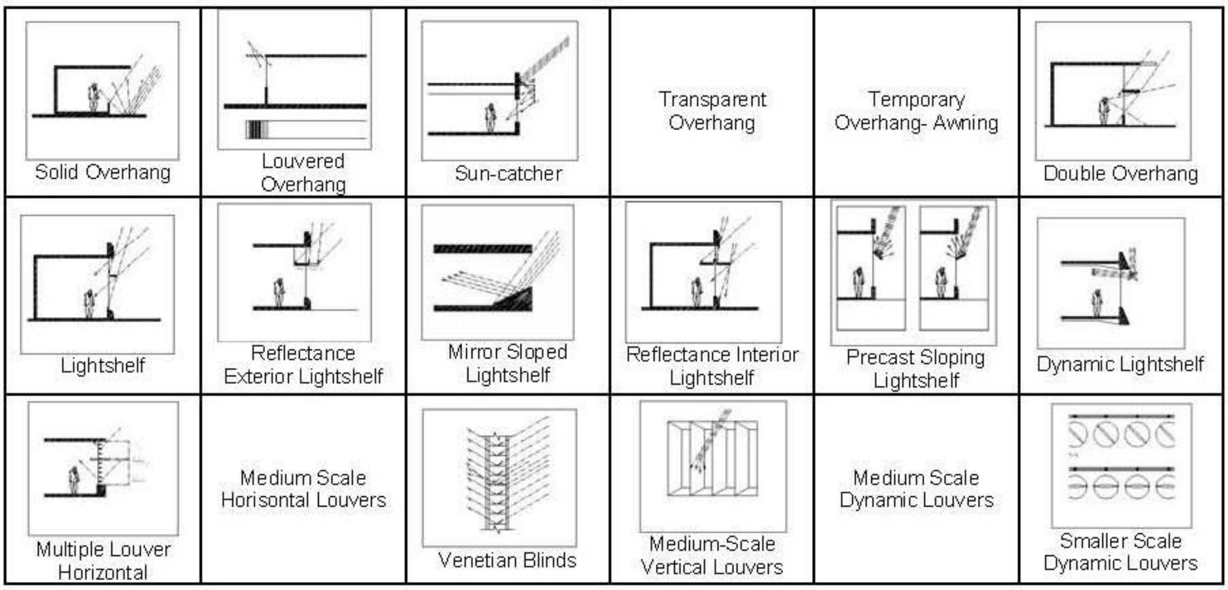



*Illustration showing various options for the sun shading using projection elements, as well as louvers & blinds.*

*e) Passive exploitation of solar energy (Heating Period: Winter)*
This is one of the most important strategies and on which we can exercise our power of decision. The sun is the most important energy resource. The proposed strategies have to capture the energy first, store it and then distribute it. There are direct systems: the building warms up by the direct action of the solar rays; and indirect systems: the energy warms up a thermal mass located between the exterior and the space to be heated, and afterwards this heat passes on to the building, like in the greenhouse or stopper space (Fig. 3), the Trombe wall and accumulations in other elements of the structure (cover, frameworks) and later distribution to the interior of the building.

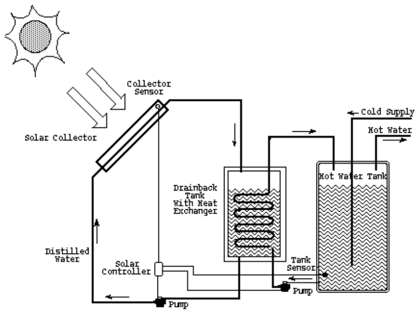
*The external shading system sits like a skin on the outside of a building, moving around on tracks to shield the sun while still allowing daylight to penetrate. The sunshield is made from a lightweight frame incorporating photovoltaic cells.*

*Winner of the 2nd International Competition for Sustainable Housing by Knafo Klimor Architects and Town Planners, Israel*

*f) Active exploitation of solar energy  (Heating Period: Winter)*
It consists of transforming the solar energy in other types of energy by means of elements integrated in the building or elements that are added on the cover of it. The European Union is boosting the development of these strategies by creation of the programs like THERMIE and JOULE that sponsor research projects with a huge technological component. There are two usual types of strategy:

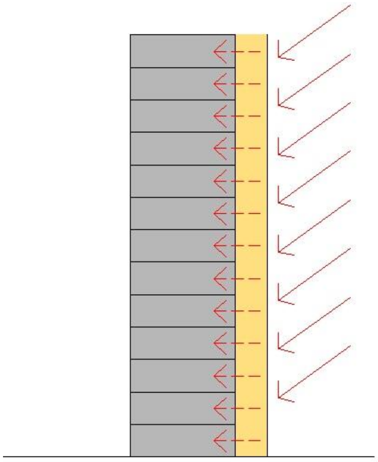
-Photoelectric systems, where solar energy is captured by silicon photovoltaic cells and then transformed into electric energy, which can be accumulated in batteries for later use. Or if the system is connected to a network, distributors can sell electric energy.

-Photothermal systems. By heat accumulating systems, hot water can be obtained (for sanitary use and/or heating). The elements are simpler than in photoelectric systems.



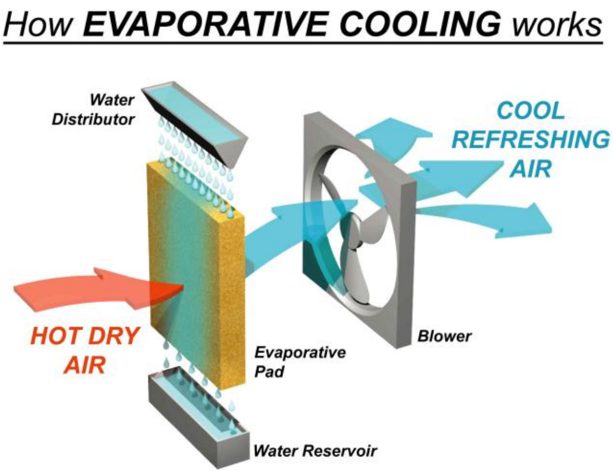

*Solar Panels with Photovoltaic Cells* *Solar Water Heating System* *Working Diagram of Solar Heating*

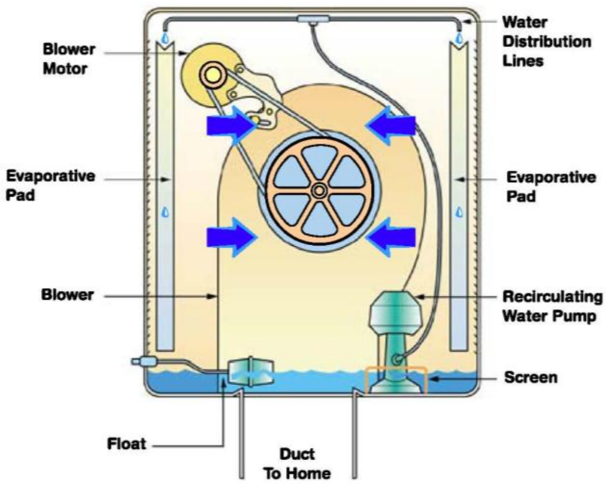
*g) High thermal inertia*



It is a design strategy that depends on the construction materials used. Its functionality is shown in climates where thermal oscillations are high, since it works on reducing extreme temperatures and delaying the cycle. Thermal inertia of a material is the difficulty it presents to change its temperature and it depends on the mass, the density and specific heat.
In old buildings where walls had the double function of enclosure and structure, thermal inertia was high due to the thickness of the material used. Nowadays, closings are not practically used for structural function, getting to the point where the closing is just like an exterior skin a few centimetres thick. To get the effect of thermal stability that inertia provides, we should find a balance between both extremes, although the cost of a construction element of bigger mass is higher, we must take into account the possible savings in HVAC that could be achieved with this strategy. Moreover, they provide an acoustic and light isolation which is essential to the elaboration process.

*h) Cooling by evaporation.*
In this strategy, we try to use the energy (vaporization latent heat) needed for the change of phase of the water for the air-cooling in the interior of buildings. For this system to work, we need a low relative humidity environment. There are two modalities of cooling by evaporation: the active cooling, where the water source is meant for that finality; the passive cooling, where existing situations provide humidity to the system is used.




The different methods that can be used are:

- -Underground water pipes
- -Fountains, pumps or water layers
- -Lush vegetation
- -Patios with fountains or vegetation
- -Water pulverization in the surroundings of the building or in structural parts of it.

*i) Insulation*

Insulation is the most efficient way of reducing the energy flow in a construction work, besides being a requisite in all building to comply with all the regulations. Increasing the isolation of a closing implies increasing its thermal resistance. This is accomplished by the use of insulating materials that enclose huge quantities of air in their interior in cells and as watertight as possible. We must reconcile the benefits produced by the thermal insulators and the cost they involve, since from a determined thickness of the insulator, the reduction of the energy flow created does not compensate the increment of the cost. We must also take into account the execution of it in order to avoid thermal bridges, where, besides of wasting energy, condensation can happen that could lead to exhausting the insulating capacity of the material. Regarding the insulation, it must be considered that not only the wall must have a proper level of thermal insulation, but the glazing must have a transmission rate that does not allow a massive outlet of the heat accumulated in its interior. For this reason, double glasses are recommended, since between the two layers of glass it comes an air or inert gas layer that works as isolation.

*j) Natural ventilation*

In the summer of Sub-Tropical countries, natural ventilation is the most effective system of passive cooling. It consists of inducing the passage of air from the exterior to renew the hot air from inside the building. This is basically accomplished by the design (mainly dimensions and orientation) of the holes in the façade, but there are also other mechanisms that force the movement of the air. The mechanisms that promote the air movement in buildings can be classified in two: by action of the wind and by difference of temperature. To use the favourable action of the wind, we need to know its distribution in the season we are interested in (usually summer). The more used strategies to favour ventilation are: crossed ventilation, stack ventilation or vertical suction ventilation, ventilation in patios, forced ventilation by fan in the upper part of the building, chimney effect, solar camera, static aspiration and wind tower.

*k) Day-lighting*

The day lighting analysis can be performed with the use of the programs like *Ecotect and Desktop Radiance*. When using these programs, the analysis is based on isolux contour diagrams and day-lighting simulation of selected interior spaces. The analysis (see below) shows an example of a building where day-lighting levels and distribution are adequate, even with overcast sky conditions. This is a result of the appropriate choice of vertical and roof openings in combination with the external shading elements.

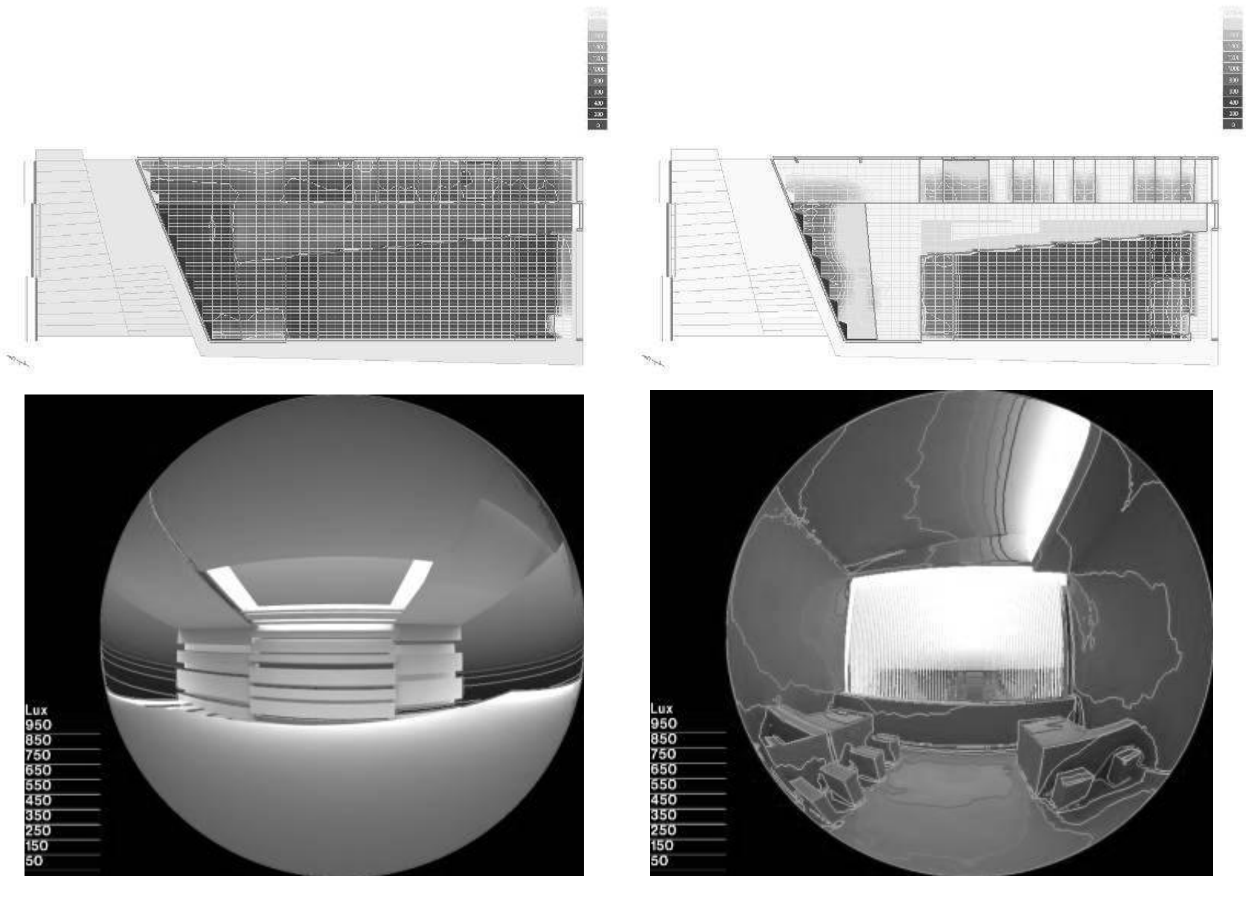



*Illustration showing the images obtained from the softwares Ecotect & Desktop Radiance to analyze the lighting conditions.*

*l) Microclimatic modification*
Utmost care must be given to the existing flora, fauna and any other type of natural or otherwise available resource like trees, water bodies, etc. and they should be preserved and the proposed vegetation must involve local or indigenous plants which are able to with-stand local summer conditions (increased temperatures and availability of water). Irrigation needs can be partly covered with the collection of rainwater in an underground reservoir.

*m) Construction and Green Materials*
The use of green building materials and products represents one important strategy in the eco-design of a building. Green building materials offer specific benefits to the building owners and building occupants:

Reduced maintenance/replacement costs over the life of the building.
Energy conservation.
Improved occupant health and productivity.
Lower costs associated with changing space configurations.
Greater design flexibility.

## *Tools & Features of Ecomimesis*

Following the above mentioned strategies of an ecomimetic approach, we shall now look at some of the tools and ideas that can be engaged as a part of our design. Though we must understand that this is only to set examples and is not an exhaustive list. These Bio-climatic features include:

*Continuous Green Ramps & Vertical Landscaping*
*Eco-Cells*
*Roof gardens*
*Sky Courts / Sky Terraces*
*Solar Photovoltaic Cells*
*Rain Water Harvesting*
*Grey water Recycling*
*Solar Shaft / Light Pipes*
*Bio-swales*
*Vertical Boulevard*
*Wind Funnels*
*Climate Responsive Facade*
*Red / Gray / Green / Blue Infrastructure Relationship*

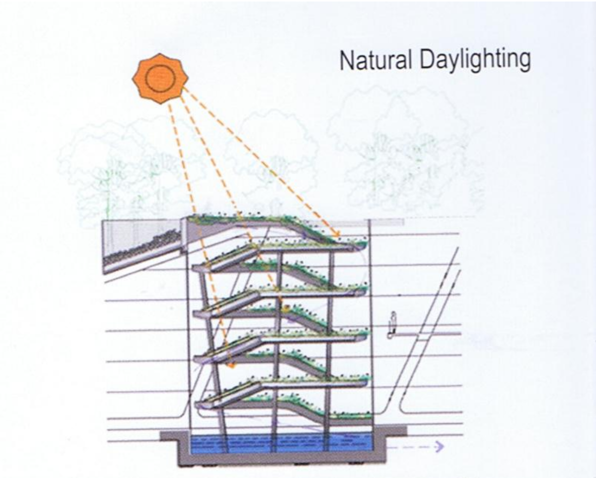

*Continuous Green Ramps*
Introduction of continuous Green Ramps provides the necessary vertical green connection in a skyscraper – the vertical Eco-Link. The placement and orientation of the Green Ramps are of extreme importance, as they have a direct bearing on the life of vegetation used in them. They can be excellent links to lush green Roof Gardens and series of Sky Terraces. These systems act as thermal buffers protecting the building from direct solar heat gain and create spaces for events, interactions and relaxation.

*Vertical Green Wall Systems*
These systems act as a bio-diverse smart skin for the facade by purifying the air before it enters the interior spaces and thereby creating a symbiotic balance between the nature and the built environment. The impact

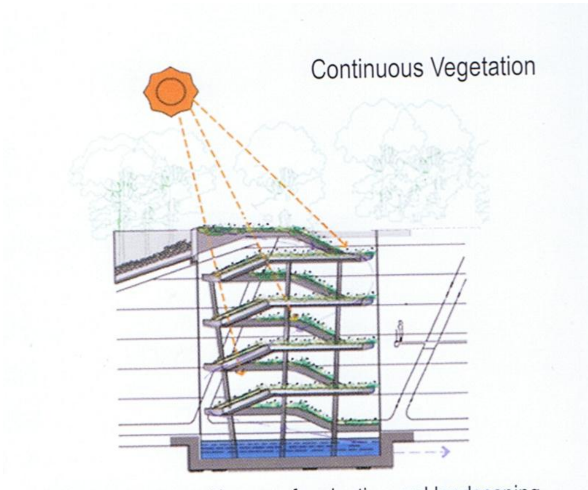
of the morning and evening solar heat gain is mitigated via a combination of modular Green Walls with trellis. These kind of systems shade the building facade, create habitable and comfortable microclimates on the external landscape terraces and facilitate natural ventilation.

*Eco-Cells*

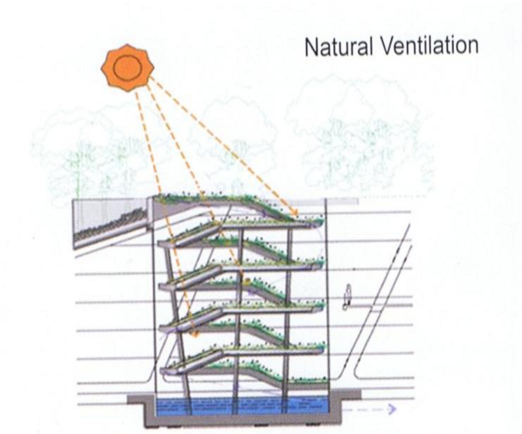
Eco-cells are vertical cellular voids, or slots, integrated into the building's podium, located between the Ground Floor and the Roof Garden, over the podium. These voids allow daylight to penetrate the full depth of the basement levels. In the process they also serve as excellent devices for the ventilation of the lower levels. This sustainable passive ventilation strategy requires no additional investment. They also help in extending the green into the upper basement levels. The landscape from the ground level can weave their way in and out of the basement levels in order to create flowing green connections. These plants also act as biological air filters in the otherwise dingy subterranean spaces.



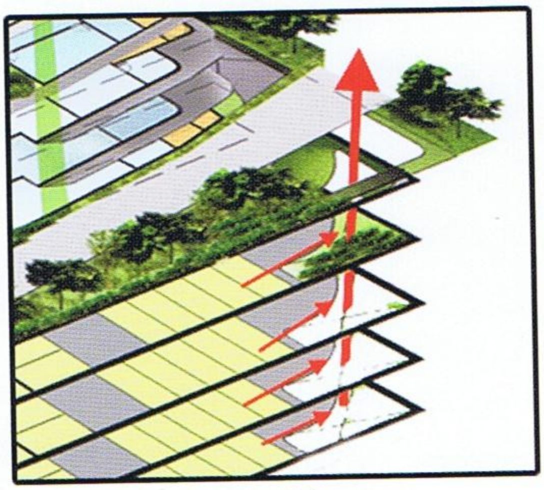

To bring natural daylight into the inner depths of the floor




Vegetated ramp with areas for planting and landscaping to experience external environment directly




Natural ventilation of carpark and exhibition spaces



Carpark Ventilation Diagram

*Roof Top Gardens*
The Roof top serves as a viewing deck, the location of executive lounges and areas for special activities and functions. Roof Top gardens allow interaction between the occupants and the nature, offering the opportunity to experience the tower's external environment and to enjoy the views from the tower top. Their orientation and placement however is very crucial in their successful functioning. A series of sky courts in the north facade can, for example, provide a variety of outdoor environments, for the users' creative and social interaction, comfortable throughout the day.

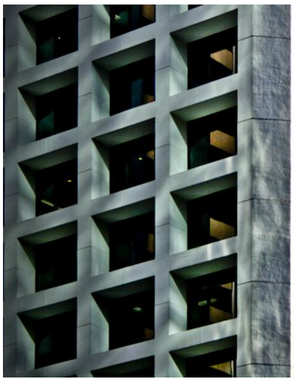
*Sky Courts/ Sky Terraces*
The Sky Courts/ Terraces can turn out to be the most vital and lively social interaction spaces in a skyscraper if devised properly. These spaces need to be designed with a certain degree of flexibility, to not only sense the functional requirements, but also to a go a step further by increasing the quality and ambience of the connecting spaces. They can serve as connections to a variety of spaces, thereby eliminating the conventional corridors, and can be used for several other purposes apart from circulation. They tend to bring about a certain degree of pleasantness in the building. The type of species selected to be grown as vegetation is very important. It should be the one that can enhance the bio-diversity of the flora of the natural environment.

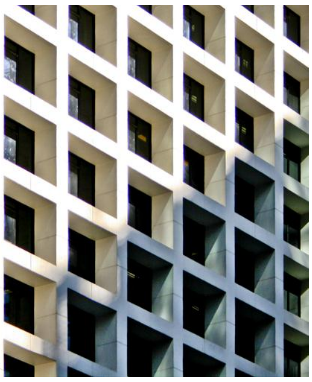
*Rain water Harvesting*
In north India, given the plenty of rainfall received during a major part of the year, the building's extensive landscaped areas can be irrigated via a large-scale rainwater recycling system. Rainwater can be collected from the drainage downpipes via siphonic drainage. It can then be stored in roof top tanks or in the basement level, beneath the eco-cell. Typically, a storage capacity of 700 cubic meters allows for more than five days of irrigation via recycled water. The green ramps and landscaped terraces act as filtration and collection devices, channelling rainwater into tanks located in the basement. This harvested rainwater can be used to irrigate the building's extensive landscaped areas, significantly reducing the project's consumption of water.

*External Views*
They are, although not active contributors to the energy efficiency of the building, but, extremely important in uplifting the overall habitation experience of the users, thereby improving the quality of internal spaces.

*Sun Shades/ Louvers*

Shading devices, when designed, calculated and judiciously used on the facade, cannot only serve to reduce the solar heat gain but also maintain comfortable thermal conditions within the sky courts and internal spaces. Any project's climate responsive facade design originates with the analysis of the site's sun path. Facade studies analysing the solar path determine the shape and the depth of the sunshade louvers, which can also double as light-shelves. This solar shading strategy can also further reduce the heat transfer across the building's perimeter facade, contributing to low External Thermal Transfer Value (ETTV). In conjunction with the spiral landscaped ramps, sky gardens and deep overhangs, the sunshade and louvers also assist in establishing comfortable microclimates in habitable spaces.





*Sky Courts*

Sky Courts create lush environment for the people inside the building. Their recessed design shades interior spaces from direct sunlight and reduce glare. Integrated landscaping reduces the ambient temperature of the building, increasing thermal comfort and the efficiency of the engineering systems. Plants also act as a visual screen and sound diffusers to reduce pollution from the surrounding areas.

The benefits of Sky Courts are:

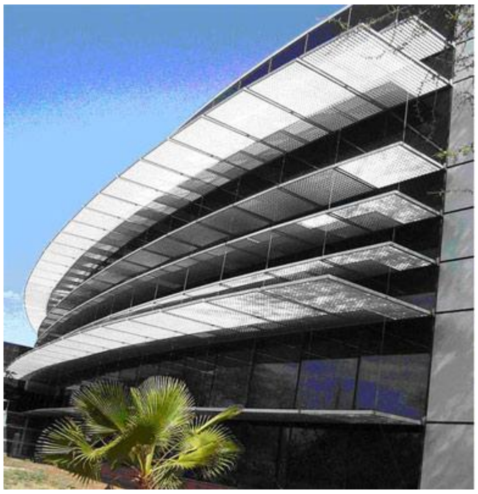
- Shading for the building
- Emergency evacuation zones
- Areas for planting and landscape
- Flexible interstitial zones for future expansion
- Provide direct experience of external natural environment on the upper floors and view of the gardens outside

*Vertical landscaping*

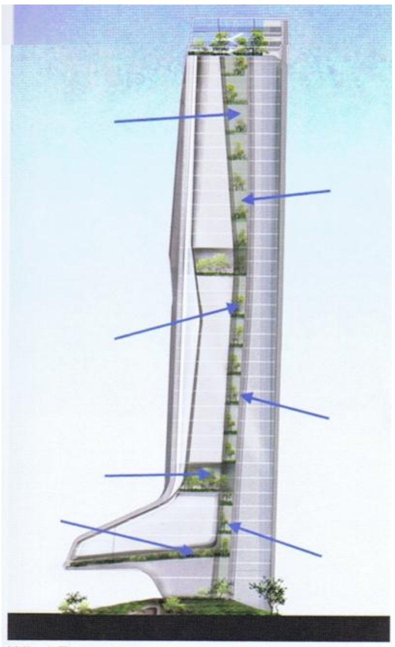
Vertical landscaping acts as a thermal buffer and creates event spaces and areas for relaxation. These extensive gardens allow for interaction between the building's occupants and the nature, offering the occupants the experience of the external environment and the views. As it reaches each corners of the building the spiral ramp expands into the generous double-volume sky terraces. The sum of the project's vegetated areas can sometimes also exceed the footprint of the site on which the building sits.

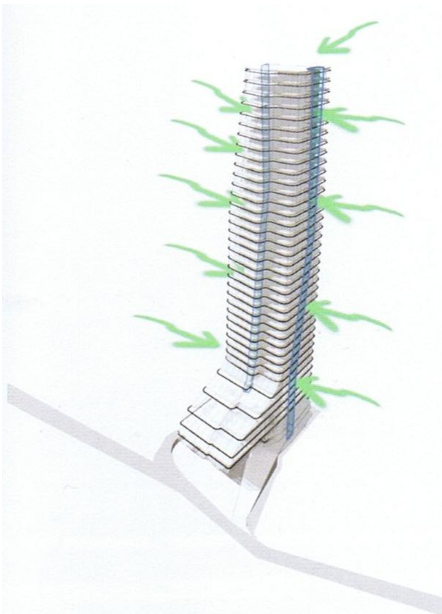
*Vertical Boulevard*
These continuous zones of vegetation connect plants from the boulevard to the roof of the any skyscraper. This vertical landscaping may rise along the wing walls of the 'vertical boulevard'. This integrated greenery further enhances the cooling effect of the sky terraces thereby lowering the temperature of the wind passing through them into adjacent workspaces. It also reduces ambient air temperatures during summer and heat loss during winter.

*Climate Responsive Façade*
Applying the principles of bioclimatic design in a building is a proven and efficient way to improve the energy performance of buildings and provide occupants with maximum comfort. The façade, being the interface where most of the thermal exchanges take place is key in this process. That is why the role of bioclimatic façades in the development of sustainable buildings is essential today. Automated solar shading and window opening devices integrated within the façade help to optimize the use of natural sources and therefore contribute to increasing the energy efficiency in buildings. Designing the façade based on bioclimatic principals reduces energy-related costs.

*Wind Funnels*
Wind funnels can be specially created and designed corridors or specially shaped spaces carved out of a particular wall enclosure or they could be usual protruding walls that channel wind into building core and service areas. They provide cross ventilation for most of the spaces that do not have an external surface to draw natural ventilation, like the rooms in the interior of the buildings. It is a highly sustainable natural ventilation strategy with low maintenance costs.


Wind Funnels


Naturally Ventilated Cores

*Light pipes & Solar Shafts*
This strategy includes the use of light shelves to increase the passive illuminated zone, and the use of horizontal light pipes to decrease the dependence on electrical light of the active zone. The light pipes are designed to channel sunlight into the deep zone of the building plan. The light deflecting panel at the aperture of the light pipes enhances the performance by redirecting sunlight more directly along the axis of the light pipes.

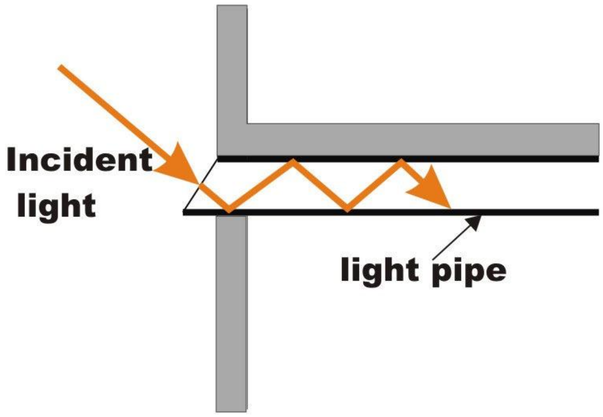



***Figure 4**: Light pipe with clear glazing. Light at any high angle coming into the pipe will be lost due to multiple reflections.*

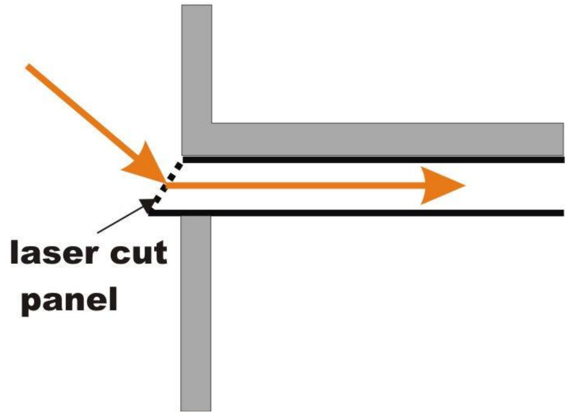



***Figure 5**: Light pipe with LCP. LCP redirects the light along the pipe reducing the number of reflections and therefore loss of intensity.*

The light deflecting panel at the aperture of the light pipes enhances the performance by redirecting sunlight more directly along the axis of the light pipes (figures 4 and 5).

Apart from the afore mentioned tools, there are a few other bio-climatic features that include:

*Service core positioning, Roof as fifth façade, Recycling of Waste, Mixed Mode Cooling, Conservation of water & use of water-efficient fixtures, Pocket Parks / Plazas (Ground Level), Motion-Sensor Controlled Lighting*

## *Case Studies & Sample Projects*

Here are a few of the cases studied to establish the above characters and features of bio-climatic design. These cases were analysed from various points of view, including those of green building design and eco-friendly methods of construction. The idea of these examples is to illustrate the potentials of ecomimetic design approach and to show how various architects are actually applying the principles of bio-climatic design. These studies show in part or in whole, the tools discussed above and their feasibility and utility.

### *Bahrain WTC*

Bahrain WTC towers have three, 32-yard diameter propellers that supply about 11-15 % of the buildings' energy needs, or about 1100 to 1300 megawatts per year. The shape of the towers creates an airflow tunnel through the buildings for improved energy generation output and each turbine will be suspended on a bridge connecting the buildings. According to BWTC designer Shaun Killa, solar panels available at the time of construction lost their efficiency due to the high Bahrain temperatures, so wind technology was the better choice for renewable supply.

*New York Times Building*

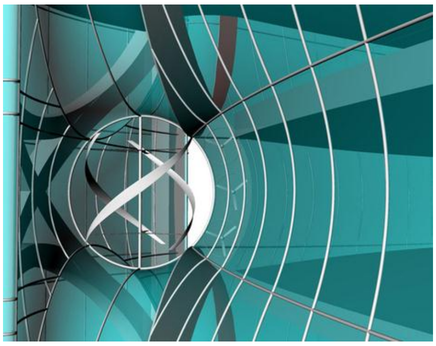
The Times Company installed a total light management system that includes daylight, occupant, target set point, time clock, and emergency lighting controls. Although the building was originally designed to use approximately 1.28 watts/sq. ft. of lighting power, it is actually using only 0.38 watts per sf of lighting power — a 70% reduction in lighting use. That means, based on New York City electric rates, they are saving ~$315,500 and preventing the emission of 1,250 metric tons of $CO_2$ annually.

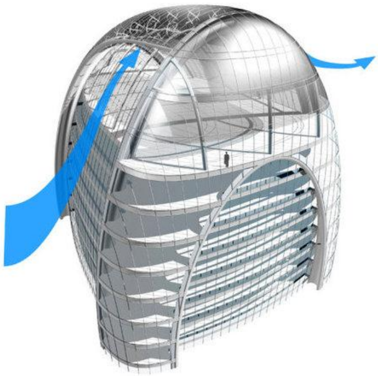
Here is where they recognized the most in terms of lighting energy savings:

- 30% – daylight harvesting
- 10% – occupancy sensing
- 2% – scheduling
- 58% – light level tuning


*Clean Technology Tower*

Clean Technology Tower, builds on principles of bio-mimicry and utilizes technology and building systems to interact with the surrounding environment. The wind turbines are located at the building's corners to capture wind at its highest velocity as it accelerates around the building. The number of turbines in the structure increases as you climbs up towards the apex, where there is a veritable wind farm! Also at the top of the skyscraper, where winds are at a maximum, is a domed double roof cavity that captures air for the wind farm. The dome itself is also clad in photovoltaic cells that harness the sun's energy.



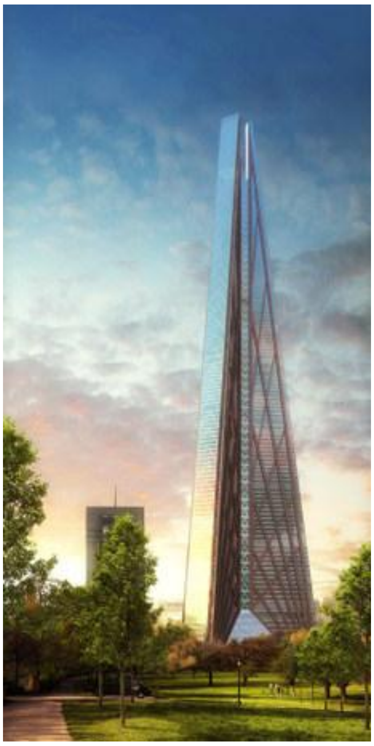


## *Elithis Tower*

Elithis Tower recently opened in Dijon, France. It has 1,600 sensors that examine energy and emissions. This information is then displayed on a special public sign in full transparency for everyone to see. With this information, owners, tenants, and stakeholders are empowered to make choices that positively affect the performance of the building. The goal is not to reach the highest level of a certification system. The goal is to actually generate more power than is used. Elithis Engineering wanted to know whether it was possible to create an environmentally sound building at equal cost to a traditional building. They examined materials based upon their global environmental impact, and ended up using recycled insulation and wood, as opposed to something like aluminum. They minimized excess space and wrapped the building in windows to create abundantly lit spaces. They topped the roof with roughly 330 solar panels. And they designed a custom solar shield to block out excess heat and glare.

## *Russia Tower*

Russia Tower is expected to be the tallest building in Europe. It'll be the largest building in the world with a natural ventilation system. Foster + Partners designed the building with an "energy cycle" system, which is a hot water circuit that runs through the building distributing the energy to regulate temperature and heat water. The energy cycle system is intended to chart new territory in sustainable architecture. The pyramidal design also maximizes exposure to natural lighting, which provides both light and warmth in the winter. Additionally, There will be a series of green sky-gardens rising up the core of the building that draw in natural ventilation and provide social space for the occupants.



## *Waterfront House*

Waterfront House, Kuala Lumpur, Malaysia (Fig. 1), located in the city centre, sited adjacent to the Petronas Towers (Fig. 2). A 20 m deep plan floor is not susceptible to good natural lighting, and therefore four light pipes per floor, coupled with laser cut panels have been proposed to improve the day lighting performance of office space in the building (Fig. 3). The light pipes are designed to channel sunlight into the deep zone of the office plan as sunlight falls on the western façade of the building. The Light pipes in plan (yellow), are aligned to come through the westerly core, (source Greg Evans). Passive zone: spaces located on the perimeter that can benefit from the ambient environment (daylight, solar gain, ventilation, view), it is normally twice the floor to ceiling height (Baker and Steemers, 2000).


*Fig. 1*

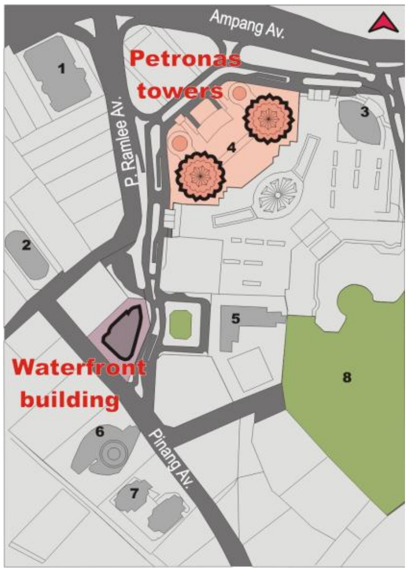



*Fig. 2*

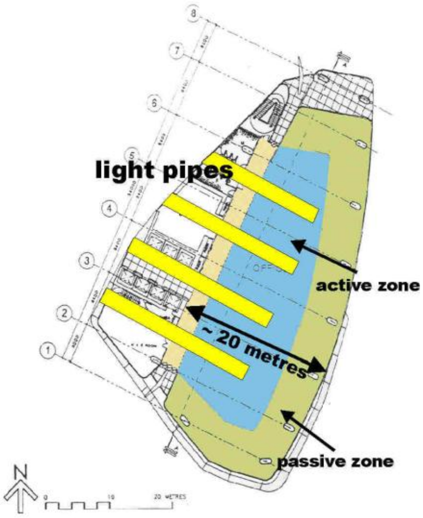
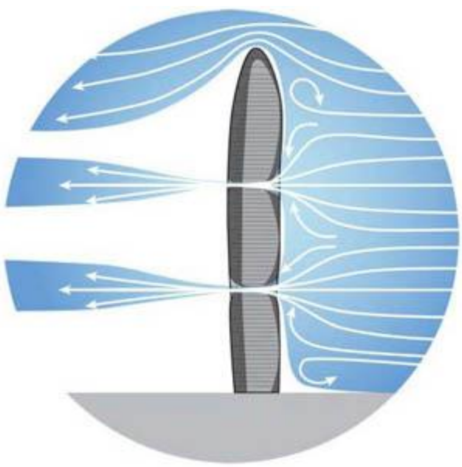
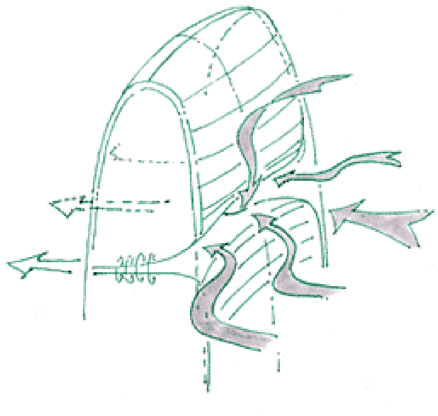



*Fig. 3*

## *Pearl River Tower*

This is the architectural rendering of a building designed by Skidmore, Owings & Merrill. It is planned to be 71 stories, 2.2 million square feet, and have a "net" zero-energy footprint. The building is designed to use wind turbines, radiant slabs, micro-turbines, geothermal heat sinks, ventilated facades, waterless urinals, integrated photovoltaic, condensate recovery, and daylight responsive controls. The building's facade was designed "to accelerate the wind as it moved through the opening in the building." Power potential is the cube of wind velocity, and SOM initially estimated that the design would increase wind velocity to 1.5 times ambient wind speeds. Actually, models tested wind speeds of up to 2.5 times ambient wind speeds in some cases. In translation: the building design could generate power 15 times greater than a "freestanding" turbine.





Wind Turbine Concept

## *Epilogue*

The various alternatives of high-rise buildings developed are signs for the ongoing search for both technological and aesthetic solutions to a building, uniting them into a new synthesis and a typology which has proven to be of fundamental necessities for the city in the 21 century. The key principles and means to design the skyscraper 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.

Application of computer programs available in the market might be useful to proof the claim advantage in more precise technique. Software package such as ***Ecotect and ASHRAE Thermal Comfort program*** or others simulation based program can be used to analyse the data for a particular area. At the moment, the authors are processing similar investigation on another four buildings that have similar characteristics in order to provide more evidence to substantiate the hypothesis. From the environmental measurement rating, we found that all elements indicate that bioclimatic design has better indoor environment than that of a conventional one however, based on user's perception from the survey data, there were no clear advantages in building performance in either "bioclimatic" or "conventional" high rise building.

## *References & Bibliography*


**Green or Grey? The Aesthetics of Tall Building Sustainability**
Antony Wood RIBA
**Sustainable design of tall building structures and facades**
Kyoung Sun MOON
**Designing the Eco-skyscraper: Premises for Tall Building Design**
**Part 1: theory and premises**
Ken Yeang
**Bioclimatic Passive Designs Rural Buildings**
Cañas, P. Núñez, S. Martín-Ocaña, F. R. Mazarrón, J.L.García-Grinda
**Yeang, Ken. *The Skyscraper Bio-climatically Considered: A Design Primer*. Academy Group, Ltd.: London, 1996**
Peter L. Kantor
**Bioclimatic parameters in the Design of Contemporary Buildings: The Proposal for the new Town Hall of Deryneia, Cyprus**
A. Michael, C. Hadjichristos, F. Bougiatioti and A. Oikonomou
**The use of light pipes for deep plan office buildings: A case study of Ken Yeang's bioclimatic skyscraper proposal for KLCC, Malaysia**
Veronica Garcia Hansen, Ian Edmonds, Richard Hyde
**Bioclimatic Performance of High Rise Office Buildings: A Case Study in Penang Island**
Lokman Hakim Ismail and Magda Sibley
**Sun-shading design method for multi-storey office building in Jakarta at preliminary design stage**
Dewi Larasati ZR
**The Tall Building And The City: The Discussion About Urban Sustainability**
Joana Carla Soares Gonçalves
**How Tall is a sustainable building?**
Rovers Ronald
**An Analysis Into The Tropical High-rises of Ken Yeang**
PuteriShireenJahnkassim,
Kenneth Ip,
**Bioclimatic Design And Energy Conservation In Buildings**
Despina Kyprianou Serghides