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Authors: Joana Goncalves, Professor, Universidade Cidade de São Paulo
Klaus Bode, Co-Founder, BDSP Partnership

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Joana Gonçalves

Klaus Bode

Authors

Joana Gonçalves, Professor

Faculdade de Arquitetura e Urbanismo da Universidade de São Paulo (FAUUSP)
Departamento de Tecnologia da Arquitetura,
Rua do Lago 876, Cidade Universitária
São Paulo-SP, CEP 05508-080, Brazil

t: +55 11 3091 4538
f: +55 11 3091 4539

Klaus Bode, Co-founder

BDSP Partnership
Summit House
27 Sale Place
London W2 1YR, United Kingdom

t: +44 207 298 8383
f: +44 207 298 8393
e: klaus.bode@bdsp.com
www.bdsp.com

Joana Gonçalves
Joana Gonçalves is an Architect and Urbanist from the Faculty of Architecture and Urbanism at the Federal University of Rio de Janeiro, where she graduated in 1993. She practiced as an architect in Ana Maria Niemeyer SA, in Rio de Janeiro, between 1992 and 1995. In 1996 she moved to London to study environmental design in the Architectural Association (AA) Graduate School, obtaining an MA degree from the Environment and Energy Studies Program in 1997. Since 1998 she has been involved in teaching at under-graduate and graduate levels and research activities related to environmental design in FAUUSP, visiting and collaborating with educational and research institutions in Brazil and in the UK. She also has been contributing to teaching and master supervision in the Environment and Energy Studies Program at the Architectural Association Graduate School in London since 2009.

Klaus Bode
Klaus Bode graduated at the University of Bath in 1987. Klaus joined J. Roger Preston & Partners and between 1987 and 1995 worked with design and M&E services co-ordination responsibilities for projects in the UK, France and Germany. In 1993 he was appointed primary responsibility for RPP's German operations, including the Commerzbank HQ in Frankfurt. In 1995, Klaus Bode was a co-founder of BDSP Partnership; a firm of environmental and M&E consultants. The work has exposed him to collaborate with a wide range of international acclaimed Architects and projects across Europe, North America and the Far East. Klaus manages the BDSP Environmental Group. He is also a tutor of the Environment and Energy Studies Program, AA Graduate School, London.

"One of the main causes of energy efficiency failures is LEED rewarding projects for their predictions, but not for proving the savings."

Examining the general profile of energy consumption over the lifetime of buildings. And considering a lifespan of approximately 50 years, including heating, cooling, ventilation, lighting and other technical systems, energy consumption in the operation of buildings in OECD countries accounts for approximately 85% of the total. Manufacturing, transport and construction, encompassing embodied energy, accounts for 12%, and maintenance accounts for the remaining 4% (see Figure 1). Such a high percentage of energy consumption for a building's operation highlights the importance of understanding clearly the real impact of energy conservation measures in the design and operation of buildings in general.

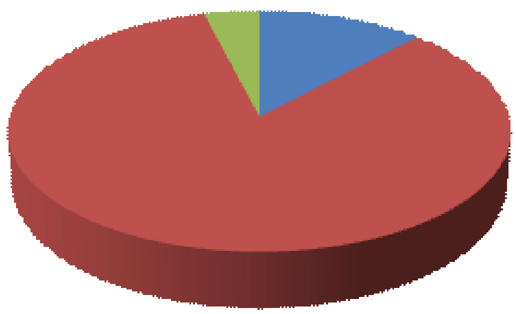

Figure 1. Energy Consumption in Buildings in OECD Countries © Joana Gonçalves

Discussion on the impact of height on the energy consumption of buildings raises questions and a great deal of criticism of the tall building typology, based on the idea that the tall building consumes significantly more amounts of energy than any other building form because of its height. From the point of view of building operation exclusively, what can be verified in the case of the commercial tall building is that the energy consumption is highly influenced by the impact of conventional economic values, and not height per se. Once the building is taller, the central core is bigger for structural and service reasons, and therefore, to keep the net to gross efficiency of the space, the floor plate needs to be deeper. Such spaces consume more energy to maintain given environmental conditions. On the other hand, the challenges imposed by the verticality upon structural and construction techniques are likely to affect the embodied energy of the tall building. In addition to that, as operational energy becomes more efficient, the importance of embodied energy will consequently increase.

The use of environmental design guidelines carries the potential to change this picture. Moreover, the issue of operational energy use in a tall building is more complex than simply attributing this to the impact of height or to any other single aspect of the design. In this respect, the energy consumed during the building operation is highly relative to the architectural response to the brief, as well as the climatic context and occupant behavior, which need to be considered together and investigated on a case by case basis.

Since the early 90s, the issue of environmental performance has gained increasing importance in the design agenda of tall buildings in European and North American cities (Gonçalves, 2010) aiming for the title of a "sustainable" or "green" tall building. This quickly reached the building sector in South America and parts of Asia in less than a decade, which in general has brought both potential and questionable proposals. In this context, a key question arises in relation to the environmental tall building: *is a paradigm shift actually happening, or do tall buildings remain rooted in conventional commercial design but with a new image laid over the top?*

While a series of design proposals for tall buildings are based on innovative design features, including unusual shapes and different types of atriums, gardens, double skin façades and others, as well as alternative technologies, only a few have been built and are operational under the claim of "environmentally responsive" buildings, from which real-life operational data is rarely disclosed. With the trend for visual and written imagery in environmental design and few real-life examples and operational data to assess actual building performance to substantiate the environmental claims, as well as to formulate a valid statement for or against the performance of tall buildings, there is a clear risk of creating false paradigms, in which buildings end up consuming yet more energy than the conventional models of tall buildings.

Furthermore, in buildings are major polluters, especially in countries where energy consumption is directly related to CO_2 emissions. The global target of achieving a 60% reduction in energy consumption by buildings by 2050, in order to achieve the relevant Intergovernmental Panel on Climate Change (IPCC, 2007) target, is a valuable and potentially effective parameter by which to measure and judge the improvement of the environmental performance of tall buildings. Therefore, a comprehensive understanding of building energy performance requires both figures: energy consumption, in a more local context, and CO_2 emissions in a global context. While the building's operational efficiency can be ascertained from the amount of metered energy used,[1] the global environmental impact can only be correctly defined by means of carbon emissions, which in turn relate to primary energy[2] consumption.

Given the challenges imposed by global sustainability targets on building performance and the uncertainties about the real energy performance of buildings, a series of questions emerges that focuses on the future of the design of the tall building: what is meant by "good environmental performance" and how do we assess it and measure it? In other words, how much better should the environmental performance of the new tall building be compared to the current conventional model? Only after being able to answer these questions is one in the position to respond to the ultimate question of: *what is a sustainable tall building?*

The indicators "net-to-gross areas (percent)" and "energy consumption per square meter (kWh/m^2) per month or per year," related to space and energy efficiency, are commonly used to assess the economic efficiency of tall buildings. More recently, CO_2 emissions from operational energy has been mentioned among environmental targets of "green" tall buildings. However, with the exception of the emissions related subjects, the other indicators represent values of the conventional commercial building design (including the traditional kWh/m^2) being insufficient and, when looked at in isolation, can be misleading to express the values of a new generation of environmentally responsive buildings. Complimentary to that, new measures of environmental quality and energy efficiency need to be incorporated into the tall building assessments for the recognition of environmental design ideas, key measures include: annual hours of natural ventilation, useful area benefited by daylighting and views per net usable area, and energy consumption per person (rather than only per area).

In the realm of design, theory and practice have both shown that as a result of the various possible combinations of architectural and technological solutions, there is no singular design response to the envisioned environmental tall building. Therefore, environmental performance does not dictate architectural aesthetics, but instead it questions conventional architectural engineering, as well as economic values found in the commercial domain all over the world. When critically and truthfully considering the environmental performance of tall buildings in particular, only in a few cases actual numbers are publicly shown and usually refer to design predictions. Lack of project specific feedback on the real environmental performance of buildings is a major barrier for the understanding beyond the limits of theoretical design and further design developments, by means of critically reviewing and re-addressing design approaches, so as to actually achieve theoretically declared objectives and environmental performance targets.

Despite the key role of predicted data in establishing references of environmental and energy performance, practice has shown a major gap between prediction and real-life out-comes. This is because the energy performance of a building in operation is affected by factors which lay beyond design, including management routines, occupants' behavior and climatic changes. Therefore, the true measure of sustainability becomes only evident through time. For that reason, unless operational data are openly displayed and discussed with constructive feedback, understanding the influence of occupants, the true achievements of environmentally iconic examples will remain doubtful, with a risk that future projects will eventually perpetuate similar misconceptions and be constrained by theoretical limits. An example of that is the complicated thermal dynamics of atriums and double skin façades in different design solutions and climatic contexts, which can ultimately lead us to design flaws.

[1] The energy performance of a building is the calculated or measured amount of energy actually used or estimated to meet the different needs associated with a standard use of the building, which may include energy use for heating, cooling, ventilation, domestic hot water and lighting (ISO, 2008: 3.84).

[2] Primary energy is the energy that has not been subjected to any conversion or transformation process. It can be either resource energy or renewable energy or a combination of both (ISO, 2008: 3.177). Primary energy defines the level of emissions associated with the energy consumption of a building, considering whether the energy comes from the different sources of fossil fuels or from renewable sources.

Figure 2a. Commerzbank Headquarters, Frankfurt © Joana Gonçalves

Figure 2b. The gardens of the Commerzbank – meeting place and climatic mediator © John Perry.

Consequently, claims to the label of environmental tall building will continue to be based more on a created image rather than real performance, unless energy prediction through advanced computer simulations are assessed and verified in post-occupancy evaluation routines.

To avoid the creation of false paradigms, iconic buildings recognized worldwide for their environmental features, such as the Commerzbank Headquarters in Frankfurt (see Figure 2a and 2b) and 30 St. Mary Axe (also known as the Swiss Re building) in London (see Figure 3a & 3b), which became references of an environmental generation in European cities, should be critically challenged beyond their strong image value. These have been followed by a number of other environmentally-claimed tall buildings in European and North American cities (since the beginning of the 2000 decade, London and New York, especially have received a significant amount of design proposals with particular interest in claims of environmental performance).

From an energy and environmental perspective, the architectural design of the environmental tall building involves a complete review of the conventional model, including: building form, façades, materials and layout of the internal spaces. Based on environmental guidelines, specialized design features may include, for instance, deep floor plates becoming narrower in order to allow for better daylight, views and, in some specific cases, natural ventilation; or the over-glazed façade is redesigned to allow shading devices and operable windows for natural ventilation. However, what is the actual impact of each of these design parameters in the final environmental performance of the tall building? What is the role of verticality and the form of the tall building? Does it facilitate or contradict natural ventilation? In fact, tallness is also a central issue in the discussion about the environmental performance of tall buildings, being often used as an argument of impediment of natural ventilation.

Challenging this concept, the tallness and building form are at the core of the ventilation strategy of the Commerzbank, built in 1998 in Frankfurt, probably the best well known built tall building for its environmental design features, in particular natural ventilation. In this case, according to data registered by the building management system (BMS), the achievement of natural ventilation for more than 80% of the year typically relies on both the architectural

Figure 3a. 30 St. Mary Axe,London © Antony Wood

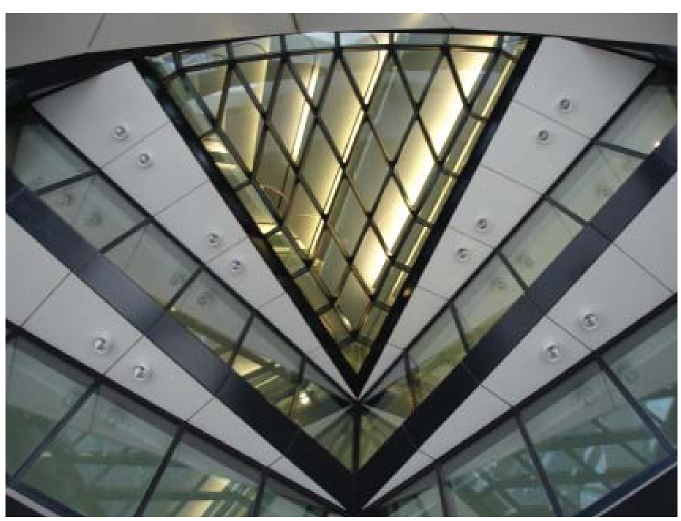

Figure 3b. The atrium of the 30 St. Mary Axe – an area for the distribution of daylight © Erica Mitie Umakoshi

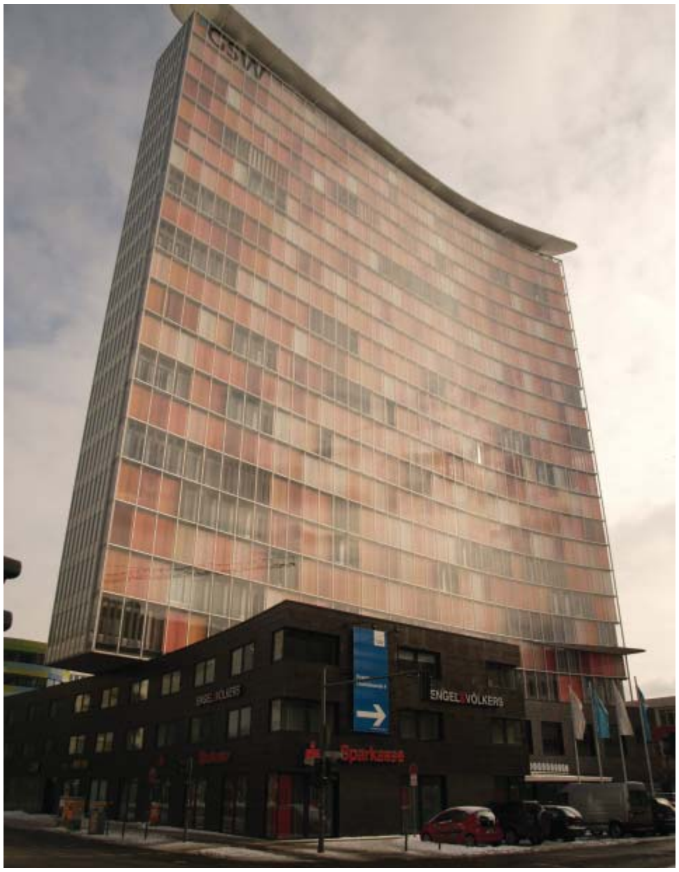

Figure 4. GSW Headquarters, Berlin – the building form of the narrow slab tall building, with movable shading devices on the west elevation within the operable double-skin façade, as part of the strategy for the natural ventilation © Carsten Ernest.

...rentals

> "I think any high-rise residential developments will be rentals… there is no pipeline anymore. We've got about 2,400 units unsold …It's going to take another two to three years to absorb all this."
>
> *Gail Lissner, Vice President of Appraisal Research Counselors, Chicago. From "Chicago Spire's Foreclosure Marks the End of an Era," Engineering News Record, October 25, 2010.*

attributes coupled with the occupants' adaptability to climate and control of the windows.[3] Architecturally, the key features are the triangular form with narrow floor plates and 12-story office villages, formed by the central atrium and lateral multi-story gardens (see Figure 2b), resulting in a vertical compartmentalization for natural ventilation, in order to address the issue of temperature stratification that may occur in tall buildings.

Few iconic cases have provided successful reports on the issue of verticality and the possibilities of natural ventilation, such as the Commerzbank Headquarters in Frankfurt, alongside other tall commercial buildings in Germany, including the GSW Building in Berlin (see Figure 4) and the Deutsch Post Office Tower in Bonn. Inevitably, more naturally ventilated tall buildings will appear in European cities, where some of the iconic environmental tall buildings have taken the initiative, even if it is naturally ventilated for only periods of the year. Certainly, the change from the sealed air-conditioned tower to the mixed mode and naturally ventilated tower designs will reduce the figures of energy consumption of tall buildings, with a substantial reduction of air-conditioning energy use.[4]

Notwithstanding, this impact still needs to be verified for a significant number of cases, so that results can be broadly understood and generalized to inform further design application.

In general, a minimum period of two years of occupation is advisable before valid energy assessments are carried out. This is because facility management needs a reasonable time to fine-tune the building's operation most appropriately and efficiently, balancing user needs, environmental expectations and energy conservation. Some feedback has already demonstrated that not only can building controls be simplified but equally that some design criteria (e.g., internal design temperatures, humidity levels and illuminance levels) can be less stringent by introducing adaptive opportunities in the control of the local environment (Nicol & Roaf, 2007), enabling the user to determine the actual environmental conditions of the space they occupy through physical interaction rather than maximizing automation, with the potentially positive consequential impact on reducing energy consumption, such as seen in the case of the tall building of the Commerzbank Headquarters in Frankfurt.[5]

[3] The technical and behavioral information about the operational routines of the Commerzbank Headquarters was provided by the building's facility manager, Peter Muschelknautz. A post-occupancy evaluation was carried out in 2010 to verify the satisfaction of the occupants with the building, mainly regarding its environmental conditions and the means to control them. Observations show that the occupants feel comfortable with their working environments and the available adaptive opportunities (interview with P. Muschelknautz, 2009).

[4] The alternative to the fully air-conditioned approach is the "mixed-mode strategy," by which buildings can be naturally ventilated as long as the external climatic conditions are favorable to internal thermal comfort, switching to mechanical ventilation and active cooling or heating systems when such conditions change (CIBSE, 2005). The mixed-mode approach has been the key feature for environmental claims in a great number of commercial buildings, especially in Germany since 1990s (Goncalves, 2010).

[5] International standards for thermal comfort originated in developed countries (for example ISO 7730 (ISO, 1994) disseminate the culture of the artificially controlled environments, being extremely energy intensive to maintain, while not being necessarily representative of occupants' real expectations of comfortable conditions, as they are based on the physiological paradigm that considers comfort as a pure physiological phenomenon and, therefore, achieved only within clearly defined and actually narrow temperature bands. Having had a significant influence in the required internal thermal conditions, especially in commercial buildings across the world, these standards clearly impose a series of barriers upon global environmental targets (Shove, 2003), while dismissing the potential of occupants' adaptability to thermal environments.

The value of real-life data is generally acknowledged in order to benefit both client and design team, not least in that some institutions recognize this, like the Royal Institute of British Architects (RIBA), through the introduction of "Stage M" in the Architect's Appointment (i.e., feedback on post-completion occupation focusing on "lesson learned" through the whole design and construction process, as well as operational routines). Despite this fact, the actual translation of this intent in practice remains poor. This is generally attributable to the lack of funds allocated for such tasks at the end of a project, or in some cases a lack of understanding as to the value offered through such post-occupancy studies. A common barrier to the access of operational data is also related to the required approval from buildings' owners and occupants, which is often associated with fear of bad publicity and shared by architects and engineers as well.

In order to change this demoralizing reality, incentives to promote such post-occupancy data and make it readily available can be found in the regulatory and voluntary initiatives in different parts of the world. The Green Mark certification in Singapore created in 2005, for example, is a rating system that requires buildings to undergo post occupancy testing to verify if predicted performance matches the real-life of buildings in operation (BCA, 2005).

In the European Union, as part of the implementation of the Energy Performance Building Directive (EPBD), it has been mandatory under national regulations for every new building to present an Energy Performance Certificate (EPC), based on both predictions of energy consumption (asset rating) and actual measured performance data (operational rating), since the beginning of 2007 (EnBau, 2007), contributing to a more realistic overview of a building's energy consumption. It is very likely that this measure will expose a great number of environmentally-claimed tall buildings in the EU and their true environmental performance.[6] Taking the example of the office building in the UK, a good practice naturally ventilated building should consume one-third of the energy used by the standard air-conditioned building (CIBSE, 2004).[7] Design predictions from famous environmentally-claimed tall buildings in London designed in the last decade have shown the potential for improved energy performance but have not yet met such a target. For example, the 30 St. Mary Axe concluded in 2004 in assessing the impact of the building form and the internal layout in the natural ventilation strategy (open plan versus cellular offices) prediction of energy savings were between 30 and 50 kWh/m^2 per year less, between approximately 14 and 20% less than the 250 kWh/m^2 per year for a similar "good practice" fully air-conditioned office building in London (CIBSE, 2004),[8] with a consequential reduction in CO_2 emissions being between 30 and 50 kg CO_2/m^2 per year (Foster + Partners, 1998). Architecturally, a potential for 20% energy savings was identified as a consequence solely of the round and compact building form (BDSP, 1998). However, despite all these motivating figures, following up over five years of occupation, whether natural ventilation is actually being used and the final energy consumption figure related to the building's environmental control remain in question.

Another case, the 110 Bishopsgate (also known as the Heron Tower) built in 2010 (see Figure 5), showed estimations of more ambitious energy savings in the very early design stages with figures between 25 and 30% reductions, also compared to the local good practice of a fully air-conditioned building defined by CIBSE (250 kWh/m^2 per year). It should be said that the achievement of IPCC objectives demands better performance than those expected results, in both cases. In fact, the strong environmentally-driven architectural concept of this tall building, featuring a south face lateral service core, a central north-facing atrium, double skin façades with internal solar protection and operable windows for natural ventilation, altogether carry a great potential for real low energy figures due to internal environmental control, yet remain to be seen with the occupancy.

Among real life case studies of tall buildings in Europe, the Commerzbank is one of the very few tall buildings in full operation from which energy figures have been published (Gonçalves, 2010). The annual thermal energy consumption values of this tall building which is naturally ventilated for approximately 80% of the year, for more than a decade (between 1998 and 2009) have been below all of the national benchmarks (EnEV, 2007) for equivalent air-conditioned offices (which are mechanically ventilated and heated, but not artificially cooled), showing 160 kWh/m^2 against 190 kWh/m^2 are rather exciting results of what can be actually achieved in terms of energy reductions, compared with benchmarks which are already quite challenging.

In addition, the total annual electrical energy consumption of the Commerzbank has varied slightly over the last ten years, ranging between 105 kWh/m^2 and 120 kWh/m^2. It is worth noticing that the annual electrical energy consumption figures are also below the national benchmarks (EnEV,2007) of not only equivalent air-conditioned offices which is 155 kWh/m^2, but interestingly also just below the benchmark for offices that are mechanically ventilated and heated but not artificially cooled, this being 125 kWh/m^2. Interestingly enough, the Commerzbank, occupied in 1998 and probably the most successful iconic naturally ventilated and low energy tall building in Europe, never went for a green certificate, as opposed to the huge number of environmentally-claimed tall buildings which came after.

[6] Benchmarks, to a certain extent, are influenced by climatic, cultural, technical and operational factors that are essentially contextual design parameters. Comparisons between different benchmarks, or the use of benchmarks from a different context, are not advisable. It must be considered that, depending on the type of building and national standards, benchmarks are taken on different area bases. In addition, different benchmarks may consider different types of energy, for example delivered or used energy, metered energy and primary energy.

[7] In the UK, energy consumption guidelines indicate that energy use for office buildings is about 300 to 330 kWh/m^2 per year for standard mechanically-ventilated and fully air-conditioned buildings and 127 to 145 kWh/m^2 per year for naturally-ventilated buildings (savings between 55 and 60%) (CIBSE, 2004).

[8] In the design of the 30 St. Mary Axe building, it was considered that winter external temperatures below 5°C would lead to the introduction of active heating, while in summer, the limit of 24°C (or preferably 26°C) in the working spaces would bring about the closure of the building and the use of the cooling system (BDSP, 1998).

Figure 5. Heron Tower, London © Joana Gonçalves

Looking at global interest in voluntary green certificates for buildings, the rush for the green label has led many commercial buildings, including famous iconic tall buildings, to aim for maximum overall environmental rating system points, rather than carefully considering the complexity of reducing actual energy consumption. This trend is gradually being recognized and considered in the evolution of systems such as LEED and BREEAM, schemes which involve regular revisions of their "scoring" criteria and most now target energy consumption and the carbon rating of a building (future revisions of green certification systems are likely to prove this shift), hence, underlining the importance of energy consumption as a singular element in "green" design, which at the moment is still hidden and, therefore, unclear in the final classification.

As a matter of fact, recent studies on post-occupancy evaluation in 22% of certified buildings in the US were developed by the New Buildings Institute of Vancouver (Gifford, 2008). These studies show that certified buildings use on average 29% more energy than the comparable ones. Nobody denies that the image of the "green" building has been associated with LEED, but in reality those are not delivering energy efficiency as promised in the design. In this context, the main cause of energy efficiency failure is due to the fact that LEED rewards projects for their predictions, but not for proving the savings.

It must be also highlighted that "green" certificates are often applied for and acquired in the design stage, as opposed to the building in real operation, although the maintenance of the certificate will inevitably require the verification of the building in operation. Furthermore, it must be considered that, ideally, rating assessment systems should praise the best examples in a context that has been driven by environmental codes and legislation. Otherwise, there is a danger of supporting false paradigms of environmental performance, with special reference to energy issues.

In conclusion, while the issue of environmental performance is not properly addressed in design, operation and assessment of buildings in general, the energy consumption and the related environmental impact of tall buildings will remain within the limits of the conventional commercial building typology, including the so called "good practice." In reality, the true environmental performance of buildings is inevitably associated with a new building culture that starts in the design, where advanced computer simulations for the assessment of the architectural design is fundamental with rigorous environmental assessment routines and must go beyond it, encompassing occupants' behavior. It may imply higher costs during the design phase when compared to the conventional design process, which in theory will be compensated for in the building's lower operational costs and will add value to the investment. In practice, such achievement is associated with the commitment of all agents involved from the outset and in the design, construction and operation and use of buildings, with the occupants playing a key role, and is likely to overcome design predictions of energy demand. ■

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