Building Sustainability Assessment and Benchmarking

An Introduction

UN-HABITAT
FOR A BETTER URBAN FUTURE

BUILDING SUSTAINABILITY ASSESSMENT AND BENCHMARKING - AN INTRODUCTION

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GNSH GLOBAL NETWORK FOR SUSTAINABLE HOUSING

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GLOSSARY

Assessment tool	A methodology that aims to measure absolute values of a building's impact (energy consumed, GHGs emitted, etc.) without giving a comparative value judgment.
Benchmarking tool	A methodology that, firstly, assesses a building along a set of criteria; secondly, rates its performance against a given standard (e.g. reference sets of rated buildings, set criterion values or standards, national averages, modelled/simulated building behaviour, or other methods of comparison); and thirdly, communicates a value judgment about its performance.
BEST	Built Environment Sustainability Tool, developed by Dr. Jeremy Gibberd, Smart and Sustainable Built Environments Group W116 at CIB.
BREEAM	Building Research Establishment Environmental Assessment Method, developed by the UK-based Building Research Eastablishment (BRE).
BSA	Building sustainability assessment.
CCM	Common Carbon Metric, a UN-Environment protocol for measuring energy use and reporting GHG emissions from the operational phase of buildings.
CEN/TC 350	Comité Européen de Normalisation/Technical Committee 350, standards committee mandated with the development of a harmonized European assessment methodology.
DECoRuM	Domestic Energy, Carbon Counting and Carbon Reduction Model, developed by Pr. Rajat Gupta, Oxford Institute for Sustainable Development (OISD).
DfD	Design for Disassembly; the process of designing products so that they can easily, cost-effectively and rapidly be taken apart at the end of the product's life so that components can be reused and/or recycled.
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen, German Sustainable Building Council.
EF	Ecological Footprint.
EPD	Environmental product declaration, a standardized way of quantifying the environmental impact of a product or system, allowing the easy comparison of the environmental impact of different products and services. EPDs are calculated following product category rules (PCR).
ESUCO	European Sustainable Construction database.
EN 15804	European standard which provides core product category rules (PCR) for Type III environmental declarations for any construction product and construction service.
EN 15978	European standard which defines the rules for evaluating and reporting on the life-cycle impact of a building.
HDI	Human development index.
HQE	High Quality of Environment, Cerway certification scheme originating in France.
ISO 13790:2008	Provides calculation methods for the assessment of the annual energy use for space heating and cooling of a residential or non-residential building.
ISO 14040:2006	Describes the principles and framework for life-cycle assessment (LCA).
ISO 14044:2006	Specifies requirements and provides guidelines for all phases of life-cycle assessment (LCA).
LCA	Life-cycle assessment.
LCCA	Life-cycle cost analysis.

LCEA	Life-cycle energy analysis.
LCEM	Life-cycle energy modelling.
LCI	Life cycle inventory.
LEED	Leadership in Energy and Environmental Design, U.S. Green Building Council certification scheme.
PCR	Product Category Rules, common and harmonised LCA calculation rules for particular product groups to ensure that similar procedures are used when creating environmental product declarations (EPDs), enabling the comparability of EPDs of different products within the same product group.
POE	Post-occupancy evaluation.
QSAND	Quantifying Sustainability in the Aftermath of Natural Disasters, developed by the International Federation of the Red Cross and Red Crescent Societies.
SBAT	Sustainable Building Assessment Tool (SBAT), developed by Dr. Jeremy Gibberd, Smart and Sustainable Built Environments Group W116 at the Council for Research and Innovation in Building and Construction (CIB).
SBMI	Sustainable Building Materials Index, developed by Dr. Jeremy Gibberd, Smart and Sustainable Built Environments Group W116 at the Council for Research and Innovation in Building and Construction (CIB).

EXECUTIVE SUMMARY

Buildings, the majority of which are in residential use (Buildings Performance Institute Europe, 2011), accounting for 19 per cent of global total final consumption (IEA, 2014), are a major contributor to environmental degradation. The building sector is estimated to consume 40 per cent of the world's energy and materials while the construction industry, and its supporting industries, account for 16 per cent of the world's water used (Hoffman & Henn, 2008; Roodman, Lenssen, & Peterson, 1995; Dixit, Fernández-Solís, Lavy, & Culp, 2010). On a business-as-usual trajectory, **energy demand from the building sector is expected to rise by 50 per cent by 2050** (IEA, 2013).

At the same time, the building sector's potential for reducing GHG emissions is considered the largest of all sectors—a mitigation opportunity not to be missed. In addition, the built environment has the potential to contribute positively towards social-economic development along a range of indicators. But what are the real obstacles to action, especially given the urgency yet again made clear in the Sustainable Development Goals, the Paris Agreement, and the 'New Urban Agenda'[1]?

For one, the large number of stakeholders involved in the production and consumption of buildings creates coordination problems with competing interests. Due to their long lifespan and the long-lasting effects of associated climate pollutants, sub-optimal decisions at the design stage of building processes can cast in concrete unsustainable usage patterns and lower the quality of life for building users for generations.

The building sector is a complex issue-focused, multi-stakeholder system (Feige, Wallbaum, & Krank, 2011). In order to positively influence decisions of this system's stakeholders, the **scientific, accurate and meaningful assessment** of existing and new buildings along a wide range of indicators has developed as a credible tool for achieving this objective.

Over the past 30 years, the number, scope and complexity of tools for assessing the environmental impact of buildings has increased dramatically. Examining the emergence of building sustainability assessment and benchmarking as a global phenomenon as well as some of their political and practical barriers can be useful in order to understand their possible role in realizing objectives of the 'New Urban Agenda' and the policies to be influenced by it.

Historical background

The potential of building assessment and benchmarking is no recent discovery. Section 69 e) of the *Habitat Agenda* (United Nations, 1996) already called to:

> *The first step would be to establish the current state of affairs in developing countries (on a country-by-country basis) in respect of the impact of the built environment, the broad construction process, the capacity of the construction industry (including the built environment professionals), and* ***the life-cycle properties of existing technologies used in these countries****.*

More specifically, in relation to developing countries, 'Agenda 21 on Sustainable Construction', published by the International Council for Research and Innovation in Building and Construction (CIB) in 1999, highlighted the need for more life-cycle data (Section 4.2.1):

[1] 'The New Urban Agenda' is the outcome document of the Third United Nations Conference on Housing and Sustainable Urban Development.

> *Promote the free exchange of information on the entire range of the environmental health aspects of construction, including the development and dissemination of databases on the adverse environmental effects of building materials, through the collaborative efforts of the private and public sectors.*

Furthermore, Agenda 21 called to:

> *...establish the impact of the built environment in developing countries. The range of built environment types in developing countries is far broader than that in developed countries, covering a range from ultra-modern skyscrapers to different types of informal settlements, and down to deep rural traditional settlements.* ***Each of these has different socio-economic and environmental impacts that need to be determined.***

While 18 years on, the **lack of accurate data** especially in developing countries remains, *Agenda 21* did set a new global context for building evaluation, initiating active research into different sustainability indicators and accompanying methods (Ahankoob, Morshedi, & Rad, 2013).

In the wake of increasing awareness on issues of sustainability, especially in relation to the building sector, the field quickly developed from an academic and commercial niche to a highly specialised and contested area, causing many practitioners to not be able to "see the forest for the trees". Developing a critical attitude towards how and where we build may be hindered by the daunting complexity of the subject as well as widely diverging definitions of sustainability.

Naturally, **previous attempts** have been made to provide such an overview (Haapio & Viitaniemi, 2008; Wallhagen, Glaumann, & Westerberg, 2008; Kaatz, Barker, Hill, & Bowen, 2002; Abd'Razack & Muhamad Ludin, 2013), such as the European Union-funded 'Open House' project. The project identified 37 international and 64 European "qualitative assessment methods"; however, not all ended up meeting the project's inclusion criteria. Open House provided a review of the status of the development of international standards (TC59/SC 17, CEN/TC 350...), global initiatives (SB Alliance, iiSBE...) and international methodologies (LEED, DGNB...) targeting the assessment of sustainable buildings. The review was then used to define a baseline for Open House's own methodology. Some comparative research on the accuracy, relevance and impact of different schemes is available. However, where it has been undertaken, it is not available for all schemes in equal measure.

To what extent these attempts have found a wide audience, especially among policy-makers, is uncertain. The present report, therefore, is based on the assumption that, as the world has agreed on a New Urban Agenda in October 2016, a brief and accessible introduction to the field could be useful, while building on existing research, and widening the scope to discuss how building sustainability can be promoted in low-income countries, where the vast majority of construction is going to take place during the course of this century.

Structure, scope and purpose of the report

As part of UN-Habitat's mandate to promote sustainable urban development through knowledge-creation and management, this report intends to address some of these concerns and contribute to four objectives:

a. **Establish the rationale** for building sustainability assessment and benchmarking (Chapter 1);

b. **Identify challenges** and limitations that occupants, policy-makers and building practitioners face in applying or interpreting building sustainability assessment or benchmarking tools (Chapter 2);

c. **Provide a sample overview** of some environmental sustainability assessment and benchmarking tools for buildings and housing as well as those attempting to measure social and economic impacts (Chapter 3);

d. **Identify pathways for the wider uptake** of assessment tools by industry, professional bodies, policy-makers, vocational and higher education, and other actors working within the built environment (Chapter 4).

This is intended to provide newcomers with a brief introduction to the field, ranging from its smallest components—indicators and weightings—to the legislative mechanisms and policies used to promote them. While comprehensiveness on this topic is clearly unattainable, some estimates pin the total number of tools or methodologies for building assessment and benchmarking at around 150. The methodologies profiled in this report have been selected with the goal of offering as wide a range of examples as possible. Some of the most widely used commercial benchmarking tools (LEED, BREEAM, HQE and DGNB) are presented alongside local initiatives (LOTUS from Vietnam, and NABERS from Australia), open-source initiatives (SBtool , SBAT and QSAND), individually as well as collaboratively produced research products (DeCoRum and CCM), in addition to briefly describing a common underlying methodology (life-cycle assessment) and a harmonization effort at the international level (CEN/TC 350).

In order to avoid unfair comparisons, this paper is opting to present the schemes with as little value judgment as possible and focus instead on their particular methodologies and scopes. Contrary to some of the existing reviews of building sustainability schemes, the individual profiles have, in most cases, been authored or co-authored by the scheme's developers themselves and consequently edited to remove subjective statements or to add third-party opinions. It is hoped that the paper has thus been able to strike a balance between subject matter expertise and relative objectivity.

Naturally, experts in the field will note the omission of a number of important national, regional and international initiatives. We hope that what is lost in comprehensiveness is gained in accessibility.

The paper's intention is that even such a rough overview can contribute to highlighting the challenges and potentials of building sustainability assessment and benchmarking for policy-makers, practitioners and the general public.■

1. WHY ASSESS AT ALL?

Traditionally the two main objectives of building sustainability assessment and benchmarking have been 1) to aid the design of sustainable buildings and 2) to help evaluate the sustainability of existing buildings.

The first objective seeks to provide designers, local authorities and project managers with guidance to take **more informed decisions** about siting, facilities, building techniques, materials, design options, affordability, social inclusion and other considerations.

The second objective gathers and quantifies *actual* information about the various impacts of a building. Several sustainability indicators are measured, weighted and evaluated, **providing an overview** of a selective—and by definition incomplete—list of local, regional and global impacts.

One can, however, also identify other objectives that building assessment and benchmarking can help to achieve. On an institutional level, benchmarking and assessment of buildings is used to **verify compliance with national and international regulations**. It can also play a role in the planning process by **strengthening the position of planning control officers** to refuse or amend developments on the grounds of sustainability concerns. Chapter 4 will briefly touch on how regulations in some jurisdictions have begun to institutionalise the use of building assessment and benchmarking in order to raise sustainability concerns with developers.

We can also avail of assessment and benchmarking methodologies as an **educational tool** for concretizing sustainability with design and planning students. Assessment tools can help make the effects of particular design decisions visible, thus enabling students to form a more thorough and systematic understanding of the complexity of sustainability in the built environment.

Assessment and benchmarking schemes can **reinforce stakeholder collaboration** by creating a platform for discussion. They can offer a common "sustainability language" to engage in discussions about design choices and the role of a project for community. Certain tools allow for considerable customization by selecting or discarding non-core indicators and weightings which may be particularly relevant to their local context.

Benchmarking and assessment can **demonstrate to building consumers the energy credentials** of a building. These may include tenants, home-buyers, investors and lenders for whom data on the operational costs, or other characteristics of a building would influence their investment or renting decision (Aspinal, Sertyesilisik, Sourani, & Tunstall, 2013; Institute for Market Transformation, 2015). In this regard, there are substantial differences between the schemes applied, stakeholder incentives for certification and other implications, when examining residential or commercial buildings. Increasingly, the property valuation community is acknowledging the importance of sustainability criteria and is integrating them into the valuation process. Certification can also be a part of a property developer's or property manager's "green" image—including associated dangers of "green-washing" (Aspinal et al., 2013).

Efficiency gains through better designs and materials can **reduce the running costs** related to energy and other amenities, especially in harsher climates. If the purchaser and operator of the building are, in fact, one and the same entity, this creates a valid selling point that benchmarking or certification can help market.

From a material supplier's perspective, conducting a life-cycle assessment (LCA), a particularly specialized and formalized type of assessment covered in this report, can help **detect weaknesses in the material supply chain** which can in turn result in benefits from both an environmental and profitability point-of-view.

Once standardized, many methodologies can help establish specific objectives and indicators for sustainable urban development. Well established assessment methods could have the ability to transform generic sustainability goals into specific performance targets (Bragança, Mateus, & Koukkari, 2007), offer a recognizable structure for tracking environmental impacts (Cole, 2005), and **create references, benchmarks and target performance levels** for future building projects. Overall, building assessment and benchmarking can **raise general awareness** regarding sustainable urban development (Aspinal et al., 2013).

In the vast majority of jurisdictions, assessment schemes are voluntary, indicating that the main objective of certification schemes especially is in fact to stimulate the market demand for buildings with improved environmental performance (Cole, 2005). It is questionable whether any methodology for assessing building impacts can have a transformative effect on the building sector, if not made compulsory or at least referenced in local policies and regulations, provided that methodologies can fall back on sound, accurate, and localized data[2].

[2] *Exceptions do exist. In Zurich, Switzerland, for instance, the Minergie label and the application of 25 per cent recycled concrete aggregates is mandatory for all public buildings (Erpenbeck & Schiman, 2009).*

2. THE CHALLENGES

Assessing the impact of buildings and especially housing—a pivotal piece in the social and economic fabric of our cities and towns—is a critical undertaking. However, there are a number of challenges.

2.1 Range of chosen indicators and credibility of "green" labelling

Beginning with the arguably most scientific of objectives—assessing the environmental impact—, several caveats have emerged.

What and *how* to measure varies widely between schemes and even between users of schemes. In terms of *assessment* tools which measure the *absolute* values of a building's environmental impact, this is of slightly lesser concern since no value judgement about "good" or "bad" performance tends to be attached. In terms of *rating* systems which intend to evaluate different buildings and communicate the alleged sustainability of a structure to consumers, this does present a problem.

Take life-cycle assessments (LCA) as an example: even though the methodology has been well-defined in a number of international standards, there can remain large variations between LCA studies due to differing **system boundaries**[3], calculation methods and environmental flows. Product category rules (PCRs) and harmonization efforts like the European Standard EN 15804 have been undertaken to address this challenge.

It has been argued that the emergence of building certification schemes has created a common misconception of viewing eco-technologies—such as solar panels or sensors—to regulate indoor climate, as the sole equivalent of sustainable building practices (Conte & Monno, 2012). At the same time, many of the existing methodologies tend to disregard variables such as location, the previous use of the building site (brownfield vs. greenfield), the impact of associated infrastructure or the transport requirements of occupants (ibid.).

[3] *Put simply, a system boundary defines the scope of the model in question, both in terms of its geographical area, the time horizon and boundaries between the life-cycle of the product considered and the lie-cycle of related products. See also Tillmann et al. (1994).*

In addition, operational energy, which is generally targeted in building projects and certification schemes that label themselves as "green", is only partially responsible for a building's life-cycle performance[4]. In response to this, **more holistic assessment schemes** have emerged in recent years, placing increased emphasis on socio-cultural and economic indicators.

While this is a positive development, it also opens the door to a fair degree of **subjectivity**. In addition, one could argue that even this expansion rarely includes **reflections informed by a human rights-based approach** and whether housing projects in particular pay enough attention, for instance, to the needs of groups in vulnerable situations, which must be addressed as essential components of sustainability. Project designers and assessors thus have to carefully consider the focus of their assessment or review ways in which both approaches could be gainfully combined.

2.2 Weighting of indicators

The weighting system determines the importance of a system's indicators. Next to the selection of indicators itself, the weighting system strongly shapes the scope and focus of assessment and benchmarking tools (Lee, Chau, Yik, Burnett, & Tse, 2002). Even though often developed as part of an extensive consultative process, it may still be considered a relatively subjective feature[5] as the relative importance of indicators in any context remains debatable, and may be subject to change.

Generally, national rating and certification schemes are based on **local regulation and standards** of the country in question. In these cases, the weighting system is "predefined according to local socio-cultural, environmental and economic reality" (Bragança, Mateus, & Koukkari, 2007). Advanced tools also tend to have separate weighting systems for assessing the sustainability of **different building types**, for example, social housing schemes versus office complexes, and even up to the neighbourhood level. Whereas the former could have a strong emphasis on participatory processes, accessibility, connectivity, social inclusion, security of tenure, access to facilities and mixed-use, the latter may consider other aspects, such as operating energy and water conservation, as more relevant.

In an attempt to internationalize, some tools feature adjustable weighting coefficients to suit local conditions such as climate or prioritized policy objectives of the area (Ding, 2008). While this increases the local appropriateness of the assessment, it also reduces the possibility of comparing results between localities. Additionally, the opportunity to customize the weighting system can, if undertaken by untrained, biased or insufficiently informed professionals, lead to disproportionately skewed results.

2.3 Reliability of data

Secondly, **reliable environmental impact data** for particular building products in a particular location are still relatively scarce in many parts of the world. This data is gathered in the so-called life-cycle inventory (LCI) analysis stage of an LCA. It contains primary and secondary data on the environmental impact of products such as energy and raw material requirements, atmospheric emissions, waterborne emissions, solid waste, and other releases for the entire life-cycle of a product, process, or activity. An assessor relies on this data to be multiplied with the material quantities in the structure.

To facilitate access to this kind of data, generic commercial databases such as EcoInvent (ecoinvent.org) have made datasets for products and activities available mainly in the Swiss and Western European context. While these generic databases can, in theory, substitute for country- and industry-specific LCI data, Lasvaux et al. (2015) have shown that results can differ substantially

[4] Stephan, Crawford and de Myttenaere (2012) calculated embodied, operational and transport energy as being almost equally important over a fifty year lifespan of two buildings in Belgium and Australia, respectively. See also Anderson et al. (2015).

[5] Incidentally, this is also true of systems that do not apply any weighting system, since giving every indicator a value of 1 would also constitute a form of weighting.

between these two types of databases (though comparatively less so for energy and CO_2-related indicators, and for building level LCAs less so than at database level). Considering that this particular study compared a generic European database (EcoInvent v2) with an industry-specific, yet still European, national EPD database (INIES), one may assume that deviations between a generic European database and building materials production in a non-European context would be even more pronounced. Lasvaux et al. have also highlighted deviations due to data becoming outdated or not reflecting efficiency gains achieved by individual production plants.

Another confounding variable is that GHG emissions resultant from a building's energy use **depend very much on a country's energy mix**. Energy mixes between countries differ quite considerably (EuroStat, 2015), and are undergoing continuous change. This increases uncertainties about the environmental impact of buildings with lifespans up to a century and more. Assessments should therefore be seen as a fleeting 'sustainability snapshot'. Wallbaum et al. (2010) rightfully point out:

> *If change and uncertainty are, according to the notion of complex systems, the only certainty we may have, then it is clearly necessary to make this much more explicit in assessment tools.'*

2.4 Comprehensiveness and user-friendliness

A central question for practical application is: how can assessment tools balance the opposing need for increased comprehensiveness with ease of application?

Environmental assessments and especially sustainability assessments are by definition complex, presenting a sizeable barrier to their wider uptake. While commercial benchmarking schemes 'solve' this problem through certification by specially trained auditors, this also leads to higher costs for certification and consequently the exclusion of large parts of the building stock.

An increase in comprehensiveness leads to an increase in time, complexity and, eventually, cost. In addition, the relative significance of each indicator decreases, thus requiring careful calibration of the weighting system.

2.5 Predicted vs. actual performance

An assessment or benchmark is by definition a 'snapshot' of a building's performance with many schemes offering little to no in-built functionality for tracking performance over the building's lifespan or easy adjustability to changing variables. The discrepancy between predicted and actual performance is well-documented. Though post-occupancy evaluations (POE) are being introduced by various schemes, gaps between predicted and measured performance remain a regular occurrence.

Possible reasons for this phenomenon range from "modelling inaccuracies, envelope and systems integration problems, construction quality issues, occupancy changes, commissioning and handover processes, operational issues, motivation of occupants, and understanding of comfort" (Bartlett, et al., n.d.). Taking two of these as an example, the actual construction process and the handover to the client can present a problem as the quality of building is often not in accordance with specifications, with insufficient attention paid to both insulation and airtightness.

Similarly, occupant behaviour is often different from the assumptions made in the design stage (de Wilde, 2014). The predicted energy savings associated with the technical specifications of specific energy labels in the Netherlands, for instance, have been shown to not occur in practice, calling into question the substantially higher investments needed to reach a "better" energy label (Majcen, Itard, & Visscher, 2013).

2.6 Subjectivity

Some aspects of assessment and benchmarking are prone to **subjectivity and uncertainties**. These range from inaccuracies in the underlying databases to utilizing a tool or a version of a tool that has not been adjusted to the local context.

Careful selection of the most appropriate assessment or benchmarking tool is thus of vital importance. This in turn depends heavily on the skills and knowledge of the users, allowing them to identify inaccuracies and weaknesses at different stages of the assessment process (Haapio & Viitaniemi, 2008). Finally, uncertainty and subjectivity can emerge during the interpretation stage, especially where social and economic indicators are concerned (ibid.).

While these dimensions are crucially important to a holistic assessment of buildings and housing projects, this broadening of scope also opens the door to an even **higher level of subjectivity**, which then begs the question: how useful is quantification of sustainability for the practitioner in the decision-making process and, most importantly, does it lead to better outcomes?

Returning to the issue of transparency, it would be crucial for tools to make visible any possible uncertainties or margins of error in their final results.

2.7 Incomparability

Most importantly, over the last twenty-five years, the field of building assessment tools and schemes has mushroomed to include dozens of methodologies, software applications and standards, ranging from the basic to the profoundly complex. This has been recognized, especially in the European context, as a problem which several harmonization efforts have tried to address. Examples include the work of the standardization committee CEN/TC 350 (see page 19), the Common European Sustainable Built Environment Assessment Association (CESBA) or the work of the EeBGuide Project.

As comparison of research results between LCA

Figure 1 - Reconstruction of a house in Bagh, Pakistan, 2007. (Source: UN-Habitat)

studies is rarely possible, despite methodological guidance provided in ISO 14040 and ISO 14044 (McGrath, Nanukuttan, Owens, Basheer, & Keig, 2013), some level of standardization for specific product groups and industries has been attempted (EeBGuide Project, 2012).

Developed by the European standardization committee CEN/TC 350, European standards EN 15804 and EN 15978 provide calculation rules for LCAs of buildings and building products in particular (ibid.). National product category rules (PCR) have also been developed for a range of other product groups.

2.8 Cost

Most of the recognized certification systems are **commercial products** often applied exclusively by accredited assessors. They thus incur expenses to those seeking certification, though costs can vary significantly between countries and are highly dependent on the type and scale of the project[6]. Lastly, LCAs incorporated in these tools tend to be very data-intensive, and collecting and updating the needed data can involve significant costs (Bragança et al., 2007). The expenses associated with these tools can therefore make them **unsuitable for many developing country contexts**, especially small-scale institutional actors. They may thus be inherently geared towards private and public actors able to afford both the investment for meeting technical specifications and the certification itself. This in turn makes assessment levels susceptible to economic downturns (Aspinal et al., 2013).

The same may also hold true for life-cycle inventory data itself. To address this issue, several initiatives are aiming to **make life-cycle inventory data and LCA software freely accessible**. GreenDelta's *openLCA* or the European Joint Research Centre's 'European Life-cycle Database' (ELCD) would be examples worth mentioning in the European context while similar initiatives should be promoted to address LCA needs in low-income countries.

2.9 Adaptability to regional contexts

Some building assessment and benchmarking tools have struggled to recognize and accommodate regional distinction (du Plessis & Cole, 2011), though **attempts at creating standardized, yet universally adaptable assessment and benchmarking tools have been made**[7]. Indeed, many of the well-known benchmarking schemes have launched versions to be used outside their countries of origin, usually either having made adjustments, or providing users themselves with the opportunities to customize.

Tools that have been created in Europe or the U.S. generally rely on **regional building product information** which, if transferred elsewhere, would need to be replaced by a native equivalent. One of the issues related to transferring these tools to new contexts is therefore whether extensive and reliable data on building materials and components is available. Lack of up-to-date and reliable national statistics may also complicate assessment of the other environmental, economic and social indicators.

There is cause for concern about the "dangers of homogenization and reduced sensitivity to the acknowledgement and promotion of regionally appropriate design strategies", requiring that the "underpinnings be made explicit within any comparison and adoption" (Cole, 2005). It should be noted that **domestic priorities related to sustainability tend to be different according to local contexts and priorities**.

Even though most assessment tools are the product of a wide participatory and expert-led

6 RREEF Real Estate (2012) offers an overview of estimated costs and time required to obtain sustainability certifications for six of the major international schemes at the time. It should be noted, however, that figures can fluctuate substantially depending on project size, project phase, membership status of the organisation seeking certification and whether consulting services are required.

7 As an example, BREEAM's international structures are designed to allow for international variations while working within a common framework and level of rigor and independence.

consultation process with the goal of increasing objectivity, individual cultural and social values and priorities still play a role. This is why the objective of creating a standardized, universally applicable scheme has been recognized as impractical and sometimes even counter-productive (Cole, 2005).

2.10 Reductionism

The building process represents an inherently complex system. What building assessment and benchmarking attempts to achieve is a reduction of this complexity to something measurable and quantifiable, in line with predetermined criteria (e.g. carbon emissions per square meter). While a number of examples of a more holistic approach are taking shape, a truly integrated systems-thinking remains far in the future. We must therefore acknowledge the limitations of building assessment to accurately reflect this complexity (du Plessis & Cole, 2011). As Wallbaum et al. (2010) duly note:

> *The complexity of the construction sector, and the even greater complexity of the social-ecological system within which it operates, limit the effect of currently framed policies, regulations, labelling schemes, subsidies or preferential financing mechanisms put forward as incentives to change. This often results in good intentions having unintended consequences and driving perverse behaviour, as has been found, for example, by reviews of the LEED assessment and label system (Shendler & Udall, 2005; Humbert, Abeck, Bali, & Horvath, 2007) as well as assessment schemes in general (Birkeland, 2005).*

3. Selected Building Sustainability Assessment and Benchmarking Tools

This section aims to provide a small sample of a limited list of assessment and benchmarking tools. The reader should be aware that the literature is not short of critical appraisals of the shortcomings of some of the schemes listed, and is encouraged to seek them out. The term "tool" in the title is to be taken broadly.

Sustainability assessment and benchmarking of buildings has undergone a long and interesting evolution, focusing initially primarily on operational energy consumption. This view was then gradually influenced by the realization that buildings are "higher order products" consisting of assemblies of raw materials which should therefore be at the raw material level, at the level of their integration as sub-components as well as at the whole-building level.

Furthermore, in the last decade, a movement towards considering buildings also as pivotal elements in the social and economic fabric of cities has emerged and found its way into subsequent iterations of many standards, tools and methodologies.

Life-cycle assessment and the spectrum of sustainability

Life-cycle assessment (LCA) is a methodology which is an integral component of many of the schemes presented in this report. It is a standardized way of assessing the **environmental impact of a product or assembly of products across their life-cycle, from raw material extraction, processing, transport, use to end-of-life disposal or re-use**. LCA has established itself as a globally accepted standard for the evaluation of environmental impacts. In the building sector, LCA can be seen as the only legitimate basis on which to compare alternative materials, components, elements, services and buildings, which is why it is central to many of the assessment and benchmarking tools profiled in this section, primarily for the assessment of the building products which constitute a particular structure. **Resultant benefits** of conducting LCAs, such as possible **supply chain optimization** and the reduction of life-cycle costs, are measurable and can accrue to a multitude of stakeholders along the building supply chain.

The **LCA methodology** has been clearly outlined through standards ISO 14040:2006 and ISO 14044:2006. **It consists of four steps** (ISO, 2006):

- goal and scope definition;
- life-cycle inventory (LCI) analysis;
- life-cycle impact assessment (LCIA);
- life-cycle interpretation.

Goal definition specifies the purpose of the undertaking and the intended audience, while the scope definition specifies the system boundaries (e.g. cradle-to-gate or cradle-to-grave) and the functional unit. LCI analysis quantifies the inputs and outputs of environmental flows required to produce a good or service, for example the amount of energy required to manufacture a tonne of steel and the resulting greenhouse gas emissions. Finally, the potential environmental impact associated with inventory results is calculated in the LCIA stage before interpretation of the results (McGrath et al., 2013).

Of the four stages, the **life-cycle inventory (LCI) stage** can be considered **the most critical**, as it represents the data used for the assessment. Three main techniques can be used to establish an LCI: process analysis, input-output analysis and hybrid analysis.

Process analysis is the most widely used and consists of mapping the different processes required to produce a product or service. It relies on bottom-up industrial data collected from manufacturers, utility providers and others. This data is generally compiled into databases (e.g. EcoInvent). Process analysis provides the most accurate estimations for a particular process but underestimates the overall requirements because it does not capture the entire supply chain.

Input-output analysis is a top-down approach based on transactions in the economy. It relies on input-output tables that represent the transactions between the economic sectors of a country or region (and possibly between countries/regions). It uses average statistical resource use over the same year and by economic sector to derive sectorial resource intensities. By linking a product to its economic sector and multiplying the product price by the sector's intensity, the average resource use associated with the product can be obtained. While input-output analysis provides only estimates and can suffer from significant uncertainty, it does capture the entire supply chain of the product.

Hybrid analysis combines both the process and input-output techniques. It uses reliable process data when available and fills all the gaps across the supply chain with input-output data (Suh, et al., 2004). This combination, which relies on sophisticated algorithms, makes hybrid analysis the most comprehensive LCI technique to date (Majeau-Bettez, Strømman, & Hertwich, 2011).

Crawford (2011), Crawford and Stephan (2013) and Stephan and Stephan (2014) have compared the embodied energy of a house, a passive house and an apartment building, using process, input-output and hybrid data. Their results show that using hybrid data can produce **embodied energy requirements up to four times higher compared to using process data**. The choice of life cycle inventory technique is therefore highly significant and can affect the sustainability assessment of a building, notably when providing absolute figures or comparing its embodied requirements to their operational counterparts.

In order to conduct a complete LCA, **specialised software**—both commercial (e.g. Sima Pro, GaBi) and open-source (e.g. openLCA) —is available.

LCA results can then be used to inform so-called environmental product declarations (EPDs) which are the most common form of eco-labels in the construction sector and are governed by product category rules (PCRs) for specific types of construction products to harmonize results and increase comparability. Few manufacturers, however, perform EPDs and diffusion in the sector is still relatively low (Berardi, 2012).

Some **challenges** related to life-cycle assessments include **data intensiveness** (Cole, Howard, Ikaga, & Nebel, 2005)**, variation in system boundaries and possible lack of adherence to the requirements of international standards**. The perceived complexity of LCA can often seem a daunting barrier for architects, engineers, businesses and public sector bodies. These should, however, not be viewed as unconquerable obstacles. The EeBGuide very usefully puts the applicability of LCA in the construction sector into perspective by proposing three increasingly comprehensive types of LCA: screening, simplified and complete. It notes that [our highlights]: "*In the construction sector, LCA studies cannot*[8] *be completed with the same level of detail as in other sectors. Users such as architects and design engineers require user-friendly tools that can be adapted to the specifics of a building project and to their needs. An architect during an architectural competition may conduct a screening LCA for supporting his/her design alternative, whereas at a later stage of the building project a complete LCA may be required. These different iterations will often not be performed by the same stakeholder. In each case the data, methodology and results need to be adapted to the goal of the study, and to the stakeholder's requirements.*" (EeBGuide Project, 2012).

In either case, even if a complete LCA is undertaken, it may overlook other building-related impacts such as those arising from adjoining infrastructure or transport requirements of occupants, impacts of other sectors in the economy only indirectly associated the making of a product (input-output-based vs process-based method)[9], in addition to social and economic aspects.

Categorisation of building sustainability assessment and benchmarking tools

Hastings and Wall (2007) recommend the following "broad brushstroke" categorization of building sustainability assessment and benchmarking tools[10]:

- **cumulative energy demand (CED)** systems, which focus on energy consumption;
- **life cycle assessment**[11] **(LCA)** systems, which focus on environmental aspects;
- **total quality assessment (TQA)** systems, which evaluate ecological, economic and social aspects.

While most tools do not fit neatly into just one of these categories, a simple labelling has been attempted provided with each of the tools profiled

[8] The qualifier "currently" should be added, if considering the status quo globally. However, in the industrialized world, and with the help of Building Information Modelling (BIM), we might have a very complete building material inventory available, which will provide us with the basis to conduct LCA studies at the same level of accuracy as in other sectors.

[9] See introduction to Chapter 3.

[10] A similar categorisation has been attempted by Bragança, Mateus and Koukkari (2010).

[11] Hastings and Wall refer to ‚life-cycle analysis'. For consistency, this has been changed to ‚life-cycle assessment'.

to give the reader a rapid overview of where along this spectrum a particular tool is located in terms of how broadly "sustainability" is being interpreted.

Secondly, an "A" has been added to the label to indicate that a particular scheme is focused on assessment rather than benchmarking, meaning it is a methodology that aims to measure absolute values of a building's or neighbourhood's impact (energy consumed, GHGs emitted, etc.) without giving a comparative value judgment.

A "B" has been added to indicate that a particular scheme is a benchmarking scheme, meaning it is a methodology that, 1/ assesses a building or neighbourhood along a set of criteria, 2/ rates its performance against a given standard (e.g. to reference sets of rated buildings, to set criterion values or standards, to national averages, to modelled/simulated building behaviour, or other methods of comparison) and 3/ communicates a value judgment about its performance.

This is also to highlight that building assessment and benchmarking should not be used interchangeably as they describe different aspects of the schemes profiled. A summary of the spread of categories covered is given in Table 1:

Table 1 - Types of tools profiled, by category, applying Hastings and Wall (2007), and assessment or benchmarking objective.

	Cumulative Energy Demand (CED)	LCA*	Total Quality Assessment (TQA)
Assessment (A)	Common Carbon Metric DECoRuM	N/A	CEN/TC 350
Benchmarking (B)	Passivhaus NABERS	N/A	LEED, BREEAM, HQE, DGNB, LOTUS, SBtool, SBAT, QSAND

**Since LCA is an integral component of many of the schemes profiled, it is covered in the introduction to Chapter 4, rather than being given a separate profile.*

3.1 Building Research Establishment Environmental Assessment Methodology (BREEAM)

BREEAM FACTSHEET

By: Building Research Establishment (BRE)

Status: Voluntary - Operational since 1990 in the UK with many updates and enhancements since then, notably in 1993, 1998, 2006, 2008, 2011, 2014. Used in 70 countries, with National Scheme Operators (NSOs) in 5 countries

Costs: The BREEAM scheme technical standards are freely available; registration and certification fees vary depending on project type, size and location; BREEAM assessor fees are determined by the market.

Scope: environmental, social, economic

Scale (spatial): From single-building to large-scale multi-building developments. A version of BREEAM for Infrastructure is now being piloted.

Scale (temporal): Schemes cover the building life-cycle from master-planning of developments (BREEAM Communities), design and construction phase, (BREEAM NC) and use (BREEAM In-use and BREEAM Refurbishment & Fit Out).

Expertise required: Assessments are undertaken by licensed BREEAM assessors

Find out more: breeam.com

Building Research Establishment Environmental Assessment Methodology (BREEAM) is a voluntary measurement rating for green buildings first developed for the United Kingdom by the Building Research Establishment (BRE) in 1990, and now established as one of the leading assessment method for sustainable buildings, in strong competition with LEED (see Page 32). Up until April 2016, more than 540,000 developments had been covered under BREEAM (roughly half of which are domestic) and over 2,230,000 buildings have been registered for assessment since it was first launched in 1990; there are over 2,450 properties that have been assessed under the BREEAM In-use scheme. BREEAM assessments have been registered in 77 countries, although over 95 per cent of these were projects within Europe (BRE Global Ltd., 2016).

Non-domestic buildings are assessed under a single 'new construction' scheme, although some tailoring of the assessment criteria is included to reflect specific functionality and opportunities that exist in different building types. This allows for common mixed-use building scenarios to be assessed easily. A 'bespoke' assessment can be used to assess buildings that are not represented in the 'standard' set. Furthermore, there is a version of BREEAM for 'simple buildings'. BREEAM Communities can be used to assess the master-planning of both single-use and mixed-use developments.

The credit criteria are grouped into categories covering Management, Health & Wellbeing, Energy, Transport, Water, Materials, Waste, Land Use & Ecology, Pollution and Innovation. 'Credits' can be attained for each section, if various requirements (which may be performance, action or process related) are met or bettered. Minimum standards are set for key areas such as energy, waste and water, although outside the mandatory criteria the schemes are structured to allow flexibility for the designer/architect to optimize their design solution to reflect the project needs. The mandatory requirements increase for higher ratings. Finally, a weighting multiplier is applied to the various sections to reflect their relative importance and make this explicit within the method. The weightings are subject to periodic review through a process of external consultation.

An international version of BREEAM is available where the first project assessed in a certain country or region triggers the review of the appropriate weightings for this locale, for that project, and subsequent projects in that country or region. Weightings are regularly reviewed to ensure they continue to reflect the local situation. The 'BREEAM International 2016 Technical Manual' notes that: "the development of these weightings is based on robust and independent information forwarded from 'local experts' who have an understanding of local conditions. This may be a member of the design team if they can demonstrate sufficient knowledge of the environmental conditions of the region/country, or another individual/organisation with the relevant expertise" (BRE Global Ltd., 2016).

Figure 2 below suggests that BREEAM has, as yet, not been widely taken up in developing country contexts, although assessments have been registered in 77 countries worldwide, including several developing countries (such as Nigeria, Myanmar, the Philippines, Sudan, Sri Lanka).

While criticism has been levelled against both BREEAM and LEED (Schmidt, 2012; Aspinal et al., 2013), from within and outside their respective development communities, BREEAM especially has made efforts to evolve according to both assessor input as well as a changing regulatory framework; its structure allows it to be focused on local standards and drivers.

Figure 2 - Certified BREEAM Assessments, 2008 schemes onwards (Source: Green Book Live, 2016).

Figure 3 - BREEAM National Scheme Operators and Countries with at least one Registered Asset (Source: BRE Global)

Figure 4 - Courtauld Road, London, mixed tenure housing scheme, refurbished Victorian warehouse.
BREEAM Score 'Excellent' (80.69 per cent) and winner of the 2016 BREEAM Residential Award. (Source: BRE Global)

3.2 CEN/TC 350

CEN/TC 350 FACTSHEET

By: CEN/TC 350
(Comité Européen de Normalisation / Technical Committee 350) Sustainability of Construction Works

Status: Operational since 2005, developed 9 European Standards and 2 Technical Reports

Costs: None

Scope: Sustainable development (environmental, social, economic)

Scale (spatial): Envisioned for product, building and framework level; all buildings and civil engineering works; product level standards

Scale (temporal): entire life-cycle

Where to use it: For the development of ratings, certification, assessment schemes, EPDs, regulations

Find out more: portailgroupe.afnor.fr

CEN/TC 350 (Comité Européen de Normalisation/Technical Committee 350) is the standards committee mandated with the development of a harmonized European assessment methodology and performance indicators for environmental aspects, social aspects—such as, accessibility, adaptability, health, comfort, safety and security—and economic measures of cost and value. The committee's objective is the production of horizontal[12] standards for the transparent quantification of the sustainability aspects of new and existing construction works (buildings and engineering works) over their entire life-cycle and for standards for environmental product declarations (EPD) of construction products. Among other benefits, the standards:

- **clarify the information** necessary to support sustainability assessment of construction works;
- **provide a structured format** for the product information so that it can be applied to the assessment of construction works;
- **provide essential elements** in a strategy leading to the mitigation of climate change and other sustainability aspects, such as use of resources, through understanding the effects of decisions taken;
- allow industry to **demonstrate compliance** with emerging regulations and policies.

The developed standards of CEN/TC 350 are then envisioned to be implemented into national building regulations as well as voluntary building assessment, certification and rating schemes, which is already partly the case with several commercial benchmarking schemes referencing CEN/TC 350 standards. In its development, it heavily leans on and incorporates existing CEN and ISO standards relating to dangerous substances, energy efficiency in buildings, waste and others. A major benefit from the CEN/TC 350 standards is the fact that methodologies for environmental, social and economic assessments are interlinked through the same definitions, scenarios and system boundaries.

Up until today, TC 350 has developed nine European standards, including:

- General framework on the economic, social and environmental assessment of buildings;
- Specific frameworks for the economic, social and environmental assessment of buildings;
- Calculation methods for the environmental performance of buildings based on LCA and other quantified environmental information;
- Calculation methods for the economic performance of buildings based on life-cycle costing (LCC) and other quantified economic information;
- Methods for the assessment of social performance of buildings concentrating, in the first version, on the use stage of the building, which means mainly health and comfort

[12] "Horizontal" or "general" standards apply to any employer in any industry.

aspects from the user's point of view, as well as safety and security aspects taking into account functionality and technical characteristics;

- core product category rules (PCR) for Type III environmental declarations for any construction product and construction service;
- the communication format for the information defined in EN 15804 for business-to-business communication to ensure a common understanding through consistent communication of information.

While CEN/TC 350 developed a standard on business-to-business communication of environmental product data, no consensus currently exists with regards to business-to-consumer communication. This points to an ongoing dilemma with building assessment schemes, but it will be tackled in the near future by CEN/TC 350.

The committee also produced technical reports on the sources and methodology to be used when preparing generic data for environmental product declarations.

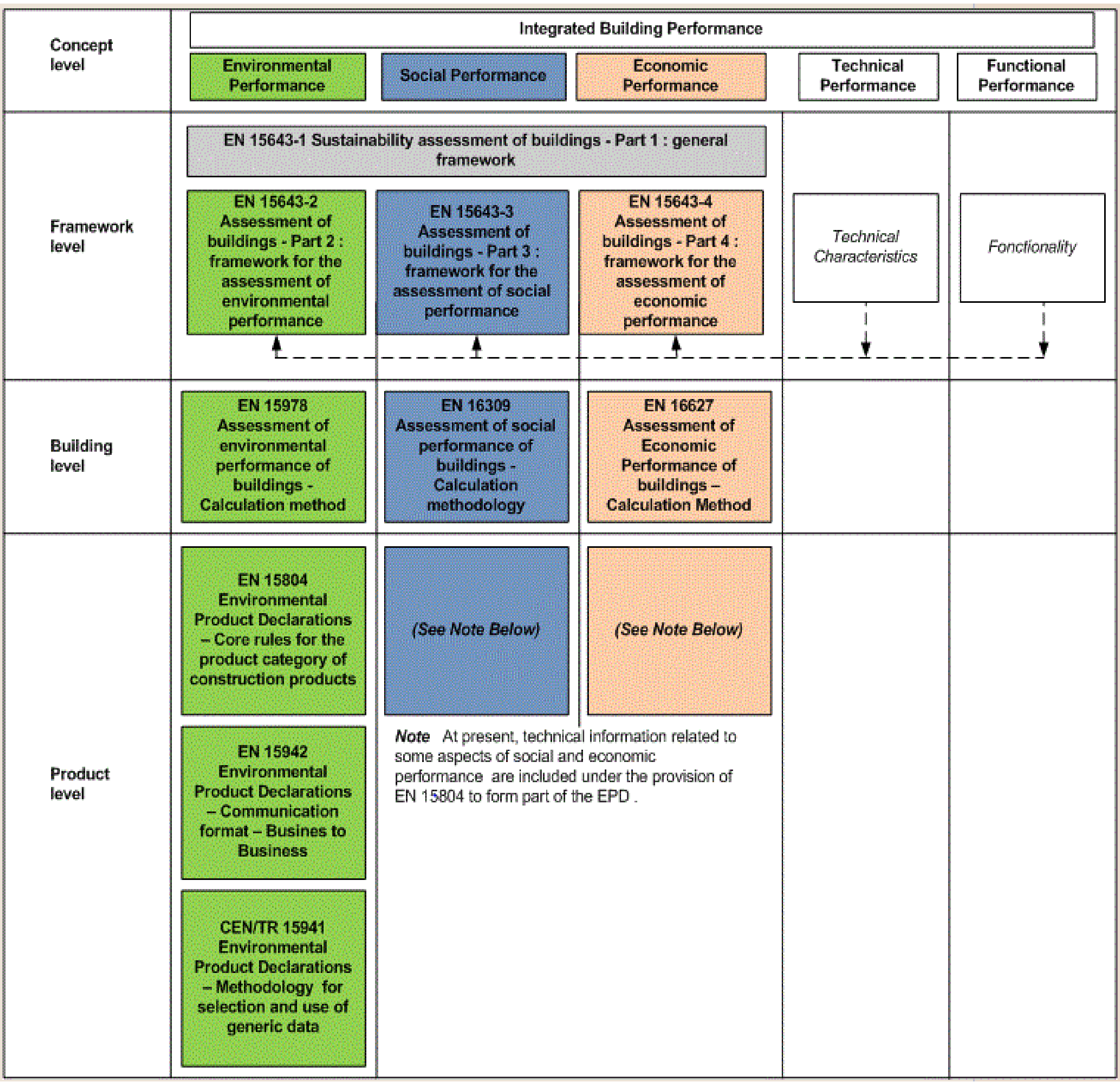
It should be pointed out that European Standards are voluntary which means that there is no automatic legal obligation to apply them. However, laws and regulations may refer to these standards and make compliance with them compulsory.

Naturally, the extensive regulatory framework governing energy and resource efficiency in the European Union provided a political mandate to develop this set of standards. This clearly is a fortunate and relatively unique context which provides an example for how political decisions can initiate consensus-finding among all industry stakeholders and, eventually, the regulation—and possibly transformation—of the industry.

Regarding LCIA indicators for environmental assessment given in EN 15804 and EN 15978, CEN/TC 350 is currently evaluating possibilities for inclusion of new indicators such as human toxicity, eco-toxicity, particulate matter, land use (effects on biodiversity), water scarcity and ionizing radiation. Those indicators were not included in the final set of indicators contained in the CEN/TC 350 standards, because during development of EN 15804 and EN 15978 between 2005 and 2012, the CEN/TC 350 members considered at that time that there was a lack of sufficiently robust methodologies and data.

The above mentioned lack of robust methodologies may still be the case with those new indicators, but nevertheless EC has given recently a subsequent standardization request (amendment of original mandate M/350) to CEN/TC 350 to amend EN 15804 and EN 15978, not only to take into consideration the findings and certain rules of recent EC initiatives i.e. the product environmental footprint (PEF), but also to strengthen the position of EN 15804 and EN 15978 within the EU policies in the field of sustainable construction.

Figure 5 - Mapping of standards developed by CEN/TC 350 (Source: CEN/TC 350)



3.3 Common Carbon Metric (CCM)

The Common Carbon Metric (CCM) tool allows for measurement of energy use and reporting on greenhouse gas emissions from buildings' operations around the world in a consistent, reportable and verifiable manner,. This work is intended to support policy-makers, cities, and owners of building portfolios in establishing baselines for the performance of their building stock. The CCM tool is a simple and transparent Excel spreadsheet that:

- can be filled by participants with estimated or measured energy data (annual or monthly);
- is consistent with principles and standards for environmental performance assessments (ISO standards and WRI/WBCSD Greenhouse Gas protocol);
- meets the requirements that reporting is measurable, reportable and verifiable (MRVA allows for bottom-up and top-down data compilation);
- normalizes building performance by degree day information;
- uses custom emission factors in addition to the default IPCC and IEA emission factors as defaults;
- allows input fuel consumption data by month through the top-down and bottom-up approaches;
- allows input information on multiple fuels for the same building;
- records the year of last building retrofit;
- records the amount of purchased green power or amount of renewable energy generated on-site and returned to the grid;
- uses the UN Framework Convention on Climate Change (UNFCCC) list of building types (e.g. for residential: single family, multi-family; for non-residential: office, hotel, healthcare, mercantile and service, food service, entertainment, etc).

CCM FACTSHEET

By: Sustainable Buildings and Climate Initiative of UN-Environment (UNEP-SBCI)

Scale (spatial): Buildings and groups of buildings up to neighbourhood and city level

Scale (temporal): Monthly / Annual

Data required: Estimated or measured energy data (annual or monthly)

Find out more: unep.org/sbci/activities/ccm_Pilot.asp

The CCM tool takes two complementary approaches: one assesses performance at the building level (bottom-up), and the other at the regional or national level (top-down). The data provided under either approach is then used to develop performance metrics for both energy consumption and GHG emissions, on a per-area and a per-occupant basis, if occupancy is known. Occupancy of residential buildings can be determined using the number of persons sleeping within the defined area. Occupancy of non-residential buildings for the bottom-up approach may be determined using the "full-time equivalent" (FTE) concept, which requires users to estimate how many people occupy a given building for approximately eight hours.

The two approaches:

1. **Top-down approach:** Performance of the whole (regional, city or national level) is characterized at a coarse level using estimated data on fuel and electricity consumption.
2. **Bottom-up approach:** Performance of individual case-study buildings is characterized at a fine level using measured data on fuel and electricity consumption. Ideally sample size will be statistically valid, enabling verification of the whole.

Data requirements for the two approaches naturally differ.

Building category	kWh / m²	kg CO_2e / m²	kWh / occupant	kg CO_2e / occupant
Average performance baselines for specific building types, measured through the bottom-up approach				
Office	222.8	151.9	8,387.9	5,568.1
Retail	221.5	147.0	7,859.0	5,217.0
Hotel	302.8	142.8	14,305.3	6,745.3
Other	156.0	103.6	2,736.1	1,816.3
Performance baselines for the Whole, measured through the top-down approach				
Non-residential	282.4	182.8	5,831.7	3,774.6
Residential	51.5	32.8	3,733.7	2,376.5

Table 2 - Performance of building stock at city level, City A (Source: CCM)

Table 2 (above) is an example of data presented for the performance of a building stock at the city level:

Red cells indicate that average performance of a set of buildings of a given building type, as measured through the bottom-up approach, is worse than the performance of the whole's non-residential building stock.

Using the top-down approach, City A provided data on a geographically defined Whole (total area: 176 km2) with an occupancy of 3,700,000 and a total energy use of 63,152 TJ.

City A was able to generate performance baselines for its residential and non-residential building stocks at the level of the Whole. City A also provided data on 10 non-residential buildings through the bottom-up approach, allowing it to compare the average performance of these buildings with that of the Whole's non-residential stock.

Table 3 (below)is an example of a table indicating the performance baselines of a single building type:

Company A provided information on 11 office buildings, which together had a total occupancy of 3,797 individuals and a total floor area of 84,717 m². Based on the electricity and fuel use of these buildings, the CCM computed performance baselines for Company A's portfolio.

In this submission it is possible to identify buildings that belong to the same building type, but vary in their performance due to their reliance on different fuel sources.

For instance, Building 1 has markedly better performance than Building 5, because Building 1 relies entirely on electricity for its energy needs, while Building 5 relies on a combination of electricity and fuel. The inclusion of Building 5 in the sample set decreases the sample's average performance.

Building name	kWh / m²	kg CO_2e / m²	kWh / occupant	kg CO_2e / occupant
Building 1	128.1	71.6	3258.8	1820.5
Building 2	358.0	137.1	8831.6	3382.7
Building 3	438.1	244.8	5457.9	3049.1
Building 4	221.9	87.1	5541.8	2174.4
Building 5	799.5	442.3	13551.2	7496.2
Building 6	403.4	188.5	15446.6	7216.2
Building 7	124.9	69.8	3179.4	1776.2
Building 8	288.9	126.6	13109.1	5745.8
Building 9	393.0	187.8	7114.9	3400.2
Building 10	188.7	105.4	3081.0	1721.2
Building 11	211.8	118.3	5811.3	3246.5
Baseline for portfolio	**323.3**	**161.7**	**7671.2**	**3729.9**

Table 3 - Performance baselines of a single building type, Company A (Source: CCM)

3.4 DGNB Zertifikat

The Deutsche Gesellschaft für Nachhaltiges Bauen or DGNB system is a holistic assessment tool that was created in 2009. The tool is suitable for assessing a number of different building types. So far, most of the certified buildings have been office and administrative buildings, industrial buildings or residential buildings. Essentially, the DGNB certificate is a market-driven certification scheme, where accredited DGNB auditors undertake the certification process followed by a conformity check and certificate award by DGNB. Pre-certifications are issued to building designs and certifications to completed buildings. Projects achieve a certificate/pre-certificate in "Platinum", "Gold" or "Silver" depending on the degree to which the relevant scheme criteria are met. The DGNB certification system can be applied nationally and internationally. Its international implementation is based on an adaptation to country-specific conditions. All international applications of the DGNB system for buildings are based on the core criteria catalogue, referred to as Core 14. These core criteria are used in combination with scheme sheets which provide detailed information for the relevant scheme in question.

The DGNB system covers all of the key aspects of sustainable building (economic, socio-cultural, environmental) as well as functional aspects (technology, processes and site)—see Figure 6.

Figure 6 - The DGNB Zertifikat's quality sections (Source: DGNB)

DGNB ZERTIFIKAT FACTSHEET

B
TQA

By: Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), the German Sustainable Building Council

Status: 2,000 certified and pre-certified projects by 2016

Cost: Yes

Scope: Environmental, economic, sociocultural and functional, technology and processes quality and site.

Scale (spatial): New and existing buildings (16 different schemes including interiors and buildings in-use), districts (4 different schemes)

Scale (temporal): Entire life-cycle of buildings and districts, including end of life.

Data required: LCA assessments of building products (based on ESUCO database)

Expertise required: Auditors trained by DGNB

Find out more: dgnb.de/en

The first four quality sections have equal weight in the assessment. This means that the DGNB system is the only one that gives as much importance to the economic aspect of sustainable building as it does to the ecological and the socio-cultural criteria that directly refer to human-centred aspects of the building. The quality sections are further subdivided into some 36 different criteria, e.g. thermal comfort, design for all and sound insulation. The DGNB schemes for districts include a separate set of criteria which address issues such as urban microclimates, biodiversity and interlinking habitats, and social and functional mix.

The DGNB has defined target values for each criterion. Up to 10 assessment points are awarded to reach the target specifications. Depending on the scheme, some criteria are weighted differently.

The concrete score for the six quality sections is calculated from the combination of the assessment points with the relevant weighting. The total score for the overall project is calculated from the five quality sections based on their weighting. Site quality is considered separately and this aspect is included in the marketability criterion. In the case of urban districts, site quality is incorporated in all criteria.

The environmental quality section of the tool includes also the LCA of buildings. The environmental impact assessment includes the building construction and operation phase throughout the life-cycle of the building. The LCA of the physical building components is assessed according to the international standards ISO 14040 and 14044. As a database for building materials and components, the European Sustainable Construction Database (ESUCO) has been used. As an alternative data source for more precise data, EPD (Environmental Product Declaration according to ISO 14025 and prEN 15804) can be used. Calculation of the building operational phase is based on the Life Cycle Energy Modelling (LCEM). The environmental impact assessment for energy demand throughout the building life-cycle is calculated through the LCEM and ESUCO (or other country-specific LCA databases) environmental impact factor. While the DGNB life-cycle assessment methodology is mainly based on international standards and universal data sources, the adaptability of the system is quite high.

Figure 7 - Sample DGNB Evaluation Graph (Source: DGNB)

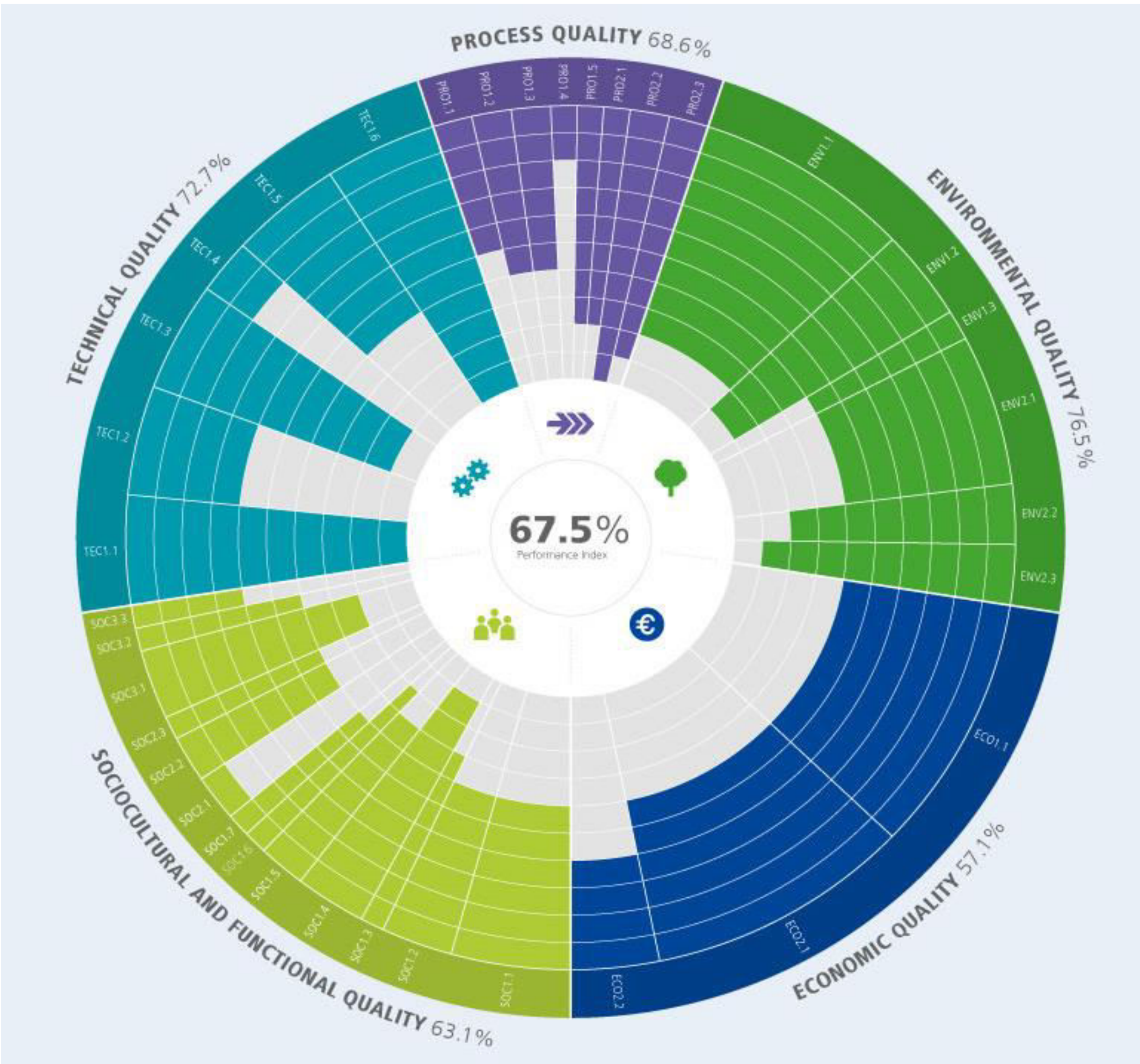


Figure 8 - Haus B1, Projekt VIER, Pelikanviertel, Hannover - DGNB Score 'Platinum'
(Source: Gundlach GmbH & Co. KG, Photographer: Clemens Born)

3.5 Domestic Energy, Carbon Counting and Carbon Reduction Model (DECoRuM)

DECoRuM is a geographical information system (GIS)-based toolkit for carbon emissions reduction planning with the capability to estimate energy-related CO_2 emissions and effectiveness of mitigation strategies in existing UK dwellings, aggregating the results to a street, district and city level (see Figure 9).

Figure 9 - Functional units employed by DECoRuM (Source: OISD)

The aggregated method of calculation and map-based presentation allows the results to be scaled-up for larger application and assessment.

The background calculations of DECoRuM are performed by BREDEM-12 (Building Research Establishment's Domestic Energy Model) and SAP 2009 (Standard Assessment Procedure) both of which are dynamically linked to create the model. BREDEM is a methodology for calculation of the energy use of dwellings based on characteristics and is suitable for stock modelling. It shares some features with the SAP methodology, but allows users to adjust inputs which are fixed in SAP.

DECoRuM FACTSHEET

A
CED

By: Pr. Rajat Gupta, Director of the Oxford Institute for Sustainable Development (OISD) and its Low Carbon Group.

Cost: Yes.

Scale (spatial): Neighbourhood / City.

Scale (temporal): Operational.

Data required: Estimated or measured energy data (annual or monthly).

Expertise required: None / Basic understanding of building level energy consumption is helpful.

SAP, based on BREDEM, is the Government-approved method for the assessment of the energy and environmental performance of dwellings. Though not as robust as dynamic thermal simulation (intensive modelling done on a building by building basis), the strength of DECoRuM is in the ability to rapidly process results for many dwellings and present them on an urban scale.

The tool is useful for communicating energy-related concepts and identifying potential areas for concern and further investigation, including simulation, house assessment and monitoring.

The results for each household are displayed on a map using GIS software. GIS allows any variable that is collected or calculated to be mapped for visual communication, for example kWh/year, CO_2 emissions/m^2/year, homes in need of cavity wall insulation, photovoltaic suitability, etc.

Previously, DECoRuM maps have been used by the Grassroots Leads Energy Efficiency community group in Highfield, Bicester, to provide residents with energy consumption information, to suggest energy efficiency improvement measures (Gupta & Cherian, 2013), and to present climate change impact and adaptation effectiveness to communities in the Suburban Neighbourhood Adaptation for a Changing Climate (SNACC) project.

Figure 10 below shows two maps used to communicate findings for the EVALOC project (evaloc.org.uk). Maps are seen to demystify the complexity of low-carbon technologies and give householders a clear view of the impacts different refurbishment measures and packages may have on the energy performance of their home. DECoRuM maps showing CO_2 reduction potential of individual houses in a neighbourhood (or any size mapped area) have been used during local authority and community group events to provide energy feedback to householders (on a community level). In addition, these events also help gather house-specific data from families through questionnaires to further refine the model.

Figure 10 - Maps from the EVALOC project. (Source: OISD)

Benefits of carbon mapping for different users

- For householders:

- makes energy use visible for the homeowner in a useful way - influencing energy literacy;
- increases awareness of energy use in homes relative to neighbours
- inspires range of changes from behavioural to full retrofits;
- creates a better understanding of what actions could be taken to reduce carbon emissions;
- assists in prioritising action and change to home.

- For community groups:

- acts as a tool for communication of ideas and plans;
- engages and empowers communities in carbon reduction efforts through knowledge of need, capacity and limitations;
- helps communities understand local housing stock and local impact;
- assists in prioritising action, e.g. pinpointing hotspots of high energy use
- influences behaviour change through education and collective action;
- platform to generate bespoke energy-, cost-, and carbon-saving scenarios for communities.

- For local authorities:

- allows area-based carbon-reduction planning and prioritisation;
- communication tool for change and/or funding;
- visual source for organising and categorising what has been done and where (stock inventory tool);
- allows comparison of housing stock to other local authorities or political / geographical boundaries.

- For energy assessors:

- provides an overview of homes most in need and a platform for initial estimates of measure impact effectiveness;
- provides a complete management tool from briefing to installation of measures;
- is a visual source for organising and categorising what has been done and where (business tool);
- assists in prioritising action;
- uses a robust filtering criteria to select the most suitable dwellings for each CO_2-reduction measure deployed;

Some limitations include:

Time required for data collection and entry; while home questionnaires are helpful in reducing this initial effort, response rates can be low.

Behaviour related assessment is limited: for example, occupancy times, heating schedules, and window-opening schedules are not available. Different scenarios must be calculated separately and cannot vary within a given timeframe; calculations are static.

The model does not calculate where specifically a homeowner should insulate walls and whether internal or external insulation is ideal (insulation is simply either solid wall or cavity).

Carbon mapping provides a way to quantify energy and carbon savings (in terms of domestic energy use) but is subject to constraints due to its reliance on the availability and accessibility of data on a large number of individual dwellings, which are often difficult to collect without the input of the individual households (Gupta & Gregg, 2014; Gupta & Gregg, 2014; Gupta & Cherian, 2013; Gupta, 2009).

3.6 High Quality of Environment (HQE™) Certification

The HQE brand, which belongs to Association HQE was created over 20 years ago and is well-recognised internationally. Cerway is the only operator that offers HQE™ outside of France, and a subsidiary of Certivéa and Cerqual, who respectively belong to CSTB (*Centre Scientifique et Technique du Bâtiment*) and *Association Qualitel*.

The main mission of Cerway is to encourage the improvement of stakeholders, building and neighbourhood performance, and to assess it within a sustainable development perspective. The performance of a building is assessed under four themes: energy, environment, health and comfort. HQE™ has been designed for building owners, managers, users, developers and investors, as well as for urban planners and local authorities.

It is not a norm but a certification that testifies that the project's owner's initiative toward sustainability—according to the principles of sustainable development—has been successful. The approach is meant to be applicable globally, whichever regulatory construction norms, organisational systems, cultural or climatic conditions prevail. It covers residential, commercial, administrative and service buildings, in all activity areas, be they under construction, renovation or already in operation. The tool also certifies urban planning and development projects.

The **benefits of the certification** are now well-documented and have been assessed economically by several studies:

- increased satisfaction of the inhabitants or users;
- quality of life and wellbeing at home or at work (productivity, staff loyalty)
- reduced fixed and operating costs (monitored energy and water consumption, waste management);
- increase in asset value;
- optimisation of sales or rental conditions (faster and at a higher price);
- pushed back obsolescence;
- reduced risks (health, equipment) sometimes allowing for lower insurance rates;
- a project management system contributing to the professionalization of the project teams and to a better control of quality, cost and delays;
- social responsibility valorisation.

The two latter benefits also apply to certification of territories.

The project team sets its own objectives within the specific framework of the project and remains free to choose its architectural and technical solutions. Objectives are then assessed according to the certification scheme requirements or, if need be, by principles of equivalence.

HQE™ FACTSHEET

B
TQA

By: Cerway

Status: Over 460,000 certified projects.

Costs: Costs vary between projects.

Scope: Environmental, social, wellbeing, economic and governance.

Scale (spatial): From single-building to large-scale multi-building developments: buildings under construction; non-residential buildings in operation; urban planning and development.

Scale (temporal): Before building (programme and design audits) and after building (completed project audit).

Expertise required: Although optional, the involvement of a HQE™ certification *Référent* gives certification applicants access to the skills and experience of a professional resulting in a smoother certification process.

Find out more: behqe.com

The certification process provides a guideline to the project owner for the entire duration of the project from design phase to full completion (see Figure 11). It encourages the reduction of the building's water, energy and waste consumption, and the improvement of health, comfort and life quality for its users.

An independent third party auditor will assess the achievement of the objectives at each main phase of the project. A certificate is then issued by Cerway for each of the phases. HQE™ also offers training of professionals in order to facilitate the development of sustainable projects, and the training of *Référents* Certification.

Figure 11 - Organisation of HQE™ audits

Figure 12 - Rendering of the 2,600 unit housing development "Reserva de Madrid" in Bogotá, Colombia, the first HQE™-certified social housing project in the country and the second in Latin America. It achieved HQE™ level 'Excellent' at the design stage. (Source: Prodesa)

3.7 Leadership in Energy and Environmental Design (LEED)

Developed through technical committees and a consensus process, LEED is the premier tool of the U.S. Green Building Council (USGBC), formed in 1993. LEED is one of the most recognized and widely used commercial benchmarking schemes. First launched in 1998, several updates have followed since. The current version is LEED v4, adopted in 2014.

Currently, the LEED portfolio consists of a suite of rating systems for design and construction, and operation and maintenance of different building types. As of January 2016, LEED v4 featured 21 different market sector adaptations to address the unique needs of each market. Within the residential sector, the Building Design & Construction (BD&C) rating system applies to high-rise and core-and-shell projects; core-and-shell projects with tenant fit-out are a common approach in some markets.

For mid-rise projects (up to eight stories) there is a specific system adaptation, and LEED Homes is used for low-rise and single family residential buildings. Affordable housing uses the same rating systems as market rate, and is estimated at about one-third of LEED housing units. Thus, LEED has developed significantly from its origins as a mainly commercial building system. LEED ND is a distinct rating system for neighbourhoods.

LEED v4 was focuses on **seven impact category goals** (see Table 4). To reward building projects that support these goals, LEED rating schemes look at **seven credit categories.** Within most of the credit categories, LEED v4 requires a minimum performance. Then, projects achieve a selection of optional credits, earning points.

LEED FACTSHEET

B
TQA

By: The U.S. Green Building Council

Status: Over 30,000 certified commercial projects, over 90,000 certified LEED for Homes residential units (Jan. 2016).

Cost: rating system is free/open access; certification fees apply and vary by project size.

Scope: Sustainable development (environmental, social, human health).

Scale (spatial): Buildings and interiors; residential systems include single family/low-rise, mid-rise, and high-rise; separate rating system for campus and neighbourhood scale (LEED ND).

Scale (temporal): Entire life-cycle; separate rating systems focus on design and construction, and operation and maintenance.

Expertise: Project teams are not required to hold specific credentials; reviews are performed by GBCI reviewers.

Adaptability: Weightings and criteria are universal (generally credits are identical regardless of where the scheme is applied), but there are some country- and region-specific adaptations.

Find out more: usgbc.org/leed

Depending on the total credits, each building will receive a rating level of "Certified", "Silver", "Gold" or "Platinum".

With its latest system, LEED is rooted in a "green" rating scheme, focusing on environmental impacts, also incorporating human health and wellness impacts. LEED generally does not address detailed social or economic evaluation, but since 2014, new pilot credits consider social equity.

LEED v4 Impact Categories

- Reverse Contribution to Global Climate Change
- Enhance Individual Human Health and Wellbeing
- Protect and Restore Water Resources
- Protect, Enhance and Restore Biodiversity and Ecosystem Services
- Promote Sustainable and Regenerative Material Resources Cycles
- Build a Greener Economy
- Enhance Social Equity, Environmental Justice, and Community Quality of Life

LEED v4 Credit Categories

- Location and transportation
- Sustainable sites
- Water efficiency
- Energy and atmosphere
- Materials and resources
- Indoor environmental quality
- Innovation

Table 4 - LEED v4 Impact and Credit categories (Source: USGBC)

Each impact is quantified according to methodologies such as energy modelling, life cycle assessment (LCA) and transportation analysis. The tool utilizes comparisons to reference buildings of the same building category as a means to estimate relative environmental and health achievement of the entire building. While LCAs are not required, LCA is incorporated into various credits.

These concepts are applied to the different building types under LEED v4, as follows:

High-rise and core-and-shell projects can apply an optional "Building Life-Cycle Impact Reduction" credit which rewards whole-building life-cycle assessment. This option allows new buildings and existing buildings to earn points for LCA demonstrating reduced impact on global warming, as well as two other categories such as ozone-layer depletion, acidification, eutrophication, formation of ground-level ozone, and depletion of non-renewable energy resources. In addition, environmental product declarations (EPD) have been introduced to obtain credits in the Materials and Resources category.

Residential buildings up to eight stories (e.g., mid-rise, low-rise, and Homes projects) can apply LCA on a project-specific basis and earn points in the environmentally preferable products and material-efficient framing credits of the Materials and Resources category.

LEED v4 also expands the system's consideration of human health and wellness, such as taking a performance-based approach to indoor environmental quality through testing and monitoring. For larger projects, health product declarations (HPDs) are recognized in the materials and resources category, and several pilot credits also relate to human occupant health and wellness, such as one focused on employee safety and health outcomes across the building life-cycle through early attention to safety and health hazards.

Buildings have achieved LEED certification in 155 countries as of January 2016. Outside of the U.S., Canada, China, India, Brazil, South Korea, Germany, Taiwan, the United Arab Emirates, Turkey, and Sweden have the largest amount of LEED certifications (in floor area). The LEED International Roundtable has 39 members and develops Alternative Compliance Paths (ACPs), which recognize regional best practices within the LEED structure. For example, ACPs have been established for India, in collaboration with The Energy Research Institute (TERI) in India. In addition, ACPs have been developed for Japan, East Asia, Europe, and Latin America.

USGBC has an education platform featuring content developed by a wide range of education partners, and increasingly offering non-English courses. Professionals may also obtain a LEED credential, and as of January 2016, there are over 200,000 LEED credentials around the globe. The platform gbig.org displays maps and data on green building certifications around the world, including LEED, BREEAM, and others.

Figure 13 - Distribution of LEED projects globally (Source: USGBC)

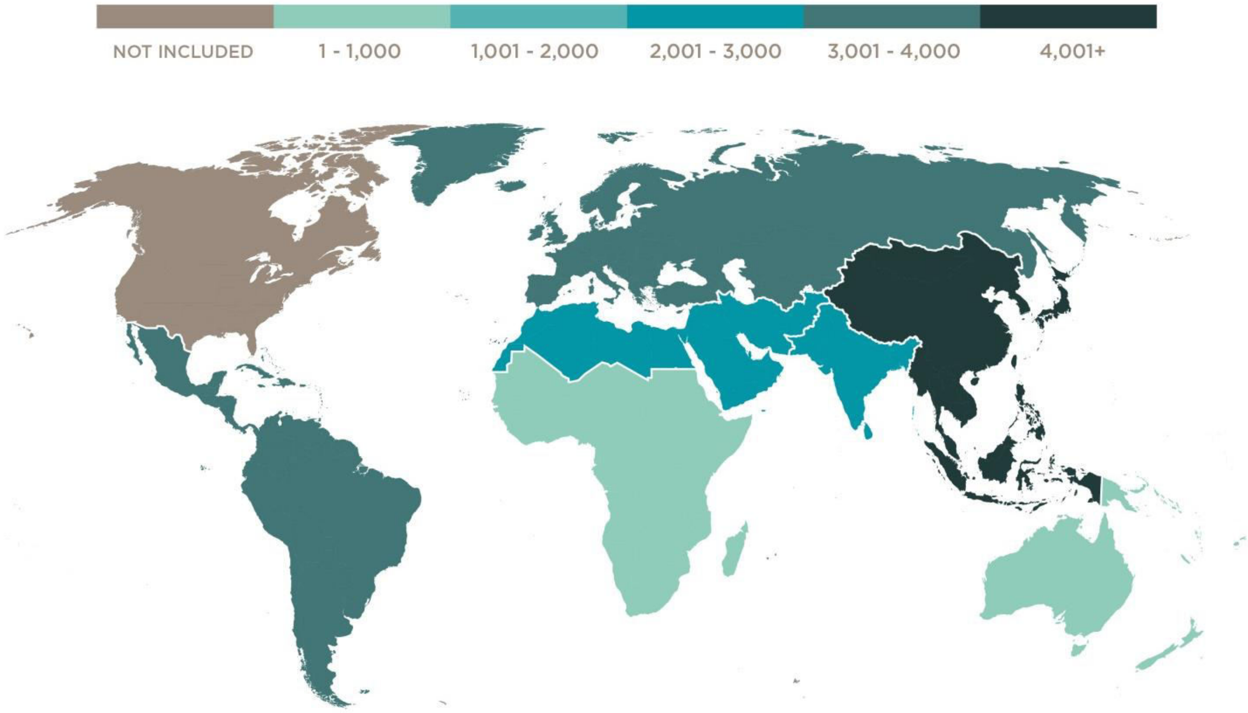


Figure 14 - Post-Hurricane Katrina homes for residents of New Orleans, by the *Make It Right Foundation.*
LEED Score 'Platinum', inspired by Cradle to Cradle thinking. (Source: USGBC)

3.8 LOTUS

LOTUS is a voluntary market-based green building certification system developed by the Vietnam Green Building Council (VGBC) specifically for the Vietnamese construction industry and built environment.

It has been developed through long-term research, with expert advice of specialists giving particular consideration to Vietnam's economic and climatic characteristics, as well as existing Vietnamese standards and policy.

LOTUS shares the same goal with existing international green building certification systems (LEED, BREEAM, Green Star, Green Mark, etc.) and aims at establishing standards and benchmarks to guide the Vietnamese construction industry towards more efficient use of natural resources, enhancement of the wellbeing of occupants while reducing the environmental impacts of buildings.

LOTUS was released in 2010 with the LOTUS Non-Residential Pilot version. As of 2016, the LOTUS green building certification system includes:

- LOTUS Non-Residential v2.0 (LOTUS NR)
- LOTUS Multi-family Residential Pilot version (LOTUS MFR)
- LOTUS Buildings in Operation Pilot version (LOTUS BIO)
- LOTUS Homes Pilot version (LOTUS Homes)
- LOTUS Interiors Pilot version (LOTUS Interiors) – under development

For New Construction & Major Renovation projects, LOTUS (LOTUS NR and LOTUS MFR) focuses on a holistic approach in design and construction of the project, requiring application of energy modelling, passive design strategies, selection of low embodied energy materials and efficient equipment/fixtures as well as solutions to enhance occupant wellbeing, and consideration of climate change adaptation and mitigation measures.

LOTUS FACTSHEET

B
TQA

By: Vietnam Green Building Council (VGBC).

Status: 20 projects (10 certified projects, 3 projects under assessment process and 7 registered projects) as of August 2016.

Cost: All rating system Technical Manuals are free/open access; registration and certification fees vary depending on project size, consultancy fees are determined by the market.

Scope: Sustainability in buildings (environmental, social, human health).

Scale (spatial): New construction & Major Renovation (LOTUS Non-Residential, LOTUS Multi-family Residential); Existing buildings (LOTUS Buildings in Operation); Single family housing (LOTUS Homes) and Interior fit-out (LOTUS Interiors).

Scale (temporal): Entire life-cycle; LOTUS Certification system focuses on building design, construction and operation.

Expertise: Project teams are not required to hold specific credentials but knowledge on green building certification is strongly recommended; certification reviews are performed by a Primary Assessment Committee composed of experts from VGBC and independent assessors.

Adaptability: Weightings and criteria are universal (generally credits are identical independently of where the scheme is applied), but there are some specific adaptations to Vietnam.

Find out more: vgbc.org.vn/index.php/pages/lotus-certification

Dedicated to existing buildings, LOTUS BIO encourages effective operation and management strategies to reduce energy and water consumption, improve occupant wellbeing together with the involvement and participation of building occupants to maintain or increase the building performance.

LOTUS Homes is a system specific to individual single-family residential houses. The aim of LOTUS Homes is to promote good and best construction practices. LOTUS Homes is released with a User Tool designed to ease the application and implementation of LOTUS Homes for projects.

Figure 15 - Available rating systems of LOTUS. (Source: VGBC)

LOTUS references mainly Vietnamese building codes and standards. References to these are included in LOTUS for their relevance to green building construction. Those which are legislated are mandatory for any construction project in Vietnam to follow.

The VGBC recognizes that it has a responsibility to ensure that LOTUS-certified buildings meet these mandatory minimum requirements as well as raise awareness of such codes in Vietnam. LOTUS achieves this by including many codes in prerequisite criteria, meaning evidence must be given of compliance with such codes in order for a building to be LOTUS certified.

Where a Vietnamese standard exists, LOTUS references or uses it as part of credit criteria, however, the construction sector in Vietnam often relies on international standards as well. VGBC has consciously prioritizes the use and awareness of local standards wherever possible.

LOTUS rating systems are generally composed of **nine categories (plus "Innovation")**, each containing a varying number of prerequisites and credits. Prerequisites are minimum performance requirements that are mandatory and must be achieved by all projects in order to obtain a LOTUS certification. Against each credit, specific criteria have been set and, when projects comply with these criteria, points can be granted. LOTUS, being a point-based system, the number of points achieved by projects determines the certification rating corresponding to different certification levels: "Certified", "Silver", "Gold" or "Platinum" (see Figure 16).

Figure 16 - LOTUS certification levels and minimum thresholds. (Source: VGBC)

Figure 18 - Categories in the LOTUS Non-Residential rating system. (Source: VGBC)

Figure 17 - Diamond Lotus Lakeview, in Tan Phu District, Ho Chi Minh City. One of the first registered LOTUS Multi-Family Residential (LOTUS MFR) projects in Vietnam. The LOTUS registration of the new Phuc Khang projects demonstrates the commitment to provide the first green building units in the market and a move towards sustainability in the local real estate sector. (Source: Phuc Khang Corporation)

3.9 National Australian Built Environment Rating System (NABERS)

NABERS assesses the performance of a building during its operational phase. There are four NABERS tools: measuring energy efficiency, water use efficiency, indoor environmental quality, and waste treatment.

These tools are independent of one another in their administration, assessments, and ratings, and do not form part of a wider sustainability assessment system characterized by categories and weightings.

Of the NABERS tools, that for energy was the first to be developed, in 1998 (although under a different name). This tool assesses the operational energy efficiency of a building by directly measuring actual energy consumption and without reference to design.

It is a performance-based system that rates a building from 1.0 to 6.0 stars on the basis of 12 months of energy use (obtained from electricity/gas invoices and meters), with the rating being valid for one year. The tool converts the energy used into greenhouse-gas equivalents according to the source of electricity generation.

The emissions values are then normalised using algorithms that account for the building’s location, size, hours of occupation, other usage factors (e.g., number of computers), and climate, to yield a value of emissions per m^2. This value is then compared with a benchmark based on a set of peer buildings, and a rating is computed on that basis.

To date, NABERS has been applied mainly to commercial buildings, and as of 2015, 2,594 office buildings have been assessed at least once for energy use efficiency, 1,030 for water use efficiency, 79 for indoor environmental quality, and 42 for waste treatment. A NABERS HOME module is now being developed for rating residential buildings. The NABERS website contains a “home rating energy explorer” that can be used by homeowners to assess the energy performance of their homes, compare them with similar homes, and identify ways to improve energy efficiency. The data inputted is the latest 12 consecutive months of energy bills. The home’s energy use is adjusted based on the number of people living in the home, how many weeks per year the home is occupied, and the climatic conditions of the location. The energy use is then compared to the average usage of thousands of similar Australian homes and an energy rating given.

NABERS FACTSHEET

By: NABERS is managed nationally by the New South Wales Office of Environment and Heritage on behalf of the national Australian and State Governments.

Status: The first version of NABERS was devised in 1998, and as of August 2016 more than 2,500 non-residential buildings have been rated, including 77 per cent of Australia’s office building market. The scheme is being extended to cover residential buildings.

Cost: Self-assessed ratings using online tools are free. The cost of accredited ratings varies according to property type and size and the NABERS tool used for assessment.

Scope: NABERS measures the environmental performance of Australian buildings, tenancies and homes for any of four stand-alone tools (energy efficiency, water usage, waste management, and indoor environment quality). The system is entirely performance-based and does not measure building design.

Scale (spatial): Individual buildings and interiors of various types of commercial property (e.g., offices, hotels, shopping centres) as well as homes.

Scale (temporal): Covers environmental performance during a building’s operational phase at yearly assessment intervals.

Expertise: An accredited NABERS rating is performed by a trained Accredited Assessor who has passed an examination and is subjected to ongoing quality control checks. Self-assessed ratings (i.e., not accredited) can be made by anyone using online tools.

Adaptability: The normalisation of energy use and benchmarking needs to be adjusted for different countries. NABERS has been applied in New Zealand (NABERSNZ) since 2012.

Find out more: nabers.gov.au

Figure 19 - Private detached dwelling in Canberra, Australia - NABERS Home Tool Score 5.5/6. (Source: NABERS)

3.10 Passivhaus certification

The Passivhaus standard seeks to combine high comfort with very low energy consumption. Contrary to some of the other schemes presented here, Passivhaus assesses mainly the energy performance of buildings but not their environmental impact in a broader sense.

The certification focuses on the reduction of final energy consumption. However, it does not include other aspects of sustainability such as building site management, efficient use of water or LCA of construction materials. The main parameters which are evaluated in the Passivhaus certifications are: heating demand, cooling and dehumidification demands, heating load, cooling load and primary energy demand and building airtightness. The Passivhaus certification criteria are summarized in Table 5:

SPACE HEATING DEMAND	not to exceed 15 kWh annually or 10W (peak demand) per square metre of usable living space
SPACE COOLING DEMAND	roughly matches the heat demand with an additional, climate-dependent allowance for dehumidification
PRIMARY ENERGY DEMAND	not to exceed 120 kWh annually for all domestic applications (heating, cooling, hot water, and domestic electricity) per square metre of usable living space
AIRTIGHTNESS	maximum of 0.6 air changes per hour at 50 Pascals pressure (as verified with an on-site pressure test in both pressurised and depressurised states)
THERMAL COMFORT	must be met for all living areas year-round with no more than 10 per cent of the hours in any given year over 25°C

Table 5 - Passivhaus certification criteria (Source: Passivhaus Institut)

The Passivhaus certification assesses low energy building performance: high quality design, attention to construction details and quality control at the building site play an essential role.

PASSIVHAUS FACTSHEET

B
CED

By: Passivhaus Institut

Status: 50,000 residential and non-residential Passivhaus units worldwide

Costs: Costs vary depending on the specific project, on the building type and size

Scope: Living comfort and energy efficiency (the following parameters are calculated: heating demand, cooling and dehumidification demands, heating load, cooling load and primary energy demand)

Scale (spatial): Buildings or group of buildings

Scale (temporal): Design and construction phases

Expertise required: High level of knowledge in the field of energy efficiency, nZEB design as well as the Passivhaus Planning Package (PHPP) software.

Adaptability: The standard can be applied worldwide and for every climate zone, international Passivhaus certification criteria have been developed.

Find out more: passiv.de/en

If a Passivhaus is well designed and realized accordingly, the outcome is meant to be a building where transmission and ventilation losses can be compensated by solar gains through windows and internal heat gains such as heat from occupants and appliances, resulting in an extremely low energy demand.

The key elements that characterize Passivhaus buildings are high quality windows, very good thermal insulation, mechanical ventilation with heat recovery, airtightness and absence of thermal bridges.

The **five basic design principles** of the Passivhaus standard are summarized in Figure 20 (below). The energy needed to cover the remaining energy demand can often be supplied without the installation of a conventional heating system.

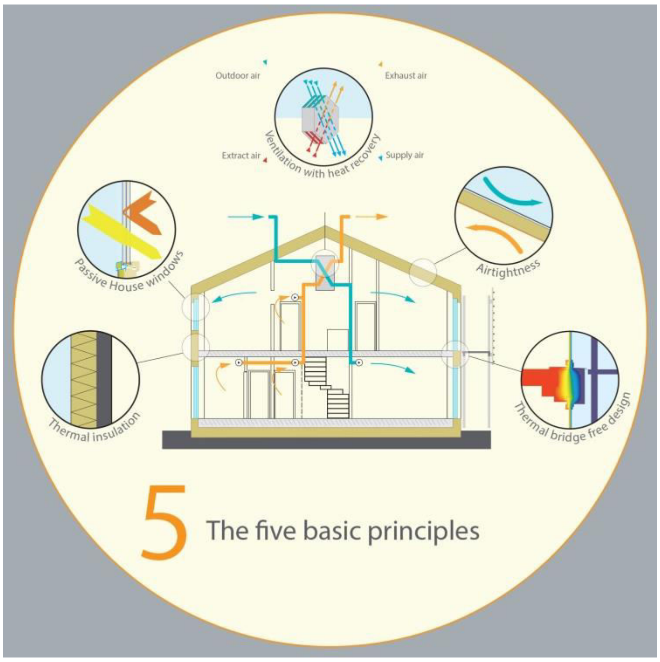


Figure 20 - Schematic representation of the basic design principles of the Passivhaus standard. (Source: Passivhaus Institut)

The Passivhaus standard was first ideated in 1988 while the first Passivhaus was realized in 1991. In the last 25 years, the Passivhaus concept has gained in popularity and has become an international standard. More than 50,000 Passive Houses have been realized worldwide. Most of them are concentrated in central Europe but in the past years, the standard has begun to spread in Southern Europe, North and Central America, as well as Asia.

The Passivhaus standard mainly evaluates the energy performance of buildings using a design tool called the Passivhaus Planning Package (PHPP), a user-friendly Excel-based tool validated over the last 25 years through comparison of thousands of monitored buildings. It calculates the building energy balance on the basis of a simple monthly calculation based on the international norm ISO 13790.

Its reliability has been tested in several research projects by comparing heating/cooling calculations with measured data of monitored buildings. These research projects have shown a very high correlation between design and obtained performances and has proven that, on average, the energy demand of a Passivhaus is significantly lower than a conventional building (Loga, Müller, & Menje, 1997; Feist, Loga, & Großklos, 2000; Peper & Feist, 2002; Ebel, Großklos, Knissel, & Loga, 2003; Reiß & Erhorn, 2003; Treberspurg, Smutny, & Grünner, 2010; Passive House Institute, 2013; Johnston, Farmer, Brooke-Peat, & Miles-Shenton, 2016). Even though the initial investment of a Passivhaus is slightly higher compared to a conventional building, the extremely low running costs make the investment cost-effective, if the respective climatic conditions would otherwise necessitate space heating and/or cooling with its associated operational costs.

Contrary to the common practice of certifying buildings "after the fact" to demonstrate compliance with energy regulations, **the energy design is as much an integral part of the design process within the Passivhaus approach** as the structural and architectural design. Design choices are based on detailed energy calculations. This leads to a maximization of the energy efficiency of the project and of its cost-effectiveness.

Benefits accrue for the end user who is assured of the precise energy consumption of the building, as well as the building designer who can rely on the certifier to improve the building's energy design. Other benefits, like an increase in market value which apply to benchmarking in general, also apply for the Passivhaus certification.

In the latest version of PHPP (PHPP 9) a new approach for the evaluation of primary energy has been introduced which evaluates the performance of buildings in a future where all energy production is based on renewables. This provides a long-term view of the sustainability of the building and also an indicator which no longer changes according to the regional energy mix. Moreover, PHPP 9 also calculates the on-site energy production and, depending on the amount of energy produced, three certification classes have been introduced: "Classic", "Plus" and "Premium" (Passive House Institute, 2016). Besides these, the Passivhaus standard is a binary certification: a project either conforms to the standard or it does not.

The embodied energy and in general the evaluation of the overall environmental impacts of the building are at present not included in the Passivhaus certification scheme. There is an ongoing discussion within the

Passivhaus community about the possibility of including an evaluation method based on a LCA approach which so far is being resisted to due to the absence of a reliable and scientific method as well as reliable databases[13]. However, PHPP 9 does offer the possibility of performing a life cycle cost analysis (LCCA) to further identify the economic benefits of the project.

Who can and should assess, and what makes sense where?

Passivhaus certifications can only be issued by a restricted number of professionals since a high level of knowledge in the field of energy efficiency and low energy building is required, in order to ensure the quality of the certification process and the Passivhaus standard as a whole.

At present there are about thirty certifying bodies globally, selected directly by the Passivhaus Institut (PHI). In Italy, for instance, the only accredited certifier is the ZEPHIR-Passivhaus Italia Institut.

The Passivhaus standard adapts to every climate, to different building types and construction methods. Furthermore, it can also be applied to refurbishments, thanks to the EnerPHit certification scheme, which guarantees the same comfort level of new buildings and reduces the energy consumption by a factor of 4 to 10 with respect to the existing building.

Figure 21 - One of the world's largest Passivhaus residential complexes, the Lodenareal housing complex with 354 apartments. (Source: Neuen Heimat Tirol, Architectsn teamk2)

[13] *See previous discussion on LCI variability in the introduction to Chapter 3. See also Lenzen (2001).*

3.11 Quantifying Sustainability in the Aftermath of Natural Disasters (QSAND)

QSAND is a free-to-use self-assessment tool to promote and inform sustainable approaches to relief, recovery and reconstruction after a natural disaster. As part of its commitment to sustainable development, IFRC, in partnership with the BRE Charitable Trust, commissioned BRE to develop the tool, drawing on the features of BRE's BREEAM standard.

After a four-year development process involving consultation and input from various organisations[14], the tool was released in May 2014. It is currently freely available to aid agencies, Governments, donors and other interested parties for download and use.

The **key objectives** of the QSAND tool are to:

- guide and inform decision-making for disaster-affected communities, while promoting more sustainable approaches to shelter and settlement activities;
- provide a coordinated framework to identify and, where relevant, assess the sustainability of solutions in post-disaster relief, recovery and reconstruction.

The QSAND tool is organised into eight categories within which issues relating to the reconstruction of a sustainable community are assessed. These categories are: shelter and community, settlement, material and waste, energy, water and sanitation, communications, natural environment, and cross-cutting issues such as resilience and participation.

QSAND FACTSHEET

By: International Federation of the Red Cross and Red Crescent Societies (IFRC) and Building Research Establishment (BRE)

Status: Voluntary - operational since 2014. Internationally applicable to locations affected by natural disasters or as disaster risk reduction activities.

Cost: None

Scope: Environmental, social, economic.

Scale (spatial): Infrastructure, spatial planning, single-shelter/building to large-scale multi-unit developments.

Scale (temporal): pre-disaster planning, post-disaster recovery and redevelopment, long-term.

Expertise required: QSAND practitioners training via free online or classroom courses.

Find out more: QSAND.org

A unique feature of QSAND's Core Assessment Tool (CAT) is its ability to give the user a simple overall performance score at the end of the process, in order to quantify the sustainability of a project or programme. This will help Governments, humanitarian agencies and funders understand the impacts of their work in disaster zones, pinpoint which strategies are the most effective and establish benchmarks of sustainability success.

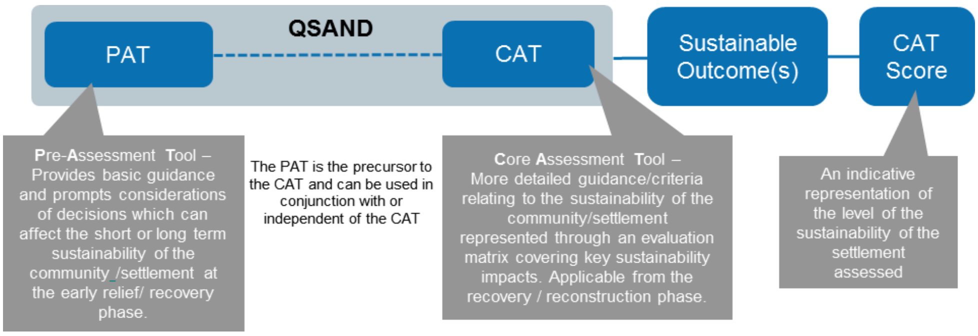


Figure 22 - The QSAND Process. (Source: IFRC)

[14] Such as but not limited to, UN-Habitat, Habitat for Humanity, the World Wildlife Fund U.S., the Norwegian Refugee Council, the IFRC Building and Social Housing Foundation, Architecture for Humanity, Practical Action, the SKAT (Swiss Resource Centre and Consultancies for Development), the UN Office for Disaster Risk Reduction, RedR UK...

3.12 SBTool

SBTool is a generic framework to support the sustainability performance assessment of buildings. The system has been developed by the International Initiative for a Sustainable Built Environment (iiSBE) as a tool that can be easily adapted to regional and building type variations, and can be used in different languages. Various versions of the system have been tested for the SB Challenge process since 1998. The SBTool has to this date been adopted in several regional contexts, most notably in Spain, Italy and Portugal, and is in the process of being imported to several other countries.

One of the distinct features of the SBTool is its **adaptability to different regions and occupancy types.** The tool is created so that third parties such as **local governments or research bodies** can develop adapted versions of the tool for end users in their region.

The tool consists of two separate files; a master file that defines the scope, benchmarks, weights and other settings for up to three generic occupancy types within the selected region, and separate project files that allow end users to enter project data that are compatible with the settings of the master file. Both the comprehensiveness and spatial scope of the tool may be adapted to suit different purposes. The system addresses a potentially wide range of sustainable building issues, while allowing the number of criteria that will be included in the assessment to be adjusted.

As for the spatial scope, the tool can be used from small buildings to large complexes, and is suited for assessing both new and existing construction. The tool includes the allocation of performance benchmarks that are developed by local third parties defined for generic occupancy types in the region. The assessment procedure itself can be carried out by the designers themselves using the separate, project-oriented file, and the scores are then submitted to authorized third-party assessors to be accepted, after which the project can receive a rating score.

While SBTool's flexibility and adaptability are undoubted advantages of the tool, there is a price to pay: performance benchmarks must be developed for all active criteria that are relevant to "Minimum", "Good Practice" and "Best Practice" performance levels for the building type and region where the tool is to be applied.

This requires a considerable amount of research by qualified researchers with access to relevant local data, requiring investments of time and funds. As a consequence, iiSBE recommends that a minimum-scope version be a starting point. This is easy to do in SBTool since the design-stage scope of the tool can be varied from a minimum set of 10 criteria to a maximum of 120 while retaining a constant 100 per cent total for the sum of all active criteria.

On the other hand, once benchmarks and weights are established for the generic occupancies in the selected location, many project files can be generated with no additional effort by the authorized local third party organisation.

SBTool FACTSHEET

B
TQA

By: International Initiative for a Sustainable Built Environment (iiSBE)

Status: The earlier version (GBTool) was the basis for a Spanish and Portuguese adaptation as well as the development of the Italian Protocollo Italia, the official rating tool for residential buildings in Italy.

Cost: Free for research purposes, negotiated payment for commercial uses.

Scope: Energy, Environmental Impacts, Indoor Environmental Quality, Economic, Site, Social/Cultural/Perceptual, Service Quality. The number of active criteria can easily be changed from 10 to 120 in the design stage, with the total of weighted criteria always totalling 100per cent.

Scale (spatial): Buildings and groups of buildings.

Scale (temporal): Design, construction and operating phases.

Expertise required: Auditors trained at cost by iiSBE.

Find out more: iisbe.org/sbmethod

SBTool's Italian adaptation Protocollo ITACA is a good example of how financial incentives can be used to promote a tool's uptake but also improve the building performance of social housing projects. In 2015, Protocollo ITACA was accepted as a national standard by the national standardization body UNI (uni.com).

Now certification for all social housing projects is mandatory. In addition, social housing companies receive a government grant of EUR 10,000 per apartment for projects which meet a challenging minimum performance score. Achieving this score requires a significant improvement against standard building practice.

3.13 Sustainable Building Assessment Tool (SBAT) and related schemes for neighbourhoods and building materials

The Sustainable Building Assessment Tool (SBAT)

SBAT is a holistic assessment tool that provides a structured way for assessing the sustainability of buildings and developing strategies and plans for improving their environmental, social and economic performance. The tool can be used both as a design aid and in the evaluation of the operational phase of the building.

The tool aims for integrated sustainability of the built environment and thus places increased emphasis on the social and economic dimensions of sustainability. SBAT, originally launched in South Africa, has been deliberately created for developing country contexts. The tool encourages a responsive approach where local needs and opportunities are prioritised and addressed within a broad sustainability framework (SBAT, 2015).

The SBAT criteria have been developed by analysing the factors that contribute to the human development index (HDI) and ecological footprint (EF) frameworks. The tool therefore assesses the capability of built environments to enable occupants and communities achieve HDI and EF targets which have been defined as being sustainable (Gibberd, 2015).

The main indicators within the tool include energy, water, waste, materials, biodiversity, transport, resource use, management, products and services, local economy, access, health, education and inclusion.

SBAT is simple to use and enables the user to rapidly evaluate the existing building and its context as well as the effect of different development strategies and options. It places emphasis on enabling communities to take action to assess their local area to improve both the physical environment as well as local quality of life, and aims to remove the perception that all development has to be led by Governmental bodies.

SBAT FACTSHEET

By: Jeremy Gibberd, Coordinator of the Smart and Sustainable Built Environments Group W116 at CIB.

Cost: Some aspects are free; some costs for training and detailed documentation.

Scope: Residential and other built environments.

Scale (spatial): Single building.

Scale (temporal): Both design and operational phases.

Expertise required: Limited, though a building background is useful.

Find out more: sustainablebuildingassessmenttool.com

The Built Environment Sustainability Tool (BEST)

The Built Environment Sustainability tool (BEST) is based on the same target levels related to HDI and EF as SBAT, and has been released by the same developer, but the scope of the BEST tool includes the evaluation of urban areas and neighbourhoods rather than individual buildings.

The tool highlights the kind of capabilities that the built environment can provide to communities, instead of focusing solely on the technical performance of individual dwellings. The BEST approach favours integrated and multi-impact solutions by recognizing a broad range of environmental, economic and social aspects.

Both SBAT and BEST seek to be cognizant of the potential of buildings in providing the capabilities to communities for supporting sustainability, defined as the ability to improve the local quality of life (HDI) whilst remaining within the environmental carrying capacity of the planet (EF). This "sustainability capability" The Sustainable Building Assessment Tool (SBAT) is then informed by the criteria contained in both sets of indices, HDI (aiming for >0.8) and EF (aiming for <1.8).

The Sustainable Building Material Index (SBMI)

The Sustainable Building Material Index is a methodology for evaluating the nature and scale of sustainability impacts of different building materials and products. The methodology has been designed to be quick and easy to apply and in the manner of the other tools of the framework, it takes into account the social and economic impacts of materials alongside a typical environmental evaluation. The aspects of the methodology are aligned with the environmental and social life- cycle assessment.■

Figure 23 - Pilot low-cost housing developed in Chilanga, Zambia. SBAT Score 2.3 (Source: Jeremy Gibberd)

SUMMARY

This chapter should have given a reasonably good impression of the breadth of tools available, both commercial and non-commercial.

What should have become immediately apparent, is that a considerable proliferation of products has taken place over the past three decades with plenty of duplication and overlap, possibly due to a need to address perceived gaps in existing assessment and benchmarking tools. These gaps may be related to a perceived lack of scientific rigour, comprehensiveness, accessibility or inadequate relevance to particular local contexts.

It should also be acknowledged that, like any industry, building assessment and benchmarking has developed into a business, especially in the upper-end of the market. Whatever the reason for their proliferation, the reader should now have a rough understanding of the limitations, approaches and delivery mechanisms for building assessment and benchmarking. This brings us to the final section of this report which will briefly look at the role building assessment and benchmarking could play in sustainable urban development and what could still be done to enhance it. ■

4. PATHWAYS TO WIDER UPTAKE

In the previous section, a broad overview of a small selection of building assessment and benchmarking methodologies was attempted, showcasing the range and diversity of approaches both in terms of business models and content. What unites these tools is an ambition to transform the building sector towards greater sustainability. But how successful has this process been up to this point?

In relation to the total number of new buildings as well as buildings in existence, only a very small portion has been assessed or benchmarked against an agreed standard, and even in pro-active countries sustainability assessment and benchmarking in the building sector has yet to become a mature practice (Berardi, 2012). While this will certainly have led to better outcomes on an individual per-structure basis and in absolute terms prevented a significant quantity of environmental and social impacts, **the relative impact can be assumed to be small.**[15]

Taking one of the industry's leading green building certification schemes, the Leadership in Energy and Environmental Design (LEED), as an example, the total number of LEED-accredited buildings globally was 69,000 as of January 2015 (USGBC, 2016). Even when adding the 540,000 buildings covered under BREEAM until 2016, this still compares poorly with the, for instance, estimated 1.8 million homes and 170,000 commercial buildings built every year in the United States alone (Hoffman & Henn, 2008).

Similarly, taking a relatively "climate-aware" country like Switzerland as an example, the proportion of 'Minergie' (minergie.ch), or low-energy-certified, buildings represents only approximately 1 per cent of the total building stock in the country (Steinemann,

[15] However, it would be wrong to assume that the coverage by such voluntary schemes has not influenced national standards and regulations over time. International standards can also be assumed to have been influenced by the experience and approach taken by such schemes. A critical evaluation of any existing research on the correlation between voluntary assessment and benchmarking schemes and regulatory changes or standards development is, however, beyond the scope of this paper.

Meins, & Guyer, 2008). In addition, very few buildings have been certified in low-income countries.

Thus, while the tools presented here have been developed to a very high standard through extensive consultations and revisions, one has to concede that the proportion of "sustainable" buildings, with all its caveats of definition, may be extremely low.

Working under the assumption that building sustainability assessment and benchmarking tools have an important role to play towards a more sustainable building sector, what then could be the conduits and catalysts available for increasing their uptake?

4.1 Enacting disclosure mandates

Assessment and benchmarking programmes exist globally in both voluntary and regulated form. While the value in voluntary assessments may lie in gradually introducing sustainability concepts into the building sector and creating certain pull effects such as peer pressure or market recognition, the impact of mandatory assessments, under the right circumstances, cannot be denied.

Public authorities at both national and local level have enacted disclosure mandates for the performance of buildings, primarily related to environmental indicators during the use stage of buildings. In the U.S., State and local authorities typically leverage the 'Energy Star' software to generate ratings based on operational use data submitted by building operators. Regulations prescribe what type of building would need to submit data as well as its minimum floor area. The Institute for Market Transformation (IMT) offers a useful overview of current building rating legislation globally at buildingrating.org with the ability of comparing policies.

While the global map offered by IMT the and replicated here in Figure 24, excludes notable countries with voluntary schemes like Qatar (QSAS), India (GRIHA and IGBC), Vietnam (LOTUS) or Indonesia (GreenShip), as well as countries where international schemes of other existing tools have been applied, the database clearly highlights large areas where no policies or schemes exist. In the coming years, it will be paramount to **ensure that policies are informed by the most appropriate locally adapted assessment schemes**, a process which should be both iterative and reflective. The EU approach of **establishing norms and standards** which are then envisioned to lead to adoption on a national or local level, could be considered as a viable example. At the same time, a cautionary must be applied: if the systems and indicators used are too poor or based on inaccurate data (such as LCI databases transposed from significantly differing economies), **mandatory performance ratings may be inaccurate or even counter-productive.**

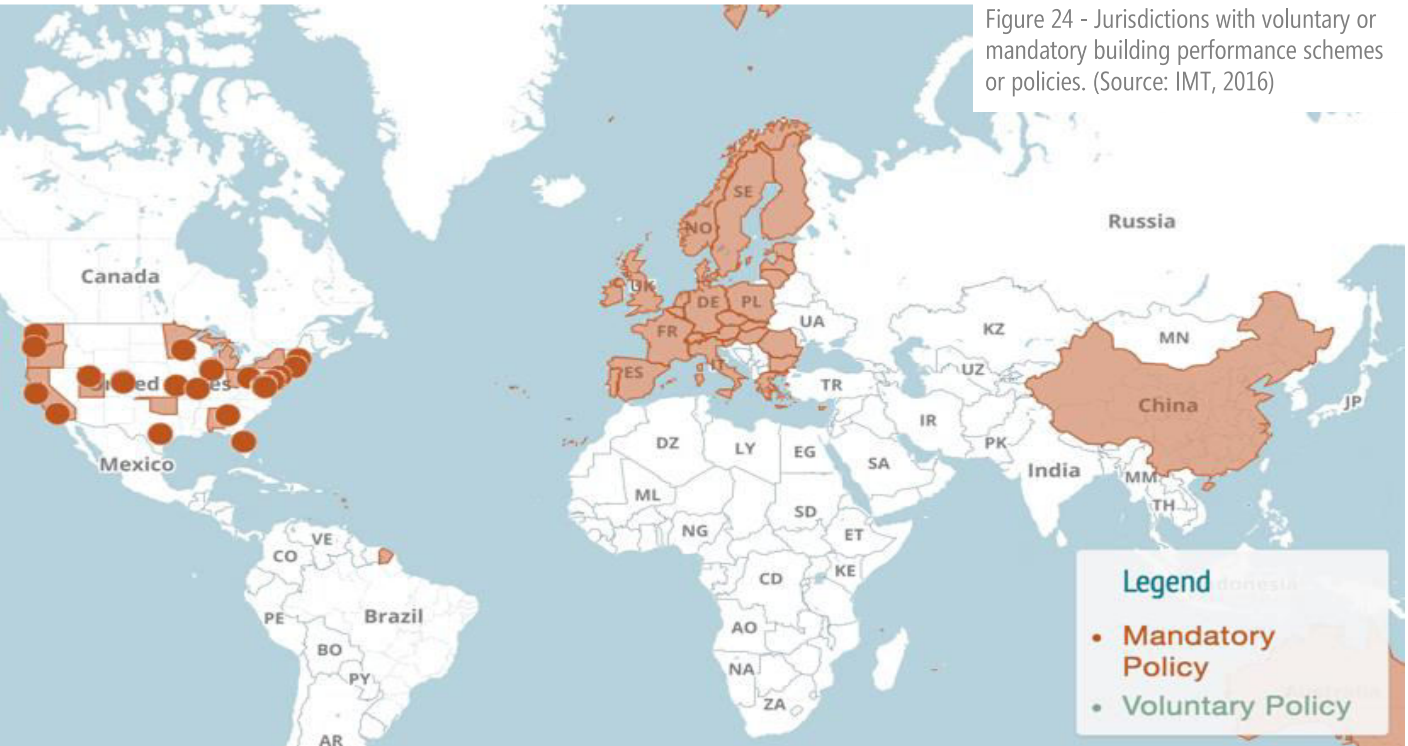


Figure 24 - Jurisdictions with voluntary or mandatory building performance schemes or policies. (Source: IMT, 2016)

4.2 Demonstrating public sector commitment

A number of jurisdictions are using benchmarking schemes to demonstrate their commitment to meeting climate change mitigation targets. It has been frequently pointed out that the public sector has to lead by example, a realisation which has led, for instance, to the requirement by the European Energy Performance in Buildings Directive for all new public buildings to satisfy 'Near Zero Energy' status by 31 December 2018, two years prior to all new non-public buildings.

4.3 Providing training in building sustainability assessment and regional, third-party adaptation

The approach advocated for by BREEAM, iiSBE and others to first develop a general framework which would then be adapted by third-parties for their regional or national contexts, demonstrates a move towards the adaptation of building assessment and benchmarking towards local conditions.

This would naturally require **introducing training in building assessment to members of professional associations**. In addition, planning departments and other public institutions dealing with the regulation of the building sector require sufficient funding, staffing and training in building assessment and benchmarking, especially when **engaging with developers at pre-planning stage**.

An energy expert should also be an integral part of the project development and approval process (UN-Habitat, 2015). A viable financial model which keeps costs for training of auditors as well as assessment or certification to a minimum is also essential, especially in developing country contexts.

Finally, the concepts and methods of building sustainability assessment and benchmarking need to be included in curricula of vocational and higher educational institutions.

4.4 Finding the right business model

Rick Jacobus (2016) in a recent article for the *Stanford Social Innovation Review* made a compelling case for identifying the right customers to pay for social impact data and developing the most suitable business models for the right context. A strong argument can be made for a similar review in the case of building sustainability assessment and benchmarking. Apart from the simplest of sustainability checklists, understanding the myriad of impacts of a building or home over its life-cycle will always be complex and incur costs to varying degrees. These are costs which only a small subset of built environment stakeholders will be willing to pay.

It is clear that conventional commercial models which transfer the onus of costs to developers, and thus eventually to tenants or buyers, will be unsuitable, if the vast majority of building projects, especially in low-income countries and transition economies, are to be covered.

This research has demonstrated a strong difference in opinion between the commercial assessment and benchmarking tools and those of open-source or "community" initiatives. While few of the latter fail to acknowledge the costs involved in ensuring the scientific rigour of comprehensive assessment or benchmarking, there seems to exist, concurrently, a conviction that this is too crucial an area to risk limiting its impacts through high certification fees. While the legitimacy of this argument will remain debatable, it is clear that **financially viable business models**, will have to be sought out **to cover the costs of benchmarking and assessment at reasonable levels of detail for countries at all stages of development**. It may be time to discuss whether it should be considered as much a requirement of sustainable urban development as sewer lines or road connections, and whether it should thus be covered through similar mechanisms such as betterment fees or infrastructure levies.

A loosening of regulations is one non-monetary way to incentivise wider uptake. Following a notification on green buildings by the Indian Ministry of Environment and Forests, for instance, several State and municipal Governments have begun offering streamlined approval processes or increased Floor Aspect Ratios (FARs) to GRIHA or IGBC registered ('pre-certified') or certified projects. These incentives do translate into monetary terms for the developer. The difference between "certified" and "registered" is crucial, however. As the Centre for Science and Environment rightfully points out (n.d.), the Ministry is offering these incentives

> *with the faith that the green rating agencies have carried out the due-diligence of these project designs and will be accountable for the environmental performance of such projects. However, pre-certification is only a pledge and there is no legal provision for requiring the project proponents to achieve the level of rating promised in the pre-certification application.*

Should a regulatory route be taken to promote green building certifications, States must ensure that a rigorous monitoring system at the local level is put in place.

In addition, for clients, lenders and investors, social and environmental concerns are rarely high on the agenda, if a return on investment in these measures cannot be proven (Hoffman & Henn, 2008). While Life-cycle cost analyses (LCCA) can be essential for making this connection visible, generally only in a build-and-operate scenario would one see the benefits of such an approach. This disconnect between building stakeholders as well as the lack of information about the environmental, social and economic life-cycle impacts of a building's design and materials are major barriers which need to be overcome. Building assessment tools have a role to play in unlocking these information flows.

In either case, for this to occur, two processes may have to coalesce in the near future in order for assessment and benchmarking to become meaningful, mainstream, affordable and widely influential: **an open-source revolution in terms of access to life-cycle inventory data** and the **regulatory integration of locally adapted assessment and benchmarking tools or, at least, easy to apply sustainability checklists**.

4.5 Limitations of the report

Limitations of time and resources compromised to some degree the report's purpose of providing an introduction to the field for policy-makers, practitioners and the public, especially with regards to comprehensiveness and reflecting the latest scientific findings. It was thus not possible to provide an overview of existing critical reviews of the profiled schemes, or to include additional schemes. Geographically, and despite the inclusion of NABERS, LOTUS and SBAT, the latter point especially led to a European-US bias of the profiled schemes, which must be acknowledged.

The reasons for the limited uptake of building sustainability and benchmarking in low-income countries in particular, could also not be explored to the degree hoped. Further research could provide more insights into the extent of the data gap, the resources needed for closing it, as well as the barriers to increasing consumer demand. ■

CONCLUSION

The evolution of building assessment and benchmarking which began almost three decades ago has continued unabatedly and led to the proliferation, increased complexity, commercialization, but also in some cases, the democratisation of the building assessment process. What have we learned and in which direction are we heading?

Three observable trends

In terms of benchmarking schemes, one paramount trend is the conceptual change from a mere rating "after the fact" towards tools which ***guide*** **the design process right from inception**. We have seen that many benchmarking schemes are, in fact, trying to find early stage entry points in order to affect the design of projects, while being cognizant of the entire life-cycle impacts of the building and to also Design for Disassembling (DfD), utilizing concepts on how to separate different material fractions and components at the end of life of every individual product or component. This may be even more important in low-income countries where most of the building stock is yet to be built. Countries should strive to avoid costly and cumbersome retrofits several decades on. As Meadows points out,

> *physical structure is crucial in a system, but it is rarely a leverage point because changing it is rarely quick or simple. The leverage point is in proper design in the first place.*

Secondly, the importance of **local adaptation has been widely recognized**. Transplanting benchmarking schemes into contexts where the original indicators do not make sense or are of lesser importance could lead to architects and designers scrambling to implement features which either require importing materials from abroad or focus on applying merely technological "solutions" while the building's context would demand entirely different interventions. This could be especially true of commercial benchmarking schemes directly applied in a developing country context where concerns about employment, health, inclusion, accessibility and others may be much higher on the priority list of residents and policy-makers. Deciding on the specific framework of such assessments will be as difficult and arduous a task as in the developed world (Bhatt, Macwan, & Bhatt, 2012).

A third trend is the **expansion of scope**. Some assessment tools now include indicators relating to the social and economic impact of buildings and neighbourhoods, though the extent to which these are considered varies widely between schemes. This is certainly a positive development which concedes that sustainable buildings must consider more than their operational energy. Whether these calculations accurately reflect the most important socio-economic impacts in a specific location or are measuring indicators which stand in direct correlation to a desired outcome (i.e. *vicinity* to a public transport node vs. *use* of public transport), is a difficult conversation at the core of much past and current research (Boarnet & Crane, 2001).

A systems view of building assessment and benchmarking

If the recent paradigm shift from environmental benchmarking to more holistic assessments of buildings can be any indication, the potential benefits could be significant. Building assessment tools could, for instance, become a means for **introducing a human rights-based approach to housing development** by focusing on process as much as product, and making energy efficiency as much a requirement as the principle of participation[16] or the consideration of *all seven components* of the right to adequate housing[17]: legal security of tenure; affordability; habitability; availability of services, materials, facilities and infrastructure; accessibility; location; and cultural adequacy. Even though none of the tools profiled here as yet make specific reference to these components, they could form an integral part in the formulation of indicators.

It is the **recognition of the built environment as a complex adaptive, socio-ecological system** (du Plessis & Cole, 2011) which requires us to look beyond the counting of GHG emissions—crucial as it may be—to look for less measurable signs of whether progress towards sustainable development has been achieved while acknowledging the impact of time. Of what importance will a "Platinum" rating be in several decades when the environment around our buildings has morphed, the climate itself has changed, new habits of use have emerged and we realise that what once was "Platinum" may at best be "Bronze" today?

Presuming that the building industry is an inherently complex system, one could turn to system analysis to identify how building assessment and benchmarking may be useful tools for effecting change. Meadows (1999) argues that "**fiddling with the numbers**" by means of parameters and standards is one of the least effective ways of changing the behaviour of systems. While voluntary, and static benchmarking schemes may fall within this category, Meadows does, however, acknowledge that this "fiddling with the numbers" could, under the right circumstances, lead to reinforcing feedback loops elsewhere. This requires that "the numbers" reach critical mass, a process which may require large-scale regulatory reform and enforcement.

Assessment and benchmarking schemes can also **add a new information flow** to the system, and as such have very high leverage scores. Hereby, it is crucial *what* information is being made available to *whom* and in *how* accessible a format. While certain kinds of information can provide perverse incentives to continue along a destructive path[18], others may be entirely irrelevant for affecting large-scale change. To quote Meadows again, "*it is important that the missing feedback be restored to the right place and in compelling form'*.

Very much connected to this point is the fact that the need for better building performance represents a relatively weak social norm. While the need for clean air, clean water or safe food presents itself to us as immediately relevant

[16] *Some schemes developed for the neighbourhood level and, to a lesser extent, at building level, do cover stakeholder engagement and consultation processes in some detail.*
[17] *As defined by the GeneralComments to the 1966 International Convenant on Economic, Social and Cultural Rights.*
[18] *An example would be an increase in price for a limited resource, such as fish, signalling increased profitability through further reducing the supply, i.e. catching more fish.*

and important, the impacts of the building process at times may appear too far removed from our everyday experience to trigger the kind of societal response necessary to demand the transformative policy changes needed. Assessment and benchmarking tools offer us a valuable opportunity of **making the importance of these impacts visible and quantifiable**.

Finally, building assessment tools can help us **create a platform** on which to reflect, anticipate, respond and "*harmonize conflicting interests*" (Wallbaum et al., 2010). They can allow us to create a network of "*co-learners*" in which all stakeholders in the building process can take part. For this process of co-learning to achieve true impact and representativeness, it is necessary "*to redefine stakeholders in design and construction in a way that moves beyond the traditional triad of built environment professionals, developers/clients and government regulators as those responsible for creating the built environment, and the 'community' as an interested/affected stakeholder*" (du Plessis & Cole, 2011). This definition of stakeholder must necessarily include and give voice to "*silent*" stakeholders such as the socio-ecological system within which the project is situated, future generations as well as the poor and marginalized (ibid.).

What this eventually points to is **a dual *raison d'être* for building assessment and benchmarking**. Firstly, there will be tools at the heart of a technical movement to scientifically quantify progress in reducing the environmental impact of the building sector and to also feed into regular global reporting on energy use disaggregated by sector, especially in light of countries' recently made commitments under the 2030 Agenda for Sustainable Development, the Paris Agreement and the New Urban Agenda. And secondly, there will be tools specifically "*geared towards the enhancement of the building process and the empowerment of stakeholders through their direct experience in sustainability-oriented decision-making*" (Kaatz, Root, Bowen, & Hill, 2006). ■

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