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The environmental value of buildings: a proposal for performance assessment with reference to the case of the tall office building

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Buildings consume approximately 33\% of the world’s energy, equivalent to 21\% of global CO\textsubscript{2} emissions (IEA 2009, \textit{World energy outlook} 2009, http://www.iea.org/weo/electricity.asp). Given the current scenario of energy consumption in buildings, the objective of this paper is to present some of the key issues related to assessment of the environmental performance of buildings, supported by the proposal of strategic indicators (with reference to the tall office building), followed by a critical review of the value of environmental design. Fieldwork has shown that a group of European case-studies show signs of change beginning to emerge considering value ahead of first cost, challenging the conventional commercial model. Energy savings and environmental quality in the operation of buildings bring marketability benefits to tenants, whilst future-proofing investments are of benefit to investors. In addition, buildings need to go beyond governmental targets to be able to remain competitive, adding value to environmentally considerate design.

Keywords: buildings; environment; quality; value; assessment; criteria

Introduction

Globally, approximately 33\% of the world’s end-use energy takes place in buildings (IEA 2009). In parallel to that, buildings are responsible for 21\% of the total GHG (greenhouse gases) emissions, most of which are related to energy consumption during building occupation. The projections based on the IPCC (International Panel of Climate Change) CO\textsubscript{2} emissions from buildings in operation could be about 30\% of the total by 2030 (IPCC 2007). With such significant figures, the building sector is the single largest contributor to global greenhouse emissions, offering great potential to reduce this alarming environmental impact through a number of actions, including behavior, design changes and technology, together with public policies and financial instruments to enable the design and construction of more environmentally responsive buildings.

Looking in more detail at buildings’ demands for energy, 60\% of the world’s electricity is consumed in residential and commercial buildings (Laustsen 2008). In this context, it is important to consider that there is a significant difference between the pattern of consumption between developed and developing countries, owing to

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their different lifestyles and economic development, as well as between countries from different climatic regions (WBCSD 2009).

In countries located in cooler regions of the world (most of them being developed countries), space heating represents 60% of total national energy consumption (WBCSD 2007), while buildings in warmer regions do not usually require space heating, saving significant amounts of energy. Within the realm of commercial buildings, artificial lighting systems are often the largest single use of electricity in commercial buildings, although in hot climates in particular (most of the developing countries), air-conditioning tends to be the largest use. In Brazil, for instance, air-conditioning systems in non-residential buildings are responsible for approximately 47% of the total national electricity consumption, followed by artificial lighting with 22% (Correia 2007).

Given the current scenario of energy consumption in buildings, the objective of this paper is to put forward some key issues related to the assessment of the environmental performance of buildings, including barriers, challenges and the main design and performance parameters to be addressed. This discussion is supported by the proposal of a short list of key indicators, which uses the case of the tall office building as a reference, followed by a critical review of the value of a new generation of environmental buildings. The International Energy Agency uses the terminology "green buildings" to describe more energy efficient buildings with lower environmental impact, and gives the following definition (IEA 2008): “Green Buildings are those with increased energy efficiency, but at the same time reductions are made on water consumption, use of materials and assessment of the general impact on health and environment”. Although, in the context of this article, we will use the terminology “environmental responsive buildings” or, simply, “environmental buildings”, the definitions associated with these terms are the same as that put forward by the IEA.

In the search for the reduced energy consumption in buildings and less carbon emissions, on the supply side the macro measure for the provision of cleaner energy demands high public investment over the medium to long term, while on the demand side the micro strategy is likely to show results in the short term, for instance, through the implementation of building regulations and energy codes, performance standards, such as Passivehaus (Feist 2007), and voluntary certificates, such as LEED, Leadership in Energy and Environmental Design, originally to be applied in the United States (USGB 2009) and BREEAM, BRE Environmental Assessment Method, in the UK (BRE 2009).

In the context of enabling conditions for more environmentally responsive buildings, codes and standards have proved to be a method of quickly achieving results in the building sector, also being more effective regarding energy reduction targets than voluntary certification (UNEP 2011). Nevertheless, if regulations are too rigid, they can stifle design and technological innovation and constrain the potential of behavior change.

In summary, changes in the environmental performance of buildings are related to changes in market forces and political pressure, in which environmental quality is valued. Figure 1 shows an environmental timeline with key global events and the creation of building codes, regulations and certificates since 1973, the first oil crisis of
Figure 1. Environmental timeline of buildings’ design targets. Source: BDSP Partnership.
worldwide impact, moving towards tougher measures for CO₂ emission reductions by 2050. One can say that the international market for buildings has started a gradually increasing phase of more public exposure to environmental issues, coupled with the fact that environmental targets are finding their way into legislation and politics.

Certification systems and the myth of “green” buildings

With special reference to the certification systems, there is a common belief that having a building or development certified as “green” automatically translates into operationally “green” or environmental buildings. In the majority of cases of certified buildings, the real argument for environmental certification to date has been the marketability or rather competitive differentiation through energy performance or environmental quality (Gifford 2009). In addition, none of the well-known certification systems relate to continued operational performance after completion of the projects, and this is a major weakness.

From the perspective of a truthful environmental design approach, it can be argued that it is better to design “green” buildings based on basic yet sound environmental quality indicators, responding to the local context (climate, culture, infrastructure, materials, available technology and services, user interaction, etc.), which can then be tested against international or national certification schemes, so as to identify areas of potential improvement. In conclusion, environmental certification per se does not deliver green buildings, but rather functions as a catalyst towards more environmental buildings in general.

Behavior change and design

Above all, major achievements are associated with behavior change and new paradigms for building models, where the local climatic conditions have a major influence in the design and technology of buildings (Humphreys and Nicol 1998). Energy consumption by environmental control systems is directly related to the characteristics of the local climate; for this reason, targets for energy performance should be particular to the climatic context. Consequently, environmental design requires the understanding of local environmental constrains and potential, coupled with the influence and expectations of the occupants. It is interesting to notice that one of the first and more important challenges for the accomplishment of more environmentally responsive buildings is not related to the actual design of buildings, but to reviewing conventional standards of comfort criteria for internal spaces, especially in commercial buildings.

Taking the case of the conventional office building, the potential for energy savings is huge, considering that internal spaces are usually artificially climatically controlled during the entire period of occupation as well as often being deprived of appropriate daylight, conditions which were created by international standards of consumption and economic status and strongly associated with cultural values rather than being climatically justified. In artificially heated and cooled buildings, the acceptance of slightly higher temperature set points in hot periods and slightly cooler ones in winter has a significant impact on the reduction of heating and cooling loads.

Furthermore, as opposed to the notion of a universal and narrow thermal comfort zone for the internal environments of commercial buildings (Fanger 1972, ASHRAE 2004), the concept of adaptive comfort has increased the possibilities of
passive buildings, and reduced the period of artificial heating or cooling (Dear and Brager 2002). According to this concept, building occupants can potentially respond and adjust to thermal situations in order to achieve comfort by changes in clothing, activity and posture. Adjustments of indoor thermal conditions can also be achieved through controls such as windows, blinds, fans or alternative mechanical heating or cooling. For all that, the adaptive model is related to a major cultural change in the use and control of buildings' internal environments.

By providing the opportunity for buildings' occupants to adjust their indoor climate to suit their needs, higher levels of satisfaction can be achieved alongside significant energy savings. In addition to that, based on the concept of acclimatization, different climatic conditions and climatic expectations (owing to cultural aspects and functional requirements) will have different comfort zones.

Occupants living and working in air-conditioned buildings develop higher expectations of thermal comfort, becoming unsatisfied with conditions that deviate from their narrow comfort zone, whereas occupants from non-air-conditioned buildings are better able to control their environments and are more tolerant of climatic variations (Humphreys and Nicol 1998; De Dear and Brager 2002). This cultural shift needs to be accompanied by a change in the conventional design of buildings in order to better respond to the local climate and, therefore, offer more adaptive opportunities.

**Design of environmentally responsive buildings**

From a design perspective, unlike the conventional model, environmental design takes an all-encompassing approach, blurring the division between architecture and engineering. In this context, the approach to low-energy buildings can be summarized in four steps. The first one is to reduce the demand for energy through architectural design and to review comfort criteria. The second step involves the use of efficient technical systems. Steps 3 and 4 are ideal conditions for low (or zero) environmental impact, which involves renewable energy generation (solar, geothermal, wind power and others), coupled with other alternative means of energy supply, including passive systems, such as ground and evaporative cooling, district heating, thermal cooling plants and others. Zero CO₂ buildings include steps 1–3 and, in some cases, 4 (see Figure 2).

Owing to the technical and scientific complexity involved in the development of more energy-efficient buildings, analytical assessment with the support of simulation tools plays a determining role in adding precision, speed and better visual communication of environmental issues to the design process, ultimately increasing the technical aspect of the design phase, in order to reduce the dependency on technology later on, for the control of the environment in buildings.

From an energy and environmental perspective, the architectural design of the environmental tall office building involves a complete review of the conventional architectural model. For instance, deep floor plates become narrower in order to allow for better daylight, views and, in some specific cases, natural ventilation, and the over-glazed façade is redesigned to have shading devices and openable windows, among other features.

With regards to the use of passive strategies (those design strategies that contribute to the environmental conditions in buildings without the demand for energy, i.e. natural ventilation and daylight), the value of daylight is associated with its direct impact on well-being, productivity and the overall quality of a building’s...
internal space (Baker and Steemers 2002). By contrast, natural ventilation is a more controversial issue, although it has been proved in buildings from different climates that natural ventilation is possible and advantageous (Gonçalves 2010).

A significant sample of commercial buildings in North America, Europe and Asia have achieved a minimum 50% reduction in overall energy use, compared with current local conventional practice. A study by the National Renewable Energy Laboratory of the US Government on 5375 commercial buildings and their potential for energy savings showed that in new buildings the use of energy-efficient lighting, daylight, shading and elongation of the building form on an east–west axis can achieve energy savings of 65% (Torceline et al. 2006). Particularly in the UK, energy consumption guidelines indicate that energy consumption in office buildings can achieve savings of between 55 and 60% with the introduction of natural ventilation (representing 127–145 kW h/m² per year; CIBSE 2004).

**Environmental assessment of buildings**

Considering the environmental assessment of buildings, a key barrier for further progresses is the gap between theoretical data and performance-based data,
especially regarding energy consumption. Although predictions about the energy performance of buildings are an essential part of “greenering” the building stock, the most important data is the operational energy consumption measured after a period of occupation (minimum advisable of two years). This is because the energy performance of a building in operation is affected by factors beyond design, including management routines, occupants’ behavior and climatic changes.

Moreover, the success of the energy performance of buildings cannot be guaranteed by design measures and simulation predictions alone; facility managers need to take ownership and occupants need to learn how to use the building and its technical systems. One of the biggest challenges for simulation techniques is to bring closer together predictions of energy consumption and operational figures, so that the design of forthcoming buildings can learn from the experience of existing structures. However, there is little real life data, or operational data, available to substantiate the claims of low energy consumption. The lack of project-specific feedback on actual environmental performance of buildings is a major obstacle in furthering the understanding of the effectiveness of specific design features.

Within the broad subject of environmental assessment of buildings, with respect to the issue of performance indicators, in a global perspective it can be argued that carbon alone is the only important parameter to measure the environmental impact of buildings. Nevertheless, a low to zero carbon-rated building can still be energy-inefficient, in cases where the building relies on renewable energy sources to offset carbon emissions and the design is not driven by environmental principles. Hence, in order to have a realistic and comprehensive understanding of a building’s energy performance, both indicators should be considered: energy consumption and CO₂ emissions.

In complement, it is important to consider that energy efficiency and environmental quality are two different subjects and the second cannot be measured merely by means of indicators of energy consumption. In other words, “good” energy performance does not necessarily imply that a building will be of good environmental quality. Alongside concerns about energy efficiency, a strong argument about the future of office buildings refers to the concept of the quality of the working environment.

During the first 25 years of the life of an office building, in general, 85% of the costs are staff-related (WBCSD 2007). Where the highest costs of an organization correspond to people and salaries, the economic advantages of better-quality environments are obvious. However, while this idea is accepted, with the exception of iconic buildings, the issue of quality in the internal environment of buildings has not yet changed the conventional design parameters, including the culture of artificially controlled environments and the economic interests of the market.

In order to support the transformation of market views, it is necessary to critically re-evaluate what constitutes “environmental quality” as well as what defines “value”, particularly in the design of tall office buildings. The classical definition of maximizing net to gross floor area ratios, as well allocating same “rental value” to all types of usable floor areas, is oversimplified, and represents a major obstacle to the development and propagation of environmentally quality in commercial developments. Such conventional commercial indicators are typically used in assessing an “economically successful” development, but these fail to consider the overall performance, quality and, therefore, value of a building.

In the design of contemporary buildings, particularly those declaring themselves to be environmentally considerate, it is essential to broaden the definition of “value”,
beyond the oversimplified single-grade net area interpretation and begin to apply a wider range of assessments that include other parameters, such as areas well served by daylight, semi-open spaces for social interaction, internal visual communication and others, as well as criteria such as flexibility and adaptability in change of use with minimal intervention in design and construction.

Energy performance and the use of benchmarks

In Europe, a significant and well-represented group of countries leads the field of energy conservation, implementing rapid developments. In the European Union, as part of the implementation of the Energy Performance Building Directive, it will be mandatory under national regulations for every new building to present an Energy Performance Certificate, based on both predictions of energy consumption (asset rating) and actual measured performance data (operational rating), contributing to a more realistic view of buildings' energy consumption.

Benchmarks, to a certain extent, are influenced by climatic, cultural, technical and operational factors and are essentially contextual design parameters. Comparisons between different benchmarks, or the use of benchmarks from different contexts, are not advisable. It must be considered that, depending on the type of building and national standards, benchmarks are taken on different area bases. For example, many of the UK benchmarks use gross areas whereas the German benchmarks use net areas. Furthermore, the methodology for area calculation, particularly the definition of net area, once again varies between countries.

Given the emphasis put on the "green" office building in cities around the world, especially owing to the relatively high energy consumption of artificially controlled environments in overall building energy consumption, exploring energy benchmarks for commercial buildings is an important step to qualify new proposals. In the European Union, building regulations and national energy benchmarks from Germany are some of the toughest, with empirical data from the national programme German Energy Saving Ordinance (known as EnEV 07) based on net areas (see Figure 3).

In the UK, more detailed benchmarks are found for offices, according to a series of categories: air-conditioned and naturally ventilated, subdivided according to the internal fit-out (open plan or cellular office), with figures for "standard practice" and "good practice". In the UK, energy consumption guidelines indicate that energy use for office buildings is about 300–330 kW h/m² per year for standard mechanically ventilated buildings, 173–186 kW h/m² per year for good practice (a saving of 40–45%) and 127–145 kW h/m² per year for naturally ventilated buildings (a saving of 55–60%; CIBSE 2004). In comparative terms, a good-practice, naturally ventilated building in the UK should consume a third of the energy used by the standard air-conditioned building (see Figure 4).

Other factors to be considered include normalization against climate variations, occupancy densities and functional areas included/excluded in the energy consumption data. All of these can distort data and ideally should be accounted for in any comparative study. In the absence of these details of the energy consumption of a building, care must be taken in drawing comparative conclusions. While the building’s operational efficiency can be ascertained from the amount of metered energy used, the global environmental impact can only be correctly defined by means of carbon emissions, which in turn relate to primary energy consumption.
Buildings assessment criteria

In the global scenario, the issues of height, efficiency of space, suitability and energy consumption are among the most sensitive and discussed parameters regarding the overall efficiency of commercial buildings, including the tall office building. Nevertheless, the first two variables are related to conventional values of commercial

Figure 3. German energy consumption benchmarks. Source: Deutsche Energie-Agentur German (2007).

Figure 4. A group of energy consumption benchmarks for building services related to internal environmental conditions (heating, ventilation, lighting and cooling).
architecture, and while energy matters have been the subject of much discussion over recent decades, with the exception of a few iconic buildings, they have rarely been an influential design parameter.

Within the global perspective of more environmentally responsive tall buildings, the conventional indicators of commercial design, including height, efficiency of space and suitability, as well as energy consumption (kW h/m²), are far too simple to classify the environmental performance of the tall building. These indicators alone cannot provide a comprehensive understanding of the tall building’s performance according to more contemporary environmental, architectural and economic values. They do not examine issues of environmental quality and occupants’ well-being, energy consumption, actual occupation density and, ultimately, CO₂ emissions, which are all far more complicated than conventional indicators. In addition, the broader debate on urban impact is often neglected.

Based on principles of environmental design and energy efficiency, a proposal for the environmental assessment of the tall office building is formulated below. Structured in two parts, the assessment starts with a qualitative overview of the environmental performance, followed by a quantitative analytical approach to measure actual building performance. Whereas the quantitative approach requires detailed information about the architectural design and the building’s energy consumption, the qualitative approach can be based on site observations, study of planning and conceptual information and understanding of the architectural design, supported by some basic rules of thumb according to building function and climatic context. In both phases, not all parameters of the assessment are exclusively applied to tall buildings, thus serving any architectural typology and different end-uses. This proposal for assessment criteria of buildings, with reference to the office tall building, has been extracted from Gonçalves (2010).

While the qualitative part of the assessment presents urban and architectural conditions to which the building needs to respond, the quantitative part provides a series of performance indicators. Irrespective of numbers, in the realm of environmental design the exclusive view of quantitative indicators can mislead the interpretation of quality. As an example, a room that may be totally compliant in terms of thermal comfort, but dull and with a window looking out onto the wall of another building is likely to attract more “comfort criticism” than one that may be slightly warm, but is well served by daylight and fabulous views.

Considering a more environmentally responsive design, although the main four performance criteria are comfort, energy, cost and environmental impact, the design should extrapolate these quantitative performance criteria, providing for quality-of-life, future flexibility and minimum overall environmental impact, leading to higher standards of productivity and creativity, and also providing insights into how the occupants will be positively affected.

The elaboration of an environmental assessment that contains qualitative and quantitative complementary approaches is fundamental to cover the facts without losing the perspective of overall quality. In following such an approach, the risk of not considering eventual design differentiations, which might make a major contribution to a building’s environmental quality, is avoided. In summary, the proposal is based on the hypothesis that one single index cannot adequately define environmental quality, which is reflected in the design synthesis and the users’ experience of the space.
Technical systems, including all operational aspects of the tall building, have a determining role in energy performance. Notwithstanding, unlike the usual “green” certificates, the assessment criteria proposed focus on essential urban and architectural aspects of buildings, the related environmental strategies and the final energy performance. However, they exclude other relevant parameters associated with technical systems (heating, cooling, mechanical ventilation, lighting), as the aim is not to cover all the aspects involved in the building’s performance, but to highlight and examine in detail the architectural aspects.

The prioritization and weighting of criteria are not included in this assessment proposal, as they should be established for specific design contexts. This is a sensitive issue for assessment methodologies, as it values the impact of some design decisions over others in the final scoring of the building. In parallel, once different priorities and weights are established for different contexts, comparative analysis between cases of different contexts can no longer be validated. However, comparative assessments can include the weighting of different design criteria as a useful means to test different design scenarios.

In contrast to the qualitative assessment, where the impact of the verticality in the urban realm is critically considered, in the quantitative approach none of the indicators is particular to the tall building typology. The methodology is dedicated to environmental design, focusing on the specific use of offices.

**Qualitative approach to the assessment of buildings**

The qualitative approach is not meant to be tested against any benchmarks, and the order of priority should be established locally. Its application allows for a comparative analysis in that buildings are ranked against a set of criteria, encompassing impacts on the urban environment and aspects of environmental performance regarding occupant well-being and architectural design for energy efficiency.

The qualitative assessment is structured in five categories of impact: urban context, covering issues of urban form, skyline, infrastructure and urban mobility; ground conditions and urban microclimate, bringing observations on the impact upon surrounding buildings and open spaces; well-being, including thermal comfort, daylight and views; energy performance, looking at the architectural features thought to respond to specific environmental conditions; and environmental identity, in which the synthesis achieved by the design is presented, bringing together architectural and environmental values. The first two are exclusive to tall buildings, whereas the last three categories are important to the environmental performance of tall buildings but are also applicable to other building typologies.

The five categories summarize the qualitative aspects of the urban, environmental and architectural dimensions of the tall building. The selected criteria encompass the most critical issues related to the urban impacts of the tall building (especially at the local scale), the environmental quality of the internal spaces and ultimate energy consumption, concluding with the question of design synthesis, which is the main challenge of architectural design. These criteria constitute the essential core of the qualitative assessment, with the possibility of being expanded according to the particularities of the design context.

Responses to category 1 refer to principles of urban design and planning, while categories 2–4 are more scientific, being based on principles of physics and basic
rules of thumb, while still being qualitative. With regards to the environmental quality of the buildings described in categories 3 and 4, architectural features are established to guide the assessment. Responses to category 5 express the ability of the design to develop a synthesis between architecture and environmental strategies. A number of urban conditions and issues of environmental design are listed within each category with which the building needs to comply in order to qualify in the rating process. Although the indicators in this first phase of the assessment are qualitative, points can be attributed to them to facilitate comparative analysis.

**Category 1: urban context**

*Urban form and skyline* – this covers whether the building is to be part of a cluster of tall buildings, existing or planned. Alternatively, the tall building can refer to a “tall building policy” developed or supported by local authorities, or to be inserted in a broader urban plan that includes consideration of the location and impact of tall buildings. The standalone tall building scores in this assessment since it is part of a specific urban strategy or vision.

*Infrastructure and mobility* – this covers whether the building is to be supported by an efficient public transportation system, so that the tall building does not impose any negative impact on the urban mobility. In addition, the use of automobiles should be inhibited by reducing the number of parking spaces in the development and promoting more sustainable means of transportation, including bicycles and walking.

In principal, the positive impact of tall buildings on mobility in urban centers is related to the efficiency of public transportation. However, if the location of the tall building is not served by public transportation but the fluxes of vehicles created by the building do not compromise the efficiency of local urban mobility owing to the nature of the specific urban environment and the local transportation systems, the tall building cannot be considered to have a negative impact. An example is the office tower located at the junction of highways. Besides transportation systems, the other infrastructure utilities needed to respond to the demands of tall buildings, including provision of energy, water, communication systems and collection of waste and sewage, should be in place prior to the development of the tall building.

*Building function vs local socio-economic structure* – the basic functions and socio-economic activities brought by the tall building should be appropriate to the “vocation” of the local context, possibly adding economic value and incrementing the socio-economic dynamics of the place.

**Category 2: ground conditions and environmental impact**

*Solar access and daylight availability to neighboring buildings and open spaces* – negative impact of the tall building on solar access and daylight availability to neighboring buildings must be avoided. Solar access is a critical issue for residential buildings, as is daylight availability for offices and buildings of other uses. To control such impacts, consideration of the uses of the neighboring buildings should be followed by the assessment of the impact of the tall building on the sky-view factors from strategic points in the surrounding buildings, such as windows from residential buildings and green and seating areas in public spaces.
Pollution dispersion – this criterion is particular to urban environments polluted by vehicles (cars and buses), where the effects of the tall building on the air flow around other buildings can make a substantial contribution to pollution dispersion.

Quality of public space and pedestrian comfort – the building should contribute to socio-economic vitality at street level and to the communication between public spaces, avoiding an oppressive impact on the pedestrian domain (owing to difference in scale) and avoiding pedestrian discomfort through undesirable turbulence and overshadowing effects.

Category 3: well-being

Thermal comfort – the building must achieve recommended levels of thermal comfort (prescribed by local or international regulations or recommended by theoretical models/studies) and avoid risks of discomfort. The building can be fully air-conditioned, or fully naturally ventilated, or have a mixed-mode environmental strategy (combining both possibilities). Each approach has its own merits and limitations and thus design decisions must consider these strategies elementally and collectively to assess their applicability in a given climatic context. Temperature set points established for summer and winter are important parameters to assess in the approach to thermal comfort, considering their impact on energy consumption.

A number of architectural features and environmental strategies that can improve the energy performance of air-conditioned buildings as well as increase the possibility of natural ventilation should be considered, including building form and orientation, and solar protection in the design of the façades to avoid direct solar radiation on the occupants. In addition, occupant control over environmental conditions is part of the design strategy and can be applied to maximize well-being and productivity, within the limits of energy efficiency. The main controls operable by occupants include windows, solar protection, artificial lighting, temperature set points and changing work places in the building for certain periods.

Daylight and visual comfort – the building must achieve recommended levels and good uniformity of daylight in the working spaces, prescribed by local and/or international regulations and recommendations. Architectural features and environmental strategies to be considered include building form and orientation, depth of floor plate, floor to ceiling height, atria, window wall ratio (WWR), disposition of windows, shading devices, light shelves, special glass technology to control glare and innovative technical systems to incorporate daylight and control glare.

Views, social interaction and privacy – it is necessary to promote the social integration of the occupants and visual communication between inside and outside environments as well as among internal spaces. Architectural features to be considered include spaces for communal use, including leisure or cultural activities, atria and gardens. The design of the office layout and internal partitions, whether open plan or cellular, combined with the depth of floor plate and the floor to ceiling height, will also have an impact on views towards the outside and internal visual communication vs. privacy.

Acoustic comfort – acoustic comfort is a sensitive issue for working spaces, and comfortable levels of noise, as prescribed by local and/or international regulations and recommendations, should be aimed for. In addition, acoustic privacy is expected for the overall environmental quality of the internal spaces. Architectural features to be considered are layout of offices, including the design of internal partitions and
finishing materials, plus density figures. Internal acoustic conditions are highly dependent on the finished design of the internal spaces. Moreover, acoustic comfort and the problem of noise generated in the working spaces of open-plan layouts are not just a matter of environmental standards but are also a cultural issue. Office environments in certain urban cultures tend to be nosier than in others and tolerance to noise varies.

**Category 4: energy and environment**

*Architectural features* – these constitute the reduction of a building’s energy consumption in comparison to local standards through architectural design. Architectural features and environmental strategies to be considered are building form and orientation, façade technology, materials, depth of the floor plate (to justify the influence of the façade on the overall performance of the building), the presence of gardens, atria, balconies and other types of buffer zone, internal space sectorization and any other architectural particularity. The environmental strategies and more detailed architectural features listed within category 3 should be reviewed in this subsection of the analysis.

*Adaptability to future changes* – the success of the environmental performance of the building in the near future will most likely depend on the adaptability of the design to accommodate changes of use, technology, environmental legislation, economic values and climate change. Spatial adaptability allows ease of converting open-plan spaces into cellular offices, or multiple different arrangements, raising the question of the environmental efficiency of these models when they are in passive mode. All the architectural features listed in categories 3 and 4 support this subsection of the assessment.

**Category 5: environmental identity**

*Architectural expression* – this is the synthesis between architecture, environment and technology in order to achieve good environmental performance and identity. Architectural features and environmental strategies to be considered are building form, design of the façades, organization of the internal spaces and integration with technical systems. It is expected that the architectural concept will be informed by principles of environmental design and the detailed design will be in accordance with the results of technical environmental assessments, carried out throughout the design process.

**Quantitative approach to buildings’ assessment**

The quantitative part of the assessment is focused on the environmental and energy performance of the building and its related impacts, including indicators of environmental quality and energy consumption, as well as global issues such as the impact of the building’s energy consumption on CO₂ emissions. A group of indicators related to space efficiency and environmental performance are commonly used in the global scenario, such as net to gross areas (per cent) and energy consumption per square meter (kW h/m²) per month or per year. However, these indicators refer to values of the conventional commercial building design; they are insufficient to express the values of a new generation of environmentally responsive buildings and can be
misleading. Therefore, more elaborate assessments are necessary. In order to respond
to a new environmental design approach, a group of indicators is proposed in addition
to conventional ones, creating the opportunity for the recognition of environmental
principles and design ideas.

Different from the qualitative assessment, quantitative indicators can be
measured against benchmarks. However, the new indicators proposed in this critical
review of a building’s environmental and energy performance do not yet have
benchmarks. It is the role of the designers and engineers of the new generation of
environmental buildings to define them. As mentioned before, in the quantitative set
of criteria, none of the indicators is particular to tall buildings; they address
commercial buildings in general.

The quantitative assessment is structured in three categories: space efficiency;
environmental performance, and energy efficiency and environmental impact. In the
first category, all indicators, with the exception of the last (annual operational cost
per construction cost), are part of conventional market assessments, whereas in the
second category, all indicators are new. The same is observed with the majority of
indicators of well-being and energy and environment, in which only the first
indicator (energy consumption per square meter) can be found in the conventional
market approach to assessing a building’s energy performance.

The topics of the qualitative criteria that refer to well-being, energy and
environment are transferred to the quantitative assessment, focusing on environ-
mental and energy performance. More conventional indicators related to the
economic efficiency of the tall building, such as perimeter wall (façade) to floor
area ratio and capital cost per square meter, although not included in this proposal,
are still relevant to this quantitative assessment, however, not to the same standards/
criteria and extent given by the current global market. Besides conventional and other
relevant indicators, consideration should be given to new indicators in relative
measure, in accordance with the expectations, restrictions and possibilities of the local
context. The categories of assessment are complementary, and therefore the indicators
of space efficiency should be analyzed together with the indicators for environmental
quality, energy efficiency and environmental impact, in order to give a comprehensive
overview of the building’s economic and environmental performance.

**Category 1: space efficiency**

*Net lettable area (NLA) of the building/gross internal area (GIA) of the building
(per cent)* – the NLA includes all areas in the floor plate used by the occupant,
excluding the areas of vertical circulation and access to the floor plate. This is usually
used as the base for letting. The GIA is the total area of the floor plate calculated
from the internal limit of the building’s façades. In the case of buildings with equal
floor plates, this indicator can be based on the dimensions of one floor plate only.
Differently, for buildings with floor plates of different sizes and multiple tenants, this
indicator should be calculated on a floor by floor basis. In the case of a sole occupier,
the indicator should consider the total area of the building. This indicator is in the
economic interests of the developer in the case of a multi-tenant building as well as in
an owner-occupied one.

*Net usable area (NUA) of the building/NLA (per cent)* – the NUA is the area
actually dedicated to serve as the working space, excluding any other uses such as
kitchens, toilets, halls and horizontal circulation areas. This indicator is especially
important in multi-tenant buildings, as it measures the ratio between the area against which the renting costs are calculated and the actual area occupied by the working space.

**NUA per person (m² per person)** – this indicator shows the density of the building’s occupation. The usual typical area per person varies between countries; however, the most common figure is 10 m² per person. Occupation is a design factor of significant impact on a building’s energy efficiency, especially in the office building. The indicator of square meters per occupant is a measure of economic efficiency as well as of the environmental quality of the space. However, the optimum square meter area per person in both economic and environmental terms is an open question.

Certainly, if the occupant has a wide range of adaptive opportunities, including break-out spaces, social spaces and areas in which to work other than the conventional office space, the pure office net area per person can be smaller than the conventional 10 m², while enhancing the overall quality of the working environment. This can be proclaimed as ‘enhanced environmental performance’ (improved occupant satisfaction equals enhanced productivity). While 10 m² is typical, even with the advantages offered by highly adaptable working spaces, there is a natural minimum area per person at which such advantages are eroded and cannot be compensated for by “quality” attributes; this figure is typically 7 m² per person. This minimum figure also accords with fire and safety codes in various countries.

**Category 2: environmental performance**

**Leisure area/NLA Class 1** – the formal concept of the leisure area in office buildings was developed for this specific set of criteria and includes areas for relaxation, social interaction and alternative working spaces, such as gardens, balconies, atria that can be occupied and other type of spaces. Likewise, the concept of NLA Class 1 was also elaborated for this specific set of criteria and indicators, including the area dedicated to the occupants (according to the conventional definitions of lettable and usable areas), which is well served by daylight.

This indicator was elaborated to highlight the contribution of leisure areas, usually with differentiated environmental conditions, to working activities, which are not covered by the conventional indicators of space efficiency. For this specific reason, it is important that this indicator is considered, together with indicators of space efficiency, so that the new spaces created to improve the environmental quality of the building do not have a negative impact on the economic efficiency of the building.

**Hours of natural ventilation/hours of outdoor thermal comfort** – this indicator measures the environmental efficiency of the building in its climatic context by demonstrating the number of hours that the working spaces can be naturally ventilated as a factor of the number of hours that the external climate is within the pre-established (locally specified) comfort zone. If the number of hours of ventilation is the same as the number of hours of comfort provided by the external climate, the result equals 1 (good performance), but if the number of hours of natural ventilation is less, the result will show a figure smaller than 1 (unsatisfactory performance, covering different degrees of dissatisfaction). However, if the number of hours of natural ventilation is greater than the hours of comfort offered by the external
climate, the result will be greater than 1 (very good performance). Obviously, the greater the result, the more environmentally responsive is the design.

The harsher the climate (typically, the hottest), the fewer hours of comfort will be offered by the external conditions.² For this reason, in the case of two buildings in different climatic contexts with the same number of hours of natural ventilation, the one in the harshest climate will score highest on the index. In this way, the degree of difficulty of the climate is considered. Such differences in the actual meaning of the result are revealed through comparative analysis. The contribution of this indicator to an overview of the energy performance of the building is to reveal the percentage of the year during which a certain occupied area can dispense with cooling and ventilation systems.

**Grade 1 area/NUA (per cent)** – the grade 1 area is the area of the floor plate with sufficient daylighting levels to fulfil the environmental requirements of the building’s functions. It must be calculated as part of the NUA. In the case of occupied buildings, daylighting levels can be measured in situ; however, the definition of the grade 1 area requires calculation methods as it must be identified within the period of a typical year. The contribution of this indicator to the overview of the energy performance of the building is to reveal the percentage of the occupied area that can actually benefit from daylight and therefore dispense with artificial lighting for a certain part of the year.

**Category 3: energy efficiency and environmental impact**

_**CO₂ emissions from total energy consumption (t/m² per year)**_ – CO₂ emissions will be related to the nature of the primary energy³ and the total energy consumption, which for the purpose of this indicator is known as operational energy, being the energy needed to operate the building’s technical system services such as heating, cooling, ventilation and mechanical systems, artificial lighting, equipment and lifts. In occupied buildings, the operational energy is measured, while in case of design proposals, the energy figure needs to be calculated.

_**Energy consumption (kW h/m² per year)**_ – this is the typical energy consumption of similar local buildings (percent). The comparison of energy consumption with the performance of a similar, conventional local building reveals the actual contribution to the improvement of energy efficiency of the assessed building in its local context.

_**Energy consumption/NLA (kW h/m² per year)**_ – this indicator shows the energy consumed during the building’s operation per square meter of lettable area. Regarding more in-depth analysis of the energy consumption in buildings, it must be highlighted that separation of the areas of different functions, including offices, circulation, halls and toilets, together with separation of the various end-uses of a building’s technical systems, including lighting, heating, cooling, mechanical ventilation and equipment, are necessary steps.⁴

_**Energy consumption/person (kW h/person per year)**_ – this indicator shows the energy consumed per occupant during the building’s operation. Since occupation is the ultimate role of the building and the issue of environmental quality is inextricably linked to energy consumption related to the control of the environmental conditions, the indicator of energy consumption per person reveals an important aspect of the energy efficiency of the building.

**Summary of the quantitative analyses** – the group of five indicators summarizes the proposal for the quantitative assessment, highlighting the most representative
issues of a building’s performance relevant to economic, environmental and energy matters. All the other criteria are either directly or indirectly contemplated by the five indicators selected, gathering data on aspects of environmental comfort, energy consumption and carbon emissions: total net usable area per person (m$^2$ per person); hours of natural ventilation/hours of outdoor thermal comfort; grade 1 area/NUA (percent); emissions from total operational energy (tonnes/m$^2$ per year); and energy consumption per person (kW h per person year).

**Qualitative assessment: the application of performance indicators**

The environmental efficiency of the new generation of iconic buildings is assessed in Gonçalves (2010) through a comparative analysis of buildings from different socio-economic contexts, based on the selection of quantitative indicators. The cases from the European scenario are located in London and in Frankfurt, and are highlighted in Figure 5.

The European case studies show early signs of change beginning to emerge considering value ahead of first cost. The European model is characterized by an architectural approach that challenges the conventional commercial model (maximizing lettable area), as observed through the introduction of atria and sky-gardens with a resulting reduction of rentable area, while exploring differentiated design solutions, opening up the building more to the outside in terms of views, daylight in a number of cases and design changes towards natural ventilation.

Regarding the overall environmental quality of a building, the European case studies emphasize access to daylight through narrower plans (instead of higher floor to ceiling heights), views towards the outside and transparency between external and internal environments, visual communication between internal environments, energy performance of the façades, and integration between building services and architecture, resulting in design solutions of environmental architectural expression.

Looking at some particularities of the case studies, although the characteristics of architectural design present innovations compared with the conventional model, and have a strong iconic value, the environmental performance of the 30 Saint Mary Axe, in London, is not fully optimized owing to specific aspects of its design and operation, such as: it is still a central core tall building (which could compromise better environmental performance through natural ventilation and daylight) and the façades of the atria are darker glass (preventing more daylight access). As opposed to that, the lateral cores in 110 Bishopsgate and 122 Leadenhall, both also in London (as in the Commerzbank, from 1998), show a major change in the architectural design from the conventional commercial model (one of the most effective changes for the improvement of the environmental performance of the building).

Examining the specific case of natural ventilation in tall office buildings, the Commerzbank Headquarters is one of the key precursors of this new generation of “environmentally claimed tall buildings” in Europe in adopting this basic strategy. It is in Germany, where natural ventilation in office spaces, including tall buildings, is most popular. Nevertheless, the guarantee of comfort of a system that offers steady environmental conditions still predominates even in the European context, such as in the UK. In addition to the Commerzbank Headquarters, natural ventilation appears in the design proposals for two iconic buildings in London (30 Saint Mary Axe and 22–24 Bishopsgate), but it is still not being widely embraced.
### Case Studies

<table>
<thead>
<tr>
<th>Case studies</th>
<th>Year of completion</th>
<th>Methodological considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Commerzbank HQ, Frankfurt</td>
<td>1998</td>
<td>The scoring attributed to the buildings is related to their role in city skyline as well as to morphological aspects of the urban area and public policies regarding the design of clusters of tall buildings.</td>
</tr>
<tr>
<td>2. 30 Saint Mary Axe, London</td>
<td>2004</td>
<td></td>
</tr>
<tr>
<td>3. 110 Bishopsgate, London</td>
<td>2011 (recently completed)</td>
<td></td>
</tr>
<tr>
<td>4. 122 Leadenhall Str., London</td>
<td></td>
<td></td>
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<tr>
<td>5. 22-24 Bishopsgate, London</td>
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</table>

#### 1. Urban context

1.1 Urban form and skyline

1.2 Infrastructure and mobility

1.3 Building’s function and local socio-economic structure

* The start mark was attributed for mixed-use developments including residential buildings and commercial areas in the site.

Most of the scoring attributed to the buildings is more related to the characteristics of the site and urban area/neighborhood than to the design of the building.

Figure 5. Comparative analysis of European case studies: environmental assessment criteria. Source: Gonçalves (2010). Picture 4 by Roger Stirk Harbour and Partners. Picture 5 by Cityscape Digital Ltd. All other photos by Joana Carla Soares Gonçalves.
<table>
<thead>
<tr>
<th>2. Ground conditions and environmental impact</th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>2.1 Solar access and daylight availability to the surrounding</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<tr>
<td>The assessment considered the identification of design measures against undesirable impacts.</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>2.2 Pollution dispersion</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>This topic of the assessment is only important is places of air pollution in the urban environment at the street level associated with the intensity of vehicles in the urban environment.</td>
<td></td>
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<tr>
<td>2.3 Quality of the public space and pedestrians' comfort</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>With regards to the issue of pedestrians' comfort, it is important to highlight that the local climatic conditions are fundamental to identify whether the impact of the tall building is likely to be positive or negative and, therefore, would need special attention.</td>
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</table>

<table>
<thead>
<tr>
<th>3. Well being</th>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Thermal comfort</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Assuming that thermal comfort is guaranteed through building systems, the assessment scored more than one mark to the designs that allow thermal comfort by means of natural ventilation.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3.2 Daylight and visual comfort</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>One mark was attributed to designs with at least one aspect in favour of better daylight related to the facades. In colder climates this means the use of clear glass, whilst in warmer climates it means glass with higher shading coefficients.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3.3 Views and social interaction x privacy</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>The cases that received that maximum scoring have a significant area dedicated to social interaction, composed with the working environments and associated with atriums and rich visual communication, in addition to areas in the ground floor, open to the general public.</td>
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</table>

Figure 5. (Continued)
| 3.4  | Acoustic comfort | 9 |   |   |   | The topic of acoustic comfort is usually and easily dealt with the design of the internal fittings of the working spaces, including the features of working stations. |
|---|---|---|---|---|---|
| 4.1 | Architectural features | √ | √ | √ | √ | √ | √ | One mark has been attributed to designs which the facade has been specified for better environmental performance. Two marks are related to additional changes in the conventional building form. Three marks represent a number of architectural features for the benefit of environmental performance and architectural expression. |
| 4. | Energy & environment | | | | | | |
| 4.2 | Adaptability for Future Changes | √ | O | O | O | O | Apart from the 1st case (from which more detailed info about the design and operational of the building was obtained), the topic of capability to adapt to future change was assessed based only on the number of tenants that each floor plate can take, which is insufficient to make the assessment. |
| 5. | Environmental identity | √ | √ | √ | √ | √ | This topic of the assessment is inextricably linked to the previous one which relates to the architectural expression and environmental identity of the design. |

Criteria for comparative assessment

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</thead>
<tbody>
<tr>
<td>✓</td>
<td>Positive scoring due to design measures. √ = good, √√ = very good, √√√ = excellent.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>○</td>
<td>Not enough information is available to the elaboration of the qualitative assessment.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>😞</td>
<td>Design aspects were identified so that the impact of the tall building was either not negative or ameliorated.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>😞</td>
<td>Not enough information is available to the elaboration of the qualitative assessment, however, given the local conditions, the impact of the tall building is unlikely to be negative.</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
With regards to the operation of buildings and the implications for energy performance, lessons learned from the Commerzbank Headquarters in Frankfurt have shown that, through occupants’ interaction and control over the environmental conditions of the internal spaces, energy consumption can be substantially reduced when compared with fully automated controls. In conclusion, the European case studies can inform and inspire more environmentally challenging buildings, but they must not be taken as universal solutions.

**Final considerations: the value of environmental design**

The design of buildings for the twenty-first century faces a series of challenges regarding environmental performance. The big challenge is to change the outdated universal model and that basic economic formula that generate artificially controlled environments in buildings. For multi-tenant tall buildings, it can be argued that the direct economic benefits of better environmental performance do not go to the initial investors and, for this reason, investment in more environmentally responsive buildings is not considered economically attractive.

Examples from around the world show that owner-occupied buildings are those where innovation is pushed further. Nevertheless, in the case of multi-tenant buildings, the energy savings in the operation of the buildings and the improved environmental quality (if, indeed this is of interest in addition to the reduced running

<table>
<thead>
<tr>
<th>Considerations about the qualitative assessment of the case studies (with reference to table 1):</th>
<th>5 – The third mark was not attributed to these buildings because there are still significant deep plan areas, pulling people away from the facades and, therefore, way from daylight and external views. 6 – The third mark was not attributed in this case because the atriums work for visual communication and daylight access (to a certain extent), but it is not a place for social interaction. 7 – A considerable area in the ground floor added to the first seven floors of the tall building is dedicated to activities which promote social interaction, being also open for the general public. The view galleries at the top of the tall building are another opportunity for social interaction of the building’s occupants. 8 – When the building is completed, the ground floor and the first floors are meant to be open to the general public, with public with a retail area and public amenities. In addition to that, two floors in the tall building are dedicated to social interaction of the occupants of the building. 9 – The cellular office layout has a potential for good acoustic environments, allowing for more privacy. The panels used for the chilled ceilings have also the properties of acoustic absorption. 10 – The tall building has gone through a change from a major cellular office layout to an open plan, with no proven major impact either on the natural ventilation strategy or on the building’s energy consumption.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – The tall building is located in the centre of the site, away from the pedestrians and street environment. 2 – The inclined facade provides wider sky-view factors from the lower levels of the surroundings, compared to the square building form. 3 – Given the condition of air pollution in these localities, it is likely that the air turbulence created by the tall building would impact in positive effects on pollution dispersion. 4 – The third mark was not attributed to the building because the facade of the atriums is clad by dark glass, reducing daylight penetration in the areas supposed to be source of daylight to the deeper parts of the floor plates.</td>
<td></td>
</tr>
</tbody>
</table>
costs), can be attractive to tenants, with benefits such as marketability as well as securing/future-proofing investments being of benefit to the investor; the latter is becoming an increasingly important and effective mechanism for changing attitudes.

The economic case for green buildings goes beyond energy savings, opening up the idea of asset value. The conventional or classic fiscal “cost vs. benefit” model to assess and value financial investments in green buildings is outdated and inappropriate. Understanding both the economic benefits (energy savings, reducing environmental damage, fund raising, enhancing competitiveness, maximizing asset value, etc.) and limiting exposure to risks (energy supply security, carbon exposure, tax exposure, etc.) are equally fundamental in the whole debate.

Historically, the arguments tabled to support the case for embracing environmentally considerate design have typically been on the grounds of either reducing possible damage to the environment or alternatively achieving operational cost savings associated with energy or water saved. Whilst these are valid arguments, cost savings have been insufficient to justify the required capital investment required; in general, energy is too cheap and often does not reflect its true economic cost/value. Both changes in the markets and legislative measures attributable to environmental pressures have the potential to foster a re-evaluation of costs and benefits associated with environmentally considerate design.

Unlike the classic argument, cost savings associated with energy savings as “bonuses” or “secondary savings” and focus more on substantial savings attributable to “adding value” on future investments is a stronger one. Some of the factors that ought to be considered, as they become relevant in future investments in the built environment include the potential exposure to future carbon taxation regimes relative to energy consumption and maintaining a competitive edge in a market where legislation typically tightens up the buildings environmental standards at about the same pace as it takes to realize such projects, so that by the time a buildings is completed and is marketed a whole set of new legislative conditions apply, thus demanding current projects to be designed beyond current minimum standards and attracting funding from various financial institutions who through more limited fiscal resources being available are now more cautious in their assessment of financial risk with preferential investments for “greener” projects. In the end, the whole debate shifts to one of risk management, asset protection and thereby enhancing asset value.

Whilst it is not possible to definitively predict the future impact of current and future market forces on the design and realization of green buildings, one particular aspect is certain and that is that issues that were once of medium- to long-term impact are now becoming short-term, given global environmental problems and associated concerns demanding rapid public and political action. In this context, it must be understood that buildings not only require longer periods of realization (typically between three and four years, depending on scale of development/project) but also cannot respond that quickly to rate of change in market forces, as other products are able to (such as cars, information technology, etc.), or keep up with changing lifestyles. This renders them more vulnerable and susceptible to such changes and as a consequence impacts their economic stability and value.

With both uncertain market trends, albeit certainty in increasing legislative and regulatory forces, and increasing speculative competition (through voluntary certification schemes) in the building sector, the decision to consider environmental quality and performance in the design of green buildings is a strategic one. Buildings need to go beyond governmental targets to be able to remain competitive, adding
value to environmentally considerate design of buildings. Even when positively considering the (long-term) economic advantages that may be “bought” by considering investment in green buildings, often counter-arguments are levied that such increased investments outweigh the positive returns. Where considerable figures apply, the design depends substantially on the application of technologies and systems introduced to compensate for the lack of passive design features or poor performing base building designs; realistic figures actually range from 0 to 3% (WBCSD 2009). In the light of the current environmental agenda for the design of buildings, the notion of qualitative indicators in addition to the quantitative assessment comes enriches the discussion about the real performance of buildings.

Acknowledgements

Many thanks to Dr Neil Campbell, from BDSP Partnership, for providing the data on energy benchmarks of buildings in the UK and Germany.

Notes

1. The definitions of areas applied in the formulation of the indicators presented in category 1 follow those commonly used in the UK (Marmot and Eley 2000), based on the work of the Royal Institute of Chartered Surveyors.

2. For the diagnosis of the local climate and the calculation of outdoor thermal comfort, it is recommended that the Physiologically Equivalent Temperature index to be used (Höppe 1999).

3. Primary energy is the energy source; it measures not just the energy efficiency of the building itself but also the energy systems supplying it, whether they are local or remote. For example, in the case of gas-fired boilers, the owner would pay directly for the primary energy consumed. However, for grid electricity in Germany, the measurement from the meter is typically multiplied by three to account for the average efficiency of the power stations. Benchmarks can be measured on different area bases. For offices, figures can be normalized on gross external area, net internal area or metered area (permanently heated or cooled spaces) (CIBSE 2008).

4. Considering the comparative assessment of buildings in different climatic contexts with regards to the energy consumption of cooling and heating systems, once the figures are broken down according to different functions and end-uses, a second level of analysis is required. One option is to apply the concept of “degree days”, which establishes a common denominator for the comparison and avoids the influence of climatic differences in the comparative analysis of building performance. However, degree-days include only air temperatures and not the influence of humidity and solar radiation, which will have a key impact on the energy performance of buildings. A degree day is a measure of energy, in terms of heating or cooling. It is computed as the integral of a function of time that varies with temperature (typically, each day's temperature profile is treated as a sine wave with amplitude equal to the day’s temperature variation, measured from maximum and minimum temperatures (Szokolay 2008).

References


