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Towards a Sustainable Architecture

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HACIA UNA ARQUITECTURA SOSTENIBLE

ABSTRACT

The growing awareness of the importance of ecology in the last decades has led many architects to rethink their construction proposals to make them more respectful of the environment and sustainability. The present article analyzes the legislation, conferences and international declarations (*Earth Summit*, *Declaration of Interdependence for a Sustainable Future*, *Introduction to Sustainable Design*) that have advocated the practice of a more ecological architecture. Also examined are the technological guidelines used to create an architecture that is both sustainable and harmonious with the natural surroundings, the construction materials employed in these buildings, their processes of air conditioning and lighting, and the physical and spiritual health of their occupants. Reference is made to the pioneers in the development of this sustainable architecture: Charles Correa, Brenda and Robert Vale, Kenneth Yeang. Finally, we provide some current examples of cities and buildings that have been the object of special ecological attention, realized by architects such as: Richard Rogers, Renzo Piano, Norman Foster, Jean Nouvel and Herzog & de Meuron.

Keywords
Sustainable architecture, Ecological architecture, Green architecture, Low energy architecture.

RESUMEN

La fuerte concienciación que en los últimos decenios se ha venido produciendo dentro del campo de la ecología ha motivado que los arquitectos se replanteen sus propuestas constructivas para hacerlas cada vez más respetuosas con el medio ambiente y la sostenibilidad. En el presente artículo se analiza la legislación, conferencias y declaraciones internacionales (*Earth summit*, *Declaration of Interdependence for a Sustainable Future*, *Introduction to Sustainable Design*) que han venido defendiendo un práctica de la arquitectura más ecológica. Se estudian los principios tecnológicos que pretenden hacer sostenible la arquitectura y buscar su armonía con el entorno natural, los materiales constructivos, los procesos de climatización e iluminación, y la salud física y espiritual de sus ocupantes. Se referencia aquellos personajes que fueron los pioneros en el desarrollo de esta arquitectura sostenible: Charles Correa, Brenda & Robert Vale, Kenneth Yeang. Finalmente se aportan algunos ejemplos actuales de aplicación a ciudades o edificios que han sido objeto de una atención ecológica especial, realizados por arquitectos como: Richard Rogers, Renzo Piano, Norman Foster, Jean Nouvel o la firma Herzog & de Meuron.

Palabras Clave
Arquitectura sostenible, Arquitectura ecológica, Arquitectura verde, Arquitectura de baja energía.

1 INTRODUCTION

During the second half of the 1960s there developed a strong consciousness regarding environmental problems and artistic practice. The term *ecology* was coined in 1873 by a German naturalist, Ernst Heinrich Haeckel, to refer to the study of the relations of living beings with the natural environment. The movement gathered strength and protagonism among the more restless artists of the moment. In the field of Fine Arts this focus of attention gave rise to artistic trends seeking to recover materials taken from nature itself, or aimed at protecting ecosystems, or guided by both these purposes.

The concern for environmental themes coincided with the whole process of consciousness that the western world began to experience in the decades of the sixties and the seventies with regard to human behaviour damaging to nature. This interest is evident in the enactment in 1970 in the United States of a series of laws such as *Clean Water Act*, *Clean Air Act*, *Endangered Species Act* and *National Environmental Policy Act*. In 1971 the ecological organization Greenpeace was founded in Canada. Ecologically-minded political parties began to appear in various countries of Western Europe, for instance, *Die Grünen* (The Greens), founded in 1979.

These concerns for Nature are linked somewhat with the whole genre of landscape painting that the Romanticism of the nineteenth century put into practice. Impressionism and its different evolutions at the end of that century maintained the prevalence of this artistic genre. The historical vanguards of the twentieth century left aside this world of landscapes upon becoming interested in the investigation of artistic languages and the scope of the industrial city. Their gaze focused on the urban world –synonym of modernity– where they found more real themes and a new direction for their creations. Landscascape remained anchored in the nineteenth century tradition, a theme of the past related to a rural, traditional and antiquated world.

Neither post-war Informalism, nor Abstract Impressionism, nor the new iconic options, like the Pop Art of the sixties, were particularly interested in Nature. We must wait until the second half of the sixties for the energetic resurgence of the attractiveness of the natural environment. This new view will not be merely romantic or nostalgic, desirous of an immediate and satisfactory enjoyment of Nature. We will find artistic concerns with a critical objective and a protest for a new frame of relations between humanity and its living environment.

Some exhibitions, such as *Ecological Art*, celebrated in the John Gibson Gallery in New York in 1969, actualized the new artistic orientations. With these manifestations, the materials taken from Nature, their properties and the transformations they could experience attained

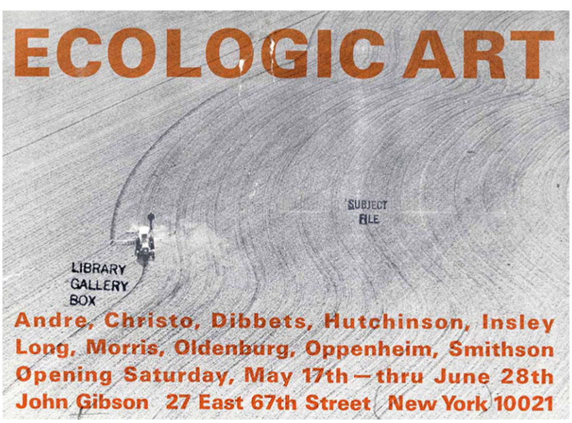


Figura 1: *Ecologic Art.* John Gibson Gallery, New York, 1969

protagonism. The appearances of Land Art and *Arte Povera* are a clear exponent of all the new preoccupations that were going to be developed in the artistic scene.

In architectural milieus, the development of ecological consciousness was slower but equally intense. In 1993 some representatives of High Tech decided to found the group READ, coinciding with the Florence International Conference on solar energy and urban planning. This group urged the use of renewable energy in construction—energy that was much more respectful of the environment. From this, a new architectural tendency of ecological orientation emerged which would receive various names: Sustainable Architecture (Broto Comerma, 2011. Kibert, 2012. Krauel Vilaseca, 2012. Minke, 2006. Sassi, 2006. Turrent, 2007), Ecological Architecture (Gauzin-Müller, 2006. Heleno et al., 2014. Jodidio, 2009. Muller, 2014. Uffelen, 2009), Green Architecture (Attmann, 2010. Chambers, 2011. Kruger, 2013. Wines, 2008), Bioclimatic Architecture, Eco-architecture, Environmentally Conscious Architecture, Intelligent Architecture, Bioconstruction, Bionic Architecture, Low Energy Architecture… The common denominator of all these tendencies was its respect for the environment and the use of technologies that are compatible with it.

This tendency is greatly related to High Tech, and some even consider it to be a vertex of High Technology that puts all available scientific advances at the service of ecology. In fact, some of the authors pertaining to High Tech have assumed the ecological principles in their work, as is the case of Norman Foster, Richard Rogers and Renzo Piano. Nevertheless, it must be stated that some architects began to be concerned with themes related to energy and climate in the seventies and may be considered pioneers of this architecture.

The term *Sustainable Architecture* is the most diffuse and the most suitable. The term comes from the concept of *sustainable development*, a term used by the Norwegian Prime Minister Gro Brundtland in his report *Our Common Future* (Borowy, 2014) which she presented at the 42nd Session of the United Nations in 1987. Sustainable development is understood to be that which satisfies the present necessities without creating future developmental problems and without compromising the demands of future generations. After this report, other declarations appeared which advocated a reformation of the relations between the human being and the planet and touched on the theme of sustainable development. One of the most significant is the *Earth Summit* (United Nations, 1991), celebrated in Rio de Janeiro in 1992 during which the participating heads of state promised to urge a development that covers the necessities of the present without affecting future generations negatively. During this summit there were many parallel meetings to study this theme in each specific field. Among the many works presented, some architects disclosed their ecological positions.

The Congress of Architects, organized in Chicago in 1993 by the International Union of Architects, defined the principle of sustainability in its *Declaration of Interdependence for a Sustainable Future* (International Union of Architects, 1993), as a guide for progress, and stated its commitment to "place environmental and social sustainability at the core of our practices and professional responsibilities". For environmental architects, the Chicago declaration became the first serious document within their reach to confront the ecological challenges of architecture. In 1998 the School of Architecture and Urban Planning of the University of Michigan published the document *Introduction to Sustainable Architecture* in which the principles of sustainable architecture were contained: Economy of Resources, Life Cycle Design, and Humane Design (Kim and Rigdon, 1998).

Energy studies indicate that fifty percent of the world's energy is consumed in domestic activities (Corrado, 2004. Costa Durán, 2010. Uffelen, 2013), twenty-five percent in industry (including the construction industry), and the other twenty-five percent in transport and other activities. Therefore, housing and architectural materials are responsible for more than half of the contaminating gases that are spewed into the atmosphere for the production of the energy that they need. For this reason a constructive design must play an important role in the rationing and use of energy in order to reach a situation of sustainability. The comfort in which the developed world lives has been inclined to create hermetic dwellings with artificial climates in keeping with the comfort of its users. This situation has increased consumption immoderately. Some authors posed the energy question –like Le Corbusier with the *brise soleil* (Siret, 2004) or double wall which tried to palliate excessive exposition to the sun– but their incidence in the field was not remarkable.

The first architects characterized by an awareness of sustainability and related questions emerged in the sixties, in the heat of the ecologist movement. Little by little a philosophy was created with regard to the obligation to develop an architecture respectful of and linked to the environment of each particular place. The petroleum crisis of the seventies sharpened awareness even more; the first generation of buildings called bioclimatic appeared and they attempted to take maximum advantage of the solar bonanza. An unconventional configuration did not exist and its appearance oscillated between a technological construction and a hothouse. Many times everything was reduced to the incorporation of devices for the maximum use of energy on current structures. The eighties saw an increase in the consciousness of the subject, but it is in the nineties when all these concerns crystallized into a kind of constructive activity that we can call sustainable or ecological.

Figura 2: Le Corbusier. *The Hight Court building,* Chandigarh (India), 1953-1962

2 TECHNOLOGICAL PRINCIPLES OF SUSTAINABLE ARCHITECTURE

Today we can define *Sustainable Architecture* as a way of designating buildings that make maximum use of natural resources and also reduce as much as possible the environmental impact on the ecosystem and its inhabitants. It is not a question of isolated or occasional solutions, but of developing an integral plan (Appleby, 2011. Edwards, 2009) characterized by the use of concrete materials and constructive procedures. This type of architecture does not present a special typology like that which we can find in other concerns, but a technological common denominator that seeks the greatest respect possible for the environment and that better assimilates the renewable energy that Nature offers.

Evidently, in order to achieve the objectives that sustainable architecture proposes, a series of fundamental technological principles (Hernández Pezzi, 2012) must be applied at the time of construction. First, it is important to know well the characteristics of the environment (Jones, 2002) where the intervention is going to take place, especially its climate, hydrography and ecosystem, for the purpose of taking the best advantage of its possibilities and reducing to a minimum its negative effects. Second, it is crucial to choose the construction materials carefully (Schröpfer, 2012), preferring those that require little energy in their fabrication, come from recycling, or do not produce toxic residues. Third, architects must plan well the processes of climatization (Brown, 2013. Hausladen, 2012) and illumination (Stiller, 2012) of the building in order to reduce as much as possible the consumption of energy and make good use of renewable energy. Fourth, designers have to create dwellings with optimal conditions for their occupants (Eleb-Vidal and Simon, 2013. Guenther, 2013. Lopez, 2012), respectful of the quality of life, lighting, hygiene, comfort, toxicity, and physical and spiritual health. With the passing of years, global proposals with an eye to these challenges have come to light so that Sustainable Architecture has been able to develop technological strategies to fulfil its objectives.

One of the most unerring approaches is to look for harmony with the locale where construction will take place. The solar orientation of the buildings must be taken into account; some have even been constructed that turn daily, following or retreating from the sun. Make use of rainwater for various purposes like the toilet, the shower, clothes washing, watering of plants, etc. Plant deciduous trees that block the sun in the summer and permit its entrance in the winter; utilize perennial trees to fix a permanent barrier against cold winds. Vegetable coverings instead of synthetic materials are very efficient technical insulators. Finally, attempt the least possible environmental impact and the lack of alteration of the ambience, avoiding the modification of the morphology, the introduction of acoustic contamination, or a change in the autochthonous flora and fauna.

Another aspect to be taken into account is the use of renewable energy to substitute traditional energy. The sustainable projects strive to construct a building that is itself a generator of the energy that it requires through the sun (solar panels, photovoltaic cells, solar collectors), the wind (eolic generators), the interior of the earth (geothermic energy) or the organic material of refuse (biomass). With these sources of energy, the heating of water, heat-refrigeration, lighting, etc. can be covered. Much saving of energy results from the construction of low ceilings to avoid having to climatize large spaces and the design of buildings proportionate to the needs they must cover; unnecessary space is anti-ecological.

Constructions materials have a very significant role in this architecture. Natural insulators, like cork, cellulose, hemp, wood, linen, coconut fibers, straw and cotton, are used in the walls because they are not noxious to health nor do they leave contaminating residues. The construction of walls is oriented toward the sun with an interior water chamber, as the Trombe-Michel wall (Trombe, 1957. Zrikem and Bilgen, 1987), created in France in 1957 by the chemist Felix Trombe and the architect Jacques Michel, which maintains the heat or the coolness for a long time. Materials that permit the accumulation and maintenance of the temperature are preferable: cement, adobe, brick, stone, cement floor, tapia. Recyclable materials are preferred: masonry, wood, concrete, ceramic coatings, pipes, iron, railings, roof tiles, etc. while recycled material from the demolitions of other buildings or the residue from the construction of new ones are re-used. Local materials that avoid the energy costs of their transport are more adequate. One should opt for materials with "energy incorporated", that is, those which in their process of extraction, industrialization and transport, use little energy.

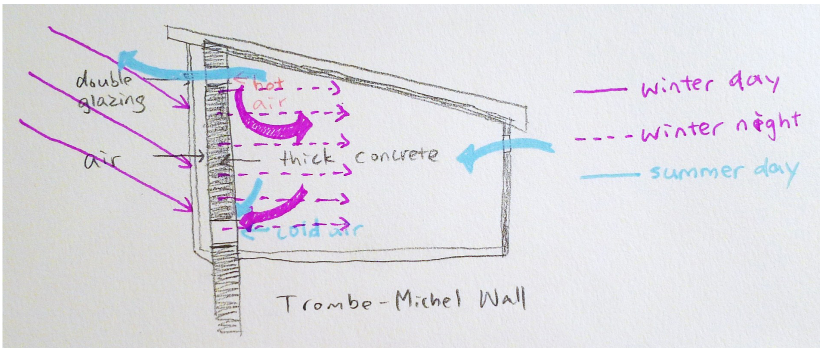


Figura 3: Trombe-Michel wall, 1957

Growing environmental consciousness has led to the conception not only of ecological buildings but of entire ecological cities. This is one of the great challenges of architecture and urban planning of the 21st century. There are some examples of cities planned according to this principle of sustainability. *Masdar City* (Ouroussoff, 2010. Stanton, 2010. Walsh, 2011) (Abu Dhabi Emirate, United Arab Emirates) in the Persian Golf, designed completely by Norman Foster, is the first city of these characteristic in the world. Its construction was begun in 2009. It

Figura 4: *Masdar City,* Abu Dhabi Emirate, United Arab Emirates

is expected that seven year later it will be inhabited by 50.000 people. The project contemplates solar energy as the only source of energy. The pedestrian streets are narrow to protect from the burning winds of the desert and are covered with solar plaques that provide shade at the same time that they are generating energy. Public transport is carried out in automatic coaches on magnetic rails. The climatization of the houses takes advantage of the cold from the deepest layers of the earth. Fresh water is acquired by means of desalinators and the residue is recycled for agrarian and garden use.

3 THE PIONEERS OF SUSTAINABLE ARCHITECTURE

Some architects showed a clear awareness of the problem of ecology even during the era of energy waste. Their proposals join the process of consciousness towards the sustainability of the planet and the rational use of energy, with concern for the utilization of renewable energies in the construction and maintenance of their buildings.

Charles Correa (India, 1930) studied architecture in the United States. His architectural language has been to a large extent influenced by the work of Le Corbusier, who was able to couple ecological concerns with the cultural and spiritual roots of India. In 1958 he established an architectural studio in the city of Bombay. His creations (Adjaye, 2013. Correa, 2000. Correa, 2010), carried out mainly in India, are characterized by an interest in themes like energy, the conservation of resources and the climate. In order to alleviate the extreme climate conditions of India, he believes in open spaces where the majority of human activities take place: cooking, leisure and living together. He employs traditional materials such as brick and cement. One of his major concerns has been the construction of low cost buildings in the Third World:

> many attempts at low-cost housing perceive it only as a simplistic issue of trying to pile up as many dwelling units, (as many cells) as possible on a given site, without any concern for the other spaces involved in the hierarchy. The result: environments which are inhuman, uneconomical -and quite unusable. Their planners have ignored the fundamental principle, namely, that in a warm climate -like cement, like steel- space itself is a resource (Correa, 1989, p. 36).

Some of his buildings are clear examples of his ecological vocation, especially in its climatological aspect. The *Gandhi Smarak Sangrahalaya* (Anand, 1963, 61-62) (Ahmedabad, India, 1958-1963) is a museum erected on the same spot where Gandhi lived from 1917 to 1930. It is a work marked by simplicity, using brick pillars, reinforced concrete beams, and tile-covered square pavilions separated by landscaped areas. Lighting and ventilation are attained ecologically by means of mechanisms made of wood, avoiding the use of glass. The *Kanchanjunga Apartments* (Ebben, 2009) (Bombay, India, 1970-1983) are inspired by traditional bungalows in the Western world, but care has been given to orient them to the east and west to take advantage of the view and the natural ventilation. They have large courtyards to encourage outdoor living and combat the summer heat. The *Bharat Bhavan Art Center and Museum* (Bhopal, India, 1975-1981), dedicated to different art forms, is the main cultural center of the city and one of the most important in all India. It stands on the hills of Shamla. The lighting and ventilation of the building come from verified openings in the concrete structure and the railings of the terraces. It has a combination of glass and movable panels that facilitate the movement of air depending on weather needs.

Figura 5: Charles Correa, *Gandhi Memorial Museum,* Ahmedabad, India, 1958-1963

Figura 6: Charles Correa, *Kanchanjunga Apartments,* Bombay, India, 1970-1983

Figura 7: Charles Correa, *Bharat Bhavan Art Center and Museum*, Bhopal, India, 1975-1981

The married couple formed by architects **Brenda & Robert Vale** have devoted themselves to researching the issue of sustainable housing (Vale and Vale, 1991. Vale and Vale, 1992. Vale and Vale, 2008. Vale and Vale, 2009). In 1975, they published *The Autonomous House* (Vale and Vale, 1975), a technical guide for developing renewable energy in domestic constructions, to permit a greater respect for the environment and to save energy. This book advocates a type of building that looks traditional but is absolutely innovative with respect to energy maintenance processes. It analyses the issues of wall and window insulation, use of solar and wind power, rainwater harvesting, etc. The book is considered a basic text on this subject.

Throughout the decade of the eighties these architects had the opportunity to implement their proposals in a number of British commercial buildings and in the *Superinsulated Woodhouse Medical Centre* (Sheffield, United Kingdom). In the nineties, they carried out environmental projects such as *The New Autonomous House* (Southwell, United Kingdom, 1993-1994), with four bedrooms, which uses solar energy for heating, electricity, drinking water production, and wastewater recycling. Only the phone line is connected to the network. It was the first building of its kind in the United Kingdom to contain a type of “house operating independently of any

Figura 8: Brenda & Robert Vale, *The New Autonomous House,* Southwell, United Kingdom, 1993-1994

inputs except those of its immediate environment. The house is not linked to the mains services of gas, water, electricity or drainage, but instead uses the income-energy sources of sun, wind and rain to service itself and process its own wastes" (Vale and Vale, 2000, p. 9). In 1996, they emigrated to New Zealand and work as professors at the University of Auckland. On behalf of the Australian Government they have developed a building rating system called NABERS, which is used to measure the environmental impact of a building.

Kenneth Yeang (Malaysia, 1948) was educated in the United Kingdom and opened his studio in 1976. He has dedicated his career to fighting against the dangers that high-rise architecture can have for the environment (Hart, 2011). He is a pioneer in incorporating elements that allow energy saving in skyscrapers (Yeang, 1994. Yeang, 1995. Yeang, 2002. Yeang, 2007. Yeang, 2008. Yeang, 2009). He defends a design that he calls *green*, which is aimed at integrating human activities and the built environment with the natural environment of the locality in a seamless and benign way.

In the book *Bioclimatic Skyscrapers*, Yeang's theoretical position presents enviroscience ambitions, because "the design of energy-efficient enclosures has the potential to transform architectural design from being an uncertain, seemingly whimsical craft, into a confident science" (Yeang, 1994, p. 17) and "this energy equation in design is only part of a greater gestalt in environmental design" (Yeang, 1994, p. 17). Yeang's principles translate into building facades as either "clad in a ventilated rain-check aluminium skin which traps heat and dissipates it" (Yeang, 1994, p. 43) or window areas whose "faces have external aluminium fins and louvers to provide sun shading" or "glazing details [that] allow the light-green glass to act as a ventilation filter" (Yeang, 1994, p. 59). Inspired by the natural sciences, their design principles expose technology reduced to a wall application, and architecture as a specialization indebted to climatology.

He supports the idea that the different ecosystems of the world are stable without human intervention; thus, the architect must learn their balance mechanisms and apply them so as not to interfere with them. He favours giving up some comfort in the temperature of our buildings (1 or 2 degrees), and using natural ventilation systems to combat winter cold or summer heat. This would drastically reduce energy consumption. To this end he advocates economic incentives, legislative adaptation and penalizing waste.

His architectural practice has become synonymous with *eco skyscrapers* because it was one of the first to incorporate bioclimatic energy-saving elements into these city giants, as the only way to make population growth compatible with ecology. Departing from the suppositions of the Modern Movement, he believes that the universality of the rationalist skyscraper, i.e., its appropriateness for any location, should be abandoned and substituted by the development of a plan in which the building to be constructed is adapted to the climatic conditions of the space where it is to be built, thus making possible its integration into the landscape as well as energy saving. At the same time, the skyscraper must also be designed with economy in mind; this can be achieved on the basis of three principles: suitable materials, renewable energy, and reduced project costs.

To achieve his goals, he applies a number of premises to his skyscraper projects: concentration of service nuclei, suitable orientation, windows and openings in accordance with solar incidence, balconies that provide shade and serve as open areas, transition spaces between the centre and the periphery, permeable walls as interactive environmental elements, vegetation that reflects life and cultural patterns, connection to the outside by means of an open and airy ground floor and vertical landscapes along the façade and roof. His projects are thus based on considering the skin of the buildings as an element of bioclimatic communication, interchange and interaction with the surrounding environment (landscape and other structures), and not as an isolating system. As he himself indicates: “Ecological design requires the architect to regard and to understand the environment as a functioning natural system and to recognize the dependence of the built environment on it” (Yeang, 1999, p.31).

In 1995, he published the book *Designing With Nature. The ecological basis for architectural design*, one of the first studies on the design of bioclimatic buildings. In this work he develops his theory on *vertical landscaping*, considered the fundamental point of his architectural philosophy. It consists of enabling the presence of nature on the outer surface of a skyscraper by applying vegetation in a staggering way. This allows the occupants to interact with natural light, rain and breezes and thus have contact with nature at great heights, because integrating vegetation on roofs and facades reduces the overall heat island effect and also reduces the energy consumption of a building by 5 to 10 %; moreover, the facades are cooler in summer and the vegetation provides insulation. Under these premises he creates true vertical gardens, which not only improve the bioclimatic conditions, but also benefit the users, as they better the quality of working life and increase productivity by providing a less artificial and technical environment. As he points out, putting vegetation on skyscrapers is something necessary to rectify the imbalance of organic mass in our current constructed environment.

His finished projects and buildings implement these bioclimatic theories. His experimental laboratory begins with the *Roof Roof House* (Kuala Lumpur, Malaysia, 1985), his own home, where he applies measures to save energy and combat the tropical heat-measures later used in skyscrapers. He develops a kind of open-umbrella cover to provide shade to the roof. He orients it north-south to protect the most heavily inhabited areas from solar radiation. The pool is located in an area that receives winds, cools them and refreshes the building. He also uses blinds and adjustable panels to regulate the temperature.

Figura 9: Kenneth Yeang, *Roof Roof House*, Kuala Lumpur, Malaysia, 1985

Atrium Plaza (Kuala Lumpur, Malaysia, 1981-1986) is an example of the application of these experiments. It consists of a skyscraper covered with a Z-shaped section roof, which has the task of filtering the rain, dispersing the accumulated hot air and diffusing the sunlight. Interior offices overlook rear landscaped terraces. The *Menara Mesiniaga* (Kuala Lumpur, Malaysia, 1992) includes a supporting structure on the outside of the building, forming a spiral that moves to the top of the building. The design includes a series of terraced cascading gardens that provide protection from the sun and reduce cooling needs. The windows facing east and west have protective elements that also mitigate direct sunlight, while the north and south facades are provided with windows that let in light and enable the occupants to enjoy the outside views. On the roof there is also a metallic structure for avoiding heat, which can be adapted to install solar panels.

Similar climatization procedures can be found at the headquarters of *Mewah-Oils* (Port Kelan, Malaysia, 1992). This is basically a horizontal building dedicated to offices. The axis of the building is an elongated atrium with dense vegetation, which climbs a ramp from the street to the roof garden. This natural area functions as a lung and provides ventilation for the entire building. It also has waterfalls to cool the air. The *MBF Tower* (Penang, Malaysia, 1993), dedicated to offices and apartments, also applies ventilation systems, and in the *Tokyo-Nara Tower* (Tokyo, Japan, 1994) gardens climb the walls to give the building a climatic filter to improve air quality, cool the atmosphere and muffle noise. The *UMNO Tower* (Penang, Malaysia, 1998) employs wind conductors in the walls to collect and redirect the wind toward the building.

Other architects who have maintained a certain relation to sustainable architecture or concern for the environment are: Emilio Ambasz (Argentina, 1943), Glenn Murcutt (United Kingdom, 1936), Tom Bender (United States), Walter Segal (Germany, 1907-United UK, 1985), William McDonough (Japan, 1951), Joseph Picciotto (México), Wladimiro Acosta (Ukraine, 1900-Argentina, 1967), Enrico Tedeschi (Rome, 1910-Argentina, 1978), Elio Ricardo Di Bernardo (Argentina), Elijah Rosenfeld (Argentina) and Victor Olgyay (Hungary-United States, 1970).

Figura 10: Kenneth Yeang, *Menara Mesiniaga,* Kuala Lumpur, Malaysia, 1992

4 SOME CURRENT EXAMPLES OF SUSTAINABLE ARCHITECTURE

As noted above, sustainable architecture cannot be characterized by any particular language, but rather by the ecological orientation with which the authors seek to imbue their constructions. Hence, in the western context, a clear coexistence can be found between this ecological dimension and different architectural movements. This is especially true in the field of High Tech or Technicist Architecture, where ecological concerns are paramount. The contributions of the British group Archigram and the Japanese group Metabolism paved the way for a group of architects, mainly British, who introduced significant changes in architectural practices starting in the decade of the 1970s. These changes involved the incorporation of procedures, materials and models used in the naval, aerospace, automobile and military industries. Nevertheless, this new orientation was made compatible with the principles of Sustainable Architecture. Along with these architects, other authors from different trends focused their proposals in the same direction, i.e., towards finding a way to build that respects and improves the environment.

Richard Rogers (Italy, 1933) is considered one of the founders of High Tech with his architectural projects (Cinqualbre, 2007. Melvin, 2013. Powell, 2006. Rogers, 2005. Rogers, 2008). He was born in Italy of Anglo-Italian parents, but he studied in the United Kingdom and the United States. He teamed with architect Renzo Piano to participate in the competition held by the Georges Pompidou National Center of Art and Culture (Paris, 1971-1977), and in 1977, he created his own firm in London. He rejected Postmodern Historicism and opted for technology as a language of expression. However, he does not consider technology as an end in itself, but rather as a means for solving social and environmental problems.

For *Heathrow Airport Terminal 5* (Doherty, 2008) (London, 1989-2008) he designed a total of three constructs (T5A, T5B and T5C) interconnected underground, which allow parking 60 aircraft. The ecological orientation is manifest. The residual heat from the Heathrow power station is channelled to T5 through an underground pipe to meet 85% of the heating demand of the building. A series of sunscreens and low eaves on the east and west facades help to reduce the caloric impact and avoid excessive consumption of air conditioning in hot weather; in this case, natural ventilation is not possible because the building must be completely closed to avoid noise and pollution from the aircrafts. 70% of the water needs are provided by rain and nearby wells.

Figura 11: Richard Rogers, *Heathrow Airport Terminal 5,* Londres, 1989-2008

Adolfo Suárez Madrid-Barajas Airport Terminal 4 (Hesse and Asensio Almodóvar, 2008). (Madrid, 1997-2005) is part of a remodelling of a complex that was on the point of saturation. The *Plan Barajas* project included building a new T4 terminal with three aboveground and three underground levels, 3 kilometres north of the old facilities. It is completed with a satellite building (T4S), located 2.5 miles from the main terminal and connected to it by an underground automatic train to transport passengers and baggage. The ecological effect is achieved through the abundant natural lighting provided by glass walls in a metal framework. In the undulating roof there are circular skylights with slats that open and close to control the solar radiation, regulating its intensity depending on the weather. The set of environmental measures is completed with an ingenious cooling system, the use of materials that respect the environment and the implementation of a system that collects and reuses rainwater.

National Assembly of Wales (Gelder and Witte and Heaton, 2006) (in Welsh: *Cynulliad Cenedlaethol Cymru*, Cardiff, United Kingdom, 1998-2005) is the seat of the Welsh legislature. The building consists of a working space inside a glass envelope which allows a privileged view of the sea. The enormous transparency aims at bathing the interior with natural light, but it also symbolises the opening of political life to the public. In the centre of the building, a latticed wooden cone injects natural light into the Chamber and allows the parliamentary activity of the MPs to be observed, thus ensuring a permanent connection between the representatives and the represented. This cone emerges from the floor socle and rises to the ceiling like a bell structure culminating in a lantern. The inside cover is a huge wavy wooden mantle that extends over all units. The sustainability of the building is based on its maximum use of sunlight. The public lobby is naturally ventilated, and the potential of the floor as a cooling mechanism is used.

Renzo Piano (Italy, 1937) is an atypical architect in the Italian panorama, because he was able to separate himself from the national tradition and dedicate himself to High Technology. After working with Rogers on the Pompidou Centre, in 1981 he founded his own studio, the Renzo Piano Building Workshop, with offices in Paris, Genoa and New York. He has continued developing a High Tech architecture that incorporates the surrounding landscape by keeping in mind the particular characteristics of the environment and culture (Agnoletto, 2009. Cassigoli, 2005. Jodidio, 2005. Conforti and Dal Co, 2007). These elements have brought him close to Organic Architecture and Postmodernism, especially in recent years. One of his constructions with greatest ecological impact is the *London Bridge Tower* (Flint and Healy and Monaghan, 2012. Parker, 2012), also known as the **S***hard of Glass Tower* (London, 2004-2012). It is a skyscraper of 70 floors and 306 meters high in the London area of Southwark, near London Bridge Station.

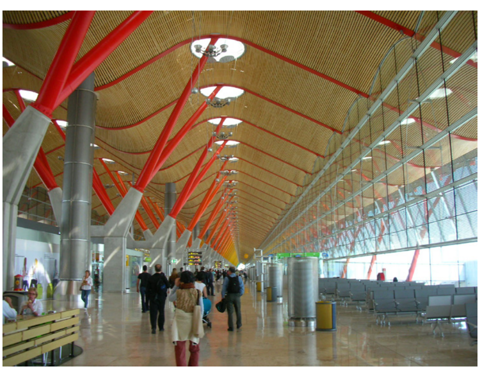


Figura 12: Richard Rogers, Adolfo Suárez Madrid-Barajas Airport Terminal 4, Madrid, 1997-2005

Figura 13: Richard Rogers, *National Assembly of Wales,* Cardiff, United Kingdom, 1998-2005

It is designed as a glass pyramid which dominates the skyline of the city. The inspiration comes from the churches of London and the sails of the ships coming across the Thames. Each facade has a plane of glass gently inclined to form the upstream direction. The lower parts are devoted to offices, the intermediate zone is a hotel and the upper floors are apartments. A double-skin facade ventilates and reduces the temperature without the loss of interior light. The excess heat from the offices is used to heat the hotel and apartments. Each floor is provided with naturally ventilated greenhouses that allow users to get in touch with nature.

Norman Foster (United Kingdom, 1935) trained initially at the University of Manchester and followed this with doctoral studies in the United States. His High Tech work is characterized by research into lightweight materials and by incorporating into architecture all the technological components and procedures provided by cutting-edge industry. From the formal point of view, his buildings (Jenkins, 2011. Sudjic, 2012) maintain models and elements typical of Rationalist or Organic Architecture. His most significant contributions date from the 1980s on. At one point, he led a team of more than one-thousand collaborators, with offices and projects in many parts of the world.

The *Hong Kong & Shanghai Bank* (Foster Associates, 1986) (Hong Kong, China, 1979-1985) is the first major project he carried out, as the result of a competition. Its technological grandeur and glitz aimed at making it a symbol of the power of the banking entity. The building is a 180-meter-tall glass and steel skyscraper with 47 floors and 4 basement levels. The interior consists of a large atrium. At the time of its construction, it was the most expensive building in history, with a cost of 2.500 million dollars. Prefabricated pieces from Japan, the U.S., Britain and other European countries were used. The final work presents the appearance of a skyscraper with three bodies of different heights. It features an exterior structure from which three units hang, following the example of suspension bridges. The larger facades make use of glass curtain walls to illuminate the interior. On their surfaces are placed, like a second skin (the *brise soleil* of Le Corbusier), horizontal sunshades that allow maintenance, protect from Asian typhoons, and

Figura 14: Renzo Piano, *Shard of Glass Tower,* London, 2004-2012

Figura 15: Norman Foster, *Hong Kong & Shanghai Bank,* Hong Kong, China, 1979-1985

moderate the light and solar heating. A series of mirrors, situated in the central atrium of the highest part, disseminates the light to the interior. The auxiliary air conditioning system employs sea water instead of drinking water. The use of natural light and sea water makes this bank one of the first constructions built from an ecological perspective during the 80s.

The headquarters of *Commerzbank* (Davies and Lambot, 1997) (Frankfurt, Germany, 1991-1997) is a skyscraper dedicated to banking use. It is 299 meters high with 62 floors and a triangular floor plan. Interior gardens are distributed along its three facades. It is considered one of the first office buildings with an ecological design and, at the time of its construction, it was the tallest in Europe. The project incorporates nature to relax the working environment. The hanging gardens surrounding the building bring fresh air to the central atrium and are visual centres for the offices.

The remodelling of the *Reichstag* (Foster and Abel, 2011) (Berlin, Germany, 1992-1999) is another important milestone in Foster's trajectory, not only in terms of the project itself but because of the historical significance of the building. The first German Parliament was built in 1894 by the Teutonic architect Paul Wallot in the neoclassical style. In 1933, it was burned down by Adolf Hitler. The dome was destroyed and the rest of the building was severely damaged. After German reunification in 1990 and the reinstatement of Berlin as the capital, the issue of recovering the building and its function was proposed. Foster won the competition and organized and conducted a reconstruction which maintained the existing structure while adapting the interior to the needs of a modern parliament. The most significant novelty was the new glass dome with steel nerves. The heart of the dome has an inverted cone, coated with 360 inclined mirrors, which generates effects of luminic reverberation. By day the mirrors reflect natural light and illuminate the plenary hall. In turn, the artificial light in the room is reflected externally and illuminates the dome. It becomes a beacon signalling the work of the Parliament members as well as a symbol of a reunified Germany. Ecologically, it serves for ventilation and harnesses the energy of the hot air waste. The rest of the building also has an environmental planning. Electricity is extracted from vegetable oil, which reduces by 94% the emission of carbon dioxide. The excess heat is diverted to an aquifer, located 300 meters below the building, which is used in winter to heat the building.

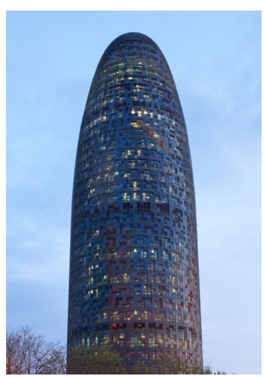
Figura 16: Norman Foster, *Dome of The Reichstag*, Berlin, Germany, 1992-1999.

The *Palacio de Congresos de Valencia* (Borgos and Foster, 1999) (1993-1998) provided the city with two multi-purpose halls for conducting mass events, with a total capacity of 2.000 people and nine rooms of different sizes. The glass curtain wall provides the large foyer with a surprising illumination and allows the visitor to enjoy the area's outdoor gardens and fountains. The ecological nature of the building is further shown in the installation of solar panels on the roof to prevent the emission into the atmosphere of more than 335.000 kilograms of carbon dioxide.

The *Beijing International Airport Terminal 3* (Foster and Abel, 2010) (Beijing, 2003-2008) made this the largest and most modern airport in the world, with a capacity of about sixty million passengers per year. It has nearly one million square feet of space. It became a showcase that opened China to the Western world for the 2008 Olympic Games in Beijing. It is a summary Foster's forty-year trajectory in the field of High Tech: technical sophistication, aesthetic elegance, efficiency, connection with the natural and cultural context of the place, sustainability and ecology. It is a mega building consisting of three interior terminals connected by rail. It successfully combines the Chinese Eastern tradition with the Western world. The overall form resembles a giant dragon with a wide head and a long tail; the triangles covering the ceiling evoke the scales of the reptile. From the outside, the two domes with triangular skylights resemble turtle shells. The ecological character can be seen in the south-facing skylights which capture sunlight in the morning and in an environmental control system that minimizes energy consumption and carbon emissions to the atmosphere.

Jean Nouvel (France, 1945) represents the French version of High Tech as well as the recovery of his country's lost prominence on the international scene after the Second World War. He has developed a certain continuity with the Modern Movement, but in relation to the high technology of the British tradition. His production (Nouvel, 2008) is characterized by the prominence of light and shadows through the habitual use of transparency, opacity and reflection. He also attempts to integrate his buildings into the environment. His most significant contribution to architectural ecology is the *Agbar Tower* (Nouvel, 2007) (Barcelona, 2001-2003), a spectacular concrete, glass and steel skyscraper, 142 meters tall and 35 floors, located on Diagonal Avenue and commissioned by the Aguas de Barcelona (Barcelona Water) group. It has a cylindrical structure with more than 4.000 windows, crowned on top with a dome-like form. The most characteristic feature is the coating consisting of some 16.000 sheets of clear glass that change colour under different solar intensities. Natural light tinges the building with a polychrome of some forty changing colours; to show its relationship with water Nouvel creates

Figura 17: Norman Foster, *Beijing International Airport Terminal 3*, Beijing, 2003-2008



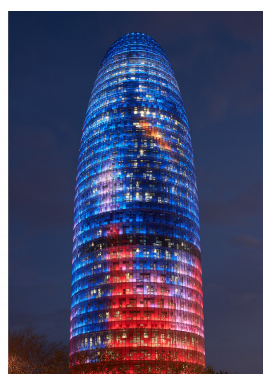


Figura 18: Jean Nouvel, *Agbar Tower,* Barcelona, 2001-2003

a smooth and continuous emerging form, which metaphorically resembles a powerful geyser. The facade has a double skin of aluminium and glass in mobile scales, with a passage between the two surfaces. This peculiarity takes maximum advantage of solar energy for lighting and temperature graduation according to the season of the year. Changing the angle of the mobile scales insulates the building from the cold of winter and the heat of summer.

The architects **Jacques Herzog** and **Pierre de Meuron** (Switzerland, 1950), representatives of Minimalist Architecture, created the firm *Herzog & de Meuron* in 1978, with headquarters in Basel, although they have other branches in Madrid, Beijing, London and New York. Their studio houses architects from around the world, with some two-hundred employees. They design residential, sporting, cultural, banking, and other buildings (Mack, 2009. Mateo, 1991. Stungo, 2002. Wang, 1990. Wang, 2004). They made their appearance on the international architectural scene in the eighties, when the spirit of Postmodernism began to show a certain weariness. They opted for simple, geometrically pure volumes in line with the minimalism of sculptors such as Donald Judd. Nevertheless, their minimalist spirit is made compatible with ecological concerns.

The *Sammlung Goetz* (Munich, Germany, 1989-1992) is a gallery destined to receive the collection of art Goetz (Köb, 1995). It marks the way towards their architectural personality. It is in the shape of a horizontal parallelepiped divided into three sections. The opaque glass surface covering the facade generates a diffuse and intimate clarity in the interior. Light becomes the true protagonist to the point that the windowpanes extend to the very corners. The same interest in light can be found in the *Signal Box Auf dem Wolf* (Terence, 1995) (Basil, Switzerland, 1994-1998). It is a geometrically pure, closed prism with six floors. To protect the electronic systems that control the movement of the trains from any interference, the facades and roof are trimmed in copper strips. These metal strips act like venetian blinds; their mobile nature regulates the amount of light that enters. The different positions of the strips and the variety of lighting nuances generated by the action of sunlight introduce aesthetic elements which contribute to the process of dematerialization of the wall, typical of Minimalism.

The *Dominus Winery* (Matthews, 2007) (Napa Valley, United States, 1995-1998) demonstrates how the construction material itself can be vital in shaping the language of a building. This building comprises a kind of stone rigging which, instead of joining the irregular stones with mortar to make the walls, follows the traditional dry-stone method of creating a wire structure to retain the rocks as if in a basket. This system is called *gabion* and is used in hydraulic engineering. The wire container attached to the wall insulates the rooms and protects them from daytime heat and nighttime cold. This type of set up has proved very effective in the maturation process of grape musts. Thus, the value of tradition has both a practical and an aesthetic effect.

The *Forum Building* (Moore, 2002) (Barcelona, Spain, 2000-2004) was built for the 2004 *Barcelona Forum*, an international meeting lasting almost five months to debate three major themes of the XXI century: cultural diversity, sustainable development and conditions for peace. The building is an equilateral, flat and horizontal prism, 180 meters wide by 25 meters high, located at the beginning of the Diagonal Avenue. It became the emblem of the event. It has a 3.200 seat auditorium and an exhibition hall of 5.000 m^2. The flat roof has a pool with shallow water, intended to serve as a thermal insulator of heat. The water on the roof seems to overflow down the rough indigo-coloured facade in vitreous stripes. The entire building is suspended over seventeen points of support, so that access to the interior is a continuum from the street. Several skylights provide the necessary light to the interior.

Figura 19: Herzog & de Meuron, *Signal Box Auf dem Wolf,* Basil, Switzerland, 1994-1998

Figura 20: Herzog & de Meuron, *Forum Building,* Barcelona, Spain, 2000-2004

BIBLIOGRAPHY

Adjaye, D. (2013). *Charles Correa: India's Greatest Architect*. London: The Royal Institute of British Architects.

Agnoletto, M. (2009). *Renzo Piano*. Milan: Motta.

Anand, M. R. (1963). Gandhi Smarak Sangrahalaya. *Marg* 1, 61-62.

Appleby, P. (2011). *Integrated sustainable design of buildings*. Washington: Earthscan.

Attmann, O. (2010). *Green architecture: advanced technologies and materials*. New York: McGraw-Hill Professional.

Borgos, E. and Foster, N. (1999). *Foster and Partners, Palacio de Congresos de Valencia*. Valencia: AUMSA.

Borowy, I. (2014). *Defining sustainable development for our common future: a history of the World Commission on Environment and Development (Brundtland Commission).* New York: Routledge.

Broto Comerma, C. (2011). *Arquitectura sostenible*. Barcelona: Links Books.

Brown, G. Z. (2013). *Sun, wind, and light: architectural design strategies*. Hoboken: Wiley.

Cassigoli, R. (2005). *Renzo Piano: la responsabilidad del arquitecto, conversación con Renzo Cassigoli*. Barcelona: Editorial Gustavo Gili.

Chambers, N. B. (2011). *Urban Green: Architecture for the Future*. New York: Palgrave Macmillan.

Cinqualbre, O. (2007). *Richard Rogers+Architects: From the House to the City Exhibition*. Paris: Editions du Centre Pompidou.

Conforti, C. and **Dal Co, F**. (2007). *Renzo Piano: gli schizzi*. Milan: Electa.

Corrado, M. (2004). *La casa ecológica*. Barcelona: De Vecchi Ediciones.

Correa, Ch. (1989). *The New Landscape: Urbanization in the Third World.* New York: A Mimar Book-Concept Media.

Correa, Ch. (2000). *Housing and urbanisation*. New York: Thames & Hudson.

Correa, Ch. (2010). *A place in the shade: the new landscape & other essays*. New Delhi: Penguin Books India.

Costa Durán, S. (2010). *La casa ecológica: ideas prácticas para un hogar ecológico y saludable*. Barcelona: Loft Publications.

Davies, C. and **Lambot, I.** (1997). *Commerzbank Frankfurt: prototype of an ecological high-rise*. Basel: Birkhäuser.

Doherty, Sh. (2008). *Heathrow's Terminal 5: history in the making*. Hoboken: John Wiley & Sons.

Ebben, O. (2009). *Kanchanjunga Apartments*. Delft: Delft University of Technology.

Edwards, B. (2009). *Guía básica de la sostenibilidad*. Barcelona: Editorial Gustavo Gili.

Eleb-Vidal, M. and **Simon Ph**. (2013). *Entre confort, désir et normes: le logement contemporain, 1995-2012*. Brussels: Mardaga.

Flint, G., Healy, D. and **Monaghan, A.** (2012). Shard London Bridge. *The Arup Journal*, 2, 93-97.

Foster Associates (1986). Hong Kong and Shanghai Bank. *The Architectural Review* 1070, 30-117.

----- (1986). Hongkong & Shanghai Bank. *Domus* 674, 34-47.

----- (1986). The Hong Kong and Shanghai Banking Corporation, GA Document 16, 2-140.

Foster, N. and **Abel, Ch.** (2010). *Beijing international airport*. New York: Prestel Pub.

----- (2011). *The Reichstag*. New York: Prestel Pub.

Gauzin-Müller, D. (2006). *La arquitectura ecológica: 29 ejemplos europeos*. Barcelona: Editorial Gustavo Gili.

Gelder, A. J. van, Witte, H. J. L. and **Heaton, P.** (2006). A ground source energy plant for the New Assembly for Wales. *ECOSTOCK-The Tenth International Conference on Thermal Energy Storage*. New Jersey: Richard Stockton College.

Guenther, R. (2013). *Sustainable healthcare architecture*. Hoboken: John Wiley & Sons.

Hart, S. (2011). *Ecoarchitecture. The Work of Ken Yeang*. Hoboken: John Wiley & Sons.

Hausladen, G. (2012). *Building to suit the climate: a handbook*. Basel: Birkhäuser.

Heleno, R. et al. (2014). *Ecological networks: delving into the architecture of biodiversity*. London: Royal Society.

Hernández Pezzi, C. (2012). *Un vitruvio ecológico: principios y práctica del proyecto arquitectónico sostenible*. Barcelona: Editorial Gustavo Gili.

Hesse, J. M.; Asensio Almodóvar, F. (2008). Nueva Terminal del Aeropuerto de Madrid-Barajas. *Revista de Obras Públicas* 3484, 20-55.

International Union of Architects (1993). Declaration of Interdependence for a Sustainable Future, World Congress of Architecture, Chicago, 18-21 June.

Jenkins, D. (2011). *Norman Foster works 6*. New York: Prestel Pub.

Jodidio, Ph. (2005). *Renzo Piano*. Los Angeles: Taschen.

----- (2009). *Arquitectura ecológica hoy*. Madrid: Taschen.

Jones, D. Ll. (2002). *Arquitectura y entorno. El diseño de la construcción bioclimática*. Barcelona: Art Blume.

Kibert, Ch. J. (2012). *Sustainable construction: green building design and delivery*. Hoboken: John Wiley & Sons.

Kim, J-J. and **Rigdon, B**., (1998). *Sustainable Architecture Module: Introduction to Sustainable Design*. Michigan: College of Architecture and Urban Planning, The University of Michigan.

Köb, E. (1995). *Herzog & de Meuron: Sammlung Goetz*. Stuttgart: Hatje, 1995.

Krauel Vilaseca, J. (2012). *Arquitectura para un futuro sostenible*. Barcelona: Links Books.

Kruger, A. (2013). *Green building: principles and practices in residential construction*. Clifton Park: Delmar Cengage Learning.

Lopez, R. (2012). *The built environment and public health*. San Francisco: Jossey-Bass.

Mack, G. (2009). *Herzog & de Meuron, 1997-2001*. Basel: Birkhäuser.

Mateo, J. Ll. (1991). *Herzog & de Meuron***.** Barcelona: Editorial Gustavo Gili.

Matthews, K. (2007). Dominus in Depth. *ArchitectureWeek* 339.

Melvin, J. (2013). *Richard Rogers: inside out*. London: Royal Academy of Arts.

Minke, G. (2006). *Building with earth: design and technology of a sustainable architecture*. Boston: Birkhauser-Publishers for Architecture.

Moore, R. (2002). The world of Herzog. *Domus* 844, 44-47.

Muller, B. (2014). *Ecology and the architectural imagination*. New York: Routledge.

Nouvel, J. (2007). *Torre Agbar: dialogues avec Barcelona*. Barcelona: Lunwerg.

----- (2008). *Jean Nouvel by Jean Nouvel*. Paris: Taschen.

Ouroussoff, N. (2010). In Arabian Desert, a Sustainable City Rises. *The New York Times*, September 25.

Parker, J. (2012). *Building the Shard*. Ingenia, 52, 24-30.

Powell, K. (2006). *Richard Rogers: architecture of the future*. Boston: Birkhäuser.

Rogers, R. (2005). *Richard Rogers Partnership*. Barcelona: Loft Publications.

----- (2008). *Ciudades para un pequeño planeta*. Barcelona: Editorial Gustavo Gili.

Sassi, P. (2006). *Strategies for sustainable architecture*. London: Routledge.

Schröpfer, Th. (2012). *Ecological urban architecture: qualitative approaches to sustainability*. Basel: Birkhauser Architecture.

Siret, D. (2004). Généalogie du brise-soleil dans l'œuvre de Le Corbusier. *Cahiers thématiques* 4, 169-181.

Stanton, Ch. (2010). Masdar City completion pushed back, but total cost falls. *The National*, October 10.

Stiller, M. (2012). *Quality lighting for high performance buildings*. Lilburn: Fairmont Press.

Stungo, N. (2002). *Herzog & de Meuron.* Rivas-Vaciamadrid: Asppan.

Sudjic, D. (2012). *Norman Foster: a life in architecture*. London: Phoenix.

Terence, R. (1995). *Light construction*. New York: Museum of Modern Art.

Trombe, F. (1957). *Considérations générales sur l'énergie solaire, son captage, son utilisation*. Paris: Centre de perfectionnement technique.

Turrent, D. (2007). *Sustainable architecture*. London: Riba Pub.

Uffelen, Ch. van (2009). *Ecological architecture*. Salenstein: Braun.

----- (2013). *Eco living*. Salenstein: Braun.

United Nations (1993). *Conference on Environment and Development. Rio de Janeiro, 1992*. Ottawa: International Development Research Centre.

Vale, B. and **Vale, R.** (1975). *The Autonomous House*. New York: Universe Books.

----- (1991). *Towards a Green Architecture: six practical case studies*. London: The Royal Institute of British Architects.

----- (1992). *Green Architecture: Design for an Energy-Conscious Future*. Boston: Bulfinch Press Little Brown and Company.

----- (2000). *The New Autonomous House*. London: Thames & Hudson.

----- (2008). *New Domestic Detailing*. Oxford: Butterworth-Heinemann.

----- (2009). *Time to Eat the Dog? The Real Guide to Sustainable Living*. London: Thames & Hudson.

Walsh, B. (2011). Masdar City: The World's Greenest City? *Time*, January 25.

Wang, W. (1990). *Herzog & de Meuron: projects and buildings, 1982-1990*. New York: Rizzoli.

Wang, W. (2004). *Herzog & de Meuron*. Barcelona: Editorial Gustavo Gili.

Wines, J. (2008). *Green architecture*. London: Taschen.

Yeang, K. (1994). *Bioclimatic skyscrapers*. London: Artemis.

----- (1995). *Designing with nature. The ecological basis for architectural design*. New York: McGraw-Hill.

------ (1999). *The green skyscraper. The basis for designing sustainable intensive buildings.* Munich: Prestel Verlag, p. 31.

----- (2002). *Reinventing the skyscraper: a vertical theory of urban design*. Chichester: Wiley-Academy.

----- (2007). *Eco skyscrapers*. Mulgrave: Images Publishing.

----- (2008). *EcoDesign: a manual for ecological design*. Hoboken: John Wiley & Sons.

----- (2009). *Ecomasterplanning*. Chichester: John Wiley & Sons.

Zrikem, Z. and **Bilgen, E.** (1987). Theoretical study of a composite Trombe-Michel wall solar collector system. *Solar Energy* 39, 409-419.