Sustainable Cities and Society 8 (2013) 72–78

Contents lists available at SciVerse ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs

Clarifying the new interpretations of the concept of sustainable building

Umberto Berardi*

Worcester Polytechnic Institute, CEE, 100 Institute Road, Worcester, 01609, United States

ARTICLE INFO

Keywords:
Sustainable development
Green building
Sustainable building

ABSTRACT

A review of definitions of sustainable building shows that the terminology needs clarification as many difficulties exist in identifying sustainability in the built environment. The study starts by examining the recent evolution of the concept of sustainable development. Latest interpretations of this terminology are considered, before analysing what sustainability means in the built environment. This paper focuses on constrains which prevent a simple definition and identification of what is a sustainable building. Systems for sustainability assessments are often insufficient to recognize sustainability of buildings given the strong environmental and technological approach of these systems. In particular, the dependence of the concept of sustainability on time, scale, domain and social uncertainties is discussed. Some requirements for a better definition of a sustainable building are indicated. This paper shows that a greater attention should be given to social and economic aspects. The importance of the cross-scale relationships between a building and its surroundings, together with the ever changing flows between them, limits the possibility to define the sustainability at the level of single building, and it encourages looking at larger and crossing scales. Finally, this paper shows that a building is sustainable if it contributes to the sustainability through its metabolism and by doing this it favours a regenerative resilience of the built environment among all the domains of sustainability.

1. Introduction

This paper was born from the difficulty defining sustainability in the built environment and hence, identifying sustainable buildings. Despite the absence of a largely shared definition, the use of the terminology "sustainable building" is rapidly increasing. In the literature, few definitions of sustainable building have been proposed, meanwhile, journals and books use this term daily. Unfortunately, the available definitions seem incomplete and often prove to be useless because they are unclear and biased (Cole, 2004; Fowke & Prasad, 1996). This paper discusses sustainability across the built environment in order to help clarify the new interpretations of the concept of sustainable building.

A good starting point for this study is the concept of sustainable development. Although it is an often abused term and many definitions have been given of it in the last three decades, it is not difficult to recognize that the concept of sustainable development needs clarification (Basiago, 1995; Martens, 2006). This paper briefly recalls the ongoing discussion about the practical and new meanings of sustainable development. Several papers have recently discussed what is sustainable (Martens, 2006), what sustainable development means (Hueting & Reijnders, 2004) and how it can be operationalized and identified (Hopwood, Mellor, & O'Brien, 2005). Through this paper, the author hopes to bring the ongoing debate about sustainable development into the building sector in order to help to reconceptualise what a sustainable building is.

The building sector is receiving increasing attention in worldwide policies for sustainable development (UNEP-SBCI, 2009). This attention to the building sector arises from its energy consumption and GHG emissions which, in developed countries, represent 30 and 40% of the total quantities respectively (IPCC, 2007; UNEP-SBCI, 2009). Eurostat (2011) has recently shown that the consumption in the household sector is larger than the consumption in the transport or industrial sector. Moreover, the data of the Energy Information Administration show that the energy consumption and GHG emissions in buildings are increasing at a higher rate than in the other sectors (Akashi & Hanaoka, 2012; EIA, 2012). According to the IPCC (2007), GHG emissions from buildings may increase up to 15.6 $GtCO_2$-eq/y in 2030, whereas the building sector alone could save almost 6 Gt CO_2-eq/y. The increasing relevance of the building sector in undeveloped and developing countries justifies greater attention towards sustainable buildings too. In fact, in these countries, the building sector is showing high growth rates: as a matter of fact, by 2015 more than half of the building stock of China will have been constructed during the previous 15 years (UNEP, 2003).

The previous data demonstrate the importance that sustainable buildings could have for sustainable development (Sev, 2009), and

* Tel.: +1 508 831 6545; fax: +1 508 831 6545.
E-mail address: uberardi@wpi.edu

2210-6707/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scs.2013.01.008

hence, they justify the necessity for ways to identify sustainable buildings (Parr & Zaretsky, 2010).

This paper is structured in six sections: Section 2 reviews recent interpretations of the concept of sustainable development, Section 3 discusses the role that sustainable buildings can have in the context of sustainable development, whereas Section 4 discusses the factors of uncertainty for the defining of a sustainable building. Section 5 proposes identifiable characteristics for a sustainable building and, finally, Section 6 summarizes the findings of this work.

2. Recent interpretations of sustainable development

Sustainable development is not a single and well defined concept worldwide. At least one hundred definitions have been given (Hopwood et al., 2005). New meanings are continually added to this term, clouding its concept in a way that every time a definition has been formulated, it has always been incomplete as some of the possible meanings of sustainable development were left out (Robinson, 2004).

The concept of sustainable development goes back to the 1970s. Its theoretical framework evolved after the publication "The Limits to Growth" by the Club of Rome (Meadows, Randers, & Meadows, 1972). The UN Conference on the Human Environment, in the same year, was the first major international gathering to discuss sustainability on a global scale. It created considerable momentum and a series of recommendations which later led to the establishment of the United Nations Environment Programme (UNEP). A few years later, the UNEP Symposium discussed the meaning of sustainable development and stressed the importance of considering future generations and long term perspective (Cocoyoc Declaration, 1974). However, the most famous definition was given in 1987 by the Brundtland Commission (WCED, 1987) which stated that "sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs". Although the Brundtland definition of sustainability has received many different interpretations, especially in recent years (Basiago, 1995; Steurer & Hametner, in press; Yanarella & Bartilow, 2000), a resistance to determining an "official" definition has emerged (Fowke & Prasad, 1996; Martens, 2006). Paradoxically, sustainability and sustainable development have also been recognized to suffer from definitional ambiguity by the United Nations, but the diversity of definitions has often been represented as a point of strength of these concepts (IPCC, 2007).

Looking at the common denominator of the definitions of sustainable development, Grosskurth and Rotmans (2005) identified some peculiarities and uncertainties: it is time dependent, it includes several levels of space (and scale), multiple dimensions and it has social dependencies.

The time dependence, already presented in the intergenerational approach of the Brundtland definition, requires us to consider a long term perspective. This raises the question of how far into the future. In fact, the farther in time we go, the more uncertainty emerges (Kemp & Martens, 2007). Bagheri and Hjorth (2007) suggest adopting a dynamic approach which considers transformable processes towards sustainability as it cannot be a fixed goal, but it evolves continually. In this sense, sustainability requires an adaptive flexibility according to the available knowledge at any given time (Kemp, Parto, & Gibson, 2005; Walker & Salt, 2006).

The second aspect of the concept of sustainability regards spatial dependence. Brand and Karvonen (2007) argue that sustainability is locally specific, and more a matter of local interpretation than a universal goal. The local perspective opens the discussion about the possible boundaries of the system which has to be sustainable, because the interconnections of systems, people and markets counteract a local approach. In fact it is evident that the impact of every action spans from a local scale up to a global one, so that sustainability requires continuous evaluation at several scale levels (Daly, 1996).

The third aspect of sustainability regards the domains in which it can be divided. The concept of sustainability has been categorized in the environmental, social and economic dimensions (WCED, 1987). However, increasing pressure towards an explicit recognition of the cultural and political dimensions has recently been recorded (Hopwood et al., 2005; Vallance, Perkins, & Dixon, 2011). Despite the practical scope, the conceptualization in different dimensions has fragmented the concept of sustainability leading to several misunderstandings (Williams & Millington, 2004; Yanarella & Bartilow, 2000). This division has also been criticized because sustainability has often been considered and evaluated exclusively according to the environmental dimension (Hueting & Reijnders, 2004), leaving out several aspects of sustainability (Hugé, Waas, Dahdouh-Guebas, Koedam, & Block, 2012). In fact, the eco-centred approach has been criticized for being elitist and insufficiently democratic. Roe (1998) condemned it as a version of managerialism that perpetuates a technocratic control which is antisocial because it tries to consider sustainable development as a scientific blueprint the contents of which can be determined by environmental scientists alone. On the contrary, what sustainable development means is more often a decision between several possibilities which also involves non-environmental aspects (Hajer, 1995; van Zeijl-Rozema, Cörvers, Kemp, & Martens, 2008). The 2002 World Summit on Sustainable Development in Johannesburg gave a shift in the perception of sustainable development towards a more comprehensive consideration of social and economic dimensions of development. This change was driven by the emerging needs of the developing countries and was strongly influenced by the discussion to reach the Millennium Development Goals. However, a too optimistic view has recently interpreted economic growth as a possible solution to sustainability goals being confident that innovations and technologies will be able to generate a more sustainable world (Hopwood et al., 2005). The limits of this approach have recently increased the attention towards the social sustainability (Vallance et al., 2011). Finally, Martens (2006) refused the division into domains affirming that sustainable development lies precisely in the interrelations between dimensions.

The fourth peculiarity of sustainability regards the multiple interpretations of the concept by different people. In fact, the necessity of considering different points of view requires acceptance of uncertainty and differences. Sustainable development has shown the need for a pluralistic approach which has to take into account multiple actors. This is the only way to create a common vision of sustainable development, minimizing trade-offs and the different perceptions of the stakeholders. According to this, many governments have recently started measuring sustainability mainly through the quality of life and the well-being of citizens (DEFRA, 2011). McCool and Stankey (2004) stress that sustainability is socially related, and any definition needs to be cultural. In this sense, the participation of the people and their different expectations and interpretations of sustainable development are unavoidable (Albino & Berardi, 2012).

As evident from previous discussions, many definitions of sustainability are possible. In the past, it was considered an objective and clear concept based on scientific evidence and consensus, whereas recently, it has more often been reinterpreted as relative, socially rooted and contextually dependent (Martens, 2006; Yanarella & Bartilow, 2000). The process of revision of the meaning of sustainability has recently led to systemize the concept of sustainability science (Kates et al., 2001), to overcome the Galilean and technocratic view of the world and to accept

uncertain and participative processes of interpretations (Kemp & Martens, 2007; Miller, 2012).

Given the ambiguity and uncertainty, the concept of sustainability is continually revised (Buter & Van Raan, 2012). For example, a worldwide discussion is currently underway to reconnect the different dimensions in a more balanced perspective (Martens, 2006). Together with this an ongoing discussion is focusing on the several levels of sustainability. On the basis of the pioneer work of the economist Herman Daly (1996), Williams and Millington (2004) have distinguished strong and weak sustainability. Strong sustainability moves from the belief that it is not possible to accept an exchange between environment and economy. Following this discussion, Kemp (2010) stated that the sustainable attribute may not be related to technology and cannot be used as a label for an object. In fact, an object cannot be evaluated independently from the ideation and production processes, the way and intensity of its use and the dismantling policies. Finally, the recent interpretations of the concept have shown that sustainability is better used as a relative point of view for evaluations in a long term path than as a fixed and rigid status which is considered in a categorical way. In the next section, the possible contextualization of the recent interpretations of sustainability in the building sector are discussed.

3. Contextualizing sustainability in sustainable buildings

Difficulties have always existed in defining sustainable building. Measurement tools have recently been offered by sustainability assessment systems which, although several differences, share a common framework of what is a sustainable building (Berardi, 2012; Cole, 2012). Through the years, these systems have contributed to increase the awareness about criteria and objectives of sustainability, and they have become a framework of reference to assess the sustainability of buildings. According to these systems a building is sustainable if it is built in an ecologically oriented way which reduces its impact over the environment. However, many limits have recently showed in these systems (Berardi, 2011): their evaluation is limited to the physical boundaries of the building, and it is mainly (or only) interpreted from the environmental perspective (ISO 15392, 2008). Consequently, sustainability assessment methods have been accused of reduction the sustainability of a building to the functioning of individual environmental criteria reflecting an idea of a building as a consumer of resources (Conte & Monno, 2012).

To understand the limits of this approach it is useful to trace how sustainability has been defined in the building sector. Hill and Bown (1997) discussed the environmental principles in sustainable buildings. According to these, a building is sustainable if it represents a healthy built environment, based on ecological principles and resource efficiency (Kibert, 1994). By breaking down this definition, a sustainable building has to have high efficiency in the use of energy, water and materials, and reduced impacts on the health and the environment throughout its life-cycle (Cassidy, 2003; EPA, 2008). In this line, reduced energy consumptions and GHG emissions have often been considered the parameters to assess sustainable buildings (Lowe, 2007).

This brief review shows that a high attention to the environmental impacts of buildings has generally been considered. However, this approach had already emerged before and independently from the concept of sustainable development. In fact, the attention to environmentally responsible building started in the middle of the last century when several communities, driven by the ambition of an ecological world, advocated green buildings (Kibert, 2012). Green buildings were required to be disconnected from the service grids and made of natural materials. A few years later, the energy crisis which followed the embargo by OPEC led to the promotion of regulations to limit the energy consumption of buildings (Berardi, in press). As a result, energy consumption became a *de facto* measurement for the sustainability of a building. Still now, energy performance is the most used parameter to assess the sustainability of a building (Berardi, 2012; Cole, 2004). In fact, sustainable buildings are often confused with energy efficient buildings, as it is shown by the interchangeable use of the terms sustainable building, green building and high performance building in the U.S. (EPA, 2008).

Table 1 contrasts the major issues of green and sustainable buildings, by adapting information provided in UNEP (2003). In summary, the main differences consist of the economic and social requirements of the sustainability, applicable to sustainable buildings. This means that sustainable buildings at least enlarge the requirements and dimensions of sustainability.

Until a few years ago, the sustainability of buildings only looked at the operational life of buildings and at the genesis of building materials. However, given that 70% of all the materials ever extracted are in the built environment (Kibert, 2007), the awareness that sustainability of buildings has to consider the materials in a long term perspective is increasing. In this sense, cradle-to-cradle and end-of-life approaches have increasingly been adopted for sustainability evaluations (McDonough & Braungart, 2002).

Considering the request for long-term evaluations, multi-scale impacts, and multi-domain criteria, a new paradigm of sustainable buildings is emerging. According to this, a building together with being designed and operated to match the appropriate fitness for use with minimum environmental impact, must contribute to encourage improvements towards a strong sustainability (Berardi, 2011). This represents a significant evolution from the simple environmental approach.

Reed (2007) has described the necessity to consider and design building materials as biological nutrients which provide nourishment after use and circulate through the world's systems in closed-loop cycles of production, recovery and re-manufacture. Reed also proposed shifting from green design towards a regenerative design which considers the evolution of the building within nature in a systemic way. The regenerative design requires the integration of material and functional attributes in an integrative perspective where systemic thinking and a reconciled partnership with nature have to replace the technocratic approach to sustainability in the built environment (Cole, 2012; du Plessis & Cole, 2011). This concept of a sustainable building exceeds the environmental perspective and looks at the building as a live system with dynamic flows with nature (Reed, 2007). This means that the building cannot be considered as a simple consumer of resources of the planet. Consequently, a sustainable building should be an active entity which is designed to help a metabolism of human beings that regenerates the built environment within the natural capital.

4. Factors of uncertainty in defining sustainable buildings

In this section, a few factors of uncertainty concerning the definition of a sustainable building are discussed. In particular, the section looks at the uncertainty of the concept of sustainable building in relation to time, site, domain and people-related factors.

4.1. Time uncertainty

The evaluation of sustainability is always carried out with one time horizon and at one time. In Section 3 it was shown that sustainability of buildings requires consideration of the whole life-cycle. This is difficult to predict because buildings can exist much longer than expected (du Plessis & Cole, 2011). Regarding the time interval within which the evaluation of sustainability is done, it

Table 1
Major issues in green and sustainable buildings, adapted from UNEP (2003).

Major issues of the building performances	Green building	Sustainable building
Consumption of non-renewable resources	x	x
Water consumption	x	x
Materials consumption	x	x
Land use	x	x
Impacts on site ecology	x	x
Urban and planning issues	(x)	x
Greenhouse gas emissions	x	x
Solid waste and liquid effluents	x	x
Indoor well-being: air quality, lighting, acoustics	(x)	x
Longevity, adaptability, flexibility		x
Operations and maintenance		x
Facilities management		x
Social issues (access, education, inclusion, cohesion)		x
Economic considerations		x
Cultural perception and inspiration		x

should be recognized that sustainability is a time dependent concept which depends on the knowledge available at the time of the evaluation. Consequently, what is considered sustainable at one moment can be assesses as unsustainable in another.

Considering the several adaptations which can occur to a building during its life cycle, paradigms such as flexibility and adaptability have recently emerged as fundamental aspects for a sustainable building that needs to easily accommodate new requirements (Parr & Zaretsky, 2010). Sustainability of buildings requires considering requirements and functions dynamically. Buildings are ever-changing and are characterized by continuous adaptations according to unpredictable patterns so that a sustainable building must be able to accommodate different changes. This recalls the contribution of sustainable buildings to the resilience of the built environment (Cole, 2012). The resilience was defined as the ability to resist to changes brought by external and internal impacts (Walker & Salt, 2006). This concept is receiving an increasing attention for sustainability because it considers the long term capacity to sustain changes (Edwards, 2010). A sustainable building should hence increase the resilience of the built environment by adapting to the metabolism of its context.

4.2. Scale uncertainty

The dependence of sustainability on the built environment from the spatial scale of evaluation has often been considered in tools for sustainability assessments (Berardi, 2012). Regional adaptations of the requirements of sustainable building have been proposed to consider the connections of a building within its neighbourhood and community, although often in an insufficient way (Kibert, 2007). In fact, although a general framework for sustainable buildings can be drawn at a regional level, the interaction of a building with its environment makes the sustainable attribute specifically related to each building. This means that a sustainable building is difficult to be defined in absolute terms. In a certain way, this relates to the idea that the sustainable attribute cannot be applied to a technology (Kemp, 2010). In fact, if an ecological product is promoted far from its production site, it becomes unsustainable in the same way as it would be difficult to consider a highly efficient skyscraper built in the desert as sustainable.

The importance of the interaction of the building with its surrounding environment has also increasingly been recognized in sustainability assessment systems at the scale of neighbourhoods (Berardi, in press). In fact, the interconnections of a building with the surrounding infrastructure (public transportation, workplace, public buildings) are more and more recognized as unavoidable aspects of a sustainable building (Berardi, 2011). The previous discussions have shown the limits of evaluating sustainability at a building level and they ask for cross-scales evaluations which have to exceed the boundaries of the building (Berardi, 2011; Conte & Monno, 2012). In fact, the spatial dependence of sustainability makes uncertain which is the most appropriate scale in sustainability evaluations and the boundaries of the inter-connections between a building and its surroundings should be adapted case by case.

4.3. Domain uncertainty

The importance of considering all the dimensions of sustainability is increasingly emerging with the diffusion of sustainable building policies in less developed and developing countries. The inevitability of considering the different meanings of the economic and social dimensions in different countries increases the uncertainty of the sustainable label (UNEP-SBCI, 2009).

A way to highlight the domain uncertainty of sustainable building is the identification of an economically sustainable building. The economic domain implies the affordability to support the direct and indirect costs of the building, without neglecting other essential needs (Son, Kim, Chong, & Chou, 2011). This requisite depends on the context and people and also recalls the time uncertainty of economic sustainability. In fact, a change in what is an economically sustainable choice in buildings is possible according to economic cycles.

Finally, recalling the critics to the division of sustainability into domains (Martens, 2006), also for the identification of sustainable building is more and more necessary to consider all the domains and the interrelations between dimensions.

4.4. Social uncertainty

The most ignored dimension of the concept of sustainability is the social one. People perceive a building, its impact and effects in different ways. This is a constraint on the spread of sustainable buildings given the difficulty of establishing common sustainable requirements between people (Dempsey, Bramley, Power, & Brown, 2011). The differences between stakeholders imply different points of view in sustainability priorities, and consequently, they make the identification and the characteristics of a sustainable building dependent on the point of view (du Plessis & Cole, 2011; Parr & Zaretsky, 2010).

Numerous attempts at defining the social aspects of a building have generally considered concepts as quality of life or sustainable livelihood (Dempsey et al., 2011; Vallance et al., 2011). These attempts have increased the uncertainty of social sustainability.

The importance for a building to contribute in creating a sense of community is surely an important requirement of sustainable building. However, the practical meaning and the forms to prove these aspects remain uncertain. As discussed previously, the relativity of the concept of sustainability gives a social character to the meaning of sustainable. From this emerges that the social dependence of sustainability in the building sector could be addressed through a participative process in which different stakeholders express and contribute with their idea of sustainability (Moffat & Kohler, 2008). This requires a social context with knowledge sharing between individuals, where sustainability emerges through participative decisions (Bagheri & Hjorth, 2007).

5. The identification of a sustainable building

The discussion in Section 3 has shown that a sustainable building is a broad concept. Section 4 then looked at a few aspects which make it an uncertain and relative term. This section tries to clarify the concept of sustainable building.

Af Kemp (2010) stated a sustainable technology does not exist, a doubt about the application of the attribute to a building makes sense. The dependence on scale has shown the importance of enlarging the spatial boundaries in the evaluation of sustainability in order to consider the connections between a building and its surrounding site. Consequently, the community can often represent a better unit of analysis for a complete evaluation of sustainability. In fact, it allows better evaluations of the cross-scale effects of sustainability. Moreover, many requirements of a sustainable building, as its social dimension may require a larger scale of evaluation.

The social aspects of a sustainable building are still rarely investigated topic. As a point of reference, it is possible to affirm that a building which encourages social sustainability should (Chiu, 2002; Dempsey et al., 2011; Parr & Zaretsky, 2010):

- adhere to ethical standards by ethical trading throughout the supply chain and by providing safe and healthy work environments;
- provide place that meets needs with a mix of tenure types and ensure flexibility wherever possible;
- conserve local heritage and culture;
- integrate the building in the local context also guaranteeing access to local infrastructure and services.

Returning to the distinction between green and sustainable buildings, it is possible to agree that if an environmentally friendly building can be realized almost everywhere by minimizing its environmental impact, a sustainable building asks for more. The sense of a community becomes fundamental for a sustainable building. A sustainable building should increase social equity, cultural and heritage issues, traditions, human health, and social infrastructure, as well as safe and healthy environments. A sustainable building has to consider the impact of the building on the physical and mental health of the occupiers too. For example, psychological and social functions of a residential building shift the meaning of the building from that of a physical living place to that of a home: this encourages considering the social network of community that a sustainable building must contribute to create. Strategies and objectives for addressing sustainability in the built environment must hence be locally valid.

CIB has recently reinterpreted the visions of sustainable buildings which was originally adopted after the First International Conference on Sustainable Construction (Kibert, 1994). According to this new interpretation (CIB, 2010), ten new principles for a sustainable building have been declared (Table 2). The convergence between these new principles and other recent requirements for sustainable building, such as the principles reported in the Sustainable by Design Declaration of the International Union of Architects (UIA, 2009) suggests that a new common vision of sustainable building is emerging.

Table 2
Principles of the Conseil International du Bâtiment for sustainable building (CIB, 2010).

Principles for sustainable building
1. Apply the general principles of sustainability, and hence, promote continual improvement, equity, global thinking and local action, a holistic approach, long-term consideration of precaution and risk, responsibility, and transparency.
2. Involve all interested parties through a collaborative approach, so that it can meet occupants' needs individually and collectively, and be respectful of and consistent with collective social needs through partnership in design, construction, and maintenance processes.
3. Be completely integrated into the relevant local plans and infrastructure, and connect into the existing services, networks, urban and suburban grids, in order to improve stakeholder satisfaction.
4. Be designed from a life-cycle perspective, covering planning, design, construction, operation and maintenance, renovation and end of life, considering all other phases during the evaluation of performance at each phase.
5. Have its environmental impact minimized over the (estimated or remaining) service life. This takes into consideration regional and global requirements, resource efficiency together with waste and emissions reduction.
6. Deliver economic value over time, taking into account future life-cycle costs of operation, maintenance, refurbishment and disposal.
7. Provide social and cultural value over time and for all the people. A sustainable building must provide a sense of place for its occupants, be seen as a means of work status improvement for the workers, and should be related and integrated into the local culture.
8. Be healthy, comfortable, safe and accessible for all. Health criteria include indoor air quality whereas comfort criteria include acoustic, thermal, visual and olfactory comfort. It must allow safe working conditions during its construction and service life, and full accessibility to everyone in the use of building facilities.
9. Be user-friendly, simple and cost effective in operation, with measurable performances over time. Operation and maintenance rules must be available for both operators and occupants at any time. People should understand the philosophy and the strategies included in the building and should be incentivized to behave sustainably.
10. Be adaptable throughout the service life and with an end-of-life strategy. The building has to allow adaptation by changing performance and functionality requirements, in accordance with new constraints.

Summarizing these recent interpretations, a sustainable building can be defined as a healthy facility designed and built in a cradle-to-grave resource-efficient manner, using ecological principles, social equity, and life-cycle quality value, and which promotes a sense of sustainable community. According to this, a sustainable building should increase:

- demand for safe building, flexibility, market and economic value;
- neutralization of environmental impacts by including its context and its regeneration;
- human well being, occupants' satisfaction and stakeholders' rights;
- social equity, aesthetics improvements, and preservation of cultural values.

6. Conclusions

This paper has discussed factors of uncertainty and new interpretations in identifying a sustainable building. The evolution of the concept of sustainable development suggested that a reflection on the term sustainable building is necessary. The paper has reviewed the most recent interpretations of the concept of sustainable development and has tried to show how these can influence the identification of a sustainable building. Later, the paper has

indicated a few requirements for the identification of a sustainable building. In particular, the importance of considering a sustainable building as a path characterized by constraints and uncertainties has shown that an agreed definition of sustainable building is difficult because time, space, domains and social constrains increase the uncertainties in identifying sustainability in the built environment. These factors show that sustainability implies a consistent rate of uncertainty and suggest that it is more a transition path than the label given to a building.

However, the paper has shown that a greater importance has to be given to the social and economic context of a building. The importance of considering the relationships between the building and neighbourhood encourages cross-scale evaluations of sustainability. Finally, the paper has established that a sustainable building has to promote in a long term perspective its economic value, a neutral environmental impact, human satisfaction and social equity.

Future research should show through real case studies how sustainable buildings are promoted, realized and managed. This will help clarifying the criteria which buildings have to meet to be defined as sustainable.

References

Akashi, O., & Hanaoka, T. (2012). Technological feasibility and costs of achieving a 50% reduction of global GHG emissions by 2050: Mid- and long-term perspectives. *Sustainability Science*, *7*(2), 139–156.

Albino, V., & Berardi, U. (2012). Green buildings and organizational changes in Italian case studies. *Business Strategy and the Environment*, *21*(6), 387–400.

Bagheri, A., & Hjorth, P. (2007). Planning for sustainable development: A paradigm shift towards a process-based approach sustainable development. *Sustainable Development*, *15*(2), 83–96.

Basiago, A. D. (1995). Methods of defining 'sustainability'. *Sustainable Development*, *3*(3), 155–162.

Berardi, U. (2011). Beyond sustainability assessment systems: Upgrading topics by upscaling the assessment. *International Journal of Sustainable Building Technology and Urban Development*, *2*(4), 276–282.

Berardi, U. (2012). Sustainability assessment in the construction sector: Rating systems and rated buildings. *Sustainable Development*, *20*(6), 411–424.

Berardi, U. Sustainability assessment of urban communities through rating systems. *Civil Engineering and Environmental Systems*, in press.

Brand, R., & Karvonen, A. (2007). The ecosystem of expertise: Complementary knowledges for sustainable development. *Sustainability: Science, Practice, & Policy*, *3*(1), 21–31.

Buter, R. K., & Van Raan, A. F. J. (2012). Identification and analysis of the highly cited knowledge base of sustainability science. *Sustainability Science*, http://dx.doi.org/10.1007/s11625-012-0185-1

Cassidy, R. (2003). *White paper on sustainability. Building design & construction* (p. 11). Reed Business Information. Available at: http://www.usgbc.org/Docs/Resources/BDCWhitePaperR2.pdf

Chiu, R. (2002). Social equity in housing in the Hong Kong special administrative region: A social sustainability perspective. *Sustainable Development*, *10*(3), 155–162.

CIB, Conseil International du Bâtiment. (2010). *Towards sustainable and smart-eco buildings*. Summary report on the EU-funded project smart-ECO buildings in the EU. Rotterdam: CIB.

Cocoyoc Declaration. (1974). UNEP/United Nations Conference on Trade and Development (UNCTAD) symposium in Cocoyoc, published in Development Dialogue, No. 2. Dag Hammarskjöld Foundation, Uppsala.

Cole, R. J. (2004). Changing context for environmental knowledge. *Building Research & Information*, *32*(2), 91–109.

Cole, R. J. (2012). Regenerative design and development: Current theory and practice. *Building Research & Information*, *40*(1), 1–6.

Conte, E., & Monno, V. (2012). Beyond the *buildingcentric* approach: A vision for an integrated evaluation of sustainable buildings. *Environmental Impact Assessment Review*, *34*(4), 31–40.

Daly, H. E. (1996). *Beyond growth: The economics of sustainable development*. Boston: Beacon Press.

DEFRA, Department for Environment, Food and Rural Affairs. (2011). *Mainstreaming sustainable development – The Government's vision and what this means in practice*. Available at: http://sd.defra.gov.uk/documents/mainstreaming-sustainable-development.pdf

Dempsey, N., Bramley, G., Power, S., & Brown, C. (2011). The social dimension of sustainable development: Defining urban social sustainability. *Sustainable Development*, *19*(5), 289–300.

du Plessis, C., & Cole, R. J. (2011). Motivating change: Shifting the paradigm. *Building Research & Information*, *39*(5), 436–449.

Edwards, A. R. (2010). *Thriving beyond sustainability: Pathways to a resilient society*. Gabriola Island: New Society Publishers.

Energy Information Administration. (2012). *Annual energy outlook 2012*. U.S. Energy Information Administration. Available at:. http://www.eia.gov/forecasts/aeo/

EPA, Environmental Protection Agency. (2008). *Green Building Strategy – Defines green building and explains EPA's strategic role in facilitating the mainstream adoption of effective green building practices*. Available at: www.epa.gov/greenbuilding/pubs/greenbuilding_strategy_nov08.pdf

Eurostat. (2011). *Energy consumption by sector in European countries*. Available at: http://epp.eurostat.ec.europa.eu/

Fowke, R., & Prasad, D. (1996). Sustainable development, cities and local government: Dilemmas and definitions. *Australian Planner*, *33*(2), 61–66.

Grosskurth, J., & Rotmans, J. (2005). The scene model: Getting a grip on sustainable development in policy making. *Environment, Development and Sustainability*, *7*(1), 135–151.

Hajer, M. (1995). Politics on the move: The democratic control of the design of sustainable technologies. *Knowledge and Policy*, *8*(4), 26–29.

Hill, R., & Bown, P. (1997). Sustainable construction: Principles and a framework. *Construction Management and Economics*, *15*(3), 223–239.

Hopwood, B., Mellor, M., & O'Brien, G. (2005). Sustainable development: Mapping different approaches. *Sustainable Development*, *13*(1), 38–52.

Hueting, R., & Reijnders, L. (2004). Broad sustainability contra sustainability: The proper construction of sustainability indicators. *Ecological Economics*, *50*(3–4), 249–260.

Hugé, J., Waas, T., Dahdouh-Guebas, F., Koedam, N., & Block, T. (2012). A discourse-analytical perspective on sustainability assessment: Interpreting sustainable development in practice. *Sustainability Science*, http://dx.doi.org/10.1007/s11625-012-0184-2

IPCC, Intergovernmental Panel on Climate Change. (2007). *Summary for policymakers, climate change, IPCC WG1 fourth assessment report*. New York: Cambridge University Press.

ISO 15392 (2008). Sustainability in building construction – General principles.

Kates, R., Clark, W., Corell, R., Hall, J., Jaeger, C., Lowe, I., et al. (2001). Sustainability science. *Science*, *292*(5517), 641–642.

Kemp, R. (2010). Sustainable technologies do not exist!. *Ekonomiaz*, *75*(3), 2–17.

Kemp, R., & Martens, P. (2007). Sustainable development: How to manage something that is subjective and never can be achieved? *Sustainability: Science, Practice, & Policy*, *3*(2), 5–14.

Kemp, R., Parto, S., & Gibson, R. B. (2005). Governance for sustainable development: Moving from theory to practice. *International Journal of Sustainable Development*, *8*(1–2), 12–30.

Kibert, C. J. (1994). Principles of sustainable construction. In *Proc. of the first international conference on sustainable construction* Tampa, FL, USA, (pp. 1–9).

Kibert, C. J. (2007). The next generation of sustainable construction. *Building Research & Information*, *35*(6), 595–601.

Kibert, C. J. (2012). Sustainable construction: green building design and delivery. *Hoboken: Wiley*,

Lowe, R. (2007). Addressing the challenges of climate change for the built environment. *Building Research & Information*, *35*(4), 343–350.

Martens, P. (2006). Sustainability: Science or fiction? *Sustainability: Science, Practice, & Policy*, *2*(1), 36–41.

McCool, S. F., & Stankey, G. H. (2004). Indicators of sustainability: Challenges and opportunities at the interface of science and policy. *Environmental Management*, *33*(3), 294–305.

McDonough, W., & Braungart, M. (2002). *Cradle to cradle*. New York: North Point.

Meadows, D. J., Randers, J., & Meadows, D. L. (1972). *Limits to growth*. New York: Universe Books.

Miller, T. (2012). Constructing sustainability science: Emerging perspectives and research trajectories. *Sustainability Science*, http://dx.doi.org/10.1007/s11625-012-0180-6

Moffat, S., & Kohler, N. (2008). Conceptualizing the built environment as a social–ecological system. *Building Research & Information*, *36*(3), 248–268.

Parr, A., & Zaretsky, M. (2010). *New directions in sustainable design*. London: Taylor & Francis.

Reed, B. (2007). Shifting from 'sustainability' to regeneration. *Building Research & Information*, *35*(6), 674–680.

Robinson, J. (2004). Squaring the circle: On the very idea of sustainable development. *Ecological Economics*, *48*(4), 369–384.

Roe, E. (1998). *Taking complexity seriously. Policy analysis, triangulation, and sustainable development*. Boston: Kluwer Academic.

Sev, A. (2009). How can the construction industry contribute to sustainable development? A conceptual framework. *Sustainable Development*, *173*(3), 161–173.

Son, H., Kim, C., Chong, W. K., & Chou, J. S. (2011). Implementing sustainable development in the construction industry: Constructors' perspectives in the US and Korea. *Sustainable Development*, *19*(5), 337–347.

Steurer, R., & Hametner, M. Objectives and indicators in sustainable development strategies: Similarities and variances across Europe. *Sustainable Development*, http://dx.doi.org/10.1002/sd.501, in press.

UIA. (2009). *Sustainable by design declaration*. Available at: http://www.uia-architectes.org/cop15_en.html

UNEP, United Nations Environment Programme. (2003). *Sustainable building and construction: Facts and figures*. Industry and Environment. (p. 5)

UNEP-SBCI, United Nations Environment Programme - Sustainable Buildings & Climate Initiative. (2009). *Buildings and climate change: A summary for decision-makers*. Paris: UNEP DTIE Sustainable Consumption & Production Branch.

Vallance, S., Perkins, H. C., & Dixon, J. E. (2011). What is social sustainability? A clarification of concepts. *Geoforum*, *42*(3), 342–348.

van Zeijl-Rozema, A., Cörvers, R., Kemp, R., & Martens, P. (2008). Governance for sustainable development: A framework sustainable development. *Sustainable Development*, *16*(6), 410–421.
Walker, B. H., & Salt, D. (2006). *Resilience thinking. Sustaining ecosystems and people in a changing world*. Washington: Island Press.
WCED, World Commission on Environment and Development. (1987). *Our common future*. New York: Oxford University Press.
Williams, C. C., & Millington, A. C. (2004). The diverse and contested meanings of sustainable development. *The Geographical Journal*, *170*(6), 99–104.
Yanarella, E., & Bartilow, H. (2000). Dreams of sustainability: Beyond the antinomies of the global sustainability debate. *International Journal of Sustainable Development*, *3*(4), 370–389.