

International Journal of Sustainable Construction

ISSN: 1647-0621
eISSN: 2182-2743

Volume 1
Number 1 - 2012



Editor-in-Chief
Rogério Amoêda

IJ Sustainable
Construction

green
lines
institute
for sustainable development

<http://www.ijsc.greenlines-institute.org>

ijsc@greenlines-institute.org

The International Journal of Sustainable Construction is owned and published by Green Lines Institute for Sustainable Development, a Portuguese NGO devoted to research and education.

IJSC is a non-political and non-religious scientific Journal, independent and dedicated solely to academic work and scientific research.

IJSC aims at publishing original scientific contributes in the field of sustainable construction and built environment.

IJSC core and innovative subject is the thematic of building sustainability beyond environmental issues, thus bridging also with cultural, social and economic aspects of sustainable development.

The conceptual basis upon which this Journal stands is precisely that sustainability in building construction is a result of relationships between a complex set of variables, the analysis of which requires complementary approaches.

Within this focus, IJSC seeks for original contributions from academics, scholars and researchers who pursue a broad perspective on the subject, placing buildings and sustainability at the core of their research.

All research articles in the Journal will undergo peer review, based on initial Editor's screening and anonymous refereeing by two members of the Editorial Board.



© 2012 Green Lines Institute for Sustainable Development

Instructions for Authors and call for papers available at:

<http://ijsc.greenlines-institute.org>

Contact the Editor-in-Chief:

ijsc@greenlines-institute.org

International Journal of Sustainable Construction
Volume 1 – Number 1 - 2012



Guest editors

Rogério Amoêda

Luis Bragança

Ricardo Mateus

Editor-in-Chief

Rogério Amoêda

Editorial and Referees Board

Chi-Ming Lai

National Cheng-Kung University, Taiwan

Chih-Ta Tsai

National Cheng-Kung University, Taiwan

Erminia Attaianesi

University of Naples "Federico II", Italy

Gabriella Duca

University of Naples "Federico II", Italy

Guillaume Habert

Université Paris-Est, France

Holger Wallbaum

Chalmers University, Sweden

Jacqueline Glass

Loughborough University, United Kingdom

Jia-Chong Du

Tungnan University, Taiwan

José Fernández-Solís

Texas A&M University, USA

Marco D'Orazio

Università Politecnica delle Marche, Italy

Pedro Lima Gaspar

Technical University of Lisbon, Portugal

Ricardo Mateus

University of Minho, Portugal

Umberto Berardi

Worcester Polytechnic University, USA

Yan Xiao

Hunan University, China



International Journal of Sustainable Construction

© 2012 Green Lines Institute for Sustainable Development

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, without prior written permission from the Publisher.

Cover image:

Net-Zero Energy Building: Rehabilitation of watermills, Gavião, Portugal (2012)

Author's Project: Norte-Arquitectos.

ISSN 1647-0621 (print)

ISSN 2182-2743 (on line)

Published and owned by



Green Lines Instituto para o Desenvolvimento Sustentável

Green Lines Institute for Sustainable Development

Av. Alcaides de Faria, 377 S.12

4750-106 Barcelos, Portugal

mail@greenlines-institute.org

<http://www.greenlines-institute.org>

Published in electronic format.

Print on demand.

Legal Notice

The Editors and the Publisher are not responsible for the use which might be made of the following information.

Contents

Editorial	5
Rogério Amoêda, Luís Bragança & Ricardo Mateus	
 Articles	
<i>The cultural values embedded in building environmental assessment tools: a comparison of LEED®- Canada and CASBEE</i>	7
Aiste Blaviesciunaite & C Raymond J. Cole	
<i>The need of harmonization: from building product information to the whole process of the construction</i>	17
Beatriz Rivela, Cesar Bedoya & Alfonso García-Santos	
<i>Sustainability assessment tool of green building renovation in Taiwan: an introduction to EEWH-RN</i>	25
Chung-Yi Chang, Hsien-Te Lin & Ming-Chin Ho	
<i>Patterns in green building practice: analysis of LEED project data</i>	33
Joel Anne Todd & Robert Tufts	
<i>Sustainability assessment of materials used in façade cladding</i>	43
Jorge Orondo & Cesar Bedoya	
<i>Green Building classification system for developing countries</i>	51
Prashant Kapoor	
<i>Environmental assessment of wood-based panels: a comparison of life-cycle-based tools</i>	63
Rita Garcia & Fausto Freire	
<i>Multicriterion assessment of existing buildings in reSBToolCZ</i>	73
Stepan Mancik & Jan Ruzicka	

Editorial

Rogério Amoêda

Green Lines Institute, Barcelos, Portugal

rogerio.amoeda@greenlines-institute.org

University Lusíada, Vila Nova de Famalicão, Portugal

rogerio.amoeda@fam.ulusiada.pt

Luís Bragança

University of Minho, Guimarães, Portugal

braganca@civil.uminho.pt

Ricardo Mateus

University of Minho, Guimarães, Portugal

ricardomateus@civil.uminho.pt

The editorial board would like to express sincere gratitude to all contributors and participants of the 1st issue of the International Journal of Sustainable Construction (IJSC).

This first issue of the IJSC is focused in the themes of Building Sustainability Assessment (BSA) and Life-cycle Assessment (LCA) and contains the eight best papers submitted to the 1st International Conference on Building Sustainability Assessment (BSA 2012). These best papers were ranked by the conference's Scientific Committee. This much focused conference had more than 100 papers submitted, and was considered a huge success by the scientific community.

Building sustainability involves various relations between built, natural and social systems and therefore comprises a complex of different priorities that require consideration at each stage of a building's life-cycle. To cope with this complexity and to support sustainability, systematic, holistic and practical approaches to building design need to be developed. These approaches are aimed to support the development of a building design that achieves the most appropriate balance between the different sustainability dimensions and can be used with two different objectives: to support the sustainable building design; and to assess and recognize the efforts of the design teams in developing high-performance buildings. Building sustainability assessment methods and tools can be used since the very beginning of the design stage in order to gather and report information for decision-making during the different life-cycle stage of a building.

Until now there is no standardised methodology to support decision making during design phase and to assess the sustainability of buildings. In order to overcome this constraints, both the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN) have worked actively in the last few years to define standard requirements for the environmental and sustainability assessments of buildings. Based on this standardization bodies, a new generation of Building Sustainability Assessment (BSA) systems and Life-cycle Assessment (LCA) tools are being developed worldwide

This first issue of the new born IJSC Journal comes in the right moment and brings an overview of some results of the research and development that is being developed at international level in the fields of BSA and LCA, as follows: "The cultural attitudes towards building controls as embedded in building environmental assessment methods: a comparison of LEED - Canada and CASBEE"; "The need of harmonization: from building product information to the whole process of the construction"; "Sustainability assessment tool of green building renovation in Taiwan: an introduction to EEWH-RN"; "Patterns in green building practice: analysis of LEED project data"; "Sustainability assessment of materials used in façade cladding"; "Green building classification system for developing countries"; "Environmental assessment of wood-based panels: a comparison of life-cycle-based tools"; "Multicriterion assessment of existing buildings in reSBToolCZ".

The research and development in the fields of the BSA and LCA tools is still in its infancy, and therefore the editors would like that future issues of this journal will be on the edge of the discussions on this context.

The cultural values embedded in building environmental assessment tools: a comparison of LEED®- Canada and CASBEE

Aiste Blaviesciunaite *Azbil Corporation, Building Systems Company, Tokyo, Japan* b.aiste.jh@azbil.com

Raymond J. Cole *School of Architecture & Landscape Architecture
University of British Columbia, Vancouver, Canada* rcole@sala.ubc.ca

This paper examines two different contexts – Canada and Japan – to illustrate how these cultures understand nature, technology and building controls, and how this understanding is manifest in their corresponding environmental assessment methods – LEED-Canada and CASBEE. It explores culturally specific values by analyzing the expected interactions between inhabitants and buildings in Canada and Japan and the technological approaches that support this interaction. The work supports the argument that the assessment methods are culturally bound and their importation and exportation should be carefully considered from this standpoint.

© 2012 Green Lines Instituto para o Desenvolvimento Sustentável. All rights reserved.

Introduction

Attitudes towards technology are culturally bound – they are both derived from the cultural context and evolve with it. Moreover, attitudes toward technologies supporting the environmental control and performance of buildings are equally shaped by the attitudes towards and, responses to, “nature” in their specific locales.

This paper examines how Canadian and Japanese cultural attitudes towards building controls and the methods of engaging them – from full automation to manual operation – are embedded in their respective environmental assessment methods – LEED-Canada and CASBEE. Firstly, it explores how the attitudes towards nature in both countries shape qualitatively different understandings of the human role and analyses tendencies to ascribe vertical and horizontal relationships (1) among the humans and (2) between the humans and nature. Secondly, drawing on Verbeek’s (2006) speculations that technologies can be described not simply in terms of their obvious functionality – but also as mediating the subjective and objective relation between human beings and their world, the arguments are presented to illustrate (1) the variety of interpretations of the role of technology and expectations towards it and (2) the impossibility to define technology as the “other” opposite pole of nature in the dichotomous understanding. Diverse perspectives are organized and summarized by positioning them along the continuum and, by doing so, exposing not only the complexity, but inherent interrelationship with attitudes towards nature. Finally, in order to analyze how cultural values both influence and are embodied within assessment methods without losing the intrinsic complexity evidenced in the understanding of technology, technology is referred to by its indirect and direct consequences. The former approach is based on the notion that the assessment methods can be understood as “techniques” for the designer in a similar manner to how technical devices are considered in buildings. The focus here, therefore, is on the formulation and structure of the assessment methods. The latter looks at technical approaches that support the interaction between inhabitants and the building. Cultural comparisons of attitudes towards nature and technology continuum serve as conceptual underpinnings that help to distill the emphases prevalent in the building environmental assessment methods. As a result – the analysis enables exposing the differences that bear the particularities of their cultural contexts.

Nature in CANADA and JAPAN: dichotomy vs. continuum

Canadian and Japanese attitudes towards nature have directly and indirectly shaped how the relationship between the natural and built environments have evolved in the two countries. While the demarcation of human and natural worlds is evident in the prevailing Canadian understanding, a more ambiguous, contextual, and linear relationship is observed in Japan. These cultural emphases have consequently effected different distributions of vertical-horizontal relationships between humans and nature.

Humans separate from nature

The prevailing Western world-view still emphasizes humans as separate from nature. Nature is considered as a commodity – valued primarily in terms of the services it provides and as a “constellation of waste disposal services, with the nature of those services being defined in terms of what we need from nature” (Bromley, 2008 p.13). Such beliefs, White suggests, led Western cultures to view themselves as “superior to nature, contemptuous of it and willing to use it for our slightest whim” (1968 p.90). The roots for this split, Worster notes, lie deep in Judeo-Christian traditions and in the philosophical questions posed by the Enlightenment (1985). These were consolidated into scientific thought and practice with Descartes’ proposition that the subjective and objective can be separated, are independent, and therefore subject to deductive reasoning. Watsuji Tetsuro – one of the most influential Japanese philosophers – acknowledged that this dichotomy in particular, was the main reason why the Marxist and Christian positions failed to be fully accepted in Japan. In his analysis of Watsuji Tetsuro’s seminal work – *Climate (fudo)* – Harumi Befu references “...fault[ing] Marxism for not being able to establish firm ground in Japan [due to] its neglect of environmental considerations... [and] (in considering the failure of Christianity in seventeenth-century Japan)...blam[ing] the Jesuits’ unawareness of environmental relevance for religion” (2004 p.113).

The understanding of nature in Canada

Qualities assigned to nature in Canada emphasize two main ideas: (1) nature as a powerful, great wild North – a source for the human spiritual and physical well being (regenerative power) as well as society’s wealth and (2) nature as a unifier, something distinctive that becomes (or rather is conceived to be) the basis for the national identity.

In Canadian culture, nature has served “...as a signifier of “Canadian-ness” (Payne, 2007), [enunciated as] ...a function of nordicity... (Stacey, 2007) a distinct race found in the wilderness... (Husser, 1926) cover[ing] the total expanse of Canadian geography” (Lamoureux, 2007). These attitudes not only ascribed the predominant values of the “...individualistic, conservative, loyal, independent, virile, industrious, dignified...” (O’Brian, 2007) nation, but it also positioned the Canadian as the controller or the owner of all the goods in nature. It was assumed that the “...wealth and the hope of her [Canada] future lie in the wilderness (Reid, 2007), [which is] a cornucopia overflowing with natural resources...(Walton, 2007), “empty” land for the taking...(O’Brian and White, 2007) the Land that has everything (Payne, 2007) [and therefore] promising unlimited growth...” (Walton, 2007).

Nature as understood in Canada, stands apart from the human beings as “the other”. Human beings are considered as superior to nature since they have seemingly managed to conquer it by being united and equal among each other or, as in the environmental discourse – as intruders/ destroyers of nature. In one way or the other, the clear distinction between the humans and nature is evident, reinforcing not only the dichotomy, but also – a hierarchical understanding of the relationship between them.

The understanding of nature in Japan

In Japan, nature generally is interpreted to be closely associated with the life of the human beings. As a result, the discussion is not so much about defining the qualities and the role of humans as opposed to nature, but rather about defining the interaction between humans and nature. And this interaction is twofold. On the one hand, nature is altered to be part of the human world by “taming” it and hence enabling an indication of an “insider”, that is, by changing the “other” so that it could be idealized for the beauty and aspired as an ideal. On the other hand, humans themselves are taught to accept the changeability or the evanescence of things by observing and understanding nature. Both processes require a set of ways, methods, techniques that have been forwarded from generation to generation from as early as the Taoist thought reached Japan and has been sculpted and molded into a unique style. These ways, methods, techniques are often known as a “Way”=‘dou’ (‘tao’ from Taoism in Chinese), and popularly recognized overseas through the activities like tea ceremony=‘sadou’, bushidou, etc. (Obayashi, 2005)

Japanese approaches aimed at harmonizing the coexistence of what was considered as “separate categories” in the Western world are not so much based on analyses and understanding, but rather on the set of activities that involved the whole experience – perceptual as well as social. As such, they defined how one should relate to his/her surrounding context. When the set of practices assigned to human were perfected, any contextual change could be encountered without losing one’s inner peace. In other words, these strictly defined approaches are not questioned until they become one’s second nature and manifest “naturally” or spontaneously without a second thought.

Consequently, learning these approaches inscribes hierarchical structure in the society in order to keep it very "civilized, orderly and polite" (Inoue, 2008). This is further enhanced by explicitly communicating that the human world (referred to as "inside"/uchi) is inseparable/exists within the larger, natural world (or the "outside"/soto). The "outside" can become dangerous, and therefore the cooperation and agreement among the members of the "inside" – stabilized and strengthened by the hierarchical order – is considered to be necessary for reaching the harmonious interaction with the "outside". These attitudes "...are the inherent part of the collective understanding, [with uchi and soto being] inclusively recursive... [and] moving from Japan as uchi and the world as soto down through regional identities and intimate social relations" (Ball, 2004 p.375).

Differences between the Canadian and Japanese understandings

In contrast to Canada, there is an obvious difficulty when one attempts to define natural versus cultural/human-made in Japan. Everything in accord with the context can be perceived as natural, and a number of ways, methods, techniques are employed to "polish" the surroundings in order to achieve this "natural" state. In Japan, it is difficult to find "...an opposition between culture and nature... Rather, nature and culture are inscribed on each other. Contextual variations in culture, including social relations, are understood in terms of variations in nature" (Rosenberger, 2004 p.147). Kyburz (2004) reinforces that there "...exist[s] a fundamental difference in the way Western and Japanese cultures each conceive the world and existence. He argues that "...Japanese culture is not characterized by the conceptual fracture which in Western consciousness and anthropological usage opposes 'culture' as a distinctively human sphere, and 'nature' as that which lies outside of it." (p.258) Moreover "... the Japanese world view does not conceive of man and nature as polarities, but as mutual parts of an all-comprehensive whole... [and] mankind... is felt to be one of the numerous potential forms of existence, with no particular vocation for supremacy" (Kyburz, 2004 p.258). This can be illustrated through a "nature continuum" and vertical-horizontal relationships.

The nature continuum

Japanese perception tends to emphasize the continuum rather than mutual exclusion composed of "...pairs which in their ideal states are to be found at opposite poles of a continuum, with actual cases located somewhere in between depending on the context... [and] the emphasis is placed on processes... something being or becoming... always in the making... [and therefore regarded as] more important than the absolute state" (Kalland and Asquith, 2004 pp.11-12). This continuum is illustrated in Figure 1 which shows the binary division of the opposite poles as commonly interpreted in the West. Simultaneously, however, it also suggests a range of "in betweens" that take on different meanings with the changing context.



Figure 1. The Nature Continuum (Kalland and Asquith, 2004)

Vertical-horizontal relationships

The predominant vertical-horizontal relationships also differ between Japan and Canada. Equality among humans is valued in Canada (horizontal), and the vertical relationship exists between the human world and nature. In Japan – the relationships among humans in the "inside" tend to be more hierarchical (vertical), but the horizontal interaction between the "inside" and the "outside" is implied.

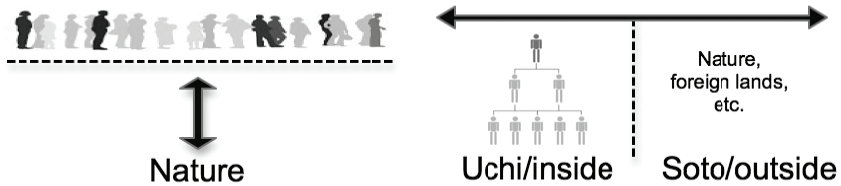


Figure 2. Vertical and Horizontal relationships in Canada (left) and Japan (right)

Technology in Canada and Japan: an understanding derived from the attitudes towards Nature

The qualitatively different understanding of human-nature relationships in Canada and Japan represent one of the key ways that cultural complexity can be described and analyzed. Further, these differences suggest that the resulting interpretations of technology have developed to reflect the cultural emphases. Technology therefore acts as a lens through which organizational practices and corresponding systems and processes can be compared in the two countries.

Deriving the technology continuum

It can be argued that technology per se is universal and widely adopted in almost every country around the world. However, a variety of interpretations have been proposed regarding the role of technology and expectations towards it by presenting a number of qualities that define the interaction between the technology and humans. Further, as Ihde (2008) emphasizes, two prevailing conceptions of technology – utopian views that technology is capable to solve humanities problems of any kinds and dystopian views that technology is having potentially negative longterm consequences. Both “...tend to be rooted in misunderstandings of the complexities...” (Riis, 2008) such as technology’s “...concrete specificity, variability, context dependency, tendency to defy prediction, historical and cultural ‘embeddedness’”. (Rosenberger, 2010, pp.133-4). It is therefore evident that technology cannot be simply defined as a separate category, because technology can take on both roles – influencing the cultural context it is applied to and consequently changing according to the expectations prevalent in that cultural context.

In order to illustrate the variety of interpretations of the role of technology and expectations towards it and the impossibility to define technology as the “other” opposite pole of nature in the dichotomous understanding, qualities assigned to technology are organized by positioning them along the continuum. Table 1 summarizes a variety of qualitative aspects of technology in six categories. These are then positioned along the technology continuum similarly to the nature continuum: the left side being ‘automated’ as corresponding to the “cooked, bound/ wrapped, tamed/ domesticated” nature and the right side being ‘manual’ as the “raw/ uncooked, unbound/ unwrapped, wild” nature (Figure 3).



Figure 3. The Technology Continuum

Table 1. Qualitative aspects of Technology.

Selected Attributes	References	Keyword(s)
Cultural, Unifying, Embedded within historical and cultural context		Cultural
Intrusive, Invading, Autonomous, Modifying, Translating, Infecting, Influential, Mediating, Altering, Alienating, Destructive, Compelled to dislodge, Engendering	Vesely, 2004; Merleau-Ponty, 1962; Smith, 2008; Ellul, 1964; Latour, 2002; Riis 2008; Thackara, 2001; Bakker, 1965 in Viljoen 2009; Ihde 1983, 1986, 1979, 2009;	Modifying
Connecting, [causing] global autism, Tiding in a sort of anonymous existence, Universal, Trans-cultural, Applicable to different cultures and contexts	Takeo, 1972; Heidegger, 1977; Gibson, 1986;	Anonymous connectivity
Opaque, Forgetting, Habitual, Familiar, Layered labyrinth, Tending to defy prediction, A comfortable cocoon, Encompassing all dimensions of our relations, One-sidedness/ narrowness, inability to think and see the essence of things and happenings		Opaque
Correct, Trustworthy, [Assuring] the continuity of our actions, Uniform, Ordered, Shaped, Enframing, Rational, Money-generating		Stable/ safe
Innovative, Opening new possibilities, Empowering, Intelligent, Service-oriented, Adaptable to the new environment, Flowing, Speedy, Mobile, Playful, Intuitive, Moving, Surprising, Fun		Innovation & Empowerment

On the far right of the continuum (1st row, Table 1) are the most "local" or place-specific qualities. They communicate the direct needs of the particular place, are relatively simple and therefore can be controlled manually by the individual. Then follows the understanding of technologies as capable to "intrude" and alter the precious cultural environment of the place (2nd row, Table 1). Technologies are perceived as being beyond the human capacity to easily take control of them and therefore as dangerous. However, besides the number of fears, the inescapability and some degree of universality of technologies are acknowledged (3rd row, Table 1). The views are simultaneously positive (the development of new things could be encouraged) and negative (due to "global autism" and increasing "anonymity").

When technologies become so pervasive that the origins are no more visible, interaction with technologies is "habitual" and "forgetful" (4th row, Table 1). As a result, the human beings are not capable to "see through it" or to control it. Massive adoption of and reliance on the technological devices, though, creates a sense of stability and safety (5th row, Table 1). The continuous shaping, ordering and framing are thus favored to assure accuracy and predictability.

Lastly, when the stable and safe framework is established, creativity can be unleashed to foster innovation and empowerment (6th row, Table 1). Especially in the Japanese culture, Inoue affirms, the right balance between the form and the new things that change (he calls it evanescence) is essential for any development: "Creativity affirms change. It tests and challenges form... [searching] for the balance... Without embracing a vision of change, formality can be antithetical to life. On the other hand, without form, change is impossible and even meaningless. If form without change imprisons us, then change without form leads to chaos and despair" (Inoue, 2008, p.4).

Implications to the understanding of technology in Canada and Japan

When the nature becomes the "other" (as emphasized in the Canadian attitudes), the human world and everything related to it (including technologies) is similarly distinct. By contrast, if the nature and the human world are not clearly separated but rather continually changing, the human aims for the most "ideal" combination between the two. This combination then is context- and time-dependent and therefore process-oriented. Technology thus, Ashkenazi (2004) argues, is understood as "...in effect, a part of the 'natural' landscape for most Japanese who, being an urban rather than a rural population, exist 'naturally' in an urban environment." (p.209) Therefore, he continues, "...machines, in their nature, are neither artificial nor natural. It is in what they do that they are defined, if necessary, as either." (Ibid p.217) In other words, since there is nothing exclusively natural or artificial, only the relationship between the humans and the technology in a particular context can define what it is.

Building environmental assessment methods are deeply interwoven into the organizational practices that operate within the specific Canadian and Japanese cultural contexts. As a result, differences in the predominant societal attitudes governing their formulation, structure and decisions to support one or the other technical approach defining the interaction between inhabitants and the building expose the cultural embeddedness of the assessment methods. Acknowledging that the understanding of technology expands to include not only its functional aspects but also its role and the expectations towards it, the following analysis of the LEED-Canada and CASBEE highlights some that reveal cultural differences of the assessment methods. Further, LEED-Canada and CASBEE are addressed on two levels:

1. The assessment methods themselves are understood as "techniques" used to correspond to the expectations prevalent in the society. As such, the technology is analysed indirectly, and the focus here is on the formulation and structure of the assessment methods.
2. Technical approaches in LEED-Canada and CASBEE that support the interaction between inhabitants and the building are examined. Here, the concrete requirements towards technology in the assessment methods are discussed, and therefore the analysis is

thought to be direct. In other words, the focus is on the expectations that are communicated through the assessment methods.

Indirect aspects of technology in LEED-Canada & CASBEE

The formulation and structures of LEED-Canada and CASBEE are qualitatively different and correspond to the previously explored cultural emphases. While in the former a more definitive, simplified and straightforward evaluation method is used, a relatively complex and contextual approach can be observed in the latter. Further, vertical positioning of human and natural worlds in LEED-Canada contrasts with the horizontal conception in CASBEE.

Formulation of the LEED-Canada & CASBEE: definite vs. a range of possibilities

Although in both LEED-Canada and CASBEE, the number of points attained reflects the success of the environmental performance of buildings, their evaluation descriptions reveal divergent attitudes. Credits in LEED-Canada are composed of "intents" expressing the overall goals of the credits; "requirements" with the descriptions of the specific actions/performance to be achieved and "potential technologies and strategies" that could be deployed. Individual credits carry an implied weighting through the number of points allocated to them in the overall total available points.

In CASBEE, the specific performance requirements are not pronounced as clearly as in LEED-Canada. Rather, it communicates the importance to evaluate the range of efforts invested in achieving these goals differently. The credits are assessed on a five scale, where "1 is earned for satisfying the minimum conditions required by laws, regulations and other standards of Japan... and a building at what is judged to be general, ordinary level earns 3" (JSBC, 2010). Levels 4 and 5 then, obviously, are assigned to cases that exceed the ordinary. Table 2 summarizes the requirements of some of these credits.

LEED-Canada assigns points for achieving specific performance requirements whereas CASBEE distributes points in a way that corresponds to the level achieved. Further, LEED-Canada does not aim to evaluate "the level of consideration given to", "efforts to conserve", "how far [it] enhances", "[the] appropriate[ness in] maintenance management", "how well [it is] considered" or "the level of efficiency" (JSBC, 2010). These tendencies in LEED-Canada to evaluate the specific requirements and the range of those results in CASBEE can be explained as culturally embedded. LEED-Canada echoes the dichotomous, fixed and result-oriented Western worldview, and CASBEE acknowledges the contextual possibility of change therefore positioning the evaluations along the continuum with the range of permutations.

Table 2. Summary of the requirements in LEED-Canada (CaGBC, 2009) and CASBEE (JSBC, 2010).

LEED-Canada requirements	CASBEE requirements
The minimum percentage debris to be recycled or salvaged for each point threshold is as follows: 1pt.=50%, 2pts.=75% (MR, 2 (NC)).	Evaluate the level of consideration given to selection of materials (Q1, 4).
Do not develop buildings, hardscape, roads or parking areas on portions of sites that meet any of the following criteria: [i.e.] land within 30.5 metres of any wetlands...; previously undeveloped or graded land that is within 15.2 metres of a water body...; etc. (SS, 1 (NC)).	Evaluate efforts to conserve and create habitat for wild organisms... how far plans are supposed to enhance the quality of the environment... and whether appropriate maintenance management guidelines have been set (Q3, 1).
Demonstrate a percentage cost improvement (1pt.=25%, 19pts.=56%) in the proposed building performance rating compared with the reference building performance rating (EA, 1 (NC)).	Evaluate the level of efficiency improvement of various equipment types (i.e. A/C, ventilation, lighting, hot water supply and elevators) (LR1, 3).
*Similar credit does not exist in LEED-Canada.	Evaluate how well urban context and scenery have been considered... examine the level of consideration to [guidelines] (Q3, 2).

Structure of the LEED-Canada & CASBEE: inherent simplicity vs. complexity

The cultural tendencies distinctively separating either/or in order to reduce the complexity and allow deductive analysis manifest in Canada versus recognizing the contextual abundance of interactions in Japan are also evident in the difference of inherent simplicity of LEED-Canada and relative complexity of CASBEE. This is particularly evident in the process of scoring, weighting and presenting the evaluation results.

LEED-Canada allocates the number of points for each credit by weighting their importance based on the US Environmental Protection Agency's TRACI environmental impact categories and weightings developed by the National Institute of Standards and Technology (NIST), with "all LEED credits receiv[ing] a single, static weight" (CaGBC, 2009 xiv). Certification is awarded according to the overall number of points attained (80 points and above for Platinum, 60-79 points for Gold, 50-59 points for Silver, 40-49 points for Certified) out of 100. This final designation is the most significant measure used in communicating success.

In CASBEE, the process of allocating points, weighting and presenting the results is more complex. Firstly, the points obtained from each credit on the five level-scale (1-5) are summated. Secondly, the scores are weighted using coefficients that "...should not just be determined from scientific knowledge... [but] take into account the value and perceptions of various interested parties..." (JSBC, 2010 p.25). Thirdly, the overall scores for Building Environmental Quality (Q) and Building Environmental Loads (L) categories are derived (6 scores corresponding to Q1~3 and LR1~3). The 6 obtained scores are presented numerically and graphically to show the distribution in each of the Q and LR categories, and the overall scores for Q and LR are calculated. Then, the Building Environmental Efficiency (BEE) score is derived as the ratio of Q and LR and plotted on the coordinate plane with Q as Y and LR as X. The position of BEE falls in one of the five levels from S down to C. Moreover, stars are assigned according to the obtained S~C level. Finally, a separate evaluation process is used for Lifecycle CO₂ (LCCO₂) in order to assess the "LCCO₂ performance... more precisely... based on the nature of CO₂ reduction initiatives" (JSBC, 2010 p.8).

CASBEE is therefore based on a more diverse approach in both assigning points and presenting the results. This complex way of analyzing performance information is expressed as an aspiration of "giving a multi-faceted and comprehensive grasp of the environmental characteristics of the evaluated building" (JSBC, 2010 p.16). Further, using several types of graphical representations is also a particular aspect of CASBEE, in comparison to LEED's singular representation.

Structure of the LEED-Canada & CASBEE: vertical-horizontal

When LEED-Canada and CASBEE are examined from the vertical-horizontal perspective described above, one obvious difference becomes evident: CASBEE uniquely uses the hypothetical boundary as "...the basis of [its] framework" (JSBC, 2010) to explicitly divide the human space on site (Q=Building Environmental Quality), which evaluates "...improvement in living amenity for the building users within the hypothetical enclosed space" (JSBC, 2010 p.277), and the "other" (L=Building Environmental Load), which evaluates "...negative aspects of environmental impact which go beyond the hypothetical enclosed space to outside" (JSBC, 2010 p.278).

Further, a closer analysis reveals that point allocations and the descriptions of the credits are also different in the two systems. In LEED-Canada, there is no specific order how the requirements are fulfilled, and the importance of the credit entirely relies on the weightings. Cole (2012) observes that in "...LEED... particularly for the Certified, Silver and Gold levels, it is possible to select (or 'cherry pick') from a basket of potential credits in order to attain the necessary overall performance level." (p.42) In CASBEE, however, the distribution of the credits is not fortuitous but growing from the smaller to the bigger therefore implying a somehow hierarchical relationship between them (i.e., Q1 evaluates separate categories of the indoor environment, Q2 – how well the separate categories are integrated and Q3 aims to relate the building with its surroundings).

While the LEED-Canada credits tend to be more or less horizontally distributed (no specific order of what comes first), the relationships between the credits in CASBEE are more vertical. Simultaneously, CASBEE uses the hypothetical boundary to explicitly mark the border between the "inside" (Q) and the "outside" (L). Figure 5 illustrates the difference in approach.

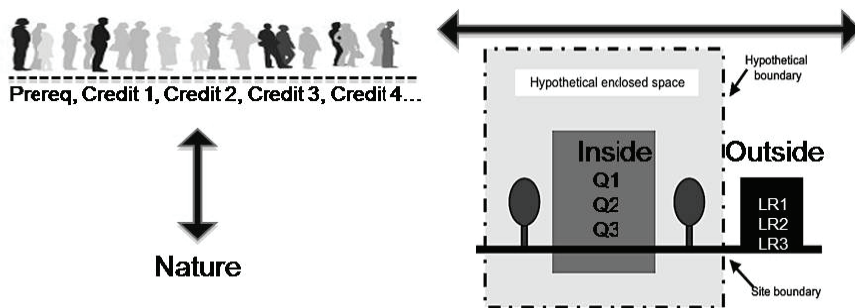


Figure 4. LEED-Canada and CASBEE structures as derived from cultural attitudes

It should be noted, however, that this division does not deny the existence of the continuum. Rather, it shows that the combined effort between Q & L is necessary to harmonize the interaction between the opposite poles.

Direct aspects of technology in LEED-Canada & CASBEE

There is a common belief that the main distinctions between Japanese and Canadian building practices are evidence of the former's emphasis on automation and technological prowess and the latter's emphasis on user control in the environmental building design. Indeed, this is manifest in CASBEE's and LEED-Canada's qualitatively different approaches of providing comfort while minimizing negative environmental effects.

Technical approaches that support the interaction between inhabitants and the building: personal controls vs. service

Similar goals to simultaneously provide comfort and minimize negative environmental effects are evidenced in both LEED-Canada and CASBEE. However, LEED-Canada distinguishes "Controllability of Systems" for the Lighting and Thermal Comfort, which requires "...system control by individual occupants or groups in multi-occupant spaces (e.g., classrooms or conference areas) to promote their productivity, comfort and well-being" (CaGBC, 2009 pp.88-90). Even though Individual Controls are mentioned in CASBEE, this applies only to Hospitals, Hotels and Apartments (in the case of temperature and humidity) or can be substituted with automatic controls (in the case of lighting) (JSBC, 2010 p.99). Further, sophisticated monitoring systems are required for temperature controls in Retail and Restaurants and, humidification/ dehumidification equipment as well as automatic air conditioning controls are required for all buildings, including offices (JSBC, 2010 pp.84-9). Thus it is evident that CASBEE's focus is rather on the Quality of Service (Q2) – the indispensable collective effort in order to enhance "...the indoor environment, which has a major impact on the health, comfort and intellectual productivity of occupants...[and is regarded as] basic performance of the building" (JSBC, 2010, p.19).

It was shown earlier that in Canada, the human world (with technology being part of it) is distinct from the nature. It is therefore desirable to either "isolate" nature or, in the case when this is not possible (i.e., building design) to provide the highest comfort levels by creating a possibility for every building inhabitant to personally control his/ her environment. Since in Japan there is no clear definition of the "natural", and the understanding of nature is continually changing, the focus is to come as close as possible to the harmonious balance by harvesting the collective human effort. In other words, instead of defining the relationship between the inhabitant and the building, the highest level of maintenance management corresponding to the contextual changes in the long term is expected to assure the ease of occupants. These attitudes are clearly expressed in CASBEE through the emphasis on "Service" and the evaluation of its quality as a separate category. Differently than LEED-Canada, productivity of the building inhabitants is not promoted by providing means to personally control their environment. Rather, due to "...the relatedness of environmental performance assessment items (Q1 Indoor Environment and Q2 Quality of Service) and intellectual productivity" (JSBC, 2008 p.8), continual improvement is achieved by integrating a number of different strategies through the Service.

Conclusions

The work presented in this paper is directed at cultural attitudes towards technology in two countries – Canada and Japan – and shows that these attitudes are derived from the collective attitudes towards nature. Cultural differences are revealed by comparing indirect and direct aspects of technology in the corresponding assessment methods of the two countries. These are examined by distinguishing between: (1) the indirect differences in the formulation of the credits (definite, fixed requirements vs. the evaluation of efforts in the range of possibilities) and the structure of the assessment methods (inherent simplicity in LEED-Canada vs. the greater complexity in CASBEE), and (2) the direct aspects such as Canada's emphasis on individual controls and Japan's emphasis on technical prowess and, especially, service. These explanations are based on the culturally rooted understanding towards nature and, since this understanding inevitably shapes the understanding of technology – a wide range of subtle distinctions within the formulation, structure and technological approaches in LEED-Canada and CASBEE are presented.

The consequence of the results of the study is two-fold. Firstly, it provides a critically important lens through which to view side-by-side comparisons of building environmental assessment systems. Secondly, by using this lens to contrast the differences and identify similarities in the two countries, the work exposes the culturally rooted elements that otherwise might not be evident. As such, it supports the argument that the assessment methods are culturally bound and their importation and exportation should be carefully considered from this standpoint.

References

- Ashkenazi, M. (2004). The Can-nonization of Nature in Japanese Culture. In P. J. Asquith & A. Kalland, eds. *Japanese Images of Nature*. Richmond: Curzon Press, pp.206-220.
- Asquith, P. J. & Kalland, A. eds. (2004). *Japanese Images of Nature, Cultural Perspectives*. London: Routledge Curzon.
- Ball, C. (2004). Acts of Alterity, Repertoires of registers: dialect in Japanese discourse. *Language & Communication*. [online]. 24(4), pp.355-380.

- Befu, H. (1997). WatsujiTetsuro's ecological approach: its philosophical foundation. In P. J. Asquith & A. Kalland, eds. *Japanese Images of Nature*. Richmond: Curzon Press, pp.106-120.
- Bromley, D.W. (2008). The emergence and evolution of natural resource economics: 1950–2000. In J. Wu, P.W. Barkley & B.A. Weber, eds. *Frontiers in Resource and Rural Economics: Human-Nature, Rural-Urban Interdependencies*, Washington, DC: Resources for the Future, pp.11-28.
- Canada Green Building Council (CaGBC) (2009). *LEED Canada for New Construction and Major Renovations 2009* [online]. Available at http://www.cagbc.org/AM/PDF/LEED_Canada_NC_CS_2009_Rating_System-En-Jun2010.pdf [Accessed 10 October 2010].
- Cole, R.J. (2012). Transitioning from green to regenerative design. *Building Research & Information* [online]. 40 (1), pp.39-53. Available at <http://dx.doi.org/10.1080/09613218.2011.610608> [Accessed 9 December 2011].
- Ellul, J. (1964). *The Technological Society*. NY: Vintage.
- Gibson, J. G. (1986). *The Ecological Approach to Visual Perception*. London: Lawrence Erlbaum.
- Heidegger, M. (1977). *The Question Concerning Technology and Other Essays*. NY: Harper & Row.
- Housser, F.B. (1926). *A Canadian Art Movement: The Story of the Group of Seven: 32*. Toronto: Macmillan Company of Canada.
- Ihde, D. (1979). *Technics and Praxis: A Philosophy of Technology*. Dordrecht: D. Reidel Publishing.
- Ihde, D. (1983). *Existential Technics*. Albany: State University of New York Press.
- Ihde, D. (1986). *Consequences of Phenomenology*. Albany: State University of New York Press.
- Ihde, D. (2008). *Ironic Technics*. Copenhagen: Automatic Press.
- Inque, C.S. (2008). *Evanescence and Form: An Introduction to Japanese Culture*. NY: Palgrave Macmillan.
- JSBC (Japan Sustainable Building Consortium) (2008). *CASBEE (NC) Technical Manual: 2008* [online]. Available at <http://ibec.or.jp/CASBEE/english/download.htm> [Accessed 25 September 2010].
- Kalland, A. & Asquith, P.J. (2004). Japanese Perceptions of Nature. In P. J. Asquith & A. Kalland, eds. *Japanese Images of Nature*. Richmond: Curzon Press, pp.1-35.
- Kyburz, J.A. (2004). Magical Thought at the Interface of Nature and Culture. P. J. Asquith & A. Kalland, eds. *Japanese Images of Nature*. Richmond: Curzon Press, pp.257-279.
- Latour, B. & Venn, C. (2002). Morality and Technology: The End of the Means. *Theory, Culture & Society*, 19. p.247.
- Merleau-Ponty, M. (1962). *Phenomenology of Perception*. Great Britain: Routledge & Kegan Paul.
- Lamourex, J. (2007). Interview with John O`Brian & Peter White. In J. O`Brian & P. White, eds. *Beyond Wilderness*. Canada: McGill Queens University Press, pp.307-312.
- O`Brian, J. (2007). Wild Art History. In J. O`Brian & P. White, eds. *Beyond Wilderness*. Canada: McGill Queens University Press, pp.21-37.
- O`Brian & White, P. (2007). Interview Introduction. In J. O`Brian & P. White, eds. *Beyond Wilderness*. Canada: McGill Queens University Press, pp.3-7.
- Payne, C. (2007). "How Shall We Use These Gifts?" Imaging the Land in the National Film Board of Canada`s Still Photography Division. In J. O`Brian & P. White, eds. *Beyond Wilderness*. Canada: McGill Queens University Press, pp.153-160.
- Reid, D. (2007). Introduction to The Group of Seven. In J. O`Brian & P. White, eds. *Beyond Wilderness*. Canada: McGill Queens University Press, pp.101-107.
- Stacey, R. (2007). The Myth- and Truth- of the True North. In J. O`Brian & P. White, eds. *Beyond Wilderness*. Canada: McGill Queens University Press, pp.258-263.
- Walton, P. (2007). The Group of Seven and Northern Development. In J. O`Brian & P. White, eds. *Beyond Wilderness*. Canada: McGill Queens University Press, pp.141-144.
- Obayashi, T. (2005). The Role of Sadou and Bushidou in Contemporary Society (Aiste Blaviesciunaite, Trans.). *Nagasaki International University Essay Collection* [online]. 5, pp.146-156. Available at <http://library.niu.ac.jp/NiuDA/RNS/PDF/RN05-015.pdf> [Accessed 10 December 2011].
- Riis, S. (2008). Review essay: Postphenomenology: 'Festschrift' for Don Ihde (Underconsideration: Evan Selinger's Postphenomenology: A Critical Companion to Ihde). *Philosophy & Social Criticism* [online]. 34, p.449.
- Rosenberger, N.R. (2004). Interpretations of Nature and the Legitimation of Gender Differences. P. J. Asquith & A. Kalland, eds. *Japanese Images of Nature*. Richmond: Curzon Press, pp.145-165.
- Rosenberger, R. (2010). Deflating the overblown accounts of technology: a review of Don Ihde`s Ironic Technics. *AI & Society* [online]. 25, pp.133-136.
- Smith, D.W. (2008). *Phenomenology (Stanford Encyclopedia of Philosophy)* [online]. Available at <http://plato.stanford.edu/entries/phenomenology/> [Accessed 2 December 2011].

- Takeo, O. (1972). The seven great sins of a technician (Aiste Blaviesciunaite, Trans.). *Technology and Humans* [online]. 1 (1), pp.70-77. Available at <http://opac.ndl.go.jp/articleid/348658/jpn> [Accessed 2 December 2011].
- Thackara, J. (2001). The Design Challenge of Pervasive Computing. *Interactions*. [online]. 8 (3), pp.46-52.
- Verbeek, P.P. (2006). Materializing morality: Design ethics and technological mediation. *Science, Technology & Human Values* [online]. 31 (3), pp.361-380.
- Vesely, D. (2004). *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production*. London: MIT Press.
- Viljoen, M. (2009). *The body as inhabitant of built space: the contribution of Maurice Merleau-Ponty and Don Ihde* [online]. Available at <http://upetd.up.ac.za/thesis/submitted/etd-10072010-121323/unrestricted/dissertation.pdf> [Accessed 5 December 2011]
- White, L.T. (1968). *Machina Ex Deo: Essays in the Dynamism of Western Culture*. Cambridge: MIT Press.
- Worster, D. (1985). *Nature's Economy: a history of ecological ideas*. Cambridge: Cambridge University Press.

The need of harmonization: from building product information to the whole process of the construction

Beatriz Rivela

*Department of Construction and Technology in Architecture
Technical University of Madrid, Spain*

b.rivela@abio-upm.org

Cesar Bedoya

*Department of Construction and Technology in Architecture
Technical University of Madrid, Spain*

cesar.bedoya@upm.es

Alfonso García-Santos

*Department of Construction and Technology in Architecture
Technical University of Madrid, Spain*

LCA has been traditionally concerned with product design, but by limiting the functional unit of an LCA to a building material or component, a number of functions that should be provided by buildings cannot be properly taken into account. Nowadays there is an intensive standardization process on building environmental assessment and CEN/TC 350 is doing a remarkable job by providing a reference framework and developing voluntary horizontal standardized methods for the assessment of the environmental performance on both new and existing buildings. The objective of the present work is to assess the importance of harmonization in the field of building environmental assessment. More than 80 case studies have been reviewed in order to describe and classify the results of the LCA studies regarding their goal and scope and their practical methodology implications, by discussing the variability associated to main hypotheses such as the functional equivalent selected and the choice of impact categories.

© 2012 Green Lines Instituto para o Desenvolvimento Sustentável. All rights reserved.

Introduction

Sustainable development in construction sector

Sustainable development requires methods and tools to measure and compare the environmental impacts of human activities. Providing society with goods and services contributes to a wide range of environmental impacts (Sharma et al., 2011). In this sense, the construction sector is of strategic importance for the economy, social well-being, energy & climate change and environment protection.

It can be stated that the current situation of the European residential buildings stock in terms of environmental performance is far from the currently discussed low-energy standards and there lies a tremendous potential for improvements (Nemry et al., 2008).

More than ever, the application of LCA is fundamental to sustainability and improvement in building and construction. LCA is recognized as an innovative methodology which improves sustainability in the construction industry throughout all stages of the building life cycle.

The standardization process towards sustainable construction

Nowadays there is a wide range of initiatives and instruments for sustainable construction, innovation, rethinking the value chain and international competition. However, initiatives pursue different objectives; there are large disparities between countries and still significant room for improvements.

The construction sector is the biggest single area of work in CEN with +/- 3000 work items, both product standards and test methods. Considering the requirements of the Construction Products Regulation (CPR), a number of harmonized product standards will need amendments to allow for the establishment of DoP (Declaration of Performance) as from the 1st July 2013 (CEN, 2011).

The sustainability assessment quantifies impacts and aspects to assess the environmental, social and economic performance of buildings using quantitative and qualitative indicators, both of which are measured without value judgments. In carrying out assessments, scenarios and a functional equivalent are determined at the building level. Assessment at the building level means that the descriptive model of the building with the major technical and functional requirements has been defined in the client's brief or in the regulations, as illustrated in Figure 1 (EN 15643-1:2010).

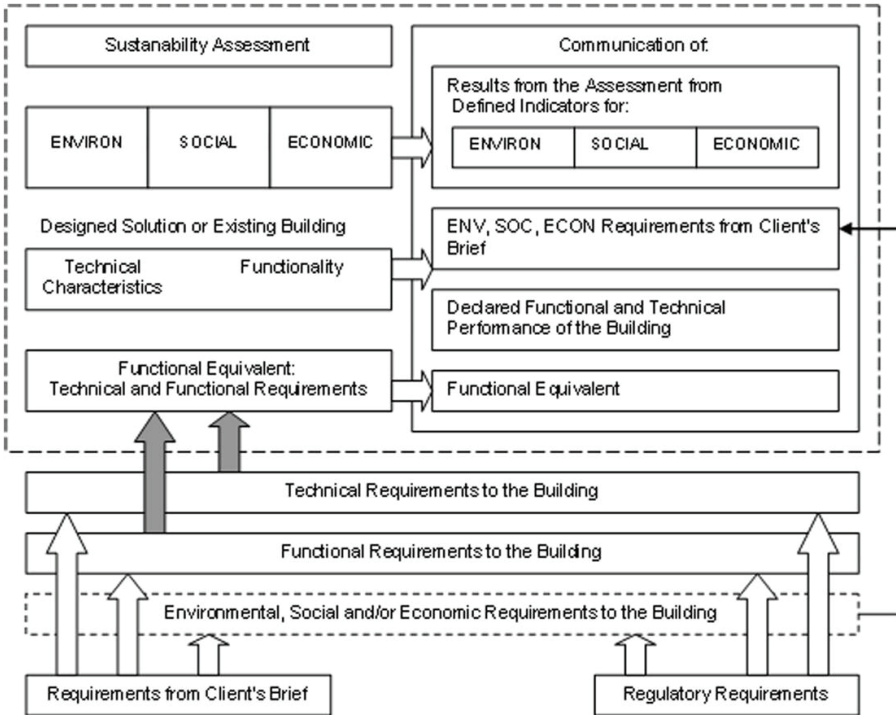


Figure 1. The concept of sustainability assessment of buildings (EN 15643-1:2010)

Assessments can be undertaken for the whole building, for parts of the building which can be used separately or for elements of the building. By reference to the functional equivalent the results of assessments can be presented in a systematic way. The functional equivalency forms the basis for comparison at the building level. In concept, the integrated building performance incorporates environmental, social and economic performance as well the technical and functional performance, and these are intrinsically related to each other, as illustrated in Figure 2 (EN 15643-1:2010).

Framework for the assessment of environmental performance

The work of CEN/TC 350 "Sustainability of construction works" will be used when mandates to cover the Basic Requirements for Construction Works (BRW) will be issued. Development of CEN/TC350 standards has taken into account the needs of the relevant EU policies related to the construction products relying on the performance based approach & the level of works. Manufacturers are request to give environmental information in a form of Environmental Product Declaration (EPD) according to the unified European method by CEN/TC350 (EN 15804:2012). CEN/TC350 provides the European standardized basket of indicators for sustainable construction. From the regulatory point of view, the indicators defined

in CEN/TC350 standards (e.g. in EN 15978:2011 and EN 15804:2012) should be regarded as the basket of environmental indicators that have an existing European unified method.

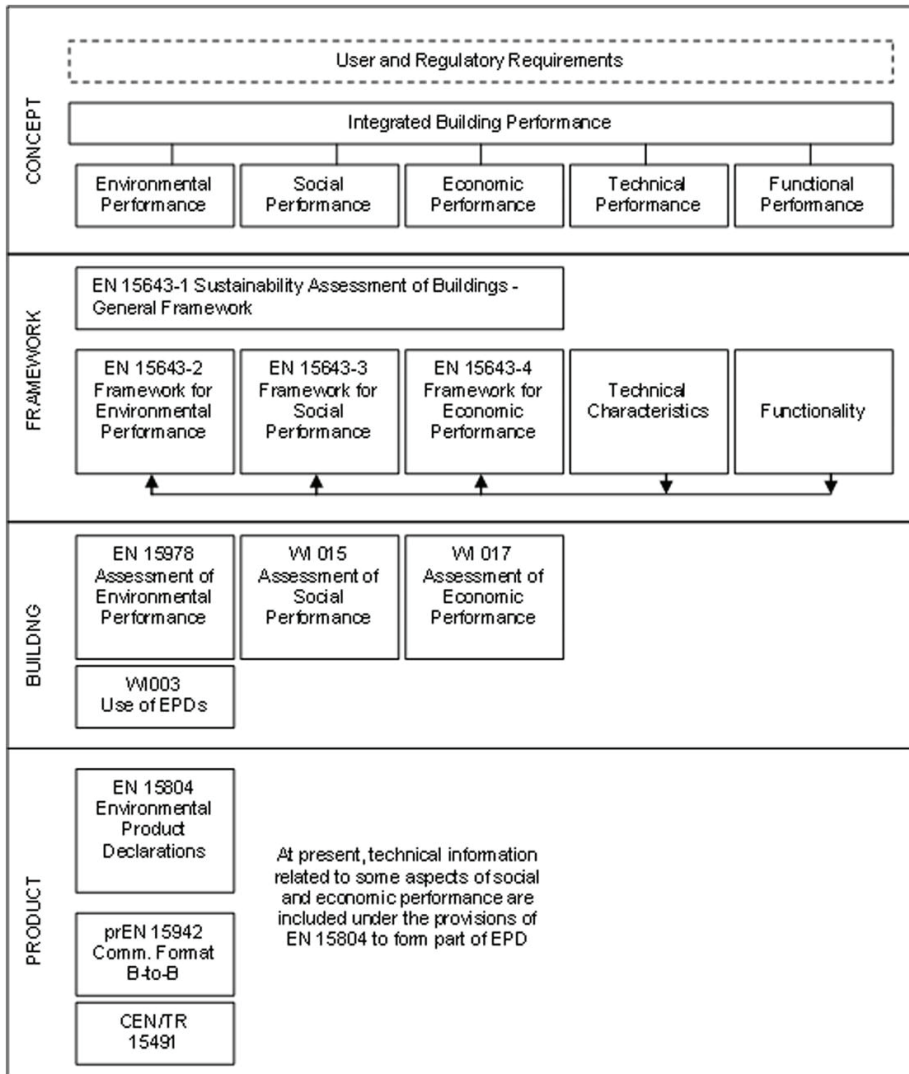


Figure 2. The work programme of CEN/TC 350 (EN 15643-1:2010)

The purpose of the European Standard EN 15643-2:2011 is to provide a framework with principles, requirements and guidelines for the assessment environmental performance of buildings. In the drafting of this European standard, ISO 21930 and ISO 21931-1 have been taken into consideration (EN 15643-2:2011).

Environmental product characteristics derived from BWR3 and BWR7 should become "essential product characteristics" and part of Declaration of Performance as soon as any Member State or the European Commission (e.g. caused by other directives) have requirements to declare the defined environmental indicators or they set actual limit values to the buildings on the life cycle basis, or on the products in its intended use (as part of the works) e.g. for:

- Emissions of greenhouse gases as part of BWR3,
- Materials for recycling after demolition as part of BWR7 or;
- Use environmentally compatible raw and secondary materials as part of BWR7

Impacts and aspects shall be assigned to the information modules of the building life cycle in which they occur, as it is described in Figure 3.

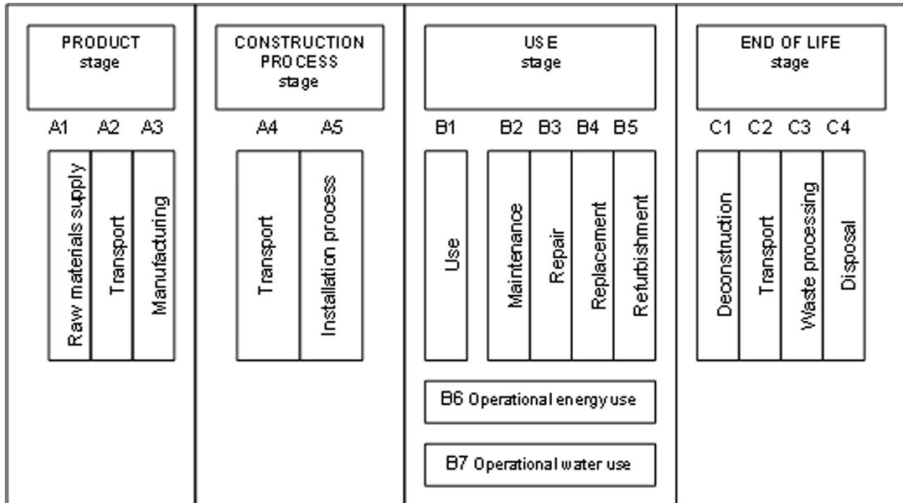


Figure 3. The building life cycle information modules applied in the assessment of environmental performance of a building.

Within this environmental framework the building life cycle starts with the acquisition of raw materials. It proceeds through the manufacture of products, construction work processes, actual use including maintenance, refurbishment and operation of the building, and finally at the end of life, deconstruction or demolition, waste processing in preparation for reuse, recycling and energy recovery and other recovery operations, and disposal of construction materials. Information from these activities is needed to assess the environmental impacts and aspects of the building (EN 15643-2:2011).

A building assessment requires information on the environmental impacts and aspects for all information modules A to C. The environmental impacts and aspects beyond the building life cycle shall be represented by information module D (additional module not showed in Figure 3). This supplementary information module D is optional.

It is remarkable that the environmental performance of a building is only one aspect of its sustainability. The social and economic performances of the building (described in the framework standards EN 15643-3:2012 and EN 15643-4:2012) are also aspects of sustainability that should be assessed as part of a sustainability assessment. The evaluation of technical and functional performance is beyond the scope of the standard; technical and functional characteristics are taken into account by reference to the functional equivalent, which also forms a basis for comparison of the results of assessments.

To provide calculation rules for the assessment of the environmental performance of new and existing buildings is the purpose of the European standard EN 15978:2011. The standard gives the description of the object of assessment; the system boundary that applies at the building level; the procedure to be used for the inventory analysis; the list of indicators and procedures for the calculations of these indicators; the requirements for presentation of the results in reporting and communication; and the requirements for the data necessary for the calculation. The object of assessment is the building, including its foundations and external works within the curtilage of the building's site, over its life cycle; the assessment can be also restricted to a part of a building or to an assembled system (part of works). Comparisons between the results of assessments of buildings or assembled systems shall be made only on the basis of their functional equivalency (EN 15978:2011).

Bearing in mind the ongoing standardization process and the future requirements that will be promoted within the European context, the purpose of the present work is to analyse the current scenario of the environmental building assessment practices as a basis to highlight the importance of harmonization in this field.

Methodology

In a first step, more than 80 case study publications corresponding to the period 2001-2011 were systematically reviewed in order to describe and classify the results of LCA studies in terms of goal and scope and practical methodology implications. It was observed that several studies were focused on building materials and components.

Publications related to LCA of the whole process of the construction were selected for a further analysis, following a multicriteria perspective of transparency, accessibility and geographic diversity. The selected case study publications are shown in Table 2.

For the purpose of this work, buildings are categorised according to their usage. Residential buildings are defined as buildings primarily constructed for residential occupancy. The classification for residential buildings was defined according to IMPRO-Building Project (Nemry et al., 2008):

- Single-family houses: Single-family houses include individual houses that are inhabited by one or two families. Also terraced houses are assigned to this group.
- Multi-family houses: contain more than two dwellings in the house.
- High-rise buildings were defined as buildings that are higher than 8 storeys.

Non residential buildings are those which are used for commercial purposes. Commercial buildings studied were classified into offices and hotels.

Table 1. Selected case study publications

Building use / Country	Reference
Residential buildings	
UK	Yohanis and Norton, 2002
Several	Kotaji et al., 2003
USA	Scheuer et al., 2003
Switzerland	Matasci, 2006
Several	Sartori and Hestnes, 2007
Scotland	Asif et al., 2007
Japan	Gerilla et al., 2007
Greece	Koroneos and Kottas, 2007
Belgium	De Meester et al., 2009
India	Shukla et al., 2009
Spain	Ortiz et al., 2009
Spain-Colombia	Ortiz et al., 2010a,b
Sweden	Gustavsson and Joelsson, 2010
Sweden	Gustavsson et al., 2010
Italy	Blengini and Di Carlo, 2010
Italy	Aste et al., 2010
Several	Sharma et al., 2011
Commercial buildings	
	Office
Finland/USA	Junnila, 2004
Thailand	Kofoworola and Gheewala, 2008
China	Xing et al., 2008
Hotel	
Spain	Rosselló-Batle et al., 2010

The degree of methodological consistency of research with the future European standard in the field of building environmental assessment has been analysed in depth. The variability associated to main hypothesis such as the equivalent functional selected and the choice of impact categories was examined in relation to EN 15643-1:2010 and EN 15978:2011 standards as follows:

Functional equivalent

According to EN 15643-1:2010, the functional equivalent of a building or an assembled system (part of works) shall include but is not limited to information on the following aspects:

- Building type (e.g. office, factory, etc.);
- Pattern of use (e.g. occupancy);
- Relevant technical and functional requirements (e.g. regulatory framework and client's specific requirements);
- Required service life.

The standard states that "Other specific requirements and exposure to climate and to other conditions from the immediate surroundings may be relevant for inclusion in the information on the functional equivalent".

Environmental indicators

Predetermined indicators that shall be included in the assessment are summarized in Table 2. The environmental indicators used in the EN 15978:2011 standard represent the quantified environmental impacts and aspects caused by the object of assessment during its whole life cycle. Indicators have been chosen on the basis that there are agreed calculation methods for the indicators referred to in this European Standard. Other indicators, for which there is no scientifically agreed calculation method within the context of LCA - e.g. human toxicity, eco-toxicity, biodiversity, land use - are not included.

Table 2. Indicators describing environmental impacts. Source: EN 15978:2011.

Indicator	Unit
Global warming potential (GWP)	kg CO ₂ equiv
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC 11 equiv
Acidification potential of land and water (AP)	kg SO ₂ equiv
Eutrophication potential (EP)	kg (PO ₄) ³⁻ equiv
Formation potential of tropospheric ozone photochemical oxidants (POCP)	kg Ethene equiv
Abiotic resource depletion potential for elements (ADP_elements)	kg Sb equiv
Abiotic resource depletion potential of fossil fuels (ADP_fossil fuels)	MJ, net calorific value

Following these two main methodological aspects, the discussion of the degree of consistency of research with the future European standard is presented. Finally, the need for a harmonization process is outlined, identifying major obstacles and opportunities.

Results and discussion

The study of building characteristics in different geographical contexts shows the high degree of diversity in specificity construction techniques and architectural style. We build differently because of climatic conditions, geology, different safety levels, uses and traditions. The variation in each design can affect the environment during all life cycle stages of a building.

Regarding the functional equivalent description, it is observed that pattern of use (e.g. occupancy) and relevant technical and functional requirements (e.g. regulatory framework and client's specific requirements) are not adequately described in most of the case study analyzed. With the exception of the work presented in Ortiz et al. (2009) and Aste et al. (2010), the description of the scope of the studies does not meet the requirements of European standards to ensure comparability of results. The most common required service life established is 50 years in most of the case studies, but it also varies, reaching 100 years in Gustavsson et al. (2010).

It should be noted that there is no specific mention of occupancy or use patterns, factor highly relevant in relation to the environmental impacts associated to the use phase of the building. As a general rule, the results of the studies indicate that when building is used for the purpose for which it is constructed, the maximum energy consumption is during the use phase.

With respect to the environmental categories under study, the review has demonstrated that most LCA studies focus on energy consumption. Although studies have been focused on energy use and greenhouse gas emissions (GHC), the concept of CO₂ equivalent emissions has not been correctly introduced in many cases, restricting the analysis to CO₂ emissions as the only element considered (excluding, the remaining GHC).

The results of IMPRO-Building project showed the similarity of trends over the different impact categories when the different building types according to zones are compared. This reflects the important role of energy use in most of the environmental impacts quantified, first as a result of fuel combustion for space heating, and, second, as a result of the industry processes involved in the manufacturing of building products. Consequently, the conclusions of the project recommend both primary energy use and greenhouse gas (GHG) emissions as good proxy indicators to assess the environmental performance of the buildings (Nemry et al., 2008). Moreover, environmental burdens of global warming potential (GWP) have received special attention in the international political arena, and become a priority for improvement

actions in the European context. These two factors, coupled with the increased availability of data to quantify GHG, justify the fact that GWP has been the indicator most commonly analyzed in the literature.

Nevertheless, although they have received much less attention, some studies show the results of other environmental impacts. Six of the case studies analyzed present data related to acidification potential of land and water (AP). The environmental impact categories of depletion potential of the stratospheric ozone layer (ODP), eutrophication potential (EP), abiotic resource depletion potential for elements (ADP_elements) are found in only three of the works under study. The formation potential of tropospheric ozone photochemical oxidants (POCP) is just included in one case study.

The results of this review show the lack of consistency of research works with the future European standard and also illustrate the need for improving the harmonization of existing instruments based on life cycle approach for the assessment of the sustainability performances. Comparisons between the results of assessments of buildings or assembled systems (part of works) – at design stage or whenever the results are used – shall only be made on the basis of their functional equivalency. This requires that the major functional requirements shall be described together with intended use, and the relevant specific technical requirements. This description allows the functional equivalency of different options and building types to be determined and forms the basis for transparent and reasonable comparison (EN 15643-1:2010).

Remarkably, the building climate context is a determining factor on which guidelines of classification should be established in order to analyze the environmental performance. In recent work, there is a wide variation in energy consumption during the use phase of the building from 18.7 to 150 KWh/m²year. The valuation of the environmental of performance of the building can not be done in isolation without regard to specific geographical context. In this sense, it should be noted that the standards developed under CEN 350 framework do not set the rules for how different building assessment schemes may provide valuation methods; nor do they prescribe levels, classes or benchmarks for measuring performance. Providing guidelines and normalization factors that allow the identification of the relevance of the environmental impacts calculated in the assessment is a priority task to be performed by the scientific community towards a tangible reduction in overall environmental impact.

Final remarks and future outlook

LCA has been traditionally concerned with product design, but by limiting the functional unit of an LCA to a building material or component, a number of functions that should be provided by buildings, such as thermal conditioning, cannot be properly taken into account: decisions based on isolated LCA for materials or components might lead to erroneous conclusions. Maybe because of the complexity of the life cycle of a building, researchers in the past often opted for building materials, building products or building components as subject for LCA research. However, recently, research has been executed on the application and adaptation of the LCA framework to buildings as a whole.

The present review, though not claiming to be exhaustive, reveals the progressive evolution of LCA in the building sector during the last years. In order to contribute to a more sustainable construction it is necessary to improve the coherence, consistency and completeness of construction standards. The Commission and CEN need to seek joined-up thinking in the field of sustainability and ensure the recognition of existing standards as far as possible. Guidance should be developed by the CEN Construction Sector Network, in conjunction with CEN/TC 350, to ensure consistency between product standards and the standards for assessment of sustainable construction. In addition, the development of Building Information Modelling (BIM) should be encouraged.

The participation of all stakeholders directly concerned by the development of a standard should be promoted as a priority. Getting stakeholders involved can be accomplished by making standardization activities known, reducing thresholds, provide explanation regarding the standardization system and developing consistent data sources and metrics on “green” buildings valuation via creation of calculation software.

Adapting “real life” to the new normative environment is a challenge we are facing nowadays. By systematically directing environmental issues towards standardization, the environmental impacts of products and services could therefore be reduced. To promote an environmentally friendly construction it is necessary to define properly the basis for comparison at the building stage: to establish appropriate functional equivalent scenarios considering that the climatic area conditions relevant impacts (i.e. the ones generated by energetic consumption for conditioning purposes during the use phase) and to enforce coherent practical methodology issues.

References

- Asif, M., Muneer, T. & Kelley, R. (2007). Life cycle assessment: A case study of a dwelling home in Scotland. *Building and Environment*, 42(3), 1391–1394.
- Aste, N., Adhikari, R.S. & Buzzetti, M. (2010). Beyond the EPBD: The low energy residential settlement Borgo Solare. *Applied Energy*, 87, 629–642.
- Blengini, G.A. & Di Carlo, T. (2010). The changing role of life cycle phases, subsystems and materials in the LCA of low energy buildings. *Energy and Buildings*, 42(6), 869–880.

- De Meester, B., Dewulf, J., Verbeke, S., Janssens, A. & Van Langenhove, H. (2009). Exergetic life-cycle assessment (ELCA) for resource consumption evaluation in the built environment. *Building and Environment*, 44, 11-17.
- EN 15643-1:2010. *Sustainability of construction works - Sustainability assessment of buildings - Part 1: General framework*.
- EN 15643-2:2011. *Sustainability of construction works - Assessment of buildings - Part 2: Framework for the assessment of environmental performance*.
- EN 15643-3:2012. *Sustainability of construction works - Assessment of buildings - Part 3: Framework for the assessment of social performance*.
- EN 15643-4:2012. *Sustainability of construction works - Assessment of buildings - Part 4: Framework for the assessment of economic performance*.
- EN 15804:2012. *Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products*.
- EN 15978:2011. *Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method*.
- European Committee for Standardization (2011). *General situation of European standardization under the Construction Products Directive* [online]. Available at <http://www.cen.eu>.
- Gerilla, G.P., Teknomo, K. & Hokao, K. (2007). An environmental assessment of wood and steel reinforced concrete housing construction. *Building and Environment*, 42, 2778-2784.
- Gustavsson, L. & Joelsson, A. (2010). Life cycle primary energy analysis of residential buildings. *Energy and Buildings*, 42, 210-220.
- Gustavsson, L., Joelsson, A. & Sathre R. (2010). Life cycle primary energy use and carbon emission of an eight-storey wood-framed apartment building. *Energy and Buildings*, 42(2), 230-242.
- ISO 21930:2007. *Sustainability in building construction -- Environmental declaration of building products*.
- ISO 21931-1:2011. *Sustainability in building construction -- Sustainability indicators -- Part 1: Framework for the development of indicators and a core set of indicators for buildings*.
- Junnila, S. (2004). *The environmental impact of an office building throughout its life cycle*. Unpublished thesis (PhD.). Helsinki University of Technology Construction Economics and Management.
- Kofoworola, O.F. & Gheewala, S.H. (2008). Environmental life cycle assessment of a commercial office building in Thailand. *International Journal of LCA*, 13(6), 498-511.
- Koroneos, C. & Kottas, G. (2007). Energy consumption modeling analysis and environmental impact assessment of model house in Thessaloniki—Greece. *Building and Environment*, 42, 122-138.
- Kotaji, S., Edwards, S. & Schuurmans, A. eds. (2003). *Life cycle assessment in building and construction. A state-of-the-art report*. SETAC press.
- Matasci, C. (2006). *Life Cycle Assessment of 21 buildings- analysis of the different life phases and highlighting of the main causes of their impact on the environment*. Unpublished thesis (MSc). Université de Genève and Swiss Federal Institute of Technology Zurich.
- Nemry, F., Uihlein, A., Makishi, C., Wittstock, B., Braune, A., Wetzell, C., Hasan, I., Niemeier, S., Frech, Y., Kreibitz, J. & Gallon, N. (2008). Environmental Improvement Potentials of Residential Buildings (IMPRO-Building). Luxembourg: Office for Official Publications of the European Communities.
- Ortiz, O., Bonnet, C., Bruno, J.C. & Castells, F. (2009). Sustainability based on LCM of residential dwellings: A case study in Catalonia, Spain. *Building and Environment*, 44, 584-594.
- Ortiz O., Castells, F. & Sonnemann, G. (2010a). Life cycle assessment of two dwellings: One in Spain, a developed country, and one in Colombia, a country under development. *Science of the Total Environment*, 408(12), 2435-2443.
- Ortiz O., Castells, F. & Sonnemann, G. (2010b). Operational energy in the life cycle of residential dwellings: The experience of Spain and Colombia. *Applied Energy*, 87(2), 673-680.
- Rosselló-Batle, B. et al. (2010). Energy use, CO₂ emissions and waste throughout the life cycle of a sample of hotels in the Balearic Islands. *Energy and Buildings*, 42(4), 547-558.
- Sartori, I. & Hestnes, A.G. (2007). Energy use in the life cycle of conventional and low energy buildings: A review article. *Energy and Buildings*, 39, 249-257.
- Scheuer, C., Keoleian, G.A. & Reppe, P. (2003). Life cycle energy and environmental performance of a new university building: modeling challenges and design implications. *Energy and Buildings*, 35, 1049-1064.
- Sharma, A. et al. (2011). Life cycle assessment of buildings: A review. *Renewable and Sustainable Energy Reviews*, 15, 871-875.
- Shukla, A., Tiwari, G.N. & Sodha, M.S. (2009). Embodied energy analysis of adobe house. *Renewable Energy*, 34(3), 755-761.
- Xing, S., Xu, Z. & Jun, G. (2008). Inventory analysis of LCA on steel- and concrete-construction office buildings. *Energy and Buildings*, 40, 1188-1193.
- Yohanis, Y.G. & Norton, B. (2002). Life-cycle operational and embodied energy for a generic single-storey office building in the UK. *Energy*, 27, 77-92.

Sustainability assessment tool of green building renovation in Taiwan: an introduction to EEWH-RN

Chung-Yi Chang

Department of Architecture

National Cheng-Kung University, Tainan, Taiwan

joybox2003@hotmail.com

Hsien-Te Lin

Department of Architecture

National Cheng-Kung University, Tainan, Taiwan

linsiraya@yahoo.com.tw

Ming-Chin Ho

Architecture and Building Research Institute

Ministry of the Interior, Taipei, Taiwan

ho@abri.gov.tw

The Green building evaluation system, EEWH, has been widely promulgated in Taiwan building construction since its establishment in 1999. However, the potential energy savings and sustainability improvement of existing buildings have not been explored. In response, the Taiwanese government developed a sustainable assessment tool called EEWH-RN in 2010 that focuses on Green building renovation and, in doing so, became the fourth member of the EEWH evaluation family. While introducing two evaluation methods of EEWH-RN (i.e. the EEWH performance method and carbon reduction method), this study assesses the improved EEWH performance and carbon reduction ratios, based on examples of the Green Building Renovation Plan funded by the Taiwanese government. In addition to providing a valuable reference for devising a preliminary EEWH-RN rating standard, results of this study significantly contribute to future policy making decisions for Green buildings renovation in Taiwan.

© 2012 Green Lines Instituto para o Desenvolvimento Sustentável. All rights reserved.

Introduction

Among the numerous building sustainability assessment tools developed in the last two decades include BREEAM, LEED, SBTool, CASBEE, and Green Star. Taiwan's Green building evaluation system, EEWH, became the fourth building sustainability assessment tool worldwide in 1999, behind BREEAM, LEED and GBTool, and the first system developed specifically for tropical and subtropical climates. Taiwan demonstrated its determination in promoting green building by mandating that all new public buildings with total construction costs exceeding \$US 1.67 million obtain EEWH Green Building Candidate certification before receiving a construction permit. Upon completion of building construction, Green Building Label certifications must also be acquired for building use license. Until now, the EEWH evaluation system was applied to 3164 Green Building Candidate and Green Building Label certifications in Taiwan.

Despite the success of above legislative efforts in regulating the sustainable quality of new buildings in Taiwan, permit applications for new construction projects have gradually reduced annually owing to highly developed land-use. Statistics indicate that newly constructed buildings reduced to just 3% of the total building stock during 1990 to 2008, while existing buildings represented 97%. The lack of sustainability design concepts in existing buildings often leads to inferior green building performance and wasted energy consumption. A research program was subsequently initiated to devise a Green Building evaluation tool specific for building renovation. Following a survey of worldwide sustainability assessment tools for existing building and previous experiences of Taiwan's Green Building Renovation Plan, the fourth member of the EEWH evaluation family, EEWH-RN (Renovation), was officially launched in 2010.

Background of Sustainability Assessment tools for existing building

This study investigated three major sustainability assessment tools developed specifically for existing buildings (i.e. BREEAM, LEED and CASBEE).

BRE Environmental Assessment Method (BREEAM) of the United Kingdom is an environmental assessment tool for use in the design, construction, and refurbishment stages of a broad range of building types. Schemes focusing on existing buildings include BREEAM In-Use and BREEAM Refurbishment (Domestic & Non-domestic). BREEAM In-Use was developed to encourage better building management and to reduce energy consumption in existing building, while BREEAM Refurbishment is scheduled for completion in early 2012.

LEED developed in the United States is one of the most recognized assessment tools globally. Eight building-oriented assessment schemes are currently available. The LEED for Existing Buildings (LEED-EB) was established to evaluate the operating efficiency of existing buildings, as well as their environmental impact and maintenance. The energy performance must be based on metered energy consumption of 12 continuous months.

In Japan, the core concept of CASBEE assessment is building environmental efficiency (BEE). CASBEE-EB (Existing Building) targets existing building stock, based on operation records for at least one year and measurement value of indoor environment quality after completion. Also, CASBEE-RN (Renovation) attempts to determine the degree of increased building environmental efficiency (ΔBEE) or energy saving (ΔBEE_{ES}) before and after renovation.

Most policies and certifications of building sustainability assessment tools worldwide focus on newly constructed buildings. However, according to related studies, the fact that current legislative efforts are insufficient to achieve national environmental or carbon reduction targets (Radhi, 2009), demonstrates the necessity of voluntary initiatives such as building renovation, equipment system retrofit or building energy management. Although the above mentioned building sustainability assessment tools differ in categories, score systems, and assessment schemes (see Table 1), environmental impact and energy use are of priority concern. However, older buildings find it extremely difficult to achieve EB certification, while the EB standard is nearly the same or slightly lower than the new construction (NC) standard. For instance, despite the promulgation of LEED-EB and CASBEE-EB since 2004, relatively few certified buildings exist in comparison with the success of the NC scheme (Ciochetti & McGowan, 2010).

Table 1. Characteristic of Building sustainability assessment tools for existing building.

BAS Tools	Country	Categories and Weightings	Scoring system	Rating
BREEM In-Use	UK (2009)	Energy (26.5%) Water (8%) Materials (8.5%) Waste (5%) Health & Wellbeing (17%) Pollution (14%) Transport (11.5%) Land use & Ecology (9.5%)	The points each category is attain in weighted according to the perceived importance of their environmental impact	Pass Good Very Good Excellent Outstanding
LEED-EB	USA (2004)	Sustainable sites (26) Water efficiency (14) Energy & Atmosphere (35) Materials & resources (10) Indoor environmental quality (15) Innovation (6) Regional priority (4)	The allocation of points between credits is given based on the environmental impact of each category	Certified Silver Gold Platinum
CASBEE-EB	Japan	Q1.Indoor environment Q2.Quality of service Q3.Outdoor environment on site L1.Energy L2.Resources & Materials L3.Off-site environment	1-5 score levels apply to concerned items in each category (Q: Quality of building; L: Environmental load; BEE: Q/L)	Poor Fairy poor Good Very Good Excellent

Green Building evaluation family in Taiwan

The development of EEWB evaluation family involved collaboration between scholars, research institutions, companies and organizations under research programs were funded by the Architecture and Building Research Institute (ABRI) of Taiwan. EEWB evaluation systems are categorized according to ecology, energy saving, waste reduction, and health (EEWB). Each category has weighted and accumulative indicators with different scoring ranges, totaling 100 maximum points (continuous and including decimal points), and graded on five rating levels: Diamond, Gold, Silver, Bronze and Qualified. By using progressive formulas in each indicator, the EEWB scoring system differ from the point system of

BREEAM and LEED, thus avoiding drawbacks such as an overemphasis on simplified quantifications and priority consideration over easy yet non-environmental related factors (Humbert et al., 2007).

Enacted in 1999, the first edition of EEWB Green Building evaluation system is extensively adopted for newly constructed buildings. However, applying a single evaluation system for various building types is clearly insufficient and fails to develop the full potential of green building evaluation systems. ABRI subsequently amended the original Green Building evaluation system and named it EEWB-BC (Basic Version). Accompanied by four specific evaluation systems, EEWB-RS (Residential), EEWB-GF (Green Factory), EEWB-RN (Renovation) and EEWB-EC (Ecological Community), a complete EEWB evaluation family was formed in 2011. EEWB-BC, EEWB-RS and EEWB-GF are applied to new and existing building (see Table 2), while EEWB-RN evaluates the improved green building performance and energy efficiency before and after renovation.

Table 2. Indicators and applicable schemes for EEWB-BC, EEWB-RS and EEWB-GF.

System	Categories	Indicators	Schemes
EEWB-BC (2011)	Ecological	Biodiversity Greenery On-site Water Retention	New or existing buildings not covered in EEWB-RS and GF (Total score: 100)
	Energy Savings	Daily Energy Savings Building envelope AC systems Lighting systems	
	Waste Reduction	CO ₂ Reduction Construction Waste Reduction	
	Health	Indoor Environment Water Resource Sewage & Garbage Improvement	
EEWB-RS (2011)	Ecological	Biodiversity Greenery On-site Water Retention	New or existing residential buildings served for long or short term accommodation (Total score: 100)
	Energy Savings	Daily Energy Savings Building envelope U value of exterior wall U value of windows AC systems Lighting systems Fix equipment	
	Waste Reduction	CO ₂ Reduction Construction Waste Reduction	
	Health	Indoor Environment Water Resource Sewage & Garbage Improvement	
EEWB-GF (2010)	Required	Executives Promise Equipment TAB verification	New or existing factories with primarily indoor operations (Total score: 100)
	Ecological	Greenery On-site Water Retention	
	Energy Savings	Daily Energy Savings Building envelope AC systems Lighting systems (Energy cost method)* Green transportation Renewable energy	
	Waste Reduction	CO ₂ Reduction Construction Waste Reduction Daily Water Saving Sewage & Garbage Improvement	
	Health	Indoor air quality controls Indoor Acoustic environment Indoor Lighting environment Indoor Ventilation Interior Building Materials (Low-VOC) Recreation and Health Management	

*An optional energy cost simulation by software such as DOE-2, e-QUEST, Energy plus...etc

Considerations in the tool development process

Green Building renovation plan of Taiwan

This study examined Taiwan's previous experiences of building retrofitting. Between 2002 and 2011, the Taiwanese government invested \$US 56.7 million in a program aimed at renewing existing buildings, called the Green building renovation plan (GBRP). In the recent decade, 468 government buildings and national universities were renovated as model projects for green building renovation. Only one or two improvement measures were normally adopted owing to financial and technical constraints. Equipment system retrofitting is the most frequently adopted improvement measure, followed by building envelope/shading improvement and on-site water retention improvement (see Table 3). Indoor environment improvement and utilization of renewable energy are less frequently adopted because of related technical difficulties, higher equipment prices, and lack of public awareness. Equipment retrofit measures applied to existing buildings include high performance AC systems, energy-saving lighting systems, heat pump systems, and energy management. Investment costs for equipment system retrofit are around \$US 100,000, while other improvement measures of GBRP cost \$US 134,000.

Table 3. Adopted frequency of improvement measures for Green Building Renovation Plan

Adopted measures in one case	Amount of cases	Improvement measures adopted in GBRP	Adopted frequency (times)
One measure	293	Equipment system retrofit	426
Two measures	129	Building envelope/opening shading	82
Three measures	28	On-site water retention	63
Four measures	13	On-site greenery/roof garden	56
Five measures	1	Utilization of water-saving systems	52
Six measures	3	Indoor environment improvement	20
Seven measures	1	Renewable energy utilization	18

Basic considerations of Taiwan's EEWH-RN

Conventional assessment tools incorporate two applicable schemes for existing building: a) operating efficiency and environmental sustainability (EB) and b) improved performance after renovation (RN). For most existing buildings in Taiwan, the EB standard is difficult to achieve without significant retrofitting costs and efforts. Owing to widely anticipated applications, EEWH-RN is assumed to be flexible, quantifiable, achievable, and structure under the existing EEWH Green Building evaluation systems (e.g. EEWH-BC, RS and GF). Considering the experiences of implementing GBRP, the potential energy savings and carbon reduction are equally important as improving green building performance. Moreover, financial and technical difficulties in the renovation process explain why the rating standard of EEWH-RN should not be too high in order to encourage voluntary green building renovation.

Evaluation methods of EEWH-RN

EEWH renovation performance and carbon reduction performance are two methods to evaluate the EEWH-RN system. The former evaluates the overall improved green building performance based on the scores of EEWH systems, while the latter focuses on improving equipment systems, resulting in carbon reduction and energy savings during operations. Applicants can choose the most favorable or most easily implemented methods for evaluation.

EEWH renovation performance method

New or existing buildings can apply for EEWH-BC, EEWH-RS and EEWH-GF certification if compliant with requirements. EEWH performance represents the scores under its 100 maximum points system. For renovated building, EEWH renovation performance represents the improved ratio of EEWH performance scores (ΔRSr) under the same criteria as EEWH-BC, EEWH-RS and EEWH-GF, where the maximum improvement potential RSc ($RS_{max} - Rsb$) as the denominator and the improved EEWH performance scores ΔRS ($Rsa - Rsb$) as the numerator. The EEWH renovation performance (ΔRSr) is determined using Eq.1.

$$\Delta RSr = \left(\frac{RSa - Rsb}{RS_{max} - Rsb} \right) \times 100\%$$

(1)

Where R_{sb} = EEW performance scores before renovation; R_{sa} = EEW performance scores after renovation; and R_{smax} (maximum achievable scores) = maximum scores determined based on previous certified buildings, 70 points for BC and RS; and EEW-GF with a central AC systems and a non-central AC systems have 83 points and 73 points, respectively.

Carbon reduction performance method

The carbon reduction performance method focuses on improving the efficiency of equipment systems such as AC systems, lighting systems, and heating systems, as well as incorporating renewable energy use. However, equipment systems vary in energy source requirements (e.g., electricity, fuel, and gas), explaining why the corresponding energy use must be converted into equivalent CO_2 emissions before and after renovation while, simultaneously, calculating the annual carbon reduction ratios (ΔCR_r). Here, the carbon reduction performance is determined using Eq.2, where the annual carbon emissions before renovation (CE_b) is assumed to be the denominator and the reduced annual carbon emissions ΔCR ($CE_b - CE_a$) is assumed to be as the numerator.

$$\Delta CR_r = \left(\frac{CE_b - CE_a}{CE_b} \right) \times 100\% \quad (2)$$

Where CE_b = the annual carbon emissions before renovation ($kg-CO_2/yr$), and CE_a = the annual carbon emissions after renovation ($kg-CO_2/yr$).

Equipment renovation involves a central AC systems, the annual energy consumption can be calculated by simulation software such as DOE-2, e-QUEST, or Energy plus. For a lighting systems, non-central AC systems renovation or renewable energy utilization, the reduced annual carbon emissions (ΔCR) can be determined using simplified calculations such as improved equipment efficiency multiplied by annual operating hours. All central AC systems renovation must be verified by testing, adjusting, and balancing (TAB) to ensure that systems are functionally tested and operated.

EEWH-RN rating scores

EEWH-RN uses the same five rating levels as the other EEW systems do. The improved ratio (%) of the EEW renovation performance and carbon reduction performance are rated as Qualified ($5\% \leq \Delta RS_r$ or $\Delta CR_r < 10\%$), Bronze ($10\% \leq \Delta RS_r$ or $\Delta CR_r < 14\%$), Silver ($14\% \leq \Delta RS_r$ or $\Delta CR_r < 17\%$), Gold ($17\% \leq \Delta RS_r$ or $\Delta CR_r < 20\%$) and Diamond ($20\% \leq \Delta RS_r$ or ΔCR_r).

Applicability and calibration of rating system

This study tests and calibrates the EEW-RN rating system by selecting a renovated wine storage warehouse as a case study for the EEW renovation performance method. Before renovation, the building condition was very poor, as evidenced by problems such as insufficient greenery and on-site water retention, unfit insulation and poor indoor environment, and inefficient water appliances. In 2005, as a demonstrated project of GBRP, this building received funding of over \$ US 1.06 million for renovation into a government office. Following the adoption of various improvement measures, the improved ratio of EEW performance scores (ΔRS_r) is 58.63% under the EEW-BC criteria (see Table 4), which qualifies for Diamond certification of EEW-RN (Lin et al., 2010). However, for most renovated buildings that could only afford to adopt one or two improvement measures in GBRP, the expected ΔRS_r is about 7.3 ~ 13.6%, which is Qualified or Bronze certification.

Table 4. Improvement measures and scores of renovated wine storage warehouse

Indicator	Improvement measures	RSa	RSb
Biodiversity	Site is smaller than one hectare hence exempted from evaluation	-	-
Greenery	Increase on-site greenery and adopt roof garden with shrubs and vines	0.00	3.29
On-site Water Retention	Increase permeable paving, roof garden soil and rainwater retention pond	0.00	2.18
Daily Energy Savings-Building envelope	improve roof/wall insulation and install horizontal/vertical shading for openings	3.00	4.47
AC systems	Install high efficiency chiller/air-to-air heat exchanger/ CO_2 sensors/nature ventilation tower	3.00	4.63
Lighting systems	Install daylight guide plates/task-ambient lighting systems/high efficiency lamps & ballasts	3.00	5.17

Table 4. Improvement measures and scores of renovated wine storage warehouse (continued)

CO ₂ Reduction	Old building structure conservation/light partition/durability pipe design	1.50	8.00
Construction Waste Reduction	Balance of excavation earth/air pollution control during renovation	0.70	3.29
Indoor Environment	Improve indoor acoustic/lighting/ventilation environment and adopt green materials	0.00	3.68
Water Resource	Install saving toilets, urinals, taps and rainwater recycling system	1.50	6.50
Sewage & Garbage Improvement	Install sewage/garbage facilities and recycling receptacles	1.50	2.01
Total scores		14.20	43.22
RSmax =	70-6.3=63.7(6.3 corresponding points was deducted from RSmax when exempted from the Biodiversity indicator)		
RSc=RSmax-ΣRSb=	63.7-14.2= 49.5		
ΔRSr=ΔRS/RSc=	29.02/49.5=58.63%		



Figure 1. Wine storage warehouse before and after renovation.

In a case study of the carbon reduction performance method, this study calculates the potential energy savings of 16 interior lighting systems retrofitting projects in 2009, and 12 AC systems retrofitting projects in 2010 associated with GBRP. In Taiwan, the AC systems and lighting systems consume almost 45% and 35% of total energy use, respectively. Reducing AC systems and lighting systems energy consumption are thus highly promising means of reducing carbon emissions during operations, as well as the easiest means of construction. The main measures for GBRP AC systems retrofit include testing, adjusting, and balancing (TAB); install building energy manager system (BEMS); replace over-designed chiller with smaller capacity one; install frequency conversion to original systems, so as to become variable water volume(VWV) and variable air volume(VAV) systems; utilize CO₂ concentration control and pre-cooling air systems.

A previous study demonstrated that AC systems retrofit can reduce total energy use by 11.75%(Chang et al., 2012.); meanwhile, replacing T8 fluorescent lamps with T5 fluorescent lamps and LED indicator lights can achieve a 10-17.5% reduction in energy consumption for existing buildings (Chang & Lin, 2011.). Because all retrofitting projects use only electricity for energy source, the annual carbon reduction ratios (ΔCR_r) of AC systems and lighting systems retrofitting appear to be around 10%, which roughly qualifies for Bronze certification of EEWH-RN.

As for above mentioned considerations of EEWH-RN, that the rating standard should not be too high for most GBRP projects. Both case study results of the EEWH renovation performance method and carbon reduction performance method demonstrate that the current rating system for EEWH-RN is practical, achievable and conducive to the experiences of green building renovation in Taiwan.

Conclusions

Given growing public awareness of global sustainability, improving the green building and energy performance of existing buildings is undoubtedly of priority concern in developing building sustainability assessment tools. However, mandating that existing buildings with inferior sustainability performance achieve the same standard as newly constructed buildings is impractical without a large amount of money and effort invested. For most common buildings, the desired evaluation standard appears to be the degree of increased performance after renovation. To facilitate a voluntary upgrade of sustainability performance and efficient energy performance for existing buildings, the Taiwanese government devised a sustainability assessment tool EEWH-RN, based on the structure of EEWH Green Building evaluation systems (e.g., EEWH-BC, RS and GF). In addition to the EEWH renovation performance, the carbon reduction performance is also an alternative method for EEWH-RN evaluation.

In summary, EEWH-RN provides two generalized approaches for dealing with sustainable renovation and improving the efficiency of equipment systems. However, even with considerable effort and money, the improved performance is limited due to financial and technical difficulties in renovation projects. Owing to widely anticipated applications, the rating system of EEWH-RN is calibrated in this study and demonstrated to be an achievable standard. Meanwhile, regulation policies aimed at the design and construction of new buildings should maintain a high standard to fully optimize the potential sustainability in all building stages.

References

- Chang, C.Y. & Lin, H.T. (2011). Energy saving and payback period for retrofitting of lighting systems in Taiwan. *Applied Mechanics and Materials*, 71-78, 2190-2195.
- Chang, C.Y., Lin, H.T., Tzeng, C.T., Yang, K.H., Chuah, Y.K. & Ho, M.C. (2012). Energy saving and payback period for retrofitting air conditioning systems in Taiwan. *Applied Mechanics and Materials*, 121-126, 2850-2854.
- Ciochetti, B.A. & McGowan, M.D. (2010). Energy Efficiency Improvements: Do they pay? *The Journal of Sustainable Real Estate*, 2(1), 305-333.
- Humbert, S., Abeck, H., Bali, N. & Horvath, A. (2007). Leadership in Energy and Environmental Design (LEED) A critical evaluation by LCA and recommendations for improvement. *International Journal of LCA*, 12(1), 46-57.
- Lin, H.T., Chang, C.Y. & Ho, M.C. (2010). *Green Building Evaluation manual for Building Renovation*. Taipei: Architecture and Building Research Institute, Ministry of the Interior.
- Radhi, H. (2009). Can envelope codes reduce electricity and CO₂ emissions in different types of buildings in the hot climate of Bahrain? *Energy*, 34(2), 205-215.

Acknowledgements

The authors would like to thank the Architecture and Building Research Institute, Ministry of the Interior for the financial support and data providing.



Patterns in green building practice: analysis of LEED project data

Joel Anne Todd

Environmental Consultant, Cabin John, Maryland, USA

joeltodd@cpug.org

Robert Tufts

U.S. Green Building Council, Washington, DC, USA

Over the past decade, the field of building sustainability assessment has matured, with an increasing number of assessment systems and countries implementing such systems. There have been many studies comparing the methodologies used by these certification systems, but there has been little quantitative analysis of the projects that have achieved certification. This paper analyzes data on LEED-certified projects in the United States. This research will contribute to a better understanding of the certification systems in practice, their effects on practitioners and markets, and trends in markets and practice over time.

© 2012 Green Lines Instituto para o Desenvolvimento Sustentável. All rights reserved.

Introduction and methodology

The U.S. Green Building Council launched its LEED Rating System in 1998; since then, LEED has undergone several significant updates, most recently in 2009 with another update projected in 2012, and has expanded to include new markets and building types. Since 2000, LEED has certified 12,320 projects worldwide under the commercial rating systems with 11,329 in the United States; LEED for Homes and LEED for Neighborhood Development are excluded (USGBC LEED Project Database, 2012). The numbers of projects certified under the various versions of the LEED Rating System are summarized below (USGBC LEED Project Database, 2012)

New Construction	6410
Commercial Interiors	2535
Existing Buildings	1679
Core and Shell	964
Schools	286
Retail (Interiors)	260
Retail (New Construction)	195
Total	12,329

LEED certifies projects at four levels: Certified (the lowest), Silver, Gold, and Platinum (the highest). The versions of LEED addressed in this paper – LEED for New Construction, Existing Buildings, Core and Shell, and Commercial Interiors – contain prerequisites and credits in the following categories:

- The Sustainable Sites, which addresses project location, access to alternative transportation, site development, stormwater control, heat islands, and light pollution.
- Water Efficiency, which addresses overall water use reduction from landscaping and domestic water consumption.

- Energy and Atmosphere, which addresses energy performance, commissioning, refrigerants, renewable energy, green power, and measurement and verification.
- Materials and Resources, which addresses building and materials reuse; use of recycled content materials, local materials, rapidly renewable materials, and certified wood; and construction waste management.
- Indoor Environmental Quality, which addresses indoor air quality, ventilation, low-emitting materials, control of environmental tobacco smoke and indoor chemicals/ pollutants, controllability of systems, thermal comfort, and daylight/ views.
- Innovation in Design, which includes the LEED Accredited Professional and credits which can be earned for exemplary performance or innovative strategies. This category of credits is not included in this analysis since the content varies widely.

More information on the LEED Rating System can be found on the USGBC web site.

The analysis is based on a USGBC database that contains information from certified projects that has been gleaned from the LEED Online system. In order to have a concise analysis, we queried projects from the database that were only located in the United States and we did not include any projects that were residential or owned by foreign governments. The analysis updates and compares findings reported in a paper presented at the SB11 conference in Helsinki with data currently available in the database (Todd et al, 2011). This updated analysis includes more recent certified projects from LEED NC 2.1 and 2.2 (the versions of the LEED Rating System addressed in the SB11 paper) as well as projects certified under LEED 2009, the more recent version. The paper also expands the analysis beyond LEED for New Construction to include LEED for Existing Buildings, Core and Shell, and Commercial Interiors.

Findings: characteristics of LEED projects

Projects by certification level

LEED contains four certification levels that are defined by the number of credits earned: Certified (the lowest), Silver, Gold, and Platinum (the highest). As an example, in LEED 2009, the levels for Building Design and Construction (new construction and major renovations) are defined as follows:

Certified	40-49 points
Silver	50-59 points
Gold	60-79 points
Platinum	80 points and above

Total points and levels were defined differently in previous versions.

As shown in Figure 1, the first projects that certified under LEED in 2000 were at the lowest, Certified and Silver, levels. There was only one Platinum project and no Gold projects in the first year. Over time, however, the percentage of projects certifying at higher levels has increased, with Gold certification becoming the highest percentage of total projects certified in 2009. The percentage of projects at the Certified level has decreased significantly. Platinum projects have remained a small and relatively stable percentage of the total although the total number of Platinum projects has increased.

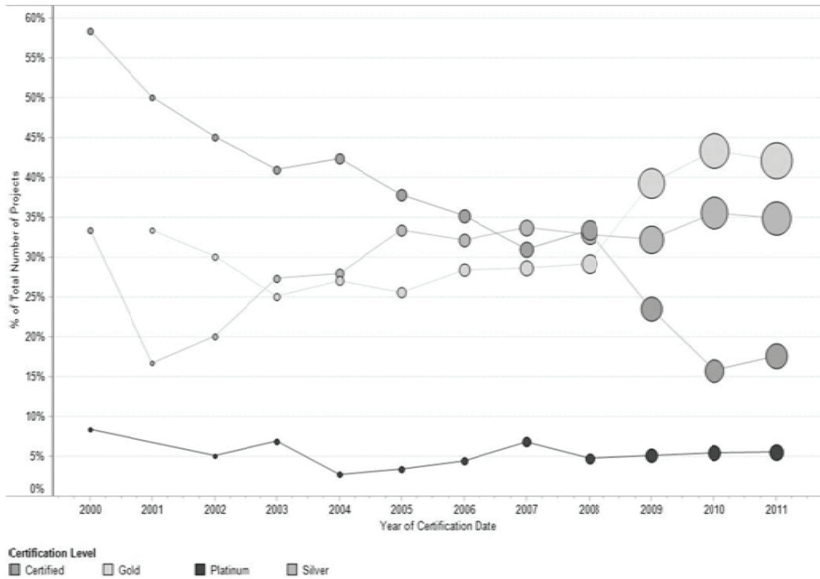


Figure 1. Yearly trend of % of projects certified by achievement level and sized by number of projects certified each year.

When certification levels are examined by rating system (New Construction, Existing Buildings, Core and Shell, and Commercial Interiors) as shown in Figure 2, trends emerge. In New Construction, Certified projects have decreased consistently as a percentage of total projects certified yearly while Gold projects has increased. The percentage of Platinum projects has not changed significantly. In 2008, there was a noticeable increase in Certified projects under the Existing Buildings and Commercial Interiors systems, but the levels returned to pre-2008 percentages. This figure starts at 2005 since not all rating systems had certified projects until that year.

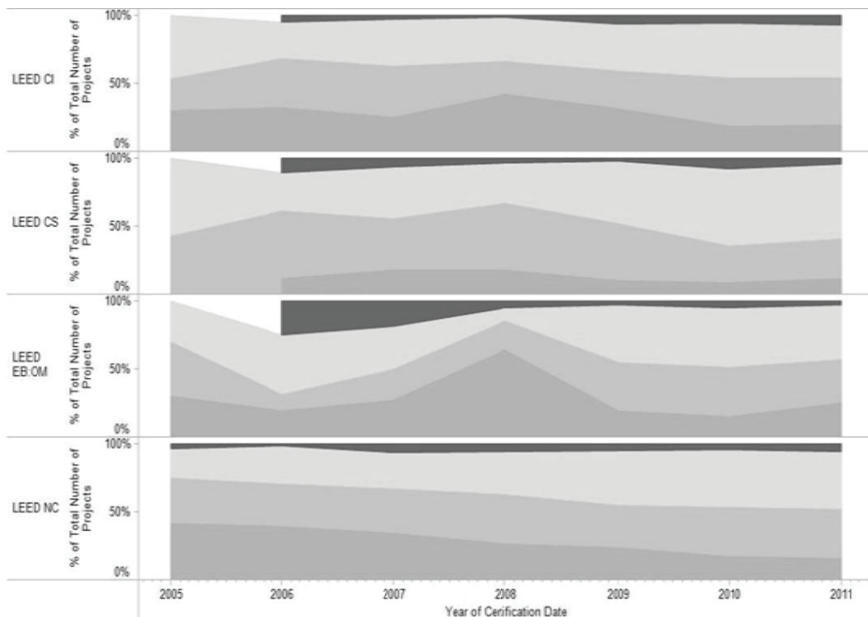


Figure 2. Yearly trend of % of level of achievement for certified projects listed by rating system.

Projects by size

LEED projects include a wide range of sizes, from small offices to huge skyscrapers. This analysis explored whether the size of the project related to other characteristics.

There is variation among rating systems in the total floor area represented at different certification levels in the rating systems. As Figure 3 shows, projects certified under LEED for Existing Buildings are, on average, larger than projects in other certification systems. For example, the average project size for Gold level projects is 516,006 sq ft, while the average project sizes are 104,928 sq ft for New Construction projects, 237,127 for Core and Shell, and 50,788 sq ft for Commercial Interiors projects.

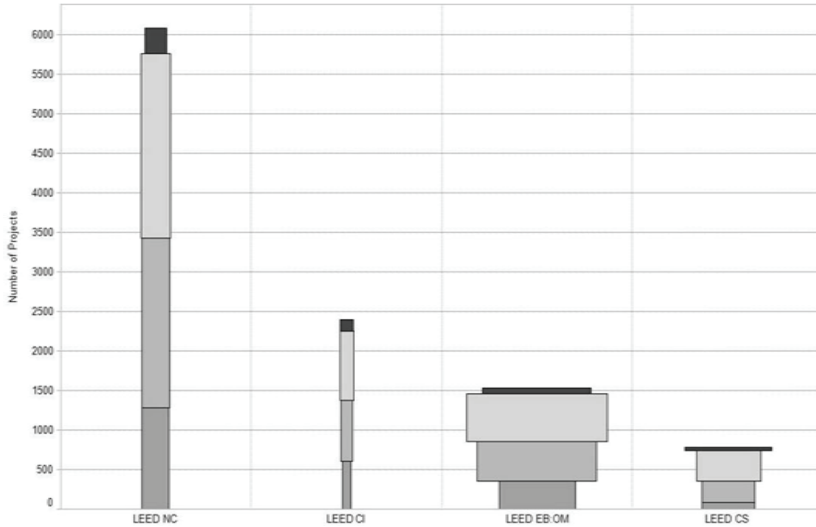


Figure 3. Number of certified project for each rating system shaded by the level of achievement and sized by the average gross square footage for each level of achievement.

Figure 4 shows the number of projects and their average size by rating system. Platinum continues to be the smallest number of projects in each rating system. CI and NC do not show as much variation among certification levels as do CS and EB.

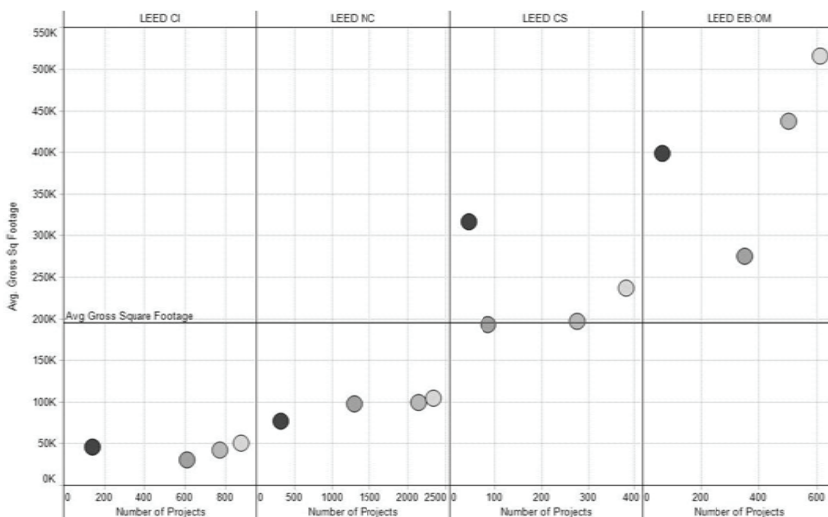


Figure 4. Number of certified projects and average gross square footage for each level of achievement within each rating system.

When LEED projects are classified by size, in increments of 50,000 sq ft, the largest category of projects is those under 50,000 sq ft, as shown in Figure 5. The width of the bars illustrates the total number of projects. The next largest category is 50,000 to 99,000 sq ft, then 100,000 to 149,999 and larger than 500,000 sq ft, which have a similar number of projects. While there is some variation in percentages of projects at each certification level within each size category, the percentages are quite similar across size categories for each level.

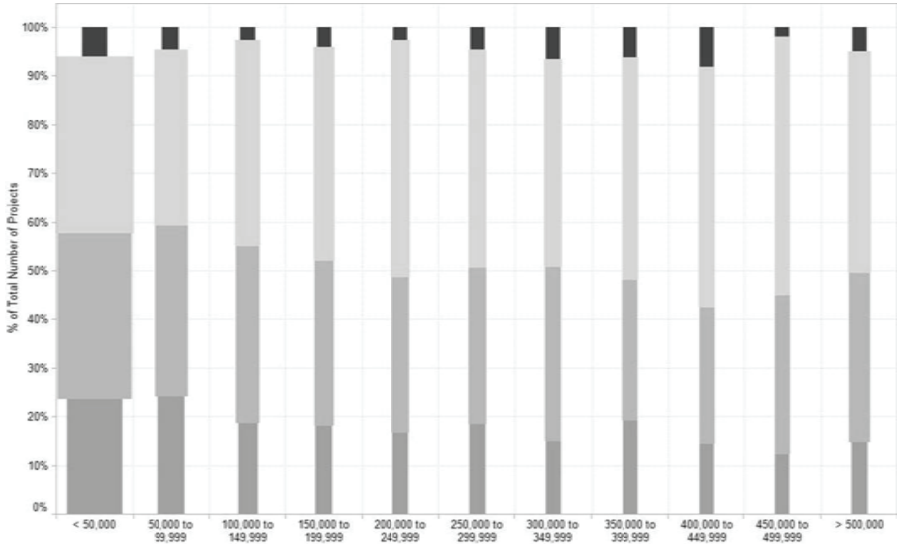


Figure 5. Certified projects grouped in bins 50,000 gsf . Colored by percent of level of achievement for projects within each grouping. Sized (width) by number of projects.

Figure 6 clearly indicates that total number of projects and total floor area certified at each level over time vary independently. The trends in total numbers of projects certifying at each level show increasing percentages of Gold projects and decreasing percentages of Certified projects, with more stable percentages of Platinum and Silver projects. Total floor area, shown in gross square footage, shows a similar trend in starting and ending points, but with several interruptions in the overall trend lines.

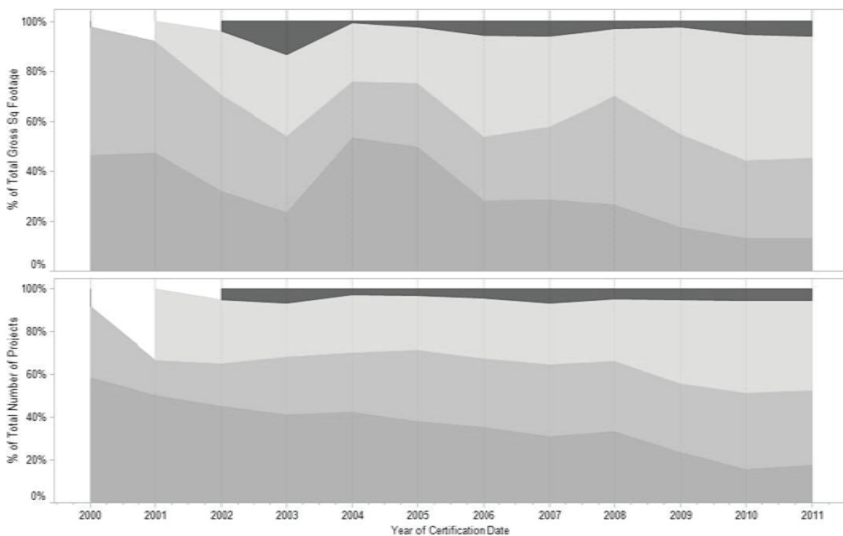


Figure 6. Yearly trend of total percentage of projects and the total percent of gross square footage colored by achievement level.

Projects by ownership

Projects show variation by type of owner. Figure 7 shows that new construction projects with corporate or investor owners tend toward lower levels of certification for all years and sizes, while projects owned by non-profits tend toward higher levels of certification. Non-profit projects have almost double the percentage of Platinum projects as compared to Gold, Silver, or Certified levels of achievement. Platinum level projects show the least difference between owner type while certified projects show the greatest difference.

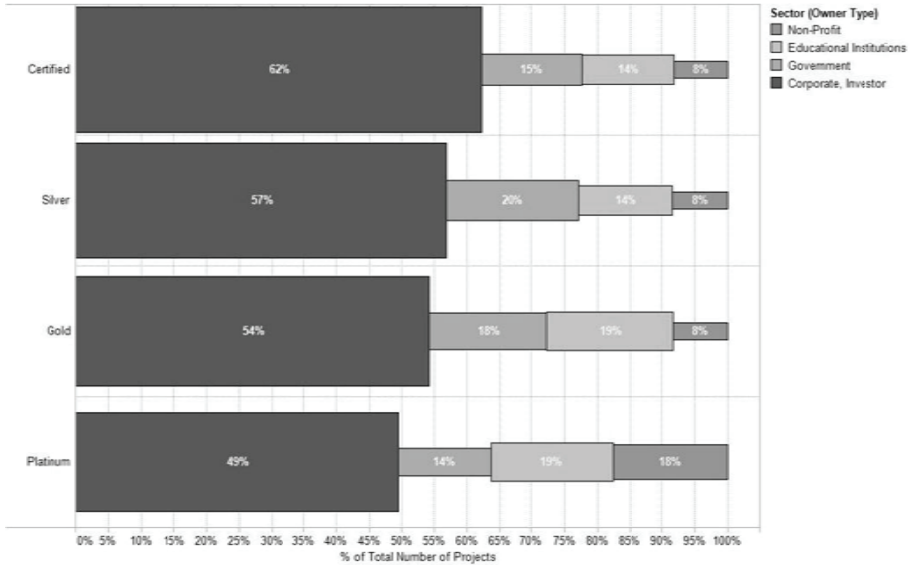


Figure 7. Percentage of ownership by achievement level (bars are sized to reinforce % of ownership).

Figure 8 shows that although non-profits account for 18% of all Platinum projects, Platinum projects only account for just over 10% of all certified projects owned by non-profits. Further, Gold accounts for the highest percentage of certified projects owned by non-profits. In fact, the trend for level of achievement of projects owned by non-profits, is similar to the trend for all certified projects.

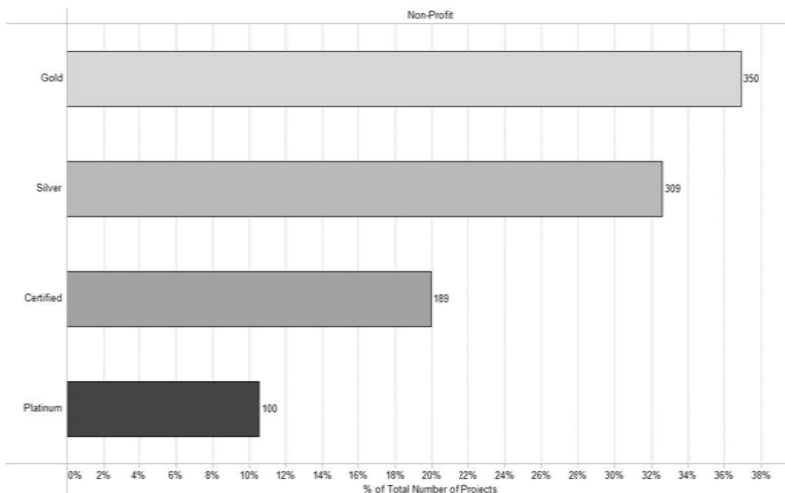


Figure 8. Percentage of projects owned by non-profits by level of achievement. Label indicates the actual number of projects.

LEED Platinum projects

The preliminary analysis conducted in 2011 focused on Platinum projects, exploring whether they were, in fact, different from other LEED certified projects in aspects other than number of points achieved. The authors updated this analysis and expanded it to include additional versions of the rating system.

To further explore Platinum projects, we looked at geographic distribution of platinum projects in relation to other certified projects in the continental United States. Figure 9 shows that while California and New York account for the largest numbers of Platinum projects, their Platinum projects are a smaller percentage of all their certified projects. States that have a high percentage of Platinum in relation to their overall number of certified projects are Montana and Oregon. The map on the right side controls for just platinum projects owned by non-profits. The trend is similar to what we see on the left. However, looking at the total number of Platinum projects in some of the states, we can start to see that non-profits do have a significant impact on the percentage of Platinum projects in certain states.

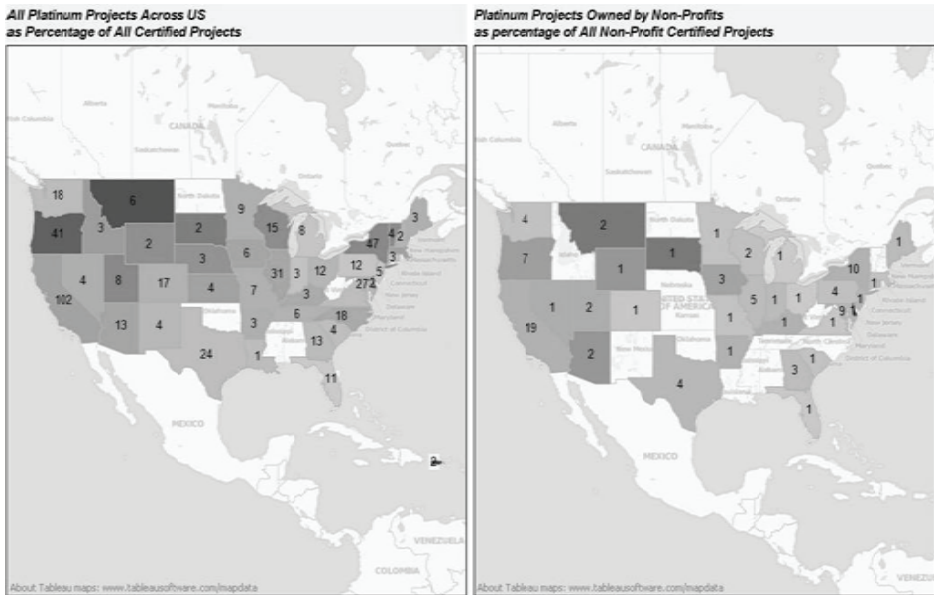


Figure 9. Map of distribution of LEED Platinum projects by U.S. states (excludes HI and AK).

Figure 10 shows trends in Platinum projects over time, by rating system and average size based on a 12-month rolling average. Platinum projects under LEED for new construction show a steady increase in size. Commercial interiors projects have seen an increase, although the overall size of these projects is much smaller on average. Core and Shell also has seen an upward trend in the average size of projects. However, the outlier is Existing Buildings. The overall trend for the average size of EB:OM Platinum projects has declined over time.

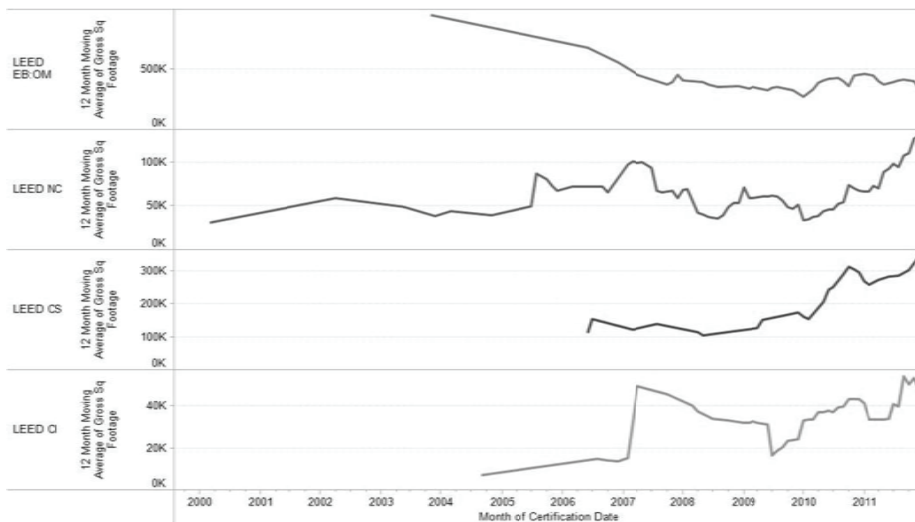


Figure 10. 12 month rolling average of certified square footage for Platinum projects.

Discussion and conclusions

The analysis presented in this paper is primarily descriptive, exploring characteristics of LEED projects, their trends, and the relationships among some of these characteristics. In most cases, the analysis is not able to explain the patterns that emerge, although the authors suggest possible connections that could be explored in future research.

The trend over time is for projects to certify at higher levels, with Gold certification becoming the largest percentage overall and having the largest number of projects in 2009 and continuing through 2011. This trend is most evident in projects certified under LEED for New Construction and Core and Shell. LEED for Existing Buildings shows a different pattern, with increases in percentage of Gold projects but a dramatic spike in Certified projects in 2007-2008. It should be noted that changes in 2009 are not likely to be associated with the new version of LEED that was released that year, since it usually takes several years for a project to progress from initial registration to final certification. The overall increase in higher levels of certification could be a reflection of several factors, although additional research would be needed to explore these ideas: the level of expertise and interest among owners and project teams has increased; green materials, services, and technologies have become more widely available; expectations of the overall market have increased; green requirements have been written in policies and government incentives; and other indicators of wider acceptance of green buildings. Further, some of the thresholds in LEED credits have not been raised significantly, so actual practice might be catching up; LEED 2012 proposes to “raise the bar” in many credits to address this issue. Finally, the impact of the economic downturn and its effect on the construction industry is not clear.

While LEED projects vary widely in size, they cluster in the smaller and very large categories. The largest number of projects is in the category less than 50,000 square feet (square meters), followed by the next largest categories, 50,000-99,999 (meters) and 100,000-149,999 (meters) square feet, and the largest category, more than 500,000 square feet (meters). The categories in between contain very similar numbers of projects. Average sizes of projects vary significantly by rating system; projects certified under LEED for Existing Buildings are much larger on average than other rating systems at all certification levels. As expected, projects certified under LEED for Commercial Interiors are smallest at all certification levels. Projects certified under LEED for Existing Buildings show the widest range of average project size by certification level, while those certified under LEED for New Construction and Commercial Interiors show much less variation. Finally, the size of project by certification level has varied over time. Certified level projects have had the most variation, while Silver projects had one spike in 2008.

Different types of owners are more likely to achieve different certification levels. Corporate/ investor owners are most likely to certify at the lower levels and non-profits have almost double the percentage of total projects certified as Platinum, as compared to all other owner types. Some factors that affect certification levels are government agency and corporate policies that mandate specific achievement levels.

The initial analysis of projects certified under LEED NC 2.1 and 2.2 indicates that Platinum projects are different from projects certifying at other levels in ways other than total point achievement (Todd et al, 2011). Some of these differences were corroborated by the current paper:

- Both papers found that Platinum projects are increasing in number but are not increasing as a percentage of total projects certified because other levels of certification are seeing larger increases in number of projects.
- Both papers found that Platinum projects tend to be smaller than projects at other certification levels.
- Both papers found that non-profit organizations most often own Platinum projects while projects at other certification levels are most often owned by for-profit organizations. Platinum projects are less likely to be owned by Federal or local governments than projects at other certification levels.

Other results of the 2011 study on credit achievement are beyond the scope of the current paper. Although the current study has added data from other rating systems and more current data, the number of Platinum projects is still small and hampers detailed analysis. For example, the analysis of location found that many states only had one Platinum project and the authors chose not to base analyses on such small numbers.

Future research would be useful in understanding the causes for some of these patterns. It would be useful to explore the extent to which patterns track with trends in the market, how differences in ownership affect certification levels, and how certification varies by space type.

References

Todd, J. A., Pyke, C. & Rohloff, A. (2011). Understanding trends in characteristics and achievement of LEED Platinum buildings. In *SB11 - World Sustainable Building Conference. Helsinki, October 2011*. Helsinki: Finnish Association of Civil Engineers RIL.

USGBC LEED Project Database, U.S. Green Building Council.

Sustainability assessment of materials used in façade cladding

Jorge Orondo

Department of Construction and Technology in Architecture

Architecture UPM, Madrid, Spain

jorgeorondo@gmail.com

Cesar Bedoya

Department of Construction and Technology in Architecture

Architecture UPM, Madrid, Spain

cesar.bedoya@upm.es

During the project process and later construction of a building, many times it will be difficult to assume the price and time of doing a complete life-cycle assessment (LCA) for each material and building system. Because of this, and until the environmental product declarations (EPD) are more extended, an assessment tool is needed in order to give quick and easily enough arguments to select the best façade cladding according to its sustainability. In this paper it is shown a sustainability assessment of ceramics cladding, by comparing its environmental and economical properties with other construction materials used in similar circumstances. As the use of the material is attached to the constructive system, it is also analyzed the most common types of façades cladding, in order to evaluate the contribution of this materials to the sustainability of the whole enclosure.

© 2012 Green Lines Instituto para o Desenvolvimento Sustentável. All rights reserved.

Introduction

Until the Industrial Revolution, the development of architecture has been taking into account the energy implications of its construction. This is evidenced in the control of resources carried out by tribal architecture, using forms of minimum consumption, adapted to the climate and executed with abundant, next and renewable materials (Araujo, 2009).

Currently, the construction and use of the buildings are responsible for 25% of the extraction of materials from the Earth's crust, 30% of CO₂ emissions, 20% of the drinkable water consumption and between 30% and 40% of the generation of solid waste (Azpilicueta, 2010). The construction sector consumes more raw materials than any other industry, extract more crude than any other sector, and the construction and operation of the buildings are at least 50% of the European energy consumption (Alvarez-Ude, 2010).

We must take into account that the building sector has been an essential component in the development of many countries, for example Spain, where 50% of the economic growth, experienced between 1998 and 2008, is related to construction (Raya et al., 2011). In that period it has been built approximately 30% of all the square meters built by today in Spain, mobilizing large amounts of manpower, generating a demand of materials that allowed industrial development in that area, and holding a financial system intended to enable the economic resources to manage the sector and allow the marketing of their products (Cuchí, 2010).

It is a fact that today there is a particular alliance between market, advertising and ecology, which requires architecture legitimates by its sustainability (Fernández-Galiano, 2005). This has produced an increasing demand of more information related to this and has generated an increase of interest in sustainability assessment tools to determine how sustainable a building is and how could it be made more sustainable (Forsberg & von Malmborg, 2004). As Foster said, architects cannot solve all the world's ecological problems, but if sustainability is to be more than a fleeting fashion, architects in the future must ask themselves some very basic questions.

Background

In the current context of political commitment to sustainable development, it is not surprising that sustainability assessment is frequently used to anticipate the consequences of the possible actions to be implemented. Sustainability assessment can be defined as a process that directs decision making towards sustainability (Bond & Morrison-Saunders, 2011).

The traditional objectives of cost, time and quality are no longer enough arguments and there is a need to develop new techniques and procedures to achieve environmental, social and economic requirements (Fernández-Sánchez & Rodríguez-López, 2010). There is a demand of tools focused on buildings and components performance assessment, which could provide quantifiable information that can be used by agents of the construction sector, to create buildings that improve indoor comfort condition with low environmental impact (Assefa et al., 2007).

Considering the net growth in world population over the last decade, which has reached 7.000 million inhabitants, it is estimated that it must be built about 17 million new accommodations around the world annually. That means around 680 million square meters, like produce over 600 million cubic meters of construction materials, about 1,500 million annual tonnes of materials, building components and construction subsystems (IETcc, 2008).

The placement of materials determines the functional behavior of the building and, with it, the future demand for resources to keep its habitability. About 60% of the materials used are in the structural elements. Between 25% and 30% goes to the primary enclosures (roofs and façades), and the rest to partitions, linings, facilities, etc (Cuchí, 2010). The materials used in the building are a high weight on the environmental impacts caused by the building over its life cycle. These impacts are generated in all transformations suffered from extraction feedstock until his departure from factory as material prepared for use in work.

The choice of a material depends on many factors, such as the duration of their life cycle, its potential for reuse and recycling and their environmental impacts. These impacts can be known through the environmental product declarations (EPD), prepared according to ISO 14025 (ISO, 2006) and ISO 21930 standards (ISO, 2007). If a product does not have an EPD, a life-cycle assessment (LCA) can be carried out, according to ISO 14040 (ISO, 2006) and ISO 14044 standards (ISO, 2006). The life-cycle assessment is an objective process to evaluate the environmental burdens associated with a product, which is based on material and energy balance of the studied system. In this way inputs and outputs of the system are identified and, subsequently, different environmental impacts that may cause are evaluated.

During the project process, especially in the initial stages of design, and later construction of a building, many times it will be difficult to assume the price and time of doing a complete LCA for each material and construction system. We must bear in mind that the design process is crucial in the achievement of a sustainable building, since the ability to influence the behavior of a building is greatly reduced throughout the project, at the same time that increases the cost of implementing any strategy (ASHRAE, 2006). Because of this, until the environmental product declarations (EPD) are more extended, an assessment tool has been developed in this paper in order to give quick and easily enough arguments to select the best façade cladding according to its sustainability. Following the structure defined in UNE EN 12973 standard (UNE, 2000) for the product value analysis, understood as the relationship between satisfied needs and the resources used to satisfied them, assessment credits and their related indicators can be established for each stage of the façade cladding life-cycle, evaluating them by weighted comparison.

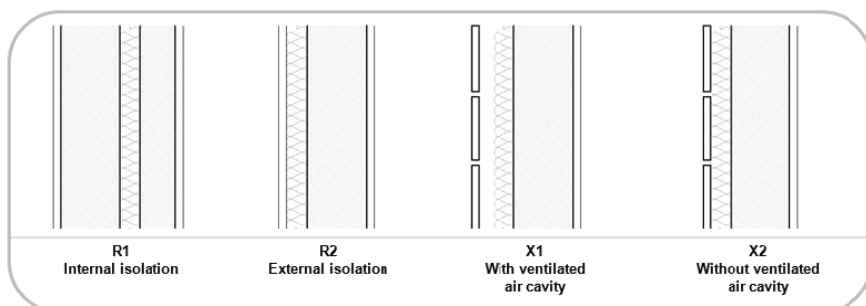


Figure 1. Analyzed façade systems

Methodology

The ISO 14040 standard (ISO, 2006) sets the life cycle stages as the ones consecutive and interrelated in a product system, from its obtention from natural resources to its final elimination.

The product stage includes the processes assumed in the environmental declaration, including the production cost. The construction stage includes material’s transport from the factory to the working place, the waste produced during the construction and its costs. The operation stage includes weight and thickness of the materials and constructive systems, and the operation cost understood as energetic demand. The last stage is end of life and includes the processes of reuse, recycling and waste from demolition.

Four material families and four construction systems have been selected for the assessment development. The materials are extrude ceramic (CE), ceramic tiles (CP), aluminum composite (CA) and precast concrete (HP).

To define the façade systems, each material is analyzed into two different systems, with (1) and without (2) ventilated air cavity, as are sown in Figure 1. Two reference systems defined by the Spanish Edification Technical Code are also used, one of them with the isolate layer situated in the interior side of the wall (R1) and the other one with the isolation on the outside (R2).

Following the exclusion principle for the identical activities in comparative analysis, the substructure and the façade’s interiors layers are considered identical in all systems, so this way they will not interfere in the evaluation.

Table 1. Analyzed categories

Stage	Credit	Indicator	Source
Product	Eco-label	[EPD]	COAATC
	Embodied energy	[MJ/m ²]	BEDEC
	CO ₂ emissions	[kgCO ₂ /m ²]	BEDEC
	Recycled content	[%]	Producer
	Product cost	[eur/m ²]	COAATGU
Construction	Certificate	[DIT]	IETcc
	Transport	[km]	Elaborated
	Construction waste	[m ³ /m ²]	BEDEC
	Construction cost	[eur/m ²]	COAATGU
Operation	Overweight	[kg/m ²]	Producer
	Wide	[mm]	Producer
	Operation cost	[kWh/m ² a]	Elaborated
End of life	Reuse	[%]	Elaborated
	Recycle	[%]	Producer
	Demolition	[m ³ /m ²]	Elaborated

Information

In order to establish how much do the construction products contribute to a sustainable development it is important to consider context: many products which are not in themselves particularly environmentally friendly could be exactly the right products for reducing a building’s environmental impact. Creating a low environmental impact building means matching products to the specific design and site in order to optimize overall environmental impact. What is clear from taking a life-cycle thinking approach is that it is not only the type of product used that is important, but also how it is produced (with clear links to environmental management systems) and even more importantly how it is used (and treated when its first life is over) (Edwards & Bennett, 2003).

In each life-cycle stage are defined the needed credits for the definition of the analysis object through specific aspects. Each credit is linked to an indicator which gives a measuring value and its measurement unit.

The selection of credits and indicators is carried out through the analysis of scientific papers, specialized literature and evaluation methodologies such as LEED (USGBC) and VERDE (GBCe). They have to comply with two features: represent the most significant qualities to analyze and have accessible information from the initial stages of the project.

In materials and façade systems selected are analyzed: embodied energy (energy consumption from the extraction of raw materials until his departure from the factory as material ready to use at work), CO₂ emissions in the same period, percentage of recycled material incorporated in their production, cost of production, distance between the factory and the work (which suppose an energy consumption during transport), waste produced during the construction process, construction cost, overload to the structure, thickness (which reduces the available floor area), energy demand of the constructed building, if can be removed to reuse in other buildings, if can be recycled in new applications, the volume of waste from

demolition and finally, if they have any environmental declaration or document of technical suitability that present and endorsing its characteristics.

To guarantee the reliability of this tool, all the credits used have indicators that come from official data bases or at least professional recognize. For the credits in which the commercial information was needed to be used, it is guaranteed its reliability by comparing data from enough reliable commercial references and obtaining the mean value.

Table 1 indicators mentioned as elaborated, are the ones whose value cannot be obtained by any of the previous mentioned ways. For example, in the transport credit it is calculated the distance from the factories of the chosen manufactures, to five reference Spanish cities and the mean value is calculated. For the credit of the operation cost, an energetic simulation is done with Design Builder program with every façade, and the annual energetic demand is obtained.

Analysis

The values obtained for the cladding products and façade systems analyzed are reflected in Tables 2 and 3.

When there is no information of credit or it may not be properly proven, is not included in the analysis and is taken into account in the subsequent assessment. The eco-labeling credit (EPD) refers to the material, so it is not taken into account for the analysis of constructive systems. However, technical certificate and operation cost credits are applied only in the analysis of constructive systems.

Table 2. Analyzed cladding materials

Stage	Credit	Indicator	CE	CP	CA	HP
Product	Eco-label	[EPD]	IP	Y	Y	N
	Embodied energy	[MJ/m ²]	666,93	252,85	907,00	320,64
	CO ₂ emissions	[kgCO ₂ /m ²]	40,61	15,79	-	21,04
	Recycled content	[%]	> 0	> 80	0	-
	Product cost	[eur/m ²]	40,08	21,01	77,70	76,77
Construction	Certificate	[DIT]				
	Transport	[km]	695,08	659,04	918,50	476,01
	Construction waste	[m ³ /m ²]	0,0036	0,0015	0,0002	0,0016
	Construction cost	[eur/m ²]	92,34	54,91	122,83	105,69
Operation	Overweight	[kg/m ²]	53,85	27,90	5,50	33,00
	Wide	[mm]	33	10	4	14
	Operation cost	[kWh/m ² a]				
End of life	Reuse	[%]	100	100	100	100
	Recycle	[%]	0	0	90	0
	Demolition	[m ³ /m ²]	0,033	0,010	0,0002	0,014

Table 3. Analyzed façade systems

Credit	R ₁	R ₂	CE ₁	CE ₂	CP ₁	CP ₂	CA ₁	CA ₂	HP ₁	HP ₂
Eco-label										
Embodied energy	768,91	585,33	1230,4	1230,4	816,33	816,33	1470,5	1470,5	884,12	884,12
CO ₂ emissions	84,45	65,89	102,44	102,44	77,62	77,62	-	-	82,87	82,87
Recycled content	0	0	> 0	> 0	11	11	0	0	-	-
Product cost	18,57	14,94	53,58	53,58	34,51	34,51	91,20	91,20	90,27	90,27
Certificate	N	N	Y	N	Y	N	Y	N	N	N
Transport	1240,8	818,12	1513,2	1513,2	1477,1	1477,1	1736,6	1736,6	1294,1	1294,1
Construction waste	0,0190	0,0137	0,0158	0,0158	0,0137	0,0137	0,0124	0,0124	0,0138	0,0138
Construction cost	90,02	68,64	143,21	143,21	105,78	105,78	173,70	173,70	156,56	156,56
Overweight	300,11	213,38	229,04	229,04	203,09	203,09	180,69	180,69	208,19	208,19
Wide	255	185	233	203	210	180	204	174	214	184
Operation cost	37,87	42,14	42,38	41,97	42,38	42,08	42,38	42,08	42,38	41,65
Reuse	0	0	23,5	0	13,75	0	3,05	0	15,85	0
Recycle	0	0	0	0	0	0	3,05	3,05	0	0
Demolition	0,255	0,185	0,203	0,203	0,180	0,180	0,174	0,174	0,184	0,184

Assessment

On the basis of the results obtained in the analysis phase, each cladding product and facade system is valued in comparison with the other analyzed options. The resulting score determines the improvement potential of every analyzed option, so that the option with a lower score will be the most favorable.

When the values in the different options are very close, the highest score may be equal to the number of evaluated alternatives. However, when there is much variation between alternatives, this system of value allocation does not reflect the difference between them. For a more concise assessment, the difference between the more and less favorable of each indicator value is divided into 10 sections and gets the score of each alternative depending on in which section it is included.

Eco-labeling (product stage) and certificate credits (construction stage) will get the most favorable value (V=1) if the material or system has some kind of eco-label (EPD) or certificate, the more unfavorable if they do not (V=10) and intermediate (V=5) if it is in process of obtaining it. The rest of the credits will get better value (V=1) for smaller indicator, according to Equation 1 below, except the credits of recycled content (product stage), reuse and recycling (end of life stage), which are valued in reverse.

$$\left\{ \begin{array}{l}
 V(x) = 1; \text{ if } x \ni [\min, D1) \\
 V(x) = 2; \text{ if } x \ni [D1, D2) \\
 V(x) = 3; \text{ if } x \ni [D2, D3) \\
 V(x) = 4; \text{ if } x \ni [D3, D4) \\
 V(x) = 5; \text{ if } x \ni [D4, D5) \\
 V(x) = 6; \text{ if } x \ni [D5, D6) \\
 \dots \\
 V(x) = 10; \text{ if } x \ni [D9, \max]
 \end{array} \right. \quad (1)$$

where $x \ni$ indicator value; $\min \ni$ minimum indicator value; $\max \ni$ maximum indicator value; and $V(x) \ni$ assessment value.

Table 4. Cladding materials assessment

Stage	Credit	CE	CP	CA	HP
Product Fx ₁ = 25%	Eco-label	5	1	1	10
	Embodied energy	7	1	10	4
	CO ₂ emissions	10	1	10	6
	Recycled content	9	1	10	10
	Product cost	4	1	10	7
Construction Fx ₂ = 10%	Certificate				
	Transport	7	4	10	1
	Construction waste	10	4	1	7
Operation Fx ₃ = 60%	Construction cost	4	1	10	7
	Overweight	10	4	1	7
	Wide	10	4	1	7
End of life Fx ₄ = 5%	Operation cost				
	Reuse	1	1	1	1
	Recycle	10	10	1	10
	Demolition	10	4	1	7

Table 5. Façade systems assessment

Credit	R ₁	R ₂	CE ₁	CE ₂	CP ₁	CP ₂	CA ₁	CA ₂	HP ₁	HP ₂
Eco-label										
Embodied energy	2	1	8	8	4	4	10	10	6	6
CO ₂ emissions	8	1	10	10	3	3	10	10	6	6
Recycled content	10	10	7	7	1	1	10	10	10	10
Product cost	2	1	6	6	4	4	10	10	8	8
Certificate	10	10	1	10	1	10	1	10	10	10
Transport	2	1	8	8	6	6	10	10	4	4
Construction waste	10	5	9	9	5	5	2	2	7	7
Construction cost	2	1	6	6	4	4	10	10	8	8
Overweight	10	7	9	9	4	4	1	1	6	6
Wide	10	4	9	5	7	2	6	1	8	3
Operation cost	1	6	8	3	8	5	8	6	8	3
Reuse	10	10	1	10	3	10	4	10	2	10
Recycle	10	10	10	10	10	10	1	1	10	10
Demolition	10	7	9	9	4	4	1	1	6	6

All the options have a value between 1 and 10. When two or more alternatives have the same value on some credit of the analysis stage, they are evaluated with the same score. When they do not have the necessary data, it is assumed the worst option and is evaluated with the highest score (V=10). The assessment of the credits of each option, according to Equation 1, is reflected in Tables 4 and 5.

To get the potential improvement in each alternative, Equation 2 is used, in which the credits are the same value in the assessment of each stage, and each of them ponders according to their relevance within the life cycle (Fxi), according to the weights assigned by VERDE tool (GBCe): Fx1 = 25%; Fx2 = 10%; Fx3 = 60%; Fx4 = 5%. Table 6 presents the assessment of the cladding materials and façade systems analyzed.

$$V_T = \sum_{i=1}^4 Fx_i (Vx_i / Cx_i) / F_T \Rightarrow \tag{2}$$

$$V_T = [Fx_1 \sum (Vx_1 / Cx_1) + Fx_2 \sum (Vx_2 / Cx_2) + Fx_3 \sum (Vx_3 / Cx_3) + Fx_4 \sum (Vx_4 / Cx_4)] / F_T$$

where VT ≡ total value; Vxi ≡ indicator assessment value in each life-cycle stage; Fxi ≡ weighting factor of each life-cycle stage; Cxi ≡ number of credits considerer in each stage; and xi ≡ life-cycle stages.

Table 6. Assessment value

Total	CE	CP	CA	HP	R ₁	R ₂	CE ₁	CE ₂	CP ₁	CP ₂	CA ₁	CA ₂	HP ₁	HP ₂
Product	6,8	2,4	3,2	5,5										
System					6,7	5,1	8,1	6,6	5,2	4,0	6,2	5,1	7,3	5,4

In order to normalize the assessment and to express it in percentage, two hypothesis are included, representing the best alternative with 0% of possible improvement and the worst, with 100% of improvement potential. The values are reflected in Table 7 and are represented in Figures 2 and 3.

Table 7. % Improvement potential

Total	CE	CP	CA	HP	R ₁	R ₂	CE ₁	CE ₂	CP ₁	CP ₂	CA ₁	CA ₂	HP ₁	HP ₂
Product	83	22	33	65										
System					63	45	79	63	47	33	58	46	70	49

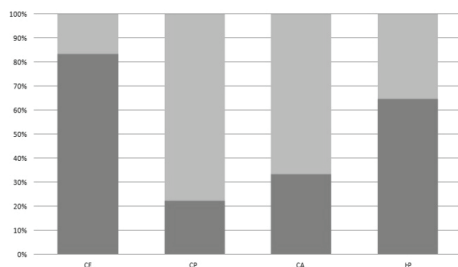


Figure 2. Cladding materials assessment

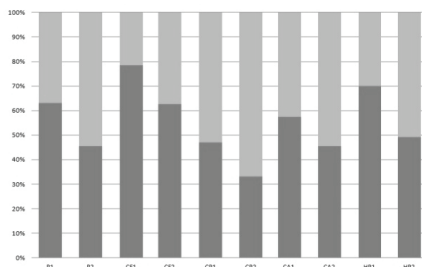


Figure 3. Façade system assessment

Discussion

The proposed assessment methodology is defined by three aspects: the selection of the analysis credits and indicators, the assignment of a value to each alternative depending on the evaluated credits and, finally, assessment of each alternative based on the values of each credit.

The selection of the analysis credit must be argued by the review of specialized documentation, to ensure that considers the necessary credits and in sufficient numbers to characterize each option.

The credit assessment for each option should be considering the difference between the minimum and maximum value, divided into intervals. If the value is assigned consecutively between the better alternative and the more unfavorable, considering n options, assessment would not reflect the dispersion

between them and will only be valid when assessing very similar options. The difference between the two systems of assessment is presented in Table 8.

Table 8. Credit assessment

		Indicator	CE	CP	CA	HP
Credit	Embodied energy	[MJ/m ²]	666,93	252,85	907,00	320,64
Value V □ [1, n]			3	1	4	2
Value V □ [1, 10]			6	1	10	3

For the options assessment (V_T) it should be considered the mean value of each option at each life-cycle stage ($\sum V_{xi} / C_{xi}$) and a weighting factor (F_{xi}) depending on the importance of each life-cycle stage in the reduction of environmental impacts. If it did not include this weighting factor, it would be considering with the same importance the impacts produced at every life-cycle. Tables 9 and 10 reflects the final assessment of each option and their corresponding improvement potential, depending on if they are not considered mean values either of weighting factors (V_{Ta}), considering mean values but not the weighting factor of the life-cycle stage (V_{Tb}), considering the weighting factors but not the mean values (V_{Tc}) and, finally, considering mean values and weighting factors (V_T).

$$V_{Ta} = \sum_{i=1}^4 (V_{x_i}) \tag{3}$$

$$V_{Tb} = \sum_{i=1}^4 (V_{x_i} / C_{x_i}) \tag{4}$$

$$V_{Tc} = \sum_{i=1}^4 F_{x_i} (V_{x_i}) / F_T \tag{5}$$

$$V_T = \sum_{i=1}^4 F_{x_i} (V_{x_i} / C_{x_i}) / F_T \tag{2}$$

Table 9. Value assessment

	CE	CP	CA	HP	R ₁	R ₂	CE ₁	CE ₂	CP ₁	CP ₂	CA ₁	CA ₂	HP ₁	HP ₂
V _{Ta}	97,0	37,0	67,0	84,0	97,0	74,0	10,0	11,0	64,0	72,0	84,0	92,0	99,0	97,0
V _{Tb}	27,7	11,7	16,9	23,1	28,5	22,2	29,1	31,3	19,0	20,9	22,8	24,7	28,1	27,4
V _{Tc}	23,9	7,7	13,7	20,1	22,0	16,5	26,8	22,7	16,9	13,3	21,6	18,6	24,5	18,9
V _T	6,80	2,40	3,20	5,50	6,70	5,10	8,10	6,60	5,20	4,00	6,20	5,10	7,30	5,40

Table 10. % Improvement potential

	CE	CP	CA	HP	R ₁	R ₂	CE ₁	CE ₂	CP ₁	CP ₂	CA ₁	CA ₂	HP ₁	HP ₂
V _{Ta}	72	21	46	61	66	48	69	76	40	46	56	62	67	66
V _{Tb}	73	24	40	59	68	50	70	76	42	47	52	57	67	65
V _{Tc}	80	18	41	66	62	44	78	64	45	33	61	51	70	52
V _T	83	22	33	65	63	45	79	63	47	33	58	46	70	49

Conclusions

The comparative assessment method does not give results from the reduction of the environmental impact, although it helps to know easily and quickly the best option for each situation, and gives improvement ideas to help to achieve the ideal hypothesis. This way, client and architect can orientate themselves to more sustainable solutions without having to assume time and economic over cost. This tool could be used with different building elements (structure, facilities, roof, etc.), by adjusting the analysis credits to each of them and by adapting the weighting system.

The selected cladding materials assessment shows that ceramic tile (CP) is the best option from all the analyzed, although it has a little improvement margin compared to aluminum composite (CA).

Reducing its thickness, and with this, its weight, 11% improvement can be achieved. This way is the one followed by the industry, already having achieved important improvements.

The reference system with the outside isolation (R_2) includes the same materials, except for the cladding, as the rest of the alternatives. Because of this, it is the best reference to evaluate the sustainability input coming from the cladding material. From all the studied options, only the one including ceramic tile in a system without ventilated air cavity (CP_2) gets a better score than the reference (R_2), although it is closely followed by the systems without ventilated air cavity of aluminum composite (CA_2) and precast concrete (HP_2).

This is because the Edification Technical Code of Spain, in the document Energy savings DB-HE1 (CTE, 2009), states that the total thermal resistance of an enclosure with a highly ventilated air cavity is obtained neglecting the thermal resistance of the air cavity and the other layers between the air cavity and the outside environment. Therefore, options without ventilated air cavity are better valued because the qualities of the cladding are considered in the calculation of the enclosure thermal transmittance, which reduces energy demand during operation stage and, therefore, the cost of use credit.

References

- Álvarez-Ude, L. (2010). ¿Sostenibilidad en la edificación?, un reto para todo el sector. *Habitat Futura*, 10, 18.
- Araujo, R. (2009). El edificio como intercambiador de energía. *Tectónica*, 28, 4-27.
- ASHRAE (2006). The Design Process-Early Stages. In *The ASHRAE GreenGuide* (Second edition). Burlington: ASHRAE Press, Butterworth-Heinemann, pp.73-100.
- Assefa, G. et al. (2007). Environmental assessment of building properties - Where natural and social sciences meet: The case of EcoEffect. *Building and Environment*, vol. 42 no. 3, 1458-1464.
- Azpilicueta, E. (2010). Hacia un óptimo energético. Instalaciones y energía. *Tectónica*, 31, 6-33.
- Bond, A.J. & Morrison-Saunders, A. (2011). Re-evaluating Sustainability Assessment: Aligning the vision and the practice. *Environmental Impact Assessment Review*. 31 (1), 1-7.
- CEN (2000). *UNE EN 12973: Gestión del valor*. Madrid: AENOR.
- Cuchí, A. (2010). *Cambio global España 2020/50*. Madrid: Sector edificación, GBCE.
- Edwards, S. & Bennett, P. (2003). Construction products and life-cycle thinking. *Industry & Environment*, 26 (2), 57-61.
- Fernández-Galiano, L. (2005) Etiqueta verde. *Arquitectura Viva*, 105, p.3.
- Fernández-Sánchez, G. & Rodríguez-López, F. (2010). A methodology to identify sustainability indicators in construction project management—Application to infrastructure projects in Spain. *Ecological Indicators*, 10 (6), 1193-1201.
- Forsberg, A. & Von Malmborg, F. (2004). Tools for environmental assessment of the built environment. *Building and Environment*, 39 (2), 223-228.
- GBCE. Valoración de Eficiencia de Referencia De Edificios (VERDE). Available at www.gbce.es [Accessed November 2011].
- Gobierno de España. Ministerio de Fomento (2009). *Código Técnico de la Edificación. Documento Básico Ahorro de energía. Limitación de demanda energética (CTE DB HE 1)*. Madrid: Ministerio de Fomento.
- IETCC (2008). La industria de materiales básicos de construcción ante las ingentes necesidades actuales de edificación. *Materiales de Construcción*, 58 (292), 129-148.
- ISO 14025: 2006. *Environmental labels and declarations. Type III environmental declarations. Principles and procedures*.
- ISO 14040: 2006. *Environmental management. Life cycle assessment. Principles and framework*.
- ISO 14044: 2006. *Environmental management. Life cycle assessment. Requirements and guidelines*.
- ISO 21930: 2007. *Sustainability in building construction. Environmental declaration of building products*.
- Raya, J.M., Isasa, M. & Gazulla, C. (2011). *Development of European Ecolabel and Green Public Procurement criteria for office buildings. Economical and market analysis*. Seville: CIRCE/IPTS/JRC.
- USGBC. (n.d.) Leadership in Energy and Environmental Design (LEED). Available at www.usgbc.org [Accessed October 2011].



Green Building classification system for developing countries

Prashant Kapoor

International Finance Corporation, Washington, DC, USA

pkapoor1@ifc.org

This paper explores the current issues with existing green building rating systems. It also addresses how the lack of a universal definition of what constitutes a "Green Building" and the current absence of consistent data sources, benchmarks, and metrics on Green Buildings has prevented greater participation in the industry. The drivers behind creating Green Buildings in developing countries are briefly reviewed and the case for a new Green Building qualification system is proposed (EDGE). This new system is supported by a tool that provides technical solutions and quantifies the cost savings with investment paybacks. The paper explains the need for three main innovations to create a large-scale adoption of Green Building Standards in developing countries. These are: 1) Simplification of assessment criteria by removing subjective, weighted 'credits scores', 2) Sharp focus on areas of resource use in buildings, i.e. consumption of energy, water, and materials, and 3) Provision of an integrated tool which recommends cost-effective solutions to make the building design and specification at a level universally defined as 'green'. The paper then describes how the EDGE tool can create a market transformation by providing quick and inexpensive means for building owners and developers in developing countries to classify their building as 'green' and enabling financial institutions interested in Green Building investments to assess risk reduction due to lower utility bills.

© 2012 Green Lines Instituto para o Desenvolvimento Sustentável. All rights reserved.

Keywords: buildings, developing countries, energy, carbon, resource efficiency, cost savings

Introduction

Background – buildings and greenhouse gas emissions

Today, buildings account for 15% of the world's Greenhouse Gas (GHG) emissions (IPCCa, 2006). The building sector is also one of the fastest growing. The IPCC estimates building-related GHG emissions to double by 2030 under a high-growth development scenario (Levine, 2007). This increase would take place almost entirely in the developing world.

McKinsey forecasts that the majority of low-cost abatement measures are to be found in the building sector (McKinsey, 2009). Developing countries present the greatest opportunity for GHG reductions through the design of Green Buildings, underscoring the need to adopt sustainable building practices and to capitalize on this emission reduction potential.

State of Green Building rating tools

Success of Green Building rating tools

Despite the compelling GHG abatement and business opportunity, the real estate industry, among other stakeholders, lacks a universal definition of what constitutes a "Green Building" as well as consistent data sources and metrics on Green Buildings. These deficits make an assessment of the profitability of Green Building investments difficult and therefore hold back stronger investor interest to implement them.

Existing Green Building rating tools such as LEED, Green Star and BREEAM are being widely used globally. Local indigenous systems are emerging but most use the basic platform outlined in LEED or

BREEAM. Many countries are either currently pursuing Green Building standards or are planning to pursue them in the near future. This reflects the popularity of voluntarily labeling a building as "green."

These systems share inherent problems such as:

- Details and specifications that should be basic to fundamental practice are included as 'green' elements (Lstiburek, 2008), Measures like 'indoor environmental quality', 'durability', disability access or occupational safety and health issues can be found in many of the rating tools, taking the focus away from the primary issue of GHG.
- The mandatory minimum performance is too lenient in many cases and fails to provide adequate reassurance that the "green" building will provide lower energy costs.
- They make subjective judgments [weighting] of different environmental issues [health, energy consumption, water consumption] in the name of contextual economic and social concerns or priorities. The importance of the issues vary widely across the systems for instance, BERDE awards only 9% of the 'credits' for energy efficiency as compared to LEED which offers 33% and BREEAM that puts forward 19%.
- They do not suggest technology solutions to improve efficiency and related cost savings.
- They rely on complex energy simulation software to predict energy use (Schendler, 2005), which often lack accuracy in specific local contexts. These software packages rarely provide design direction in the initial conceptual stage. This results in a large number of iterations to the design and a time and budget loss for the Green Building project.
- The assessment process is lengthy and expensive (Schendler, 2005), especially for clients in developing countries. This limits the number of prospective builders/owners adopting Green Building strategies.
- Banks and financial institutions need to be able to assess the financial viability of a Green Building investment through reduced risks from lower utility bills, which is not possible with the present rating systems.

Understanding priorities in developing countries

In order to affect market transformation, it is important to understand the drivers for green buildings in developing countries which are largely unlike those in developed countries. The key drivers that will push the adoption of green buildings in developing countries are as follows:

Table 1. Key drivers

Avoiding growth	emissions	Developed countries account for the vast majority of buildings-related CO ₂ emissions, but the bulk of growth in these emissions over the past two decades was seen in developing countries (IPCC 2007b).
Reducing the financial burden of fossil fuel imports and capital investments in energy/water infrastructure	in	<p>Developing countries could significantly increase global GHG emissions. They will experience the largest growth in population, new construction, and a rise in consumer standards, with a corresponding growth in use of air-conditioning and electrical gadgets and the building of larger homes. As an example, the World Bank estimates that about 50% of the world's new building construction between 2008 and 2015 will take place in China (World Bank, 2008)</p> <p>Energy security is an issue for almost all countries. The steep increase in the cost of fossil fuels has a major consequence for socio-economic growth in the poorest countries. Efficiency improvements provided by greener buildings will result in direct benefits to the balance of trade of fossil fuel importing countries.</p> <p>Reducing the infrastructure investment requirement (e.g., power stations, water supply reservoirs, and supply lines) and making the best use of existing supply capacities to improve access to energy are also very important drivers, especially in high-growth countries (such as Brazil, and India) and in those countries where there is no readily available local sources of energy.</p> <p>Efficient buildings can help governments supply energy to more people with the existing supply capacities. This is often a limitation in poor countries of Africa and Asia (World Energy Council, 2008).</p>
Reducing utility costs		In several developing countries, urban households allocate more than 5% of total expenditure to energy, indicating its direct importance in household budgets (Bacon, 2010). The prices of electricity have been rising rapidly over the last decade and should continue to do so as countries remove subsidies and fuel costs rise.

Table 1. Key drivers (continued)

Minimise resource depletion	While energy costs are rising, water, metals, wood, cladding materials, and other resources are becoming critically depleted. Lack of regular access to clean, potable water is a major socio-economic issue in many developing countries, particularly low-income countries.
Providing a market stimulus to the 'sustainability industry'	The specification of new or innovative products such as solar panels or rainwater harvesting systems can stimulate a market for the development of these products. Incentives in this field will enable developing economies to compete in a growing market for more sustainable products.
Balance between mandatory regulations and financial incentives	Unlike in developed countries where energy efficiency is largely tackled by mandatory building regulations that require a minimum level of energy efficiency, most developing countries lack building energy efficiency regulations or governments technically capable of implementing them (Katrina, 2011). A large part of the building industry in developing countries is also unable to access the necessary capital to adopt higher efficiency standards. It is in these cases that a voluntary system linked to financial incentives needs to play a catalytic role in promoting resource efficiency.

The need for a new Green Building rating tool

Developing countries currently lack a green building assessment and rating tool that addresses their unique needs. Most existing green building tools are complex, expensive, and time-intensive, as they require a considerable investment in training and a laborious data entry effort -- making the entry into this field unnecessarily difficult. This underscores the need for a simple, quick, and affordable tool that focuses on the efficient use of energy, water, and materials while exposing investment costs and length of payback time.

Factors that can lead to higher penetration of green building practices

In order to achieve significantly better market penetration in developing countries and a meaningful impact on resource efficiency, a GB rating system needs to have the following features:

- Ability to provide efficiency impacts: GB tools must have the ability to provide various resource efficiency measures (REMs). The stakeholders of the GB project will be enabled to choose those REMs that make the most impact. e.g.: it would be better for stakeholders to choose 5 REMs that result in an aggregate of 25% of cost savings compared to 15 REMs that provide an aggregate of 20% of savings in that particular locality. This a la carte capability to rapidly determine the best technical solutions is critical in new, emerging markets where a streamlined process compensates for an absence of technical expertise and administrative skills.
- Capability to provide design direction early: There is a clear need for a tool that starts informing decisions based on efficiency early in the design process. It is preferable to have a ballpark estimate early in the design process rather than use complex accurate modeling, particularly in new developing markets, which may or may not get used in the design and may not actually give any more accuracy.
- Ability to provide cost information: Choices of REMs should be based on investment costs and payback, as stakeholders in developing countries are particularly sensitive to the bottom line. With information on the capital costs, as well as potential savings in operation costs, the stakeholder can calculate the payback and make a more financially informed decision.
- Capacity to measure building performance objectively: The classification system must provide some level of certainty in terms of efficiency. e.g., 20% reduction in energy, water, and embodied CO₂ of materials correlates to 20% lower bills. The rating tool must provide efficiency information that is objective, un-weighted, and tangible.
- Potential to manage without expensive consultant resources: Most developing countries do not have access to Green Building professionals. The tool must assume a level of simplicity that eliminates the need for GB professionals, enabling competent building consultants (architects, civil engineers, mechanical engineers, electrical engineers, and plumbing/sanitary engineers) who have no prior knowledge of green buildings.

Three main innovations are required to create a large-scale adoption of Green Building Standards in developing countries: 1.) Simplification of assessment criteria and therefore reducing the time and cost to meet the standard, 2.) Sharp focus on areas of resource use in buildings i.e., energy consumption, water

consumption, and materials consumption, and 3.) Provision of an integrated tool which recommends cost-effective solutions to make the building design and specification 'green'.

It is with this background that Excellence in Design for Greater Efficiencies (EDGE) was conceptualized and initiated.

The EDGE classification system

The EDGE classification system assesses the efficiency of a new building at the design stage with respect to its energy, water and materials consumption. The EDGE classification system is supported by an 'EDGE tool' that provides a choice of technical solutions for improving resource efficiency and quantifies the cost savings with investment paybacks associated with such solutions. In this way, a building's inherent efficiencies are revealed quickly, easily, and affordably. The supporting market-specific criteria make the cost-savings tangible while reducing environmental impact.

Green Building criteria has been defined in a manner that enables customization to local conditions, including the following: passive design and energy efficiency, use of renewable energy, efficient water use (including rain water management), waste water treatment and recycling, and environmentally sustainable construction materials.

Why is EDGE important?

The large-scale adoption of Green Building Standards in developing countries requires an innovative approach to assessing buildings.

EDGE expects to create a market transformation by providing quick and inexpensive means for building owners and developers in developing countries to classify their building as 'green' and enabling financial institutions to assess the viability of a Green Building investment due to risk reduction from lower utility bills.

The EDGE tool is a key platform of the assessment system that aims to accomplish the following objectives:

- **Global Tool for Green Buildings:** Developing countries across the world would be able to use the tool. This tool is not only a rating tool but also provides the users with benchmarking and simplified energy simulation capability. EDGE can be used by building professionals without the need for expensive green building specialists.
- **"Green measures" Investment-Planning Tool for Building Owners and Developers:** EDGE enables quick but well-informed decision-making. Building owners and developers are able to understand the nuances of green investment and the returns that they would be able to expect.
- **Assessment Tool for Financial Institutions:** Financial institutions currently lack a simple and effective tool by which they can judge the financial viability of a Green Building investment. Moreover, there is no global standard available by which they can assess risk reduction from lower utility bills. The Green EDGE Classification system provides the basis on which financial institutions can benchmark a building as 'green'. While it is not mandatory that financial institutions need to use the EDGE tool to arrive at the classification, the tool has been developed to make the adoption easy.

The EDGE Tool

The tool has been created in MS Excel spread across four spreadsheets. The logic behind choosing this particular application was its inherent flexibility in offering possibilities of complex calculations without the need to resort to specialized proprietary software.

Sheet 1: Design Parameters: This worksheet is an interface to enter the building design and location parameters. Data requirements include the number of floors, number of rooms (in a hotel), total built-up area, geographic location of the building, and type of fuel and electricity rates. EDGE has built-in default data on electricity and fossil fuel rates, location characteristics (degree cooling / heating days, etc.).

Figure 1. Screenshot of EDGE - Data Entry Sheet for Design Parameters

Sheet 2&3: Energy and Water Efficiency options: There are a number of measures outlined that lead to energy and water efficiency. By selecting one of the measures, the software demonstrates the savings potential and the operational savings that is possible as a result. The user is provided with direct inputs as to which measure would earn the project the maximum savings.

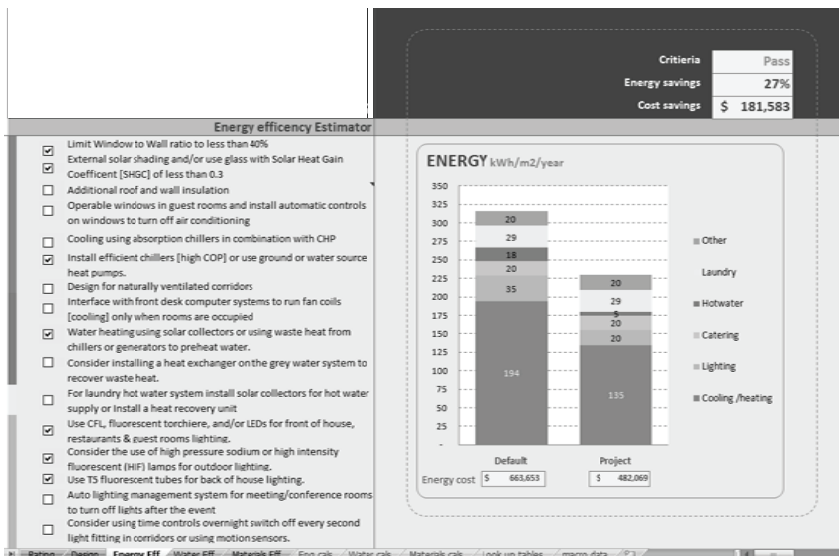


Figure 2. Screenshot of EDGE - Energy Efficiency Sheet

Sheet 3: Water Efficiency Parameters: This is the next most important resource efficiency measure towards making a building green. Dwindling fresh water sources and increased urbanization leading to inefficient catchment of rainwater makes water efficiency an important parameter for judging the 'greenness' of a building.

Sheet 4: Materials Efficiency Parameters: This is the third and last of the measures for making a building green. The measure for materials efficiency lies in low GHG emissions (measured in tons of CO₂) for the material. Available data on Life Cycle Analysis (LCA) on the GHG emissions data of construction materials from across the world has been incorporated into the tool. The major point of reference for LCA data has been the Inventory of Carbon and Energy (ICE), developed by the University of Bath. This data is available in the public domain (Geoff, 2010).

The EDGE classification system focuses on efficiency

The intelligence of the classification system lies in its simplicity. The rating is a simple pass / fails system. In order to secure a "pass" in energy efficiency, water efficiency, and materials efficiency the project must show a minimum percentage saving of 20% compared to a baseline model which does not incorporate energy / water / material saving measures. Reliance on percentage savings as a measure of efficiency keeps the focus on efficiency. Most rating tools use nomenclatures (like Platinum, Gold, etc. or 1-star, 2-star, etc) which brings in a certain level of haziness and uncertainty to the issue of efficiency. The focus on minimum efficiency is a conscious effort to bring a level of certainty and to keep the classification objective.

Methodology for the Tool

The development process of EDGE began with gaining an understanding of constructing a baseline. In order to do this, studies of various national and international minimum performance standards were carried out. After an exhaustive research, base case models were constructed. The next step was to create a list of resource efficiency measures that required to be adopted. This list has been derived out of a wide set of best practices that are currently utilized across the world. A performance calculation engine based on building physics, water efficiency, and material embodied energy was then created which essentially is the central intelligence of the entire system.

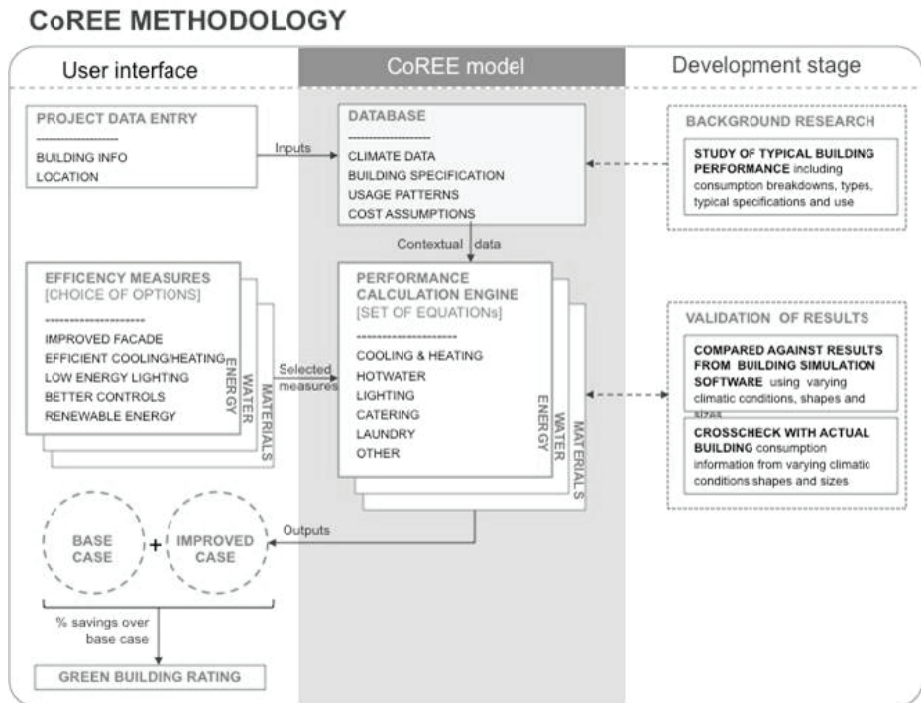


Figure 3. EDGE Methodology

Creating a base case model

First a base case model was created to represent the properties of a typical building that would be found in a particular context. The factors considered in the base case are classified into the following four divisions:

- a. Climatic Data: The climate of a locality is one of the key elements in understanding building performance. Data such as annual temperatures, average maximum and minimum temperatures, humidity (both relative and absolute), rainfall patterns and quantities, solar radiation, etc. are input into the model.
- b. Building Specifications: The model of a building has various properties such as height, width, and length, number of floors, height per floor, number of car parks, approximate size of the plot, where it is located, etc.
- c. Usage Patterns: The model of the building is then subjected to a further set of usage parameters like occupancy numbers, hours, intensity, and patterns.
- d. Logic of the Baseline Model Properties and Reference with Other Systems: The baseline parameters are broadly classified into Energy, Water, and Materials efficiency. For energy efficiency, for commercial buildings, ASHRAE-90.1-2004 has been referred to since it is an internationally accepted standard. There are differences based on localization that needed to be considered since EDGE will be used in developing countries. Some of the highlights of issues considered while establishing the baseline properties are as follows:
 - i. Lighting and HVAC System: The logic behind establishing the baseline has been to verify if there is an Energy Efficiency Code (EEC) in practice in any of the target countries. E.g. China already has an EEC in place. In such cases, the Baseline parameter is automatically derived from the EEC. In the absence of EEC in a particular country, ASHRAE Baseline (as outlined in ASHRAE-90.1-2004) has been adopted. HVAC consultants across the world are aware of the standards set by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers).
 - ii. Building Envelope: The energy efficiency of the building envelope is characterized by the following parameters. In the absence of an EEC governing the building envelope energy efficiency, ASHRAE baseline standards were referred.
 - Roof and Wall U-value: Considering that EDGE is focused on developing countries, it was the team's view that most developing countries would not adopt insulation practices unless they are regulated as this adds to the capital cost of the building owner/developer. The U-values of un-insulated concrete for roof and 230mm brick masonry have been considered for roof and wall respectively.
 - Window to Wall Ratio (WWR): The baseline for WWR in ASHRAE has been fixed at 40%. An Internet image study of facades of building typologies across various regions show wed that commercial buildings have an average WWR ranging from 50-60%. Therefore as the baseline WWR of 55% was set.

Performance Calculation Engine (PCE)

This is the core intelligence of the programme and the key differentiator between other software programmes and EDGE. The PCE is essentially a set of mathematical equations based on the principles of climatology, heat transfer, building physics, water use, carbon footprint of materials, and other such aspects. It is a large set of calculations that are synthesized into creating a single picture of building performance. The final performance is expressed in terms of energy used (kWh – kilowatt-hours), water used (liters / cubic meters), and GHG emissions (in tons of Carbon Dioxide). Performance parameters like heating loads, cooling loads, water consumption, and energy consumption have been calculated using the following variables:

- Cooling / Heating Loads from outdoor environment: Window to wall ratio, U-value of windows, U-value of walls, Delta T (difference between the mean outdoor temperature and the desired temperature for indoor), cooling / heating degree days, solar absorption factor, shading coefficient, air-conditioning usage factor, etc.
- Cooling / Heating Loads due to indoor factors: equipment heat loads, number of pieces of equipment, people heat loads, people occupancy numbers and density, etc.
- Water usage loads: occupancy, usage rates, rate of water flow through the fixtures, etc.
- Hot water loads: ambient temperature of water, solar water heating potential, etc.
- Materials: Inventory of Carbon and Energy (ICE) developed at the University of Bath has been used to measure the energy consumed during the extraction, processing, and use of the materials measured in mega joules.

The EDGE PCE is uses a quasi-steady state model for the assessment of the annual energy use for space heating and cooling. The calculation methodology is based on the European CEN standards and ISO 13790¹. Although accredited dynamic simulation models will also be acceptable in the future to show compliance with EDGE Standard.

A similar approach has been taken by energy efficacy building codes (e.g., COMcheckⁱⁱ in the US, Simplified Building Energy Model (SBEM)ⁱⁱⁱ and SAP^{iv} in UK) and Energy Performance Certificates (EPCs in EU) to find a quick and cost effective way to benchmark buildings and to quantify carbon emission reductions.

Validating the logic

In order to ensure that the PCE was reasonably accurate, the base case was modeled for 9 locations across the world with differing climates. The logic of the equations was validated by using the following two methods:

- Building Energy Simulation Software (BESS): The base case parameters were fed into the BESS (in this case, eQuest Software was used) and results were taken for each of the 9 locations and then compared with the PCE results.
- Actual Building Data: Actual building energy usage of similar buildings in these 9 locations were also taken and then correlated with the PCE results.

It was found the results largely correlated although there were slight discrepancies, which could later be diagnosed and accounted for.

Improved case

After the creation of a baseline, the model was then subjected to a variety of performance parameters. By changing the performance parameters of the existing base building, the new model started to show improvements in the relevant parameter. As an example, the introduction of an energy-efficient chiller would show an automatic improvement in the energy efficiency. Hence the new model would suggest the amount of energy saved and thereby the savings in operational cost. It would also show the difference in capital investment required and would calculate the simple payback of the particular measure.

Innovative features of the EDGE Tool

The methodology used in developing the tool leads to some innovative features.

Some of the innovative features of EDGE are:

- Adherence to Good / Best Practice for Buildings in Developing Countries: In decades to come, the bulk of new construction (as a portion of the global total) will occur in developing countries. This makes EDGE an important intervention as it encourages practices leading to more resource efficient buildings. Energy-optimized façade design, energy efficient chillers, energy efficient lamps, and water efficient taps and fixtures are some of the examples.
- Compatible with National Building Performance Regulations: Most of the measures for a particular country are compatible with the respective national building performance codes. Care has been taken to ensure that the relevant base cases would reflect the presence of the building codes and therefore the owners are encouraged to design buildings that perform 20% better than those existing building regulations.
- Weighting Indicators to Suit Different Climate Zones: The data from different climate zones has been incorporated into the tool and therefore the building performance mimics that of the real-case scenario.
- Translation of Green Practices into Economic Savings: The calculations and inclusion of capital and operational costs of various green measures address economic and business concerns.
- Inexpensive Software Platform: The tool has been created in MS Excel and thus brings down the level of investment required for software purchase. Professionals across the industry can use it without having to purchase expensive proprietary software.
- Open Source and Transparent Calculation Method: As the tool has been built on MS Excel, it is simple enough to create a transparent calculation method that can easily be peer reviewed, corrected, and updated.
- User-friendly from Broad Usage: This is a tool that requires minimal entry of data. The type of data required is simple and obvious, such as "total built-up area", "number of

rooms in hotel”, etc. and therefore can be utilized by people who are not necessarily specialists in the areas of energy efficiency.

- Quick Assessment at a Reasonable Cost: EDGE will be offered at an affordable price for use in developing countries.

How will EDGE aid market transformation

Better Value due to Green Label

As the diagram below shows, the potential of EDGE is to cater to the projects that fall in between – those that can afford to perform above the statutory regulations but do not have access to the more expensive rating systems. EDGE intends to democratize the green buildings market – making it accessible to people across the different sectors of the building industry -- by creating a better value-building labeling system for clients in developing countries.

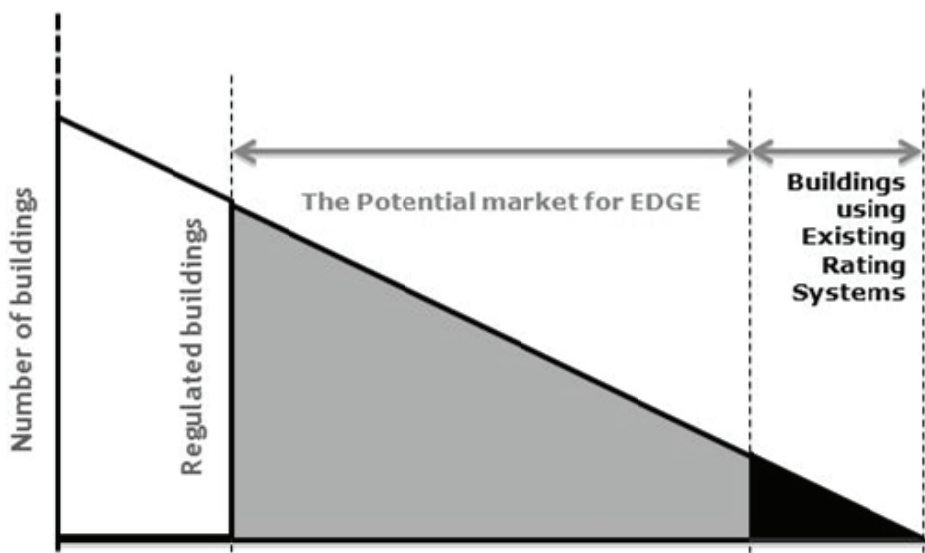


Figure 4. Potential of EDGE tool

Ability for financial institutions to administer green mortgages

A green mortgage is simply a type of mortgage that provides borrowers with a bigger loan than normally permitted or a money-saving discount as an acknowledgement for making energy-efficient improvements or for buying a home that meets particular energy-efficiency standards.

Green mortgages hinge on the principle that a more energy-efficient home means lower utility bills and, as a result, greater net income for the homebuyer over the course of the loan, allowing the purchase of a more expensive house. EDGE will allow a bank to make an assessment of the exact resource savings that the owner will be able to achieve through the employment of certain measures. This assessment provides the financial institutions the ability to gauge their investment in a transparent and objective manner.

- Improved loan performance (since socially responsible homeowners tend to have better on-time payment records)
- Better image branding as a provider of “green” products.

Conclusion

EDGE will be rolled out on a pilot basis across projects. The feedback gained will be used to improve and debug the product in preparation for its first launch.

In conclusion, there are a variety of reasons why developing countries would benefit from the wide-scale adoption of Green Building practices. Not only would there be a reduction in buildings-related CO₂ emissions and the depletion of valuable resources, but there would be positive economic benefits from less fossil fuel imports, less infrastructure investments, reduced utility costs, and the birth of a new sustainability industry. Since most buildings in the coming decades will be constructed in developing countries, it is essential that a classification system exists that correlates directly to the unique drivers of these marketplaces.

EDGE matches the exact needs of emerging markets with answers in a way that other prominent classification systems have not: by prioritizing efficiencies and the reduction of GHG emissions, by providing a technical set of solutions at the early design phase, and by basing the calculations on market-specific metrics for the most objective and accurate results. EDGE avoids the pitfalls of other systems by offering an easy-to-use tool built on commonly available software that does not require a lengthy process or expensive consultants for implementation. Instead, EDGE spells out the most effective technical measures to reduce the building owner's utility costs, measuring the short amount of payback time required.

Through the simple requirement of a reduction of energy, water, and materials by 20%, EDGE offers a pass/no pass formula that guarantees Green Buildings will out-perform conventional buildings, no matter where they are located. The performance calculation engine that exists below the surface of EDGE's simple interface was built upon the standards of ASHRAE and the Inventory of Carbon and Energy with the logic validated and models tested in different regions of the world. EDGE will continue to be test piloted repeatedly across various markets to ensure the accuracy of results and will remain open source, allowing other professionals to refine it over time to ensure the highest level of integrity.

EDGE fills the chasm between regulated buildings in the developing world and buildings in developed countries that can afford expensive rating systems. By lessening environmental impacts while simultaneously providing cost incentives, EDGE provides the financial traction that has long been missing in order to gain momentum from investors, buildings owners, and developers, providing a strong catalyst for the future of Green Buildings in emerging markets.

Endnotes

ⁱ ISO 13790 (2008) www.iso.org/iso/catalogue_detail.htm?csnumber=41974

ⁱⁱ COMcheck product group <http://www.energycodes.gov/comcheck/>

ⁱⁱⁱ SBEM – Simplified Building Energy Model www.ncm.bre.co.uk

^{iv} Standard Assessment Procedure SAP 2005 <http://projects.bre.co.uk/sap2005>

References

- Bacon, R. S., Bhattacharya, S. & Kojima M. (2010). Expenditure of Low-Income Households on Energy: Evidence from Africa and Asia. In *Extractive Industries for Development Series No. 16*. Washington D.C.: World Bank.
- Hammond G. et al. (2010). *Inventory of carbon & energy (ICE) - Annex A: Methodologies for Recycling* [online]. Available at www.bath.ac.uk/mech-eng/ser/embodied/ [Accessed 15 December 2011].
- IGBC (2012). Indian Green Building Council. *Scorecard*. Available at www.igbc.in/site/igbc/index.jsp [Accessed 10 December 2012].
- IPCCa (2006). *Sectoral trends in global energy use and greenhouse gas emissions*. Cambridge: Cambridge University Press.
- IPCCb (2007). *Summary for Policy-makers, Climate Change 2007: Mitigation*. Cambridge: Cambridge University Press., Fourth Assessment Report of the IPCC.
- Katrina, M., Layke J & Araya, M. (2011). Building Driving Transformation to Energy Efficient Buildings: Policies and Action. *Institute for Building Efficiency*. Available at www.buildup.eu/publications/21878 [Accessed December 2011].
- Levine, M., D. Ürge-Vorsatz, K. Blok, L. Geng, D. Harvey, S. Lang, G. Levermore, A. Mongameli Mehlwana, S. Mirasgedis, A. Novikova, J. Rilling & H. Yoshino (2007) Residential and commercial buildings. In B. Metz, O.R. Davidson, P.R. Bosch, R. Dave & L.A. Meyer, eds. *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.
- Lstiburek, J. W. (2008). Building Science: Why Green Can Be Wash. *ASHRAE Journal*, 50, 28-36.
- McKinsey (2009). *Pathways to a Low-Carbon Economy: Version 2 of Global Greenhouse Gas Abatement Cost Curve* [online]. p.7. Available at [//solutions.mckinsey.com/ClimateDesk/default.aspx](http://solutions.mckinsey.com/ClimateDesk/default.aspx) [Accessed 15 December 2011].
- Schender, A. & Udall, R. (2005). LEED is Broken; Let's Fix it. *Grist Environmental News and Commentary*. October 2005.
- World Bank (2008). *World Bank Weekly update*, 14 April 2008. Washington, D.C.: World Bank.

World Energy Council (2008). *Energy Efficiency Policies around the World: Review and Evaluation*. London: World Energy Council.

Acknowledgements

The author would like to acknowledge the following people for their contributions: Farida Lasida Adj, Mahesh Basavanna, Sabin Basnyat, Abhishek Bhaskar, Vasudevan Kadalayil, Rebecca Menes, Bernard Micallef, Stephanie Miller, Russell Muir, Ajay Narayanan, Debra Perry, Thomas Saunders, Elena Sterling, Ommid Saberi, Aparna Zaveri and Nina Zegger.

Environmental assessment of wood-based panels: a comparison of life-cycle-based tools

Rita Garcia

*ADAI-LAETA, Department of Mechanical Engineering
University of Coimbra, Coimbra, Portugal*

rita.garcia@dem.uc.pt

Fausto Freire

*ADAI-LAETA, Department of Mechanical Engineering
University of Coimbra, Coimbra, Portugal*

This paper aims at comparing three tools to assess the environmental impacts of building products: i) the ISO 14040/44 life cycle assessment methodology; ii) the environmental product declaration (EPD); and iii) PAS 2050. The particleboard was selected to illustrate this comparison. Four methodological differences between the tools were analyzed: biogenic CO₂ emission accounting, inclusion of capital goods, allocation procedure and cut-off criteria. Results show that the total environmental impacts for each impact category are different for each tool. In global warming, differences are very significant (above 100%), since PAS 2050 accounts for biogenic CO₂ and includes carbon storage, which reduces the impact in global warming, in opposition to ISO 14040/44 and the EPD. In other impact categories, differences vary between 3 and 25%, and are mostly related to the inclusion/exclusion of capital goods. The different allocation procedures and cut-off criteria used result in minor differences.

© 2012 Green Lines Instituto para o Desenvolvimento Sustentável. All rights reserved.

Keywords: Environmental product declaration, life cycle assessment, particleboard, PAS 2050

Introduction

The building and construction sector is increasingly demanding information on the environmental performance of buildings and building products. There are various environmental life-cycle-based tools that can be used to assess and communicate the environmental impacts of building products and materials, such as: the ISO 14040 series (for life cycle assessment methodology); environmental product declarations (EPD); and carbon footprint methods. Nevertheless, these tools adopt different methodological approaches. To understand the differences between these tools as well as how they can influence the results is of key importance for decision makers. This paper intends to support companies, particularly from the wood and furniture sectors, in implementing environmental life-cycle-based tools for assessment, management and communication purposes. Additionally, it aims at contributing to the improvement of these tools among the technical and scientific community.

Life cycle assessment (LCA) is a methodology that allows a systematic assessment and quantification of the potential environmental impacts associated with a product life cycle (ISO 2006a,b; Guinée, 2002). It has been applied to a number of building product systems, including wood-based panels (e.g. Rivela et al., 2006, 2007; González-García et al., 2009; Wilson, 2010a; Garcia & Freire, 2011). The generic LCA methodology has been standardized by the International Organization for Standardization, resulting in the ISO 14040 series standards. These standards are the basis for the development of several life-cycle-based tools, such as environmental product declarations and carbon footprint methods.

Environmental product declarations (EPD) are business-to-business and business-to-consumer communication tools that provide quantified life-cycle environmental data for a product, namely environmental impacts, resource consumption and additional environmental information (ISO, 2006c). The

ISO 14025 (ISO, 2006c) standard provides the principles and requirements for developing EPD for products in general, while the ISO 21930 (ISO, 2007) standard is specific for building products. An EPD is based on a LCA study developed according to product category rules (PCR) established for products with similar functions, in order to enable comparisons. The PCR identify and define the requirements that need to be fulfilled in the development of an EPD of a particular product category, such as the goal and scope of the data, the life-cycle phases to be included, the impact categories to be analyzed and the presentation of results. These PCR are developed according to LCA studies based on the ISO 14040 series standards. There are several EPD programs and different PCR for building products. Nevertheless, in recent years, there has been an effort to harmonize the PCR from different EPD programs (Ingwersen & Stevenson, 2012). The most recent PCR for wood-based panels is from the International EPD System (Environdec, 2012).

Other life-cycle-based tools frequently used are carbon footprint methods. The carbon footprint of a product is usually defined as the quantification of the life-cycle greenhouse gas (GHG) emissions of a product. There are several carbon footprint methods both available and in development. The British Standards Institution (BSI) has recently published a revised version of the Publicly Available Specifications (PAS) 2050 regarding the assessment of the life-cycle GHG emissions of goods and services (BSI, 2011). The ISO is preparing a standard on the requirements and guidelines for the quantification and communication of the carbon footprint of products (ISO/DIS, 2012). The Greenhouse Gas Protocol Initiative, from the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), developed a standard to quantify and report the life-cycle GHG emissions of a product (WRI/WBCSD, 2011). All these approaches are based on the ISO 14040 series standards, but introduce specifications in the GHG emission calculation method.

This paper aims at comparing three different tools to assess and communicate the environmental impacts of building products: i) the ISO 14040 series LCA methodology (ISO 14040/44); ii) the environmental product declaration (EPD); and iii) PAS 2050. This comparison has been performed based on an application to particleboard, which represents about 43% of the Portuguese wood-based panel production and is an important product in the context of the building and furniture sectors (AIMMP, 2010). A particleboard is a wood-based panel made from wood particles, mainly wood residues from different sources, usually aggregated using urea-formaldehyde resin. For EPD, the most recent PCR for wood-based panels from the International EPD System were used (Environdec, 2012). A comparative assessment of the methodological differences of the three tools and a critical assessment of the results obtained by their application to the particleboard case-study are the main outcomes of this paper.

Life-cycle-based tools applied to particleboard

Life-cycle model

Figure 1 shows the life-cycle model flowchart. Both cradle-to-gate (from raw material extraction/cultivation to panel production) and cradle-to-grave (whole life cycle) models have been developed. The cradle-to-gate model includes the forest operations of site preparation, planting and logging (harvesting and forwarding) of wood, the sawmill process, the production of urea-formaldehyde resin (UF resin) used to bind the wood particles and the particleboard production. The wood used to produce particleboard comes from four different sources: sawmill sub-products (30%), post-consumer wood (30%), pine forest residues (25%) and eucalyptus forest residues (15%) (Garrido et al., 2010). In addition, the model takes into account the production of fuels, electricity and other chemicals as well as transport of raw and ancillary materials. The cradle-to-grave model also includes transport of particleboard to the distribution platform and the end-of-life, for which three scenarios are considered: i) landfill disposal (100%); 2) incineration 100%; and 3) recycling (30%) and incineration (70%). The particleboard life-cycle model builds on research previously presented in Garcia (2010) and Garcia & Freire (2011).

The functional unit is 1 m³ of uncoated particleboard for non-structural use (density of 640 kg/m³), which is consistent with EPD. The ISO 14040/44 standards and PAS 2050 do not establish a functional unit for specific products. Nevertheless, similar guidance for the definition of the functional unit is given by all the methodologies under analysis.

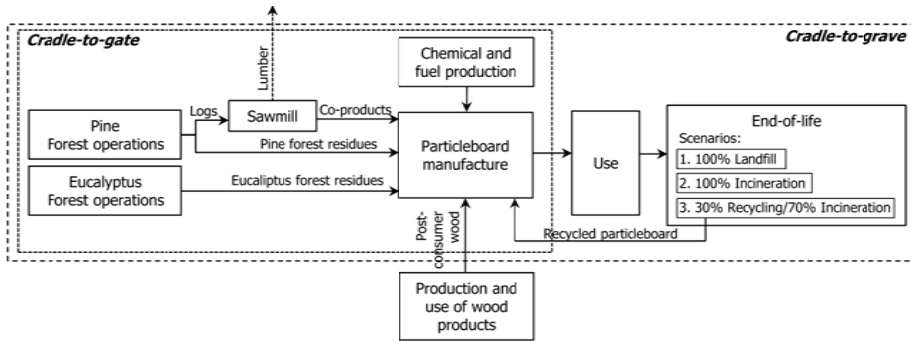


Figure 1. Particleboard life-cycle model flowchart.

The main sources of data are peer-reviewed literature and databases. Whenever possible, specific data for the Portuguese context was gathered. Fuel consumption (diesel and gasoline) in eucalypt and pine forest activities have been estimated based on Nunes (2008) and Dias et al. (2007), respectively. Data regarding the sawmill process was collected from Milota et al. (2006) and the production of UF resin process was modeled based on data from Wilson (2010b). The main data source for particleboard manufacturing process was Rivela et al. (2006). Average transport distances for Portugal of materials for the main production processes and distribution of the particleboards were considered. Electricity generation for the main processes was modeled using the Ecoinvent database, with reference to the 2010 Portuguese mix (REN, 2011). Data regarding other raw and ancillary material and fuel production is from the Ecoinvent database (Ecoinvent, 2012). Regarding particleboard end-of-life, both Ecoinvent data for sanitary landfill disposal and incineration of wood were considered (Doka, 2009). The latter was modified to include NOx emissions from particleboard, according to Risholm-Sundman&Vestin (2005), since other emissions were assumed similar to those from wood incineration.

The impact categories selected for the life cycle impact assessment (LCIA) are those referred in the PCR for the EPD, namely global warming (GWP100), ozone layer depletion, photochemical oxidation, acidification, and eutrophication (Envirodec, 2012). ISO 14040/44 standards do not provide guidance on which specific categories to include in the study, but state that their choice shall be consistent with the goal and scope and shall provide a comprehensive set of environmental issues related to the product system. For the purpose of comparison of results, the previously selected impact categories are also analyzed using the ISO 14040/44 standards. Regarding PAS 2050, only global warming is assessed, since these standards apply only to product life-cycle GHG emissions.

Methodological differences

The main methodological differences between the three tools analyzed in this study (ISO 14040/44, EPD and PAS 2050) are presented in this section. These differences are related to the cut-off criteria used, the inclusion or exclusion of capital goods, the approach used to deal with multifunctional processes and biogenic CO₂. Table 1 summarizes the approaches used by each tool regarding these issues.

Table 1. Main methodological differences between the tools.

	ISO 14040/44	EPD	PAS 2050
Cut-off criteria	Not specified	<5% environmental impacts	<5% total GHG emissions
Capital goods	Included	Excluded	Excluded
Multifunctionality	Scenarios	Mass allocation	Economic allocation
Biogenic CO ₂	Not specified	Excluded	Included
No. of impact categories	5	5	1

ISO 14040/44

The ISO 14040 series standards for LCA methodology is the basis for the development of the EPD and PAS 2050. Nevertheless, modeling choices and different approaches to some methodological issues exist, as discussed below.

Cut-off criteria are established to determine the input and output flows to be included in the assessment. Contrary to the other tools, the ISO 14040/44 standards do not define quantified thresholds but state that those should be based on mass, energy and environmental significance. In this study, no cut-off criteria were defined. Other difference between the tools concerns capital goods, which are explicitly included in the system boundaries in ISO 14040 (ISO, 2006a, Section 5.2.3), in opposition to the EPD and PAS 2050.

The approach used to deal with multifunctional processes is another important difference between the tools. In this study, the sawmill process is a multiple output process since it simultaneously produces planned lumber for the construction industry (main product) and sawdust, chips and shavings used in the production of particleboard. Since the focus of this study is on particleboard, it is necessary to allocate the burdens to the product under analysis. ISO 14044 establish a hierarchy of procedures to deal with multifunctional processes (ISO, 2006b). Whenever possible, allocation should be avoided by sub-dividing the unit process or by system boundary expansion. Where allocation cannot be avoided, the burdens should be partitioned based on physical relationships. Where these cannot be established, other criteria should be used, such as the economic value of the co-products. Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted. In this study, two allocation procedures were used: mass allocation (ma) and economic allocation (ea). The allocation factors calculated for each procedure are presented in Table 2.

Biogenic CO₂ emission accounting is particularly important in the assessment of wood-based products. During photosynthesis, there is an uptake of CO₂ by trees. This CO₂, known as biogenic CO₂, is eventually released back to the atmosphere and is thus considered neutral. Biogenic CO₂ accounting is, however, a controversial issue among the LCA community (Guinée, 2009; Brandão and Levasseur, 2011). The ISO 14040/44 standards do not mention any specific approach regarding biogenic CO₂. In this article, biogenic CO₂ emissions were not accounted (i.e. Global Warming Potential for biogenic CO₂ is assumed 0). This complies with the approach used by the most recent IPCC GWP100 v1.02 impact assessment method (Solomon, 2007).

EPD

According to ISO 14025 (ISO, 2006c), an Environmental Product Declaration (EPD) is based on a LCA study developed according to product category rules (PCR) established for the category of the product under analysis. In this study, the PCR used is the most recent one for wood-based panels from the International EPD System (Environdec, 2012). Compared to PAS 2050, the environmental assessment of the EPD is more similar to the ISO 14040 standards, since several impact categories are analyzed. The main methodological differences of the EPD compared to the other tools are presented next.

The EPD states a minimum of 95% of total inflows to be considered in the assessment and allows the exclusion of processes that contribute to less than 1% of the total environmental impacts and/or that represent less than 1% of the mass input. Due to these cut-off criteria, the production of the ammonium sulfate used in the particleboard production was not taken into account. Moreover, according to the EPD, personnel activities, building of site, infrastructure and equipment, i.e. capital goods, were also excluded from the system boundaries. The procedure defined in the EPD to deal with the allocation of burdens between co-products is the one based on mass and no other criteria is allowed. Thus, that was the procedure used in this study for allocating burdens in the sawmill process. Regarding biogenic CO₂, EPD excludes both the uptake of CO₂ and the emissions of biogenic CO₂ from the GWP calculations. As a result, carbon storage in wood products is not taken into account.

Table 2. Allocation factors for sawmill co-products.

Sub-process	Co-products	Mass allocation	Economic allocation ^a
Sawing	Rough green lumber	56%	85.7%
	Sawdust	7%	2.3%
	Chips	37%	12.0%
Planing	Planed dry lumber	85%	96.4%
	Shavings	15%	3.6%

^aINE, 2010

PAS 2050

The assessment of the carbon footprint using PAS 2050 may be regarded as a reduction of the scope of an ISO 14040 LCA study, since only one environmental impact category is analyzed: global warming. PAS 2050 requires the inclusion of all the processes that contribute to more than 1% of the anticipated life-cycle emissions of the functional unit and at least 95% of the total GHG emissions associated with the product. As a result of these cut-off criteria, GHG emissions associated with the production of biomass, ammonium sulfate and paraffin used in particleboard production has been excluded from the system

boundaries. Similarly to the EPD, the production of capital goods, transport of workers to and from the place of work and transport of costumers to and from the point of purchase have also not been taken into account.

Regarding multifunctionality, PAS 2050 uses a similar approach to the ISO 14040 standards. Firstly, allocation shall be avoided by sub-dividing the unit process or by system boundary expansion as in ISO 14040/44. Where neither of those approaches is practicable and there are supplementary requirements available, these should be used. Lastly, if none of these procedures is applicable, allocation shall be made according the economic value of the co-products. In this study, economic allocation was used.

Concerning emissions and removals of biogenic CO₂, PAS 2050 has a different approach compared to the other tools, since these are included in the assessment of the life-cycle GHG emissions of the product (global warming impact). Based on the fact that, during biomass growth, there is an uptake of CO₂ from the atmosphere which is temporarily stored in wood-based products and left out of the atmosphere for a certain period of time, which results in postponing its effect on global warming, PAS 2050 also proposes a method for the calculation of the weighted average impact of a delayed release of the stored carbon (BSI, 2011, Annex E, p.33). Nevertheless, that assessment is not mandatory and has to be done in parallel with the identification of the impact without the effect of timing of emissions (single release assessment). For the calculation of the weighting factor, a service life of 10 years for particleboard was considered.

Application of the tools: comparative assessment

Cradle-to-gate assessment

Table 3 shows the cradle-to-gate impact assessment results of the three tools. The life-cycle impact assessment method used was CML 2 v2.05 (Frischknecht et al., 2003). The upstream processes include production of biomass, UF resin, other chemicals and fuels, their transport to the industrial site and electricity generation. The core processes encompass the industrial process of particleboard production and on-site energy production. As can be seen in Table 3, the total environmental impacts calculated for each impact category are different for each tool. For all impact categories, mass allocation (ma) ISO 14040/44 presents the higher values, followed by economic allocation (ea) ISO 14040/44, EPD and, finally, PAS 2050, with the lowest results. The major differences occur when comparing PAS 2050 (negative value) and the other tools (positive values) in global warming and are mainly due to the inclusion of emissions and removals of biogenic CO₂ in PAS 2050. For the other impact categories, differences vary between 3%, when comparing mass allocation ISO 14040/44 and economic allocation ISO 14040/44 scenarios for ozone layer depletion, and 25% regarding eutrophication for mass allocation ISO 14040/44 versus EPD.

Capital goods account for 7 to 25% of the impacts and are the main responsible for the differences in results between ISO 14040/44 scenarios and EPD. Despite the exclusion of capital goods being a common practice in LCA studies (Frischknecht et al., 2007), results show that, for particleboard, they have a significant impact and should not be neglected. The allocation approach used can result in smaller differences, about 3 to 6%, since sawmill co-products represent less than 30% of the mass inputs to particleboard production. The different cut-off criteria account for differences of 0.8% (EPD) and 3.5% (PAS 2050).

Concerning the processes that contribute the most to the environmental impacts (except global warming and photochemical oxidation), the results of all the tools are consistent and show that the upstream processes are the ones with higher impacts, representing between 69% (EPD, eutrophication) and 99% (EPD, ozone layer depletion) of the total impacts. UF resin production alone is responsible for 26 to 53% of the impacts. Nevertheless, the higher absolute differences in the results of the various tools come from the upstream processes. This is due to a combination of methodological differences that are related to the assessment of these processes, namely different cut-off criteria, different approaches regarding capital goods and different allocation procedures used. The differences in the core processes are caused only by differences in the inclusion of capital goods, and, for that reason, are much smaller. For global warming and photochemical oxidation, the relative importance of upstream and core processes is different depending on the tool.

Table 3. Cradle-to-gate impact assessment results per m³ of particleboard.

Impact categories	Tools	Total	Upstream processes	Core processes
Acidification (kg SO ₂ eq)	ISO 14040/44 (ma)	0,68	0,49	0,18
	ISO 14040/44 (ea)	0,64	0,46	0,18
	EPD	0,59	0,42	0,17
	PAS 2050	-	-	-
Eutrofication (kg PO ₄ ³ eq)	ISO 14040/44 (ma)	0,21	0,16	0,06
	ISO 14040/44 (ea)	0,20	0,15	0,06
	EPD	0,16	0,11	0,05
	PAS 2050	-	-	-
Global warming (kgCO ₂ eq)	ISO 14040/44 (ma)	187	122	65
	ISO 14040/44 (ea)	182	116	65
	EPD	172	109	63
	PAS 2050	-936	-1313	377
Ozone layer depletion (g CFC-11 eq)	ISO 14040/44 (ma)	0,0195	0,0192	0,0004
	ISO 14040/44 (ea)	0,0190	0,0186	0,0004
	EPD	0,0181	0,0179	0,0002
	PAS 2050	-	-	-
Photochemical oxidation (kg C ₂ H ₄ eq)	ISO 14040/44 (ma)	0,048	0,025	0,023
	ISO 14040/44 (ea)	0,045	0,022	0,023
	EPD	0,043	0,021	0,022
	PAS 2050	-	-	-

ma: mass allocation; ea: economic allocation

Cradle-to-grave assessment

Table 4 shows the cradle-to-grave impact assessment results for the three tools and end-of-life scenarios. Analogously to the cradle-to-gate assessment, results are different for each tool in all impact categories and are higher for mass allocation ISO 14040/44 and lower for PAS 2050. The major differences appear in global warming, when comparing PAS 2050 and other tool results for recycling/incineration and landfill disposal scenarios. If carbon storage is taken into account, as in PAS 2050, both recycling/incineration and landfill scenarios show a great benefit in this category, resulting in less 335 and 1125 kg CO₂eq/m³ of particleboard, respectively, compared to mass allocation ISO 14040/44 results. Since this benefit is not taken into account by the other tools, the comparison with other products which do not store carbon can be compromised. Regarding incineration, accounting for the fact that delayed GHG emissions have less impact in global warming, as in PAS 2050, can result in less 53% impacts in global warming compared to mass allocation ISO 14040/44.

For the other impact categories, differences in results can reach 18%, when comparing mass allocation ISO 14040/44 and EPD recycling/incineration scenario in eutrophication, and are mainly due to the inclusion or exclusion of capital goods. The end-of-life scenario with higher environmental impacts in acidification is incineration, regardless of the tool used for the assessment. For eutrophication and photochemical oxidation, landfill disposal is the scenario that presents higher contributions in all the tools. Regarding global warming and ozone layer depletion, different tools provide different rankings for end-of-life scenarios.

Table 4. Cradle-to-grave impact assessment results per m³ of particleboard.

Impact categories	Tools	End-of-life scenarios		
		100% Landfill	100% Incineration	30% Recycling + 100% Incineration
Acidification (kg SO ₂ eq)	ISO 14040/44 (ma)	0,89	1,06	0,91
	ISO 14040/44 (ea)	0,85	1,03	0,88
	EPD	0,75	0,94	0,87
	PAS 2050	-	-	-
Eutrophication (kg PO ₄ ³ eq)	ISO 14040/44 (ma)	1,93	0,47	0,40
	ISO 14040/44 (ea)	1,92	0,46	0,39
	EPD	1,87	0,40	0,33
	PAS 2050	-	-	-
Global warming (kg CO ₂ eq)	ISO 14040/44 (ma)	433	230	228
	ISO 14040/44 (ea)	426	223	222
	EPD	287	201	204
	PAS 2050	-692 ^a -645 ^b	193 ^a 108 ^b	-107 ^a -170 ^b
Ozone layer depletion (g CFC-11 eq)	ISO 14040/44 (ma)	0,026	0,026	0,026
	ISO 14040/44 (ea)	0,026	0,025	0,025
	EPD	0,022	0,023	0,023
	PAS 2050	-	-	-
Photochemical oxidation (kg C ₂ H ₄ eq)	ISO 14040/44 (ma)	0,078	0,060	0,058
	ISO 14040/44 (ea)	0,078	0,057	0,055
	EPD	0,073	0,052	0,051
	PAS 2050	-	-	-

ma: mass allocation; ea: economic allocation

^a Single release assessment

^b Includes the effect of delayed emissions

Conclusions

There are several environmental life-cycle-based tools to assess and communicate the environmental impacts of building products. These tools adopt different methodological approaches. The main purpose of this article is to compare the outcomes and implications of using the following three well-known tools: i) the ISO 14040 series LCA methodology (ISO 14040/44); ii) the environmental product declaration (EPD); and iii) PAS 2050. This comparison has been performed based on an application to particleboard. Both cradle-to-gate and cradle-to-grave assessments were performed, and three scenarios for particleboard end-of-life were considered, namely 100% landfill disposal, 100% incineration, and 30% recycling/70% incineration.

Results show that the total environmental impacts for each impact category are different for each tool, both in cradle-to-gate and cradle-to-grave assessments. These differences can surpass 100%, in global warming. Four methodological differences between the three tools were found to have an influence in the results: biogenic CO₂ accounting, the inclusion/exclusion of capital goods, the approach used to deal with multifunctional processes and the cut-off criteria used.

The treatment of biogenic CO₂ is responsible for the main differences in global warming. Compared to the other tools, PAS 2050 results for recycling/incineration and landfill disposal scenarios show a great benefit in global warming (up to less 335 and 1125 kg CO₂eq/m³ of particleboard, respectively) due to carbon storage. Since this benefit is not taken into account by the other tools, the comparison with other products that do not store carbon can be compromised. For incineration, PAS 2050 results show up to less than 53% of impacts in global warming, when the assessment of delayed emissions of biogenic CO₂ was included. These outcomes show the importance of the treatment of biogenic CO₂ emissions in the global warming results of wood-based products. Thus, this issue should be further analyzed in future research.

The inclusion/exclusion of capital goods is the main responsible for the differences in results in the cradle-to-gate assessment, and accounts for 7 to 25% of the impacts in the cradle-to-gate assessment. Exclusion of capital goods is a common practice in LCA studies (Frischknecht et al., 2007) and is the approach followed by both EPD and PAS 2050. Nevertheless, results show that, for particleboard, they have a significant impact and should not be neglected. The allocation procedure used (mass, in EPD; economic, in PAS 2050; both scenarios, in ISO 14040/44) can result in smaller differences, about 3 to 6%,

since sawmill co-products represent less than 30% of the mass input to particleboard production. The different cut-off criteria represent minor differences, since only processes which account for less than 0.8%, in EPD, and 3.5%, in PAS 2050, of total impacts were excluded.

EPD allows for a comprehensive assessment of the environmental impacts since several impact categories are analyzed. However, EPD implementation is based on Product Category Rules (Envirodec, 2011) that do not account for the benefit of carbon storage and exclude capital goods, which were found to be important. PAS 2050 also exclude capital goods from the assessment of the life-cycle GHG emissions. Nevertheless, both emissions and removals of biogenic CO₂ are included in the assessment and a method for the assessment of delayed emissions is suggested, which are important methodological aspects especially for wood-based products. PAS 2050 has the potential to introduce and promote the implementation of life-cycle approaches at company level. On the other hand, it only considers one environmental aspect, which may compromise the assessment of potential tradeoffs. This is particularly important in wood-based products, since the benefit of carbon storage can mask worst performances in other categories.

References

- AIMMP (2010). *Boletim informativo: Indústrias da Madeira e do Mobiliário*. Março/Abril 2010. Available at <http://www.aimmp.pt> [Accessed 12 January 2012].
- Brandão, M. & Levasseur, A. (2011). *Assessing Temporary Carbon Storage in Life Cycle Assessment and Carbon Footprinting: Outcomes of an expert workshop*. Luxembourg: Publications Office of the European Union.
- BSI (2011). *PAS 2050 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services* [online]. Londres: British Standards Institution. Available at <http://shop.bsigroup.com/en/forms/PASs/PAS-2050> [Accessed 12 January 2012].
- Dias, A.C., Arroja L. & Capela I. (2007). Carbon dioxide emissions from forest operations in Portuguese eucalypt and maritime pine stands. *Scandinavian Journal of Forest Research*, 22(5), pp.422-432.
- Doka, G. (2009). Life Cycle Inventories of Waste Treatment Services. *Ecoinvent report No. 13*. St. Gallen: Swiss Centre for LCI.
- Ecoinvent (2012). Ecoinvent Centre. Available at <http://www.ecoinvent.org> [Accessed 26 January 2012].
- Envirodec (2012). PCR 2012:05 Particle and Fibreboard. Available at www.envirodec.com [Accessed 20 April 2012].
- Frischknecht, R. & Jungbluth, N. eds. (2003). Implementation of Life Cycle Impact Assessment Methods. *Final report Ecoinvent 2000*. Swiss: Swiss Centre for LCI.
- Frischknecht, R., Althaus, H.J., Bauer, C., Doka, G., Heck, T., Jungbluth, N., Kellenberger, D. & Nemecek, T. (2007). The environmental relevance of capital goods in Life Cycle Assessments of products and services. *International Journal of Life Cycle Assessment*, 8, pp.806-816.
- Garcia, R. (2010). *Avaliação comparativa de instrumentos de ciclo de vida aplicados a dois sistemas com biomassa: painéis e electricidade*. Unpublished thesis (MSc). University of Coimbra.
- Garcia, R. & Freire F. (2011). Modelação energética e ambiental do ciclo de vida de painéis aglomerados de partículas. *Construlink*, 28(9), pp.22-30.
- Garrido, N., Martins, J., Pereira, J., Carvalho, L., Mendes, J., & Costa, C. (2010). Effect of recycled wood and alternative species on particleboard machining. In Processing Technologies for the Forest and Bio-based Products Industries. Campus Kuchl, Austria 7-8 October 2010.
- González-García, S., Feijoo, G., Widsten, P., Kandelbauer, A., Zikulnig-Rush, E. & Moreira, M.T. (2009). Environmental performance assessment of hardboard manufacture. *International Journal of Life Cycle Assessment*, 14, pp.456-466.
- Guinée, J.ed. (2002). *Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards*. Dordrecht: Kluwer Academic Publishers.
- Guinée, J.B., Heijungs, R. & Voet, E. (2009). A greenhouse gas indicator for bioenergy: some theoretical issues with practical implications. *International Journal of Life Cycle Assessment*, 14, pp.328-339.
- IEC (2008). General Programme Instructions for Environmental Product Declarations. Available at www.envirodec.com [Accessed 20 December 2011].
- INE (2010). *Estatísticas da Produção Industrial 2009*. Lisboa: Instituto Nacional de Estatística.
- Ingwersen, W.W. & Stevenson, M.J. (2012). Can we compare the environmental performance of this product to that one? An update on the development of product category rules and future challenges toward alignment. *Journal of Cleaner Production*, 24, pp.102-108.
- ISO 14040:2006. *Environmental management – life cycle assessment – principles and framework*. Geneva: International Organization for Standardization.
- ISO 14044:2006. *Environmental management – life cycle assessment – requirements and guidelines*. Geneva: International Organization for Standardization.
- ISO 14025: 2006. *Environmental labels and declarations – environmental labeling type III – principles and procedures*. Geneva: International Organization for Standardization.

- ISO 21930:2007. *Sustainability in building construction – Environmental declaration of building products*. Geneva: International Organization for Standardization.
- ISO/DIS 14067: 2012. *Carbon footprint of products – Requirements and guidelines for quantification and communication* (Draft International Standard). Geneva: International Organization for Standardization.
- Milota, M., West, C. & Hartley, I. (2006). Gate-to-gate life cycle inventory of softwood lumber production. *Wood and Fiber Science*, 37, pp.47-57.
- Nunes, J. (2008). *Avaliação Integrada da produção de electricidade com base em biomassa lenho-celulósica em Portugal: emissões de GEE, análise tecnológica e energética de ciclo de vida*. Unpublished thesis (MSc), University of Coimbra.
- REN (2011). Dados Técnicos 2010. Available at www.ren.pt [Accessed 06 December 2011].
- Risholm-Sundman, M. & Vestin, E. (2005). Emissions during combustion of particleboard and glued veneer. *European Journal of Wood and Wood Products*, 63(3), pp.179-185.
- Rivela, B., Hospido, A., Moreira, M.T. & Feijoo, G. (2006). Life cycle inventory of particleboard: a case study in the wood sector. *International Journal of Life Cycle Assessment*, 11, pp.106-113.
- Rivela, B., Moreira, M.T. & Feijoo, G. (2007). Life cycle inventory of medium density fibreboard. *International Journal of Life Cycle Assessment*, 12(3), pp.143–150.
- Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. eds. (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the 4th Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge and New York: Cambridge University Press.
- Wilson, J. (2010a). Life-cycle inventory of particleboard in terms of resources, emissions, energy and carbon. *Wood and Fiber Science*, 42, pp.90-106.
- Wilson, J. (2010b). Life-cycle inventory of formaldehyde-based resins used in wood composites in terms of resources, emissions, energy and carbon. *Wood and Fiber Science*, 42, pp.125-143.
- WRI/WBCSD (2011). Product Life Cycle Accounting and Reporting Standard. *World Resources Institute and World Business Council for Sustainable Development* [online]. Available at <http://www.ghgprotocol.org/files/ghgp/Product%20Life%20Cycle%20Accounting%20and%20Reporting%20Standard.pdf> [Accessed 12 January 2012].

Acknowledgements

Rita Garcia gratefully acknowledges financial support from Fundação para a Ciência e a Tecnologia (FCT), Portugal through grant SFRH/BD/51299/2010 and from the Energy for Sustainability Initiative of the University of Coimbra. The authors would also like to thank FCT for support under the projects MIT/SET/0014/2009, MIT/MCA/0066/2009, and PTDC/SEN-TRA/117251/2010.

Multicriterion assessment of existing buildings in reSBToolCZ

Stepan Mancik

Czech Technical University in Prague, Prague, Czech Republic

stepan.mancik@fsv.cvut.cz

Jan Ruzicka

Czech Technical University in Prague, Prague, Czech Republic

jan.ruzicka@fsv.cvut.cz

Multicriterion assessments of buildings, placing an emphasis on their environmental profiles, are becoming increasingly important in building practice. It is generally known that the greatest deal of energy savings in the building sector is achieved through improving the existing building stock. New buildings represent just a small part of the existing building stock. The key question with existing buildings is, what approach should be adopted towards existing buildings which can look very different depending on their construction, typology, building style and also the value of their historical and cultural quality. The assessment methodology reSBToolCZ for building renovations for residential purposes is based on SBToolCZ which was implemented according to Czech conditions and requirements. It considers current standards, legislation and approaches in cultural heritage protection of existing buildings and also the possibilities of their improving from the point of view of sustainability and environmental quality. ReSBToolCZ also includes historical monuments in the assessment, taking into account their historical quality so that they are not disadvantaged in comparison with buildings without any cultural or historical quality. The development of the methodology was finished and the assessment tool and benchmarks settings will be verified through case studies.

© 2012 Green Lines Instituto para o Desenvolvimento Sustentável. All rights reserved.

Introduction

SBToolCZ (www.sbtool.cz) is a Czech methodology (Vonka et al., 2011) for the evaluation of complex quality of buildings and is based on international methodology SBTool (www.iisbe.org) developed by iISBE – International Initiative for a Sustainable Built Environment. ReSBToolCZ for existing residential buildings and their renovation is an assessment method which evaluates building and location qualities with reference to sustainable development and cultural-historical values. Analogically as in the SBToolCZ for new residential buildings, a building's impact on the environment is assessed as well as socio-cultural aspects, functional and technical quality, economics and management and also the location of the building (for a complete criteria summary see chapter 8).

Several international methodologies exist which also deal with existing buildings (such as LEED, BREEAM, CASBEE, etc.) but they evaluate the scale of running efficiency of the building and its possible improvement. So they work more like a facility management tool. Its result is a list of recommended constructional interventions that would improve the overall performance of the building according to the methodology setup.

In order to be able to clearly define the essence and aims of the assessment tool for existing buildings, it is necessary first to define the specific terms that are involved:

- Reconstruction = intervention into an existing building that means fundamental changes in its construction. The fundamental part of the building is changed, and in case of need, also its purpose.
- Renovation = is such an intervention into an existing building when particular building structures are changed (for example in order to reduce energy demand of the building or to fix damaged structures) in a way that the essence of the building is preserved.
- BAT (Best Available Techniques) = currently best available technologies used for example for refurbishing a building structure.

Classification of existing buildings

The key issue of complex assessments of reconstruction or renovation of buildings is above all in the diversity of the existing building stock.

If it was possible to classify existing buildings then it would be also possible to assign specific ways of renovation or reconstruction in terms of sustainable development criteria for each category of buildings.

It is necessary to realize that during the assessment, buildings just several years old are evaluated at the same time as buildings several centuries old, buildings with a minimal cultural-historical significance and on the other hand buildings whose cultural-historical significance is immense. Buildings can naturally have different purposes. The criteria of the classification of buildings can be different according to the following parameters:

- Age
- Style
- Typology
- Structure or material
- Cultural-historical value etc.

These classification groups can overlap each other and classifying a building into one specific group can be complicated if the building is on the edge of two groups.

If it was decided to divide the assessment method according to these groups or their combinations then it would lead into a confusing state of heterogeneous approaches which would have to be divided between each other. Such a method and classification of buildings into specific subgroups could be problematic and it would be possible to confront it very easily.

The result from the above mentioned facts is that the categorization of existing buildings is not objective and transparent and it does not lead to satisfying results. An assessment method should be implemented in a way that it would not depend on classifying buildings but it would assess existing buildings in one transparent way according to their environmental, social, cultural and economic qualities.

Cultural-historical aspect of existing building

The main aspect that, in contrast to new buildings, affects renovations of existing buildings is their cultural-historical value. It has a fundamental influence on potential renovations and also on the scale of improvements of the overall building profile. It is obvious that it is necessary to approach to a building with cultural-historical value and a building with minor cultural-historical significance (Figure 1) differently.



Figure 1. Listed building after renovation (left) and renovated object without historical protection (right).

Assessment methods that nowadays exist for evaluating existing buildings do not consider their cultural-historical value.

From the point of view of the building structure, it is obvious that the cultural-historical value respectively of its preservation during renovation or reconstruction significantly limits achieving the best environmental performance quality.

Example 1 – Historical building: A very important aspect of an environmentally effective building is among others; reducing heating energy consumption. This could be achieved by improving the thermal insulation parameters of external walls or dividing into heated and non-heated rooms. However, a lot of buildings cannot be equipped with ETICS (External Thermal Insulation Compound System) considering their valuable historical façades or they can be just partially insulated. In such buildings it is often impossible to install new windows with the best thermal insulation parameters etc. These kinds of buildings would never reach the best evaluation in SBTToolCZ because of their cultural-historical quality.

In some ways, the demands on sustainable buildings and the necessity of handing them down to future generations; through the system of cultural references (Council of Europe, 1985) oppose each other. On the other hand, it is evident that the preservation of our cultural heritage, its maintenance and protection for future generations should be consistent with the principles of sustainable buildings.

Cultural-historical value in the Czech Republic

The protection of cultural heritage in the Czech Republic is defined by the Architectural Heritage Protection Law (Czech National Parliament, 1987) - as amended by further regulations. The Czech Republic has undertaken in respect to meet the standards set out in the Convention for the Protection of the Architectural Heritage of Europe (Council of Europe, 1985) issued by the Council of Europe in 1985. These documents are the fundamental pillars of architectural protection in the Czech Republic.

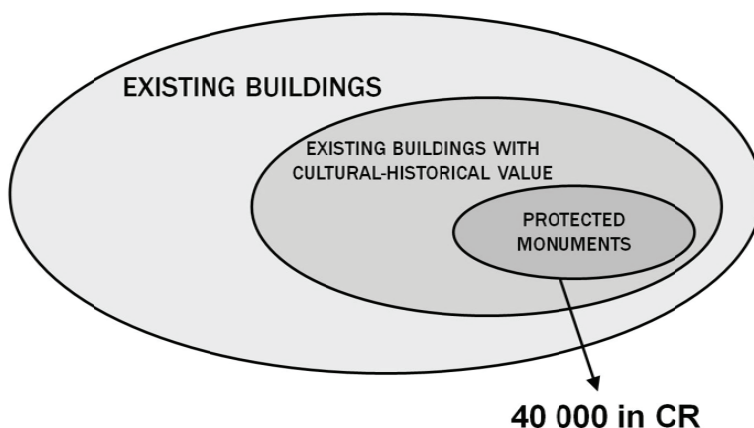


Figure 2. Diagram of existing buildings in the Czech Republic and their cultural-historical importance. There are over 40,000 recognized and protected historical monuments in the Czech Republic (National Heritage Institute, 2011).

On the basis of this law, the National Heritage Institute was established. It is an institution that administers a complex service of heritage protection (evidence of monuments, methodology of renovations, expert supervising over the maintenance, analyses etc.) and fulfills the objectives of the [aw.

Existing buildings can be illustratively divided according to the above mentioned documents into 4 categories that define their cultural-historical protection:

- A. Buildings without recognized cultural-historical significance;
- B. Buildings culturally valuable but not protected by law; buildings in the protection perimeter
- C. Buildings in a reservation or a zone
- D. Architectural monument
- G. Buildings of special importance

Every building is unique and represents a specific case and therefore requires an individual approach to its renovation as well as to its assessment.

Cultural-historical quality of every building that is to be renovated or reconstructed should be assessed by a responsible person, in this case by an authorized architect. For buildings that fall into groups C and D, the scale of the constructional intervention and its way are determined by the requirements and instructions of the authority in the field of architectural heritage protection which is the

National Heritage Institute. This institute should be a partner for the investor while searching the conception of renovation of delicate buildings. This also presumes a wider perception of reconstruction and renovation of the existing building stock not only in the context of heritage protection but also in the context of sustainable buildings.

For groups B, C and D and potentially valuable buildings from group A, it is clear that the assessment method reSBToolCZ fully respects the priorities of cultural heritage protection of those buildings that represents such values, and tries to define within the protection definition such construction interventions that improve its quality in terms of sustainable development. Buildings that do not represent such a value (group A) are not limited by the protection and can be improved any way.

Aims of the assessment method for evaluation of existing buildings

In the light of the above mentioned facts, two main goals were implemented for the proposal of the multicriterion assessment method for existing buildings:

- Assessing the complex quality of new buildings and renovated/reconstructed buildings in a way that the resulting quality of both will be comparable
- Systematically taking into account the cultural-historical qualities of buildings

This kind of assessment method will allow an evaluation of all existing buildings without the necessity of their classification into some groups, no matter what historical quality they represent. At the same time it will be able to mutually compare the complex quality of existing and new buildings. In this connection, it is necessary to keep in mind the possibility that a number of existing buildings have neither cultural-historical quality nor the potential of environmental improvement can be replaced by new buildings that have at least one of these qualities.

Such buildings will be assessed with the reSBToolCZ method as well but the benchmarks in the criteria will not be affected by cultural-historical values. So there will not be any relative setup of the benchmarks (by improvement potential) and the buildings will be assessed practically the same way as new buildings. It is necessary to take into account also the possibility that sometimes the best solution for the existing building is demolition.

Example 2 – Embodied energy and emissions: The assessed building will not be found historically valuable and will be assessed by the reSBToolCZ method with the criteria setup as for a new building (that means without implementing the principle of relative setup by improvement potential). Then in the criteria which deals with the embodied parameters of materials used in the building, an existing building will have a better position because the original materials in the buildings will not be counted into the assessment. Only those materials added to the construction during renovation/reconstruction will be counted.

Example 3 – BAT historical building vs. new building: If the renovation/reconstruction of an existing building was designed as a BAT construction in compliance with the principles of cultural-historical protection then the building gets the best marks even though the absolute quality of the renovated/reconstructed building in technical and environmental parameters are lower than those of a new building of a similar scale.

Example 4 – BAT historical building vs. standard renovation: Two existing buildings of different historical quality are assessed. Both are designed in the BAT standard in compliance with the principles of cultural-historical protection. These two buildings get the best evaluation in reSBToolCZ even though their environmental qualities are different (Figure 3).

Example 5 – reSBToolCZ as a part of investment decision making process: The renovation/reconstruction of an existing building is designed in the BAT standard and the building reaches a certain evaluation level. At the same time there is a proposal of a new building. It is possible to achieve a better evaluation with the new building. On the basis of comparison of these two assessments; the investor can decide if he wants to renovate/reconstruct the existing building or demolish it and replace it with a new one in better quality.



Figure 3. Listed building after BAT renovation and renovated building without historical protection with parameters as a new building.

Basic principles of reSBToolCZ assessment method

The cultural-historical value of buildings that takes into account valuable historical elements, constructions, details or crafts to certain extent limits the possibilities of achieving the best environmental quality. It "disadvantages" such buildings in terms of the SBTool criteria, even though in many cases, the protection of the historical value is much more important. This protection can be called cultural sustainability.

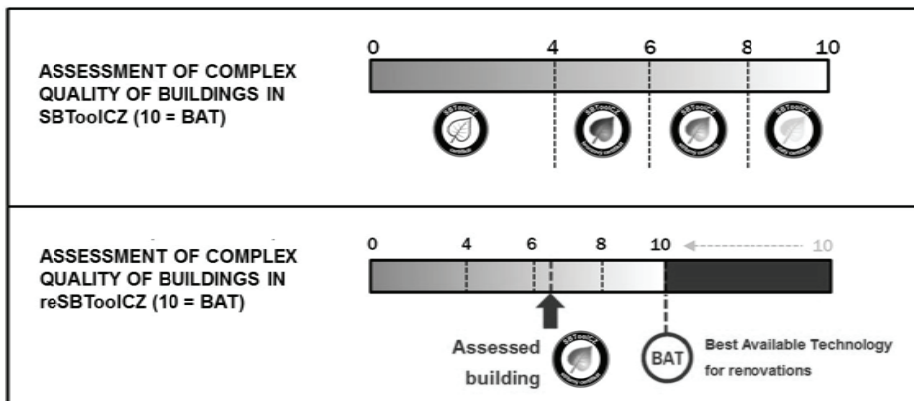


Figure 4. Comparison of assessment of buildings with and without cultural-historical value. The scale shows the evaluation in reSBToolCZ assessment method.

The criteria for assessing existing residential buildings and the evaluation system come from the existing methodology for new residential objects (Example 5). Only some definitions and benchmarks are slightly modified.

The basic principle of reSBToolCZ assessment is the relative setup of those criteria and benchmarks that are directly influenced by the cultural-historical values of the building. The setup is always made individually depending on cultural-historical significance. In these criteria, the BAT standard is defined and creates the highest outline of the benchmarks. The quality of designed renovation/reconstruction is assessed in the interval <original state; BAT>. This approach helps to avoid the categorization of existing buildings and further complications during their classification.

Division of criteria according to the matter of benchmark setting

The proposed method of multicriterion assessment of existing buildings divides the criteria into the following groups according to benchmark settings:

- A. Criteria with identical settings as for new buildings
- B. Criteria with benchmarks modified by the improvement potential
- C. Criteria modified for existing buildings

Criteria with identical settings as for new buildings

Those criteria that do not have any direct connection to the cultural-historical value of the building belong in this group. These criteria and their settings do not differ from those for new buildings. The reason is either the possibility of achieving the best available evaluation even for existing buildings or the relative benchmark setup cannot be applied in this case because of the qualitative nature of the criteria (for example those criteria that deal with the internal quality of buildings and their impact on people). In this group, there are the two following cases:

- Benchmarks are the same as those for new buildings because renovation/reconstruction can reach the best quality defined in the criteria. These criteria are represented by the social group. It is clear that internal environment of building has the same impact on a human being no matter if it is historical building or not. This aspect of building quality cannot be relativized and it is important to keep the current setting that comes from valid regulations and laws.
- Embodied energy and emissions that are already built in the existing building are not included into the assessment. Only the materials that are added during the construction within the renovation process are calculated. This automatically means a better position for existing buildings compared to new buildings. The usage of the existing buildings means a reduction of the consumption of new materials and built-up areas which are some of the basic principles of a sustainable building. At the same time, the higher design and economical complexity of the renovation is compensated (Example 6).

Example 6 – Small renovation vs. major reconstruction: The main structural part is made as a reinforced concrete shell with light suspended façade. Two variants of renovation/reconstruction are designed:

- a) The minimalistic variant where the façade is thermally insulated. The consumption of materials in comparison with a newly built object is very low and the existing building will reach the best evaluation in this criteria. On the other hand running costs will be just partially reduced and this solution will not improve the quality of the internal environment.
- b) A complex reconstruction occurs where the entire façade is changed for a new one. This means that the embodied emissions and energy rise significantly. On the other hand this step reduces the running costs for heating, air-conditioning etc. so the building achieves the best evaluation in other criteria.

Criteria with benchmarks modified by improvement potential

The criteria where it is necessary to take into account cultural-historical values are implemented relatively according to the building quality. This relative set up of benchmarks is called the improvement potential. This represents the scale of possible improvement in terms of the criteria influenced by the cultural historical value (Figure 4).

Benchmark settings are relative which means that they are always set up ad hoc building from to building according to the evaluation of original state and definition of the BAT solution for the building. Then the proposed solution lies in the interval between the original state and the *BAT <original state; BAT>*. The difference between these two points is called the improvement potential (Figure 4).

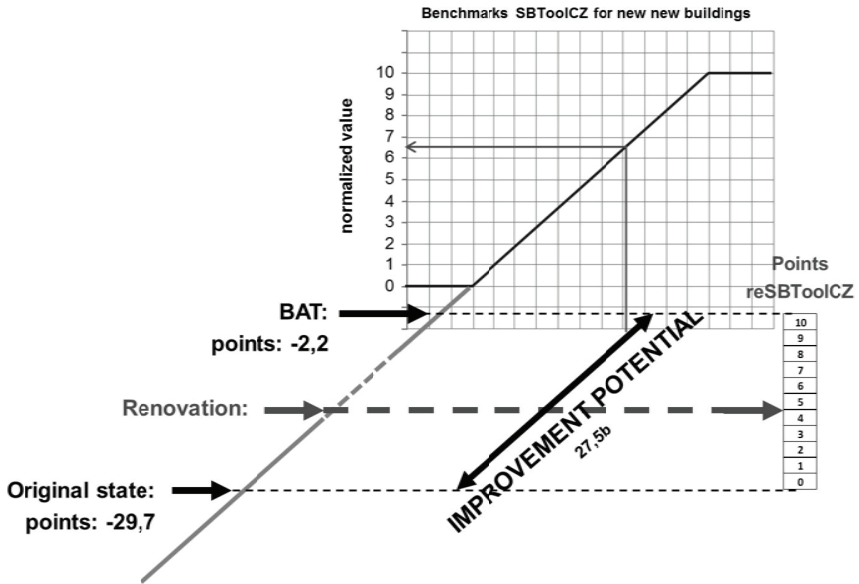


Figure 5. Benchmark setting with the help of improvement potential. Graph shows the layout of benchmarks for new buildings. reSBToolCZ point evaluation of original state, BAT and designed renovation can be seen on the stretched normalization line.

Valuable facades or decorative interiors that influence the building’s envelope are common matters of architectural protection. That is why all the criteria from the environment that are connected to the façade belong to this group. Furthermore, “User Comfort” from the social group belongs here too.

Example 7 – BAT renovation of historical valuable building: The aim is to refurbish an object with a valuable decorative façade. The thermal insulation capacity of the external walls is of a low level. The only possible intervention to the façade is a partial change of the glazing or partial internal thermal insulation. These acquisitions define for this building the BAT standard form for improving the façade and criteria connected with it.

Criteria modified for existing buildings

The last criteria are those which are necessary to be redefined because the setting for them is not appropriate for the existing buildings.

For example from the group of environmental, criterion E.11 Land use belongs here. The assessment of handling demolished waste material will be newly implemented.

Summary and comparison of criteria for new and existing residential buildings

In the Table 1 the criteria of reSBToolCZ are summarized together with a comparison with the criteria for new buildings (Vonka et al., 2011).

Table 1. Comparison of the criteria in existing methodology for new residential buildings and reSBToolCZ.

SBToolCZ for new buildings		reSBToolCZ
Environmental criteria		
E.01	Global warming potential	Improvement potential
E.02	Acidification potential	Improvement potential
E.03	Eutrophication potential	Improvement potential
E.04	Ozone depletion potential	Identical with new b.
E.05	Photochemical ozone creation potential	Identical with new b.
E.06	Use of greenery on building site	Identical with new b.
E.07	Use of greenery on roofs and facades	Improvement potential
E.08	Potable water identical with new buildings	Identical with new b.
E.09	Primary energy consumption	Improvement potential
E.10	Use of construction material	Identical with new b.
E.11	Land use	Modified for existing b.
E.12	Outcome of rainwater	Identical with new b.
Social criteria		
S.01	Lighting comfort	Identical with new b.
S.02	Acoustic comfort	Identical with new b.
S.03	Thermal comfort in summer	Identical with new b.
S.04	Thermal comfort in winter	Identical with new b.
S.05	Health safety of materials	Identical with new b.
S.06	User comfort	Improvement potential
S.07	Accessibility for disabled	Identical with new b.
S.08	Building security	Identical with new b.
S.09	Adaptability	Identical with new b.
S.10	Space Efficiency	Identical with new b.
S.11	Use of exterior building	Identical with new b.
Economics and Management		
C.01	Operation cost analysis	Identical with new b.
C.02	Provision of operation plans	Identical with new b.
C.03	Operation autonomy	Identical with new b.
C.04	Sorted waste management	Identical with new b.
Locality		
L.01	Biodiversity	Identical with new b.
L.02	Provision of place for free time	Identical with new b.
L.03	Key amenities - provision and proximity	Identical with new b.
L.04	Public transport accessibility	Identical with new b.
L.05	Site security	Identical with new b.
L.06	Natural risk	Identical with new b.

Conclusions

The aim of the proposed assessment method is not a polemic about the level and procedures of architectural protection of historical buildings. In good faith the thesis accepts that the way of current protection of cultural heritage is carried out in the best available format. The proposed assessment method uses these preservation techniques. Interventions into the reconstruction of a building must be in compliance with these principles. On the other hand, it is probably necessary to extend the view of cultural heritage protection to wider social demands and take it in as an inseparable part of a sustainable building.

From the point of multicriterion assessment of existing buildings, reSBToolCZ is a completely new method and differs from all existing methodologies. Fairness of this approach is obvious when we look at the absolute number of historical monuments in the Czech Republic. Nowadays, there are more than 40,000 (National Heritage Institute, 2011). Buildings that represent a certain cultural historical value but are not protected by law though are not included in the National Heritage Institute's overall estimate.

The assessment method reSBToolCZ and its benchmark settings are currently being tested in several case studies.

References

- Ad-hoc Industrial Advisory Group (2009). Energy-efficient Buildings (EeB) PPP, Research priorities for the definition of a Multiannual Roadmap and longer term Strategy. *European Economic Recovery Plan*. Brussels: European Commission.
- Council of Europe (1985). *Convention for the protection of the architectural heritage of Europe*. Grenada.
- Czech National Parliament (1987). *Protection of cultural heritage law*. Prague.

Faculty of Civil Engineering (2011). *About SBToolCZ*. Available at www.sbtool.cz.

National Heritage Institute (2011). MonumNet. *MonumNet*. Available at <http://monumnet.npu.cz/monumnet.php>.

Vonka, M. et al. (2011). *Methodics SBToolCZ – Manual for assessment of new residential buildings in design phase*. Prague: Faculty of Civil Engineering.

Acknowledgements

This research has been supported by grant of GA ČR 103/09/H095 „Sustainable Construction of Buildings and Sustainable Development of Urban Space“.

Contents

Volume 1 - Number 1 - 2012

Editorial

Rogério Amoêda, Luis Bragança & Ricardo Mateus

Articles

The cultural values embedded in building environmental assessment tools: a comparison of LEED®- Canada and CASBEE

Aiste Blaviesciunaite & C Raymond J. Cole

The need of harmonization: from building product information to the whole process of the construction

Beatriz Rivela, Cesar Bedoya & Alfonso García-Santos

Sustainability assessment tool of green building renovation in Taiwan: an introduction to EEWH-RN

Chung-Yi Chang, Hsien-Te Lin & Ming-Chin Ho

Patterns in green building practice: analysis of LEED project data

Joel Anne Todd & Robert Tufts

Sustainability assessment of materials used in façade cladding

Jorge Orondo & Cesar Bedoya

Green Building classification system for developing countries

Prashant Kapoor

Environmental assessment of wood-based panels: a comparison of life-cycle-based tools

Rita Garcia & Fausto Freire

Multicriterion assessment of existing buildings in reSBToolCZ

Stepan Mancik & Jan Ruzicka