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Sustainability and performance assessment and benchmarking of buildings

Final report

VTT

ISBN 978-951-38-7908-2 (URL: http://www.vtt.fi/publications/index.jsp)
ISSN 2242-122X (URL: http://www.vtt.fi/publications/index.jsp)

JULKAISIJA – UTGIVARE – PUBLISHER

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Sustainability and performance assessment and benchmarking of building – Final report

Tarja Häkkinen (Ed.). Espoo 2012. VTT Technology 72. 409 p. + app. 49 p.

Abstract

This report presents and summarises the results of the European SuPerBuildings project.

The project developed and selected sustainability indicators for buildings, develop understanding about performance levels considering new and existing buildings, different building types and different national and local requirements, developed methods for the assessment and benchmarking of sustainable buildings and made recommendations for the effective use of benchmarking systems as instruments of steering and in different stages of building projects.

The final report presents the main results of the project and makes references to the original project deliverables available on the project's web site: http://cic.vtt.fi/superbuildings/

The final reported has been edited by the project coordinator Dr Tarja Häkkinen. The main authors of the report are prof. Thomas Lützkendorf, Maria Balouktsi, Andrea Immendörfer, KIT-U, Syviane Nibel, Boris Bosdevigie, Alexeandra Lebert and Bruno Fies, CSTB, Dr Patxi Hernandez Iñarra, TECNALIA, Antonín Lupíšek and prof. Petr Hajek, CVUT, Susanne Supper, ÖGUT, Erik Alsema W/E, Laetitia Delem and Johan Van Dessel, CSTB, together with Tarja Häkkinen, Carmen Antuña, Tarja Mäkeläinen from VTT.

The final report introduces the current SB assessment systems and discusses barrier and drivers for sustainable building.

From the beginning, SuPerBuildings agreed not to add another sustainability system to the numerous existing ones. Instead, the principles for the design and development of assessment systems should be worked out, discussed and made publicly available. As the sustainability of buildings should always be assessed with the help of indicators, one of the key objectives of SuPerBuildings is to ensure "validity" for sustainability indicator systems. This determines the true possibility of an indicator system to give information about the sustainability of buildings.

Project selected indicators for further development. Regarding these indicators the final report presents information about their validity, assessment methods, and performance levels.

The final report also discusses the problematics and functional equivalent, and weighting and normalization criteria.

Finally, the report gives recommendations for the use of indicators in different stages of building processes, in connection with building information models and in connection with different steering instruments.

Keywords sustainable building, indicator, benchmark, assessment, performance

Preface

This report is the final report and summary of the main results of the European SuPerBuildings project.

The project was was funded by the 7^{th} Framework Programme (Theme Environment (including Climate Change)). The project type was Collaborative project / Small or medium scale focused research project and the project's Grant agreement number was 244087.

The project was coordinated by Dr Tarja Häkkinen VTT.

The consortium included altogether 13 members from 9 countries:

VTT Technical Research Centre of Finland	VTT	Finland
BRE Global Ltd	BRE	UK
Centre Scientifique et Technique du Bâtiment	CSTB	France
Belgian Building Research Institute	CSTC	Belgium
Karlsruhe Institute of Technology	KIT-U	Germany
CVUT, Faculty of Civil Engineering of the Czech Technical University	CVUT	Czech Republic
IAO, Institute for Industrial Engineering, Fraunhofer	IAO	Germany
TECNALIA	TECNALIA	Spain
ÖGUT, Österreichische Gesellschaft für Umwelt und Technik, Austrian Society for Environment and Technology	ÖGUT	Austria
YIT Kiinteistötekniikka Oy	YIT	Finland
VINCI Construction France	VCF	France
Werner Sobek Stuttgart GmbH	WS	Germany
W/E Consultants	W/E	Netherlands

The project started on the 1^{st} of January 2010 and it ended on the 31^{st} of December 2012.

This report introduces the main findings of the research project. The main authors of the report are as follows:

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where in important roles in case studies.

The whole project and all work packages were carried out together as a common effort of the whole consortium. However, the main responsibilities in writing the different Chapters of this report were as follows:

Chapter 1 Tarja Häkkinen
Chapter 2 Laetitia Delem
Chapter 3 Tarja Häkkinen
Chapter 4 Thomas Lützkendorf
Chapter 5 Syviane Nibel
Chapter 6 Boris Bosdevigie
Chapter 7 Patxi Hernandez Iñarra
Chapter 8 Carmen Antuna
Chapter 9 Bruno Fies
Chapter 10 Tarja Häkkinen and Tarja Mäkeläinen
Chapter 11 Thomas Lützkendorf and Tarja Häkkinen

Section 2.9, which gives information about the parallel project OPEN HOUSE, has been written by Dr Daniel Hiniesto Muñoz de la Torre (coordinator of OPEN HOUSE).

Espoo 12.12.2012
Tarja Häkkinen (ed.)

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Appendices

1. Introduction

This report summarises the outcomes of the European SuPerBuildings project.

The project developed and selected sustainability indicators for buildings, develop understanding about performance levels considering new and existing buildings, different building types and different national and local requirements, developed methods for the assessment and benchmarking of sustainable buildings and made recommendations for the effective use of benchmarking systems as instruments of steering and in different stages of building projects.

The premise of the SuPerBuildings project is that it is possible to

- develop a logical structure for the sustainability assessment of buildings considering the environmental, economic and social performance of buildings
- develop indicators for buildings with the help of which the aspects of sustainability can be assessed. These indicators should reflect the sustainability impacts of buildings, should be not overlapping, should be defined so that the comparability of assessment results is achieved.
- define benchmarking criteria for sustainable buildings
- effectively use sustainability indicators in different stages of building process, especially in target setting, design, construction and tendering processes, maintenance and building renovation and thus promote sustainable built environment
- use sustainability indicators as an instrument of sustainable building steering.

The framework for the assessment of environmental, social and economic performance is being developed within CEN and ISO. The project considered the output of the standardisation processes and focused on the development of the validity of sustainable building indicators, comparability of assessment results, benchmarking criteria and the usability of indicators in building processes. The project made recommendations for the improvement of standards.

Sustainable buildings are defined with the help of indicators; a number of different kinds of sets of sustainability indicators have been developed (Delem et al. 2010[1]). Chapter 3 characterises and summarises the existing indicator systems and makes conclusions about the needs of development.

Because the numerosity of various kinds of indicator sets there is a danger that this may decrease the general trust on the reliability of the assessment systems and impair the general understanding about their purpose. The quality and validity of sustainability indicators need to be developed. The improvement of the quality and validity of sustainability indicators of buildings was one of the main targets of the European research project Sustainability and performance assessment and benchmarking of buildings. In order to improve the validity of sustainable building indicators as indicators of sustainability, a top-down approach should be chosen (Lützkendorf et al. 2010[2], Lützkendorf et al. 2012[3]). Following a top-down approach, the development and selection of indicators starts by the definition of relevant subjects of concern of sustainable development. An indicator can be validated as an indicator of sustainable building only if it fulfils two minimum requirements: 1) the indicator is related to a subject of concern of sustainable development; 2) buildings have a significant impact on that issue (Häkkinen et al. 2011[4]). A logical approach for the development of indicators is introduced and explained in Chapter 4.

SuPerBuildings project defined a common outline for the development of indicators in order to improve the presentation and justification of indicators[5]. The group of selected indicators is presented in Chapter 5. Finally, the project selected the following indicators out of the whole group for further studies: carbon footprint, land use, use of water, waste, aesthetic quality, social indicators as a group and thermal comfort – were chosen for closer consideration. As a result of this five article manuscripts we prepared. Although SuPerBuildings addressed and developed core indicators, the selected group is not introduced as a set of indicators. The selection of the most relevant indicators depends on several issues – the type of the project, location, type of the buildings, purpose of the indicator system.

Information about benchmarks and typical values of indicators is necessarily needed in sustainable building processes. Although we have indicators and we already have a lot of information about assessment methods and the issues that

[1] Delem, Laetitia et al. 2010. Conclusions about the needs for development of sustainability indicators and assessment methods. Deliverable D2.1

[2] Lützkendorf , Thomas et al. 2010. Concept and framework. Deliverable D4.1

[3] Lützkendorf , Thomas et al. 2012. New trends in sustainability assessment systems - based on top down approach and stakeholders needs. Journal of Sustainable Building Technology & Urban Development.

[4] Häkkinen, Tarja et al. 2011. Potential of sustainable building assessment methods as instruments of steering of sustainable building. Deliverable D3.2

[5] Nibel, Syviane et al. 2011. Description and explanation of the selected indicators and related measurement methods with special focus on reliability and, comparability and validity. Deliverable 4.1

affect the comparability of results, we still lack information about benchmarks. SuPerBuildings tried to improve knowledge by developing benchmarking criteria[6] and by collecting information about the typical performance of buildings[7] with regard to different core indicators. Results are introduced in Chapter 6. However, a lot of information is still needed.

Defining a functional equivalence for the sustainability assessment of buildings is a challenging task. SuPerBuildings studied the problematics in detail. Results are presented in Chapter 7 together with the discussion about normalisation and weighting.

The purpose for the development of indicators is the belief that those can be successfully made use of in sustainable building processes. SuPerBuildings developed information about the barriers and drivers for sustainable building[8],[9], and described and gave recommendations for the use of indicators in steering processes[10],[11] and in the different stages of buildings processes[12]. These results are introduced in Chapter 2 (Barriers and drivers) and in Chapters 8 and 10. SuPerBuildings project addresses that – because sustainability management of buildings requires a lot of information – Building Information Model based design and building are best capable to utilize indicators for briefing, programming, desing and implementation for sustainable buildings[13],[14]. The recommendations are presented in Chapter 9.

The project also test used the core indicators in real building projects in order to get information about the usability of indicators[15]. A summary of the results is given in Appendix A.

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[6] Bosdevigie, Boris et al. Conclusions about the performance levels of buildings considering the requirements of sustainable building and considering the economic and technological barriers and regional differences. Deliverable 5.1.

[7] Hernandez, Patxi et al. Benchmarking criteria for sustainable buildings in Europe. Deliverable 5.2

[8] Häkkinen, Tarja, Belloni, Kaisa. Barriers and drivers for sustainable building, Building Research and Information . Taylor & Francis. Vol. 39 (2011) No: 3, 239–255.

[9] Lupisek, Antonin et al. Literature and interview survey about stakeholders' needs and requirements for SB assessment and benchmarking methods. Deliverable 3.1

[10] Häkkinen, Tarja et al. Opportunities to integrate sustainable building benchmarking methods with steering mechanisms and potential effect of sustainable building benchmarking methods on promoting sustainable building Deliverable 3.2.

[11] Häkkinen, Tarja et al. Recommendations for the use of sustainable building assessment and benchmarking methods and systems in steering of sustainable building. Deliverable 6.2

[12] Antuña, Carmen et al. Summary of the results and recommendations for the use of sustainable building assessment and benchmarking systems in different phases of building process. Deliverable 6.1.

[13] Fies, Bruno et al. Needs, levels and potentials of integrating SB assessment and benchmarking with BIMs. Deliverable 3.3.

[14] Fies, Bruno et al. Recommendations for the integration of sustainable building assessment and benchmarking methods with BIMs. Deliverable 6.3

[15] Delem, Laetitia and Supper, Susanne et al.. Report on the selection of the case studies, Summary report on the results of the case studies, Feedback report on the results of the piloting phase. Deliverables 7.1, 7.2 and 7.3

The main objective of the project was to develop sustainability indicators and to develop the use and usability of indicators in design and implementation for sustainable buildings. The project hopes that the outcomes of the project will be useful and support sustainable building and the development of next generation assessment systems. Future needs are discussed and recommendations are given in Chapter 11.

2. Current assessment systems and conclusions about needs of development

2.1 Introduction

Information about the content and characteristics of the current assessment systems were collected in order to

- summarise the existing results on sustainable building indicators and assessment and rating systems
- make conclusions about the main topics of sustainable building indicators and related assessment methods that need further development
- study the availability of indicators that describe the potential environmental, social and economic impacts of buildings and the degree of common understanding about these indicators
- study the availability of methods, which properly measure performance levels for each indicator, and the degree of common acceptance of these methods
- find information about the existence of good principles for establishing benchmarking levels
- find information about the availability of aggregation and weighting methods with the help of which the results can be expressed in terms of key figures or labels.

In practice the work consisted of a review of pertinent European and international initiatives and standardization activities, as well as existing national building evaluation tools (see Table 1). The collection of information on national building evaluation tools was done with the help of a questionnaire, which was issued to all partners. This questionnaire was divided into two parts. The first part invited the partners to provide information on their national building evaluation tool (available versions, general structure and detailed information about each indicator, way of expressing results, aggregation and setting weighting factors). In the second part, the partners were asked, based on their personal expertise, to list indicators that are lacking, for existing indicators to list the ones for which they think the measurement method should be improved, to identify a core set of indicators, and list principles they support for aggregation of resultsTo insert images use the paragraph style Picture, otherwise the picture won't show.

Table 1. Overview of international and European initiatives, harmonisation and standardisation activities and existing national building evaluation schemes, analysed within this project.

International and European initiatives and harmonisation and standardisation activities	National building evaluation tools	
CEN TC 350[16]	BREEAM & Code for Sustainable Homes (U.K.)	LEED (U.S.A.)
ISO TC59 SC17[17]	BNB/DGNB (Germany)	SBTool CZ (Czech Republic)
Sustainable Building Alliance (SBA)[18]	PromisE (Finland)	klima:aktiv Gebäude-standard (Austria)
UNEP SBCI[19]	HQE (France)	TQB (Austria)
LEnSE[20]	Valideo (Belgium)	GPR Gebouw (The Netherlands)
Perfection[21]	CASBEE (Japan)	

2.2 Indicators and assessment methods

The review of European and International initiatives and standardisation activities revealed that CEN and ISO standards start from a common life-cycle analysis based approach, supplemented with additional environmental and technical information. However, the standards only fully address environmental performance

[16] CEN Technicla Committee 350 Sustainability of Construction works http://www.cen.eu/cen/Sectors/Sectors/Construction/SustainableConstruction/Pages/CEN_TC350.aspx

[17] ISO TC59 SC 17 Sustainability in buildings and civil engineering works http://www.iso.org/iso/standards_development/technical_committees/other_bodies/iso_technical_committee.htm?commid=322621

[18] http://sballiance.org/

[19] http://www.unep.org/sbci/index.asp

[20] Methodology development towards a label for environmental, social and economic buildings http://www.lensebuildings.com/

[21] http://www.ca-perfection.eu/index.cfm?n01=general_info

assessment, while currently work is continuing to address more fully the social performance of buildings. The SBA and UNEP initiatives focus on a much narrower set of metrics than included in the standards. Within the LEnSE project, 31 environmental, social and economic issues are identified and an assessment method is developed, starting from a review of existing evaluation tools and standardisation and harmonisation activities. Finally, the Perfection project focuses on setting up a framework and a set of indicators concerning the overall quality of the indoor environment of buildings.

The review of national sustainable building evaluation tools was mainly based on the information provided by the SuPerBuildings' partners with the help of the questionnaire. The main objectives of this review were to identify:

- indicators that are (almost) not covered by existing tools and therefore eventually need to be developed
- indicators that are covered by several tools but for which the evaluation method may need some harmonization
- core indicators.

In order to be able to draw the above conclusions based on the information received (list of indicators and description of corresponding evaluation methods from 11 tools) a broad table of issues that could potentially be covered by existing tools was made. For each national tool, the indicators were then classified in that table (each indicator under the issue(s) it covers). This enabled to identify issues that are not, little or well covered by existing tools and, for issues that are covered by more than one tool, a comparison of evaluation methods could be made.

The list of issues that served as framework for the analysis was mainly based on the issues covered by LEnSE, ISO 21929-1 and to make it as exhaustive as possible it was also completed with additional issues encountered in the reviewed tools but which did not fit into the originally established framework. For practical reasons (to make the tables readable), those issues were separated into social, economical en environmental issues.

Table 2 gives a summary of those issues that are covered by less than 3 of the reviewed tools and Table 3 of those issues that on the contrary are covered by almost all of the reviewed tools. When an issue is covered by very little tools it may indicate further needs of development. However, it may also be an indication that the issue is not considered relevant/important enough for sustainable building evaluation or that the indicator is already well developed but not implemented yet. For example LCA indicators are not commonly used yet, but there are already many efforts to develop those indicators within CEN TC350. So it is just a matter of time for them to be included in most tools.

On the other hand, the fact that an issue is covered by most tools, indicates that it is generally considered as important and relevant. Those issues are thus potential core indicators. Concerning the later, Finally, regarding the issues covered by many tools, the assessment methods used in the different tools were compared. This showed that there is a need for harmonization. The most important differences between the tools relate to:

- the use of qualitative versus quantitative indicators
- performance based indicators versus indicators based on an evaluation with a checklist of measures (assessment of building features, which are never the same for all tools)
- system boundaries considered (e.g. CO2 only for the use phase or also for materials)
- level of detail and number of sub-indicators.

Table 23 also includes the answers from the partners on the free question "which indicators do you consider as core indicators". As it can be seen, for the environmental and social issues the core indicators identified by the partners are already covered by most of the analysed tools. However, this is not the case with regard to economical indicators.

In the questionnaire partners were also asked to list indicators that in their opinion need to be further developed or harmonized. Some of the indicators listed here were previously also identified as core indicators or as lacking indicators in most of the reviewed tools. They are written in Italics in Tables in Appendix B.

Additional issues that were identified as issues to be further developed (proposed by at least one partner) are:

- local depletion caused by exploitation of primary surface resources (e.g. gravel)
- LCA impact from using different types of wood (from sustainably managed forests or not)
- protection from domestic accidents
- space efficiency
- building aesthetics and context.

Finally, regarding the issues covered by many tools, the assessment methods used in the different tools were compared. This showed that there is a need for harmonization. The most important differences between the tools relate to:

- the use of qualitative versus quantitative indicators
- performance based indicators versus indicators based on an evaluation with a checklist of measures (assessment of building features, which are never the same for all tools)
- system boundaries considered (e.g. CO_2 only for the use phase or also for materials)
- level of detail and number of sub-indicators.

Table 2. Overview of indicators and issues that are not (commonly) covered by existing evaluation tools.

	Indicators present in less than 3 of the reviewed tools
Environmental	LCI indicators for land use, use of (non) renewable resources, water consumption and production of (non) hazardous or *radioactive waste*
	LCA indicators, other than CO_2 emissions
Economic	Improve building user productivity
	Changes in economic system
	Housing affordability and commercial viability
	Service life
	Management[22]
Social	Vibrations
	Social and ethical responsibility
	Consideration of user's needs

[22] Improvement of economic feasiblity, reducing construction costs, improvement of construction and management standards.

Table 3. Overview of indicators and issues that are covered by most or all of the considered tools (based on the responses of the different partners on the questionnaire).
ET = based on the review of existing tools (covered by minimum 9 of the reviewed tools)
EX = based on response from partners of free questions (response based on own experience and expertise)

	Core indicators	ET	EX
Environmental	Primary energy consumption	x	x
	Water management	x	x
	Materials (rational use and low impact)	x	x
	Waste (construction and operation)	x	x
	Global warming potential (CO_2 emissions)	x	x
	Land use and Ecological value of the site	x	x
Economic	*Building adaptability*	x	x
	Ease of maintenance	x	x
	Life cycle costs		x
	Process quality (planning and preparation)		x
	Innovation		x
Social	Indoor air quality	x	x
	Access to transport (for building users)	x	x
	Comfort (visual, thermal, acoustic)	x	x
	Access to public services and amenities	x	
	Access for users with physical impairments	x	x
	Safety and security		x

2.3 Benchmarking criteria and weighting methods

The collected information about the existing national building evaluation schemes as well as the data on current international and European standardisation and harmonisation activities was studied and the following conclusions were made about the performance levels and benchmarking criteria and weighting methods.

Concerning performance levels and benchmarking criteria, the following conclusions can be drawn:

– There are few or no reference values for indicators given in standardisation framework and environmental standards on building performance (see

EN 15978). We need to define reference values for benchmarking for these indicators and calculation methods. Furthermore, reference values will change when we will consider whole life cycle indicators (LCA, LCC).

- All evaluation tools considered have a performance rating scale at both the building and the indicator level.
- It is ineffective to compare currently used performance levels and benchmarks from different tools, because of the absence of harmonised and consensual indicators (e.g. disparity in calculation rules, system boundaries) and imminent change to LCA indicators.
- For new or system-specific indicators, a methodology has to be defined on how to set performance levels when there are obviously lack of experience and feedback data.
- Even if the trend is to develop more performance-based indicators than solution-based ones, some indicators cannot easily be measured by quantitative data, e.g. maintainability, flexibility, functionality, usability, protection from domestic accidents, social diversity, ecological value of the site, biodiversity, or climate change adaptation. Therefore, contents have to be defined for these indicators, as well as a performance scale. Here, a system of grades may be a solution, a class including several descriptive criteria, together with possible sub-indicators.
- When setting performance levels, it is important to avoid lobbying by industry or other actors.
- It is often important to take into account contextual data (climate, socio-economical factors, etc.).

Also aggregation and weighting methods within the considered national building evaluation tools were analysed. Based on this analysis, all tools appeared to have a single global score as the result of a total aggregation process with weighting factors. Most of them are based on a four-level aggregation scheme, using the weighted sum method. CASBEE is the only system that considers at the higher level another aggregation method based on eco-efficiency (ratio benefits / loadings). Discussions may concern the consistency of the final set of criteria, establishing rules that clearly define weighting factors based on rational arguments and intermediate levels of aggregation.

Regarding aggregation and weighting methods the following attention points were identified:

- There is a need to align benchmarking, weighting and aggregation methods with the general principles of sustainable construction defined in ISO 15392 (mainly transparency, involvement of interested parties and holistic approach).
- When an issue is composed of several indicators or parameters that can be aggregated by calculation rules, this calculation method should be preferred to weighting factors (e.g. LCC).

- When a comfort or health issue is defined by several sub-indicators or parameters, it is often difficult to calculate a single indicator for this issue. It can be difficult even at the premise scale and moreover at the building scale.
- When some indicators or sub-indicators are not applicable within an issue (i.e. not relevant for the case under study), it is necessary to have rules in order to redistribute useless weighting factors to the other items.
- The multi-assessment of the same ecological effects has to be avoided; but it is important to distinguish between double-counting and the fact that an aspect (e.g. use of fossil energy resources) may have several and distinct environmental impacts (global warming, acidification, depletion of non-renewable energy resources).
- The weighted-sum method may be used, but together with rules that limit the “compensation” effect between good performances and bad ones.
- It is difficult to mix a determinist assessment with a probabilist one (e.g. risk assessment) with regard to the same topic or between different topics.
- The establishment of rules that clearly define weighting factors based on rational and transparent arguments is important.
- It is useful and certainly preferable to keep separated environmental, social and economic performance; this allows dialog between interested parties and expression of political views, resulting in concerted trade-offs and decision-making.
- An interesting approach could be having an expert weighting for the low levels, and then a political weighting for the top levels (see BNB/DGNB method).
- In order to allow appropriate interpretation and decision-making, and to respond to all stakeholders’ needs, aggregated results must not prevent access to intermediate and detailed results.

2.4 Stakeholder needs

Stakeholder needs with regard to SB assessment systems were studied with the help of surveys and interviews. In the beginning, a list of relevant stakeholders for the sustainability assessment methods was developed (Table 3).

Table 3. The main stakeholders for sustainability assessment methods of buildings.

	Role			
Stakeholder group	Order assess-ments	Provide information for assessment	Elaboration of assessment	Use assessment results
Architects and designers	(■)	■	(■)	■
Banking sector	□	□	□	□
Certification entities	□	□	■	□
Community representatives	□	□	□	■
Consultants	□	(■)	■	□
Contractors	□	(■)	□	□
Estate agents	□	□	□	■
Facility managers	□	■	□	□
Funding providers	□	□	□	■
Insurers	□	□	□	(■)
Neighbors of the site	□	□	□	■
National and regional authorities	■	□	□	■
Product manufacturers	□	■	□	□
Property investors	■	■	□	■
Property valuers	□	□	□	■
Real estate developers	■	□	□	■
Researchers and academics	□	■	■	■
Users of the building	■	□	□	■

Information about the needs of the users of assessment systems was gathered through surveys carried out in 2010. Paper surveys were distributed during two sustainable building conferences: Central Europe towards Sustainable Building conference 30.6.–2.7.2010 Prague, Czech Republic, SB10 Finland: Sustainable Community 22–24.9.2010 Espoo, Finland. During those two events 450 paper survey questionnaires were distributed, from which 73 were collected back (return ratio over 16%). In addition, in the period between July and September 2010 a web survey was done. This resulted in 58 responses. At the same time interviews of local stakeholders across Europe were organized.

The major groups of respondents were researchers (49), academics (48), architects and designers (42) and users of the buildings (35). On the other hand the groups of grant providers, insurers, banking sector, planning authorities, community representatives and estate agents were minor.

The main questions that were asked were as follows:

- What kind of assessment and benchmarking tool would best support different stakeholder groups in their decision-making?
- How do they evaluate the potential of positive change due to the use of such tool?
- How can the assessment and certification of buildings increase marketing value of buildings in short term (selling price) and in long-term perspective (operational cost)?
- How can the assessment and certification of buildings increase technical quality (quality performance and durability) of buildings within entire life cycle?
- What is the maximum acceptable extra cost because of the assessment work?

Complete information about the survey and its results are available on the project website http://cic.vtt.fi/superbuildings and in D3.1.

In general, sustainability assessment is important for architects and designers, authorities and planning authorities (see Figure). However,

- Clients see the assessment most important for property owners and valuers.
- Facility managers see the assessment most important for authorities, clients, contractors, and manufacturers.
- Manufacturers see the assessment most important for professional associations, researchers, planning authorities, valuers.

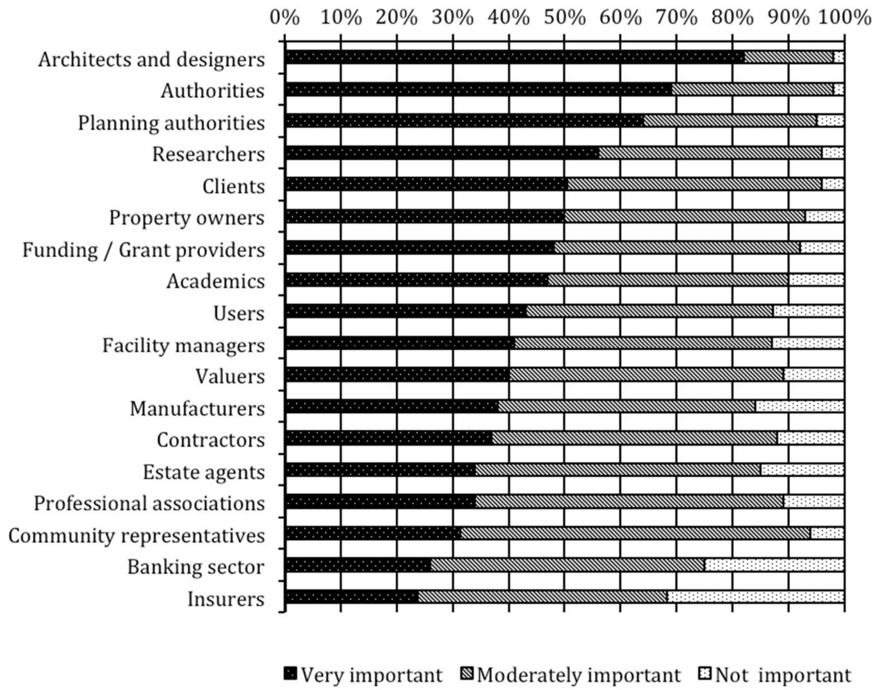

Figure 1. Importance of buildings' sustainability assessment for particular stakeholder groups.

On the basis of the survey results, the main reasons for SB assessment are as follows:

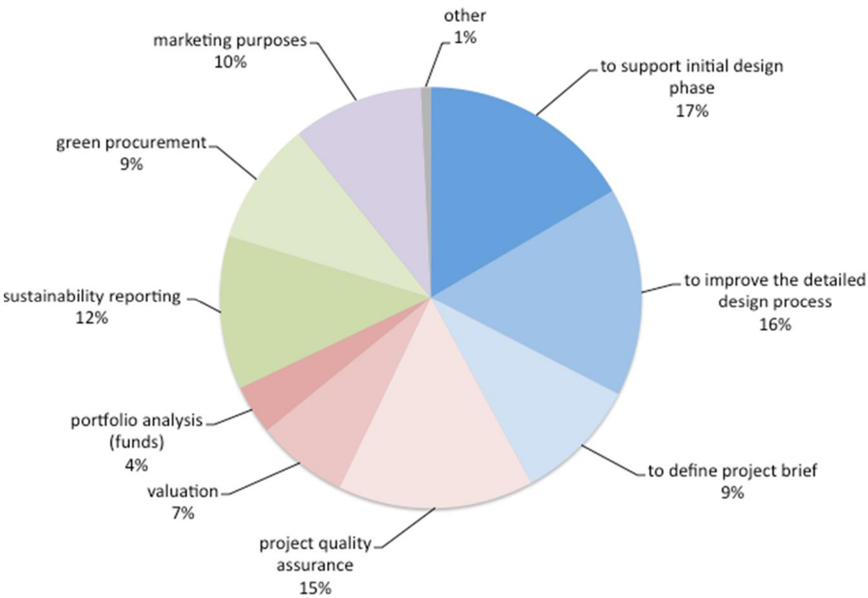

Figure 2. The main reason for SB assessment.

According to the responses the main reasons for assessments are related to the improvement of design process (support initial design phase – 17%; improve detailed design process – 16%; initial design phase is also connected to the definition of project brief – 9%).

The preferred level of the aggregation of assessment outcomes is as follows:

Table 4. Users of sustainability assessment results and preferred level of aggregation.

Stakeholder group	Main reason for assessment	Preferred aggregation level
Architects and designers	Design support	Individual criteria
Community representatives	Green procurement	Partially aggregated
Estate agents	Increase property value	Fully aggregated
Funding providers	Design features check	Fully aggregated
Insurers	Proof of building features and estimate risks	Partially or fully aggregated
Neighbors of the site	Avoid negative impacts of the building	Partially aggregated
National and regional authorities	Quality assurance and reporting	Partially aggregated
Property investors	Initial and detailed design support	Partially aggregated
Property valuers	Proof of building features	Partially aggregated
Real estate developers	Increased property value	Partially aggregated
Researchers and academics	Proof of new design concepts	Individual criteria
Users of the building	Proof of building features	Partially aggregated

It is important to note that architects & designers, and researchers & academics require very detailed sustainability assessment outputs.

Most of the respondents (47%) indicated that the knowledge that the building's sustainability has been thoroughly assessed could increase value of the building up to ten percent (up to five percent – 22% respondents; five to ten percent – 27% respondents). Respondents indicated that the energy costs of sustainable buildings are in general more than 20% lower compared to average buildings and costs of water bills of sustainable buildings are up to 10% lower compared to average buildings.

According to the results, the main purposes of SB assessments are related to the improvement of design process. Another important purpose is related to project quality and value assurance (project quality assurance – 15%; valuation – 7%; portfolio analysis – 4%).

Respondents were also asked to evaluate impact of the existing assessment systems on overall building sustainability. The results were as follows:

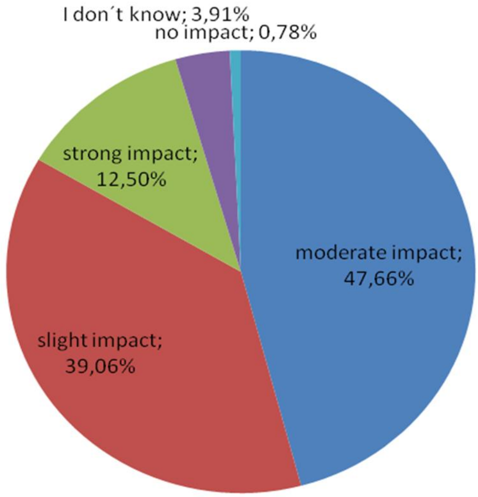

Figure 3. Assessed impact of existing assessment systems on overall building sustainability.

2.5 SuPerBuildings and other parallel projects – OPEN HOUSE

As it has already been pointed out, following a top-down approach, SuPerBuildings aims at defining a common framework for the selection, development and improvement of sustainable building indicators with a special emphasis on their validity and comparability. The underlying need for clarification and convergence at a European level in relation to the selection and use of sustainability indicators for buildings is not exclusive of SuPerBuildings project. OPEN HOUSE, another FP7 project running in parallel to SuPerBuildings, shares the same final objective even though with a different approach.

During the development of both projects, SuPerBuildings and OPEN HOUSE have exchanged information and results as well as attended each other's workshops whenever possible. What follows is a summary of OPEN HOUSE's main goals and methodology.

OPEN HOUSE

The European project OPEN HOUSE has been established under the framework of a FP7 R&D[23] programme by a European consortium of 20 partners from re-

[23] FP7 is the short name for the Seventh Framework Programme for Research and Technological Development. This is the EU's main instrument for funding research in Europe and it runs from 2007–2013.

search institutions, the building industry and the political sector (see Figure 4). Running from February 2010 to July 2013, its objective is to merge existing methodologies for sustainability assessment of buildings towards a common view. With the aim of being widely adopted in Europe, the OPEN HOUSE methodology is developed in a fully transparent, collective and open process, with extensive communication and interaction between all stakeholders.

The OPEN HOUSE methodology has been developed on the basis of current certification systems like BREEAM[24], DGNB[25] Certificate, HQE[26] or LEED[27], international initiatives like iiSBE [28] or SB Alliance [29]as well as standards from ISO TC 59/SC 17 and CEN/TC 350. It also includes outcomes from former or current EU projects, like LEnSE[30] or SuPerBuildings[31], with the adoption of a common structure for sustainability assessment of buildings.

Figure 4. OPEN HOUSE partners.

Thus, the current OPEN HOUSE methodology is composed of six categories in coherence with the European standards and recommendations from the SuPer-Buildings project (see Figure 5). The three traditional pillars of sustainability (environment, economy, society) are equally weighted.

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24 BRE Environmental Assessment Method
25 Deutsche Gesellschaft für Nachhaltiges Bauen
26 Haute Qualité Environmentale
27 Leadership in Energy and Environmental Design
28 http://iisbe.org
29 http://sballiance.org/
30 www.lensebuildings.com
31 http://www.superbuildings.eu/

Figure 5. OPEN HOUSE categories for the assessment.

Each category is composed of several indicators which are themselves described by one or more sub-indicators. The analysis of more than 60 assessment methodologies led to the identification of more than 500 indicators used worldwide. Finally, 56 sustainability indicators were selected after being grouped into the six categories and questioned on their acceptability and feasibility in different European countries.

In order to refine the methodology and identify national practices, OPEN HOUSE indicators have been tested in 68 case studies distributed in 35 European countries. To that end, OPEN HOUSE assessors were trained to use the methodology, guides and tools in workshops organised by the consortium.

The assessment process was facilitated thanks to the use of an online assessment tool specially developed to support the assessment and the review with the OPEN HOUSE methodology. Every assessor could enter and upload the necessary project data to get an automatic evaluation of the project accompanied with a standardised end report. A first version of the online tool is publicly available at: http://oh.building-21.net/.

The refinement process of the OPEN HOUSE methodology has started with the detailed analysis of the feedback from case studies and continues as an on-going process beyond the end of the project.

The European initiative lead by SuPerBuildings and OPEN HOUSE projects will give birth to a European methodology and open online platform for the sustainability assessment of buildings, providing free tools and guidelines as well as an open discussion platform.

Therefore, it will set the basis for a better communication and comparison of building performance in European countries, paving the way for more sustainable construction practices.

3. Barriers and drivers for sustainable building

3.1 Introduction

SuPerBuildings carried out a study about barriers and drivers for sustainable building (SB). The study was a review of literature mainly found in academic journals. The results were published in Häkkinen and Belloni (2011). The results are summarised here as a background.

On the basis of the study, the following outline was developed for the barriers of SB:

- Steering mechanisms
- Economics
- Client understanding
- Process
  - Procurement and tendering
  - Timing
  - Cooperation and networking
- Underpinning knowledge
  - Knowledge and common language
  - Availability of methods and tools
  - Innovation.

3.2 Steering mechanisms

Different kinds of instruments are used for steering. These include normative regulatory instruments such as building codes, informative regulatory instruments such as mandatory labelling, economic and market based instruments such as certificate schemes, fiscal instruments and incentives such as taxation and support and voluntary action such as public leadership programmes (Köppel et al. 2007). The wrong type of steering may hinder SB; on the other hand SB can also be promoted to some extent with the help of regulations. Normative regulations may appear as an effective way to achieve results but because requires societal agreement it is a time-consuming process. The fragmentised nature of the sector and the high number of actors involved (Femenias 2005) may lead to a situation where regulations are considered as the only possible way to proceed. However, rigid normative steering mechanisms may also hinder the adoption of sustainable innovations. Regulations can be prescriptive or performance based regulations. The latter approach is often considered better because it better supports innovations, but on the other hand, defining performance is difficult (Meacham et al. 2005). Regulations can mainly be directed to new building (Köppel and Ürge-Vorsatz 2007) and to the existing building stock.

Economic incentives and fiscal methods may stimulate innovation and create demand for new solutions before those become cost-effective along with experiences (Dewick and Miozzo 2002, Pitt et al. 2009). Priemus (2005) addresses the importance of institutional barriers for SB. The inadequate ecological inducements in the taxation system and the fragmentation of responsibility in the construction and real-estate sectors are the main barriers.

Research does not typically address the lack or inadequacy of regulations as barriers for SB but a new kind of orchestrating and pioneering role of the building authorities and other public actors in the building sector is called for (Rohracher 2001). Dohrmann et al. (2009) emphasise the significance of large programmes and strategies as an instrument to promote SB. They say that especially large owners and developers and also design/build contractors should be targets for such programme planners.

Regulations can also be made in terms of required activities (such as mandatory declarations). The building industry, researchers and standardisation bodies have made large efforts to develop methods for the management of SB. It is believed that SB can be promoted if there are methods that help to set targets for SB, assess the results, and show the achievements for clients. The lack of methods is a barrier, but methods as such do not improve the sustainability of built environment. Implementation should be supported with the help of steering instruments.

3.3 Economics

One of the most commonly reported problem is that the SB improvements are hindered by a lack of effect on property prices. This is also the most common reported hinder for the energy efficient renovation of existing building stock (Tuominen et al. 2012).

The fear of higher investment costs for SB compared to traditional building, the risks of unforeseen costs and problems with financing are often addressed as barriers for SB. Adoption of SB solutions may be hindered because clients are concerned about the higher risk (Hydes and Creech, 2000; Larsson and Clark, 2000, Nelms et al. 2005) based on unfamiliar techniques, the lack of previous experience, additional testing and inspection in construction, lack of manufacturer and supplier support, and lack of performance information. Although a fear of new technologies exists due to the perception of risks as a process related hindrance, it may also reflect the actual defects in the supply of well developed and tested SB technologies. Although a number of studies show that improved energy-efficiency does not cause significant increases in investment costs, there is no unambiguous answer for the cost effects of SB. Some countries have designated credit institutions providing financing for energy efficiency investments (Tuominen et al. 2012).

Energy efficient buildings can offer major cost savings during operation (as shown for example by Häkkinen 2012. Häkkinen et al. 2012, Ala-Juusela et al. 2006). However, this may not have been adequately communicated to a wide audience. Bon and Hutchinson (2000), Hydes and Creech (2000) and Zhou and Lowe (2003) claim that the primary barriers to the implementation of SB are the misperception of incurring higher capital costs and the inadequate market value. Bordass (2000) states that life-cycle thinking is often ignored because those who pay the upfront costs do not receive the benefits or those benefits are rapidly discounted. According to Bartlett and Howard (2000) the cost consultants have been overestimating the capital costs of energy efficient measures and underestimating the potential cost savings. Higher costs may also come from the increases in the consultant's fees and indirectly from the unfamiliarity of the design team and contractors with SB methods (Hydes and Creech 2000). More recent studies by Sodagar and Fieldson (2008), Sayce et al. (2007) and Lam et al. (2009) still suggest that one obstacle for the wide uptake of SB design is the fear of additional construction cost. To overcome this barrier, financial incentives and innovative fiscal arrangements should be available so that the extra costs could be accepted with the help of financing arrangements and claimed back later through increased rents. Especially to accelerate energy efficient renovation of existing buildings new financial solutions should be developed. Rönkä and Paiho (2012) claim that the impact of current solutions on environmental and energy/efficient renovation is rather limited. Subsidies should be developed with having a longer perspective. The change of subsidies from year to year causes harm both to the development of renovation services and to the planning of renovation projects.

Casino et al. (2011) compare the effectiveness of subsidies and tax deductions to support the use of renewable energy solutions for heating and cooling. Subsidies are the most widely used instrument to employed by EU member states to encourage the adoption of specific renewable energy technologies. Subsidies are an easy method because it is based on a simple scheme. However, subsidies have the disadvantage of being closely linked to budgetary resources and therefore to budgetary constraints. Moreover, the subsidies could lead to increased equipment costs because manufacturers tend to raise prices in anticipation of the discounts granted to customers. In contrast, the use of tax deductions has the advantage of being an ex-post incentive due to investors being able to receive financial compensation after they have carried out the installation of equipment. This type of instrument is appropriate, especially in those cases where investment costs are relatively high. However, tax deductions do not lower the hurdle of the initial upfront payment and therefore do not help low-income households.

Carter (2007) addresses the economic benefits from producing SBs arising from reduced volumes of waste, being able to anticipate forthcoming legislation, access to investment capital, and improved brand and reputation.

Cole and Sterner (2000) and Sterner (2000) address the importance of life cycle costing (LCC) methods in SB projects. Reasons for insignificant use include the lack of motivation and reliable data and methodological limitations. However, the relevance of LCC for SB has also been questioned because it ignores items that have no owner, such as the natural environment (Gluch and Baumann 2004). Kohler (2008) elucidates that when cost-benefit analysis is applied to buildings the costs and benefits attach to an array of different individual owners and users, but also that buildings constitute a collective good and produce other types of social costs and benefits.

In order to be willing to invest in SBs, clients should be able to rely on the positive effect of SB on the market value and/or the use value of the building. The increase in market value may be difficult to achieve because some aspects like energy-efficiency and low environmental impacts are not directly visible. However, Waddel (2008) claims that improved energy-efficiency and corresponding lower operational costs are becoming an issue that affects the attractiveness and market value. Banks and other financial institutions increasingly rate environmental and social impacts as important. In order to support the use of sustainability aspects in marketing, labelling systems have been developed (e.g., BRE Environmental Assessment Method (BREEAM) in the UK, Leadership in Energy & Environmental Design (LEED) in the US and PromisE in Finland). According to Lockwood (2008) the shift towards "green building" took place in the USA around 2007. Since then it has been seen as an issue that affects positively the market value of properties and reduces risks.

Health and user satisfaction can be defined as some social aspects associated with SB. These have an influence on economic aspects, because they affect tenant's turnover rates, letting and selling prospects as well as the risk of losing the tenant. Hence the market for SB may increase significantly. Making sustainability considerations mandatory within lending procedures would substantially support the realization of SB (Lützkendorf and Lorenz 2005). Heerwagen (2000) says that SBs are relevant to business interests because of portfolio issues and the improved quality of workspace. The high performance of SBs may influence the outcomes of organisations (such as workforce attraction, work output, and customer relationships); hence SB can provide benefits in terms of reduced costs and added value.

Mills (2003) claims that insurers will become more interested in energy-efficiency and renewable energy because: 1) there are different kinds of loss-prevention benefits; 2) insurers are major players in real estate markets also as commercial building owners and landlords; 3) competitive pressures continually motivate them to develop new services that differentiate firms from others. However, barriers remain for example due to the lack of quantitative documentation of benefits and uncertainties. Lorenz and Lützkendorf (2008) address the key role of property valuation processes in achieving a broader market penetration of SB.

3.4 Client understanding

The demand and the willingness of clients eventually determines the development of SB. Demand is closely related to such issues as supply, knowledge, methods, and costs and value. Few investors may have a significant desire to own SBs (Bon and Hutchinson 2000), but Bordass (2000) found that UK's pioneering SBs have often been procured by owner-occupiers, who are less constrained by market norms.

Different kinds of clients can exert different influence. Governmental and local authority organisations that own and develop public buildings may affect significantly the development of SB, if they adopt SB methodologies and metrics. This is based on the strength of exemplary projects and the diffusion effect of cooperation. By setting sustainability targets, public building processes may initiate private construction and design companies into SB methodologies. Bossnik (2004) emphasises the importance of municipal organisations in the role of drivers of SB in situations where obvious market pull is absent. The Federal Research and Development Agenda (Anon 2008) addresses the various roles of the U.S. Federal government in ensuring the building sector's effective use of natural resources. The role is important in the R&D of new technologies; federal departments operate large building programmes and can promote the use of new technologies; professional societies and research institutions working with their federal counterparts can develop the ideas into working models; and finally public and private sector partnerships can create the products and industry alliances that will ultimately influence the marketplace.

Waddel (2008) highlights the relevance of corporate policies and market related issues. SB may become more important for companies when they have committed to corporate social responsibility and related reporting. For example retailers regard environmental responsibility as a competitive issue. Leading actors have extended the consideration of environmental aspects to life-cycle performance of retail buildings and this has affected their behaviour as users and owners of buildings.

3.5 Process

Procurement and tendering

One of the most important obstacles for successful SB is the difficulty to define measurable targets. SB projects should be able to express the targets quantitatively and address methods that enable comparisons, quality control and monitoring. Because SB is about achieving the required performance with the minimum of environmental impact and at the same time encouraging economic, social and cultural improvement at a local, regional and global level (ISO 2008) the challenge is big. According to Sodagar and Fieldson (2008) SB is hindered if there is insufficient knowledge to develop a project brief with clear targets and mitigating strategies for sustainability impacts and these targets and strategies remains as a guide for facility management, refurbishment and end of life. Adetunji et al. (2008) mention the focus on price in procurement practices and the low-risk culture as the main barriers for SB supply chain. Ang et al. (2005) also address that in a successful project all performance requirements should refer to a separate library of assessment methods. It is also necessary to integrate sustainability criteria into the assessment procedures of architectural competitions (Rohracher 2001).

Timing

Process related possible barriers for SB include the models of cooperation and networking, models of communication, roles of different actors, decision making and management processes and scheduling. The right timing and the presence of all needed actors are often addressed as key issues for the success of projects. A number of studies emphasize the importance of the availability of all needed expertise and knowledge in very early stages of projects. A big part of SB potential is lost if the possibilities and right design options are not considered early enough. This concerns not only the building projects but also the preceding planning processes (Rydin 2006). Access to basic services and the supply of sustainable energy services are examples of planning issues that have an important effect on SB. Horman et al. (2005, 2006) address early adoption of sustainable objectives, early selection of an experienced design and construction team and the avoidance of haste in order to ensure that the team members share the goal. Also Williams and Dair (2007) emphasize the importance of scheduling: SB is hindered, if designers are involved in the process too late. Riley et al. (2003) points out the role of construction organizations in SB projects. It is important for SB that construction organizations are included in the team during design because their role is essential in providing estimating services. Accurate estimation of costs in early phases of SB projects supports projects to select such solutions of SB that fit with the owner's budget.

Ang et al. (2005) emphasise the role of the project manager. This professional represents the client and organises evaluation processes. End-users' active involvement in demand specification is one of the drivers of process innovation, so the management of end-user participation is important. However, the performance-based procurement and tendering does not solve the problem of requirements that cannot be verified objectively. One major technical barrier that hinders SB is the absence of a common framework that integrates the aspects and tasks of SB with construction practices at an operational level (Matar et al. 2008).

Cooperation and networking

SB is a comprehensive solution; it requires good cooperation and effective communication between the members of the project team. SB requires close interaction of suppliers, professionals and users, because SB requires high compatibility of all domains of design, construction and user behaviour. The models of cooperation can be improved through integrated methods and information technological solutions (see below). However, SB also requires the participation of different actors in various process tasks and phases and real team working. One of the big challenges of sustainable development is that it requires innovation, new knowledge and learning within organisations (Rydin 2006). Mills and Glass (2009) suggest that the necessary skills for managing/leading the design of a SB include awareness, communication, comprehension, experience, lateral thinking, leadership, negotiation, passion and technical knowledge.

Horman et al. (2006) address the importance of cooperation in SB projects and suggest the use of Design-Build-Operate-Maintain (a delivery method that integrates the designers, contractors and operation and the maintenance managers under one contract to the owner). Deane (2008) states that the preferred design model for delivering a SB is an integrated design process, which includes all involved parties (the owner, the developer, the designers, the builder, the tenant and the facility operator) from the beginning. SB projects require intense interdisciplinary collaboration, highly complex design analysis, and careful material and system selection already in early phases of the project delivery process. Ballard and Kim (2007) point out that the power to implement the project roadmap is distributed roughly in the following order: owner, owner agent, process manager (design and construction), specialist (design and construction), and supplier. Everybody can act but within the limits of their own power to create more value and less waste. The present construction sector is characterised by a complex supply chain, the various players of which may have competing interests. This hinders the consideration of sustainability requirements. The public sector could have a remarkable role in initiating the transformation of the supply chain towards better cooperation and joint goals (Anon 2007).

The role of design is essential in interpreting and solving these complicated multilevel requirements. Rekola et al. (2011) analysed current design management practices in Finnish construction projects. They found that the role is defined and practiced mostly as a technical supervisor. The general shared definition of a more fundamental meaning of the role is shallow. The means and mechanisms of performing the task, however, rely on social interaction, influencing and leadership. A lot more power and effect could be got out of design management if these would be consciously involved. SB does not necessarily create more tasks but it affects several existing tasks by bringing new substance to be considered in the design decisions. The key impact that the chief designer can make is created through successful leadership of human creative competence.

3.6 Underpinning knowledge

Knowledge and common language

The wide content of SB makes it difficult to assess the profitability or cost impacts of SB. The plurality of the meanings of green building and SB can result in widely differing problem formulations and contradictory solutions (Stenberg 2006). This hinders cooperation, which in turn hinders the creation of innovative solutions.

Rydin et al. (2006) claim that while designers demonstrate confidence in their ability to access and use knowledge in general, this confidence falls when SB is addressed. Mills and Glass (2009) assessed the ability of construction design managers to integrate sustainability into building design; it requires that the sustainability issues are clearly communicated in a project's brief.

Sodagar and Fieldson (2008) point out that in order to design a truly SB, the design team need to have an access to best available information on products and tools. This data should be transferred and used in calculations. This can only be achieved by the construction industry working together towards a common goal.

SB knowledge should also be available as specialized service packages, as many companies are too small to stay competent in the whole range of issues involved (Rohracher 2001). Especially in the residential sector the lack of information is a problem for energy-efficient building (Ala-Juusela et al. 2006, Tuominen et al. 2012, Williams and Dair 2007). The normal house builder who makes the decisions about energy systems has often very little knowledge about energy-efficiency.

Bosch and Pearce (2003) have analysed the contents of documents which give guidance for sustainability in public facilities. While good quality is available for designers and owners, significantly less information is targeted at facility managers. There are protocols for building diagnostics and for performing post-occupancy evaluations but much less attention has been paid for monitoring issues, education, commissioning, and proactive maintenance. Similar operational gaps occur in the residential sector, where occupants are not informed how to operate their building (Stevenson and Rijal 2010). Although the lack of common language has been addressed as a barrier to SB, this problem may significantly diminish as the standardisation proceeds. The completion of the CEN standards worked out by CEN TC 350 – Sustainability of construction works will probably improve the situation at least in Europe.

Availability of methods and tools

The efficient use of all necessary information and the effective cooperation of all actors call for methods that enable the management and sharing of information. One of the key issues in making construction projects more sustainable is overcoming the obstacles of capturing and managing the knowledge needed by project teams to affect such change (Shelbourn et al. 2006). According to Kohler and Lützkendorf (2002) the crucial issues for design tools include their scope, the number of performance aspects simultaneously addressed and the degree of integration with the usual design environment (e.g. through sharing data with other design tools). Building performance assessment practices also lack continuity throughout the building life cycle (Sullivan et al. 2004).

The design phase lacks powerful methods (Jonge 2005, Erbasea and van Djika 2012). The existing SB rating methods provide SB indicators for designers. Life cycle assessment tools, energy consumption estimation methods and service-life prediction methods are also available, but all these methods entail significant amounts of extra work. The problem is not only about the access to data but also the availability of automatic calculation procedures (Tucker et al. 2003). Design for SBs needs integrated methods that provide the process with product information and enable the comparison of design options easily or with reasonable extra work also in early stages of design. There is also a need for decision support tools that integrate energy simulation into early design of zero energy buildings in the architectural practice (Attia et al. 2012). Building information models (BIM) will probably partly solve these problems as addressed by Kiviniemi (2010) and Häkkinen and Kiviniemi (2008). At present, the assessment process is usually carried out when the design of the project is almost finalized. Environmental matters need to be considered in an early stage of design, because alterations to the brief may be expensive. According to Ding (2008) the assessment tools should also be reconfigured so that they do not rely on detailed design information before that has been generated by the designer. Environmental and financial issues also need concurrent consideration as parts of the evaluation framework. Sustainability should be pursued through integrated approach which is able to recognise the sustainability aspects in all selections (Sodagar and Fieldson 2008). According to Häkkinen et al. (2007), an industrialised building process is characterised with two main elements: a building concept-based approach and efficient information management. A building concept-based approach enables:

- the product development of the end product
- repetition of the basic elements of the building from one project to others
- customisation of the end-product.

Information management enables the consideration of wide spectrum of aspects including building performance, environmental aspects, life cycle costs and service life, and rapid adapting of the design to the specific requirements of the case. The lack of these elements hinders SB.

Effective tools are needed not only in the stages of design and building but also in the operational stages of buildings and other construction assets. Tools are needed that support understanding about the value, risks, remaining service life, needed maintenance and optimal scheduling of life cycle operations of buildings (Lützkendorf and Lorenz 2007).

Innovation

Sustainable development requires changes compared to the current situation. Foxon et al. (2004) have criticized the lack of connection between the innovation policy and sustainability policy in the UK and recognised that change is happening due to greater understanding of innovation processes and their importance for sustainability. Zhou & Lowe (2003) point out that the UK government's policies encourage the construction industry to move from traditional construction methods towards sustainable methods. A number of guidance and incentive mechanisms exist to encourage the take up of more sustainable solutions. SB has also been improved through innovative research. Bossnik (2004) emphasises the importance of municipal organisations in the role of clients as drivers of innovations for SB.

Users' role is important in the innovation process of SB (Rohracher 2001). One of the key issues is to establish platforms between designers and user groups such as consumer associations. Broadening the design process in such a way improves the possibilities to design widely-accepted products which are better adapted to the needs of customers. There is also a need for processes where new products can be used within a limited scope to learn about how those products are used. SB innovations also need certain freedom. Performance-based specifications – in contrast to prescriptive, solution-based specifications – have proven to be good in attracting high-performance designers and in inspiring innovation in design and building technology though at the same time improved quality management may be needed (Ang et al. 2005, Meacham 2010).

The transition to sustainability needs to be managed. Halme et al. (2005) have studied drivers for energy-efficient housing. They state that there is not a single barrier that keeps energy-efficient housing from taking-off but a whole range of issues has to be considered. The commercialisation of energy efficient single-family houses is as problematic as the commercialisation of any environmentally sustainable product, because it conflicts with the current industry structures, organisations and institutions and with the general behaviour of different actors. Special measures are needed to promote commercialisation.

4. Top-down approach

Part of the aim of the SuPerBuildings project is the development and establishment of principles for the design of new systems or further development of existing systems for describing, measuring and reporting the sustainability of buildings and facilities. These principles may be applicable both during the planning stage of new buildings or at the time of delivery for demonstrating the quality of a property to third parties as well as in the evaluation and upgrading of existing buildings. In any case, it should be ensured that all aspects of sustainability and sustainable development are taken into account. For this reason, a systematic approach is needed that results among others in an appropriate structure of assessment systems.

The reason for dealing with this issue is the fact that although numerous sustainability rating systems already exist in EU, many countries face the question of whether and how to develop and apply a customized assessment system that suit the regional characteristics.

From the beginning, the working team of SuPerBuildings agreed not to add another sustainability system to the numerous existing ones. Instead, the principles for the design and development of assessment systems should be worked out, discussed and made publicly available. However, it is assumed that a number of rating systems are confronted with the tasks of revision and further development. This should be supported by SuPerBuildings project. As a result of SuPerBuildings, a contribution to the content-related approach of existing systems is achieved, while at the same time their independence and identity is preserved.

As the sustainability of buildings should always be assessed with the help of indicators, one of the key objectives of SuPerBuildings is to ensure “validity” for sustainability indicator systems. This determines the true possibility of an indicator system to give information about the sustainability of buildings. So, validity is given to the proposed system by following a top-down approach starting from the subjects of concern and from there leading in a logical way to indicators, while considering also the relevance/significance of each indicator for the building sector. Of course, the fact that indicators must reflect a practical assessment of building characteristics and should be able to influence the different actors is not neglected.

To address all the requirements of the task as described above the following analysis was chosen:

a) Clarification of the tasks covered
b) Analysis of the current situation
c) Development of recommendations

Below is presented a summary to the listed points.

a) Clarification of the tasks covered
An exact description of tasks needed to be covered with formulation of boundaries and starting points is a prerequisite for the achievement of goals. As part of the task of developing principles and recommendations for the design and further development of assessment systems for describing, measuring and reporting the sustainability of buildings and in conjunction with the overall context of the SuPer-Buildings project the following objectives are pursued:

- To ensure a general application in the European Union environment
- To include the up to date state of international and European standardization projects
- To ensure the involvement of all aspects of sustainability in the full breadth of the work
- To develop a basis for the design and application of appropriate assessment criteria
- To develop a basis for the identification and classification of appropriate indicators
- To consider the information needs of relevant stakeholder groups.

The description of the tasks has an impact on the actual analysis.

b) Analysis of the current situation
First, it should be stated that the current state of design, further development and application of sustainability rating systems shows a high dynamic range. Super-Buildings had on the one hand to identify and include the occurring developments and changes while on the other hand to be able to actively shape this process by publishing interim results.

It was analyzed:

- The framework in the EU
- The state of standardization
- The state of the sustainability assessment systems currently used or developed
- The state of existing methodologies and approaches
- The state of demand for assessment results by stakeholders.

In the European Union the area of "sustainable construction" is one of the six key market areas. This underlines the importance of the topic. The current construction product regulation extends the requirements for construction works to the aspect of sustainable use of resources. The individual EU states are called upon to integrate beyond the topic of energy efficiency also the other aspects of sustainability into their procurement processes and to play an exemplary role in achieving this. A prerequisite for this among others is the availability of suitable principles related to the describability and measurability of the sustainability of buildings. This demand has led also to efforts in the field of standardization.

The results of the international and in particular the European standardization activities have led in recent years to the development of a unified understanding of sustainability in construction. Significant contributions were provided among others by the ISO TC 59 SC 17 and CEN TC 350 projects. Now with the ISO 15392:2008 and EN 15643-1:2010 the appropriate principles exist. It is a fact that a sustainability assessment of buildings and facilities always requires the simultaneous examination of the environmental, economic and social dimensions of sustainability. A focus on one or two aspects is not acceptable. The standards give a comparable importance to the 3 dimensions of sustainability and emphasize the interrelationships and interactions between these aspects. Over the last years, contributions to the development of assessment criteria as well as to the clarification of the basic principles and rules for their calculation and assessment have been provided. The standards, however, do not set rules for the development and interpretation of benchmarks.

In the analysis of existing assessment systems (see also the results of deliverable 2.1) it became clear that a large part of these has its origin in the description and evaluation of energy efficiency and the environmental- and health-related impacts of buildings. Thus, they mostly stand in the tradition of green building. Indicator systems are often used that have been developed from the compilation of existing indicators. These are partially qualitative and describe the presence or quality of specific building components (green roofs, rainwater harvesting, etc.). In addition, the simultaneous use of object-and process-oriented criteria takes place (energy consumption of the building and the presence of a monitoring plan). They are known in the chronological order of systems as the first generation sustainability assessment systems. With respect to their starting point, in the SuPerBuildings project when dealing with existing indicators the term “bottom-up approach” is introduced. It can be noted that these systems do no longer correspond to the current state of discussion and standardization and therefore these must be revised and significantly supplemented. It is further clear that a comprehensive discussion of the topic of sustainability in the construction sector cannot be guaranteed just only by evaluating previously existing rating systems (a very common practice).

In the past, the assessment partly relied on qualitative criteria. However, this situation has changed. Both the standards and the practice have driven to the development and application of a methodological basis for quantitative assessment. So today, the assessment of the environmental performance can be supported by the results of a life cycle assessment (LCA) and the assessment of economic performance by the results of a life cycle cost calculation. Today, through EPD's a substantial data basis for the environmental evaluation of buildings is available.

Originally sustainability rating systems were developed and applied with the aim to indicate the sustainability of a building to third parties. The focus was on the marketing aspect as well as for the public sector on giving the right example. Meanwhile, a lot more actors used such systems for different purposes. These systems become responsible for the formulation of objectives during the planning phase as well as for the comparison of variant design solutions. These become also a tool for a sustainable procurement and source of information for valuation experts. The systematic processing and documentation of building information becomes an essential side effect. This sets new and additional requirements for the structure of the systems and the way of processing and presenting the results – specific to individual target groups and users. This was confirmed by a relevant part of the project (see results of deliverable D3.1).

Meanwhile, even clients proceed to formulate requirements for the economic, environmental and social performance of buildings. No longer is the main interest for them the demand for such Eco-components (e.g. green roofs) but the performance-oriented portfolios.

The results of the above described analysis that actively incorporates the results of further subparts of SuPerBuildings project were the basis for the development of proposals to support a systematic approach to the design and development of sustainability assessment systems for buildings.

c) Development of recommendations

Recommendations will be developed and presented in relation to:

- the basic approach and the starting points
- the object of assessment and the reference study period
- the basic structure
- the selected issues
- the various forms of presentation of the results

In the project as a starting point was and is also considered the formulated sustainability understanding from the international and European standardization. This requires that environmental, economic and social aspects must be taken into account during the evaluation of the sustainability of buildings. The standards represent a basis for the transfer of the general principles and management rules of the sustainability to the construction sector. In the context of this transfer an addition of the functional and technical performance was judged to be important, as the fulfilment of the user requirements is not possible to be proved without these two aspects. Therefore, the fulfilment of the technical and functional requirements is a prerequisite for the sustainability of buildings. Sustainable development presupposes the active acting of stakeholders and the consideration of all the consequences of their decisions leading to the inclusion of all dimensions of sustainability into their decisions. The starting point is individual, institutional and/or social moral values that can be expressed in "subjects of concern" (sometimes referred to as "areas of protection") and "goals" to protect these values. All these points here form the starting point.

In the project the systems that among other things deal with all aspects of sustainability and follow a prevailing quantitative evaluation approach are called second generation sustainability assessment systems. Also for systems that derive their structure and assessment criteria from the "subjects of concern" and "protection goals" the term "top own approach" is introduced.

The concept of the "areas of protection" comes from the environmental discussion and needs here to be expanded. Values worthy of protection are – in the interest of humanity – environmental, economic and social aspects. On the one hand it is about the preservation of the environmental, economic as well as social resources and on the other hand about the preservation of the environmental, economic and social balance – here also in terms of the preservation of the capacity to act of todays and future generations. From these "areas of protection" that can be assigned to the environmental, economic and social dimensions of sustainability in each case, are derived goals to help protect these values. Accordingly the goals of the conservation of natural resources and the preservation of the ecosystem, the preservation of social and cultural values as well as the health, comfort and security, the optimization of the life cycle costs as well as the preservation of the economic value exist during the planning, construction, use and management of buildings.

From this a general structure for sustainability assessment systems of buildings can be developed according to the top down approaches. The consideration of environmental, economic and social aspects is suggested, which must be supplemented by the proof that the technical and functional requirements are also fulfilled. This also agrees with the current state of the European standardization. Since functional and social aspects are usually very difficult to be distinguished, these also can be treated together in the same group.

The achievement of these goals must be for each actively engaged and/or responsible actor verifiable and in this sense also recordable and measureable. Therefore, assessment criteria and benchmarks are needed. In this respect, the assessment criteria are referred to the subjects of concern that are again arranged according to the sustainability dimensions. The assessment criteria have to be mainly quantitative and follow a performance oriented approach. It is important that some features and characteristics of the buildings can have an impact on more than one criterion (i.e. the energy quality of the building envelope on the durability (technical), on the energy consumption and CO_2 emissions (environmental), on the life cycle costs and value (economic) as well as on the thermal comfort (social)). The assessment criteria can have in turn an impact on more than one dimension of sustainability – where applicable in form of consequences. For example the climate change has an influence not only on the environment but also as a result on the society and economy. This is not a double counting but an acknowledgement and assessment of multi-effects. Further investigations related to the consequences of this subject are required.

Assessment criteria can be grouped into criteria groups. Possible weighting inside the criteria group should be a result of scientific considerations, while a weighting of the criteria groups among themselves is usually a convention.

Depending on the object of assessment, planning phase or point in time of the evaluation specific indicators (e.g. the calculated energy demand in the planning phase and/or the measured energy consumption in the utilization phase) can be assigned to the criteria. To the indicators apart from concrete calculation and evaluation rules also benchmarks must be assigned (see results of deliverable D5.2).

As the name suggests, the SuPerBuildings project as a whole concentrates on the building as object of assessment. This contains all parts of a building including foundations as well as the site on which the building stands and all landscaping on the site. Site and building are therefore seen as one unit.

This can be supplemented by assessing a separate module designed for the location to reflect the different levels of influence on the surrounding area. Reference study period is – if not defined differently, the assumed design life.

Finally, the evaluation results must be documented and presented in such a way that they correspond to the respective needs for information of the stakeholders. The following aggregation levels are suggested:

- Raw building data (unweighted) behind the assessment per indicator
- Aggregated into an assessment result at indicator level (the score achieved for this indicator)
- Aggregated at indicator group level, with information of the weighting factors used (the score or the percentage fulfilled across a group of indicators)
- Aggregated at main group level (the score for each of the main categories: environmental, social, economic, technical and location)
- Aggregated into one main result.

The second generation sustainability assessment systems will have to follow this top down approach, in order to fulfil all requirements. Therefore, the description of this approach is a central partial result of SuPerBuildings project and the basis for the handling of the following sub-topics.

5. Description and explanation of the selected indicators and related measurement and assessment methods with special focus on reliability, comparability and compatibility

5.1 Introduction

The objectives of the work were as follows:

- to select / develop key sustainability indicators
- to consider a building life cycle approach and performance-oriented results
- to address also qualitative indicators and ensure reliability of assessment;
- to focus on the significant improvement of the validity of the sustainability assessment results
- to produce a detailed documentation for compatibility of data definitions in EU member countries, in order to improve comparability of results
- to explain calculation / measurement methods for each indicator, for the pre-design, design and operation phases.

The focus was directed work not only on quantitative indicators but also on qualitative indicators. The topics Land use, Architectural quality, and Cultural heritage were paid attention to.

5.2 Methodology for selection / development of indicators

The focus of the work was on the following issues: validity, reliability, comparability, assessment method in design and operation, quantitative and qualitative methods, applicability.

The general subjects of concern identified in SuPerBuildings are as follows:

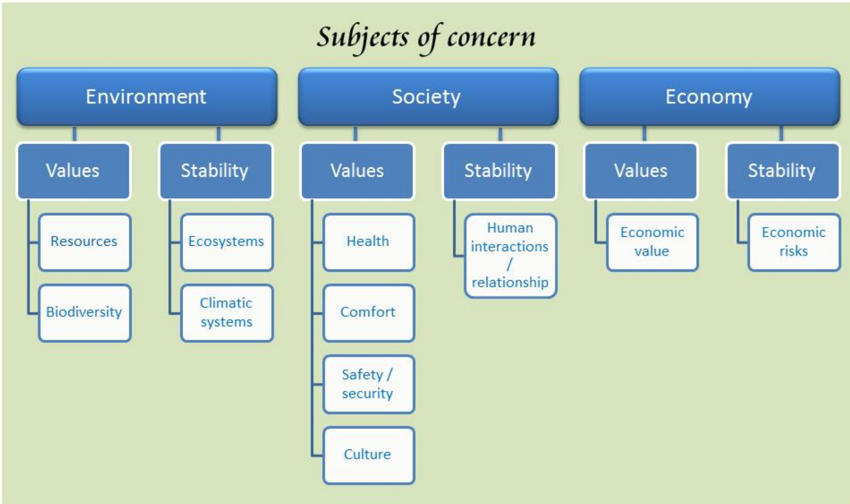

Figure 6. Subjects of concern.

This work used the following ideal framework for the assessment systems:

– Areas of protection (issues of concern) define those issues that a) are important for sustainable development and b) are relevant for building sector because buildings have an essential impact on these areas of protection.
– Sustainability aspects of performance of buildings define those aspects of buildings that have impacts on these areas of protection.
– Sustainability indicators together with measurement methods enable the quantitative and/or qualitative assessment and comparison of these aspects of performance.
– Benchmarks provide information about the typical levels of results of measurement for buildings with regard to different indicators (see WP5 work).

Once the key issues are identified, it is necessary to determine adequate indicators. Considering existing assessment methods for sustainable buildings, other EU projects (recent or on-going), and also standardization or harmonization works, indicators may be selected or improved or developed.

More explicitly, 3 situations have been identified, leading to 3 types of indicators :

– the indicator already exists in one or several methods, is well documented, has got consensus, meets all the other requirements: selection (= type I)

- the indicator is not totally mature, not well documented, or needs some clarification, harmonisation, extension to the entire life cycle of the building, or a certain level of improvement: improvement (= type II)
- the indicator does not exist, is not mature, or is not satisfactory: needs a development (= type III).

This is illustrated in the Figure 7 below, in connection with the other WPs.

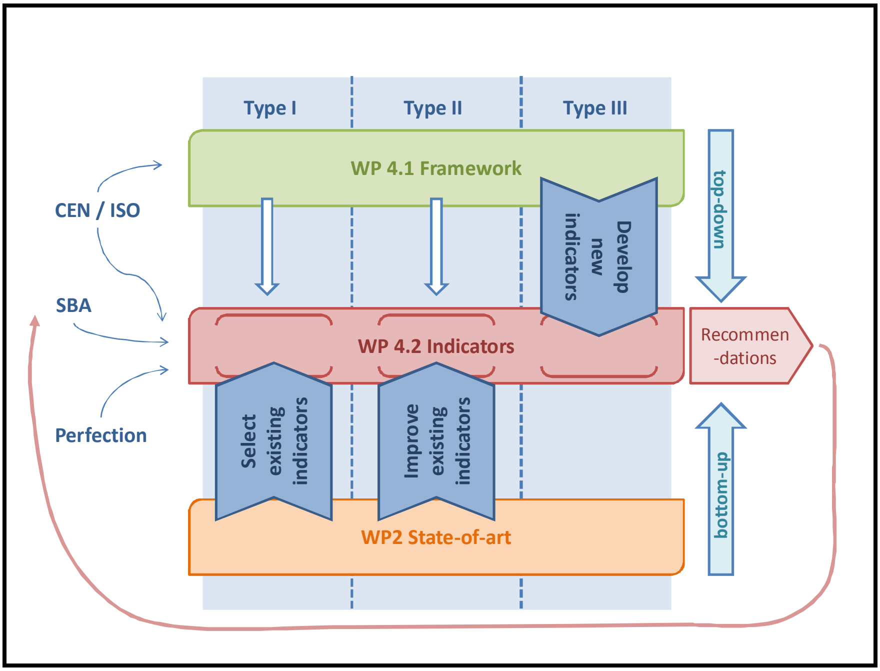

Figure 7. schematic description of the 3 types of indicator elaboration.

The work focused on the development of the validity of indicators and the data reliability for each key indicator. The objective was to develop and select appropriate measurement methods for each key indicator in order to enable the reliable assessment of performance levels. In order to achieve good data validity and reliability, the measurement methods have been developed and described in detail. This required that the project developed a deep understanding about the effect of different factors on the final assessment results. The project adopted the indicators and measurement methods for which there is a good common understanding and developed solutions for those indicators and measurement methods for which there was lack of knowledge and common understanding.

It contains the following sections:

- Indicator definition
- Validity (with explanation and justification)
- Object of assessment
- Characterization
- Assessment in design and operation
- Comparability
- Sources of information.

5.3 Description of the selected indicators and related assessment methods

The following Table 5 shows indicators that have been selected, improved or developed, and documented. Most of them are considered as ”core” or ”key” indicators, meaning their importance in terms of issue relevance and significance. Others are qualified of ”additional” because they deal with less common issues, use less mature assessment methods, and their relevance and significance has to be established case by case.

Table 5. Developed and documented indicators.

SD pillar	Subject of concern	Issue	Indicator	Core indic./ Additional
Environment	Resources	Depletion of non-renewable energy resources	Consumption of non-renewable primary energy	Core
		Non-renewable and scarce material resources	-	
		Sustainable management of renewable resources	-	
		Rational use of water	Embodied water use Operational water use Wastewater production	Core
		Land use / Change of land use	Soil sealing Change of land use	Core / Additional
	Biodiversity	Loss of biodiversity Preservation / improvement / restoration of local biodiversity	-	

SD pillar	Subject of concern	Issue	Indicator	Core indic./ Additional
	Ecosystems	Protection of atmosphere and climate (GHG)	Global warming potential	Core
		Protection of atmosphere (other pollutants)	-	
		Protection of water and soil quality (pollution and waste)	Construction and demolition waste generation - Non-hazardous waste to disposal - Hazardous waste to disposal - Nuclear waste to disposal	Core
			Water pollution due to material leaching	Additional
	Climatic systems	Climatic systems (risk of extreme climatic events) Adaptation to climate change	-	
	Transversal	Eco-mobility	Eco-mobility potential of a building in its context	Additional
Society	Health	Indoor air quality	Concentration of various pollutants	Core
	Comfort	Thermal comfort	PMV (Predicted Mean Vote) PPD (Predicted Percentage Dissatisfied) Operative temperature Air temperature Relative Humidity Air velocity	Core
		Visual comfort	Illuminance Daylight factor	Core
		Acoustic comfort	-	
	Safety / security		-	
	Human interactions / relationship		-	

SD pillar	Subject of concern	Issue	Indicator	Core indic./ Additional
	Culture	Architectural quality	Aesthetic quality	Additional
		Cultural heritage	Monument or monumental value / Historical value	Additional
Economy	Economic value	Economic value of 'goods' on the long term	Life cycle costs - Capital cost - Costs in the operational phase	Core
	Economic risks	Prosperity versus risks	Long term stability of value	Core
All	Process quality	Optimisation of the planning process	Integrated design in the planning process	Core

5.3.1 Environment – Resources

The indicators presented in this chapter relate to the following issues:

- Depletion of non-renewable energy resources
  - Consumption of non-renewable primary energy
  - Rational use of water
  - Embodied water use
  - Operational water use
  - Wastewater production
- Land use
  - Soil sealing
  - Change of land use.

5.3.1.1 Depletion of non-renewable energy resources

In EU-27 (the 27 countries of the European Union), Building sector, assimilated here to Households and Services, consume 36% of final energy (respectively 25% and 11%), which is more than the Industry sector (28%) and the Road Transport (27%)[32] .

Energy may come from non-renewable or renewable resources, but comes in majority from fossil and nuclear fuels, that are non-renewable. Considering the rate of exploitation of fossil fuels, the known reserves, and the growth of emerging

[32] Europe in figures – Eurostat yearbook 2010, Final Energy consumption (2007).

countries and of the population in general, there is an obvious threat of depletion of non-renewable energy resources, and this will happen in the relatively short term, that is several dozens of years (excepted for coal).

Europe is strongly engaged in improving energy efficiency, developing renewable energy and reducing GHG emissions, through the so-called “3 x 20 package”, which is very ambitious regarding the small remaining years before 2020. The EU Member States have committed themselves to reducing greenhouse gas emissions (GHG) by 20%, increasing the share of renewables in the EU's energy mix to 20%, and achieving the 20% energy efficiency target by 2020. As a matter of fact, the EU is currently on track to meet the first and the second targets, but will not meet its energy efficiency target unless further efforts are made. It is estimated that, with current policies, only half of the 20% energy efficiency target would be met by 2020[33] .

The building sector needs to progress, through the implementation of the new Energy Performance in Buildings Directive 2010/31/EU (EPBD recast, May 2010) and a strong effort on the energy renovation of the existing building stock.

There are also economic issues related to energy, due to the increasing price of fossil fuels and electricity, and to the location of energy sources, mainly outside Europe. An interesting factor is the Import dependency (EEA 2008), reaching 54% on average for EU-27. This energy dependency has consequences on national commercial balance and public debt, the latter to be supported by the future generations.

The economy of individual households (families), especially the more fragile, is also concerned with energy aspects. Considering the increasing prices of oil, gas, electricity, and the general socio-economic difficulties, this situation often leads to “fuel poverty” and social inequity. The quality of life, comfort and health are impacted when people live in bad quality buildings and can’t pay their energy bills.

In conclusion, non-renewable energy is the ”focal point” of many impacts, not only environmental but also economic and social.

Indicator
Name – Definition / description
Consumption of non-renewable primary energy Sum of amounts of non-renewable energies used all along the life cycle of the building, expressed in primary energy. This is a quantitative indicator. Fossil and nuclear fuels are mainly concerned, including electricity based on these fuels. Primary energy means energy which has not undergone any conversion or transformation process.

[33] Source: COM(2011) 112 final “A Roadmap for moving to a competitive low carbon economy in 2050”, Communication from the European Commission, Brussels, 8.3.2011.

Definition / description of sub-indicators

For transparency and decision-aid purposes, it is useful to be able to distinguish the calculation/measure of :

- Embodied energy in the life cycle of construction products (production, construction, use, end-of-life), taking into account the replacement of certain products during the service life of the building
- Energy consumed during the operation phase due to the building itself (building-related energy uses, with separation of EPBD uses and others (e.g. energy use of lifts, water pump for rain water use,...), see EN 15978)
- Energy consumed during the operation phase due to activity-related equipment (non building-related, optional in design phase, e.g. washing machines, cooking,..)
- Energy linked to transportation of persons due to the location / urban context of the building (optional)
- Energy embodied in water-related services during the operation phase (provision of drinkable water, treatment of waste water), distinguishing building-related and non building-related water uses (optional)

All these amounts of energy have to be converted into primary energy, whatever the source of energy may be, and expressed for one year (for embodied energy it is necessary to divide the total embodied energy by the service life of the building).

Considering the efforts made and to be made on the reduction of energy consumed during the operation phase, embodied energy in construction products is not negligible, as well as energy due to activity-related equipment.

Units

kWh_{pe} / m^2 . year or MJ_{pe} / m^2 . year

pe stands for primary energy

m^2 : net floor area (but this definition varies according to the countries)

Energy is based on the net calorific value

Principles of classification

Classes may be defined, linked to the national context (climate, policy objectives) and type of building. Confusion must be avoided with energy labels existing for operational energy.

Weighting and aggregation

As this indicator is a quantitative sum of kWh, no weighting or aggregation is necessary.

If the intention is to go further and express an indicator in terms of depletion of non-renewable resources, some conversion or weighting factors have to be used in order to be able to sum results from different energy sources.

Validity

Issue of concern	Directly: Resources Indirectly: Economic prosperity/risks, Social equity (cf. fuel poverty), Climate change (due to related GHG emissions)

Explanation

The depletion of non-renewable energy resources is relatively correctly represented by the amount of kWh described above. But it would be more precise and relevant to consider real depletion potential of each energy source and to weigh with the help of a depletion factor, taking into account the availability period (i.e. the number of years during which the energy resource will be available).

Justification			
Building sector consumes a lot of non-renewable energy, both in residential and non-residential buildings, around 40% of the total energy consumption in Europe. Especially existing and old buildings need to improve their energy efficiency. Considering the increasing prices or oil, gas, etc., the consumption of such energy costs more and more to the building owners and/or occupants, and may imply "fuel poverty". Because fossil and nuclear fuels are generally imported (from outside Europe), energy dependency is high, so energy consumption often causes problems of economic / commercial balance at the national level. In addition, there are some geo-political risks. Europe is strongly engaged in improving energy efficiency, developing renewable energy, reducing GHG emissions, and is also very concerned by public debts. The new Energy Performance in Buildings Directive 2010/31/EU (EPBD recast, may 2010) states that: *"Article 9 – Nearly zero-energy buildings – 1. Member States shall ensure that: (a) by 31 December 2020, all new buildings are nearly zero-energy buildings; and (b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings."* As fossil fuels have a high CO_2 content, energy efficiency and reduction of use of this kind of energy is a strong means to reach "factor 4" target for GHG and then limit climate change to an acceptable magnitude.			
Object of assessment			
Building		X	Many building characteristics (life-cycle of products, envelope and bioclimatic design, HVAC systems and their control, occupant needs and behaviour) have an impact on the consumption of non-renewable energy.
Site		(x)	If renewable energy is available on-site or nearby, it may decrease or compensate the amount of non-renewable energy. There is also energy embodied in products used for outdoor spaces as green spaces, access lanes, car park spaces, on-site networks, etc.
Location		(x)	Climate data influence a lot the energy consumption. The urban context and the availability of low-energy transport infrastructure is important regarding the calculation of transportation-related energy (optional).
Other (specify)			

Characterisation	
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))	X
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	

Status of the indicator		
This indicator is considered in many building environmental assessment methods, and described in several standards. It is also one of the seven core indicators defined by SB Alliance in 2009. Assumptions and conventions may vary. The main European standards are: – EN 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method – EN 15804:2012 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products – EU standards for the calculation of primary energy consumed by buildings during operation		
Assessment		
Design phase	Calculation / assessment method	Quantity surveying and EPDs of construction products Forecasted / conventional calculation of energy consumption during operation, due to the building itself (national regulation methods or dynamic simulations) and EPD of energy consumption. Calculation of other energy consumption due to activities carried out in the building (optional) Forecasted / conventional calculation of water consumption during operation, and related embodied energy (via EPD)
	Data needed and data availability	Quantities of construction products LCI/LCA data on construction products, at least LC energy flows, including the service life of each product, and necessary replacements → It is important to cover a large proportion of construction products in order to get significant results Service life of the building Building characteristics influencing energy consumption in operation Primary energy of energy fuels or carriers, included urban networks, idem for electricity Assumptions on occupancy and behaviour Consumption and scenarios of use of activity-related equipment (optional) Transportation assumptions / patterns of use (optional) Primary energy related to local transportation modes and personal cars (optional)
	Applicability	Need database with embodied energy of construction products, based on LCA, and related tool in order to facilitate calculation. Limits come from the lack of available EPDs of construction products and related databases. EPDs on technical equipment (heating, etc.) are often lacking. At early design stage, it is recommended to use generic EPDs, and at detailed design stage, it is recommended to use specific EPDs (corresponding to precise commercial products). The quantities of materials included in a building are not always available and complete, or are expressed in units not directly compatible with those used in EPDs. If dynamic simulation is chosen, adequate software is needed, knowing that it is relatively time-consuming.

Operation phase	Measurement / assessment method	Based on measured data and surveys.
	Data needed and data availability	Energy bills Energy monitoring by type and use Occupants survey about transportation (optional) Products replaced and frequency of replacement Water bills and/or metering
	Applica-bility	It is difficult to separate energy consumed for the building itself (heating, lighting, etc.) and the one for activities (computers, cooking, etc.) when energy metering is not specific per use.

Comparability

Requirements for comparability

Comparability first relies on the definition of the functional equivalent of the building (cf. standards), that needs to be consistent between the buildings to be compared. For instance, a hotel may have or not a laundry, a restaurant, or a swimming-pool, so it is not appropriate to directly compare 2 hotels with different functions.

Attention is drawn on the definition of the floor area taken into account in the indicator unit (m^2), because definition of net floor area varies according to the country. This aspect would need a harmonisation at least in Europe.

System boundaries have to be checked and similar. Regarding total embodied energy in construction products, it is necessary to check that the assessment includes the same families of products (for instance foundations, structure, envelope, distribution, doors and windows, floor coverings).

The assumptions and methodology chosen for the end-of-life strategy have to be similar (e.g. on energy recovery).

The reference to standards has to be the same (prefer CEN standards as EN 15978 and EN 15804).

When comparing results, it is important to have in mind possible local constraints as for instance seismic or geological requirements (impact on foundations and structure).

The primary energy calculated for the different energy carriers have to be based on the same methodology. Prefer conversion factors based on LCA recent studies than on conventional factors not necessarily scientific-based.

About electricity factor of conversion (between final and primary energy, if electricity comes from the grid) the geographic scale must be the same (either Europe or the country where the building is located) and the calculation method as well.

Sources of information

Source / Bibliography / Web links

- Sustainable Buildings Alliance, A Framework for Common Metrics of Buildings, Pilot Draft Version 2009 (1.7)
- EeBGuide for product and building LCA studies: www.eebguide.eu
- EN 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method

- EN 15804:2012 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products - Energy Performance in Buildings Directive 2010/31/EU (EPBD, may 2010)		
Free comments		
Important remark: Consistency and coherence must be ensured with other indicators as: renewable primary energy, GHG emissions, airborne pollution due to energy use, life cycle costs. This applies to systems boundaries, scenarios and assumptions.		
Writer and date (last up-date)	Sylviane Nibel, CSTB	10/2011, updated in 11/2012

5.3.1.2 Rational use of water

Water, and especially fresh water, is an important resource to preserve as it essential to sustain life, food crops, good health and economy. The scarcity of this resource can be illustrated by the fact that it is sometimes called the “next oil”. Indeed, according to WHO water scarcity already affects one out of three people on every continent of the globe, and globally the problem is only getting worse as cities and populations grow, and the needs for water increase in agriculture, industry and households. Moreover, climate change is very likely to exasperate the problem in many regions (e.g. reduced availability of freshwater, increased demand for irrigation, etc.).

Water consumption within buildings gives rise to a large quantity of wastewater (in urban area’s about 20% of waste water production is building related) that has to be removed from the building site and purified within wastewater treatment plants. This purification is essential to maintain the quality of our water stocks (e.g. rivers) but is not without environmental burdens.

Moreover, buildings always contain some impervious surfaces (at a minimum its roof). The rainwater that cannot infiltrate into the soil can be managed in different ways with various consequences for the fresh water resources.

Indicator
Name – Definition / description
Rational use of water On-site water management that aims at limiting the depletion of fresh water resources.
Definition / description of sub-indicators
Embodied water use Water necessary to produce, build, use, maintain and dispose off the building materials/equipment and the outdoor constructions on the building site. Contribution of building materials and equipment to the total water consumption.

Operational water use

Water use of the building-integrated technical systems and of the user, as needed for the technically and functionally defined operation of the building.

Wastewater production

Evacuation of wastewater and excess rainwater from the building site to the public sewage system.

Units

Embodied water use

m³/functional unit (e.g. m² net floor area) calculated either per year or total amount for the whole life cycle of the building

Operational water use

m³/time unit (e.g. year or day)/person (e.g. per full time equivalent or per inhabitant)

or m³/time unit (e.g. year or day)/functional unit (e.g. m^2 net floor area)

Wastewater management

m³/functional unit (e.g. m^2 net floor area) /year or m³/person (e.g. per full time equivalent or per inhabitant)/year

Principles of classification

The values of the indicators are compared to the typical values obtained for the building type in question and a score is given based on the water saving levels obtained.

Weighting and aggregation

For the operational and embodied water use, aggregation can be carried out by water type (e.g. drinking water, rain water,...). Or, if a total sum of all water consumed is required, different types of water can eventually be aggregated using weighting factors based on the quality of the water. In any case it is recommended to provide operational drinking water use separately from other water consumption as this number is needed to evaluate operational costs of the building.

The total amount of water evacuated through the sewage system is the sum of the excess rainwater and waste water that is evacuated to the sewage. A lower weighting factor can eventually be used for rainwater as it has lower levels of pollution compared to wastewater and a lower factor can certainly be used in case that rainwater is evacuated through a separate system (not mixed with the wastewater).

Validity

Issue of concern	Depletion of water resources

Explanation

Public health, food production, agriculture and trade are all closely connected with the quantity and quality of available fresh water. However, freshwater is not an inexhaustible natural resource and in many regions, water is already a key factor restricting further economic and social development. Also, although not all regions have to deal with fresh water shortages, in all cases the production and supply of water and especially high-quality drinking water consumes other resources and has an impact on the environment (mainly associated to pumping and treatment).

Moreover, not only the water consumption rate is a key factor to sustainable water use but also preservation of the quality and replenishment of the water sources. In order to preserve the quality of the fresh water resources, water supply systems must not be planned or operated without corresponding wastewater treatment. However, the treatment of sewage in central sewage treatment plants also causes high expenditures and environmental impacts. Therefore, it is not only important to limit the amount of water used but also to limit the amount of water that will require a treatment after use, as well as the level of pollution of that water.

Finally, sustainable water management also involves preserving the natural water cycles. Indeed, the latter is not only important to replenish the (ground)water resources but it has also important positive side-effects. For example, infiltration of precipitations, instead of evacuation through the sewage system, contributes to the stabilisation of the groundwater table, but also to lower peak flow rates in the sewage system and watercourses and therefore decreased risk of flooding.

Justification

Water use is widely considered as an issue of concern of sustainable development.

One of the themes addressed by UN's Commission on Sustainable Development CSD is Freshwater. This theme is subdivided into Water Quantity (Annual withdrawals of ground and surface water as a percent of total renewable water) and Water Quality (BOD in water bodies and concentration of faecal coliform in freshwater).

The EEA indicators, which can be considered to reflect areas of environmental concerns, cover the following themes: agriculture, air pollution, biodiversity, climate change, energy, fisheries, land management, transport, waste and water.

Significance of the building sector to water consumption and waste water production:

Operational water use:

- Based on best available estimates, buildings are responsible for about 20% of **global** fresh water consumption. There are however, significant regional variants, for example in Singapore building related water use has been estimated at 53%. [1, 2]
- Freshwater use in buildings is responsible for about 3 percent of world energy consumption, predominantly for pumping and treatment. [1]
- The domestic sector is good for about 60% of national **drinking water** consumption in Europe.

→ Operational (drinking) water consumption can be reduced through the application of water-saving equipment and measures and the use of other types of water, such as rainwater and wastewater.

Embodied water use:

- Little studies have been conducted on embodied water in buildings, mainly because of a lack of process-water data for building materials.
- However, some Australian studies estimate that the embodied water of an Australian house represents on average about 15 years of operational water use (for cooking, cleaning, gardening, washing, drinking, toilet flushing).[3]
- Also, another Australian study on 17 non-residential case studies concludes that there is a considerable amount of water embodied in construction (the highest value of the tested building was up to 20 m³/m² of gross floor area (medium-rise office building)), mainly due to the production phase (the water consumption during the construction phase seems to be negligible). It therefore suggests that policies focused on operational water consumption alone are inadequate.[4]
- On the other hand, studies from CSTB show that embodied water use represent only 10% of the total water use of a building, considering a mix of different building types and a building service life of 100 years. [10]

→ It is worth considering embodied water use; however, due to a lack of data on embodied water of construction materials, it is currently difficult to calculate this indicator. Also, improving a building performance on this indicator may be more difficult than for operational water use, mainly because of the multitude of building materials present in a building. However, construction product EPDs elaborated in compliance with EN 15804 shall include embodied water.

Waste water production:

- Waste water production: In urban areas buildings are responsible for about **20% of waste water production** [1, 2]

→ Buildings can reduce the amount of water they sent to the sewage by the use of water saving equipments, collection and use of rainwater from impervious surfaces, infiltration of excess rainwater, on-site treatment of waste water with subsequent infiltration or re-use (unless the sewage is not connected to a waste water treatment plant, it makes no sense to evacuate on-site treated water with waste-water into the sewage, as it will have a negative effect on the efficiency of the downstream waste water treatment plant).

Object of assessment			
Building		X	
Site		X	
Location			
Other (specify)			

Characterisation	
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))	X
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	

Status of the indicator

Water use is included in important standards for the environmental or sustainability assessment of buildings and/or building products, like for example:

- ISO 21929-1:2011 Sustainability indicators – Part 1 – Framework for the development of indicators and a core set of indicators for buildings
- ISO 21931 Framework for methods of assessment of the environmental performance of construction works – Part 1 – Buildings
- EN 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method
- EN 15804:2012 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products

Water use is also included in most national evaluation schemes for sustainable buildings. However, actually most SBA tools consider only operational water use, and mostly as a means-oriented indicator (checklist of water saving equipment) rather than a performance based indicator (quantification of water use/savings). This should however change as we move towards more LCA oriented environmental performance indicators for buildings and as more information will become available on the environmental performance of building materials (through environmental product declarations).

<table>
<tr><th colspan="3">Assessment</th></tr>
<tr><td rowspan="2">Design phase</td><td>Calculation / assessment method</td><td>Embodied water use
Lifecycle inventory of water use (EN 15978: m³ of fresh water)
Operational water use
Calculation of total (drinking) water consumption based on the characteristics of the chosen water consuming building related appliances (and eventually also non-building related appliances like washing machines) and scenarios for water use (e.g. number of flushes per day, amount of water for irrigation).
Wastewater management
Assessment of the amount of water evacuated to the sewage system based on estimated operational water use (minus water “consumed” onsite for example for irrigation), excess rainwater and onsite water recycling.</td></tr>
<tr><td>Data needed and data availability</td><td>Embodied water use
– bill of quantities
– embodied water use of building products during their entire lifecycle (based on EPD) → this data is actually often missing
– service life of the building and its components (year) (to estimate replacement rates)
Operational water use
– list of building related water-using appliances and corresponding water consumption (technical data). Eventually also characteristics of non-building related water consuming appliances (e.g. washing machines, dishwasher, ...).
– scenarios of use for considered building and non-building related water consuming appliances and processes (e.g. number of flushings per person/day, amount of water needed for irrigation)
– type of water used for each application (e.g. greywater for toilets, drinking water for showers, rainwater for cleaning)
– surface of the building (m²)
– number of occupants
– dimensioning of rainwater recuperation system (necessary to evaluate the amount of rainwater that will really be available for use within the building)
Wastewater management
– operational water use
– excess rainwater that needs to be evacuated from the site (calculated based on impermeable surfaces, typical rainwater fall, amount of water that is used or infiltrated on site)
– characteristics of on-site waste water treatment facilities
– number of occupants (given)
– service life of building (year) (assumption for the considered building)
– type of sewage system (separate system for rainwater?)</td></tr>
</table>

<table>
<tr><td></td><td>Applicability</td><td>Embodied water use
A database on embodied water use is needed for all building materials and equipments and a tool to analyse the data on the building level. Due to a lack of data, this indicator may be difficult to evaluate at the moment. However, some databases exist with embodied water data, as INIES in France, or Ecoinvent for generic data.
Operational water use
Water consumption (technical information) of appliances is needed, as well as estimations of typical patterns of use (scenarios) for different building types/users and eventually a tool to easily calculate the amount of water used based on the chosen appliances and patterns of use.
Taking into account the amount of rainwater that can be used within the building requires a tool to dimension and evaluate the efficiency of the rainwater collection system based on average rainfalls within the considered region, technical characteristics of the rainwater collection system (volume of the water tank, efficiency of filters, ...) and estimated operational water needs of the building.
Waste water management
In addition to data and tools needed for the calculation of the operational water use, additional tools are needed to dimension and evaluate the efficiency of possible infiltration systems so that amounts of excess rainwater that need to be evacuated through the sewage system can also be evaluated, and also tools to evaluate the amount of water that will be evacuated by onsite waste water treatment equipments.</td></tr>
<tr><td rowspan="3">Operation phase</td><td>Measurement / assessment method</td><td>Operational water use
Direct measurement of water consumption through water meters (preferably per type of water quality and ideally with separate meters for building related and non-building related consumption and for site-related consumption (e.g. irrigation of the garden)).
Total drinking water consumption can easily be taken from water bills (of course distinction between building and non-building related water use is impossible here).</td></tr>
<tr><td>Data needed and data availability</td><td>Data from water meters or if possible data from sub-meters (monitoring)
Water bills</td></tr>
<tr><td>Applicability</td><td>Water meters are needed (relatively easy to install). Measures should preferably cover a year in order to include seasonal variations.
Drinking water bill is usually available.</td></tr>
<tr><td colspan="3">Comparability</td></tr>
<tr><td colspan="3">Requirements for comparability</td></tr>
<tr><td colspan="3">Following parameters will influence the results and should therefore be mentioned together with the results in order to improve comparability:
– lifecycle phases considered (for embodied water use)
– service life considered (for embodied water use)
– functional unit considered (e.g. m² – net floor area of office space)
– types of water considered, e.g. drinking water, rainwater, wastewater, surface water, groundwater, ...
– system boundaries (which water consuming appliances and processes are included)</td></tr>
</table>

- if water for irrigation is included in the assessment: surface of the site
- type of use (e.g. office, home,...) and number of occupants
- for comparison of calculated values: scenarios for the pattern of use of considered appliances and assumptions concerning water use for building-related processes (e.g. cleaning)
- presence of installations for rainwater recuperation, onsite water recycling,... and for which purposes that water is used
- area and type of impervious surfaces
- average rainfall for the considered region

In order to improve comparability we recommend the following:

- Follow the principles and system boundaries set in the EN 15978
- Operational water use should at least include all building-integrated water consuming processes of the building under operation
- If water use of non-building related appliances (e.g. dishwasher, washing machines, ...) is included within the assessment, it should be reported separately from building related appliances and processes (e.g. irrigation, toilets,...)
- Document scenarios/assumptions used for the calculation of operational water use
- Calculate/measure water consumptions separately for different qualities of water (certainly keep operational drinking water separate from other water consumptions)

Sources of information

Source / Bibliography / Web links

1. UNEP-SBCI Sustainable Buildings Index Materials Technical Advisory Committee (TAC), Draft terms of Reference, May 2011
2. UNEP, Eco-housing guidelines for tropical regions, 2006
3. Bardan, S. Assessment of water resource consumption in building construction in India, WIT Transactions on Ecology and the Environment, Vol 144, WIT Press, 2011, p93-101
4. McCormack, M, et al. Modelling Direct and indirect water requirements of construction, Building research &information (2007) 35(2), p156-162.
5. EN 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method (EN)
6. EN 15804:2012 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products (EN)
7. Referentiekader Duurzame Woning, Thema evaluatie
8. United Nations – Commission on Sustainable Development (CSD), Indicators of sustainable development: guidelines and methodologies (EN)
9. European Commission, 2009, 400 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions. Mainstreaming sustainable development into EU policies: 2009 Review of the European Union Strategy for Sustainable Development
10. HQE Association, HQE Performance – first trends for new buildings – Environmental performance and indoor air quality », French/English, march 2012, see www.assohqe.org

Free comments		
Writer and date (last up-date)	An Janssen and Laetitia Delem, CSTC/BBRI	06/2011, updated 11/2012

5.3.1.3 Land use

In Europe, 4% of the total surface is covered by artificial areas. The lion's share of that – namely 80% – is allotted to housing, services and recreation (EEA SOER 2011 Soil p. 10). Regarding land cover changes "artificial surfaces increased the most in terms of both net area and percentage change since 2000, by 3.4%" (SOER 2010 Land use, p. 11).

Land use is strongly connected to the "environment" subject of concern. Drawing the line from the subject of concern "environment", land use is related to the following detailed subjects of concern:

- Natural resources (soil materials, biomass, groundwater, etc.)
- Ecosystems
- Biodiversity
- Climatic systems (land use strongly influences the ability of soil to store carbon).

Nevertheless the land use issue also has an influence on society[34] and economy[35], but here, these connections are not regarded in detail.

Indicator
Name – Definition / description
Land use The indicator refers to the land that is used for buildings.
Definition / description of sub-indicators
Sub-indicator: **Soil sealing** Soil sealing occurs because of covering earth with non-permeable or low-permeable layers as a result of construction works (roads, buildings, parking etc.). The indicator measures the degree of soil sealing on a building plot. Normally the figure does not refer to the whole area of the building plot, but only to the area which is not built-on or which is not permitted to build on. The reason for that is that during the planning and building process especially the design of those areas can be influenced. Sub-indicator: **Change of land use** As stated in ISO 21929-1:2011, *"This indicator measures the avoidance of consuming of greenfield lands through the reuse of brownfield and derelict areas, refurbishment, using infill sites and re-development of existing built environment."*

[34] See EEA SOER 2010 on land use: „The way land is used affects human health and well-being" (p. 4). Furthermore soil is an archive for natural and cultural heritage.
[35] Soil is the platform for all man-made structures. Land areas have an economic value.

Units
Soil sealing: The level of soil sealing is normally given as a ratio of areas (percentage or m^2 / m^2). • Examples: In Austria the figure indicating the level of soil sealing is the "area free of soil sealing [m^2]" divided by the "area not built-on [m^2]" and is given as a percentage. It has to be calculated for each plot; the higher the percentage is the better. In Germany the level of soil sealing is calculated by dividing the "sealed area [m^2]" by the "area not permitted to build on [m^2]". **Change of land use**: The type of land used is given as a qualitative description (e.g. use of an existing building, recycling of a previous building plot, development of new building areas, etc.). • Examples (from best to worst case): - Use of contaminated land (after decontamination) - Use of an existing building or recycling of a building plot / brownfield site - Building on already developed sites inside of an existing housing settlement - Building on plots defined as building areas in addition to an existing housing settlement - Development of new building areas (provision of services necessary) - Building on re-designated, ecologically valuable areas
Principles of classification
Soil sealing: The assessment result of a building is the better the less of a building plot is sealed. **Change of land use**: The assessment result is the better, the lower the ecological value of a building plot is.
Weighting and aggregation
There is no common way of weighting and aggregating the land use sub-indicators.
Validity
Issue of concern: Environment, including Natural resources, Ecosystems, Biodiversity and Climatic systems.
Explanation
Top-down approach, explaining the land use indicator, starting from the issues of concern and the land use related impacts on that issues ("impact chain"): At the basis of the detailed subjects of concern described above **land use related goals** can be derived. The superior goal is the **protection of the soil functions**, which are in detail: • Food and other biomass production • Environmental interactions: storage, filtering and transformation • Biological habitat and gene pool • Source of raw materials • *Physical and cultural heritage (not considered, because not related to the subject of concern "environment")* • *Platform for man-made structures (not considered, because not related to the subject of concern "environment")* These land use related goals can be translated into the LCIA-term of endpoints which show the ultimate effect of environmental impacts (see SuPerBuildings D4.1 report, chapters 7 and 8). The

endpoint level of the goal “protection of soil functions” is “loss of soil functions’”, which means in detail:

- Loss of greenfield areas
- Wildlife and plants damage
- Habitats loss
- Biodiversity loss
- Soil quality loss
- Natural resources loss

Ad midpoint level the following downstream effects of environmental impacts occur (see also EEA SOER 2010 on land use, chapter 3):

- Change of land use
- Fragmentation and isolation of habitats; disruption of ecological corridors
- Soil sealing
- Soil compaction
- Changes in the quality and amount of groundwater
- Landslides
- Contamination of soil
- *Organic matter decline*
- *Soil erosion*
- *Salinisation*
- *Acidification*
- *Desertification*

All of those effects are caused partly or fully by human activities, but of course buildings and building related infrastructure (roads, parking etc.) are not responsible for all of them. Other major contributors are agriculture and forestry.

In the next step the tangible impacts of buildings on that midpoint effects were analysed:

Change of land use: Building and building related infrastructure consume land and space. This often leads to changes of land use which means that land that is dedicated to other purposes originally (e.g. agriculture, forest, grassland, etc.) is turned into building areas. The negative impacts on environment are the more significant the higher the ecological value of the land area converted into built-up area is. On the other hand, changes of land use may also have positive effects on the environment. This is the case if contaminated area is turned into building area and thus has to be decontaminated before. The use of existing buildings (refurbishment) or the recycling of existing building plots (e.g. demolition of the former building in order to construct a new building) does not require changes of land use.

Fragmentation and isolation of habitats; disruption of ecological corridors: This issue is very much related with changes of land use. The conversion of ecologically valuable areas causes a reduction of habitats and may also lead to fragmentation and isolation of habitats as well as to a disruption of ecological corridors. This has huge impacts on fauna and flora as fragmentation increases the “border effect” and may affect the ecosystem “in such a way that the size of the population decreases more than in case of continuous area” (TISSUE 2007, p. 196).

Soil sealing: Buildings and building related infrastructure (streets, parking) cause soil sealing. In EEA SOER 2010 on soil, the impacts of soil sealing are described as follows: “Soil sealing causes adverse effects on, or complete loss of, soil functions and prevents soil from fulfilling important ecological functions. Fluxes of gas, water and energy are reduced, affecting for example, soil biodiversity. The water retention capacity and groundwater recharge of soil are reduced, resulting in several negative impacts such as higher risk of floods. The reduction ability of soil to absorb rainfall, leading to rapid flow of water from sealed surfaces to river channels, results in damaging flood peaks" (EEA SOER 2010 Soil, p. 23).

Soil compaction: In built-up areas there does not only occur soil sealing, but also soil compaction. This means, that areas (e.g. parking spaces or walkways) are not covered with non-permeable layers, but with other materials, e.g. grass pavers. Nevertheless the soil under those pavers is compacted due to high loads. "Compaction can lead to a decrease in a number of key soil functions by reducing the pore space between soil particles, increasing bulk density and reducing or totally destroying the soil's absorptive capacity. The reduced infiltration increases surface runoff and leads to more erosion. Heavy loads on the soil surface, that cause compaction in the subsoil are cumulative and in time the bulk density of the subsoil will increase significantly. Compaction results in a greatly reduced rootability for crops and permeability for water and oxygen" (EEA SOER 2011 Soil, p. 22).

Reduction of biodiversity: The reduction of biodiversity is a result of the reduction of habitats which is – originally – caused by changes of land use. But also soil sealing and compaction as well as changes in the quality of soil (soil contamination and organic matter decline) have an influence on biodiversity.

Changes in the quality and amount of groundwater: As soil sealing and compaction influence the soil's function of environmental interactions (storage, filtering and transformation) they also have a great influence on changes in the quality and amount of groundwater.

Landslides: Loads caused by buildings influence the mechanical structure of soil and thus can actuate landslides. In addition, if forest areas are changed into building areas, forest clearance is carried out with the result that roots lose their soil propping function.

Contamination of soil: "Soil sealing can lead to the contamination of soil and groundwater sources because of higher volumes of unfiltered runoff water from housing, roads and industrial sites" (EEA SOER 2010 Soil, p. 23). In addition certain building types (filling stations, refineries, chemical industry etc.) increase the risk of direct contamination of soil and groundwater.

As far as the other effects listed above are concerned, buildings don't play a major role, but they are caused by agriculture and forestry primarily.

The description of effects caused by buildings shows, that the environmental impacts take place on different levels. There exist a number of impacts which are caused by other impacts. This leads to the "**impact chain approach**".

At the beginning of that impact chain there are the impacts "change of land use" and "soil sealing". Those are responsible for the other downstream effects, like "fragmentation of habitats", which leads to the loss of biodiversity, as well as "changes in the quality and amount of groundwater", "landslides" and "contamination of soil", which lead to a decline of soil functions.

The concept of impact chains clearly points out the fundamental role of "change of land use" and "soil sealing" and thereby is an argument for the choice of "change of land use" and "soil sealing" as indicators in sustainable building assessment systems.

Justification

Change of land use:

In Europe, 4% of the total surface is covered by artificial areas. The lion's share of that – namely 80% – is allotted to housing, services and recreation (EEA SOER 2011 Soil p. 10). Regarding land cover changes "artificial surfaces increased the most in terms of both net area and percentage change since 2000, by 3.4%" (SOER 2010 Land use, p. 11).

Soil sealing:

"On average, built-up and other man-made areas take up around 4% of the total area in EEA countries (data exclude Greece, Switzerland and the United Kingdom), but not all of this is actually sealed. In the decade 1990-2000 the sealed area in the EU-15 increased by 6%, and productive soil continues to be lost to urban sprawl and transport infrastructures” (EEA SOER 2010 Soil, p.5).

Object of assessment

Building	X	Share of sealed soil
Site	X X	Share of sealed soil Change of land use
Location		
Other (specify)		

Characterisation

Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))	X
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	

Status of the indicator

The sub-indicators “soil sealing” and “change of land use” are included in several building assessment systems, for example:

- Austrian TQB
- French HQE (soil sealing)
- Belgium VALIDEO and Refentiekader Duurzame Woning
- German BNB system

In the Annex A of ISO 21929-1:2011, there is a description of environmental aspects related to building location, including protection of rare species and valuable individual natural features on-site (within the curtilage), ecological quality of the site, potential to affect surface drainage and heat island effect.

In EN 15978:2011, indicators about land use (also biodiversity) are not included, because “*there is no scientifically agreed calculation method within the context of LCA*”. A possible improvement of this indicator would be to become more LCA-oriented, considering that “land use” or “change of land use” also occurs during the production phase (extraction of raw materials, growing of plants/trees, manufacturing, transport infrastructure) and the end-of-life phase (landfill, treatment, recycling).

Assessment

Design phase	Calculation / assessment method	**Soil sealing**: Quantitative assessment of area ratios **Change of land use**: Qualitative assessment of the type of land used

<table>
<tr><td rowspan="2"></td><td>Data needed and data availability</td><td>Soil sealing: Quantitative:
• Share of sealed soil
Change of land use: Qualitative:
• To which type of land does the building plot belong (recycled area; renovation – retrofitting; dedicated building area; new dedication of building area, ecological valuable area etc.)?</td></tr>
<tr><td>Applicability</td><td>Land use is dealt with on local or community level and there is a lack of superior planning institutions. Each municipality has their own requirements for the level of soil sealing and is responsible for the designation of areas. In order to enable sustainable development in the field of land use, spatial planning should be dealt with on superior level.</td></tr>
<tr><td rowspan="3">Operation phase</td><td>Measurement / assessment method</td><td>–</td></tr>
<tr><td>Data needed and data availability</td><td>–</td></tr>
<tr><td>Applica-bility</td><td>–</td></tr>
</table>

Comparability

Requirements for comparability

The application of the land use indicator is very heterogeneous and also the benchmarks are very different. One problem is that on the basis of regulatory standards land use is handled on the level of municipalities. Therefore there are different calculation methods and benchmarks (and sometimes also indicators) in nearly every town / region.

European wide comparability of results requires the following:

- Use of the same indicators
- Use of the same calculation methods
- Use of the same reference areas

The use of the same benchmarks is not recommended, as the geographical, topographical, demographical, biological, cultural situation in each country is too different.

Sources of information

Source / Bibliography / Web links

- TQB – www.oegnb.net
- Refentiekader Duurzame Woning and VALIDEO Referentieel Kantoorgebouwen
- German government led BNB system
- French HQE certification

- Umweltbundesamt (2011): Grund genug – Flächenmanagement in Österreich – Fortschritte und Perspektiven, im Auftrag des BMLFUW, Wien.
- ISO 21929-1:2011 Sustainability in building construction – Sustainability indicators Part 1 – Framework for the development of indicators and a core set of indicators for buildings
- EEA SOER 2010 Land use (2010): The European Environment, State and Outlook 2010, European Environment Agency, Copenhagen
- EEA SOER 2010 Soil (2010): The European Environment, State and Outlook 2010, European Environment Agency, Copenhagen
- TISSUE (2007): Trends and Indicators for Monitoring the EU Thematic Strategy on Sustainable Development of Urban Environment, Final report, summary and recommendations

Free comments		
In the first draft of the indicator description, there were three land use indicators, namely the change of land use, the **efficient use of space / building density** and soil sealing. After discussion between SuPerBuildings partners, it was stated to concentrate on change of land use and soil sealing, as key indicators, but not on density. During the further development of the indicator description – focusing on the explanation of the indicator to strengthen its validity – the sub-indicators “change of land use” and “soil sealing” turned out to be valid.		
Writer and date (last up-date)	Susanne Supper, ÖGUT	10/2011, updated 11/2012

5.3.2 Environment – Ecosystems

The indicators presented in this chapter relate to the following issues:

- Protection of the atmosphere and climate (greenhouse gases)
  - Potential impact on climate change / Global warming potential / Carbon footprint
- Protection of water and soil quality (pollution and waste)
  - Construction and demolition waste generation
    - Non-hazardous waste to disposal
    - Hazardous waste to disposal
    - Nuclear waste to disposal
  - Water pollution due to material leaching.

5.3.2.1 Protection of the atmosphère – Global warming potential

It is a fact that global warming and climate change is under way. It is scientifically recognized (although it remains a small group of “sceptics”) that greenhouse gases emissions due to human activities are the most significant cause of global warming. Others have established that exceeding a 2 °C increase of global temperature will lead to huge economic, social and environmental problems, and leading to instabilities. Limiting global warming at 2 °C needs that developed countries reduced by a factor 4 or 5 their GHG emissions by 2050. This ambitious goal is crucial, but it is also necessary to adapt our life environment – and particularly our built environment – to climate change. So mitigation and adaptation are both necessary and urgent strategies. The report written by the British economist Nicholas Stern in 2006 is brilliant and very useful for awareness in this field. Unfortunately, the lack of commitment of the international community on ambitious targets will probably lead to a global warming around 3 or 4 °C by the end of the century[36].

The European Commission has set ambitious targets and released in March 2011 a "Roadmap for moving to a competitive low carbon economy in 2050". The following figure illustrates how big is the challenge, particularly for the Power sector (electricity) and the Residential and Tertiary sector.

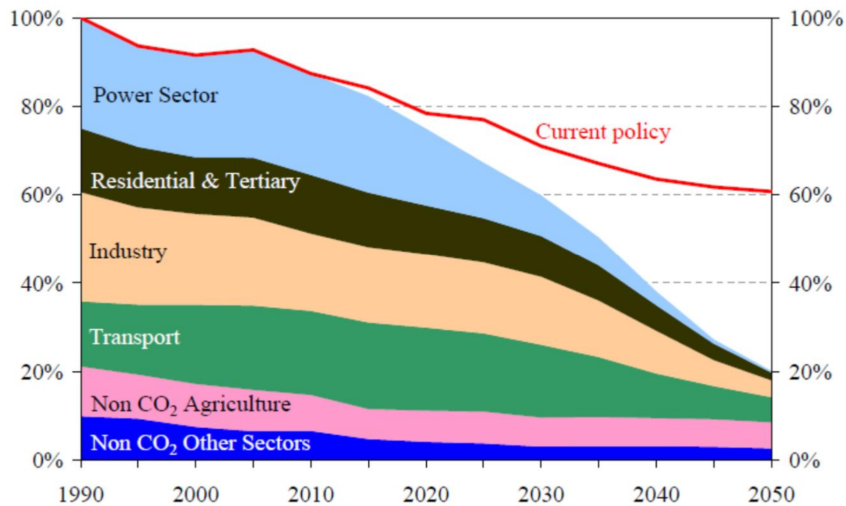

Figure 8. EU GHG emissions towards an 80% domestic reduction (100%=1990)[37].

The construction industry is a large contributor to CO_2 emissions, with buildings responsible for one third of the total European CO_2 emissions.

36 The World Bank, "Turn Down the Heat – Why a 4°C warmer world must be avoided", Executive summary, November 2012.
37 Source: COM(2011) 112 final "A Roadmap for moving to a competitive low carbon economy in 2050", Communication from the European Commission, Brussels, 8.3.2011.

The "Low carbon Roadmap" specifies, based on scenarios, the reductions needed in each sector. This is presented in the table below.

Table 6. Sectoral reductions (extract from the "Low carbon Roadmap").

GHG reductions compared to 1990	2005	2030	2050
Total	-7%	-40 to -44%	-79 to -82%
Sectors			
Power (CO_2)	-7%	-54 to -68%	-93 to -99%
Industry (CO_2)	-20%	-34 to -40%	-83 to -87%
Transport (incl. CO2 aviation, excl. maritime)	+30%	+20 to -9%	-54 to -67%
Residential and services (CO_2)	-12%	-37 to -53%	-88 to-91%
Agriculture (non-CO_2)	-20%	-36 to -37%	-42 to -49%
Other non-CO_2 emissions	-30%	-72 to -73%	-70 to -78%

It is interesting to note that the targets for Power and for Residential and services are higher than the total EU objective, in order to compensate other sectors less efficient or promising as Transport and Agriculture. So, compared to 1990, what would be necessary by 2050 for Building sector is a Factor 10 (-90%) and for Electricity production is a Factor 20 (-95%) or even more! By 2030, the Building sector should have reduced its CO_2 emissions by about 45%.

Indicator	
Name – Definition / description	
Potential impact on climate change / Global warming potential / Carbon footprint Weighted sum of greenhouse gases because of the building including its operation	
Definition / description of sub-indicators	
Greenhouse gases including at least CO_2, CH_4 and N_2O Greenhouse gases covered by IPCC Guidelines are listed in [1].	
Units	
kg (or tonnes) per m^2 (net floor area) calculated either per year or total amount during the chosen period (the chosen period may be the service life of the building).	
Principles of classification	
When benchmarking, the value of the indicator is compared to the average (or typical) value of the building type in question considering the purpose of use and the age group of the building.	
Weighting and aggregation	
Weighting in terms of global warming potential (GWP). Global warming potential according to the IPPC 4th assessment report are given in [2].	
Validity	
Issue of concern	Climate change

	Indirectly: many environmental, social and economic issues

Explanation

Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing, which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate.

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values. Carbon dioxide is the most important anthropogenic greenhouse gas. The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005.

The primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period results from fossil fuel use, with land-use change providing another significant but smaller contribution. The understanding of anthropogenic warming and cooling influences on climate has improved during recent years leading to very high confidence that the global average net effect of human activities since 1750 has been one of warming. [3]

Justification

The phenomenon and reasons are explained in IPCC fourth Assessment Report: Climate change 2007.

Climate change is widely considered as an issue of concern of sustainable development.

UN's Commission on Sustainable development CSD has approved a follow-up to the two earlier sets of sustainability indicators. It defines indicators of Sustainable Development [4]: It is claimed that these indicators cover the issues that are relevant to sustainable development in most countries. One of the themes addressed by CSD is Atmosphere (divided into Climate change, Ozone layer depletion and Air quality).

The Renewed EU Sustainable Development Strategy was adopted by the European Council in June 2006. It is an overarching strategy for all EU policies which sets out how we can meet the needs of present generations without compromising the ability of future generations to meet their needs. It addresses seven key challenges for sustainable development [5]. One of the seven key challenges is “climate change and clean energy”.

The EEA indicators (which can be considered to reflect areas of environmental concerns): cover the following themes agriculture; air pollution; biodiversity; climate change; energy; fisheries; land management; transport; waste; and water (EEA 2009 [6]).

Building sector has a significant effect on the overall release of greenhouse gases because of human activities.

The construction industry is a large contributor to CO_2 emissions, with buildings responsible for 40% of the total European energy consumption and a third of CO_2 emissions. [7]

Object of assessment		
Building	X	
Site	(X)	Soil construction and pavements may have a significant influence on the overall greenhouse gas releases because of a building and its site. [8]
Location	(X)	GHG emissions related to the building's location and access to the building may also be calculated through modelling and evaluating when assessing the influence of locating the building.

			Climate features influence energy consumption, so also GHG emissions.
Other (specify)			
Characterisation			
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)			X
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))			
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)			
Status of the indicator			

The indicator is included in important methods and standards that give (partly or fully) LCA/LCI based guidelines for the environmental or sustainability assessment of buildings and or building products. These include

- ISO 21929-1:2011 Sustainability indicators – Part 1 – Framework for the development of indicators and a core set of indicators for buildings
- ISO 21931 Framework for methods of assessment of the environmental performance of construction works – Part 1 – Buildings
- ISO 21930 Sustainability in building construction — Environmental declaration of building products
- EN 15978:2011 Assessment of environmental performance of buildings – Calculation method
- EN 15804:2012 Environmental product declarations – Core rules for the product category of construction products
- EN 15942:2011 Environmental product declarations – Communication format business-to-business
- SBA common metrics [9]

Assessment		
Design phase	Calculation / assessment method	Quantity surveying Energy consumption assessment Life cycle inventory of greenhouse gases

	Data needed and data availability	Energy demand (based on calculations) Energy sources Carbon footprint of energy carriers Bill of quantities Carbon footprint of materials and building products Service life Water consumption and waste water production Carbon footprint of water services (fresh water and waste water)
	Applica-bility	Applicable and relevant data base of carbon footprint of energy, water and materials and a calculation tool are needed.
Operation phase	Measurement / assessment method	Quantity surveying Energy consumption Life cycle inventory of greenhouse gases Water consumption and waste water production
Operation phase	Data needed and data availability	Energy demand (on-site measurement) Energy supply systems Carbon footprint of energy carriers Bill of quantities (may be limited to maintenance and refurbishment) Carbon footprint of materials and building products Service life
Operation phase	Applica-bility	Applicable and relevant data base of carbon footprint of energy, water and materials and a calculation tool are needed.

Comparability

Requirements for comparability

The comparability of the results depends on the uniformity of the system boundaries. Comparability of the results requires that the building life cycle and related issues – that are either considered or excluded from the scope – are determined equally. This concerns also the quality of background data taken from environmental data bases.

Important issues that affect the comparability with regard to the energy are for instance:

- the type of the method with the help of which the emissions are allocated to electricity and heat in CHP plants
- consideration of the seasonal and more specific variations in the production of electricity
- the use of national or European average values for electricity and the consideration of import and export
- allowing the use of separate carbon footprint for market product "green electricity"
- consideration of future changes in the production of electricity and district heat.

Important issues of material data that affect the comparability of the results (in addition to the energy remarks presented above) are for instance:

- the consideration of sequestered carbon in wood

- the consideration of final disposal and/or recycling of wooden products, modelling of the decomposition and consideration of "saved" emissions if used as a fuel
- the consideration of final disposal and/or recycling of plastic products, modelling of the decomposition and consideration of "saved" emissions if used as a fuel
- the consideration of the recycling options of metal products in the end-of-life stage.

Important issues related to the building and its life cycle include the coverage of the assessment of different building parts (like for example building foundation, installations and products of HVAC, and surfaces like floorings) and different operations (like user specific electricity) and the stages of life cycle (like for example the inclusion of the needed energy for construction and refurbishment, transportations, renewals and service life of products, demolition, final disposal).

Comparability of the results can be improved through agreeing about certain basic selections with regard to the data sources. For example the following is recommended:

If there is no specific reason to make an exception, always

- consider pre-combustion values for energy and use the values given in ELCD database [10]
- use net calorific values for energy and those greenhouse gases emission values given in IPCC Guidelines [11]
- follow the outlines (e.g. system boundaries, allocation rules) given for building parts, operations and stages of life cycle given in CEN standards (EN 15978) and give the results separately for different parts
- give all speculative parts of the assessment separately (like for example possible effects of substitution and saved emissions because of recycling)
- ensure the transparency of the results.

Sources of information

Source / Bibliography / Web links

[1] 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Chapter 1: Introduction to the 2006 Guidelines p. 1.5 http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_1_Ch1_Introduction.pdf

[2] Climate Change 2007: Working Group I: The Physical Science Basis TS.2.5 Net Global Radiative Forcing, Global Warming Potentials and Patterns of Forcing (http://www.ipcc.ch/publications_and_data/ar4/wg1/en/tssts-2-5.html)

[3] IPCC Climate Change 2007: Working Group I: The Physical Science Basis

[4] Indicators of Sustainable Development: Guidelines and Methodologies, Third Edition (2007), UN publications, 93 pages

[5] COM(2009) 400 final. Communication from the Commission to the European Parliament the Council, the European Economic and Social Committee and the Committee of Regions. Mainstreaming sustainable development into EU policies: 2009 Review of the European Union Strategy for Sustainable Development. The 7 key challenges are: Climate change and clean energy, Sustainable transport, Sustainable consumption and production, Conservation and management of natural resources, Public health, Social inclusion, demography and migration, Global poverty.

[6] European Environment Agency (2009a) Indicators about Europe's Environment. http://themes.eea.europa.eu/indicators/ (Accessed 17/07/09)

[7] Energy Efficient Buildings European Initiative. http://www.ectp.org/cws/params/ectp/download_files/36D928v2_E2BA_Brochure.pdf

[8] See for example: Vares, Sirje; Häkkinen, Tarja; Shemeikka, Jari. Assessment of the sustainable building targets and their realisation in Suurpelto kindergarten project in Espoo (Kestävän

rakentamisen tavoitteet ja niiden toteutuminen. Espoo Suurpellon päiväkodin arvio) (In Finnish with English abstract). 2011. VTT, Espoo. VTT Research Notes : 2573 http://www.vtt.fi/publications/index.jsp [9] A Framework for Common Metrics of Buildings. Pilot Draft Version 2009 (1.7) Sustainable Buildings Alliance 2009 [10] http://lca.jrc.ec.europa.eu/lcainfohub/datasetCategories.vm [11] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Energy Guidelines for National Greenhouse Gas Inventories. Chapter 2 Stationary combustion. Chapter 3 Mobile combustion. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html		
Free comments		
Writer and date (last up-date)	Tarja Häkkinen, VTT	10/2011, updated in 11/2012

5.3.2.2 Protection of water and soil quality – Construction and demolition waste

Waste represents a considerable loss of resources both in the form of materials and energy. The treatment and disposal of the generated waste may cause environmental pollution and expose humans to harmful substances and bacteria, and therefore impact on human health[38]. Moreover, landfills consume land area and impact landscape.

Construction and demolition waste represented 33% of the total waste production in the EU, EFTA, Turkey and Croatia in 2006.[39]

Indicator
Name – Definition / description
Construction and demolition waste generation Summary of construction and demolition waste generated through construction, refurbishment and end-of-life phases of the building life cycle
Definition / description of sub-indicators
Calculation of construction waste generated at the construction phase, construction and demolition waste generated by refurbishment/replacements, and demolition waste generated at the end of the life cycle when removing the building. Sub-indicators: – Non-hazardous waste to disposal

[38] Indicators of Sustainable Development: Guidelines and Methodologies, Third Edition (2007), UN publications, 93 pages.

[39] The European Environment – State and Outlook 2010: Material Resources and Waste. Copenhagen: EEA, 2010. 46 p. WWW: <http://www.eea.europa.eu/soer/europe/material-resources-and-waste>. ISBN 978- 92- 9213- 155- 5, doi: 10.2800/58607.

- Hazardous waste to disposal
- Nuclear waste to disposal

Units

kg/m^2 – amount of (each type of) waste per square meter of gross building area

Other possible units:

kg/m^2/year – amount of (each type of) waste per square meter of gross building area annualized for planned lifespan of building

% – percentage of construction and demolition waste for recycling or energy recovery (may be used as a way to evaluate waste management on site)

Principles of classification

The value of the indicator is compared to the average (or typical) value of the building type considering the purpose of use, new construction and reconstruction

Weighting and aggregation

The waste components can be combined, if one figure is needed. In this case, the amounts of different categories of waste can't be simply summed up. Weighting factors are needed, for instance based on the cost of treatment / storage / management of each waste category. This cost evolves over time, and it may vary from one country to another, or from one region to another. The cost reflects more or less the efforts that it is necessary to make in order to limit the environmental impacts of the different categories of waste.

Another possibility: we may keep the result split into the 3 sub-indicators (corresponding to the 3 categories of waste), and let the experts who set the system for local conditions to set the weights within the whole system. The weighting system must reflect the potential environmental damage or risks (also on health) of each waste category.

Validity

Issue of concern	Ecosystems

Explanation

The main purpose is to assess the generation of waste during the life cycle of building. Waste represents a considerable loss of resources both in the form of materials and energy. The treatment and disposal of the generated waste may cause environmental pollution and expose humans to harmful substances and bacteria, and therefore impact on human health [1]. Moreover, landfills consume land area and impact landscape.

Justification

Construction and demolition waste represented 33% of the total waste production in the EU, EFTA, Turkey and Croatia in 2006. [2]

Object of assessment

Building		X	Construction and demolition
Site		x	Landscaping
Location			
Other (specify)			

Characterisation

Directly impact-related (indicators that directly measure the potential impact by expressing the	

(weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))	X
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	

Status of the indicator

The indicator is included in important methods and standards that give (partly or fully) LCA/LCI based guidelines for the environmental or sustainability assessment of buildings and or building products. These include:

- ISO 21929-1 Sustainability indicators – Part 1 – Framework for the development of indicators and a core set of indicators for buildings
- ISO 21931 Framework for methods of assessment of the environmental performance of construction works – Part 1 – Buildings
- ISO 21930 Sustainability in building construction – Environmental declaration of building products
- EN 15978 Assessment of environmental performance of buildings – Calculation method
- EN 15804 Environmental product declarations – Core rules for the product category of construction products
- EN 15942 Environmental product declarations – Communication format business-to-business
- SBA common metrics [3]

Assessment		
Design phase	Calculation / assessment method	Life cycle analysis according to EN 15978 and ISO 14040 series
	Data needed and data availability	Project documentation Bill of quantities EPDs of construction products according to EN 15804 and ISO 21930 Waste management plan
	Applicability	It depends on the availability of EPDs. When EPDs don't cover all phases of life cycle (in EN 15804 only cradle to gate is mandatory, other phases are optional), it is necessary to define scenarios for the phases not covered, especially construction and end-of-life. Time consuming
Operation phase	Measurement / assessment method	Generation of construction and demolition waste measured on construction site

	Data needed and data availability	Tons (or kg) of waste by waste category
	Applicability	Tracking amounts of waste leaving site and/or being produced on site and reused (landscaping). Hard to measure into detail. Remark on units: It is preferable to express amounts of waste by tons or kg instead of cube meters, because mass is less subject to variations than volume. However, disposing waste in landfills is linked to volume (it consumes space) but cost of disposal is generally given by ton.
Comparability		
Requirements for comparability		
Comparability of the results requires that the building life cycle and related issues – that are either considered or excluded from the scope – are determined equally. Important issues that affect the comparability with regard to the waste generation: – waste categorization – calculation/logging methods and level of detail – system boundaries – building, site – life cycle stages included: production stage; construction waste; maintenance; repair and refurbishment; waste arising from energy use (optional); waste from demolition process.		
Sources of information		
Source / Bibliography / Web links		
[1] Indicators of Sustainable Development: Guidelines and Methodologies, Third Edition (2007), UN publications, 93 pages [2] The European Environment – State and Outlook 2010: Material Resources and Waste. Copenhagen: EEA, 2010. 46 p. <http://www.eea.europa.eu/soer/europe/material-resources-and-waste>. ISBN 978- 92- 9213- 155- 5, doi: 10.2800/58607. [3] A Framework for Common Metrics of Buildings. Pilot Draft Version 2009 (1.7) Sustainable Buildings Alliance 2009		
Free comments		
Writer and date (last up-date)	Antonin Lupisek	10/2011, updated in 11/2012

5.3.2.3 Protection of water and soil quality – Water pollution due to material leaching

An additional indicator was developed by CSTB (Nicoleta Schiopu) in order to document a specific phenomenon: the water pollution after run-off and contact with built surfaces as roofs, treated wood, secondary raw material based products, etc., using information on leaching behaviour of construction products.

Fresh water is an important resource to preserve in term of quantity and quality as it essential to sustain life, overall environment quality and economy.

Different processes contribute to water pollution. According to the EEA report on Freshwater quality[40], the agriculture and urban area are the main contributors. In order to meet the objectives of the Water Framework Directive (WFD – 2000/60/EC[41]) set by European legislation, most research programs have focused on assessing the quality of industrial and treated wastewater discharges. Limited information is available regarding priority substances in stormwater. Indeed, stormwater may be discharged untreated into rivers and thus have an impact on the aquatic ecosystem. Concerning the urban source pollution of the stormwater, various studies were carried out especially on some specific products such as treated wood[42] [43], metallic roofs[44], secondary raw materials (SRM) based products[45], etc. For more than 20 years now, it has been proved that roof runoff water plays an important role in the high metallic concentration levels in urban rainwater[46].

Thus, in the framework of the European Water Framework Directive (WFD – 2000/60 CE), whose aim is to obtain a good ecological state of aquatic environments, it seems necessary to reduce the production of pollutants at their sources. This implies to identify sources and to quantify emissions. Some studies highlighted that the stormwater is contaminated by 12 priority substances and 8 priority hazardous substances of the WFD and 35 other urban pollutants. Pollution is mainly particulate matters for PAHs, PCBs, organotins and metals, while pollution

[40] EEA - European Environment Agency. The European environment – state and outlook 2010. Freshwater quality — SOER 2010 thematic assessment. 34p. Available on : http://www.eea.europa.eu/soer/europe/freshwater-quality.

[41] http://ec.europa.eu/environment/water/water-framework/index_en.html Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy.

[42] Waldron, L., P. Cooper, and T. Ung. Modeling of Wood Preservative Leaching in Service. Proceedings of Environmental Impacts of Preservative-Treated Wood Conference, Orlando, FL, February 8–11, 2004, disponible sur http://www.ccaresearch.org/Pre-Conference/pdf/Waldron.pdf.

[43] Schiopu N., Caractérisation des émissions dans l'eau des produits de construction pendant leur vie en œuvre, PhD Thesis (In French), INSA Lyon, 2007, 278 p.

[44] Bertling, S., Corrosion-induced metal runoff from external constructions and its environmental interaction. A combined field and laboratory investigation of Zn, Cu, Cr and Ni for risk assessment. Thesis. Stockholm : Royal Institute of Technology, 2005, 116 p.

[45] Schiopu, N., Vernus, E., Jayr, E., Méhu, J. Technical and environmental feasibility of the use of secondary raw materials (SRM) in the construction materials and products. WASCON 2006 international conference proceedings, Belgrade, Serbia and Montenegro, May 30 June 2, 2006.

[46] Gromaire-Mertz M. C., Garnaud S., Gonzalez A. and Chebbo G. (1999). Characterisation of urban runoff pollution in Paris. Water Science and Technology 39(2): 1–8.

is distributed between both phases for phthalates, pesticides and alkylphenols. Runoff is the main contributor to pollution at the outlet of storm sewer. The direct discharge of stormwater requires, for certain substances, a dilution of 10 to 1000 with the receiving waters to meet environmental quality standards[47].

At legislative level in the construction sector, the Construction Product Regulation (CPR – 305/2011/EU) which replaced in 2011 the Construction Product Directive (CPD – 89/106/EEC) explicitly demands construction works to be built with construction products that meet the requirements on Hygiene, Health and Environment (BR 3 – Basic Requirement n°3) in force in their place of use and not to endanger the health of the occupants and neighbours, in particular as a result of the following impact: "Pollution or poisoning of the water or soil". Moreover, the CPR is reinforced with a new requiremet (BR 7 – Sustainable use of natural resources) which states, among other requirements: "use of environmentally compatible raw and secondary materials in the construction works". With the implementation of this CPR, the information on leaching behaviour of construction products will become mandatory for the CE marking.

So, the impact of a building on water pollution during operation is due to various phenomena including wastewater and related treatment, but also by the leaching behaviour of built surfaces in contact with water, as roofs, façades, terraces and foundations. The indicator presented hereafter specifically deals with the water pollution via leaching phenomena of the built surfaces, due to water runoff on the impervious surfaces and infiltration in the case of built pervious surfaces. In any case, water quality after contact with the built surfaces should be evaluated.

In order to evaluate this water quality and to meet the legislative and societal requirements, technical specifications (standards or technical approvals) were developed. Indeed, the European Commission issued in 2005 the mandate M/366 "Development of horizontal standardised assessment methods for harmonised approaches relating to dangerous substances under the Construction Products Directive (CPD) – Emission to indoor air, soil, surface water and ground water". In response to that mandate, the CEN/TC351 "Construction products: Assessment of release of dangerous substances" was created in 2006. Its WG1 is in charge of "Release into soil and groundwater". Two projects of harmonised leaching test methods are at the moment (2012) the main outcome of the work of CEN/TC351/WG1. The results issued from these tests will be complementary to the results obtained using the Life Cycle Assessment methodology (EPDs, CEN/TC 350 work).

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[47] Zgheib, S., Fluxes and sources of priority pollutants in urban water associated with different land use pattern (in French), PhD Thesis, École Nationale des Ponts et Chaussées, 2009, 349 p. V 2011 Available on: http://hal-agroparistech.archives-ouvertes.fr/docs/00/55/49/32/PDF/THESE_SallyZGHEIB2009.pdf

The specific requirements regarding the environmental compatibility of construction products will be defined nationally by the Member States. At present only few Member States have quantitative requirements on the release of regulated dangerous substances from construction products/construction works. The most important provisions for the subject of environmental protection are the Dutch "Soil Quality Decree"[48] and the German "Principles for assessing the effects of construction products on soil and groundwater"[49].

Indicator
Name – Definition / description
Water pollution due to material leaching On-site water pollution induced by the leaching phenomena (water contact with the built environment) during operation phase.
Definition / description of sub-indicators
A list of Regulated Dangerous Substances possibly associated with construction products under the CPD – Construction Product Directive / Regulation was established at European level [1]. The list is based on the database on legislation on dangerous substances relevant for construction products developed by the Commission in cooperation with Member States. This list indicates on which substances and parameters the evaluation should focus. The substances are listed in Annex A, List A "Soil and water" and structured as follows: A-1. Regulated dangerous substances in main pollutant categories of Directive 2000/60/EC (Water Framework Directive) A-2. Further regulated substances and parameters A-3. Other substances deemed relevant
Units
mg /m^2 exposed surface /time unit (e.g. year) and/or mg /m^2 exposed surface /service life
Principles of classification
The specific requirements regarding the environmental compatibility of construction products will be defined nationally by the Member States. At present only few Member States have quantitative requirements on the release of regulated dangerous substances from construction products / con**stru**ction works: The Netherlands and Germany. Classification is not possible yet, as further work is necessary in order to establish the harmonised or specific limit values for each pollutant.

48 VROM – Dutch Ministry of Spatial Planning Housing and the Environment. Soil Quality Decree (Netherlands), Decree of 22 November 2007 containing rules with respect to the quality of soil (Soil Quality Decree). Bulletin of Acts, Orders and Decrees of the State of the Netherlands 2007, 34p.

49 Grundsätze zur Bewertung der Auswirkungen von Bauprodukten auf Boden und Grundwasser –- Teil 1, Mai 2009, DIBt Mitteilungen 40 (2009) 4, S. 116–134, and Teil II – Juli 2009, Teil III – Mai 2009, DIBt Mitteilu-ngen 40 (2009) 5, S. 169–179.

Weighting and aggregation

The emissions of pollutants (cf. list of Dangerous Substances in [1]) into water should be evaluated via the CEN/TC 351 protocols. No aggregation is foreseen. For each pollutant, limit values are/will be defined at national level.

Validity

Issue of concern	Ecosystems, Biodiversity, Water resources, Land use, Health Indirectly: economic issues (effect on the drinking water price)

Explanation

Public health, food production, agriculture and trade are all closely connected with the quantity and quality of available fresh water. Not only the water consumption rate is a key factor to sustainable water use but also preservation of the quality and replenishment of the water sources. The impact of a building on the fresh water resources is determined by the way the building uses fresh water efficiently and manages waste water and rainwater on site, but also by the leaching behaviour of built surfaces in contact with water (roof, façade, terraces and foundation).

The indicator presented here concerns the water pollution via leaching phenomena of the built surfaces (runoff on the impervious surfaces and infiltration in the case of built pervious surfaces). In the framework of the European Water Framework Directive (WFD – 2000/60 CE), whose aim is to obtain a good ecological state of aquatic environments, it seems necessary to reduce the production of pollutants at their sources. This implies to identify sources and to quantify emissions. The water pollution is directly related to fresh and groundwater quality as natural resources but also to ecosystems and soil quality (water/soil pollution transfer) which influence the local biodiversity (impact chain approach).

Justification

Water quality is widely considered as an issue of concern of sustainable development. For example, the EEA – European Environment Agency report on fresh water quality [2] states that :

- Europe's freshwaters contain a number of pollutants including nutrients, metals, pesticides, pathogenic micro-organisms, industrial chemicals and pharmaceuticals. These can have adverse effects on aquatic ecosystems, degrading habitats and resulting in the loss of freshwater flora and fauna. Poor water quality can also raise concern for human health.
- The Water Framework Directive aims to attain good ecological and chemical status by 2015. For a number of freshwater bodies, substantial improvements will be required to meet this target. A substantial proportion of Europe's freshwaters are at risk of not achieving good status under the EU Water Framework Directive by 2015 (40% of surface waters and 30% of groundwaters, in 2004).
- Diffuse pollution from both agriculture and urban areas remains a major pressure on Europe's freshwater.
- Removing pollution is expensive, uses energy and chemicals, and results in the generation of wastes. Controlling pollutants at source, however, decreases their discharge to freshwaters and reduces the need for treatment. There is considerable scope for greater implementation of source control measures across all sectors.

For more than 20 years now, it has been proved that roof runoff water plays an important role in the high metallic concentration levels in urban rainwater. In Paris, experiments conducted on a 42 ha urban catchment have established that atmospheric corrosion of roofing materials could be a major source of zinc, cadmium, lead and copper during wet weather.

Moreover, stormwater may be discharged untreated into rivers and thus have an impact on the aquatic ecosystem.

Object of assessment			
Building		X	
Site		X	
Location			
Other (specify)			
Characterisation			
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)			X
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))			X
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)			

Status of the indicator	

At the EU level, the main regulations and directives concerning the water pollution induced by the water contact with the build surfaces are:

- Regulation no 305/2011/EU on construction products (CPR)
- Regulation no 1907/2006/EC on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)
- Regulation no 528/2012/EU on biocidal products
- Directive 2000/60/EC establishing a framework for Community action in the field of water policy (Water Framework Directive – WFD)
- Decision no 2455/2001/EC establishing the list of priority substances in the field of water policy
- Decision no 041/051 rev.12. Indicative list of regulated dangerous substances possibly associated with construction products under the CPD (2012)
- Directive no 2006/118/EC on the protection of groundwater

In addition to the specific documents issued from CEN/TC 351 [3] [4], water quality is included in standards for the environmental or sustainability assessment of buildings and/or building products, particularly in the standard issued from CEN/TC 350, EN 15804:2012 (Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products) which states that:

> *"7.4 Additional information on release of dangerous substances to indoor air, soil and water during the use stage – 7.4.2 Soil and water*
>
> *The following information shall be provided for products that are exposed to soil and water after their installation in buildings. The information is provided to support the use stage scenarios for soil and water pollution:*
>
> *Release to soil and water according to the horizontal standards on measurement of release of regulated dangerous substances from construction products using harmonised testing methods and other procedures according to the provisions of CEN TC 351 and the respective Product TCs, if requirements exist.*
>
> *NOTE 1: If CEN/TC 351 and other procedures of the respective technical committees for European product standards are not available, no information is required in the EPD.*
>
> *NOTE 2: Other procedures may include the concept of "without testing /without further testing (WT/WTF)".*

Water quality is often included in national evaluation schemes for sustainable buildings, but actually, most SB assessment tools consider only tap water quality and wastewater. This should however change as data on leaching behaviour of products (their pollution potential) will be integrated into the CE marking in the framework of the CPR – Construction Products Regulation, and as more information will become available on the environmental performance of the building products (through the EPDs, as complementary data to the information obtained via LCA approach).

Assessment		
Design phase	Calculation / assessment method	Simulation with numerical tools such as PhreeqC [5], Orchestra [6], based on data from databases such as LeachXS [7] and LixiBat [8] or from scientific literature, and hypothesis on specific building / site characteristics.

	Data needed and data availability	– leaching behaviour of each pollutant (cf. List of Dangerous Substances [1]), en mg/m^2/unit time (and/or mg/m^2/service life of the product)
		  – low availability for the moment; nevertheless some data are available in leaching databases such as LeachXS and LixiBat or spread in literature;
		  – high availability as soon as these data will be mandatory for the CE marking of the products ; products with always low or even no pollutants emissions into water can be subject to CE marking on basis of a "without testing" (WT) option – or a "without further testing" (WFT) option if an initial testing project showed low (to be defined) or no pollutants emissions (possibly under certain frame conditions) [9].
		– outdoor surface of each product from the building exposed to rain or groundwater (m²) : roofing, facades, terraces, foundation
		– service life of each product from the building (year) (assumption for the considered building)
		– service life of the building (year) (assumption for the considered building)
		– rainwater fall on the building site (mm/an)
		– characteristics of the groundwater on the building site (contact or not with foundation, flow rate etc.)
		– type of rainwater collection system (direct infiltration; collection system with the wastewater ; separate system from sewage)
		– amount of the collected rainwater that is used for indoor consumption (m3/an)
		– amount of the collected rainwater that is infiltrated on site (m3/an)
		– amount of the rainwater that needs to be evacuated from the site (m3/an)

	Applicability	Commercial and free models, databases and tools are available. Nevertheless, specialists are needed for data exploitation and interpretation and the process could be considered as time consuming. Moreover no consensus exists presently on different scenarios or hypothesis to be defined.
Operation phase	Measurement / assessment method	The pollutants (cf. list of Dangerous Substances [1]) emission into water should be evaluated by using the CEN/TC351 protocols: tank test CEN/TC351/WG1/TS2 [3] and column test CEN/TC351/WG1/TS3 [4]. Simulation with numerical tools such as PhreeqC [5], Orchestra [6] based on experimental data from CEN/TC351 leaching tests and/or databases (e.g. [7] or [8]) and data on specific building/site characteristics. Field test could be conducted in order to validate the models and simulations.
	Data needed and data availability	same as design phase
	Applicability	same as design phase

Comparability		
Requirements for comparability		
Simulation data are comparable if based on the same scenarios and hypothesis. All the parameters and hypothesis should be mentioned and explained together with the results in order to improve comparability. The specific requirements regarding the environmental compatibility of construction products are / will be defined nationally by the Member States.		
Sources of information		
Source / Bibliography / Web links		
[1] European Commission. Enterprise and Industry Directorate-General. Chemicals and Construction. Construction. DS 041/051 rev.12. Indicative list of regulated dangerous substances possibly associated with construction products under the CPD, march 2012, 31p. [2] EEA – European Environment Agency. The European environment – state and outlook 2010. Freshwater quality — SOER 2010 thematic assessment. 34p. Available on : http://www.eea.europa.eu/soer/europe/freshwater-quality [3] CEN/TC351/WG1 N179. Generic horizontal dynamic surface leaching test (DSLT) for determination of surface dependent release of substances from monolithic or plate-like or sheet-like construction products (TS-2), 31p. [4] CEN/TC351/WG1 N162. Generic horizontal up-flow percolation test for determination of the release of substances from granular construction products (TS -3), 37p. [5] Parkhurst, D.L. and Appelo, C.A.J, User's Guide to PHREEQC (Version 2)-A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. U.S. Geological Survey Report No. 99-4259, Denver, Colorado, 1999, Available on : http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/ [6] Meeussen, J.C.L. ORCHESTRA: An object-oriented framework for implementing chemical equilibrium models, Environmental Science and Technology, 2003, p. 1175–1182. [7] ECN – Energy research Centre of the Netherlands (P. Seignette), Vanderbilt University – USA (D.S. Kosson), DHI – Denmark (O. Hjelmar), Hans van der Sloot Consultancy (H. van der Sloot). LeachXS database. Available on : http://www.leachxs.com/lxsdll.html [8] CSTB – France (M.O. Lupsea, N. Schiopu), INSA Toulouse (L. Barna), ENTPE (N. Laurent). Lixibat – a database for the leaching characteristics of building products. World Sustainable Building Conference, 18-21 October, 2011 Helsinki, Finland [9] CEN/TR 15858 Construction products – Assessment of the release of regulated dangerous substances from construction products based on the WT, WFT/FT procedures, 2009, 37p.		
Free comments		
Writer and date (last up-date)	Nicoleta SCHIOPU, CSTB	02/2012, updated 11/2012

5.3.3 Environment – Transversal – Ecomobility

The indicator presented in this chapter relates to the following issue:

- Eco-mobility
  - Eco-mobility potential of a building in its context

We consider here the transport-related environmental impacts of buildings due to commuting transport, taking into account the location and urban context features. As buildings and urbanism choices induce transport for users, and as environmental impacts of transport are significant, it is important to assess this contributor and progress towards eco-mobility. Including users' transport enlarge the system boundaries of sustainable building assessment.

Indicator
Name – Definition / description
Eco-mobility potential of a building in its context It refers to environmental impacts due to commuting transport, or daily journeys, of persons using the building, attributable to the building and its characteristics, including its location features. From the location data of the building (urban context, distance from the building to key points), data on the occupants and from statistical data (national or regional transport surveys), the number of journeys, mode of transport and environmental impacts are identified or calculated. Eco-mobility potential of a building in its context could be an indicator on its own, but it is also considered as a contributor for others indicators. Transport is one contributor to the building environmental performances calculation. In LCA terms, transport of users during operation phase is one of the processes included within the system boundaries.
Definition / description of sub-indicators
The transversal issue of the mobility is expressed through various indicators : - It could be expressed as kilometres travelled by transportation mode as a mid-point indicator. - Because occupants' mobility is considered as a contributor to the environmental performance of the building (as energy services, construction products, etc.), environmental profiles of each transport mode are associated to kilometres travelled. According to adopted standard and environmental data, the environmental indicators are the usual LCA ones: primary energy, greenhouse gas emissions, air pollution, waste, water consumption, etc. - It would be possible to translate mobility in terms of time spent into transport as a social indicator. (non developed here)
Units
Mobility as an indicator: - kilometres by transportation mode, by square meter or occupant, or by dwelling; Mobility as a contributor : - usual units for LCA indicators

Principles of classification		
Currently, there is no method of classification for this contributor and no one at the building scale (sum of various contributors).		
Weighting and aggregation		
There is no need of aggregation of the different environmental impacts at the contributor scale. When a building is assessed from an LCA point of view, including construction products life cycle, energy and water operational services, if users' transport is also considered as a contributor, it is necessary to adopt coherent assumptions and the same units in order to have consistent, comparable and "aggregable" figures. However, it is recommended to keep results separated, so as to be able to clearly distinguish between impacts due to the building itself and those due to users' transport.		
Validity		
Issue of concern	This contributor has strong links with the protection of the environment: resources, biodiversity, ecosystems and climatic systems. Social and economic links also exist, but are not considered here.	
Explanation		
Commuting transport causes environmental impacts directly or indirectly. Fuel consumption, manufacture and maintenance of vehicles and ones for infrastructure could be translated into consumption of energy, resources, greenhouse gas emissions, etc. Interest in mobility would be also a way to question the urban form (density), the behaviour of occupants face transportation networks, the lifestyle choices (quality of life provided by housing)... Issues of concern could be social ones too. Because the contributor 'mobility' is translated into impacts on the environment, justifications on how the indicators expresses the impact on the issues of concern can be found in each indicator description document. Transport of users has generally significant environmental impacts comparing to the building itself.		
Justification		
If we consider a single-family house (140 m²NFA) built in France and with a BBC labelling (= level of the new French regulation for new buildings RT2012), its energy consumption for heating, cooling, domestic hot water and ventilation is about 50 kWh/m²NFA/year (non-renewable primary energy). If this house is located in a rural setting and has four occupants (about 35 m² per occupant), the consumption of energy for commuting transport is between 100 and 140 kWh/m²NFA/year, that is 2 to 3 times the energy consumption for regulated uses! The significance of the impacts of this contributor is very important for the energy consumption but also for greenhouse gas emissions, etc.		

Object of assessment			
Building		x	Adequacy type of building with its location.
Site			
Location		x	
Other (specify)			

<table>
<tr><th colspan="4">Characterisation</th></tr>
<tr><td colspan="3">Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)</td><td>X</td></tr>
<tr><td colspan="3">Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))</td><td></td></tr>
<tr><td colspan="3">Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)</td><td></td></tr>
<tr><td colspan="4">Status of the indicator</td></tr>
<tr><td colspan="4">In France, the methodology for this contributor was developed by CSTB, with the financial support of the Caisse des Dépôts et Consignations and the Effinergie association, between 2010 and 2012.
A first version of the tool was tested on 21 buildings with various stakeholders. An official version of this tool will be available at the beginning of 2013.
Methodology and tool are currently available only for residential and office buildings.
Expectations are very high from many stakeholders and dissemination will begin in 2013.</td></tr>
<tr><th colspan="4">Assessment</th></tr>
<tr><td>Design phase</td><td>Calculation / assessment method</td><td colspan="2">From the knowledge of distance between the building and several key points (work, amenities, etc.) and from statistical data about mobility adapted to the building context (location, occupants, distance to key points), it is possible to calculate conventional distances travelled each year with each transport mode for all the building occupants.</td></tr>
</table>

	Data needed and data availability	Assessment can be done from generic or specific data, according to the assessment phase, the knowledge of the building by the assessor. The urban context: - Name of the town (allows to identify if a survey exists for this town) - Urban context (centre, suburb, suburbs, rural, etc.) and urban zoning (predominantly rural areas, suburbs of urban centres of over 100,000 inhabitants, etc.) (allows to use the good mobility dataset) Buildings characteristics: - The building area is required in order to express results per area unit and to estimate the number of occupants if the exact number is unknown. - The number of occupants and their age class is required (people travel more or less depending on age and do not go to the same destinations). If the data is unknown, statistic data will be used to define conventional occupants. Distances - 15 keys points have been defined. The user must identify (using Google maps or equivalent) the distance to the first key point around (the nearest school, nearest supermarket, etc.). If the distance cannot be identified, statistic data are proposed (commute transport). Mobility data - Number of journeys per day per person according to his/her age - Occurrence of destinations for 100 journeys for a person of a given age group - Distance to destinations according to the urban zoning - Modes of transport used according to the reason of travel or as the distance travelled.
	Applicability	The challenge is in the availability of : - Statistical data specific for the location of the building (in France there is 80 regional surveys dataset...but 36000 municipalities); - Statistical data illustrating the influence of design elements on occupants behaviour (bicycle park spaces, restricted number of car park spaces , etc.) or the close proximity of the building to a public transport stop (currently, there is no difference in the assessment results if the building is located 500 m or 5 m from a tram stop); - Environmental data/profile for the different modes of transport for one person-kilometre.
Operation phase	Measurement / assessment method	The method remains the same, but more specific data can be used.
	Data needed and data availability	Same type of data as during design. Regarding occupant behaviour, input data may come from a survey.

Applicability	The assessments during the design or operation phase have different objectives. If we estimate a 'potential' during the design phase, during the operation phase, it is more the assessment of a current situation. If it seems possible to compare the environmental performance of buildings with a conventional method during the design phase, the assessment during the operational phase mixes the building and its occupants' lifestyle assessment.

Comparability

Requirements for comparability

To be comparable, or at least placed on the same performance scale:

The assessment results to be compared have to concern the same functional unit.

Moreover, it is necessary to use :

- the same methodology
  - same key points (if we consider that people do not have the same needs from Finland to Spain in terms of amenities, we could have a rule that the selected key points include 80% of the weekly usual destinations)
- the same type of data
  - statistical data from survey (defined itself by the same methodology, the vocabulary must be shared...)
  - environmental data (same boundaries, same indicators' methodology)
- the same units (per occupant, adult equivalent, square meter of dwelling).

Sources of information

Source / Bibliography / Web links

All documents will be available on the Effinergie website at the beginning of 2013: www.effinergie.org .

ELODIE LCA tool (developed by CSTB, now including a users' transport module): www.elodie-cstb.fr

A similar approach has been chosen for the assessment of urban planning : GES OpAm (http://www.certu.fr/fr/_Ville_et_environnement-n29/Air-n142/IMG/pdf/fiche_OpAmDGALN_version_170111.pdf)

Free comments		
Writer and date (last up-date)	Alexandra LEBERT, CSTB	20/11/2012

5.3.4 Society – Health and Comfort

The indicators presented in this chapter relates to the following issues of indoor environment. The aspects dealt with are Indoor air quality, Thermal conditions and Visual conditions which may have effects on health and comfort.

5.3.4.1 Indoor air quality – Concentrations of various pollutants

Problems of indoor air quality are recognized as important risk factors for human health in both low-, middle- and high-income countries. Indoor air is also important because people spend a substantial proportion of their time in buildings. In residences, schools, day-care centres, retirement homes and other special environments, indoor air pollution affects population groups that are particularly vulnerable owing to their health status or age (WHO 2010).

Indicator
Name – Definition / description
Indoor air quality Indoor air quality is assessed in terms of concentration levels of pollutants.
Definition / description of sub-indicators
Several pollutants are considered. The different pollutants are considered and assessed independently from each other. WHO gives guideline values for the following parameters of indoor air quality [1]: – Benzene: unit risk 1 µg/m^3 6x10 $^{-6}$ – carbon monoxide: 7mg/m^3 (24 h) – formaldehyde: 0.1 mg/m^3 (30 min average) – nitrogen dioxide: 200µg/m^3 (1 hour average) and 40µg/m^3 (annual average) – PAH B[a]P (benzo-a-pyrene): unit risk for lung cancer 1 ng/m^3 8.7 x 10 $^{-5}$ – Trichloroethylene: unit risk estimate µg/m^3 4.3 x 10 $^{-7}$ – Tetrachloroethylene: 0.25 mg/m^3 (annual average) – radon excess: life time risk for non-smokers 0.6 x 10^{-5} Bq/m^3 (and 15 x 10^{-5} for smokers) – naphtalene: 0.01 mg/m^3 (annual average) WHO also gives guideline values for biological indoor air pollutants [2]: – dampness – mould In addition, CO_2 should be included.
Units
ppm or µg/m^3 or RH (%) or cfu (colony forming unit)
Principles of classification
When benchmarking, the value of the indicator is compared to the average (or typical) value of the building type in question considering the purpose of use, corresponding ventilation requirement and occupant density.
Weighting and aggregation
No weighting or aggregation. In each class, limit values are always defined for all parameters considered.

Validity	
Issue of concern	Human health, economic prosperity (productivity)

Explanation

Problems of indoor air quality are recognized as important risk factors for human health in both low- and middle- and high-income countries. Indoor air is also important because people spend a substantial proportion of their time in buildings. In residences, day-care centres, retirement homes and other special environments, indoor air pollution affects population groups that are particularly vulnerable owing to their health status or age (WHO 2010).

The primary aim of these guidelines is to provide a uniform basis for the protection of public health from adverse effects of indoor exposure to air pollution, and to eliminate or reduce to a minimum exposure to those pollutants that are known or are likely to be hazardous. (WHO 2010)

Thus, acceptable indoor air quality can be achieved through source control and pollutant dispersion, and in particular through: application of low-emission materials and products; proper selection of the devices and fuels used for combustion indoors; the venting of products to the outdoor air; and ventilation control. (WHO 2010)

The WHO report (2010) also explains the specific health risks related to each parameter.

Justification

UN's Commission on Sustainable development CSD has approved a follow-up to the two earlier sets of sustainability indicators. It defines indicators of Sustainable Development [3]. It is claimed that these indicators cover the issues that are relevant to sustainable development in most countries. One of the themes addressed by CSD is Health including Health status and Health risks and Mortality.

It has been assessed that a 10% change in general IAQ symptoms corresponds to 1% change in work performance (productivity) [4]. The principle for the calculation of the loss of productivity is the assessment of decreased work performance and increased number of sick leaves. The influence of temperature, ventilation and perceived air quality are assessed.

The Renewed EU Sustainable Development Strategy was adopted by the European Council in June 2006. It is an overarching strategy for all EU policies which sets out how we can meet the needs of present generations without compromising the ability of future generations to meet their needs. It points out four key objectives and seven key challenges for sustainable development [5]. One of the four key objectives is economic prosperity and one of the seven key challenges is Public health.

With regard to Mortality the use of polluting fuels poses a major drawback for IAQ and burden on the health of poor families in developing countries. More than half of the world's population rely on dung, wood, crop waste or coal to meet their most basic energy needs. Cooking and heating with such solid fuels on open fires or stoves without chimneys leads to indoor air pollution. This indoor smoke contains a range of health-damaging pollutants including small soot or dust particles that are able to penetrate deep into the lungs. In poorly ventilated dwellings, indoor smoke can exceed acceptable levels for small particles in outdoor air 100-fold. Exposure is particularly high among women and children, who spend the most time near the domestic hearth. Every year, indoor air pollution is responsible for the death of 1.6 million people – that's one death every 20 seconds. [6]

The European exposure study EXPOLIS showed that exposure to VOCs was higher at homes than at outdoors or work places. [7] [8]

Object of assessment			
Building		X	
Site			
Location		x	Pollutants and particles present in outdoor air, for instance due to transport vehicles, influence indoor air quality. Radon varies according to local geological characteristics.
Other (specify)			

Characterisation	
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))	X
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	

Status of the indicator

The status of the indicator is partly based on the fact that the WHO guidelines have been developed for general use.

The building regulations in different European countries typically include specific regulations about the risk of health. For example in Finland, D2 says: "Buildings shall be designed and constructed in such a way that the indoor air does not contain any gases, particles or microbes in such quantities that will be harmful to health, or any odours that would reduce comfort." [9]

The indicator is included in important methods and standards that give guidelines for the sustainability assessment of buildings. These include:

- ISO 21929-1 Sustainability indicators – Part 1 – Framework for the development of indicators and a core set of indicators for buildings
- ISO 21931 Framework for methods of assessment of the environmental performance of construction works – Part 1 – Buildings
- SBA common metrics [10] (CO_2 and formaldehyde concentration are included).

Assessment		
Design phase	Calculation / assessment method	Simulation with the help of multi zone simulation tools such as: - CONTAM (Multizone Airflow and Contaminant Transport Analysis Software) [11] - COMIS (Conjunction of Multizone Infiltration Specialists, multizone airflow simulation program) [12] [13]. Alternative method for chemical substances, solution-oriented, when simulation tools can't be used: - Choice of low-emitting construction products, especially indoor finishes, glues and coverings, - Constructive solutions limiting radon infiltration from the ground, - Design features of ventilation (and air filtration) systems, limiting pollutants concentration.
	Data needed and data availability	Information about spaces and dimensions, occupation, ventilation conditions and pollutant source / sink strengths. Knowledge of chemical emissions of construction products, measured and attested by an official laboratory.
	Applicability	Commercial and free models and software are available. But in certain countries, such simulation tools are not broadly known and spread. CO_2 and RH can be easily anticipated by calculation models (static or dynamic) but for chemical substances (formaldehyde, VOCs…), it is much more complex.
Operation phase	Measurement / assessment method	Measurement of concentrations in accordance with relevant standards ISO 16000-6 gives guidelines for the measurement of volatile organic compounds. ISO 16000-3 gives guidelines for the measurement of formaldehyde. ISO 16000-3: Indoor air – Part 3: Determination of formaldehydes and other carbonyl compounds – Active sampling method. ISO 16000-6: Indoor air – Part 6:Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID.
	Data needed and data availability	Specific equipments are needed.
	Applicability	Equipments and standards are available. But in certain countries or regions, there is a lack of well-equipped laboratories.

Comparability
Requirements for comparability
In principle the simulations with the help of available methods and also the measurements on the basis of available measurement methods give comparable results. The biggest source of error and uncertainty is the sampling phase. Case specific outer conditions (temperature humidity and ventilation) need to be considered.

Sources of information		
Source / Bibliography / Web links		

[1] World Health Organization 2010. WHO guidelines for indoor air quality: selected pollutants. The WHO European Centre for Environment and Health, Bonn Office.

[2] World Health Organization 2009. WHO guidelines for indoor air quality: dampness and mould. WHO Regional Office for Europe.

[3] Indicators of Sustainable Development: Guidelines and Methodologies, Third Edition (2007), UN publications, 93 pages.

[4] Olli Seppänen. Indoor environment, health and productivity impacts, (In Finnish) FINVAC The Finnish Association of HVAC societies. Forssa 2006.

[5] COM(2009) 400 final. Communication from the Commission to the European Parliament the Council, the European Economic and Social Committee and the Committee of Regions. Mainstreaming sustainable development into EU policies: 2009 Review of the European Union Strategy for Sustainable Development. The 7 key challenges are: Climate change and clean energy, Sustainable transport, Sustainable consumption and production, Conservation and management of natural resources, Public health, Social inclusion, demography and migration, Global poverty.

[6] World health organization http://www.who.int/mediacentre/factsheets/fs292/en/

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[8] Saarela, K., Tirkkonen, T., Laine-Ylijoki, J., Jurvelin, J., Nieuwenhuijsen, M.J., Jantunen, M. 2003. Exposure of population and microenvironmental distributions of volatile organic compound concentrations in the EXPOLIS study. Atmospheric Environment 37, 5563–5575

[9] http://www.finlex.fi/data/normit/1921-D2s.pdf (in Finnish)

[10] A Framework for Common Metrics of Buildings. Pilot Draft Version 2009 (1.7) Sustainable Buildings Alliance 2009.

[11] Walton G. N., Dols W. S. CONTAM User Guide and Program Documentation, NISTIR 7251, *National Institute of Standards and Technology, Gaithersburg MD,* October 2005, Last revision December 14, 2010. http://www.bfrl.nist.gov/IAQanalysis/CONTAM/index.htm

[12] Feustel H.E. 1999. COMIS – An international multizone air-flow and contaminant transport model. Energy and Buildings. Vol. 30, pp. 3–18.

[13] Feustel H.E. and Smith B. V. COMIS 3.0 – User's Guide. http://epb.lbl.gov/comis/docs/composite.pdf – http://comis3.sourceforge.net/

Free comments		
Writer and date (last up-date)	Helena Järnström, VTT	09/2011, updated 11/2012

5.3.4.2 Thermal comfort

There are certain physiological limits of conditions that humans can operate, and indeed one of the main reasons for buildings is to provide a space sheltered from the weather to achieve comfortable indoor conditions. The required indoor conditions are related to the thermal balance of a human body, and therefore related to environmental parameters such as temperature, humidity or air velocity, but also to physical activity and transpiration, or indeed clothing. There is currently an international discussion regarding how strict this heat balance theory applies to the evaluation of thermal comfort, and the adaptive comfort theory suggests that humans consciously or unconsciously modify constantly our behaviour to adapt to hygro-thermal conditions, so the thermal balance equations can not be strictly applied. There are also researchers that argue that there are cultural and symbolic thermal sensibilities, which can not be homogenised by standard levels (Healy, 2008).

In terms of relationship with subjects of concern, thermal comfort is directly related to the "health and comfort" subject of concern is a social dimension, as adequate comfort levels can improve quality of life and occupant's health.

It can be also related to the "costs" as subject of concern with an economic dimension, as generally maintaining tight levels of thermal comfort (according to "traditional" vision of thermal comfort) would require an increased control and management of the space, and this could mean higher costs on equipment and/or energy costs. On the other hand, occupants who feel comfortable could increase the productivity, thus thermal comfort representing an economic benefit.

Finally, the limitation and comfort ranges in buildings have a direct relationship with the energy use, and associated environmental and economic impacts, as ensuring that comfort levels are tightly controlled generally means a higher building energy use in operation.

With low-energy and passive buildings, with reduced heating systems and in certain cases no heating system at all, the question of spatial and temporal comfort, in all seasons, is raised again.

During summer, hygro-thermal comfort is crucial under certain conditions, especially during heat waves, when high temperatures combine with a heat island effect in large urban areas. This phenomenon is expected to happen more frequently in the future, due to global warming.

Indicator
Name — Definition / description
Indoor Thermal Environment / Thermal comfort / Hygro-thermal comfort Indicators to describe hygro-thermal comfort in indoor environments.
Definition / description of sub-indicators
PMV (Predicted Mean Vote) : It is an index defined in ISO 730:2005 that predicts the mean value of the votes of a large group of persons on the 7-point scale (+3 hot +2 warm +1 slightly warm 0 neutral -1 slightly cool -2 cool -3 cold), based on the heat balance of the human body. Thermal balance is obtained when the internal heat production in the body is equal to the loss of heat to the environment. $PMV = [\ 0.303 \ .\ \exp(-0.036.M) + 0.028\ ]\ .\ L$ where M = metabolic rate, L = thermal load

PPD (Predicted Percentage Dissatisfied): Quantitative measure of the thermal comfort of a group of people under a particular thermal environment, also defined in ISO 730:2005.

$$PPD = 100 - 95 . \exp(-0{,}03353.PMV^4 - 0{,}2179 . PMV^2)$$

Operative temperature: Uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation and convection as in the actual non-uniform environment.

Percentage of hours outside a temperature range.

Air temperature

Percentage of hours outside a temperature range.

Relative Humidity (RH)

Air velocity

Units

PMV (-3, +3)

PPD (%)

Operative temperature (degree Celsius)

Percentage of hours outside a temperature range

(% winter, % summer)

Air temperature (degree Celsius)

Percentage of hours outside a temperature range

(% winter, % summer)

RH (%)

Air velocity (m/s)

Principles of classification

Human's thermal sensation is mainly related to the thermal balance of the body as a whole. This balance is influenced by physical activity and clothing, as well as the environmental parameters. Numerous indices for the assessment and design of thermal comfort conditions have been developed during the past 50 to 60 years. One of the most widely used indices in moderate thermal environments, the PMV index (predicted mean vote), predicts the mean value of the overall thermal sensation of a large group of persons as a function of activity (metabolic rate), clothing insulation, and the four environmental parameters: air temperature, mean radiant temperature, air velocity, and air humidity. The principles are described in detail in the standard ISO 7730:2005. Indoor comfort is frequently classified just by setting indoor air temperatures ranges.

Weighting and aggregation

Three different "Comfort categories" are proposed in ISO 7730:2005 which suggest the possibility of using some values for the different sub-indicators depending on the comfort requirements for a particular building. The higher comfort requirements of a building, the narrower comfort bands will be accepted.

This issue of classifying comfort is also considered in the standard EN 15251:2007 which suggests up to four categories, and tries to distance itself from the implication of closer control being superior, and to avoid the penalization of buildings with less control. However, it is suspected that categories are still used as quality indicators (Santamouris & Sfakianaki 2009). Recent research in this area even suggests that strictly controlled comfort bands offer no relative satisfaction benefits to occupants, compared to larger bands of comfort (Arens et al. 2010).

Validity		
Issue of concern	Human Health & Wellbeing Indirectly, productivity and Energy Costs (Economic) , and Primary Energy Use and CO_2 (Environmental)	
Explanation		
Comfort is a measurement of satisfaction with the environment, and therefore is directly related to wellbeing. There is also a relation to health, as when buildings cannot cope with the weather or climate conditions, it can result in discomfort or distress for the occupants. In cases of exposure to unusually high or low indoor temperatures can be related to health issues (see justification). In a working environment, higher comfort levels and higher occupant satisfaction could lead to a higher productivity. Summer comfort is also a critical issue that will become more problematic with global warming, impacting both health and productivity. Different levels of comfort requirements are related to different energy use, and therefore related to energy costs and primary energy use and associated CO_2 emissions.		
Justification		
During the heat wave in France in 2003, prolonged exposure to unusually high temperatures was a factor related to the premature death of nearly 15,000 people. Deaths from cardiovascular diseases are directly linked to exposure to excessively low indoor temperatures for long periods. It appears that 50–70% of excess winter deaths are attributed to cardiovascular conditions, and some 15–33% to respiratory diseases (WHO, 2011). Air temperature could influence performance at the work place indirectly through its impact on sick building symptoms or satisfaction with air quality. The temperature can be also directly related to productivity (Seppanen and Fisk, 2006).		

Object of assessment		
Building	X	Indoor environment. The assessment should be carried for each differentiated occupied space in the buildings (what in building simulation is called a building zone).
Site	(x)	Potentially related to site conditions and microclimate (solar access, wind effects, vegetation, albedo effect, etc), which could affect indoor environment.
Location	(x)	Potentially affected by the location, both at climate level (different climates could have different thermal expectations) and at microclimate level (e.g. urban heat island effect)
Other (specify)		

Characterisation	
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))	X

<table>
<tr><td colspan="3">Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)</td></tr>
<tr><td colspan="3">Status of the indicator</td></tr>
<tr><td colspan="3">Probably the most traditional indicator for evaluating thermal comfort is operative temperature, or even just air temperature. These have been adopted in building regulations and indoor environment classification methodologies, but completely ignore internal boundary conditions of a human (metabolic rate and clothing).
The number of hours outside a temperature range can also be used as an indicator of comfort . This is suggested for example by the Sustainable Building Alliance (2009). CIBSE Guide for Environmental Design (2006) also uses percentage of hours above a certain temperature to assess summer overheating risks.
A more holistic approach, focusing on occupant aspects, is needed to evaluate validity of design and dimensioning criteria for future buildings. Standards such as ISO 7730:2005 use Fanger's Predicted Mean Vote (PMV) method for calculation of thermal comfort. PMV method was developed based on laboratory and climate chamber studies to estimate human thermal comfort in buildings and are an excellent starting point for estimating thermal comfort. However, this PMV method is applicable only to steady-state, uniform thermal environments. Therefore, it can take into account neither time-dependant heat transfer phenomena nor local examination of different body parts, and more detailed modelling of comfort is proposed by various researchers (Tuomaala, 2002, Zhang, 2003).</td></tr>
<tr><td colspan="3">Assessment</td></tr>
<tr><td rowspan="3">Design phase</td><td>Calculation / assessment method</td><td>Simple: Expert review
Detailed: Calculated or simulated value</td></tr>
<tr><td>Data needed and data availability</td><td>Simple: Review of plans, HVAC details and control / management
Detailed: Building modelling and calculation of comfort levels PMV, PPD, temperatures, etc. Simulation preferably with standard normative such as EN 13790, or with recognised building software (for example, those which have passed the Building Energy Simulation Test (BESTEST).</td></tr>
<tr><td>Applicability</td><td>In some cases information could be gathered from building codes and regulations. For example, the tools used for certification of building energy performance generally specify some details on the indoor thermal conditions.</td></tr>
<tr><td>Operation phase</td><td>Measurement / assessment method</td><td>Simple: Expert review, simple survey methods, simplified measurements.
Detailed: Continuous measurement of multiple variables (e.g. air temperature, mean radiant temperature, air velocity, humidity)
Detailed post-occupancy evaluation (POE) surveys.</td></tr>
</table>

	Data needed and data availability	**Simple:** Plans, HVAC details, user's opinion, expertise in building management. Easily available. **Detailed:** Data on the multiple variables, rarely available as it requires installation of sensors. POE studies require expertise and time for their application. Information about measurement of variables related to thermal comfort can be found in EN ISO 7726:2001 Ergonomics of the thermal environment — Instruments for measuring physical quantities. The measurement instrumentation and measurement locations shall meet the requirements given in the standard.
	Applicability	Simple methods to evaluate comfort are generally done just by expert review and individual decision making, or in a very simplified way by requesting information from users, or by measuring air temperatures in some particular times. More detailed analysis including the monitoring over time of multiple variables that affect comfort. Detailed POE studies are infrequent.

Comparability

Requirements for comparability

Many existing energy simulation and calculation tools can calculate the thermal comfort. Some standards such as ANSI/ASHRAE 140.2001 (BESTEST) serve to test such software for comparability.

Standard methods for measurement of indoor thermal environment conditions are also available (e.g. ISO 7726:2001).

Sources of information

Source / Bibliography / Web links

- ARENS, E., HUMPHREYS, M. A., DE DEAR, R. & ZHANG, H. (2010) Are 'class A' temperature requirements realistic or desirable? Building and Environment, 45, 4–10.
- ANSI/ASHRAE Standard 140-2001 Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs (BESTEST)
- (CIBSE , 2006) Guide A. Environmental design , The Chartered Institution of Building Services Engineers London
- EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
- EN ISO 7730:2005 Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.
- EN ISO 7726:2001 Ergonomics of the thermal environment. Instruments for measuring physical quantities
- (Healy, 2008) Air-conditioning and the 'homogenization' of people and built environments. Building Research & Information, 36, 312–322.
- Santamouris & Sfakianaki (2009), COMMONCENSE Comfort monitoring for CEN standard EN15251 linked to EPBD
- (Seppänen and Fisk, 2006) Some Quantitative Relations between Indoor Environmental Quality and Work Performance or Health, ASHRAE
- SHOVE, E., CHAPPELLS, H., LUTZENHISER, L. & HACKETT, B. (2008) Comfort in a lower carbon society. Building Research & Information, 36, 307–311.
- Steskens P., Loomans (2010): T1.3 Performance Indicators for Health and Comfort. Public

report of the project PERFECTION – Performance Indicators for Health, Comfortand Safety of the Indoor Environment.

- Sustainable Buildings Alliance, A Framework for Common Metrics of Buildings, Pilot Draft, Version 2009.
- Tuomaala P. 2002. Implementation and evaluation of air flow and heat transfer routines for building simulation tools, Doctoral Dissertation, VTT Publications 471, Espoo, Finland.
- World Health Organization, 2011, Environmental burden of disease associated with inadequate housing.
- Zhang H. 2003. Human Thermal Sensation and Comfort in Transient and Non-Uniform Thermal Environments, Doctoral Dissertation, University of California, Berkeley, USA.

Free comments		
Writer and date (last up-date)	Patxi Hernandez	09/2011, updated 11/2012

As a conclusion, indicators for comfort are relatively clear although their application is generally over-simplified. Perhaps one of the reasons that comfort is not evaluated in detail is that there is little consensus on "appropriate" levels of comfort, and narrowing the comfort bands and establishing stricter control levels is not considered good practice by many building professionals and researchers.

Therefore, within SuPerBuildings it is suggested that a flexible approach is taken for the acceptance of indicators of comfort, until more robust research can define what are the desired levels of comfort. TECNALIA suggests that valuable indicators could include:

- Operative temperature. Percentage of hours out of a temperature range (% hours above a temperature in summer, % hours below a temperature in winter).
- Predicted Mean Vote / Predicted Percentage Dissatisfied (EN ISO 7730).

5.3.4.3 Visual comfort

Visual comfort is one of the key components of the indoor environment performance.

The main requirement for a satisfactory visual comfort is a sufficient illuminance for the specific visual tasks carried out in the room. Light influences the daily rhythm and well being of humans in a physiological, psychological and biological way.

Indicator	
Name – Definition / description	
Visual comfort Requirements for visual performance and daylight	
Definition / description of sub-indicators	
Illuminance The Illuminance of a surface is defined as the luminous flux per unit area at any point on a surface exposed to incident (artificial) light. [1] **Daylight factor** The daylight factor is the ratio of the illuminance from the skylight measured on a horizontal surface within the room to the illuminance from a CIE (Commission Internationale de l'Eclairage) overcast sky measured on a horizontal plane which has an unobstructed access to the hemisphere of the sky.	
Units	
Illuminance [lux] **Daylight factor** [%]	
Principles of classification	
Classes may be defined for each sub-indicator. Attention has to be paid to high classes. Indeed, comfort is a matter of balance and adequacy to user's needs, so very high values of daylight factor and illuminance are not desirable, because they may be disturbing.	
Weighting and aggregation	
From a general point of view, for comfort or IAQ indicators, two levels of assessment exist: at the premise/room scale and at the building scale. The indicators proposed above are appropriate for a single space/room, or space by space. An average value for the entire building is not appropriate because it leads to a "compensation" between good and bad performance. A better aggregation principle may be based on a combination of classes covering all the spaces of the building (e.g. see EN 15251:2007 – Annex I). [2]	
Validity	
Issue of concern	Comfort Indirectly: Energy resources, Thermal comfort
Explanation	
Visual comfort is one of the key components of the indoor environment performance. The main requirement for a satisfactory visual comfort is a sufficient illuminance for the specific visual tasks carried out in the room. Visual comfort is linked to Energy resources concerns mainly because of cooling loads due to glazed façades exposed to sun, and of electricity consumption for artificial lighting.	
Justification	
Light influences the daily rhythm and well-being of humans in a physiological, psychological and biological way [3]. Daylight factor is a measure for amount of natural light. The lack of daylight in a dwelling is a criterion for sub-standard housing / unhealthy housing. It is beneficial to take advantage of daylight inside buildings. When natural daylight is not sufficient,	

it is important to have enough illuminance provided by artificial lighting, with a level adapted to the activity.

Natural daylight has some drawbacks, as variability and glare. In summer, the challenge is to let enter the daylight without letting enter the sun, so as to limit overheating and energy consumption due to cooling.

Artificial lighting implies electricity consumption, so energy management is necessary to ensure both comfortable visual conditions and a rational use of energy. Artificial lighting should be considered as a complement to daylighting.

The selected indicators and sub-indicators are described in the European standards (see bibliography). They are also proposed within the set of key indoor performance indicators by the FP7 project PERFECTION [4].

Object of assessment			
Building		X	Design features (architectural and technical)
Site		x	Local masks around the building may limit the quantity of daylight entering the building.
Location		x	Remote masks may limit daylight (e.g. mountains) Climate (solar irradiation)
Other (specify)			

Characterisation	
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))	X
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	

Status of the indicator

Illuminance is generally accepted indicator described in:

- EN 12464-1:2003, Light and lighting – Lighting of work places – Part 1: Indoor work places. This standard has been revised and republished in July 2011.

Daylight factor is described in the standard:

- EN 15251:2007, Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.

Assessment		
Design phase	Calculation / assessment method	Illuminance quick and numeric calculation methods are described in the standard EN 12464-1:2011, Light and lighting – Lighting of work places – Part 1: Indoor work places. Daylight Factor is a ratio that represents the amount of illumination available indoors relative to the illumination present outdoors at the same time under overcast skies. Daylight Factor is typically calculated by dividing the horizontal work plane illumination indoors by the horizontal illumination on the roof of the building being tested and then multiplying by 100 [5]. Assessment may be based on numeric calculation (various software tools exist, more or less complex) or possibly on measurement with scaled model in test chamber.
	Data needed and data availability	Building geometry, orientation, exterior barriers, shading devices, glazing type, reflection of surfaces.
	Applicability	No indication of possible difficulties.
Operation phase	Measurement / assessment method	Measurement on site using lux meters.
	Data needed and data availability	Measurement in situ.
	Applicability	No indication of possible difficulties.

Comparability
Requirements for comparability
Prerequisites vary by the building types. Calculation use simplified methods and assumptions – real conditions may vary. Details in the above mentioned standards.

Sources of information

Source / Bibliography / Web links

[1] Huovila A., Prokka J., Huovila P., Steskens P., Loomans M., Botsi S., Sakkas N.: D1.5 A Generic Framework for Key Indoor Performance Indicators. Public report of the project PERFECTION – Performance Indicators for Health, Comfort and Safety of the Indoor Environment

[2] EN 15251:2007. Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and

acoustics.

[3] Steskens P., Loomans M.: T1.3 Performance Indicators for Health and Comfort. Public report of the project PERFECTION – Performance Indicators for Health, Comfort and Safety of the Indoor Environment

[4] FP7 PERFECTION project – http://www.ca-perfection.eu

[5] New Buildings Institute in partnership with the University of Idaho and University of Washington: Daylighting Pattern Guide. Online, 2011. Available at http://patternguide.advancedbuildings.net. Accessed 24.6. 2011.

[6] EN 12464-1:2011. Light and lighting – Lighting of work places – Part 1: Indoor work places.

Free comments		
Writer and date (last up-date)	Antonin Lupisek, CTU	10/2011, updated 11/2012

5.3.5 Society – Culture

About culture, two issues have been considered:

- Architectural quality
  - Aesthetic quality
- Cultural heritage
  - Monument or monumental value / Historical value

These two indicators, explicitly mentioned in the SuPerBuildings DOW, are qualitative ones. They need a specific development because they are generally lacking in existing sustainable building assessment tools. Moreover, the questions of culture and aesthetics are difficult to objectivate because the opinion of people varies inside a same community, also varies from one country/region to another, and over time.

5.3.5.1 Architectural quality – Aesthetic quality

This part was developed by KIT (Andrea Immerdörfer), assisted by ÖGUT (Christiana Hageneder) and VTT (Tarja Mäkeläinen).

Schematically, Architectural Quality can be broken down into two main aspects:

- functionality
- aesthetic quality.

Indicator

Name – Definition / description

Architectural quality – Aesthetic quality

This indicator considers architectural quality in terms of aesthetic quality (functional quality is covered elsewhere, as many guides exist).

Nevertheless, the aesthetic quality of a building can be decisive for its long-term success (making the resources invested in it worthwhile). It is also important for the buildings contribution to urban design and "place making" and contributes to the cultural value of the built environment.

What makes "good" architecture, in particular good architectural aesthetics is notoriously difficult to define and most architects will shy away from any attempt at categorising or defining what such qualities are. One fear is that the skills of architects are compromised by reducing architectural aesthetics to "pattern books".

What makes good architectural quality is:

- dependent on the context (site, socio-cultural, environmental...)
- often subjective
- near-impossible to define objectively
- changes over time with fashion etc.

Where attempts at including architectural aesthetics into sustainability indicator systems are being made, these therefore concentrate on processes of arriving at good aesthetics. e.g.:

- asking for several design options to choose from
- undertaking a formal design competition
- including arts and crafts e.g. by local artists or craftsmen

However, such processes do not per se guarantee good quality, therefore an attempt is being made further a more rational process of decision making within such processes.

Definition / description of sub-indicators

- Architectural Quality in the design stage (design competition, considering alternative design options)
- Architectural Quality in the tender stage (as obligation on contractor)
- "Educated" decision making (as part of a design competition, considering alternative design options)
- Public art in/ on/ around buildings (mandatory inclusion of art work)

N.B. This form concentrates on "educated" decision making (as part of a design competition, considering alternative design options)

Units

(qualitative)

Principles of classification

Weighting and aggregation

There is no inherent reason for weighting the indicators.

Validity		
Issue of concern	Cultural values, Long term property value, Resources	
Explanation		
If a building remains attractive due to its aesthetic value, the resources used for constructing it and the capital invested in it were worthwhile and "safe".		
Justification		
According to ISO 21929-1: "Aesthetic quality is relevant to the attractiveness of a site (curtilage), municipality or city and can contribute to the well-being and quality of life of people who live, work or visit there. Creating and maintaining aesthetic quality can contribute to well-being and quality of life of communities, can help to mitigate the impacts of cultural globalization and can become an incentive for sustainable economic development." [1] Some buildings remain successful even though they are not environmentally sustainable, others may have many qualities, but go out of fashion and become unpopular.		
Object of assessment		
Building	x	Outer skin of building, interior
Site	(x)	(Landscaping may be included to some degree)
Location		
Other (specify)		
Characterisation		
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	(x) for artwork	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))		
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	x	
Status of the indicator		
The indicator is currently subject to many discussions and considered to be important, but it is felt to be difficult to approach the issue in an appropriate manner. German systems BNB/DGNB use two related indicators: – conducting a design competition, – integrating public art into the project. ISO 21929-1 includes aesthetic quality and states the following [1]: *"5.2.14 Aesthetic quality* *The indicator measures the aesthetic quality of the building with the help of the following criteria:* – *integration and harmony of the building with the surroundings* – *impact of a new building or renovation of an existing building on the cultural value of a site (curtilage), neighbourhood, local heritage and built environment*		

<table>
<tr><td colspan="3">– consideration during the planning and design phases of the requirements of various interested parties for aesthetic quality.
The indicator is a qualitative indicator. The assessment in the design phase and the in-use stage should be executed and established as objectively as possible. The size, importance and architectural and social relevance of the building or the development should be taken into account when defining the assessment procedure and complexity. In some cases, being in accordance with local building and urban planning regulations may be sufficient. In other cases, processes such as expert assessment, architectural competitions or stakeholder commissions may be required.
This impact shall be evaluated in order to protect and add to the existing architectural and cultural value of the surrounding area.”</td></tr>
<tr><td colspan="3">Assessment</td></tr>
<tr><td rowspan="3">Design phase</td><td>Calculation / assessment method</td><td>A process for “educated” decision making was devised (see Annex), which follows the principles of a scoring model.
A structure for the model is proposed, but essentially must be tailored to the project / to client’s needs.
Qualitative assessment:
<u>sub-indicator 1:</u> have design alternatives been considered (as part of a competition or informally)? yes/ no
<u>sub-indicator 2:</u> has a scoring model been used ? yes/ no
(see Annex for further info)</td></tr>
<tr><td>Data needed and data availability</td><td>As proof for fulfilling the above indicator requirements the following is required:
– Documentation that proves that there were different design alternatives
– The scoring model used (should have at least 3 criteria)
(see Annex for further info)</td></tr>
<tr><td>Applica-bility</td><td>As there is a relatively high level of freedom for making one’s own scoring matrix with very specific, but non-obligatory examples that may be used, implementation is considered easy and straight forward.</td></tr>
<tr><td rowspan="3">Operation phase</td><td>Measurement / assessment method</td><td>(only applicable for substantial extensions and alterations, in this case similar criteria as for new-build apply)</td></tr>
<tr><td>Data needed and data availability</td><td></td></tr>
<tr><td>Applica-bility</td><td></td></tr>
<tr><td colspan="3">Comparability</td></tr>
<tr><td colspan="2">Requirements for comparability</td><td></td></tr>
<tr><td colspan="3">This indicator can only be made comparable by using the simple yes/ no criteria as described above.</td></tr>
</table>

Sources of information		
Source / Bibliography / Web links		
[1] ISO 21929-1:2011, Sustainability in building construction – Sustainability indicators – Part 1 – Framework for the development of indicators and a core set of indicators for buildings [2] Sheffield City Council on 3.2 Urban Form and City Skyline Guidance – Architectural Quality http://sccplugins.sheffield.gov.uk/urban_design/strategic_guidance_urban_guidance.htm [3] Gann D, Salter A, Whyte J: Design Quality Indicator as a tool for thinking, Building Research & Information (2003) 31(5), September–October, 318–333 [4] Macmillan, S: Added value of good design, Building Research & Information (2006) 34(3), 257–271		
Free comments		
Writer and date (last up-date)	Andrea Immendoerfer (Christiana Hageneder, Tarja Mäkeläinen)	09/2011, updated 11/2012

Annex – Suggestion for decision making process – Methodology
(summary, see more details in D4.2 report)

The methodology is based on the principle of scoring models used in economic decision making theory.

Essentially, the decision making authority (the client, the planning department, the competition jury...) has to devise their own decision making matrix to suit their specific needs.

Setting up the scoring matrix – necessary steps are:

- Setting of criteria to define aesthetic quality
- Finding local examples of buildings that perform well and badly in these indicators
- Decide whether a formal scale is necessary (numeric or graphic- a simple bar, which could be marked at any point would suffice)
- Optional: define weighting factors for the criteria

Assessment process:

When assessing aesthetic qualities of a given set of design options each criterion needs to be discussed for each design and a score assigned which would range at an appropriate position between the good and the bad example.

All criteria would need to be discussed, but the ultimate decision need not necessarily reflect the score (in an extreme case, the decision could in the end be based on just one criterion).

N.B.: the indicator requirement is only that the thought process is followed through, not that the decision is a logical consequence there-of.

A schematic example of a **scoring matrix** is provided below:

		Scores						
Issue to be assessed **(to be defined by SuPer-Buildings)**	**bad local example** **(to be set by jury)**	**1**	**2**	**3**	**4**	**5**	**good local example** **(to be set by jury)**	**weight** **(to be set by jury)**
Use of local materials			x					10%
Local character				x				20%
Location of the building	...						...	...
...								...
...								...

Example Criteria:

<u>Appropriate Location of the building</u>

Does the building type in terms of its function fit the location? Bad examples would be a residential building next to a motorway; a shopping centre in the middle of nowhere…

<u>Local character</u>

Whether the building fits the local character of the area has several aspects – it can take into account the scale of the building in relation to its neighbours, proportions, certain ornamental elements, relationship to an open space or the landscape etc.

IMPORTANT: the jury has the freedom to decide which is the negative end of the scale and which is the positive side – a contrast may be desired or undesired.

Trendiness:

A building that reflects current tastes and fashion very well may be in danger of going out of fashion and therefore become unattractive prematurely, compared to a neutral, timeless design. On the other hand, it may reach iconic status representing a certain time period over decades to come.

Resistance to weathering / aging of materials / appropriate use of materials

These aspects can be about the durability of materials in their original state or about predicting and proactively addressing weathering effects. Such effects can be predicted to some degree and a visualisation of the weathered building could be requested from the architect. Some weathering may be unavoidable and even intended (e.g. that of untreated wood). Other aspects to be considered in this context are:

maintainability of the elements and materials chosen,

possibility for easy replacement,

local sources/ local availability of key materials

Detailing that is appropriate for the material used

Resistance to graffiti

Though varying in degree, graffiti is an almost ubiquitous issue, though some it does not for all buildings distract from the original aesthetic concept to the same degree. Issues to be considered are:

Does the choice of materials allow easy cleaning?

Can the aesthetic concept "rise above" the graffiti – i.e. does the aesthetic design intention remain clear and attractive despite the graffiti?

Good collaboration between trades and consultants

Close and early coordination between the trades and consultants involved in a construction project can ensure that aesthetics will not be compromised by the continuous layering of requirements. For example the aesthetics of a facade can be compromised by outlets for ducts. A ceiling plan can be compromised by the random placement of air inlets, fire sprinklers, alarms, emergency lights. Early collaboration ensures all necessary service elements can be integrated into the design in an aesthetically pleasing manner.

Criteria by Sheffield City Council [2]:

Sheffield City council has defined certain guidance principles on Architectural Quality including aesthetic aspects – these are:

- Building form, profile, scale and massing
- Creating a connection with the street
- The design of the space around the building
- Detailing
- The use of contemporary styles and materials
- Contemporary Materials Selection

Discussion

The indicator for architectural quality as defined above is treated as a **process** related indicator, even though architectural quality in its true sense closely relates to the **object** that is the building. In so far the indicator presented here is a substitute for a building quality indicator. The reason for this was touched upon in the indicator definition but will be repeated here.

N.B.: An interesting discussion on this topic can be found in the detailed D4.2 report.

Future steps

Architectural aesthetics as an indicator for sustainability is not mature. Initial attempts at including it exist, but much further research and in particular practical trials on real-life projects are needed. It has to be discussed whether despite the sound reasoning for the process related approach taken here, an “object related” approach would be conceivable after all and if so, what would be universally valid criteria in this case.

When emphasizing the link between architectural aesthetics and sustainability another research topic may emerge. The notion that sustainability requirements can compromise the creative freedom of the architect persists. A study could be undertaken that specifically examines the design approach in buildings that are acknowledged to be particularly sustainable. Research questions could be:

1. Are these buildings different in terms of aesthetics to conventional buildings?
2. Are there aesthetical elements that communicate their sustainability visually to the public?
3. Are there apparent deficiencies in aesthetics due to sustainability requirements?
4. Can strategies be derived for dealing with conflicts between sustainability requirements and aesthetics?

5.3.5.2 Cultural heritage – Monument or monumental value / Historical value

The importance of protection and conservation of cultural heritage is in general in the field of ‘**quality of life’** (social subject of concern). However, it is also linked to economic indicators. Indeed, whether a building is considered heritage or not will have an impact on its **economic value** and may also have an impact on the value of surrounding property.

In some way maintaining cultural heritage has a positive effect on the environment as it helps to preserve material resources. However; the effect on the environmental subjects of concern will vary depending on for example the state of preservation (e.g. only the façade is original or the whole building), or the energy performance of the building (it may have a negative effect on CO_2 emissions if it has a bad energy performance and no efforts are made to improve it).

Finally, it is sometimes linked with architectural quality as the aesthetic quality of a building is one of the factors that can justify the cultural heritage value of a building. Inversely, new buildings with a high architectural quality may constitute the cultural heritage of tomorrow.

Indicator	
Name – Definition / description	
Cultural heritage – Monument or monumental value/Historical value The characterisation of the historic, historical, aesthetical significance of a building or site.	
Definition / description of sub-indicators	
The heritage value of a building or site is a result of a complex (quite often very subjective) decision process. Since part of this decision process is subjective, pragmatic (depending on a situation not directly connected to a building, such as the economic situation of a country) or emotional, a clear indication of a definition cannot be given. Giving a definition for 'cultural heritage' would imply that 'heritage value' is an intrinsic property of a building or site, and this is not the case. Examples will be given below. The decision process, to decide "which building is heritage, and which building is not" is more enlightening when it comes to 'cultural heritage value'.	
Units	
Non-quantitative or, very rarely, semi-quantitative	
Principles of classification	
Usually at least a vague classification exists: a hierarchy between different levels of heritage value (e.g. full protection, or only parts of the building), even though this may differ from country to country, and even region to region. This hierarchy is, as earlier stated, quite often subjective. **Hierarchy in classification systems** Usually we find different ways of 'listing' heritage buildings. What is quite general is the upper level, where the entire building or site is protected, and where for every single intervention the approval of the monument administration is necessary. This does not mean that nothing can be changed. 'Lower' levels are less general, and the systems differ from country to country and from region to region.	
Weighting and aggregation	
Validity	
Issue of concern	Culture – Cultural Heritage
Explanation	
Cultural heritage is a very broad, and often vary vague issue. Its definition has been changing over time, and still does nowadays. Starting from the late 18th century, with the culmination in the 19th century (a period often referred to as 'the romantic era', the longing for the past, the nostalgia, as a countermovement for the hyper-rationalism in the late 17th and 18th century), official systems have been established, in which buildings and sites are officially protected: a community or administra-	

tion cannot do whatever they want with historic buildings: all works or interventions have to be approved by a commission, which is supposed to work completely independent from any government, to ensure an objective evaluation of every work or intervention done on these buildings. Belgium was the first European country in which this Royal Commission for Monuments and Sites (Commission Royale des Monuments et Sites) was established, already in 1835. This movement goes together with the so-called revival architecture styles, referring to ancient architecture (the best-known is no doubt the gothic revival style, extremely popular in countries such as Belgium, France, Germany, the UK, Italy...). This is all a reflection of the growing respect for what our ancestors performed in the past, that should be admired, and not be forgotten.

WHY is a building or site considered as cultural heritage?

The reasons may be:

Aesthetical grounds: this is of course very subjective. What we consider as aesthetic is not for everyone, and taste changes in time. The disaster of the massive destruction of the art nouveau patrimony in Brussels is a sad example of how buildings, in our eyes very elegant and beautiful, have been demolished in the second half of the 20th century. The massive destruction of the medieval city walls (remains of which are now considered to be very interesting and beautiful) in Belgian cities under the French and Dutch reign of the beginning of the 19th century is another example.

Iconic aspect: this is somewhat related to the aesthetical aspect of a building, to its engineering performance, or to its unique nature.

Architectural grounds: aesthetics, style, organisation or functionality of the building, the fact it is a witness of changing habits or tendencies in society, etc.

Technical grounds: when the building is a representative of novel developments in engineering, in building techniques, in building materials, etc.

Age: in general we see that 'extremely old' buildings are often automatically considered as heritage, but it depends of course strongly on the country or region. The factor 'scarceness' plays an important role (as it does in the other factors as well).

Historical grounds: can be the building be associated with historical events? Did a famous artist or person live there? Needless to say that 'historical grounds' is a very large field. Everything is in a way historical. We also mention for instance buildings related to political or ideological movements. Historical grounds may include 'social history', 'scientific history', etc.

'Historical layers' factor: The presence of these historical layers in itself is a valuable source of information, and therefore protection-worthy, even if the building in itself could have less or almost no architectural value.

The above mentioned reasons are evidently not always enough to consider a building as heritage or not. And here appear other factors, not specifically linked to the buildings or sites themselves, but can be described as 'pragmatism'. Is it really worth to protect this building, is it feasible, does it block or improve the development of a region or city part, ...

A building is more likely to be considered as 'heritage' if it is preserved in a better way. The state of 'preservation' is one of these rare parameters that may be expressed quantitatively (we refer to the Dutch standard NEN 2767 in which a methodology is developed to give a number to the state of maintenance of a building, a methodology that is now extrapolated to be used to evaluate the state of conservation of cultural heritage, in the CEN/TC 346 "Conservation of cultural property").

A building is more likely to be considered as 'heritage' when it is more unique.

Another very pragmatic reason why a building, that 'deserves' to be heritage, or not, is because the 'heritage'-status usually decreases the economic value of a building: the idea of having an extra administration that interferes with everything that one does in a house, diminishes the price on the market.

As a conclusion we might say that 'cultural heritage value' is not inherent on a building. It is a value given to a building or an object, because of very different reasons. Some of them are directly linked to the building, some of them are not. These non-building related issues could be historic, but also very pragmatic: a simple financial reason could be enough to consider a building as heritage, or not.

Justification		
The justification for the recognition of buildings as 'heritage' is again a complex matter. The conservation of heritage will not have a severe impact (that we can calculate!) on the environment (even though we must realize that conservation and re-use of existing buildings has evidently a good impact compared to newly constructed buildings, because no or less energy is required to produce materials, to transport and assemble them) or other important issues nowadays. The importance of protection and conservation of heritage is in general in the field of 'quality of life'. Above mentioned was the factor 'nostalgia', the desire to keep in touch with the past, with the achievements of our ancestors. It is a psychological factor. It gives a context which we know and which is constant, it gives trust, with all of the secondary positive side-effects. The feel of context and its positive psychological consequences is sometimes objectivated as 'identity', where heritage is a material expression of this identity.		
Object of assessment		
Building	x	
Site	x	
Location	x	
Other (specify)		
Characterisation		
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)		
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))		X
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)		
Status of the indicator		
This indicator is hardly objectivated. In most cases it is a mixture of objective and pragmatic factors, and depends often quite strongly on the opinion of sometimes even a single person. It is generally lacking in existing sustainable building evaluation tools. However, the standard ISO 21929-1:2011 "Sustainability in building construction – Sustainability indicators – Part 1: Framework for the development of indicators and a core set of indicators for buildings" specifically mentions cultural heritage value; however, not as an indicator itself. Instead the norm mentions the impact of a new building or renovation of an existing building on the cultural value of a site, neighbourhood, local heritage and built environment as one of the criteria to describe the aesthetic quality of a building. This standard thereby emphasizes the contextual importance of cultural heritage: a heritage building is not an isolated museum object. On the contrary, it should be considered as an object that is in dialogue with the surroundings, an object that 'moulds' the surroundings. Something to take into account when developing changes in the surroundings.		

<table>
<tr><th colspan="3">Assessment</th></tr>
<tr><td rowspan="3">Design phase</td><td>Calculation / assessment method</td><td>Not a clear method available, since heritage value is a subjective value. Important factors (as mentioned above) are to be taken into account, even though that may not suffice to reach a final decision. Pragmatic reasons and the skill of the monument administration to 'defend' a building play an important role to make a building considered as heritage or not.</td></tr>
<tr><td>Data needed and data availability</td><td>History: building history – written sources – 'tales' (information that is never written down, traditions…), archaeological sources (non-written, such as excavation, but also building archaeology: dendrochronology, stratigraphy, compositions of mortars, stones... visual changes in facades, masonry...).</td></tr>
<tr><td>Applicability</td><td>Because of the largeness of the indicator, in principle applicable to every single construction or site.</td></tr>
<tr><td rowspan="3">Operation phase</td><td>Measurement / assessment method</td><td rowspan="3">(same as for design phase)</td></tr>
<tr><td>Data needed and data availability</td></tr>
<tr><td>Applicability</td></tr>
<tr><th colspan="3">Comparability</th></tr>
<tr><td colspan="3">Requirements for comparability</td></tr>
<tr><td colspan="3">Comparability is difficult to achieve. Simply the example, where an identical building in a rural context can be considered as heritage, whereas the same building in a fashionable part of a city might be considered as almost banal, illustrates this.</td></tr>
<tr><th colspan="3">Sources of information</th></tr>
<tr><td colspan="3">Source / Bibliography / Web links</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Free comments</td><td colspan="2"></td></tr>
<tr><td>Writer and date (last up-date)</td><td>Yves Vanhellemont, BBRI</td><td>07/2011, updated 11/2012</td></tr>
</table>

It would be probably useful to distinguish more clearly this indicator on cultural heritage and the previous one dealing with aesthetic quality, because it seems that they apply to different kinds of buildings. In most of cases, cultural heritage may be considered for old and existing buildings of a certain age, and aesthetic quality may be considered as an expression of contemporary architecture and art, for new buildings or buildings refurbished in a contemporary way. But in certain cases, new buildings may contribute since the beginning of their life to the cultural heritage of a city or country.

It is necessary, in order to make this indicator more applicable, to explicit the different criteria, but in a way that every country or region can find in these criteria, and in the related weighting, the main features of its cultural identity, that may differ from one country or region to another. Moreover, contextual factors are very important; they often influence the heritage character of a building. Subjectivity is inherent to this indicator.

It seems more important that the indicator reflects the cultural identity features of each country than to search a strict comparability of the indicator between countries.

5.3.6 Economy

Seven indicators were initially developed, but only 2 indicators and 2 sub-indicators have been chosen as key indicators. Nevertheless, the approach and the developed material were judged by the other SuPerBuildings partners as extremely interesting and valuable. See deliverable D4.2 for more information.

The 2 indicators and 2 sub-indicators relate to the following issues:

- **Economic value of 'goods' on the long term**
  - **Life Cycle Costs**
    - **Capital cost**
    - **Costs in the operational phase**
- **Prosperity versus risks**
  - **Long term stability of value.**

Note: Life cycle costs are not limited to the 2 chosen sub-indicators.

As economic indicators are relatively new in sustainable buildings assessment systems, it seems important to focus on the most crucial ones, and to develop a detailed description and assessment method based on a good consensus. The other indicators are interesting too, but it is a little premature to develop them with the same level of detail and consensus. See D4.2 report for detailed information.

The following figure shows the different Cost categories related to Buildings:

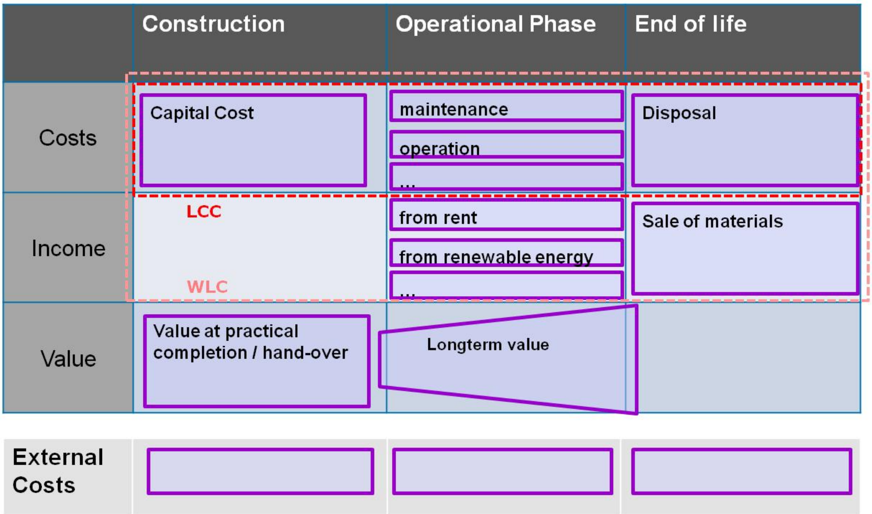

Figure 9. Cost categories.

5.3.6.1 Economic value of 'goods' on the long term – Life Cycle Costs

The principles of ISO 15686-5:2008 on LCC are referred to where-ever appropriate, however with one difference: land costs are generally included, as they are difficult to separate out. In this particular aspect the work of SuPerBuildings is closer to the approach of CEN TC350 (EN 15653-4:2011, Sustainability of construction works – Assessment of buildings – Part 4: Framework for the assessment of economic performance 2011).

No suggestions for detailed assessment methods are provided at this point, only general types of suitable assessment methods are given.

Indicator	
Name – Definition / description	
Life Cycle Costs The LCC approach is that of total cost of ownership. Only costs/ expenses, not incomes, that occur in the course of the life cycle are being captured. These have to be defined in accordance with ISO15686-5. Furthermore assumptions and parameters related to life cycle costs need to be defined. As a special case the income from electricity generated with PV or similar could be included as negative costs. This approach can also be applied to incomes from recycling. LCC generally fits the point of view of owner occupiers. If used during the design stage it can be used as a tool for design optimization. Here the trade-off between one-off (capital) cost and ongoing (in-use) costs is being weighed up.	
Definition / description of sub-indicators	
In accordance with ISO 15686-5:2008: - Construction costs - Operational costs - Maintenance costs - End of life costs	
Units	
Currency unit e.g. EUR as absolute value or discounted to present day value (net present value/ NPV).	
Principles of classification	
A typical NPV value over a given reference study period needs to be established with which the building to be assessed can be compared An assessment scale can be set in terms of performance of XXX% above or below the typical value. Generally the net present value of incomes should exceed the net present value of outgoings. In the operational phase the assessment will be qualitative and process related.	
Weighting and aggregation	
N/A – while Present Value is a way of aggregating sub-indicators (i.e. different types of cost – as above) and while these sub-indicators should be declared separately, they are not separately assessed and weighted.	
Validity	
Issue of concern	- economic capacity for actions, long-term property value - seen from the perspective of owner-occupiers, also architects/ engineers
Explanation	
LCC looks at weighing up up-front capital expenditure against long-term financial requirements for costs arising in the operational phase. It thus weighs up economic capacity to act at point of completion against long term capacity to act. It can also help support decisions that have a positive effect on long term value of the building.	

Justification

Traditionally buildings are being built with an aim to minimize up-front capital cost – follow-on costs are often ignored or neglected. It is a core notion of sustainability to consider long-term effects of buildings. LCC considers the total cost of ownership. The use of LCC can show the advantageousness of some options that carry higher initial capital costs, but result in lower over-all costs, if ongoing costs over a number of years are taken into account. It is particularly important for showing the advantageousness of investment in energy efficiency and renewable energy, therefore an important tool for giving sustainable buildings a fair chance, despite higher up-front costs.

Object of assessment

Building		x	
Site		x	Land costs should be included in line with CEN TC350
Location		-	(N.B. the location influences land costs and thus will feed into the assessment however its influence is very much indirect and there is no direct assessment of the location)
Other (specify)		(x)	In the operational phase life cycle costing could be undertaken for only part of the building (elements due for refurbishment, specific equipment...)

Characterisation

Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	X
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))	
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	x (see oper. phase)

Status of the indicator

Actual implementation of the indicator is not yet mature, but ready in principle, due to recent endeavours in standardisation.

An LCC indicator is already being used in German sustainability assessment systems BNB and DGNB and BREEAM Golf

Standards: ISO 15686-5:2008, EN 15643-4:2011

Assessment

Design phase	Calculation / assessment method	Present value calculation is the most common methodology, though costs calculated year by year (as annuity) are acceptable, too Benchmarks have to be defined for different types of buildings and their uses. Comparability has to be ensured (for type of building, type of use, types of cost captured, parameters, assumptions, conventions) EU expects lower LCC for sustainable buildings (about 10% lower than standard buildings)

	Data needed and data availability	– As a general rule the “typical scope of costs” given in ISO 15686-5:2008 Fig. 3 should be used – therefore typically costs arising from construction, operation, maintenance and end-of-life should be included. Income is in principle not included, but could be included as negative (avoided) cost (in particular when considering renewable energy installations. – discount rate – length of reference study period (50 years is proposed)
	Applicability	Calculation is straight forward in principle, but maintenance costs and end-of-life costs can be difficult to obtain.
Operation phase	Measurement / assessment method	NPV or annual cash flows (see above)
	Data needed and data availability	In the operational phase this indicator refers to the capturing of actual data and good data management. The assessment will be qualitative and process related. Separate LLC may be performed for partial replacements and refurbishment. A smaller number of cost items may be looked at in this context; “typical scope of costs” given in ISO 15686-5:2008 Fig. 3 should still be used for guidance.
	Applicability	(as for design phase)

Comparability

Requirements for comparability

- Use of same discount rate in the options to be compared
- Use of same system boundaries – “typical scope of costs” given in ISO 15686-5:2008 Fig. 3 or similar should be used in order to clearly show what is inside / outside the calculation.
- It needs to be made clear, which cost items are included and which are not.

Sources of information

Source / Bibliography / Web links

ISO 15686-5:2008 Buildings and constructed assets – Service life planning: Part 5, Whole life cycle costing

EN 15643-4:2011 Sustainability of construction works — Sustainability assessment of buildings — Part 4: Framework for the assessment of economic performance

Pelzeter, A.: Asset Management with Life Cycle Costs, ERES Conference proceedings 2006.

Free comments

LCC is considered essential in nearly all standardization work (ISO TC59 SC17, CEN TC350).

The choice of discount rate is crucial and can either reflect the point of view of the current generation (the investor) or that of future generations.

One key issue is the distinction between whole life costs (which also takes into account income streams) and life cycle costs (which only looks at cost). although ISO 15686-5: 2008 clearly defines these terms – however, the terms are sometimes used interchangeably, causing some confusion.

Writer and date (last up-date)	Prof. Thomas Lützkendorf, Andrea Immendörfer	5/10/2011

Sub-indicator : Capital Cost (=capital expenditure for the construction project)

Indicator	
Name – Definition / description	
Capital Cost The indicator aims to identify the additional capital costs for energy efficiency and sustainability in comparison to average buildings of same type and use. Capital cost is the actual initial outlay required to pay for the construction project. It includes construction and non-construction costs. Capital costs are costs incurred on the purchase of land, buildings, construction and equipment to be used in the production of goods or the rendering of services, in other words, the total cost needed of bringing a project to a commercially operable status. Often when planning and designing a sustainable building it is feared that there will be considerable extra capital costs/ construction costs. Sustainable buildings however should not be a luxury solution. Additional capital costs should be limited. Capital costs can be assessed in their own right or be considered as part-indicator of LCC, WLC or “cost/ value ratio at point of hand-over”.	
Definition / description of sub-indicators	
Additional costs for energy efficiency and sustainability can be seen as a sub-indicator of the absolute capital costs.	
Units	
currency unit e.g. EUR	
Principles of classification	
additional costs in comparison to average buildings of same type and use acceptable maximum additional capital costs need to be established, as basis for a comparison. an assessment scale can be set in terms of performance of XXX% above or below the maximum acceptable value. Switzerland restricts extra cost to a maximum of 10% extra for highly energy efficient buildings as part of the MINERGIE standard. Values of 0-10% extra can be found in literature [1].	
Weighting and aggregation	
N/A	
Validity	
Issue of concern	- economic capacity for actions - seen from the perspective of the investor and owner occupiers

Explanation		
Limiting additional capital cost will result in capital being available for other actions.		
Justification		
Fear of increased capital costs is one of the main reasons for not building sustainably, making this an important and necessary indicator		
Object of assessment		
Building	X	
Site	X	
Location		
Other (specify)		
Characterisation		
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	X	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))		
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)		
Status of the indicator		
- Capturing and managing capital costs is core to financial planning / capital budgeting of construction projects - Indicator is used by Swiss scheme MINERGIE Standards: - CEEC European Committee of Construction Economists: Code of Measurement for Cost Planning, 2008		
Assessment		
Design phase	Calculation / assessment method	Comparison with average capital/ construction costs for buildings of the same type and use. Usually values from literature are being used, i.e. values compiled by professional bodies for architects, surveyors etc.

<table>
<tr><td rowspan="2"></td><td>Data needed and data availability</td><td>ISO 15686-5:2008 Fig.3 can be used for guidance on cost items:
Construction costs:
- professional fees
- temporary works
- construction of asset
- initial adaptation or refurbishment of asset
Non-construction costs:
- land and enabling works
- finance
- strategic management (consultancy or client cost)
- administrative costs (costs to client)
in addition cost of land may be included (in line with CEN TC35).</td></tr>
<tr><td>Applica-bility</td><td>Is in principle done as part of general capital budgeting, hence easy to apply.</td></tr>
<tr><td rowspan="3">Operation phase</td><td>Measurement / assessment method</td><td>Would be used for refurbishment projects or substantial repairs, in this case assessed in the same way as in the design phase.</td></tr>
<tr><td>Data needed and data availability</td><td>Only part of the above cost items may be included, depending on type of project (e.g. when refurbishing).</td></tr>
<tr><td>Applica-bility</td><td>Is done as part of general capital budgeting.</td></tr>
<tr><td colspan="3">Comparability</td></tr>
<tr><td colspan="3">Requirements for comparability</td></tr>
<tr><td colspan="3">It is important that the year of data capture, treatment of VAT, system boundaries of costs captured etc. are comparable. It needs to be made clear, which cost items are included and which are not.</td></tr>
<tr><td colspan="3">Sources of information</td></tr>
<tr><td colspan="3">Source / Bibliography / Web links</td></tr>
<tr><td colspan="3">[1] E.g. Unholzer, M., Bartels, D., Lützkendorf, T., Spars, G. (2010): Energiekonzepte und ihre Auswirkungen auf die Lebenszykluskosten von Bürogebäuden – Methoden und Erkenntnisse aus der wissenschaftlichen Begleitung von energetisch hochwertigen Gebäuden im Rahmen des Forschungsprojektes EnOB (Energieoptimiertes Bauen), Facility Management Kongress, Frankfurt am Main, 2010
- CEEC European Committee of Construction Economists: Code of Measurement for Cost Planning, 2008
- Davis Langdon: Cost of green revisited, Davis Langdon, 2007</td></tr>
</table>

Free comments		
In social housing there is an indirect relationship between level of capital costs and the socially relevant issue of "affordability" of housing. However, affordability is not a quality of a building in a strict sense. Issues may arise due to confidentiality of cost data.		
Writer and date (last up-date)	Thomas Lützkendorf Andrea Immendörfer	May 2011

Sub-indicator : Costs in the operational phase

Indicator
Name – Definition / description
Costs in the operational phase It covers the building related costs that arise after the hand-over for the on-going running / operating of the building. It comprises maintenance, servicing, repair and replacement, as well as utility costs to ensure the building operates as intended. Costs of the use stage are influenced by decisions made at design stage. However, as sometimes the implications of decisions are not understood or discarded because they do not affect the investor (except for in an owner-occupier scenario) these costs are often not sufficiently considered. Aiming for low replacement costs and low utility costs will also mean aiming for low environmental impacts resulting from utility use or manufacture of spare parts. Operational phase costs in use can be assessed in their own right or be considered as part-indicator of LCC or WLC.
Definition / description of sub-indicators
sub-indicators are: - operational costs - maintenance costs indicators can also be subdivided in - costs that affect the tenant - costs that affect the management/ the landlord (both as defined by ISO 15686-5:2008, see also "data requirements" on this form)
Units
currency unit e.g. EUR as absolute value or discounted to present day value (Net present Value).
Principles of classification
Typical costs in use need to be established with which the building to be assessed can be compared. Often only a limited time period is considered as reference study period (e.g. 50 years). An assessment scale can be set in terms of performance of XXX% above or below the typical value.

The sub-indicators may or may not be assessed separately in this way, but the relevant figures should be shown separately. In the operational phase the assessment may include qualitative and process related elements relating to data capture.		
Weighting and aggregation		
N/A – the sub-indicators are only declared separately, but not separately assessed and weighted		
Validity		
Issue of concern	economic capacity for actions, indirectly also: long-term property value Seen from the perspective of owner-occupier, tenants, landlords (as management costs)	
Explanation		
Keeping in-use costs low in the long term will improve the economic capacity of owners and end-users for other activities. Low operating costs may also contribute to the building's long-term attractiveness and hence its long-term value.		
Justification		
Traditionally buildings are being built with an aim to minimize up-front capital cost – follow-on costs are often ignored or neglected. It is a core notion of sustainability to consider long-term effects of buildings, in this case helping to safeguard long-term prosperity.		
Object of assessment		
Building	x	
Site	x	
Location	-	
Other (specify)		
Characterisation		
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	x	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))		
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	(x) see oper. phase	
Status of the indicator		
used in the following systems & standards: – Managers of large property portfolios will capture costs of the operational phase in their accountancy and management systems – In sustainability assessment systems the indicator is so far only covered as sub-indicator of life cycle costs. standards:		

<table>
<tr><td colspan="3">– CEEC European Committee of Construction Economists: Code of Measurement for Cost Planning, 2008</td></tr>
<tr><td colspan="3">Assessment</td></tr>
<tr><td rowspan="3">Design phase</td><td>Calculation / assessment method</td><td>There is generally a lack of reliable data on in-use costs (e.g. maintenance costs), though this varies from country to country (e.g. relatively good data availability in the UK).</td></tr>
<tr><td>Data needed and data availability</td><td>ISO 15686-5:2008 Fig.3 can be used for guidance on cost items :
operational cost:
– rent (if relevant)
– insurance
– cyclical regulatory cost
– utilities (energy, water, drainage) N.B. As a deviation from ISO, income from renewable energy installations should be included as negative costs.
maintenance:
– maintenance management
– adaptation or refurbishment of asset in use
– repairs and replacement of minor components/ small areas
– replacement of major systems and components
– cleaning
– ground maintenance
– redecoration
Depending on the target group not all cost items may be of interest, however, it needs to be clear what is included and what is not.</td></tr>
<tr><td>Applicability</td><td>There is generally a lack of reliable data on in-use costs (e.g. maintenance costs), though this varies from country to country (e.g. relatively good data availability in the UK).</td></tr>
<tr><td rowspan="3">Operation phase</td><td>Measurement / assessment method</td><td>In the operational phase this indicator refers to the capturing of actual data and good data management. The assessment can be qualitative and process related or alternatively make quantitative comparisons with other buildings or standardised figures.</td></tr>
<tr><td>Data needed and data availability</td><td>(as above)</td></tr>
<tr><td>Applicability</td><td>Establishing such costs is part of general building/ facilities management.</td></tr>
</table>

Comparability		
Requirements for comparability		
It needs to be made clear, which cost items are included and which are not.		
Sources of information		
Source / Bibliography / Web links		
– CEEC European Committee of Construction Economists: Code of Measurement for Cost Planning, 2008 – various national standards		
Free comments		
Writer and date (last up-date)	Thomas Lützkendorf Andrea Immendörfer	May 2011

5.3.6.2 Prosperity versus risks – Long term stability of value

Indicator
Name – Definition / description
Long-term stability of value / positive development of value or conversely, long-term financial risk This indicator assesses certain building characteristics that can be expected to help safeguard the value of a building in the long term and that mean the building is less affected by market related fluctuation in value.
Definition / description of sub-indicators

Depending on approach used – can be assessed using consequential sub- indicators such as:
– options for easy adaptation to change of use
– ability to meet future legislative requirements (e.g. Energy legislation)
– ability to adapt to climate change (e.g. to greater over-heating risks)
– certain physical characteristics that have been proven to remain in demand over decades (e.g.” neutrality “ of spaces)
– financial risk indicators: (e.g. according to TEGOVA- PaM):
  – (Market)
  – (Location (suitability/ standing/ transport infrastructure/ facilities/ environment))
  – Property (Construction/ layout/sustainability/energy performance)
  – Cash flow
N.B. Only building/ site related indicators should be considered in this context

Units
(depending on indicators chosen may or may not be quantitative units)

Principles of classification			
So far no mature assessment method is available. Examples for the assessment of potential sub-indicators are: change of use adaptation: – qualitative assessment levels need to be defined, capturing building characteristics that allow for easy adaptation Financial risk indicators : – (proprietary risk assessment tool to be used such as TEGOVA PaM)			
Weighting and aggregation			
Depending on the choice of indicator(s), weighting factors may have to be introduced.			
Validity			
Issue of concern	long-term property value, economic capacity for actions Seen from the perspective of owner occupiers, investors, owners.		
Explanation			
This indicator is the direct expression of the subject of concern “long-term property value“. If a building retains its value in the long term, the capital invested in it is safe. As such it contributes to the capacity for action of its owners and investors.			
Justification			
It is a core notion of sustainability to consider long-term effects of buildings If the building is built to anticipate future developments or risks (regulatory, environmental...) it is more likely to retain its value in the long term.			
Object of assessment			
Building		x	
Site		x	
Location			
Other (specify)			
Characterisation			
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)			
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))			x
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)			(x) see oper. stage
Status of the indicator			

This indicator is not mature yet. However, the German systems DGNB and BNB for offices as well as a pilot scheme for housing do currently use "value-stability" indicators, based on certain building characteristics related to flexibility and future proofing (ability to meet likely future legislative requirements, in particular regarding energy efficiency).

Standards:

- TEGOVA: PaM – European Property and Market Rating

Assessment

Design phase	Calculation / assessment method	Stability of value should be ensured, meaning that there should be a positive development of the property value: – compared to similar properties and in relative terms and – compared to the capital cost at point of completion in absolute terms. Tools to be used can include property rating tools, Monte Carlo Simulation [Monte Carlo simulations make it possible to incorporate the uncertainty of valuation parameters, in particular of future cash flows, of discount rates and of terminal values]
	Data needed and data availability	Certain technical or architectural characteristics – generally available from building documentation.
	Applicability	Based on qualitative predefined levels, assessment as such is expected to be straight forward.
Operation phase	Measurement / assessment method	Same as for the indicator "cost/ value ratio" in the operational phase, the actual property value can be tracked over time and compared against the initial capital costs. An internal rate of return can be worked out in this way. Qualitative assessment of process of capturing the value or quantitative assessment, comparing to a desired rate of return.
	Data needed and data availability	The market value at regular intervals
	Applicability	

Comparability

Requirements for comparability

If qualitative assessment methods are being used, these allow for a certain amount of personal judgement by the assessor, therefore total comparability may not be given.

Sources of information

Source / Bibliography / Web links

TEGOVA: European Property and Market Rating: A Valuer's Guide, 2003

Lorenz, D. and Lützkendorf, T. 2008, Sustainability in Property Valuation – Theory and Practice,

Journal of Property Investment & Finance, Vol. 26, No. 6, pp. 482-521 Peter Champness: Real Estate Risk Assessment, 2011 (presentation)		
Free comments		
In markets with traditionally high fluctuation in property values (USA, UK) it can be difficult to define such characteristics, as they are perceived to be negligible in comparison with other market forces. Also, it is often thought that characteristics of the location override those of the building in terms of their influence on market value. Any building related aspect contributing to a more stable value can only do so within the limits imposed by the market and the location.		
Writer and date (last up-date)	Prof. Thomas Lützkendorf, Andrea Immendörfer	May 2011

5.3.7 Transversal issues – Process quality

The indicator presented in this chapter relates to the following issue:

- Optimisation of the planning process (Werner Sobek and CSTB)
  - Integrated design in the planning process.

This process-oriented indicator was developed by Werner Sobek in the framework of pilot tests (WP7) and the SuPerBuildings consortium decided to select it as a key indicator. Indeed, the adoption of an integrated design approach is a success factor for multi-criteria design optimisation and innovation with limited risks, and also makes operation phase easier and cost-effective.

Note: The description format is the same for this process-oriented indicator as for the performance-oriented ones.

Indicator
Name – Definition / description
Integrated design in the planning process Project management before, during and after design, involving a multi-disciplinary team, a collaborative and iterative work, aiming at optimising the sustainable performances of the building.
Definition / description of sub-indicators
This indicator is made of a list of qualitative sub-criteria covering several phases of the planning process of a building, from concept design to operation. Additional requirements related to the optimisation of the planning process could be integrated in the single description of the criteria of the certification schemes (environmental, social and economic).
Units
The evaluation of the integrated design can be only qualitative. The sub-criteria are organised as a structured checklist. A list of credits / points may be associated to that checklist.

Principles of classification	
According to the number of credits obtained, a level of performance may be defined (e.g. fair, good, very good, or excellent). Some credits as well as their documentation materials may be mandatory.	
Weighting and aggregation	
This is not clearly defined yet. There exist several possibilities for a process-related indicator. The simplest one consists in affecting a given number of credits to each question / item of the checklist, according to its expected influence on the building performances and project coherence. Another solution may be based on mandatory sub-criteria plus optional ones. It is also possible to implement the quality management principle "plan-do-check-act" and allow credits according to the completeness of this principle, for each sub-criterion.	
Validity	
Issue of concern	Transversal issues – Process quality Directly or indirectly, process quality issues positively influence environmental, social and economic impacts.
Explanation	

Design and operational phases are often evaluated, but the integrated design starts a step before the design phase, as it regards the development of concepts. So the proposed scheme is the following:

CONCEPT → DESIGN → CONSTRUCTION → OPERATION

Main aspects of the integral planning approach are:

- Multidisciplinary formation of the planning team: experts from different disciplines should work together to assure high quality of the planning. The team should be guided by a brad of professional with profound knowledge in the field of sustainability and planning process (so called sustainability consultant).
- Successful integration: all team members should communicate well and be team players. The integrated design team should define a sustainability-oriented overall strategy to reduce energy consumption and negative environmental impacts and to improve comfort and efficiency at the same time. The targets and the strategies should be clearly shared and understood by the planning team and the client.
- Optimisation of the planning process: this should be insured by an iterative process through simulations and calculations (to suggest the optimisation potential and chose the most effective design solution) and by guiding concepts to improve the sustainability aspects of the building.
- In case of certification: in the upstream steps, implementation of interdisciplinary communication and integration of the certification criteria to improve quality and set higher performances standards.
- Usability of criteria and corresponding indicators during the different stages of the planning process and by different planners.
- The earlier the certification assessors joins the planning team, the more efficient the certification process can be carried out and there is the effective possibility to improve the performance of the building.

Furthermore, implementing an integrated design supposes to put the stress on the following crucial aspects:

- Introduce a preliminary phase in the concept design where the concepts including alternatives are developed;
- Ensure an effective cooperation between the planning team, a sustainability consultant and the client;

- Implement the monitoring phase and the post-occupancy evaluation during operation of the building, and anticipate it during design.

Justification

The adoption of an integrated design approach is a success factor for multi-criteria design optimisation and innovation with limited risks, and also makes operation phase easier and cost-effective.

Professions such as architecture, structural engineering, building services and building physics are linked by complex dependencies. Integrated design makes these dependencies transparent and optimises them simultaneously and iteratively.

A successful integral planning process assures the achievement of an optimised solution in terms of sustainability and complexity, so that not only a specific aspect of the construction will be optimised, but also the entire building.

One reason for the lack of efficiency in sustainable building assessment may sometimes be the lack of quality in the processes involved in the building certification schemes. The quality of these processes may be improved by adopting an overall efficient management of the planning process, which will automatically have a positive impact also on the certification scheme.

In the field of sustainable building certification, we call integrated design a building design where the criteria of the certification scheme are efficiently integrated in the various project phases and the cooperation between the planner and the sustainability consultant is implemented at an early stage.

Starting with a certification process at the earliest stages brings the following advantages:

- Definition of the goals and of the strategies: the planning team is guided in the right direction, focusing on how to achieve the best possible rating and ease of achievement for the scheme.
- Effective possibility to improve the performance of the building and implement the design: the integration of the sustainability strategies in the design is easier, unnecessary work and duplication is avoided.
- Correct compilation of the required documentation: the effort and cost for the preparation of the material to deliver is reduced.

Object of assessment			
Building			
Site			
Location			
Other (specify)	Processes	X	Organisation of actors, integrated design and planning processes

Characterisation	
Directly impact-related (indicators that directly measure the potential impact by expressing the (weighted) amount of emissions, resources etc. that have a potential impact on the issue of concern)	
Building-performance or site-performance based (indicators that express the impact on the basis of the performance of buildings or site (like accessibility, maintainability, architectural quality, quality of indoor environment....; it is believed that these performance aspects have an impact on the issue of concern (like well-being, health, capital value...))	
Process-based (indicators that express the impact on the basis of the quality of the production and/or maintenance processes; it is believed that these process issues have a direct or indirect impact on the issue of concern)	X
Status of the indicator	

More and more assessment and certification systems include, at least partially, project management requirements.

For instance:

- In DGNB, process quality is a distinct category within the assessment;
- In HQE, environmental management system and related requirements is one of the two axes of the certification framework, the other one dealing with environmental performance through 14 issues.

The process quality indicators may be defined in various ways; there is not a unique model. Among them, despite its advantages, integrated design is not always mentioned explicitly. But the overall objective is always the same: defining relevant and ambitious sustainability objectives, and organizing the project and the actors from the early stages so as to achieve them with a maximum of efficiency, responsibility and transparency, with the involvement of all interested parties.

Assessment

Design phase	Calculation / assessment method	The following tasks to ensure an effective integrated design during the planning phase are the following: Client's perspective: - Contract an integral planning team (main responsible: client / project manager); Concept design: - Establish the targets, e.g. on energy and water consumption, CO_2 emissions, conversion / recycling, waste generation… (client with sustainability consultant); - Agree on targets (client with sustainability consultant) Schematic design: - Establish the concepts including alternatives, e.g. on energy, water, CO_2, waste… (client with sustainability consultant and involved specialists) Design development: - Compare alternatives ideally, LCA or LCC based (sustainability consultant + involved specialists) - Establish concept of maintenance (architect / sustainability consultant / MEP engineer) - Establish monitoring concept (architect / sustainability consultant / MEP engineer) - Refine the concepts and the calculations (involved specialists) Call for tenders and selection of firms: - Integration of sustainable aspects in call for tenders (sustainability consultant and involved specialists) - Integration of sustainable aspects in selection of firms (client and involved specialist)
	Data needed and data availability	Knowledge about the organisational aspects of the project at the different phases, including during concept design: actors, responsibilities, planning, communication, documentation, decision making processes, checking points, involvement of interested parties, simulations and calculations, etc.
	Applicability	This approach requires some investment in time and money, especially during the upstream stages, but it can lead to significant savings and advantages during the next phases.

<table>
<tr><td rowspan="3">Operation phase</td><td>Measurement / assessment method</td><td>The following tasks to ensure an effective integrated design during the construction phase are the following:
Construction:
- Adapt concepts and calculations to the last design (main responsible: sustainability consultant and involved specialists)
- Establish the energy performance certificate (sustainability consultant and MEP engineer)
- Establish user manuals (involved specialists)
- Manage a low-waste and low-impact construction site (architect and sustainability consultant)
Operation:
- Monitoring, user feedback (MEP engineer + users)
- Optimise systems through measurement (MEP engineer)
Implementation of the monitoring phase and the post-occupancy evaluation.
Physical series of measurement (consumption of energy and water, emissions of pollutants, production of waste, comfort and health parameters, operating costs, etc.), analysis and interpretation of measures, surveys about users' satisfaction, reporting, continuous improvement, communication.
Display of key indicators. Development of users' awareness.</td></tr>
<tr><td>Data needed and data availability</td><td>Knowledge about the organisational aspects of the project during operation: actors, responsibilities, planning, communication, documentation, decision making processes, involvement of interested parties, monitoring, performance assessment, etc.</td></tr>
<tr><td>Applicability</td><td>This approach requires some investment in time and money, in staff and measurement instruments (meters, probes, BEMS, etc.) but it can lead to significant savings during operation, high environmental performance and satisfaction of users.
Applicability is easier if the integrated design was correctly implemented in the previous phases (concept, design, construction, hand-over).</td></tr>
<tr><td colspan="3">Comparability</td></tr>
<tr><td colspan="3">Requirements for comparability</td></tr>
<tr><td colspan="3">Comparability needs relatively precise criteria and sub-criteria, based on facts, limiting subjective answers. However, there is a risk of difference of interpretation between two assessors.
Optimal comparability may be ensured if the checklist contains the same criteria and sub-criteria, and adopts the same allocation of credits and aggregation method.
Here we meet the same difficulties as for the other qualitative indicators.
There are no particular constraints linked to the country, even if organisational laws and rules may differ in a certain extent between countries.
In case a detailed criterion is non relevant for the building under study or for a given country or region, it may be ignored and the related credits deduced from the total sum.</td></tr>
<tr><td colspan="3">Sources of information</td></tr>
<tr><td colspan="3">Source / Bibliography / Web links</td></tr>
<tr><td colspan="3">1. ISO 14001 on environmental management system
2. ISO 21392 on general principles of sustainability in the construction sector</td></tr>
</table>

3. ISO 26000 on social responsibility of organisations 4. DGNB certification framework, process quality part 5. HQE certification framework, environmental management system part 6. Deliverable D7.2 and D7.3 of SuPerBuildings project 7. Werner Sobek and WSGreenTechnologies website : www.wsgreentechnologies.com 8. WBDG, Whole Building Design Guide, managed by the National Institute of Building Sciences (NIBS) in Washington, DC, see www.wbdg.org		
Free comments		
Writer and date (last up-date)	Sylviane Nibel, CSTB, on the basis of a report from Giulia Peretti and Floriane Abedi, Werner Sobek	20/11/2012

5.4 Analysis of indicators and remarks

5.4.1 Methodology

In the “discussion” and “future steps” parts of chapter 4 of D4.2 (see detailed D4.2 report, after each indicator table), almost each indicator has been analysed. Hereafter more general analysis is made, some questions are raised and some works are suggested.

The format for the description of indicators worked quite well and allowed a good homogeneity in the description of indicators, but we have noticed different interpretations of certain items.

Regarding environmental indicators based on LCA (provided input data exist, as EPDs), the SuPerBuildings partners paid attention to be in line with CEN TC350 standards (EN 15804 and EN 15978). That also means that it is necessary, when using indicators, to respect homogeneity and coherence between LCA-based indicators (energy, CO_2, waste, water…) regarding methodology, assumptions and system boundaries.

Some indicators have been selected among those already existing (in assessment schemes or in standardisation) and described in detail, especially regarding validity, applicability and comparability. Others were inspired by existing indicators but were completed or improved, for instance in extending them in order to cover the whole life cycle of the building. Some were developed from expert knowledge, bibliography, research works, because they were lacking in existing schemes, or existing indicators were not satisfactory.

Some indicators presented in this report are quantitative, some are qualitative, but they are all described in a common format. LCA approach fits well with certain issues, but for other issues another approach is needed: modelling of the building and its environment for assessing comfort and health, qualitative evaluation, process evaluation, mix of quantitative aspects and qualitative ones.

5.4.2 Key indicators

We started with a top-down approach in order to select key issues, then key indicators. Some issues initially identified as ”key”, due to human resource limitation and the necessity to work on WP4 and WP5 in parallel, have not been concretized by a documented indicator. Among the indicators initially described by the partners, some were declared, after discussion, as not ”key” and put apart as secondary/complementary indicators, sometimes as sub-indicators (like several economic ones).

Biodiversity is an important issue because loss of biodiversity is still a dramatic fact, but good indicators are missing. Assessing impact on biodiversity is relevant at a geographic scale broader than a building scale. Biodiversity that is foreseen strictly at the building scale makes little sense. It is preferable to assess the contribution of a building to the biodiversity of a zone or territory, by assessing the ecological value of the site, partly linked to the Land use indicator. So, Land use indicators bring a valuable contribution to biodiversity issues. It is interesting to note that biodiversity indicator is not present in CEN TC350 standards, and that several indicators in ISO 21929-1, including those of an informative annex, are linked to biodiversity.

Regarding comfort issues, Acoustic comfort has not been documented here. There is no reason to consider hygro-thermal and visual comforts as key issues without considering acoustic comfort as well, which is a very mature discipline in the building sector, and a critical social issue. Furthermore, it is a regulated issue in many countries.

It would probably be useful to develop indicators for transversal issues, as Maintainability and Adaptability, which may be seen as sub-indicators of the economic indicator dealing with Long term stability of value.

However, on the basis of CSTB works, we have documented a transversal indicator dealing with mobility-related environmental impacts (transport of persons during operation phase), implying an extension of the object of assessment.

In addition to object-related indicators, it appeared relevant to develop process-related indicators. The one we have selected and documented deals with Integrated design in the planning process.

From another point of view, we tried to fill some “gaps” regarding definition of issues and documentation of sustainability indicators. It is the case for Change of land use, Water pollution due to leaching, Eco-mobility potential, Aesthetic quality and Cultural heritage. These indicators have been qualified of “additional”.

5.4.3 Qualitative indicators

Some qualitative indicators have been developed specifically for this project, as cultural heritage or architectural quality, but with a variable degree of applicability. It would be interesting to test their robustness, their objectivity/subjectivity and their adaptability to various contexts.

From a methodological point of view, the (informative) annex B of ISO 21929-1 presents a suggestion on how to proceed in order to develop qualitative indicators (initially proposed by CSTB):

General principles for the development of qualitative indicators

For certain issues, the development of a quantitative indicator is not possible. The reasons for that are various and can include the following:

- *Direct measurement is not possible*
- *Data for calculation or measurement are not available either totally or partially;*
- *The calculation or measurement method is very complex or expensive, and tools are not readily available;*
- *The calculation or measurement method is not validated (problem of validity), still under development (problem of availability), or not mature enough or widely recognized and accepted (lack of consensus);*
- *No overall model exists that can translate the various parameters into one figure;*
- *There are several quantitative sub-indicators dealing with the issue, but they cannot be added or aggregated through a calculation model (e.g., in acoustics);*
- *For improved relevance, quantitative and qualitative information have to be combined;*
- *The assessment of the issue implies a combination of descriptive characteristics, or going through a check-list, with few or no possibilities to quantify the different points;*
- *The assessment of the issue needs both a deterministic approach and a risk assessment approach;*
- *The assessment of the issue mixes product-oriented aspects and process-oriented aspects.*

Approaches that can be considered when developing qualitative indicators:

- *Define influencing parameters / aspects regarding the issue;*
- *Establish the sensitivity of these parameters relative to each other;*

- *Define if some sub-calculations are possible for each parameter of groups of parameters;*
- *Organize the parameters into a structured list;*
- *Define an assessment or measurement method for each element of the list (calculation, description, enquiry, yes/no answers, etc.);*
- *Establish rules of normalization (through scales or points) and aggregation (after weighting the different elements according to their relative influence);*
- *Define a final scale (e.g., from 0 to 5) or several classes (e.g., A to G) in order to get a final result or score, which will be the numerical value of the indicator;*
- *Define certain points as crucial ones or as mandatory pre-requisites, leading to the given class or scale level (possibly the worst one) if related requirements are not met, whatever the other sub-assessment may be.*

Regardless of which approach(es) is considered, it is important to ensure the transparency of this process, and to justify its validity.

5.4.4 Applicability, comparability and aggregation

We need to go more deeply in the assessment method for certain indicators in order to make them more applicable by practitioners. For certain indicators, as Architectural quality / Aesthetic quality, it is more a process-related approach that is proposed than a strict and definite assessment method. On one hand this flexible approach allows the adaptation to the specificities of various contexts, but on the other hand comparability is made difficult.

Applicability of indicators sometimes meets certain limits as, for example:

- Lack of large LCA/LCI database, lack of EPDs or only partial EPDs (from cradle to gate),
- IAQ design tools not widely spread, cost of IAQ measurement,
- Discrepancies between countries about tools and databases,
- Difficulty in time and cost-effectiveness of the calculation /measurement.

The comparability information included in the indicator description format is interesting; it is an effort to explain under which conditions comparison is possible or not. This information is an interesting contribution to the definition of benchmarking criteria under Task 5.2.

There are 2 levels of aggregation:

- Aggregation specific to one issue, because the indicator is defined with the help of several sub-indicators, and no simple calculation rule allows combining sub-indicators into one (e.g. acoustic comfort, waste…),
- Aggregation at the scale of the building, because some indicators are defined premise by premise, as comfort or IAQ indicators. When aggregating, it is important to avoid compensation between good results and bad results. A classification system may help. It would be desirable to define a harmonized aggregation approach, applicable to all indicators needing a spatial aggregation.

5.5 Conclusions

Various key and additional indicators have been developed and documented by the research partners of SuPerBuildings.

Nearly 20 key indicators have been either selected, or improved or developed, and documented through a structured format. They cover the 3 pillars of sustainable development, but not all the related issues. Some are of particular interest and include added-value because they have been newly developed, as land use, eco-mobility potential, cultural heritage, aesthetic quality, long term stability of economic value, integrated design.

The applicability of these key indicators was tested in case studies. The feedback from case studies led to an improved version of the indicator descriptions.

Getting assessment results is one step, but interpretation of results is of great importance. Reference values and criteria for benchmarking (see Chapter 6) contribute to a good interpretation. The project also studied how and when to use sustainability indicators in the process of a building project (see Chapter 8).

BIMs are developing and are the object of many projects. It is an opportunity to make them evolve so as they can include sustainability performances of building products, building zones, and whole buildings.

6. Performance levels of buildings

6.1 Introduction

To develop methods for the assessment and benchmarking of sustainable buildings, SuPerBuildings project proposes to define and to select most relevant indicators. Starting from a top down approach, indicators are chosen considering their link to general subjects of concern. On the other hand, indicators must reflect a practical assessment of building characteristics, and therefore must comply with a bottom-up approach. SuPerBuildings has combined these two methods to collect typical performance levels for key indicator of sustainability. The work also collected information about the technological, economical or sociological barriers for the improvement of building performance with regard to selected indicators.

One of the objectives of SuPerBuildings was to develop knowledge on typical performance levels (those observed in practice in each country, for different building types, ages and locations). Seven key indicators were selected for that purpose, and these were the objects of an inventory of accurate and actual data, based on statistical studies, regulation standards, voluntary schemes, or even case studies, across seven European countries:

- Land Use
- Energy Consumption
- Greenhouse Gas emissions
- Water Consumption
- Waste production
- Hygro-thermal comfort
- Indoor Air Quality.

The typology of buildings is relatively complex, and performances of buildings depend on their type. The built environment data are generally structured in terms of residential and non-residential buildings, and in terms of new and existing ones. Residential and tertiary buildings often form a category, representing more than 40% of the final energy of a country, with about 2/3 for residential and 1/3 for tertiary. Tertiary buildings include very different types of buildings (offices, schools, hospitals, hotels, retail, logistics, etc.) among which a large group is constituted by offices.

When environmental certification or labelling exists in a country, it generally covers a limited number of building types. Residential and office buildings are very often covered, because the market demand is high, but the situations differ for other building types. Finding representative data (statistics, studies, surveys…) is generally possible for residential and offices buildings, either new, existing, or renovated, either certified / labelled or not, but for other building types, data are generally partial or lacking.

Considering these elements, we have finally adopted 4 categories of buildings on which we have focused the work on performance levels and reference levels:

- New residential buildings
- Existing / renovated residential buildings
- New office buildings
- Existing / renovated office buildings.

6.2 Typical performance levels

6.2.1 Land-use

Related to the indicator Land-use, the research study underlined two measurable and reliable mid-point effects used in European countries: the level of soil sealing and the land use change. For these two indicators, performance levels are set up by sustainability assessment schemes. Another indicator related to building density has been pointed out: the space ratio. However, it was considered as not relevant because the link between this mid-point measurement and the overall subjects of concern was not clear, also in terms of whether a high building density is more sustainable or not.

Level of soil sealing

Concerning "Level of soil sealing", the way to express the performance varies (see table below), however the idea behind the rating is always to improve the ratio of the building site free of soil sealing and sometimes to improve the biodiversity quality on it.

Table 7. Summary of typical performance level for indicator soil sealing.

Country	Assessment system	Indicator name	Formulation	Detailed information about comparability	Typical performance levels
Austria	TQB[50]	**Area free of soil sealing**	= area free of soil sealing/ outer area	Outer area is the plot area not dedicated to the building Performance value vary according to the presence of underground construction	Good level: >70% Mean levels: 30–70% Minimum levels: 10–30%
Germany	German government-led pilot scheme for assessing sustainability in housing	**Level of soil sealing**	= area of soil sealing not dedicated to building/outer area	Outer area=plot size minus area permitted to build the building on (as defined by the master plan of the local authority, so not the actual building footprint) Housing buildings	Good level: Maximum of 10% of the area not dedicated to the building
Belgium	Refentiekader Duurzame Woning and VALIDEO Referentieel Kantoorgebouwen	**Biotope Area Factor**	BAF = $A_{Ecologically\ useful}/(A_{total\ site} - A_{building})$	$A_{Ecologically\ useful} = \Sigma W_i \times A_i$, W_i represents the weighting factor for the considered outer space and A_i represents the surface of the considered outer space.	Good level: >0,7 Mean level: >0,6
France	HQE[51], Goal 1: Relation between the building and his immediate environment	**Rate of vegetated area**	% of plot area vegetated	All plot area is taken into account Tertiary buildings	Good level: 30% Mean level: 20%
	HQE, Goal 5: Water management, 5.2:Management of rainwater	**Soil sealing coefficient**	Waterproofing of plot area (%)	Tertiary buildings	Low urban site density: Good: <20% Mean: 20% to 40% Low: 40% to 80% In High urban site density: (%of improvement of soil sealing) Good: >10% Mean: 2 to 10% Low: 0 to 2%

[50] Austrian assessment system_ Total Quality Building
[51] High Environmental quality

Country	Assessment system	Indicator name	Formulation	Detailed information about comparability	Typical performance levels
Czech Republic	SBToolCZ for residential buildings	**Ratio of rainwater retained on site**	% of rainwater retained, calculated taking into account permeability of surfaces, water storage tanks and other means		Good level: >90%

Level of soil sealing is a quantitative mid-point effect related to Land-Use indicator. This indicator is used in several evaluation schemes around Europe but expressed in different ways according to national benchmarks. It is therefore an indicator for which we need to set-up a common assessment method, taking into account:

- The unit area: plot area, area not dedicated to the building or not permitted to build on (outer area) regarding project design or local regulation…
- The definition of "sealed area" must indicate:
  - Considerations about building related infrastructures (e.g. underground construction)
  - Considerations about different types of biodiversity quality
  - Considerations about water retention rate of the area.

Moreover, this indicator has to be tailored regarding local concerns like urban context. Therefore, performance levels must take into account local specificities.

Land use change

Land use change refers actually to the former use of the site designed to build the building on. Almost all sustainability assessment systems provide requirement means about this indicator. In every case, the main aim is to enhance the use of former built-up site or previous developed area ("area recycling") for human activities in order to manage territory consumption.

The typical performance levels can be expressed by "level of practice". With regard to differences within the countries, the level of good practice is tailored regarding local subjects of concern like urban densification, reuse of brownfield or contaminated sites, not using ecological valuable area. The table below provides different ratings according to the type of land used for the construction of new buildings.

Table 8. Summary of typical performance level for indicator Land Use change.

	Good level of practice	Mean level of practice	Low level of practice
Austria – TQB system	Building refurbishment operation or recycling of building site plot and increase of the previous built-up area or densification of existing structures	Building on previously developed sites or inside of an existing housing settlement	Development of new building area or Building on re-designated, ecologically valuable areas
Germany – BNB system	Very contaminated brownfield sites OR somewhat contaminated land with additional compensatory measures.	Use of land recycling / brownfield sites- i.e. reuse of industrial or military sites with low contamination OR non-contaminated land with additional compensatory measures.	Non contaminated previously developed sites or in-fill sites that previously served other uses than for buildings or Greenfield site that had already been designated as construction sites
Czech Republic – SBToolCZ[52] (residential building)	Contaminated land after decontamination (10 points on 10)	Brownfield (8 points/10)	Site with mature growth up to 30% (4 points/10) Site with mature growth of more than 30% (2 points/10) Conservation area (0 points/10)
France – HQE (tertiary)	Practical dispositions are justified to "limit territory consumption and to optimize urban refurbishment"	Building project is coherent with the local policy about territory sustainable territory management.	-Other
Belgium – Valideo	Requirement means: - Use of land with low ecological value; - Use of formerly built-on area, evaluated based on former use of the site for industrial, commercial or residential buildings during the past 50 years; - Use of cleaned, formerly polluted area, evaluated based on soil examination (qualitative evaluation); - Protection and/or enhancement of the ecological value of the site, evaluated based on measures taken.		

[52] In SBToolCZ for residential buildings there is criterion E.11 that evaluates the type of used land and gives 0 to max. 10 points.

The type of land used doesn't depend on building intrinsic qualities but is more about territory management policy. However, it is a major issue regarding land consumption and biodiversity conservation.

The indicator can't be linked to a quantitative midpoint effect. It is, therefore, expressed in a qualitative way. Performance criteria are generally assessed with a scale of points.

6.2.2 Energy Consumption

There are different types of energy figures that are being discussed when looking at building energy. Each type belongs to a separate area of scientific expertise. Only the briefest and simplest of outlines of different types is given here:

- **Annual operational energy consumption data:** this is the energy a building consumes during its useful life for building services and occupier-specific uses.
- **Embodied energy data:** this is the energy required to manufacture the building: to process materials, to produce all products and components, transport them to site and put them together.
- **Feedstock energy data:** this is the calorific value of the building component, were they to be combusted at the end of life for the purpose of energy.
- **Life Cycle energy data:** this covers both, the embodied energy, and operational energy over a given study period (e.g. 50 years). The figures are generated using an LCA calculation. In some cases it then deducts the feedstock energy to account for the replacement of other fuels elsewhere (in another process no longer related to the original building), resulting in lower over-all values. This approach is not allowed in Germany.
- **Life Cycle energy data – annualised:** This takes total Life cycle energy data and breaks it down into a figure per year of the reference study period.

Some example figures for annualised LCA energy data have been provided by partners, but most data referred to annual energy consumption.

The research study show that regarding countries, the way to express performances are widely different despite ongoing efforts of European standardization. Typical performance values are not comparable in its raw states and needs to be taken with caution. The factors presented hereafter influence widely the results and need to be taken into account while comparing typical performance values.

Heating Degree days

As explained above energy performance figures always need to be seen in their climatic context – therefore the following summary of heating degree days was compiled.

Table 9. Heating degree days.

Austria	4050	3080	4940
Belgium	2415	-	-
Czech Republic	3680	3740	4300
Finland	3952	4782	6058
France	2500	1400	3800
Germany	3700	3200	4700
Spain	-	10	2300

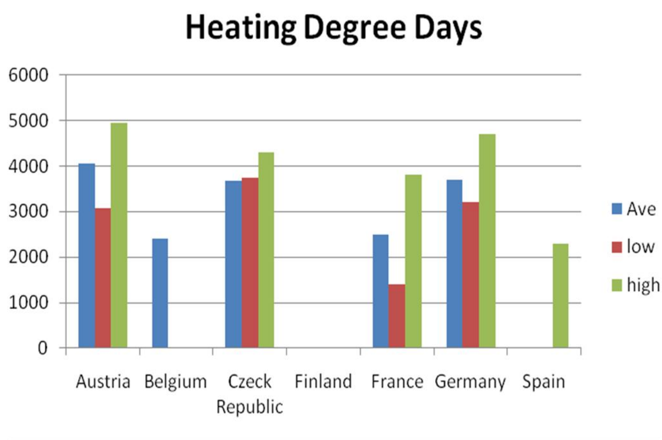

Figure 10. Heating degree days. The corresponding values for heating degree days for Finland are 3952, 4782 and 6058.

Primary Energy-factors

Primary energy factors vary from country to country. When comparing energy data from different countries given as primary energy, the primary energy factors need to be taken into account. The most important issue relating to primary energy factors are what primary energy factor is applied to electricity in the relevant countries and the factor used for wood.

Table 10. Primary energy-factors.

	Electr.	Nat. Gas	Oil	Coal	Wood
Austria	3.51	1.3	1.33	1.54	1.22
Belgium	2.5	1	1	1	1
Czech Republic	3.16	1.45	-	1.48	0.04
Finland	1.7	1.0	1.0	1.0	0.5
France	2.58	1	1	1	0.6
Germany	2.6	1.1	1.1	1.1	0.2
Spain	2.28	1.07	1.11	1.14	1.25

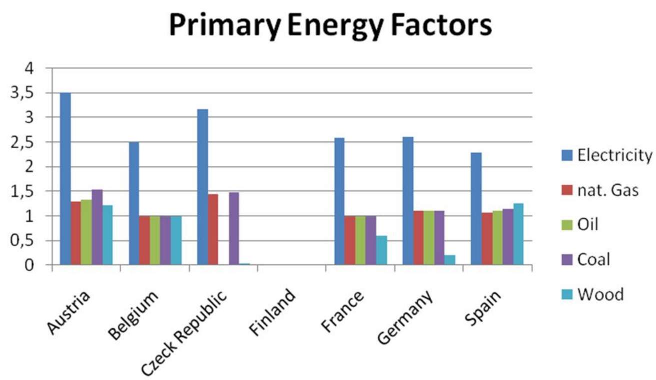

Figure 11. Primary energy-factors.

The corresponding values for Finland are 1.7, 1.0, 1.0, 1.0 and 0.5.

Reference units

Energy data from different countries may refer to different reference units sometimes. Often figures are stated as kWh/m^2/a. The square meters may refer to gross internal, gross external or net internal area or total useful floor area. Often the type of area is not explicitly stated. Even when all figures refer to the same type of area measure, definitions and measurement conventions can vary between countries. The following data was collected from SuPerBuildings partners.

Table 11. Reference units for energy measurement.

Austria	kWh/m^2*a (m²....gross external area; gross floor area) In case of non-residential buildings the reference unit in regulatory standards is the gross volume of the building.
Belgium	Available data on housing in kWh/m² or MJ/m² Energy use within offices in Belgium is mainly expressed as kWh/m².year
Czech Republic	Gross floor area minus envelope – Example: House 10 x 10 m, walls 0,5 m thick – the reference area is square of (10-0,5-0,5) = 9 x 9 = 81 m².
Finland	Net internal area in the new 2012 building regulations (kWh/m²),The area calculation contains the same principle than in Czech Republic. Energy in primaryenergy weighted by the factors of different delivered energy componenets
France	Reference Area (SHON): Net external or net gross plan area (the area is calculated removing balcony, basement, car park, attic and all unclosed space from the gross area). Prefered unit for energy consumption is kWhpe/m²/year (pe means primary energy).
Germany	NFA/ useful internal floor area is measured up to the inner line of the internal walls and excludes staircases main corridors, rooms dedicated to building services and footprints of internal walls.
Spain	Generally expressed in kWh of final energy use per m^2 of “useful floor area”.

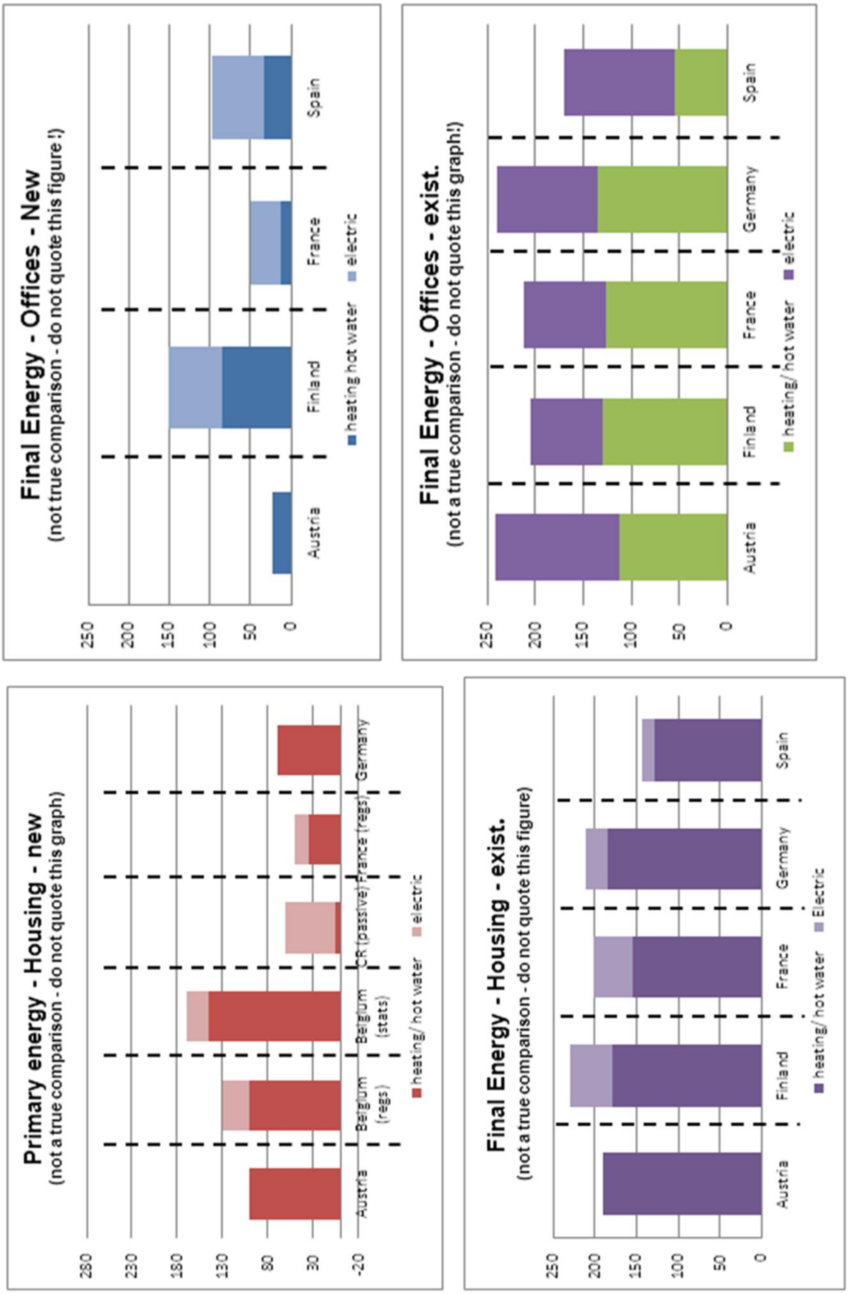

Figure 12. Juxtaposing energy performance values (not comparable because of differences in reference units, system boundaries etc.).
Annex B shows the collected values for energy.

The results of data collection pointed out that there is good country specific information available about the energy performance levels of buildings. Most countries propose reference levels of energy consumption for new buildings; however these performance levels are poorly comparable due to the following barriers:

- Unit references: main problems comes from the definition of the area which widely vary regarding countries
- System boundaries: the consideration of different contributors to energy is different regarding countries (heating, cooling, user appliances…)
- The consideration of final or primary energy to set requirement values.

Finally, true comparisons are currently not possible and may not become possible any time soon, despite ongoing efforts in CEN standardization. This is due to energy related regulations being part of building regulations, which are within the exclusive jurisdiction of each Member States (subsidiary principle).

Despite the above, the point of view that we cannot compare data across countries and to leave it at that must be transcended, by making comparisons, but being aware of the underlying issues.

For meaningful comparison of Energy standards, some of the influencing parameters need to be cut out.

Concerning life cycle energy consumption, the research pointed out that quantitative performance measurement are currently not used in sustainability assessment schemes but experiment are under process in several countries to bring performance levels through LCA calculation.

More information about the collected energy data is presented in Appendix B.

6.2.3 Greenhouse gas emissions

Due to close link to energy consumption, the research study pointed out same issues regarding typical performance levels for GHG emissions. Major performance values collected are presented in the table below:

Table 12. Summary of typical performance levels for greenhouse gas emissions.

	Existing residential buildings	**New residential buildings**	**Existing offices**	**New offices**
Country	France			
Value	32 kg/year and m² (net area)	13–25 kg/year and m² (net area)	50.6 kg/year and m² (net area)	14–21 kg/year and m² (net area) /
Coverage	Building operation	Building operation + embodied	Building operation	Building operation + embodied
Data quality	Calculated benchmark	Statistical experimentation HQEperf	Calculated benchmark	Statistical experimentation HQEperf
Country	Czech Republic			
Value		65 kg/year and m²		
Coverage		Building operation		
Data quality		Calculated benchmark		
	Belgium			
Value	4986 kg/year and dwelling			
Coverage	Building operation (statistical value Flanders 2009)			
	Germany			
Value		≤14.45 – ≤23.80 kg/year and m² (net floor area)	12.75–62.5 (conventional heating, no mechanical ventilation, no A/C) 21.5–105.1 (with mechanical ventilation, no cooling) 28.4–130.5 (with air conditioning) kg/year and m² (net floor area)	39.90–57.00 kg/year and m² (net floor area)
Coverage		Building operation + embodied	Building operation	Building operation + embodied
Data quality		Statistical benchmark (deg. days adjusted)	Used in assessment system	Used in assessment system

	Spain			
Value	40 kg/year and m² (net floor area)	30 kg/year and m² (net floor area)	71 kg/year and m² (net floor area)	40 kg/year and m² (net floor area)
Coverage	Building operation	Building operation	Building operation	Building operation
Data quality	Statistical benchmark	Statistical benchmark (unadjusted)	Statistical benchmark (unadjusted)	Statistical benchmark (unadjusted)
	Austria			
Value	30 kg/year and m² (gross floor space)	18 kg/year and m² (gross floor space)		
Coverage	Building operation	Building operation		
Data quality	Used in assessment system	Used in assessment system		
	Finland			
Value	49 kg/year and m^2 (net floor area)	32.1 kg/year and m^2 (net floor area) *	49.8 kg/year and m^2 (net floor area)	35.9 kg/year and m2 (net floor area)
Coverage	Building operation	Building operation For buildings heated with district heat	Building operation For buildings heated with district heat	Building operation For buildings heated with district heat
Data quality	Statistical benchmark (deg. days adjusted)	Calculated benchmark. Used in regulations	Typical office building. Data obtained from several sources.	Calculated benchmark. Used in regulations
* for buildings heated with district heat				

On the basis of the results it is obvious that we still have no common understanding about the typical carbon footprint of buildings in Europe.

The assessment results are influenced by two types of basic issues. The true performances of buildings naturally affect the assessment results of buildings' carbon footprint. In addition, the assessment method and especially the definition of the system boundaries significantly affect the results.

The target of benchmarking is of course to search what is the actual deviation from average values, median or certain defined good practices. With regard to the actual performance especially the energy-efficiency, usage of renewable energy sources and the type of building materials affect buildings' potential impact on climate change.

On the other side, the assessment result is influenced by several assessment methodological issues. In order to get usable results, we should be able to define the assessment method accurately so that unwanted differences in results do not hinder proper comparison.

The comparability of the results depends especially on the uniformity of the system boundaries. Comparability of the results requires that the building life cycle and related issues – that are either considered or excluded from the scope – are determined equally. This concerns also the quality of background data taken from environmental data bases.

Important issues related to the building and its life cycle include the coverage of the assessment of different building parts (like for example building foundation, installations and products of HVAC, and surfaces like floorings) and different operations (like user specific electricity) and the stages of life cycle (like for example the inclusion of the needed energy for construction and refurbishment, transportations, renewals and service life of products, demolition, final disposal).

6.2.4 Water consumption

The research study concerning Water consumption pointed out, in some way, comparable typical performance levels for operational (drinking) water consumption. Moreover, variation regarding climate, geographical localization or age of the building appears not to be significant. However, very few data have been collected regarding embodied water consumption.

Table 13. Summary of typical performance levels for embodied water consumption.

Embodied water		**Dwellings**		**Offices**	
		Building stock	New buildings	Building stock	New buildings
FRANCE	l/m².y	-	**96–126** HQE performance experiment	-	**94** HQE performance experiment
AUSTRIA	l/m².y	-	**-**	**7.5 to 13** case studies	-

Table 14. Summary of typical performance levels for operational water consumption of residential buildings.

Typical values for Residential buildings			
Country	**Reference unit**	**Operational Water Use (total drinking water consumption)**	
		Current building stock	**Goal for new sustainable buildings**
FRANCE	***l/p.d***	**141** *case study, 1 dwelling* **150** *statistics, incl. collective consumption* **137** *statistics, excl. collective consumption*	-
GERMANY	***l/p.d***	**122** *statistics, overall average, steadily reducing*	**70-80-90** *pilot scheme best-good-pass* *calculated + statistics* *2 studies on 1200 dwellings* *under review*
AUSTRIA	***l/p.d***	**130** *statistics, measurements* *55% of population*	-
BELGIUM[53]	***l/p.d***	**110** *statistics and enquiry Flanders* **113** *statistics Brussels Capital Region* **138** *statistics Walloon Region* **34±13** *(buildings with rainwater collection)* **& 81±33** *(buildings without rainwater collection)* *case studies, daily monitoring of 58 dwellings, 11 with and 47 without rainwater use, generally rainwater use ≈ drinking water use*	**32 & 91** *calculated, minimum drinking water consumption taking into account water-saving measures, with and without rainwater use*

[53] In Belgium, three regions exist, i.e. the Flemish Region or Flanders, the Walloon Region and the Brussels Capital Region. These regions are responsible for a large number of issues concerning sustainable building, environment and health, while other responsibilities are taken care of by the Federal Government in Belgium. Because of this distinction, data is provided for either the whole country, i.e. Belgium, or for one or more regions, i.e. Flanders, Walloon Region and Brussels Capital Region.

Typical values for Residential buildings			
Country	**Reference unit**	**Operational Water Use (total drinking water consumption)**	
		Current building stock	**Goal for new sustain-able buildings**
SPAIN	***l/p.d***	**130 to 160** *statistics, survey, big to small towns* **166** *VERDE, typical value*	**72 & 110** *VERDE* *excellent & good* *calculated for 1 exam-ple* **50% saving** *VERDE, best practice*
FINLAND	***l/p.d***	**155** *statistics, average value* **90 & 270** *min. & max. values*	**100** *PromisE best* **130** *target value, multi-storey residential buildings*
CZECH REPUBLIC	***l/p.d***	**96** *regulation* **104** *statistics* **120** *statistics*	-

Table 15. Summary of typical performance levels for operational water consumption of Offices.

Typical values for Offices			
Country	**Reference unit**	**OPERATIONAL WATER USE (total drinking water consumption)**	
		Current building stock	**Goal for new sustainable buildings**
FRANCE	***l/m².y***	**550** *case study, 1 office building*	-
	l/p.d	**23** *case study, 1 office building* **30** *statistics*	**9 & 16** *HQE offices and education*
GERMANY	***l/m².y***	**400 & 490** *statistics, regulation, calculated, BNB-DGNB* *good, without and with shower*	**200 & 270** *statistics, regulation, calculated, BNB-DGNB* *best, without and with shower, only in case of rainwater / wastewater (re)use*
	l/p.d	-	**7 & 22** *BNB-DGNB, calculated* *best & pass, only in case of rainwater / wastewater (re)use*
AUSTRIA	***l/m².y***	-	-
	l/p.d	-	-
BELGIUM	***l/m².y***	**170±110** *case study, daily monitoring in 98 offices*	-
	l/p.d	-	-
SPAIN	***l/m².y***	-	-
	l/p.d	**100** *VERDE-typical, reference benchmark*	**20 & 52** *VERDE, excellent & good, calculated for one example* **30% saving** *best practice*
FINLAND	***l/m².y***	-	**145** *PromisE, best* **200** *PromisE, target value*
	l/p.d	-	-
CZECH REPUBLIC	***l/m².y***	-	-
	l/p.d	**22 to 49** *regulation, depending on equipment present*	-

When comparing figures for total drinking water consumption, a rather small variation is seen between the different countries. However, when looking at data on other types of water, a wider variation is identified. For rainwater use, only one figure is available (in most countries, rainwater use is still rather limited), while for use of groundwater, reliability is much less. Data on wastewater reuse is lacking in all countries. Consequently, comparison can only be done in a consistent way when using total drinking water consumption data.

The comparison of statistical average values for total drinking water consumption in dwellings show rather close figures, between 100 and 160 l/person and per day. For offices, a rather large variation between minimum and maximum values and between countries is visible. However, it appears that there are no significant variations according to age of building, region or climate.

The following table permits to summarize current levels of total water consumption for dwellings and offices and expectation of saving potential using sustainability assessment schemes.

Table 16. Operational Drinking Water Use within Dwellings _Performance levels set by sustainability assessment schemes.

Operational drinking water consumption	**Current water consumption**	**Level set by evaluation scheme**	**Potential water saving**
DWELLINGS (litres/person.day)			
Germany (pilot scheme – new dwellings)	122	70	43%
Belgium (RefDuWo – new dwellings)	120	42	65%
Spain (VERDE existing dwellings)	166	72	57%
Finland (PromisE – new dwellings – excellent)	155	100	35%
OFFICES (litres/person.day)			
Germany (BNB/DGNB – new offices – best)	22	7	68%
Germany (BNB/DGNB – existing offices – without shower – best)	11	5,5	50%
Germany (BNB/DGNB – existing offices – with shower – best)	13	7	46%
Spain (VERDE – excellent)	100	20	80%
Finland (PromisE – excellent)	-	145 (l/m².year)	-
France (HQE – new offices – sanitary)	30	9,4	60%

6.2.5 Waste production

Concerning Waste production, specific figures are not available for most EU countries. However, some specific studies put in evidences the overall amount of waste produced in the 27 European countries by construction and demolition sector. The research on waste production is not challenging only due to lack of data in some countries, but also due to different approaches to classification of waste according to the local ways of waste management.

The report we have chosen to classify waste primarily by origin leading to figure out amounts of waste produced by buildings in relation to:

- ✓ operational energy use
- ✓ construction and demolition
- ✓ partially also in regards to the use phase of the building (the performance assessment of the building can't be done directly from this indicator because not related to building specificities.)

Secondary classification discriminated between the four groups:

- non-hazardous waste
- hazardous waste
- inert waste
- radioactive waste.

Waste production related to Operational Energy Use
The following table provides typical values of waste induced by the use of energy during the operational stage of buildings.

Table 17. Summary of typical performance levels for waste related to operational energy use.

Waste related to operational Energy Use			
Non-hazardous waste	Housing	Austria*	0,08 kg/m^2
		France**	7.16 kg/m^2
	Offices	France**	2.19 kg/m^2
Hazardous waste	Housing	France**	0.04 kg/m^2
	Offices	France**	0.013 kg/m^2
Inert waste	Housing	France**	680.38 kg/m^2
	Offices	France**	207.6 kg/m^2
Radioactive waste	Housing	France**	0.44 kg/m^2
	Offices	France**	0.13 kg/m^2
* Predominantly ashes of heating systems based on solid fuels; specific to floor area ** Average amount of waste related to gross plan area per 50 years of operation.(case study, value calculated with the assessment tool ELODIE)			

Table 18. Summary of typical performance levels for waste related to operational energy use – Finland.

Finland
The biggest part of **construction waste** comes from renovation. For example in 2007 the total construction waste volume was 1.6 million tn. The share of renovation is 57%, demolition 27% and new construction 16% (source statistics). In new building the total amount of waste is 6.4 kg/m^3 in average (all types of buildings) (Source statistics 2007: new building construction waste 256000 tn, total new construction volume 40 million m^3). Volume of **houhold waste** is 287 kg per occupant and year. the value is an average value in in Finland. Source Statistics 2010. Estimate: 100 kg bio waste, 80 kg recyclable paper and cardboard, the rest unrecyclable paper and cardboard, plastics, rubber, textile, metal and glass. The share of **municipal waste** (total 2.7 million ton in 2007) from all waste (74 million ton in 2007, source statistics) is rather small. The total amoun of municipal waste is 478 kg per occupant (2010 source statistics) and the share of household waste is 60% of this. The rest comes mainly from services, especially trade and health care. The share of offices is small.

The waste mangement law defines the basic principles for waste management. The specific requirements are given on the municipal level. The specific reqiorements with regard to residential buildings focus on sorting. For example the waste management regulations in the Helsinki metropolitan area require that all properties with minimum 10 flats have to provide a container for bio waste; all properties with at least 20 flats or which produce more that 50 kg of recyclable paper waste per week have to provide a separate container for paper waste; and all properties which produce recyclable cardboard waste at least 50 kg per week have to provide a separate container for carboard waste. (source Helsinki metropolitan area waste management regulations).

The Finnish PromisE system include an indicator Waste mangement. It benchmarks residential buildings on the basis of waste sorting possibilities (numer of separate containers, monitoring of waste generation).

Typical values for waste production related to operational Energy Use of buildings are widely influenced by boundaries and representativeness of life cycle data used for the assessment (i.e. European context or regional context, inclusion of infrastructures, etc.). It is therefore difficult to make conclusion if we consider the lack of robustness of the collected figures.

Waste production related to construction and demolition

Table 19. Generation of construction and demolition waste in EU-27 (ETC/RWM 2009 data, with new assumptions made by BIO).

Construction and demolition waste[54] (statistical figures for European countries)			
Country	**Generation of C&D waste (tonnes per capita)**	**Population 2005 (Million inhabitants)**	**Total C&D waste generation 2005 (Million tonnes)**
Austria	0.81	8.3	6.7
Belgium	1.06	10.5	11.1
Bulgaria	0.94*	7.7	7.3
Cyprus	0.94*	0.8	0.7
Czech Republic	1.44	10.3	14.8
Denmark	0.83*	5.4	4.5
Estonia	1.12	1.3	1.5
Finland	1.00*	5.3	5.2
France	0.99*	63.2	62.6
Germany	0.88*	82.4	72.3

[54] Management of construction and demolition waste in the EU - requirements resulting from the Waste Framework Directive and assessment of the situation in the medium term, 07.0307/2009/540863/SER/G2, http://www.eu-smr.eu/cdw.

Construction and demolition waste[54] (statistical figures for European countries)			
Country	**Generation of C&D waste (tonnes per capita)**	**Population 2005 (Million inhabitants)**	**Total C&D waste generation 2005 (Million tonnes)**
Greece	0.94*	11.1	10.5
Hungary	0.94*	10.1	9.5
Ireland	0.63*	4.1	2.6
Italy	0.80	58.8	47.0
Latvia	0.94*	2.3	2.2
Lithuania	0.94*	3.4	3.2
Luxembourg	1.42*	0.5	0.7
Malta	1.95	0.4	0.8
Netherlands	1.47	16.3	24.0
Poland	1.00*	38.2	38.2
Portugal	1.09	10.6	11.5
Romania	0.94*	21.6	20.3
Slovakia	0.94*	5.4	5.1
Slovenia	0.94*	2.0	1.9
Spain	0.74	43.0	31.8
Sweden	1.14	9.0	10.3
United Kingdom	0.91	60.4	55.2
EU 27	**1.09**	**492.41**	**461.37**
Note: * Estimated values.			

Table 20. Construction and demolition waste per m² of building area.

Construction and demolition waste per m² of building area.		
Construction waste (New construction)	Finland	Unit 6.4 kg/m^3 (average waste in new building construction)
	France (dwellings)	23 kg/m²
Demolition Waste (Deconstruction)	France	500–1300 kg/m²
Construction and demolition waste	Austria	380 kg / (occupant. year) (Waste building materials with earth moving works;[Source: Bauwerk Österreich; Stark 2003, p. 42])

Waste production related to the total Life cycle of buildings

Table 21. Summary of typical performance levels for construction and demolition waste.

Waste production through _LCA calculation			
Non-hazardous waste	Housing	France*	1 016 kg/m^2
	Offices	France*	413 kg/m^2
Hazardous waste	Housing	France*	46 kg/m^2
	Offices	France*	1,4kg/m^2
Inert waste	Housing	France*	3 518 kg/m^2
	Offices	France*	2 089 kg/m^2
Radioactive waste	Housing	France*	0,37 kg/m^2
	Offices	France*	0,03 kg/m^2
* Average amount of waste related to gross plan area per 50 years of operation.(case study, value calculated with the assessment tool ELODIE)			

The comparison of waste production is difficult due to lack of data in some countries, but also due to different approaches to classification of waste according to the local ways of waste management. For example in some countries, inert waste is part of non-hazardous waste.

Average figures are available for construction and demolition waste but it is very difficult to find specific values to express the performance of buildings in each region of Europe.

The indicator waste production calculated for the whole building life cycle permit to estimate the total production of waste at each building stage including the production of building components, transport, construction, use phase (replacements of products, energy and water use), deconstruction and end of life. However, figures are available only for Austria and France.

6.2.6 Hygro-thermal comfort

The evaluation of thermal comfort criteria is generally simplified to few parameters, mainly air temperature, air velocity and humidity. Overall work underlined that the existing performance levels for comfort are quite broad, and there is little data on thermal comfort levels for sustainable buildings. Therefore it is difficult to distinguish between comfort levels required for sustainable buildings and for typical buildings.

Table 22. Typical performance levels for hygro-thermal measurement.

	AUSTRIA	SPAIN	FINLAND	FRANCE	BELGIUM	GERMANY	CZECH REPUBLIC
Internal Air Temperature ranges (°C)	19–25	21–25	20—24 (28 for hot periods)	19–26	Federal 20–30 (more specific for regions)	> 20	20–28
Air velocity (m/s)	0.10	0.10–0.20	-	0.10–0,25	-	0.20	0.10–0.20
Humidity (%)	40–70	40–60	-	30-70	40–70	55–80	60–80
Temperature difference (air-surfaces of wall) (ºC)	<4 (walls) <6 (windows)	Varies with climate and construction	-	<5 (walls), 8 (window)	-	3–6	-

The evaluation of thermal comfort criteria is generally simplified to a few parameters, mainly air temperature, air velocity and humidity. These have been adopted in building regulations and indoor environment classification methodologies, assuming standard internal boundary conditions such as metabolic rate and clothing. A more detailed approach such as the PMV method described in standards such as ISO 7730 : 2005 is also used in some cases.

Overall it can be seen that the existing performance levels for comfort are quite broad, and there is little data on thermal comfort levels for sustainable buildings. Therefore it is difficult to distinguish between comfort levels required for sustainable buildings and for typical buildings. This might reflect the fact that in practice little is known about how occupant comfort is shaped; despite the significant impact it can have on green building performance (Brown 2009)[55].

The use of more flexible temperatures could be justified by some recent research suggesting that strictly controlled comfort bands offer no relative satisfaction benefits to occupants, compared to larger bands of comfort (which would generally mean lower temperatures in winter and higher temperatures in summer) (Arens et al. 2010)[56].

Some arguments about wide ranges of temperatures would be that of avoiding ‘thermal monotony’ as described by Healy (Healy 2008), that could play a role in ’removing cultural and symbolic thermal sensibilities’. There is already widespread agreement that questioning the meaning of comfort, taking into account an occupants expectations and preferences, is necessary for a lower carbon society, and on-going research and discussion calls for a revision in definitions of comfort taking into account an inhabitants perception, interaction, and their socio-cultural context (Shove et al. 2008)[57] that could allow for even more flexibility in the internal temperature.

The issue of establishing benchmarks for thermal comfort is difficult because its multiple effects: If higher expectation of comfort, this could have an effect in health and productivity, but even in social and cultural values and also on other environmental indicator performances (energy, CO_2, etc.)

However, the fact of seeing different acceptable temperatures for the work place in different countries could help to potentially challenge these limits.

55 Brown, Zofia (2009) Occupant comfort and engagement in green buildings: Examining the effects of knowledge, feedback and workplace culture, PhD Thesis, University of British Columbia

56 Arens, E., Humphreys, M. A., De Dear, R. & Zhang, H. (2010) Are 'class A' temperature requirements realistic or desirable? Building and Environment, 45, 4–10.

57 Shove, E., Chappells, H., Lutzenhiser, L. & Hackett, B. (2008) Comfort in a lower carbon society. Building Research & Information, 36, 307–311.

6.2.7 Indoor air quality

The indoor air quality is influenced by many parameters, among others the quality and the quantity of supplied outdoor air, building materials emissions, inhabitant behavior (tobacco smoke, furniture's cleaning agent etc…).

The research study for typical performance levels pointed out existing guidelines for indoor air pollutants concentration: WHO Guidelines and also the German sustainability assessment scheme BNB. These guidelines propose measurable values of concentration for major indoor pollutants. Moreover, a finish study pointed-out typical indoor air average concentration levels in residential buildings. Table 21 presents main results.

Table 23. Typical performance levels for Indoor air Quality measurements.

Germany (BNB Research project for assessment of sustainability in housing – recommendations)				
	Offices new	**Offices existing**	**Housing new**	**Housing existing**
TVOC	good: ≤1000[µg/m3] better: ≤ 500 [µg/m3]	-	good : ≤ 800 [µg/m³] better : ≤ 300 [µg/m³]	-
Formaldehyde	≤ 60 [µg/m3]	-	good : ≤ 60 [µg/m³] better : ≤ 50 [µg/m³]	-
CO_2	≤ 800 [ppm]	-	-	-
Finnish Indoor Air Quality (Statistics)				
		Office building	**Residential buildings (one year old)**	**Residential buildings (> two years old)**
	Concentration (µg/m^3)			
TVOC *	-	86	270	357
Formaldehyde	-	20	30	30
Aromatic compounds	-	15	30	80
Aliphatic hydrocarbons	-	12	25	44
Cycloalkanes	-	4	10	4
Alcohols	-	6	35	15
Aldehydes	-	8	35	29
Ketones	-	<5	10	<5
Esters	-	<5	15	14
Glycols/ glycolethers	-	7	25	8

Terpenes	-	6	70	105
Organic acids	-	5	10	<5
Halogenated compounds	-	<5	<5	<5

France_ Guidance values for indoor air quality (VGAI), proposed by AFFSET			
Sources	**Time exposure**	**units**	**Guidance value**
Formaldehyde	Short term (2 hours)	µg/m^3	50
	Long term	µg/m^3	10
carbon monoxide (CO)	8 hours	mg/m^3	10
	1 hour	mg/m^3	30
	30 minutes	mg/m^3	60
	15 minutes	mg/m^3	100
Benzene	Short term	µg/m^3	30
	Long term (with threshold effects)	µg/m^3	10
	Long term (without threshold effects)	µg/m^3	2
Naphthalene	Short term	-	-
	Long term	µg/m^3	10
Trichloroethylene	Short term	-	-
	Long term (without threshold effects)	µg/m^3	20 (for a full life time exposure correspond-ing to risk level of 10^{-5})
Tetrachloroethylene	Short term (1 to 14 days)	µg/m^3	1380
	Long term	µg/m^3	250

The present situation is that different European countries still have clearly different approaches for the control and management of indoor air quality. While others emphasize the management of ventilations rates other also give specific limit values for concentrations of harmful substances. The WHO guidelines are rather new (2010). Those may formulate good bases for common approach in the future. The REACH regulation

REACH is the Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals[58.] The main aims of REACH are to ensure a high level of protection of human health and the environment from the risks that can be posed by chemicals, the promotion of alternative test methods, the free circulation of substances on the internal market and enhancing competitiveness and innovation. REACH makes industry responsible for assessing and managing the risks posed by chemicals and providing appropriate safety information to their users. In paral-

[58] http://ec.europa.eu/enterprise/sectors/chemicals/reach/index_en.htm

lel, the European Union can take additional measures on highly dangerous substances, where there is a need for complementing action at EU level.

This has also been considered by the manufacturers of building products. The regulation will affect in such a way that the use of dangerous chemicals will be reduced. (However, the regulation allows the use of chemicals when the use is below 1 ton/year or 0.1% of the weight of the product).

CEN/TC 351 is responsible for the development of horizontal standardized assessment methods for harmonized approaches relating to the release (and/or the content when this is practicable or legally required solution) of regulated dangerous substances under the Construction Products Directive (CPD) taking into account the intended conditions of use of the product. It addresses emission to indoor air, and release to soil, surface water and ground water. This will provide a common European system for the control of harmful substances in building materials.

6.2.8 Major lessons regarding performance levels of KPI from a bottom-up approach

Among other things, important lessons that can be drawn from this work are the followings:

- **SuPerBuildings project has drawn a map of Key Performance Indicator around European countries. The enquiry put in evidence a lack of comparability due to differences within national calculation methods** (different boundaries, reference unit to express performance value like the floor area; consideration of local requirements about buildings and local concerns),
- **There is a lack of accurate data** concerning typical performance values **for Life cycle Indicators of buildings currently considered in advance in terms of sustainability**. This issue can be explained by the current paradigm shift: assessment systems evolve from one indicator – energy or CO_2- to a multi-criteria vision and from the use stage to a lifecycle approach.

6.2.9 Paradigm shift in sustainability assessment of buildings: Heading for the life cycle assessment of Key Performance Indicators

Currently, the levels of performance for KPI considered in sustainable management schemes are related to the use phase of buildings, and do not consider the provision and the end of life of building products and component.

Tools and methods for LCA of buildings are currently under development in many countries of Europe. The following tables have been drawn through an inquiry of six European countries. It permits to figure out the expected level of progress for the assessment of KPI at different building stage and for different module of the use stage.

The use stage is the most in advance stage regarding the quality and the consistency of data. However in the short or medium term, **the most in advance stage after the use stage** that might be described and used as benchmark seems to be **the product stage** as EPDs ("from cradle to gate" as declared mandatory in CEN TC350 standards) or other LCA information and database are currently under development. The following tables show the expectations for the comprehensive use of indicators primary energy and greenhouse gases.

Table 24. Expected progress of Indicator Primary Energy consumption through the map of short-term level of knowledge in Europe (based on 6 countries).

Short-term vision of expected knowledge for Indicator Primary Energy consumption through building life cycle is as follows:

% of responses "In progress" or "Available" over 6 European countries (Germany, Belgium, France, Austria, Nederland, Czech Republic)		Before Use stage		Use stage										End of life stage
				Building related Operational use										
		Product stage	Construction process stage	Heating	Cooling	Ventilation	Hot water	Lighting	HVAC control and automation	Lift /escalator /fire…	Non-building related appliances	Operational Water use	Mainte-nance /Repair /Replace-ment /Refur-bishment	
Primary energy consumption	1- Name definition	100%	67%	100%	100%	100%	100%	100%	100%	67%	67%	Contributor not taken into account during the enquiry	83%	50%
	2- Assessment method	100%	67%	100%	100%	100%	100%	100%	100%	50%	50%		83%	67%
	3- Assessment tools	100%	67%	100%	100%	100%	100%	100%	83%	33%	50%		83%	50%
	4- Availability of data input	100%	50%	100%	100%	100%	100%	100%	83%	33%	50%		83%	67%
	5- Case study	100%	83%	100%	100%	100%	100%	100%	83%	50%	67%		67%	67%
	6- Statistical data	50%	33%	100%	100%	100%	100%	100%	83%	33%	83%		33%	0%
	7- Reference levels (Best, mean, low)	83%	50%	100%	100%	83%	100%	100%	67%	0%	67%		33%	33%
	8-Label or regulation	50%	17%	100%	100%	83%	100%	83%	67%	0%	33%		17%	0%

Table 25. Expected progress of Indicator Global Warming Potential through the map of short-term level of knowledge in Europe (based on 6 countries.

Short-term vision of expected knowledge for Indicator GWP through building life cycle

% of responses "Available" or "In progress" over 6 European countries (Germany, Belgium, France, Austria, Nederland, Czech Republic)		Before Use stage		Use Stage										End of life stage
				Building related Operational use								Operational water use		
		Product stage	Construction process stage	Heating	Cooling	Ventilation	Hot water	Lighting	HVAC control and automation	Lift /escalator /fire…	Non-buiding related appliances		Maintenance /Repair /Replace-ment /Refur-bishment	
GWP	1- Name definition	100%	67%	100%	100%	100%	100%	100%	100%	67%	67%	Contributor not taken into account during the enquiry	83%	50%
	2- Assessment method	100%	83%	100%	100%	100%	100%	100%	100%	67%	50%		83%	67%
	3- Assessment tools	83%	83%	100%	100%	100%	100%	100%	83%	50%	50%		83%	50%
	4- Availability of data input	83%	50%	100%	100%	100%	100%	100%	83%	50%	50%		67%	67%
	5- Availability of case study	67%	67%	83%	83%	83%	83%	83%	67%	33%	50%		50%	50%
	6- Availability of statistical data	50%	33%	83%	83%	83%	83%	83%	67%	33%	67%		33%	17%
	7- Availability of reference levels (Best, mean, low)	67%	50%	83%	83%	67%	83%	83%	50%	0%	33%		33%	17%
	8- Used in Label or regulation	33%	17%	67%	67%	50%	67%	50%	33%	0%	17%		17%	0%

6.3 Needed levels of performance from a top-down approach

Defining levels of performance from a top down approach correspond to estimate the needed level of performance when trying to make significant improvement**.** Some of these needed improvements are set by European policy but consider a limited selection of indicators. Other research and study tried to tackle this issue. Most information available is focusing on **Energy consumption, Global Warming Potential and Water savings**.

6.3.1 Energy consumption and GHGs

In principle, any new building will add to the energy consumption (unless it replaces an older, less efficient building). As shown schematically in Figure **13.** , building new buildings to "net zero energy"-standard will simply mitigate the continual increase in consumption (which will still take place due to increased use of new appliances, increased use of air-conditioning etc.), not lead to reduced consumption per se.

As a first step, this additional energy consumption though continuing additional construction activity has to be stopped by ensuring that all new buildings are built to "net zero energy"-standard. (Issues surrounding different definitions of this term will not be addressed here – research commissioned by the EU is currently on-going). The revised energy performance in buildings directive (Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings) asks all EU-countries to make provisions for this to happen.

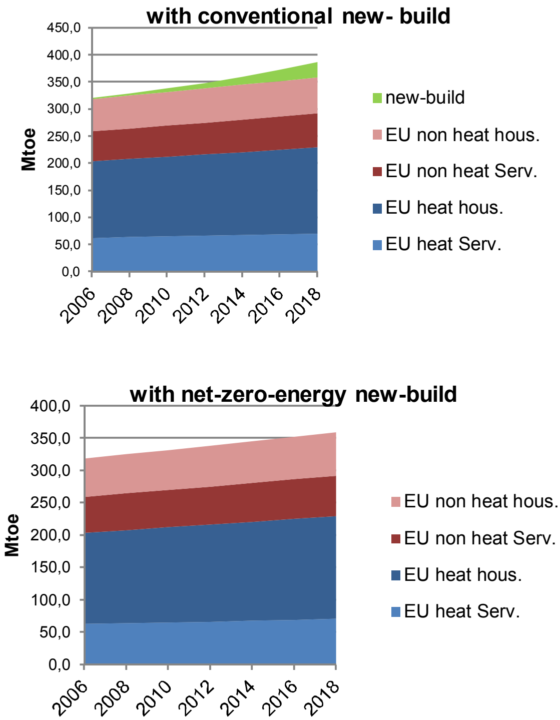

Figure 13. Schematic projection of energy consumption in buildings with conventional new buildings and with net-zero-energy new builds (business-as-usual increase factor of 1%)

Hence, the baseline consumption from existing stock needs to be tackled by encouraging "super-efficiency"-retrofitting and the replacing of inefficient buildings. As the proportion of new builds is relatively small (single percentage figures – see Figure 13.) in comparison to the existing building stock a notable difference to building related energy consumption can only be made by tackling this large baseline, by making significant improvements to existing buildings.

In this context, the EU- Action plan for Energy (2006) stated:

"Even though energy efficiency has improved considerably in recent years, it is still technically and economically feasible to save at least 20% of total primary energy by 2020 on top of what would be achieved by price effects and structural changes in the economy, natural replacement of technology and measures already in place. Partly because of its large share of total consumption, the largest cost-effective savings potential lies in the residential (households) and commercial buildings sector (tertiary sector), where the full potential is now estimated to be around 27% and 30% of energy use, respectively. In residential buildings, retrofitted wall and roof insulation offer the greatest opportunities, while in commercial buildings, improved energy management systems are very important. Improved appliances and other energy-using equipment still offer enormous energy savings opportunities."[59]

Building new buildings to "net zero energy"-standard will not lead to reduced total energy consumption – the baseline consumption from existing stock needs to be tackled and targets set accordingly.

The construction industry is a large contributor to CO_2 emissions, with buildings responsible for 40% of the total European energy consumption and a third of CO_2 emissions.[60]

Several studies made at the European level provide information about the potential saving of GHG emissions through improvement of building efficiency. You'll find below some conclusions about this research.

Petersdorff et al. (2005)[61] have assessed CO_2 saving potential of the EU-15 [62] building stock and that of the new member states. The first study analyses the potential of the European building stock in the mitigation of CO_2 emissions considering the EU-15 building stock distinguished by climatic regions, building types and sizes, building age, insulation level, energy supply, energy carrier and emission factors. The report first shows the technical potential, if retrofit measures (concerning the improvement of thermal performance of facades, roofs, floors and windows) covered by the Energy Performance Directive were realized for all the European (EU 15) building stock of 2002 at the same time:

- The overall emission savings associated with the heating of the European building stock would amount to 82 Mt/a (EPBD)
- This potential could be increased by 69 Mt/a if the Directive were extended to retrofitting all multi-family houses and all non-residential buildings (Extended EPBD >200 m^2)
- By extending the Directive to the whole of the European building stock by adding single-family houses the additional potential, compared to the Directive, rises to 316 Mt/a (Extended EPBD all houses).

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[59] Communication from the Commission, Action Plan for Energy Efficiency: Realising the Potential, 2006.

[60] Energy Efficient Buildings European Initiative.
http://www.ectp.org/cws/params/ectp/download_files/36D928v2_E2BA_Brochure.pdf

[61] Petersdorff et al. 2006. Mitigation of CO_2 Emissions from the EU-15 Building stock. Beyond the EU Directive on the Energy Performance of Buildings. Report established by ECOFYS for EURIMA. 2004. 36 p. Authors Carsten Petersdorff, Thomas Boermans and Jochen Harnisch (Petersdorff et al. 2004) and Mitigation of CO_2 Emissions from the EU-15 Building stock. Beyond the EU Directive on the Energy Performance of Buildings. Environ Sci Pollut Res 13(5) 350 - 358 (2006). Authors Authors Carsten Petersdorff, Thomas Boermans and Jochen Harnisch.

[62] Finland, Sweden, Austria, Belgium, Denmark, France, Germany, Great Britain, Ireland, Luxembourg, the Netherlands, Greece, Italy, Spain and Portugal.

They also analysed correspondingly the saving potential in Baltic countries, Poland and Central Eastern European countries (CEE) as follows (Table 26).

Table 26. Economic assessment of the refurbishment of eternal walls (Petersdorff et al. 2005).

External insulation of facade		Baltic countries	Poland	CEE countries
end-energy saving	kWh/m^2a	76	100	107
CO_2 emission savings	kg/m^2a	10	30	24

According to the recent study "Towards low Energy buildings, Energy saving and CO_2 emission reduction by changing European building regulations to very low energy standards"[63].

The standard energy saving potential in Denmark, France, Germany, The Netherlands and United Kingdom combined is 33 PJ per year, if changing from formal building regulation minimum requirements to VLEB requirements. This saving potential is represented by 226 million inhabitants in the five countries. This number represents approx. 50% of the inhabitants in the European Member States (458 million). If this saving potential can be assumed to be representative for the whole European Union, the total energy saving potential would be in the order of magnitude of 67 PJ per year.

The total European energy and CO_2 emission saving in 2020 is estimated at 568 PJ and 36 Mt CO_2 per year respectively if all new buildings are constructed as VLEB from 2012[64]. This figure may prove to be a conservative estimate as some Eastern European countries currently have just changed from a situation with no energy performance requirements to its introduction due to the EPBD.

6.3.2 Water consumption: Saving potential

The final report EU Water saving potential[65] provided by Ecologic – Institute for International and European Environmental Policy – draws the following conclusions:

[63] Towards very low energy buildings, Energy saving and CO_2 emission reduction by changing European building regulations to very low energy standards, Ole Michael Jensen Kim B. Wittchen Kirsten Engelund Thomsen EuroAce, SBI, 2009

[64] Very Low Energy Building, The definition of VLEB varies significantly across Europe, even though the EPBD (Energy Performance of Buildings Directive) gives guidelines for energy performance calculations.

[65] EU Water saving potential I (Part 1 –Report) http://ec.europa.eu/environment/water/quantity/pdf/water_saving_1.pdf

“As regards public water supply (including households, public sector and small businesses), the reduction of leakage in water supply networks, water saving devices and more efficient household appliances have the potential for up to 50% water savings. These water saving technologies are easy to introduce and implement and they also have short payback periods, further enhancing their uptake possibilities. Applying the above mentioned measures would allow for a reduction in water consumption from 150 litres/person/day (average in the EU) to a low 80 litres/person/day. A similar reduction could be applied to public water supply, leading to an estimate of potential saving up to 33% of today’s abstraction.”

The study shows that water saving potentials vary strongly among the EU members as shown in the next Figure 14.

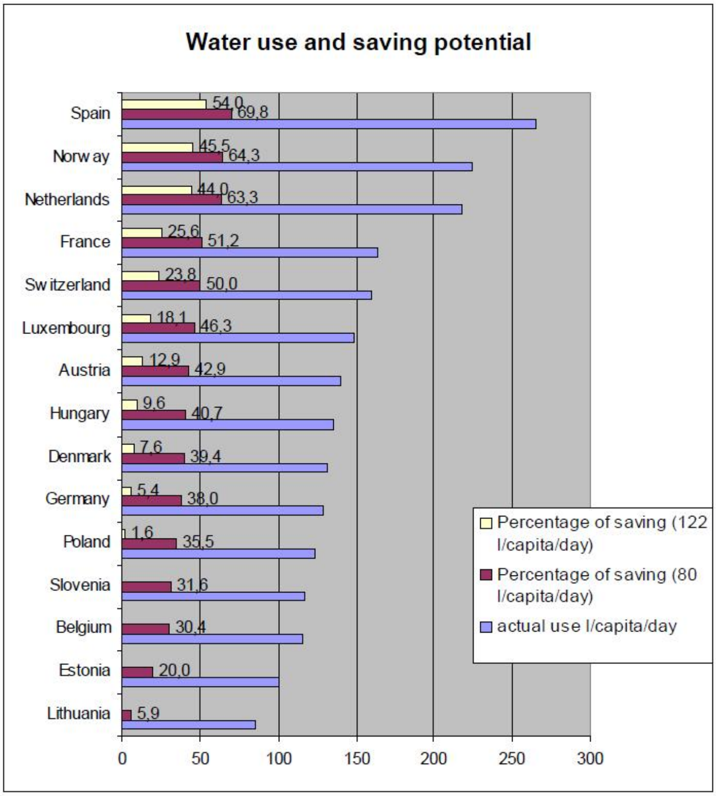

Figure 14. Water saving potential for households in EU-MS with distinction between minimum water saving potential (18%), resulting in an average water consumption in the EU of 122 l/p/d, and a maximum water saving potential (47%), resulting in an average water consumption in the EU of 80 l/p/d [source: EU Water saving potential, Ecologic, 2007].

6.4 Technological, economic or social barriers to building sustainability improvement

SuPerBuildings underlined the following barriers to the improvement of the performance of buildings regarding selected indicator.

Table 27. Specific barriers to low Energy/CO_2 buildings.

Technological barriers and possibilities		Possibilities for overcoming barriers
Lack of standard solutions and technology component	**No absolute technological barriers except sometimes lack of space to adapt renewable energy systems** Performance and longevity of some new products are not sufficiently proven (e.g. micro-generation...) Building technological and HVAC solutions are available for very low energy buildings (or passive houses)[66], and thus also for low CF buildings. **Manufacturers do not actually develop and provide solutions for low embodied energy** (=low carbon footprint) structures.	Scope for improving: - insulation technology(e. g. vacuum panel technology) - Renewable building integrated electricity generation (solar, micro cogeneration…) - solar Heating systems
Lack of expertise and skills	Lack of skills among professionals, both in the planning process and on site (in particular to airtight construction and avoidance of cold bridging), also sometimes combined with a conservative attitude.	**Energy efficiency expertise needs to be integrated as mandatory module into all relevant training and educational courses**
Lack of cooperation between different segments of the construction industry	Architects should collaborate closely with services engineers and those doing energy calculations for building regulations from initial design stage in order to minimize energy requirements effectively.	**Greater collaboration between engineers and architects from first project inception has to be encouraged.** This may be driven by the relevant trade associations/ Professional bodies and integrated into their definitions on practice standards
Lack of initiative and innovation	Conservative attitude of building sector; Reluctance of insurance companies, investors face a lack of feedback (the refusal of insurance as well to ensure the building of an innovation support, than the companies implementing them).	"The research and development of new concepts and services requires the awareness, activeness, motivation and forwards orientation of the suppliers of concepts and services. This can be supported by means of R&D programs, which offer financial support for the develop-

[66] see for example Passive House Planning Package, on http://www.passive-on.org/en/planning_package.php

		ment, and also through economic incentives which support the demand for SB concepts and services."[67]
Economic barriers and possibilities		**Possibilities for overcoming barriers**
Costs of Low energy/low Carbon Footprint building efficiency	The costs of environmental efficiency are perceived to be much higher. affect the future user, not the investor, while there is no sufficient evidence that the property value increases enough to warrant the expense.	Persuade banks to offer special financing conditions for energy efficiency improvements/ sustainable buildings **Use of annuity method instead of traditional payback method may show advantages of investment better**
Lack of investment capacities	Costs of performing an assessment[68] must be acceptable to the user community.	Council Housing Agreements to be negotiated with council housing operators with a view to bringing all properties up to standard more quickly, starting with the 800,000 most run-down properties. Negotiations to be held on completion deadlines and improved long-term funding[69]. **Update "sustainable development" tax credit, extended tax deductibility status.** **Develop innovative financial services through collaboration with the banking sector and businesses to pre-fund** investments by pledging future savings: energy performance contracts, energy-efficiency services, energy-saving certificates, and "domestic projects". Focus R&D to reduce costs.
Lack of whole life cost approach	From point of view of owner-occupiers: payback periods are perceived as being too long to make EE investment attractive From point of view of landlords: costs for energy efficiency refurbishments cannot be recovered sufficiently through rent increase New build/ developers: the payback will	Ensure a legal framework that allows rental increases that correspond to energy savings Commission independent studies on the real costs of energy efficient buildings and sustainable buildings, which have been built and conduct on-going monitoring thereof, widely publish results

[67] Building research and Information 2011-01-31 Tarja Häkkinen and Kaisa Belloni. Barriers and drivers for sustainable building.

[68] LEnSE project "Methodology Development toward a label for environmental social and Economic Building", Stepping Stone 1: Sustainability assessment of buildings, November 2006.

[69] - French National Agency for Urban Renewal (ANRU) programmes (€40 billion) conducted by applying future standards in advance (80 or 50 KWh), principle of improved funding.
- Private developments of housing and offices: requires powerful financial incentives to speed up energy renewal of existing buildings. Implementation of powerful incentive measures (proposals from group I):

<table>
<tr><th colspan="2">Social and sociological barriers and possibilities</th><th>Possibilities for overcoming barriers</th></tr>
<tr><td>Public awareness about envi-ronmental issues</td><td>Lack of sense of urgency of saving CO_2 emissions and therefore energy;
Lack of understanding of likely impact of climate change: doubts regarding validity of scientific research is being cultivated by the media;
Energy efficiency measures (e.g. bet-ter U-values) are invisible, so are CO_2 emissions
Lack of understanding on the end-user side with regard to their influence on energy consumption, due to behav-ioural patterns
No direct feedback – between behav-iour and consequences: bills come infrequently and long after the actual energy consumption</td><td>communications about sustainability ;
Availability of energy counsellor to give free advice about energy and sustaina-bility to housing owners;
Integrate un understanding of energy and sustainable living into school curricu-la (e.g. as part of sociology or geogra-phy)
For greater energy-awareness: push smart metering;</td></tr>
</table>

Specific Barriers to decrease Water consumption in building

Technological barriers		Possibilities for overcoming barriers
Lack of standard solutions and technology **Innovation**	**Many standard and innovative technical solutions** leading to important (drinking) water savings or to (re)use of rain-, ground- and wastewater are **currently already available.** An **insufficient number** of construction companies serves as a **pioneer**.	The **most important innovation issues** on the short term are: - rainwater buffering systems and rainwater infiltration techniques, such as permeable street blocks, in order to avoid flooding, - wastewater purification and treatment techniques for sustainable reuse, - separated drainage of rain- and wastewater, - low water consumption appliances (e.g. dishwasher, ...)
Economic barriers		**Possibilities for overcoming barriers**
Costs of environmental efficiency	**Generally, water-saving investments are financially more expensive than the gain that is obtained by taking the measure**, i.e. saving water. Consequently, such investments are not always favourable from a financial point of view regarding the cost of water use, which depends on the local context.	**Lifecycle costs** must be taken into account in the economic evaluation of the building project.
Public and municipal steering mechanisms barriers		**Possibilities for overcoming barriers**
Lack of incentives	Mainly incentives on energy-saving, **but much less on water-saving or (re)use of rainwater, wastewater or groundwater.** Lack of attention and support of innovation by the government.	An important development concerning water consumption consists of the implementation of the European Framework Directive on Water (23th October 2000), which aims at securing both surface and groundwater quantity and quality in Europe in 2015, as well as the implementation of the European directive on judgment and management of flooding risks**. An integrated approach, a careful planning and an increase of investments will at the long term lead to an important decrease in damage costs.**
Lack of regulation	Concerning water consumption, **regulation or regulatory requirements are generally lacking**. There is no limitation on water consumption or regulation on the types of water to be used (e.g. installation of a rainwater tank in new or renovated dwellings and offices).	

Barriers introduced by town planning documents	**Setting up town and country planning at different levels** (e.g. regional, provincial and local) and using different legislation between different regions, as well as a lack of unambiguous standards and scattered building **lead to contrasting interests between different authorities and parties.**	
Barriers introduced by national legislation	**Reusing rainwater for indoor use (toilets…) is still forbidden by the laws of several countries.** **Usually, billing of drinkable water takes into account water treatment, therefore, when you use rainwater, you don't pay for sanitation.**	**Implementing new laws in order to enhance rainwater use for indoor use**.
Social and sociological barriers / awareness		**Possibilities for overcoming barriers**
Lack of performance approach	**Evaluation schemes include means-based requirements rather than performance-based requirements**. Performance-based requirements on water consumption are often lacking (e.g. no limitation on water consumption, only lists of water-saving measures, rather than limits on water use).	Include **performance-based requirements on water consumption** within building evaluation schemes.
Lack of campaigns on water consumption	**At the moment, several campaigns are running in order to increase public awareness about environmental issues.** However, most campaigns are focusing on reducing energy consumption and increasing insulation, **while other issues, such as water saving, are currently being neglected.**	**Campaigns and other initiatives to increase public awareness must take into account water consumption issues.**

Main inputs have put crossing top-down and bottom-up approaches permit to argue about validity and relevancy of performance levels regarding needs of improvement. The cases of energy consumption and GHG emissions reveal that most significant improvements at European scale cannot be reached **focusing only on new constructions but also on refurbishment.** Concerning the indicator water consumption, the water saving potential in Europe has been set-up taking into consideration measures of efficiency on appliances and national potential of savings. From these targets, needed performance levels for building has been calculated, and finally, results are complying with the benchmark achieved within the data collection realized by SPB working partners. We end-up, therefore, with two converging information which permit to argue about the relevancy of proposing performance levels.

Top down approaches are effective when overall needed level of improvement and targets are easy to draw, which is the case for energy consumption, water or GWP for the use stage of the building. For other KPI selected in the project, only bottom-up approaches permit to define performance levels.

The enquiry made other Europe has permitted to draw-up a well understanding about typical performance levels for indicators calculated according to national methods. However, setting relevant and precise benchmark form a bottom-up approach is still difficult at a European level since rules for calculation and expression of performance are different from one country to another.

SuPerBuildings project recommends homogenizing rules for calculation and expression for the selection of key indicators. This appears to be a “sine qua non” condition to set-up transparent benchmark.

The research made about the significance of building sector has underlined that one of the main sector that contributes to GHG emissions and Energy consumption is the construction sector. A lever to respond to this issue at building level is to take into account the provision and the end of life of building when assessing building performances. When we look for assessing the selection of KPI for all building life cycle, few statistical figures are available at the moment. Some experimental enquiries has been made like in France the experimentation HQE PERFORMANCE[70], however, defining typical performance levels for LCA indicators is still difficult to apply at European level since no homogeneous and comparable LCA data are available at the moment. Nevertheless, the enquiry underlined the understanding of the LCA approach for several indicators (Energy, GWP, Water, and Waste) is currently progressing in most European countries.

To anticipate further progress in sustainability building assessment, SuPerBuildings project recommend undertaking experimental and statistical studies of LCA of buildings, in order to capitalize information at European levels for LCA indicators and to propose relevant performance levels for KPI.

[70] HQE Performance Annexe technique, bâtiments neufs, version du 22/12/2010', (Paris, 2010), 34 p. Accessed on 15/10/2011 : <www.assohqe.org> (Accessed on 12.04.2011).

7. Developing benchmarking criteria for sustainable buildings

7.1 Introduction to benchmarking

7.1.1 What is a benchmark and why we need them

The noun benchmark and the term benchmarking are frecuently used. Some common definitions of the terms are:

- a level of quality which can be used as a standard when comparing other things[71]
- a mark cut into a stone by land surveyors to secure a "bench" (from 19th century land surveying jargon, meaning a type of bracket), to mount measuring equipment. Figurative sense attested circa 1884[72]
- A benchmark is a point of reference by which something can be measured.[73]
- A set of performance criteria which a product is expected to meet. [74]
- A standard measurement that forms the basis for comparison[75]

Another definition is that from standard *prEN 16231 – Energy Efficiency Benchmarking Methodology*, is being developed to provide organizations a methodology for collecting and analysing energy data, with the purpose of establishing and comparing energy efficiency between or within entities. In this context, they benchmarking is defined as **“**process of collecting, analysing and relating performance data of comparable activities with the purpose of evaluating and comparing performance between or within entities”. Consequently, a benchmark is defined as a “*reference or standard value for comparison derived from the benchmarking”.*

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[71] http://dictionary.cambridge.org/
[72] http://en.wiktionary.org/wiki/benchmark
[73] http://searchcio-midmarket.techtarget.com/definition/benchmark
[74] http://searchcio-midmarket.techtarget.com/definition/benchmark
[75] http://www.answers.com/topic/benchmark

There is a range of groups and stakeholders that have an interest in common benchmarks for buildings across the EU:

European Commission

- To monitor and judge the progress of the different requirements of individual MS (eg., energy performance, or other environmental requirements)
- To check in which MS do the minimum requirements have a large potential to be tightened and which MS already have very strict requirements.
- To check how realistic is to expect from a MS a steep improvement on performance indicators.

Member States

- To know where they stand in comparison to their neighbours (for example, see studies on energy performance comparison in Germany[76], the Belgium[77] and Scotland[78].

Industrial parties

- To compare performance with other companies.
- In case of international property portfolios, compare and assess potential for new technologies in different countries

7.1.2 Types of purposes of benchmarks

There are only a few attempts in literature to define a systematic framework to set benchmarking levels as limit or target values. First approaches can be found in the final results of IEA Annex 31[79] and in results of working group 4 of ISO TC 59 SC17. ISO 21931-1[80] , which contains the following statement:

Reference levels and/or scale of values can be used in the quantification of indicators within the assessment method. Reference levels shall be documented and justified.

[76] Loga T, Diefenbach N, Knissel J, Energy performance requirements for new buildings in 11 countries, IWU, 2009.

[77] D'Herdt P, Van Orshoven D, Wouters P: Indicatieve vergelijking van de energieprestatie eisenniveaus in Vlaanderen, Nederland, Duitsland en Frankrijk aan de hand van 3 concrete gebouwen, WTCB, 2008.

[78] Scottish Building Standards Agency, „International comparison of energy Standards in building Regulations: Denmark, Finland, Norway, Scotland and Sweden, 2007.

[79] IEA – International Energy Agency 2005. Annex 31 – Energy relared environmental impacts of buildings.

[80] ISO – International Organization for Standardization 2010. ISO 21931-1 *Sustainability in building construction – Framework for methods of assessment of the environmental performance of construction works – Part 1: Buildings.*

NOTE: The reference level and scale of values may be related to building codes/regulations, user requirements, and/or evaluation of conditions in the area where the building is located. Quantitative information on the (environmental) performance may be referred to a predefined baseline. In such a case, the reason or basis for setting the baseline shall be clearly documented." (ISO 21931-1, 2010, 5.8.6).

For the completed assessment of sustainability of buildings appropriate assessment scales in the form of reference values or benchmarks are essential. As the standard does not propose any values or procedures, this gap has to be covered by other means. This is the case in general for quantitative assessment criteria for energy consumption, water use and for building physics related parameters and particularly for Life Cycle Analysis as a combination of Life Cycle Impact Assessment (LCA) and Life Cycle Costing (LCC).

A first formulation of scalable and adaptable structure of evaluation will be presented and could serve a basis for sustainability evaluation in general.

a) Limit value
A limit value is the lowest acceptable value of an evaluation scale representing generally the minimum acceptable performance. If this value is not reached it has to be decided, whether the whole sustainability assessment is automatically not valid or if another or no consequence arises. It must also be decided if limit values apply only to new buildings or if they also apply to existing buildings. This might have to be decided from case to case. The automatic application of the same levels to new and existing buildings might lead to negative assessment results for existing buildings and the possibility of consecutive demolition of existing buildings. Otherwise, the establishment of a range of minimum requirements also for existing buildings is absolutely essential. There is a need at a regulatory level to be outlined in which cases the failure of the minimum performance of existing buildings should lead to their demolition.

b) Reference value
The reference value represents in general the present state of the art (business as usual) and can be considered as an average or median value. For this reason, it should be noted that reference value is subject to temporal dynamics.

c) Best practise value
The best (also best-practise) value represents in general values that have been reached (measured) in experimental or demonstration projects. This value is subject to technological advances and consequently it evolves with time.

d) Target value
The target value is a value that can only be reached in medium- or long-term perspective. It represents the upper limit of the scale and can be

considered as the highest theoretically possible level (at least within a certain technology). If the target value is exceeded (which is possible) a bonus can be granted. Target values must adapt periodically to the scientific and technical progress.

The scale that includes the different values can be linear, progressive or digressive. Higher values can be more difficult to reach. In the case of complex evaluation systems a proportionally larger effort is needed to reach higher levels. By using a specific procedure to establish the values (e.g. through LCA or LCC) this problem can be avoided. Thus, it becomes clear that it is not possible to completely separate the scale of the evaluation from the overall design and "philosophy" of the assessment system.

7.2 Sources for benchmarks and their development[81]

7.2.1 Laws, prescriptions, standards

The level of legal or normative prescriptions can change considerably from country to country. As a general rule a building can only be built if all relevant laws and standards are fulfilled. Depending on how explicit these national prescriptions are formulated, they can be used as target or reference values. For new buildings the limit value often corresponds to the reference value. In countries with a low level of prescriptions, a specific value scale can be established which differs from the minimal legal prescriptions. This might be considered as an implicit critique of the national standards.

In certain countries prescriptions and standards are from the beginning performance based. This means that the technical, constructive solution is not given by the standard. Instead quality levels are indicated that allow judging technical solutions. Typical examples are sound protection levels indicating a minimal, improved and maximum performance level.

In many countries the introduction of sustainability evaluation methods has led to the introduction of or adaption of legal prescriptions and standards. This development is often seen critically and as a risk by the real estate industry. As a result the progress and the improvement of standards is delayed or avoided. In case there is a lack of existing precise prescriptions, one of the following alternatives can be chosen. This is also the case for LCA and LCC data.

[81] [This section was published in BSA 2012 conference, by Thomas Lutzkendorf (KIT) et al, as part of a paper titled: "Building Sustainability Assessment - From Calculation To Valuation"].

7.2.2 Experience based and statistical values

If assessment criteria are based on the statistical interpretation of a large set of data, average, median, upper, lower or specific quartile values can be chosen. It is important to realise that the resulting values depend strongly on the type, form, age and quality of the “basic population” of the sample buildings. Furthermore, when a sample is available it is crucial to verify how it has been determined and if the functional equivalent of the evaluated building corresponds to the functional equivalent of the sample buildings. It is important to know if the benchmarks correspond to a specific type of building and use and take into account the degree of the technical equipment (e.g. housing vs. highly equipped office buildings).

7.2.3 The existing economic or technical optimum

Value scales and benchmarks can also be constructed from theoretical values, in particular technical and economic optimum values. The problem is that these values change with time and technological progress. The economic optimum is conditioned by the technical state of the art and economic boundary conditions. This can lead to target values depending directly on the technical and economic optimum of a certain moment and technology.

7.2.4 Political target values

Often related to economic and technical optimum considerations (see 3.3) politically motivated targets exist. They can also be pure or environmental policy-oriented. Examples are the formulation of European targets for net zero energy (new) buildings by 2020 and by 2050 for the building stock[82]. Another example is the Swiss efficiency path[83] that defines operation, embodied and mobility induced energy targets resulting from the societal goal of a 2000 W society by 2050.

Political target values are often developed in a top-down way. Examples are the limit of two degrees temperature increase related to climate change or targets linked to a sustainable life style (2000 W society, 1 t CO_2/capita). These targets must be “translated” into building specific targets. The politically motivated “nearly zero energy” standard or the “positive energy house standard” are characteristic examples. Other approaches like the “improvement of resource productivity in a national sustainable development strategy” must be related to other indicators like ADP (adiabatic resource depletion). These indicators and targets are often not

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[82] ECEEE– European council for an energy efficient economy 2011. *Steering through the maze #2 -Nearly zero energy buildings: achieving the EU 2020 target.*
[83] http://www.novatlantis.ch/en/2000-watt-society.html

rooted in scientific propositions; they represent political conventions and are formulated taking into account their political feasibility.

7.2.5 Labels and self-commitment by branches

Facing the slow development of standards and the difficulty to enforce and control their application, alternatives based on a contractual obligation have been developed. The contract between the labelling / certifying board (which is private) and the builder includes not only targets and ways to measure them but also a professional assistance during the whole process. Typical examples are the Minergie Label in Switzerland and the Passivhaus Label in Germany. From the requirements of such labels, have emerged to some extend generally recognized benchmarks, that are also used in the sustainability evaluation.

Benchmarks and benchmarking systems have been partially compiled and used also in industries, associations and other organizations. Among others also the housing industry has developed benchmarks for the evaluation of the energy consumption and the energy-related CO_2 emissions in the operation phase. These targets can also be used for portfolio analysis (see following example in the following table).

Table 28. Example of a benchmarking system[84] (GWG 2009).

Energy consumption and CO_2 emissions			
Energy consumption classes kWh/m^2 year		CO_2 emission classes CO_2/m^2 year	
Between	0 and 50	Between	0 and 5
Between	51 and 90	Between	6 and 10
Between	91 and 150	Between	11 and 20
Between	151 and 230	Between	21 and 35
Between	231 and 330	Between	36 and 55
Between	331 and 450	Between	56 and 80
	> 451		> 81

7.2.6 Benchmarks based on reference buildings

For the development of benchmarks are partially used reference buildings. These are used most of the times as a typical example of a specific type of building and

[84] GWG München, 2009. Corporate Social Responsibility Report.

use, as for instance an office building. They can also be built as an statistical interpretation, and are often used for example for energy rating purposes.

7.2.7 Benchmarks for LCA and LCC

Concerning the evaluation method of Life Cycle Impact Assessment and Life Cycle Costing at the beginning there are not statistically significant reference values available. The benchmarks are developed in parallel with the development of the evaluation methods. As a result the values are directly depending on the specific database with the rules, assumptions and conventions, normally associated in a calculation tool. In certain countries (e.g. in Germany LEGEP) the existence of a calculation tool becomes the basis for the elaboration of the benchmarks.

7.2.8 Overview of types and sources of benchmarks

The typology of benchmarks can be combined with values from appropriate sources. The following table indicates which source is appropriate for which benchmark type.

Table 29. Nature of source adapted for specific type of benchmark.

Type benchmark	Possible sources for values
Target value	Political targets
	Technical optimum
	Economic optimum
Best practice value	Best practice
	Upper quartile
Reference value	Median value
Limit value	Legal minimum
	Prescriptive minimum

Having discussed the concept of benchmarking, the types and sources for the assessment, the following section of this report will look at some of the key issues of benchmark development, as for example defining what is the object of the benchmarking exercise, which we will call the functional equivalent, or issues related to the weighting and aggregation of results for communication.

7.3 Development of benchmarking criteria

7.3.1 Introduction

Performance levels for indicators of sustainability are in many cases, not comparable according to local context (i.e. national or regional differences etc.) ,building type, etc. To compare and normalize sustainable buildings performances, we need to set a framework to define the functional equivalent according to the purpose of the benchmarking process.

In this section a methodology is proposed to define a general approach to select parameters that will be taken into account in the functional equivalent and parameters that shall be reported otherwise (i.e. developing indicator or other elements of communication to understand results of building sustainability assessment).

7.3.2 Definition of functional equivalent and rules for comparison

According to ISO 14040:2006-10[85], *"A system may have a number of possible functions and the one(s) selected for a study depend(s) on the goal and scope of the LCA. The functional unit defines the quantification of the identified functions (performance characteristics) of the product. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results. Comparability of LCA results is particularly critical when different systems are being assessed, to ensure that such comparisons are made on a common basis.*

It is important to determine the reference flow in each product system, in order to fulfil the intended function, i.e. the amount of products needed to fulfil the function."

If we apply these ISO guidelines to buildings (i.e. we consider the buildings as the system and the functional equivalent as the functional unit) we should identify the reference flow needed to fulfil the intended function in order to compare building performances.

As an introduction, Figure 15 of EN 15978:2011[86] standard shows how the assessment of the environmental performance takes place within the concept of the sustainability assessment of buildings.

[85] EN ISO 14040:2006-10: Environmental management_Life cycle assessment_Requirements and guidelines, section 5.2.2.
[86] EN 15978:2011 (final draft for publication, november 2011) Sustainability of construction works - Assessment of environmental performance of buildings – Calculation method.

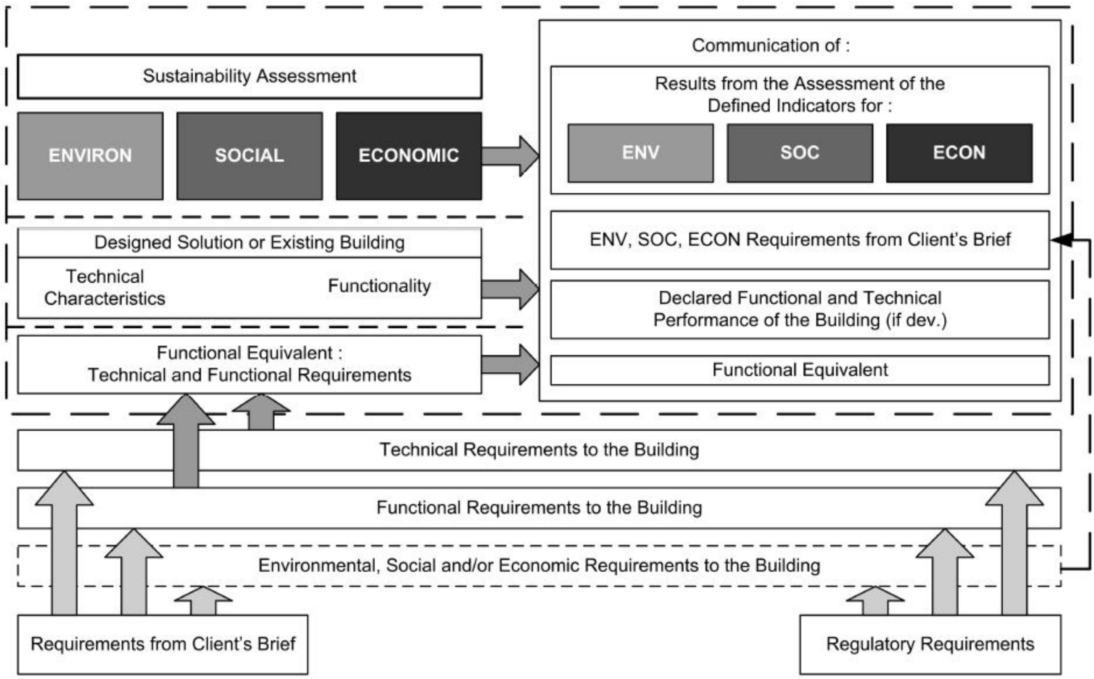


Figure 15. Concept of sustainability assessment of buildings, EN 15978:2011.

Section 7.2 of the standard provides the following recommendations:

"**The functional equivalent is a representation of the required technical characteristics and functionalities of the building**. It is the means by which the characteristics of the building are rationalised into a minimum description of the object of assessment.

Although assessments may be carried out on an individual object, they will in most instances form part of the process for the evaluation of decisions in relation to the object of assessment. This includes the decision whether to build new, or refurbish/reconstruct an existing building, the evaluation of the design options, locations, etc.

Comparisons between the results of assessments of buildings or assembled systems (part of works) – at design stage or whenever the results are used – shall only be made on the basis of their functional equivalency. *This requires that the major functional requirements shall be described together with intended use and the relevant specific technical requirements. This description allows the functional equivalency of different options and building types to be determined and forms the basis for transparent and unbiased comparison.* **If assessment results based on different functional equivalents are used for comparisons, then the basis for comparison shall be made clear.**

NOTE 1 If appropriate, the assessment results of the buildings that have different functional equivalents (e.g. design options for different types of buildings on the same site or the same types of buildings exposed to different conditions) can also be compared based on a common unit of reference. The choice of the common reference unit for all buildings being compared depends on a specific requirement of a technical, functional, environmental, social or economic aspect, or combination thereof, which is common to all these buildings and is linked to their corresponding functional equivalents.

NOTE 2 A common reference unit can be derived from the functional equivalent and be used to present the result of the indicators of the environmental assessment relative to the functional equivalent. A common reference unit may be dimensionless or qualified with a dimension (e.g. per m^2, per year, per employee, per room per year, per m^2 per year).

When combining separate assessments of environmental, social (see FprEN 15643-3) and economic (see FprEN 15643-4) performance in a sustainability assessment of the same object of assessment, ***the functional equivalent used in the assessments of the individual dimensions of sustainability shall be the same.***

The functional equivalent of a building or an assembled system (part of works) shall include, but is not limited to, information on the following aspects:

- *building type (e.g. office, factory)*
- *relevant technical and functional requirements (e.g. regulatory and client's specific requirements)*
- *pattern of use (e.g. occupancy)*
- *required service life.*

NOTE 3 Other specific requirements and exposure to climate and to other conditions from the immediate surroundings may be relevant for inclusion in the information on the functional equivalent.

The client's brief and regulations may provide information for defining the functional equivalent. Where this is not the case, the assessment shall include the assumptions made, the scenarios and the sources of information used by the assessor.

Where no required service life is specified by the client or by regulation, the design life may be used. If the design life is used (which can be longer than the required service life), how it is derived shall be described, e.g. determined on the basis of empirical, probabilistic or statistical data.

NOTE 4 Eurocodes and ISO 15686-1 provide guidance on determining the design life of a building."

7.3.3 Functional equivalent regarding rules for comparison and rules for normalisation

FE and Rules for comparison

According to EN ISO 14044: 2006[87]*, "In a comparative study, the equivalence of the systems being compared shall be evaluated before interpreting the results. Consequently,* ***the scope of the study shall be defined in such a way that the systems can be compared****.* ***Systems shall be compared using the same functional unit and equivalent methodological considerations****, such as performance, system boundary, data quality, allocation procedures, and decision rules on evaluating inputs, and outputs and impact assessment. Any differences between systems regarding these parameters shall be identified and reported."*

This statement implies that, if methodological rules are different, bias will be introduced to the comparison. Therefore, if the benchmark is indented to be applied to buildings located in places where assessment methods are different, methodological rules must be clarified otherwise the benchmark won't be reliable.

According to EN 15978, *"**comparisons between the results of assessments of buildings […] shall only be made on the basis of their functional equivalency"***. However, it is obvious that, as every building provides different functionalities and has different intrinsic characteristics, a specific and unique functional equivalent can be found for every building. The comparison between these buildings might be feasible according to EN 15978 guidance, but ***"the basis for comparison shall be made clear"***. The contents of the functional equivalent should be defined according to the purpose of the comparison.

For example, when comparing design alternative competing for a project, the functional equivalent used for the comparison is very detailed as the main functionalities and the main client's specific requirements are identical for every design alternatives. In that specific case, the client's brief requirements may be interpreted as the functional equivalent for the comparison.

When the scope of the comparison is enlarged to buildings located in different places, the functional equivalent needs to be reduced to few parameters in order to enable the comparison of buildings with different climate and regulation context (local, national, etc.).

The functional equivalent shall be adapted regarding the purpose of the benchmarking process in order to enlarge or reduce the scope of the comparison.

FE and Rules for Normalisation

Normalization is understood here as the process to compare building performances to reference values or reference levels.

[87] EN ISO 14044: 2006 Environmental management – Life cycle assessment - Requirements and guidelines ,section 4.2.3.7.

Rules for normalisation correspond therefore to any rules used to define the target values for the benchmark (see section Introduction to benchmarking, Part A). As it was said previously, the comparison shall be made on the basis of a same functional equivalent; consequently, **the reference value set for the benchmark should refer to a specific functional equivalent (i.e. one "benchmark" per functional equivalent).**.

Note: Another purpose of normalization is to figure the magnitude of environmental impact allocated to the studied system with regard to total emission for a reference system. This approach will be also developed in section 7.5.

Proposal for a short definition of functional equivalent

According to main findings underlined in the previous section, the functional equivalent can be summarized into the following description:

A functional equivalent is a set of minimum requirements or characteristics needed to compare building performances against another or against a reference for all key sustainability indicators considered into the scope of the assessment.

7.3.4 Principles to define the FE considering the scope of the benchmark

Identifying and classifying parameters related to FE

Environmental building performances might be influenced by numerous issues according to local context, technical and functional demands from regulatory or client's specific requirements. Performances might also be influenced by calculation methodology which may vary according to national context or political choices, but, according to ISO 14044[88], when comparing performance results of different systems, **methodological considerations must be the same for the assessment of each object system.** Calculation methods shall not be considered as a parameter of the functional equivalency if we consider that for a comparative study the same method shall be used.

Theoretically, regarding the purpose of the benchmark, any parameter that significantly influences building performances might be included into the functional equivalency. However, as it was said previously, adding a parameter to the FE implies that target values for the benchmark (i.e. level of performances) needs to be adjusted accordingly. For example, energy performances target will be adjusted regarding climate severity, taking into account Heating degree day and cooling degree days. However, **it may happen that the current scientific knowledge about the real influence of a given parameter on environmental performances may not permit to adjust target values**, in that case, it would be advisable not to include the parameter into the FE, but **to report the information separate-**

[88] EN ISO 14044: 2006 Environmental management - Life cycle assessment - Requirements and guidelines, section 4.2.3.7 Comparison between systems.

ly in order to understand results (i.e. indicator of local constraints like climate severity, or other information to communicate when benchmarking..). **This way of doing permits also to capitalize information and to increase the quality of the benchmark in the future.**

Some parameters describing building intrinsic characteristics are generally related to specific client's requirements. Among client's requirements it should be important to identify which parameters are related to users' requirements and needs (e.g. specific needs for healthcare facilities...) and which parameters are chosen regarding other concerns (e.g. favouring the fitness for purpose, the usability or the adaptability of the building). Some of these parameters might be included into the assessment of sustainable performance like visual or thermal comfort which might be considered as part of social dimension. In case the benchmark does not include this kind of indicator, it might be useful to report this parameter into the declared functional and technical performances.

Reference units also contribute to comparison purpose. They allow comparing buildings of different size or different occupant capacity (assessment results are respectively expressed per m^2 or per person equivalent).

7.3.5 Key issues for FE

Reference units

According to En 15978, *"A common reference unit can be derived from the functional equivalent and be used to present the result of the indicators of the environmental assessment relative to the functional equivalent. A common reference unit may be dimensionless or qualified with a dimension (e.g. per m^2, per year, per employee, per room per year, per m^2 per year).."*

The use of reference unit permits therefore to neutralize some building characteristics like the size or the occupant capacity when comparing environmental performances. For example, the building size won't be a part of the functional equivalency but reference values will be tailored taking into account the building floor area. The occupant capacity might also be used as reference units (results are then expressed per person).

Reference units are only relevant when comparing building performances. The choice of reference unit do not impact the assessment methods of indicators which are first calculated as absolute values (e.g. kWh, MJ, kg...), absolute values are then divided by the parameter corresponding to the selected reference units (number of person, number of year of reference study period, m^2...).

Note: dividing absolute results by the number of occupants or by the floor area is sometimes called "normalisation", this kind of normalisation shall not be confused with the approach of normalisation developed in section 7.5 which aims at enabling the interpretation of assessment results.

Issues linked to reference units when benchmarking environmental performances

Several approaches might be used to define the functions related to buildings. A detailed approach would be to consider that a building provides several functions, indicators of environmental performances might be expressed using different reference unit for each function. On the contrary, a global approach would be to consider that a building provides one single function, indicator of sustainability will be expressed according to this main function using a single reference unit. However, this choice might potentially leads to bias introduced by the issue of occupational density.

Considering a single or several reference units

If we consider that buildings have several functions, reference units may vary from an indicator to another regarding the main function that contributes to indicator results. For example, when assessing the operational water consumption, the indented function of the building in regard with this indicator is to provide water to users. The reference unit linked to this function shall be based on the number of user for which the building needs to provide water (ex: m^3 of consumed water per user). For energy consumption, several functions (or uses) contribute to the global results. Regarding energy used for heating, the main function is to heat the occupied spaces in the building; results are then divided by the floor area (e.g. living area or net area or conditioned area). For hot water, the main function is to provide hot water to users, results should therefore be expressed per occupants and however, domestic hot water is generally aggregated with other energy uses to the single indicator operational energy consumption which is expressed per m² of floor area. A convenient solution could be therefore to compare the performance for each energy uses (eg: hot water, heating, plug-in appliances etc...).

On the other hand, the assessment of sustainability implies to analyse several indicators (i.e. energy, water, global warming potential, waste...) for each building life stages. The application of this approach would lead to identify indicator of performance for each main contributor at each life stage (modules A, B and C). For example, the benchmark for energy could be separated into sixteen performance criteria from module A-1 to module C4 leading to a huge amount of criteria that shall be aggregated afterwards. Moreover, this approach would imply to provide a level of detail for each module that might not be reachable when using data from EPDs. The consideration of a single function or a single “functionality profile of the building” shall be therefore preferred when benchmarking building performances for LCA indicators.

If we consider that buildings have a unique and main function, a single reference units linked to this main function shall be used to express results for every indicator (i.e. results for every indicator are given per m² of floor area or per person equivalent). The table below show some example of reference units regarding different building typologies. This approach permits to consider building as a whole system and simplify the comparison. However the choice of floor area or occupant capacity when benchmarking introduces bias in assessment results between occupational density and environmental performances.

Table 30. Example of reference units that might be used for different building typology.

Building use-oriented typology		Example of reference units	
Housing	Detached house	Number of occupants	Floor area (GFA, NFA..)
	Semi-detached houses	Number of occupants	Floor area (GFA, NFA..)
	Collective housing	Number of occupants	Floor area (GFA, NFA..)
Non residential buildings	Office building	Number of workstations Number of occupation days, Full time equivalent (FTE)	Floor area (GFA, NFA..)
	Academic building	Number of workstations Number of occupation days	Floor area (GFA, NFA..)
	Social housing	Number of beds	Floor area (GFA, NFA..)
	Storage building	Available volume (m^3)	Floor area (GFA, NFA..)
	Barn	Number of heads of cattle	Floor area (GFA, NFA..)
	Sport and culture Facilities	Number of performances Number of spectators sit	Floor area (GFA, NFA..)
	Accommodation	Overnight stays	Floor area (GFA, NFA..)
	Stores	Number of customers	Floor area (GFA, NFA..)
	Transport	Number of passengers	

Interaction between environmental performances and occupational density
One of the main problem involved by the use of reference units that are not closely related to the main function that contribute to indicator results is that bias are introduced within the expression of performance assessment. An overlap can be seen between occupational density and environmental performances leading to conflicting effects (the issue of occupational density is closely linked to social concerns, i.e. welfare and user comfort which is a pillar of sustainability). This aspect can be illustrated focusing on the operational energy consumption. Typically, user's plug-in appliances and hot water are major contributors of the energy consumption for new buildings and are closely related to the number of users. In

most cases, benchmark for energy consumption is however expressed per m² of floor area. This way of benchmarking the energy performance increase inversely with the number of occupant (eg. for a same floor area, a building with few occupants will be more efficient than a building with numerous).

On the contrary, if the indicator of performance related to energy consumption is expressed per occupant, for a same number of occupants the smaller building might be more efficient, favouring buildings with high occupational density at the expense of spatial comfort and related welfare concerns.

Using a conventional factor of "occupational density"

A solution that could permit to get rid of this issue when benchmarking building performances might be to introduce a conventional factor for the calculation of the number of occupant for the building.

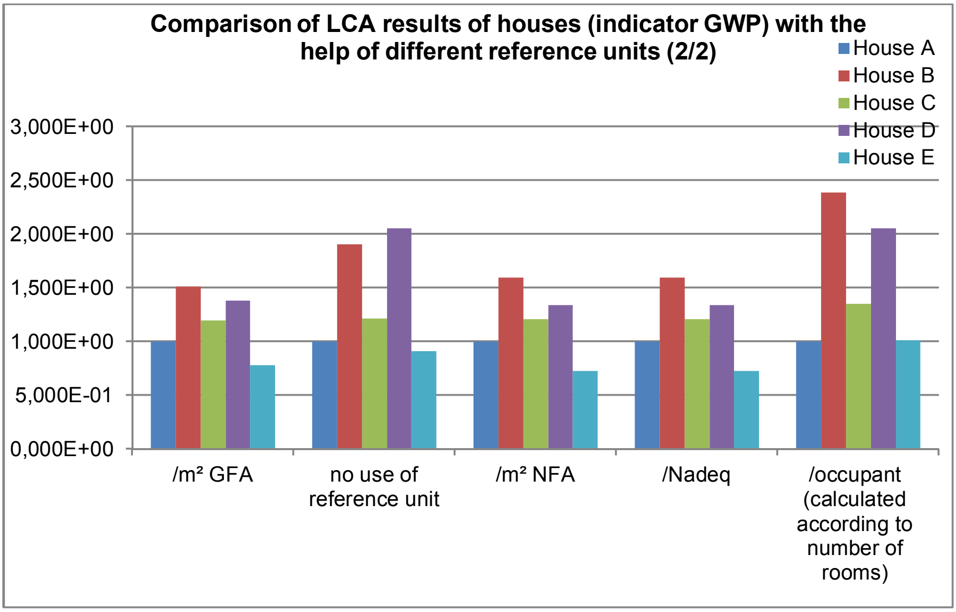
Using such rules would permit to compare performances related to building efficiency and neutralize the interrelation between occupational density and environmental performance. The occupational density calculated according to the real characteristics of the building should be reported within the assessment results if not used as indicator of social or functional performance.

Example of comparison of the environmental performances of individual houses considering different reference units

A study on importance of reference units was made through the analysis of some environmental indicators in several individual French houses. The figure below shows the comparison of the results of the 5 houses, taking house A as the basis for comparison. The following reference units were used for the analysis.

- Spatial characteristics:
  - Net Floor Area (NFA)
  - Gross Floor Area (GFA)
- Characteristics related to the occupation:
  - Number of equivalent of adult (Nadeq) (French thermal regulation);
  - Number of occupant per m² of floor area according to French statistics;
  - Number of occupant per number of rooms of the dwelling according to French statistics.

Table 31. Comparison of results of GWP for 5 house types in France, expressed with the help of different reference units, Results of house A serves for calibration of results.



This exercise puts in evidence that results of the comparison can be influenced to some extent by the chosen reference unit. Differences appear for example when the results are expressed considering the number of occupant calculated on the basis of the number of main rooms of the house, where a reversal of the ranking of houses A (blue) and E (turquoise) can be observed. Moreover, house B and D show performance gaps relative to other houses much higher than for other reference units. However, as the difference are not so considerable it is also shown that the choice of the reference units used for the benchmark would not imply serious misleading, if the description of the functional equivalent is enough comprehensive to facilitate comparison.

7.3.6 Building service life

The European standard EN 15978 provides the following definitions:

- Design life : « *service life intended by the designer » [ISO 15686-1:2000]*
- Estimated service life : « *service life that a building or an assembled system (part of works) would be expected to have in a set of specific in-use conditions, determined from reference service life data after taking into*

account any differences from the reference in use conditions" [EN 15643-1:2010]

- Required service life (ReqSL) : « *service life required by the client or through regulations* »
- Reference study period (RSP) : « *period over which the time dependent characteristics of the object of assessment are analysed. NOTE In some cases, reference study period may significantly differ from the design life of the building* »

EN 15978 (section 7.2 functional equivalent) also says that

"Where no required service life is specified by the client or by regulation, the design life may be used. If the design life is used (which can be longer than the required service life), how it is derived shall be described, e.g. determined on the basis of empirical, probabilistic or statistical data."

EN 15978 says for Reference Study period: *"The default value for the reference study period shall be the required service life of the building. Any deviations from thisshall be clearly stated and reasons explained. The reference study period may differ from the required service life given for the object of assessment depending on the intended use of the assessment, or on regulatory requirements or national guidance. However, in all cases, the assessment is based on the building life cycle. Therefore, the values for impacts and aspects shall first be calculated for the required service life."*

- *RSP 1: if the reference study period and required service life are the same, RSP/ReqSL = 1.*
- *RSP 2: if the reference study period is shorter than the required service life, the quantified values of impacts and aspects for the use stage (modules B1– B7) and benefits and loads that come from modules B1–B7, are adjusted by a factor RSP/ReqSL.*
- *RSP 3: if the reference study period is longer than the required service life, scenarios for refurbishment, or demolition and construction of an equivalent new building shall be developed. These scenarios shall provide for an extension of the service life which, when combined with the required service life of the object of assessment, is equal to or more than the reference study period. The full value of impacts and aspects for both the actual required service life and the extension to the service life shall be taken into account following the rules given above.*
- *In all cases, the quantified values obtained for the product stage (modules A1, A2, A3), the construction/process stage (modules A4, A5), and the end of life stage (modules C1–C4) are independent of the value of the reference study period. The values for impacts and aspects for modules in the use stage (modules B1–B7) are multiplied by the ratio of the reference study period to the required service life (RSP/ReqSL). The loads and ben-*

efits reported in module D derived from the modules A (DA), B (DB) and C (DC) are also scaled in the same way.

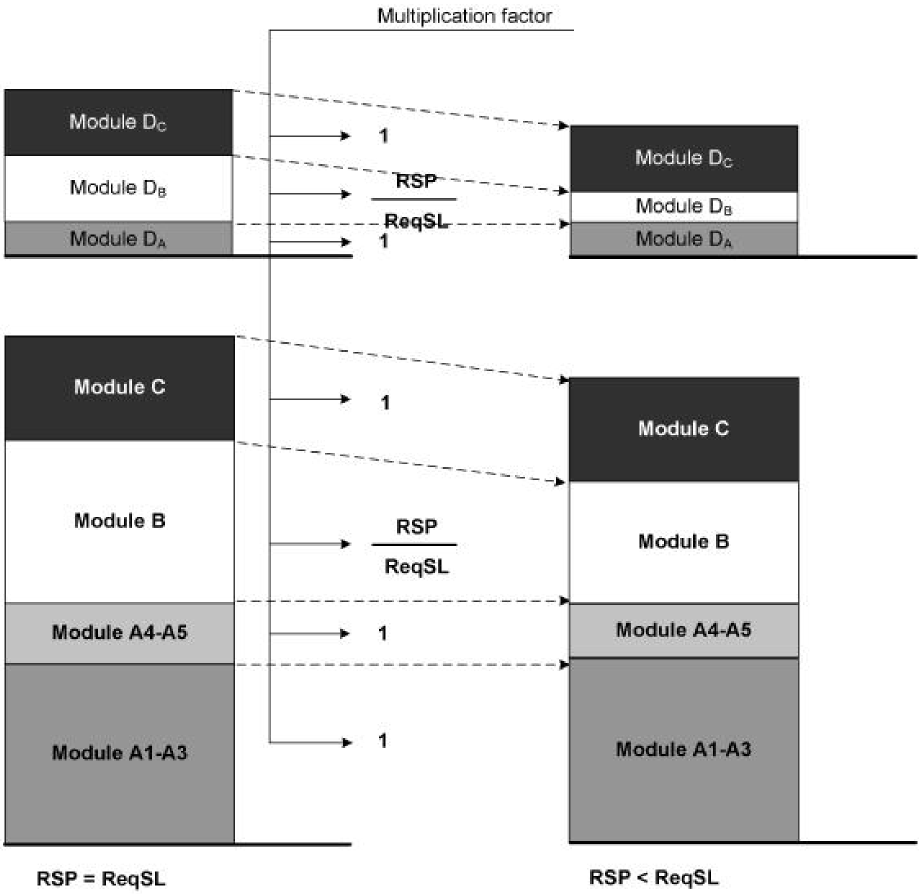


Figure 5 — Illustration of how the quantified impacts and aspects are adjusted for a reference study period that is less than the required service life (Case RSP 2)

Figure 16. Illustration of how the quantified impacts and aspects are adjusted for a reference study period that is less than the required servivice life (RSP2)

Service life and functional equivalent

Defining the Reference study period

To compare environmental building performances it is important to specify the methodological considerations regarding the building service life.

The departure point shall be to consider **the same reference study period for every building being compared** (as recommended in EN 15978).

Defining the RSP will become a difficult matter as it includes several issues:

- If RSP is selected as a "short period" no scenario for refurbishment would be included because the required service Life will be, in most case, shorter than the RSP (see below EN 159578 guidance). The "durability" of a building would not be taken into account into results of LCA indicator assessment
- If RSP is selected as a "long period" (e.g. more than 100 years), scenario for refurbishment will be included in most cases. The "durability" will be assessed in this case.

The choice of the RSP will therefore correspond to set a "cursor" to decide if scenario for refurbishment shall be taken into account or not.

Then, the consideration of the ReqSL in the benchmarking process shall be made with the view to define the functional equivalent.

Functional equivalent and required service life

Two different approaches may be used in the perspective to compare buildings.

a) **The required service life is set "conventionally":** The required service life may be a conventional way to define the service life of a building, however, in many case, it won't correspond to the real service life as many external parameters are involved (i.e. the context of use, economical considerations for refurbishment or demolition at the end life of the expected service life, consideration of new technologies for new buildings for which few feedbacks are available, etc...). In order to make neutral this parameter, the same required service life will be considered for every buildings being compared, thus **the RSP considered for the study will be set equal to the ReqSL**. The required service life might correspond to statistic or probabilistic data (i.e. 50 years for schools, 100 years for individual houses, etc...). **The functional equivalent will take into account a "conventional" service life i.e. the benchmark will be set in relation to this service life**. Using such rules won't permit to consider scenario for refurbishment into results of LCA assessment results. And, to some extent, the "**durability" of the building as a whole won't be assessed.** However it has to be noted that other activities such as replacement and maintenance which occur at lower intervals than building service life will need to be assessed in any case.
b) **The Required service life is considered for the assessment of sustainability performances:** If we consider that the required service life shall be taken into account for the assessment of environmental performance, it may be decided to **analyse buildings with different ReqSL**

> **but considering the same RSP** (the methods will take into account the requirements of EN 15978)**.** The ReqSL won't be considered into the FE in order that any buildings could be compared with the same performance scale (i.e. benchmark value). The required service life of the building will have a major influence on environmental performance.

The second approach would be the most relevant as it consider the longevity of a system. However, since the current knowledge about the appreciation of the service life of a building is poorly developed, the first approach shall be used in preference.

A thorough work would be necessary to evaluate and understand the service life of building. The fundamental parameters that involve the refurbishment or the destruction of the building need to be addressed considering technical parameter but also and especially social, cultural and financial aspects.

7.3.7 Functional performances

Differences between functional performances and functional equivalent

When we look at characteristics that may be included into functional equivalency, several are linked to the functional or the technical performances of buildings. As previously discussed, characteristics included into the functional equivalent are the minimal intrinsic characteristics which need to be the same to be able to compare buildings. Other characteristics might be considered as "secondary" ones. The identification of these "first" and "secondary" functionalities shall be made according to the purpose of the benchmark. In some cases, characteristics considered as "secondary" can considerably influence the environmental performances, and then it is recommended to consider these into the benchmark.

The way to report and express secondary parameters may vary according to the scope of the benchmark: secondary characteristics may be considered as input parameters for the assessment of functional performances, but might also be considered as input parameters for the assessment of social performances.

Functional, technical and social performance.

According to SuPerBuildings deliverable 4.1, *"functional quality can be integrated into social qualities. Technical quality is to be assessed, but the results are to kept separate from the main assessment"*[1].

Technical performances are only relevant if they are related to one of the main pillar of sustainability (i.e. technical quality might be a tool for sustainability improvement but do not correspond to a goal in itself). It makes therefore no sense to provide information about technical performance within the benchmark of sustainability if the information is not relevant for any overall subject of concern (i.e. social, environmental or economic...). On the contrary, functional performances are likely to reflect welfare or social concerns and shall be considered in the process of benchmarking buildings.

In many cases, different buildings with the same use-oriented typology won't provide the same services (adaptability, space comfort etc..). If **the benchmark doesn't take into account indicator of social performances** as for example those developed in prEN 16309[89] **it is advisable to report information on the object of assessment concerning the provided functionality.**

How to define the functional performances according to the scope of the comparison and the functional equivalent

The European standard pr EN 15686-10[90] define the functional performance as the suitability of the provided solution regarding the needs. It corresponds then to the gap between supply (eg. services provided) and demand (users' requirements).

Assessing the functional performances of different alternatives at the design stage

If the comparison is to be done between design alternative at the design stage of the project, user's requirements will correspond to the clients' brief. It is therefore possible to compare the suitability of each alternative on the basis of the user's needs specified by the clients brief.

Comparing functional performances of building in different context

If the object of the benchmark is to compare several buildings considered to provide the same functional equivalent but corresponding to different context (geographic, cultural, economic...), user's requirements for each building might consequently differ. It becomes then more complex to find common bases for the comparison of functionality as it would vary according to many parameters (user requirements and local considerations).

However, to make the comparison of results transparent, the method used to benchmark buildings should define the minimal requirement needed by the user to fulfil its activity in order to define a "threshold level of functionality". These minimal requirements can be defined for each functional equivalent. This approach is consistent with the guidance provided in EN 15643-1: *"The assessment report and communication shall include information on the main technical characteristics and functionality of the building that deviates from the technical and functional requirements given in the functional equivalent."*

[89] prEN 16309:2011 Sustainability of construction works – Assessment of social performance of buildings – Methods.

[90] ISO 15386-10:2010 Buildings and constructed assets – service life planning – part10: When to assess functional performances.

Moreover, the method defined to benchmark buildings shall specify the information needed in order to compare the serviceability of the building toward the threshold level set for each functional equivalent.

7.4 Recommendations for functional equivalent and rules of comparison

The comparison between different buildings is possible only if ***the basis for comparison is made very clear ,*** and to facilitate this clarity the contents of the functional equivalent should be defined carefully, and according to the purpose of the comparison.

The functional equivalent shall therefore be adapted regarding the purpose of the benchmarking process in order to enlarge or reduce the scope of the comparison.

Numerous characteristics related to the intrinsic description of the project but also related to some external parameters can be considered as part of the functional equivalent. Among these, the following ones have been identified:

- Type of construction project (new building, refurbishment, extension…)
- Parameters related to the location of the building site:
  - Climate aspects,
  - Geological aspects,
  - Acoustic aspects,
  - Urban context (architectural constraints, density, access to facilities, economic value of the real estate),
  - National or local regulation and requirements (safety, accessibility etc…)
- Parameters related to the functionality and quality of use:
  - Use-oriented typology (residential, offices, school, etc...),
  - Number and type of users and scenario related to their occupation,
  - Building service life,
  - Amenities and equipment provided (car park, balcony, garden...etc),
  - Size and space aspects (Floor area, occupational density, height under ceiling...),
  - Comfort requirements (e.g. temperature set-point in winter and summer)
  - …

Including a parameter into the FE implies that target values for the benchmark (i.e. level of performances) are adjusted accordingly. For example, energy performance targets might be adjusted regarding climate severity, taking into account heating degree days and cooling degree days. The more parameters and level of detail is included into the functional equivalent, the more precise and relevant the benchmark would be.

However, some parameters related to building performance might not be sufficiently detailed or known to be included in a reference values, and in this cases those parameters are better reported separately, and not be part of the functional equivalent.

There is also the case of some parameters describing building functionality or quality of use (e.g. favouring the fitness for purpose, the usability or the adaptability of the building) that may be considered into the assessment of sustainable performances, for example in the social performance. In case the assessment scheme does not include such indicators, these aspects might be either included into the functional equivalent through a practical description (e.g. indoor temperature ranges, illuminance level...) or reported in another way (e.g. declared functional performances, quality of use,etc.).

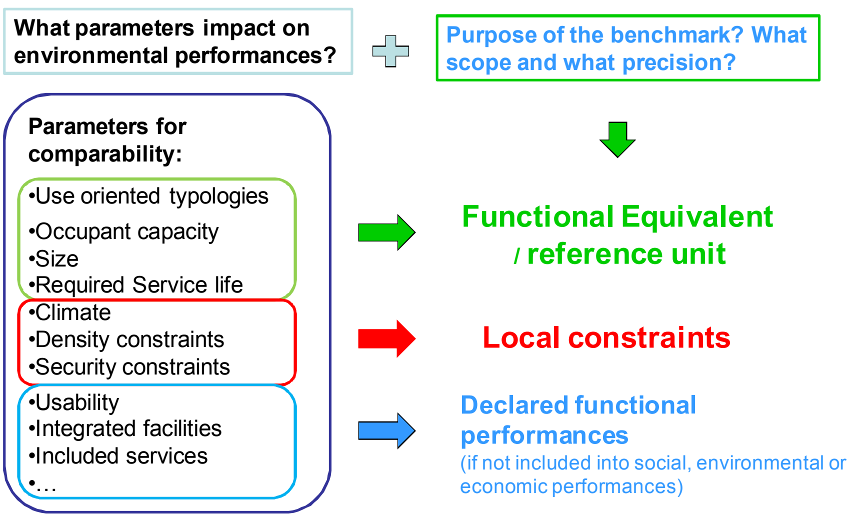


Figure 17. Example of methodology to define the functional equivalent regarding the purpose of the benchmark.

7.5 Normalisation

7.5.1 Definition from ISO 14044: 2006[91]:

ISO 14044 defines that *"Normalization is the calculation of the magnitude of the category indicator results relative to some reference information. The aim of the normalization is to understand better the relative magnitude for each indicator result of the product system under study.* ***It is an optional element that may be helpful in, for example,***

- *checking for inconsistencies*
- *providing and communicating information on the relative significance of the indicator results, and preparing for additional procedures, such as grouping, weighting or life cycle interpretation.*

Normalization transforms an indicator result by dividing it by a selected reference value. Some examples of reference values are:

- **the total inputs and outputs for a given area that may be global, regional, national or local**
- **the total inputs and outputs for a given area on a per capita basis or similar measurement, and inputs and outputs in a baseline scenario, such as a given alternative product system.**

The selection of the reference system should consider the consistency of the spatial and temporal scales of the environmental mechanism and the reference value.

The normalization of the indicator results can change the conclusions drawn from the LCIA phase. It may be desirable to use several reference systems to show the consequence on the outcome of mandatory elements of the LCIA phase. A sensitivity analysis may provide additional information about the choice of reference data.

The collection of normalized category indicator results represents a normalized LCIA profile."

7.5.2 Different approaches of normalization

Normalization is an optional element of the LCA process that might be helpful for the interpretation of the results in multi-attribute decision analysis. It is a mathematical operation which consists in dividing a result by a selected reference value

[91] EN ISO 14044: 2006 Environmental management - Life cycle assessment - Requirements and guidelines ,section 4.4.3.2.

(EN 14044) and can lead to express a multicriteria profile with different units in a multicriteria profile with a single unit. (ex. number of inhabitant equivalent). It might also be use as a first step for aggregation.

Regarding the purpose of the comparison**,** two different approaches might be used to normalize results:

1. Understanding the significance of building impact in relation to total impacts related to a given system for a given geographical area (e.g. human activities in Europe). This type of normalization can be related to overall subjects of concern.
2. Comparing results to a reference alternative (design stage of building) or to a reference scale (evaluation of building performances). This type of normalization can serve to compare different buildings alternatives.

7.5.3 Normalization and significance of environmental impact to overall subject of concerns

Objective of the approach

If the aim of the normalization is to figure out the significance of calculated impacts in relation to a whole system, the basis for the normalization will be the total sum of impacts allocated to the given system (e.g. inhabitant) in a geographical area (region, country or world) per year.

Usually, normalization factors are expressed per inhabitant equivalent and per year, tables below show some examples of data published by BRE regarding West Europe[92] and by the association RECORD[93] for different environmental aspect:

Table 32. Normalization factor for Western Europe according to BRE (2005).

Environmental aspect	unit	year-inhabitant
GWP	kg CO_2 eq.	12 300
Abiotic depletion	kg Sb eq.	39.1
Radioactive waste	mm^3	0.000241

[92] BRE, Green guide to specification, BRE materials industry briefing note 3b : Normalisation, London, 2005.

[93] RECORD association, « Valeur de normation pour les indicateurs environnementaux », juillet 2002.

Table 33. Normalization factor according to RECORD (2002).

Environmental aspect	unit	year-inhabitant	Geographical area
GWP	kg CO_2 eq.	10 839	Europe UE15
		11 227	France
Primary Energy	kWh	46 780	Europe UE15
		49 408	France
Acidification	kg SO_2 eq.	58.24[94]	Europe UE15
		-	France

Example of normalization to understand the significance of environmental aspects

The table below provide information on the significance of building impact per person for three hypothetical houses. For example, it can be interpreted that, for the inhabitant of house 2, 60% of CO_2 impacts related to "European human activities" are related to his house.

Table 34. Example of results for indicators primary energy and Global Warming Potential, expressed per person and per year of operation.

Environmental aspect		Units (before normalization)	House 1	House 2	House 3
Primary Energy	Operational stage	kWh/person/year (50 years of operation)	5000	11667	1500
	Embodied	kWh/person/year (50 years of operation)	2333	500	833
GWP	Operational stage	CO_2 eq/person/year (50 years of operation)	2500	5833	750
	Embodied	CO_2 eq/person/year (50 years of operation)	400	667	133

[94] 1 kg eq. H^+ = 32 kg eq. SO_2

Table 35. Example of normalized results of three houses for indicators primary energy and Global Warming Potential (according to data from RECORD for UE15).

Environmental aspect		**Units (after normalization)**	House 1	House 2	House 3
Primary Energy	Operational stage	Equivalent year-european inhabitant	0.11	0.25	0.03
	Embodied		0.05	0.01	0.02
GWP	Operational stage		0.23	0.54	0.07
	Embodied		0.04	0.06	0.01

This kind of normalisation can be seen as a first step for defining weighting methods.

However, the use of external normalization might lead to bias as data used to calculate normalisation factor might be uncertain or incomplete[95]. As recommended in ISO 14044, if normalised results are communicated, non-normalized results should be provided in addition.

7.5.4 Normalisation to compare the environmental profile of several alternatives

Objectives of the approach

If the goal is to compare results of different alternatives or different buildings, the selected reference value will be a design alternative or a given reference.

In order to analysis results of a multicriteria assessment (i.e. energy, water, waste, GWP..) the process of normalization may lead to divide the results of the calculation of indicators by a reference value called "normalization factor". Providing normalised results when making the comparison between different alternative permits to analyse non-commensurable indicators.

Example of normalisation to compare alternatives

In order to compare environmental performances for housing buildings, indicator results can be expressed in equivalent m² of "reference house".

[95] Heijungs, Reinout; Guinée, Jeroen; Kleijn, René; Rovers, Vera. Bias in normalization: Causes, consequences, detection and remedies, The International Journal of Life Cycle Assessment 2007-06-01.

Table 36. Example of environmental results for 3 houses and a reference house.

Environmental aspects		Units	House 1	House 2	House 3	Reference house
Non renewable Primary Energy		kWh/m²/year	150	200	45	120
GWP	Operational stage	CO_2_eq	40	22,5	25	25
	Embodied	CO_2_eq	150	15	80	80
Water	Operational stage	Liters	106	250	100	100
	Embodied	Liters	400	200	150	150
Hazardous waste		kg/m²/year	2	3,5	6	5

Table 37. Example of environmental results normalized according to the reference house.

Environmental aspects		Units	House 1	House 2	House 3
Non renewable Primary Energy		kWh/m²/year	1.3	1.7	0.4
GWP	Operational stage	CO_2_eq	1.6	0.9	0.9
GWP	Embodied	CO_2_eq	1.9	0.2	0.2
Water	Operational Stage	Liters	1.1	2.5	1.0
Water	Embodied	Liters	2.7	1.3	1.0
Hazardous waste		kg/m²/year	0.4	0.7	1.2

Normalized results provided inprevious Table 37. permit to figure out the relative performance of each house in relation to the reference house for a set of indicator using different units. For example, the contribution of products and materials for indicator GWP is not expressed per year of operation (which could lead to introduce bias as seen in previous section) contrary to the contribution of operational stage that is expressed per year, results are then un-commensurable. However, when comparing results in "m² equivalent of reference house", we are able to figure out a "performance" of each house in relation to the last one and to compare "the multicriteria profile" for each house.

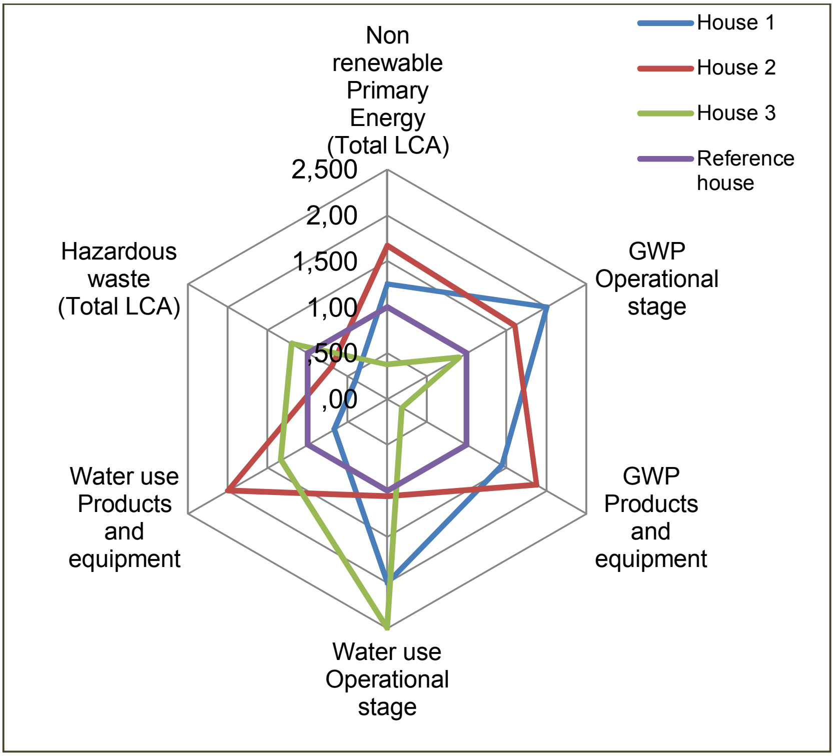


Figure 18. Representation of environmental profile with the help of normalized results (the basis for the normalization is the “reference house”).

It is important to note that normalised results for different indicator shall not be summed up to create a single “quotation”, as explained in ILCD guidance[96] : “***Note that normalised results shall not directly be summed up across different impact categories as this would imply an even weighting of all impact categories****. This is unless this even weighting is intended and identified explicitly as weighting when communicating the results.”* In the example presented above, summing each indicator would end-up to create a weighting rule (i.e. the results would be weighted according to the values of the reference house).

In the same way, it is also important to take notice that this approach is limited to the comparison of alternative but doesn’t permit to figure out the performance of the profile in regard to reference or target value when the aim of the benchmark is to express the building performances.

[96] ILCD Handbook, General guide for Life cycle assessment- Detailed guidance, 2010, provisions 8.3.

7.5.5 Conclusion about rules for normalisation

Normalization might be helpful for the interpretation of the results but may change the conclusion of the study. Indeed, it is a tool that might be help to compare and to understand the results of multicriteria analysis. If normalized results are used in view to benchmark buildings, issues of functional equivalency and reference units must be clarified. Whatever the approach considered, **it is advisable when communicating results to provide both normalized and non-normalized results.**

7.6 Weighting and aggregation issues

Weighting and aggregation are tools that are frequently used by sustainable building assessment systems to aid on the decision making process, as they allow the presentation of multiple indicators in a reduced set of results , a score, or a single classification , which can be more comprehensible for the different stakeholders. This section introduces concepts of multi-criteria decision making, and current practice and recommendations for weighting and aggregation issues.

7.6.1 Introduction to Multi-criteria decision analysis and weighting

Decision making is about choosing the most preferred alternative from a set of candidate alternatives. Decision analysis has been defined as "a formalization of common sense for decision problems which are too complex for informal use of common sense"[97]. The decision problem is divided into smaller parts which are analysed in order to better understand the whole problem. This approach is called "divide and conquer". The analysis helps to organize and support judgements and to provide a model of the problem for a better understanding of the situation[98] . Its ultimate aim is to make consistent decisions by taking into account all relevant objective and subjective factors[99].

The three main parties in decision analysis are decision makers, decision analysts and stakeholders/experts. It is important to clearly define what the objectives of the decision are, what criteria are used to measure the objectives and what measures are used to compare the alternatives with regard to the criteria. Deci-

[97] Keeney R., 1982. "Decision Analysis: an Overview", Operations Research 30(5), pp. 803–838.

[98] Seppälä J., 2003. "Life Cycle Impact Assessment Based on Decision Analysis", Doctoral Thesis, Helsinki University of Technology, Department of Engineering Physics and Mathematics, Systems Analysis Laboratory, 62 pages.

[99] Mustajoki J. and Hämäläinen R., 2007. "Smart-Swaps – a Decision Support System for Multicriteria Decision Analysis with Even Swaps Method", Decision Support Systems 44(1), pp. 313–325.

sion analysis is used to support decision making, especially when uncertainties are present and decisions depend on several persons.

Decision analysis often uses mathematical modelling. There are many tools available that can be used as support in decision making. Value is the term used to measure preference under certainty (can be translated into weights and percentages) and utility the measure of preference under uncertainty (usually uses probabilities for each decision alternative).

Multi-Criteria Decision Analysis (MCDA) is a general method that usually uses value trees. Value tree is a structured representation of the criteria that are used to measure the decision objective. For example rating schemes are usually represented as value trees (see Figure 19). Weights can be used to show the importance of different criteria. At all levels of the value tree the sum of weights must be 1 (or 100%). In non-hierarchical weighting only bottom level weights (indicator weights in Figure 19) are elicited, and upper level weights (for impacts in Figure 19) are derived as sums of weights of twigs of which they are composed. More common is however hierarchical weighting in which weights are elicited at all levels of the value tree. The weights of bottom level criteria (indicators in Figure 19) are obtained by multiplying weights vertically. In Figure 19, 100% of weights are first divided at upper level for impacts. Then 100% of weights are elicited for indicators under each impact. The final weight of each indicator is then the product of the weight of corresponding impact multiplied by the weight the indicator has received under the corresponding impact.

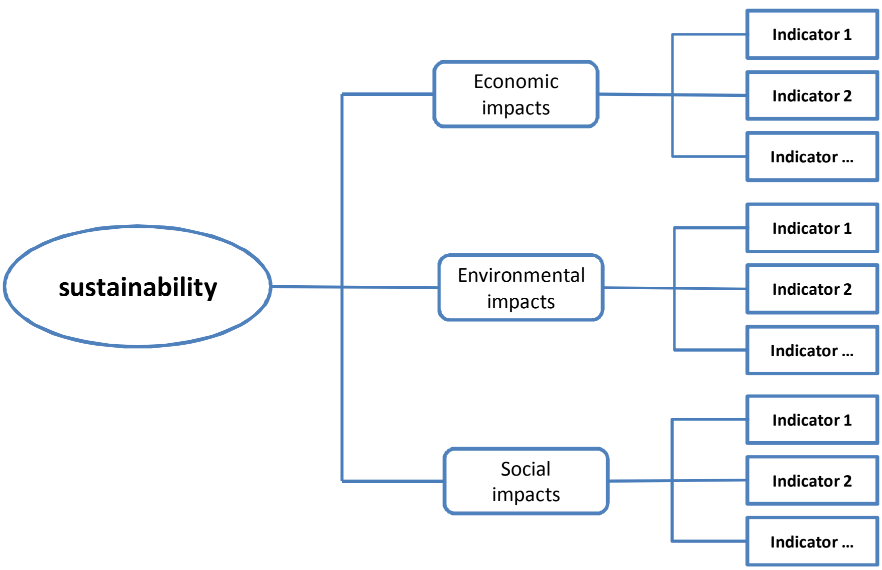


Figure 19. Example of a value tree.

Regarding this distribution of weights, **SuperBuildings recommends that environmental, economic and social dimensions shall be given equal consideration**. The main categories of the assessment system derived from the subjects of concern should be subject to a formal weighting process.

SuPerBuildings also encourages different levels in the structure of issues to be assessed, for clarity and easiness of weighting. The range of issues and related criteria are not to be put at the same level, but must be structured at several levels. For this multi-level structured list of issues, the weighting factors can be defined level by level, handling a limited number of items at a time.

Key recommendations for the definition of the weighting factors are:

- An expert forum or an alternative structured method should be used in order to arrive at weighting factors within indicator groups – the decision-making process should be transparent and should be documented.
- Weighting factors may vary between geographic regions.

For the formal weighting process, there are various possible methods. The idea of trade-off weighting is that two alternatives are compared and the decision maker is asked to set performance levels for the alternatives so that they are equally preferred. Maybe the most well-known weighting method, Analytic Hierarchy Process (AHP)[100], uses pairwise comparisons between all the criteria. These methods often require so many comparisons that they are too time-consuming. Therefore, there are simpler methods, e.g. SWING, SMART, SMARTS, which are based on comparisons against the most or least preferred alternative with the help of e.g. points. There are however some biases that have been observed in relation to weighting methods[101]. In environmental decision making, value trees and their weighting is particularly useful when comparing the opinion of different parties in decision making or the preferences of stakeholders. When the mutual importance of different indicators has been defined with weights, decision recommendations can be obtained by using a decision support tool (or simply based on the weights in the value tree). The value tree model can be associated to different options that are compared. A value tree similar to that of Figure 19 could for example be used to compare the sustainability of three buildings (see Figure 20).

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[100] Saaty T., 1986. "Axiomatic Foundation of the Analytic Hierarchy Process", Management Science, 32(7), pp. 841–855.

[101] Borcherding K. and von Winterfeldt D., 1998. “The Effect of Varying Value Trees on Multiattribute Evaluations”, Acta Psychologica 68, pp. 153–170; Weber M., Eisenführ F. and Winterfeldt D., 1998. “The Effects of Splitting Attributes on Weights in Multiattribute Utility Measurement”, Management Science 34, pp. 431–445.; Hämäläinen R. and Alaja S., 2008. ”The Threat of Weighting Biases in Environmental Decision Analysis”, Ecological Economics. 68, pp. 556-569.; Pöyhönen M. and Hämäläinen R., 2000. “There is Hope in Attribute Weighting”, INFOR 38(3), pp. 272–282.

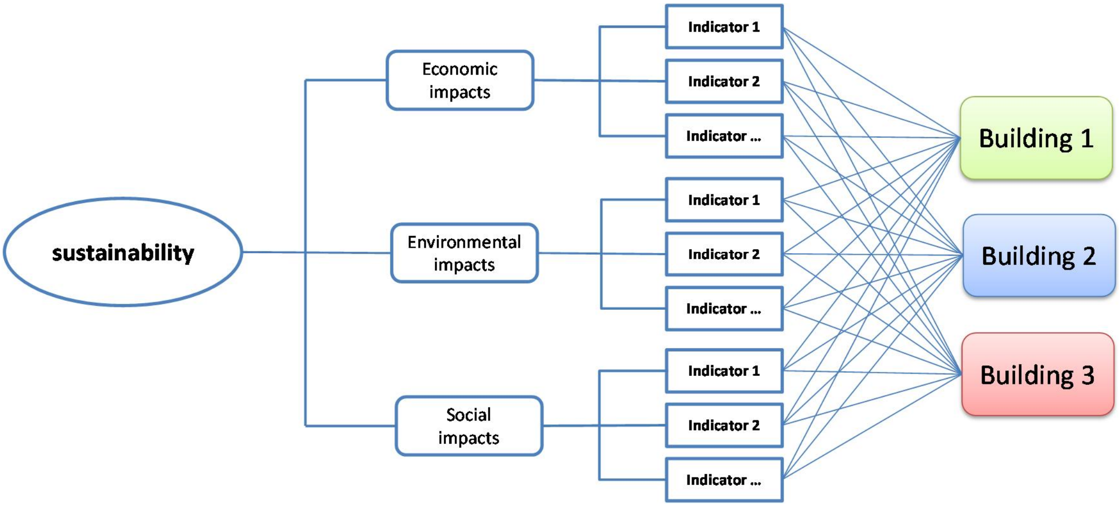


Figure 20. Comparison of options with help of value tree.

If the three buildings are assessed against the given criteria of the value tree, we are able to associate weights for each indicator in relation to the compared buildings so that the highest weight is given to the building that performs the best. Once we have the preferences of different stakeholders or decision makers (i.e. weights for the indicators), the model will then give a recommendation of preferred building option for each stakeholder or decision maker.

An important part in decision analysis is sensitivity analysis. It consists of studying how changes in weights affect the decision recommendation. It is useful to know for example if the decision recommendation would change with small changes in weights which means that the recommendation is weak. In the case of assessment of buildings' sustainability with the help of a rating scheme, sensibility analysis also helps to know how much the performance level of certain indicator should be improved so that the building would achieve a certain level of sustainability.

7.6.2 Issues related to double counting and overlapping

Within the SuperBuildings framework outlined in deliverable 4.1, it is discussed how in general double counting should be avoided, as this would increase the weight given to one issue over the others, leading to imbalances in the system. However, one issue might have different effects on different areas of protection. Measuring these would mean capturing multiple effects, as opposed to double counting.

Existing assessment systems have more or less intricate mechanisms in place to attribute more or less importance or “weight” to an indicator or an indicator group in comparison to the others. The relative importance of the issues assessed needs to be defined, in a transparent way and when possible via quantification in a mid-point indicator, and avoiding double counting. Mid-point indicators could be weighted at that point in a transparent way.

Double counting in an LCA context, as described in ISO 14044, should be avoided by recording each unit process. ISO 14044 states that *"To decrease the risk of misunderstandings (e.g. resulting in double counting when validating or reusing the data collected), a description of each unit process shall be recorded”*. ISO 14044 also states that *"the impact categories, category indicators and characterization models should avoid double counting unless required by the goal and scope definition, for example when the study includes both human health and carcinogenicity."*

Double counting could reflect two problems with LCA studies: The same information could be counted twice in the same LCA, or the same information could appear identically in two otherwise separate LCA studies which are combined in another context. The un-wanted double counting in LCAs is typically based on the unclearly described system boundaries.

In sustainability assessment methods of buildings, there is also an obvious danger for double counting when the environmental impacts are assessed with the help of an LCI/LCA , for example.

a) when performance indicators such as flexibility, maintainability, recyclability, durability etc. are simultaneously used to indicate environmental impacts
b) when technical performance or quality of technical devices are used to indicate environmental impacts.

Furthermore, current environmental assessment methods, which do not actually follow an LCA approach, have other issues that also relate to overlapping and double counting of indicators. This is further discussed in the following section.

7.6.3 Current practice in envirornmental assessment systems

Various issues can be identified within the aggregation and weighting of some of the international environmental assessment schemes, such as LEED and BREEAM. These environmental assessment methods are based on the compliance with a set of criteria or requirements on various aspects related to energy, transportation, materials, site selection, etc. Each of those aspects is evaluated providing a score which is then added to get a final score for each group.

A general discussion is presented here, and some detailed comments are related to Energy & Atmosphere, Materials & Resources and Indoor Environmental

Quality, which is present in those schemes. As a first step of analysis, and in order to get an overview of the current practice of environmental rating systems in relation to weighting and aggregation, two of the main systems (LEED and BREEAM for new office construction) have been selected and the requirements grouped regarding to the different areas analyzed.

Table 38. Different issues considered in LEED and BREEAM assessment systems and their score.

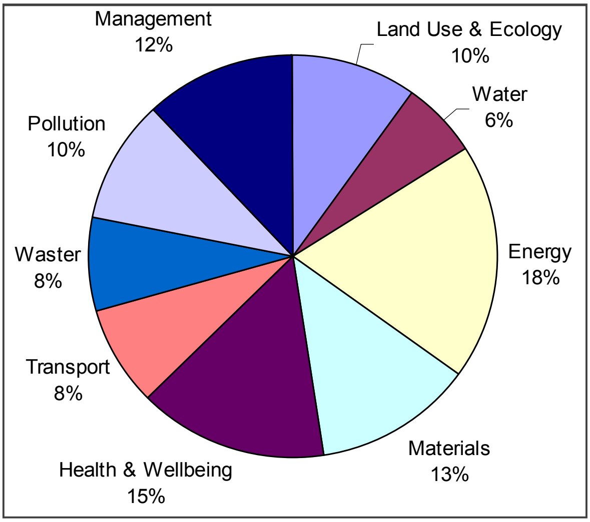
BREEAM			LEED		
SECTION	NAME	POINTS	SECTION	NAME	POINTS
Health & Wellbeing	Visual Confot	1	Indoor Environmental Quality	Daylight and Views - Daylight	1
	Exterior views	1		Daylight and Views - Views	1
	Glare control	1			
	High frecuency lighting	1			
	Levels of external and internal lighting	1			
	Areas and lighting controls	1		Controllability of Systems - Lighting	1
	Indoor aur quality	1		Minimum Indoor Air Quality Performance	1
	Volatile organic compunds	1		Low-Emiting Materials - Adhesives, Sealants, Paints, Coatings, Flooring Systems, Composite Wood and Agrifiber Products Indoor Chemical and Pollutant Source Control	1 point per section
	Thermal comfort	2		Thermal Confort - Design and Verification	1+1
	Thermal zoning	1		Controllability of Systems - Thermal Confort	1
Energy	Optimize Energy Performance	15	Energy & Atmosphere	Optimize Energy Performance	1/19
	Energy monitoring	2		Measurement and Verification	3
	External lighting	1			
	Low and zero carbon technologies	3		On-site Renewable Energy	1/7
	Energy Efficient cold storage	2			
	Energy Efficient transportation systems	3			
Materials	Life cycle impacts	4			
	Boundary protection	1			
	Structure protection	1	Material & Resorces	Building Reuse	1/3
	Responsible sourcing of materials	3			
	Designing for robustness	1		Recycled Contect	1/2

BREEM			LEED		
SECTION	NAME	POINT 5	SECTION	NAME	POINT 5
Health & Wellbeing	Visual Confort	1	Indoor Environmental Quality	Daylight and Views – Daylight	1
	Exterior views	1		Daylight and Views – Views	1
	Glare control	1			
	High frecuency lightning	1			
	Levels of external and internal lighting	1			
	Areas and lighting controls	1		Controllability of Systems – Lighting	1
	Indoor aur quality	1		Minimum Indoor Air Quality Performance	1
	Volatile organic compunds	1		Low-Emiting Materials – Adhesives, Sealants, Paints, Coatings, Flooring Systems, Composite Wood and Agrifiber Products Indoor Chemical and Pollutant Source Control	1 point per section
	Thermal comfort	2		Thermal Confort – Design and Verification	1+1
	Thermal zoning	1		Controllability of Systems – Thermal Confort	1
Energy	Optimize Energy Performance	15	Energy & Atmosphere	Optimize Energy Performance	1/19
	Energy monitoring	2		Measurement and Verification	,
	External lightning	1			
	Low and zero carbon technologies	3		On-site Renewable Energy	1/7
	Energy Efficient cold storage	2			
	Energy Efficient transportation systems	3			
Materials	Life cycle impacts	4			
	Boundary protection	1			
	Stucture protection	1	Materials & Resources	Building Reuse	1/3
	Responsible sourcing of mateirals	3			
	Designing for robustness	1		Recycled Content	1/2

Some observations arise from this comparison:

– Each evaluation system looks at different criteria and issues related to the building performance, and assigns dofferent scores to the criteria . Therefore, it is observed that there is no general agreement regarding indicators to be used, and the way those are given a certain value and weighted and aggregated through the score system.

- The score for the same criteria differs between assessment systems. For example, while in BREEAM optimizing building energy efficiency could earn a maximum of 15 points, LEED assigns up to 19 points in this particular criteria .
- Although with similar values, the final weight between categories also differs between assessment systems, as it can be observed in the following figure.



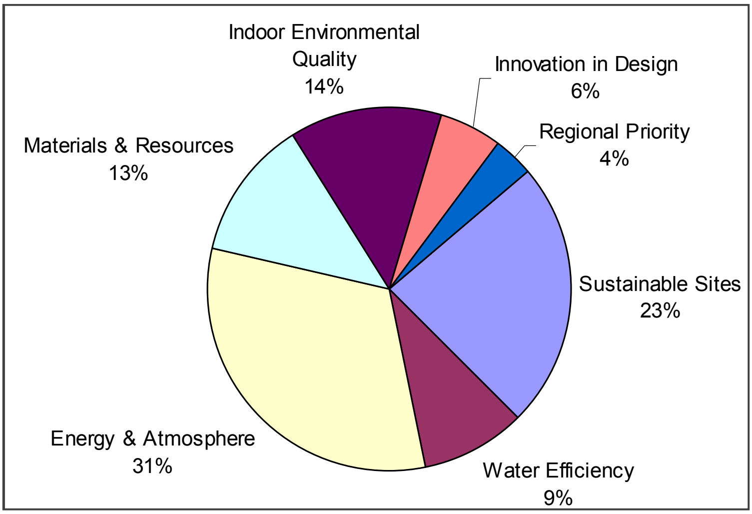


Figure 21. Weighting for different categories in LEED (left) and BREEAM (right) assessment systems.

It is also remarkable to observe that many of the scoring requirements are interrelated, both within the same category and also between the different categories, which can also create problems of "double counting", and create confusion about the weighting system used.

The following figure shows the different scores for the categories of indoor comfort, energy and materials (LEED scores are shown in this example).

Energy and Atmosphere	Possible Points:	**37**
Credit 1	Optimize Energy Performance	3 to 21
Credit 2	On-Site Renewable Energy	4
Credit 3	Enhanced Commissioning	2
Credit 4	Enhanced Refrigerant Management	2
Credit 5.1	Measurement and Verification—Base Building	3
Credit 5.2	Measurement and Verification—Tenant Submetering	3
Credit 6	Green Power	2
Materials and Resources	Possible Points:	**13**
Credit 1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 5
Credit 2	Construction Waste Management	1 to 2
Credit 3	Materials Reuse	1
Credit 4	Recycled Content	1 to 2
Credit 5	Regional Materials	1 to 2
Credit 6	Certified Wood	1
Indoor Environmental Quality	Possible Points:	**12**
Credit 1	Outdoor Air Delivery Monitoring	1
Credit 2	Increased Ventilation	1
Credit 3	Construction Indoor Air Quality Management Plan—During Construction	1
Credit 4	Low-Emitting Materials—Adhesives and Sealants	4
Credit 5	Indoor Chemical and Pollutant Source Control	1
Credit 6	Controllability of Systems—Thermal Comfort	1
Credit 7	Thermal Comfort—Design	1
Credit 8.1	Daylight and Views—Daylight	1
Credit 8.2	Daylight and Views—Views	1

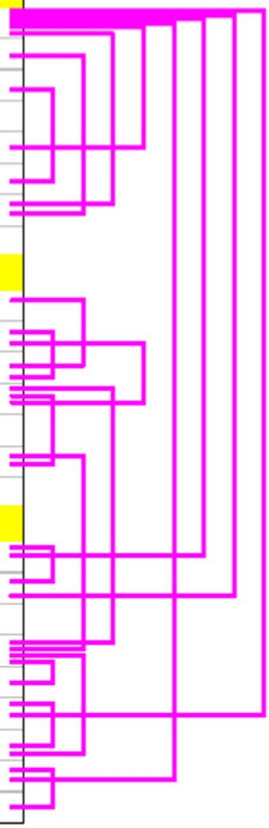


Figure 22. Relationships between different credits in LEED.

Reviewing this network of relationships, a number of questions arise about the methodology used for weighting and providing score for each credit. While optimization of the energy performance of the building is one of the most important issues within the assessment systems, issues such as natural lighting or thermal comfort, which are also linked to the overall energy performance of the buildings, are assessed separately. It is not very clear how these issues are weighted against the energy performance, particularly as their assessment methods are mainly qualitative, while in reality they have an impact on the energy performance that might be already quantified in the energy related credits. Other issues such as measurement and verification, can be a very important criteria for some buildings , for example in those buildings built with very demanding targets where , but might not be as important if original targets of performance are low level. In this systems, however, they are given equal importance independently of the building characteristics.

Another example is the consideration of renewable energies, or green power purchasing, as they are assessed in a qualitative manner (eg. % of energy), and their potential environmental impact in relation to the optimization energy performance is not assessed through a common indicator as could be the total non-renewable primary energy.

The following graph intends o relate the different criteria of a particular assessment system (LEED), to some of the core indicators of SuPerBuildings.

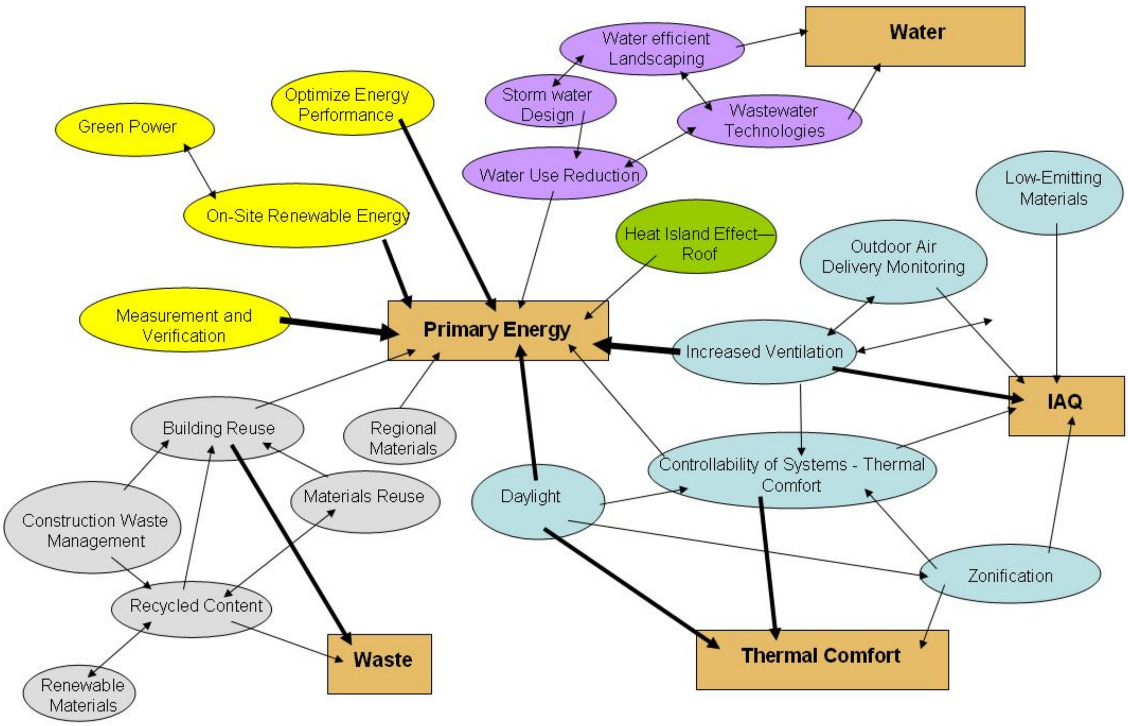


Figure 23. Relation of key SuPerBuildings indicators with LEED criteria.

Different overlapping issues and potential double counting can be observed throughout this Figure 20. There are various indicators, some of them which are quantitative and some qualitative, which in practice relate to the same indicator, and in many cases are overlapping. In practice, there is a weighting and aggregation of different criteria, through a scoring system that assign a number of points to each criteria. However, in many cases various criteria relate to the same 'mid-point´ indicator, and there is no clear and transparent information about the significance and importance of the different criteria in relation to that indicator. This practice should be avoided, and quantification of the midpoint indicators should be sought in all categories.

For the different midpoint indicators, an LCA based weighting criteria should then be applied when necessary. Regarding this LCA weighting approach, guidance from ISO 14040 series, ILCD guidelines, and the recent JRC report Evaluation of Weighting Methods for Measuring the EU-27 Overall Environmental Impact (Gjalt Huppes & Lauran van Oers, 2011), should then be followed.

7.6.4 Conclusions and recommendations

For the aggregation of results, there are two main approaches as described in SuPerBuildings framework document, (Deliverable 4.1.) :

- a top-down aggregation approach, linked to local or national political strategy (the three sustainability pillars, main subjects of concern)
- a bottom-up aggregation approach, which is more expert oriented, for the sub-tree under each subject of concern.

The main recommendations for the two approaches are as follow:

Equal importance should be given to each pillar (environmental, social, economic). Special attention should be put on indicators related to location or functional and technical quality, their relation to the functional equivalent (see section 3 of this report), and having a clear distinction that do not distort the weighting.

The process by which weightings are defined is important – it should be consensus-based. An expert forum or an alternative structured method should be used in order to arrive at weighting factors within indicator groups – the decision-making process should be transparent and should be documented.

Weighting factors may vary between geographic regions, but a clear and transparent rationale has to be followed by an assessment system

As final conclusion, weighting and aggregation methods should in any case be applied only when necessary, and with a transparent and clear methodology. Aggregation should be based on calculation whenever possible (eg. Life Cycle Costing), or else aggregation rules (weighting factors) defined through a formal weighting process by experts from various backgrounds. Results from aggregated results should not be in any case used to make comparative assertions between different buildings.

7.7 Communication

Guidelines for communication of assessment results from EN 15978[102] require that the communication of results should be given through a structured list, or simplified for a number of indicators, and for each stage of the building life cycle. It does not contemplate aggregation between the different indicators. However, a transparent and robust communication between the different stakeholders is key both inside the project team, with client, users, etc. There are cases where aggregation might be necessary to facilitate this communication, and needs to be done in different ways , particularly as communication is not only relevant at the end of the building project, but through the whole building process

Within SuPerBuildings project it has also been noted the communication of sustainability assessment results needs to be adapted to the specific stakeholders which are recipient of the final information, offering different levels of detail and aggregation. In the survey presented in Deliverable 3.2, it is shown that detailed results of the assessment are most valuable for researchers, academics, architects and designers and manufacturers. Community representatives, planning authorities, authorities (policy makers), clients and users demand partially aggregated results. Fully aggregated results are most useful for banking sector, estate agents, insurers and grant providers.

Around 40% of respondents in the survey indicated that the optimal level of detail is partial aggregation of results. Relative performance was perceived by respondents in general as easier for communication, but when communicating with professionals, absolute performance is important. It can also avoid issues with normalization.

SuPerBuildings therefore recommends that results should be communicated in a range of aggregation levels, depending on the stakeholder group the communication is directed to:

- Raw building data behind the assessment (e.g. energy consumption in kWh)
- Aggregated into an assessment result at indicator level (the score achieved for this
- indicator, e.g. in %)
- Aggregated at indicator group level (the score or the percentage fulfilled across a subgroup
- of indicators)
- Aggregated at main group level (at least the score for each of the main categories:
- Environmental, social, economic, technical and location).

[102] EN 15978:2011 – Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method.

– Aggregated into one main result (grade or global mark). This is the case of most current building assessment methodologies, as reviewed in WP 2 (see SuPerBuildings deliverable 2.2.), which communicate the performance at a building level, expressed in a grade (A, B, C, D, E, or a number of stars), or an appreciation (silver, gold, etc), or a global mark.

Another key aspect on communication is the clear description of the object of assessment, that is, he issues included as functional equivalent. A full discussion on the issue of the functional equivalent has been presented in section 2 of this report, and a list of potential issues included or excluded within the functional equivalent has been included in Table 1.

7.8 Final Description of Benchmarking Process

In this section regarding rules for benchmarking criteria, we have commented on the various types of benchmarks, and what could be the sources for benchmarking. We have also discussed the importance of properly describing the object of the assessment, which is called the functional equivalent for comparison.

Each indicator, which has specific calculation and expression characteristics, needs to be further considered in the context of specific reference units, and in relation to normalization and aggregation rules, depending on how we want to show the indicators and whole assessment result. Different bechmarking approaches might be needed to different stakeholders, depending on the use and application of the benchmarks.

The following diagram illustrates the general process to define a benchmark, which would follow three main steps, defined by the scheme below, including iterative loops to adjust each process and taking into account overall elements of context:

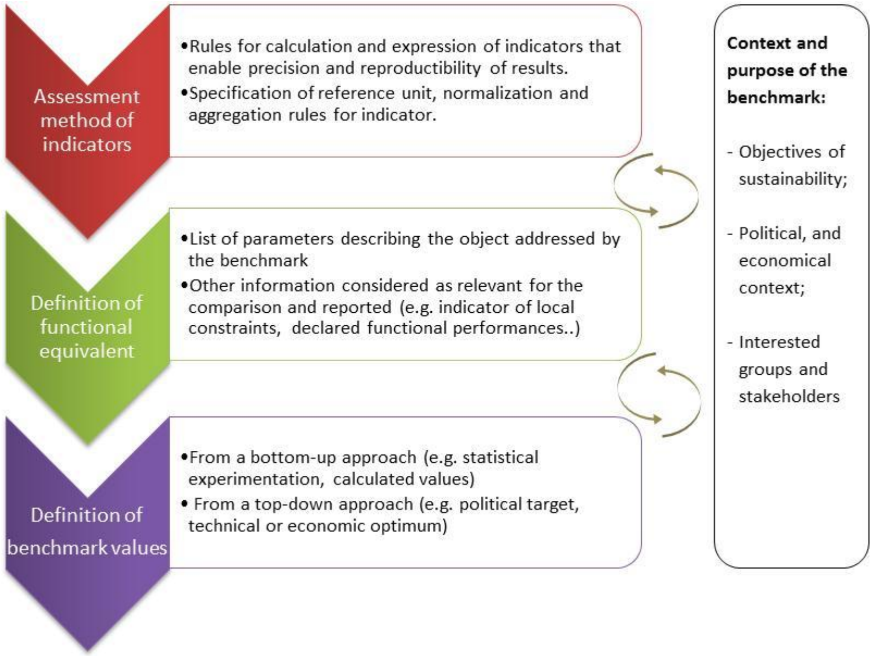


Figure 24. Description of benchmarking process.

8. Recommendations about the use of sustainability indicators in building processes

8.1 Introduction

This report makes recommendations for the use of the sustainable building assessment and benchmarking systems and sustainability indicators in different stages of the building processes. The work focuses on the possibilities to make effectively use of the systems in sustainable building target setting, design for sustainable buildings, procurement and investment /1/.

The effective use of sustainable building assessment and benchmarking systems in different phases of building processes requires the availability of needed information, communication and information flows between different actors of the process, and possibility also new services, new roles and new actors.

This report describes the sustainable building process which effectively makes use of sustainable building assessment and benchmarking systems and addresses the needed sources of information and tools and addresses the relevant actors in different phases of building processes.

The work resulted in the explanation and description of the recommended way of voluntary usage of sustainable building assessment and benchmarking methods and systems in target setting, design, construction and procurement, and investment.

8.2 Method

The recommendations for the use of sustainability indicators in building processes presented here have been developed through a series of workshops with experts. 3 of them took place in conjunction with SuPerBuildings meetings in Utrecht (The Netherlands), Brussels (Belgium) and Espoo (Finland), and all partners in the project consortium participated. Another 6 “internal” workshops, placed in between the previous 3, were carried out in Espoo involving only VTT experts. Following an iterative process, the recommendations and the maps were refined and improved after each of the workshops until their final formulation by the authors of this deliverable.

8.3 Description of building process

The process maps originally proposed by Häkkinen&Nykänen to describe the building process are used here as the main basis to develop the recommendations for the use of sustainability indicators in building processes. (Please go to ANNEX 1 to see the list of indicators)

The process is divided into the following six phases (for an enlarged view of the process, please go to ANNEX 2):

Table 39. Phases of the building process according to Häkkinen & Nykkänen.

1	**Customer briefing for sustainable building** Define sustainability targets	Sustainable customer briefing aims at the definition of the owners' and users' need for spaces considering sustainability targets
2A	**Programming for sustainable building** Interpret sustainability objectives to the programme	The documents of customer briefing create a starting point for sustainable programming and acquisition planning. Definition of targets, and assessment and selection of basic alternatives (e.g. new building versus renovation) are the main tasks associated to this phase (comparing different design options is not dealt with at this stage).
2B	**Bidding for sustainable building** Enable suppliers' sustainability competence to improve the plan	Setting sustainability requirements for the different bidding processes (direct selection, reference based selection, negotiated selection, competitive selection, etc.).
3	**Design for sustainable building** Assess the sustainability and make design decisions	The main issues presented in the building programme and specifications include goals for sustainable construction and summary objectives. The most important design decisions for sustainable building are made in this phase.
4	**Implementation for sustainable building** Monitor and manage changes	Implementation is carried out in accordance to the building programme and specifications, and system design which states the target levels and assessment results of sustainable building.
5	**Use, monitoring and maintenance for sustainable building** Monitoring and act respectively, communicate	Sustainable use, monitoring and maintenance are managed by plans and instructions from the previous phase which include performance targets.

The abovementioned recommendations are defined for each of the sub-phases considered within these main six phases.

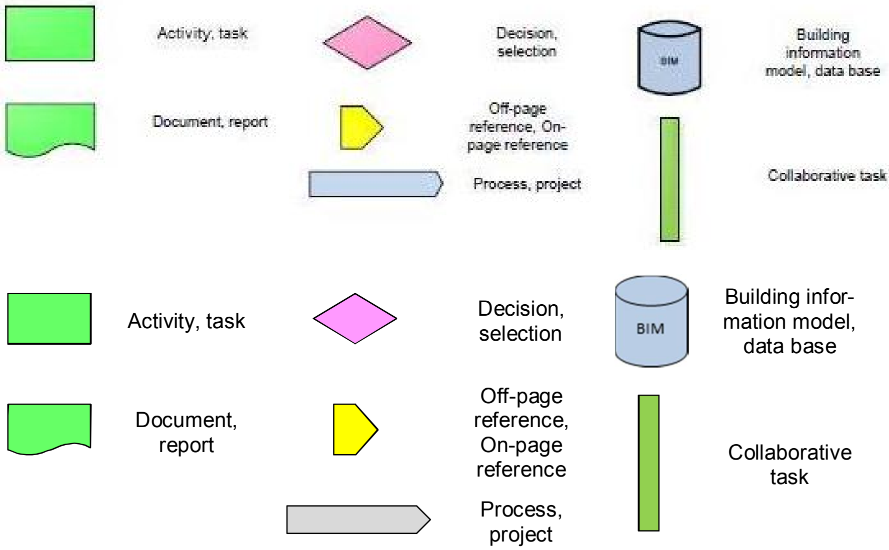
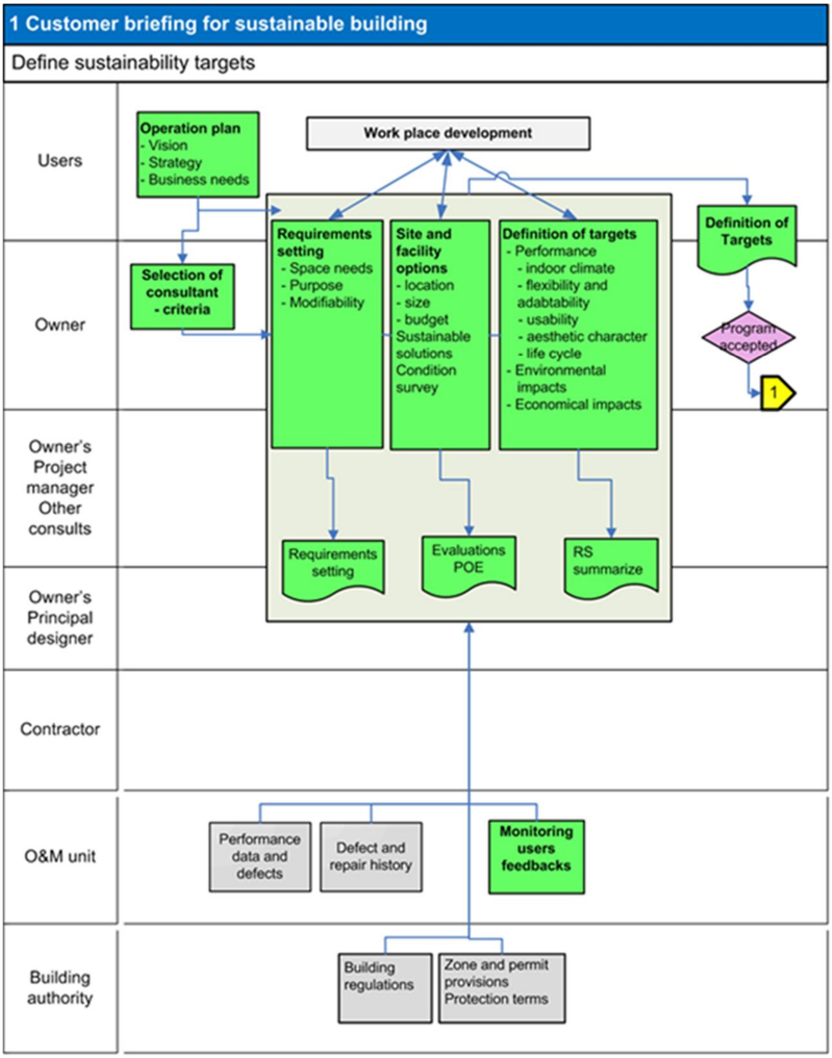


Figure 25. Legend explaining the symbols used in the process maps below.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Owner's Principal designer
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O&M unit
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- Strategy
- Business needs
Work place development
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Requirements setting
- Space needs
- Purpose
- Modifiability
Site and facility options
- location
- size
- budget
Sustainable solutions
Condition survey
Definition of targets
- Performance
- indoor climate
- flexibility and adabtability
- usability
- aesthetic character
- life cycle
- Environmental impacts
- Economical impacts
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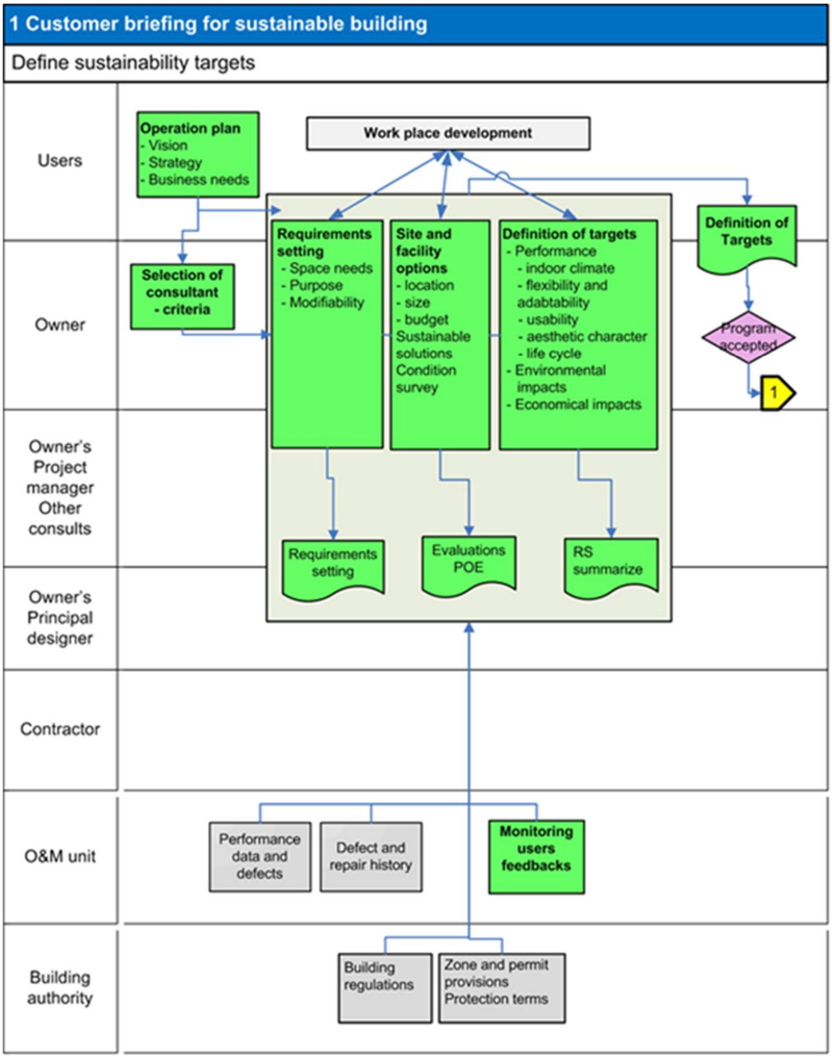
Operation plan - Vision - Strategy - Business needs	The operation plan is based on the business vision and strategy. Principles of sustainable development are written and interpreted in the organization's vision and strategy. These principles may be originally introduced as principal goals of social responsibility and then expressed as targets in the action plan.
Selection of consultant - Criteria	The selection of criteria includes the consideration of sustainable building references and sustainable management methods.
Requirements setting - Space needs - Purpose - Modifiability	The customer briefing aims at the description of the owner's and users' need for the spaces and the building. This stage describes the coming needs based on activities and explains the basic solutions for fulfilling the needs. The background material for the customer briefing includes the organization's vision about future activities, the strategy and the action plan. The stage results in the creation of the customer briefing document.
Site and facility options - Location - Size - Budget Sustainable solutions Condition survey	The first estimates about the sustainability of the different alternatives are done at this stage. The area and volume of spaces, the performance of the building and the access to services (e.g. access to public transportation to pedestrian and bicycle ways) have an essential impact for example on the carbon footprint of the organization. In addition to the preliminary budget assessments, also preliminary carbon footprint assessments are considered in the comparison of the basic alternatives. Either the selected consultant is able to carry out preliminary sustainability assessments or the process uses external assessment services. The principal options considered are a) the acquisition of a new lot and a new building, b) the acquisition of an existing building (and its refurbishment when needed), and c) the development of the organization's activities with the help of which it may be possible to adapt oneself to the existing spaces. The result of this stage is the formulation of a document describing the assessment results for the alternative options.
Definition of targets - Performance - Environmental impacts - Economic impacts	Owner, project manager and principal designer, in collaboration with a representative of the users, set such targets for spaces that correspond to the user purpose and user needs. The life cycle targets are adequately high level targets to which the organization is able to commit. When the owner accepts the targets and makes a positive decision, this stage ends up in the formulation of the target definition document.
Monitoring users feedback	Monitoring users' feedback supports the customer briefing, comparison of primary options and target setting.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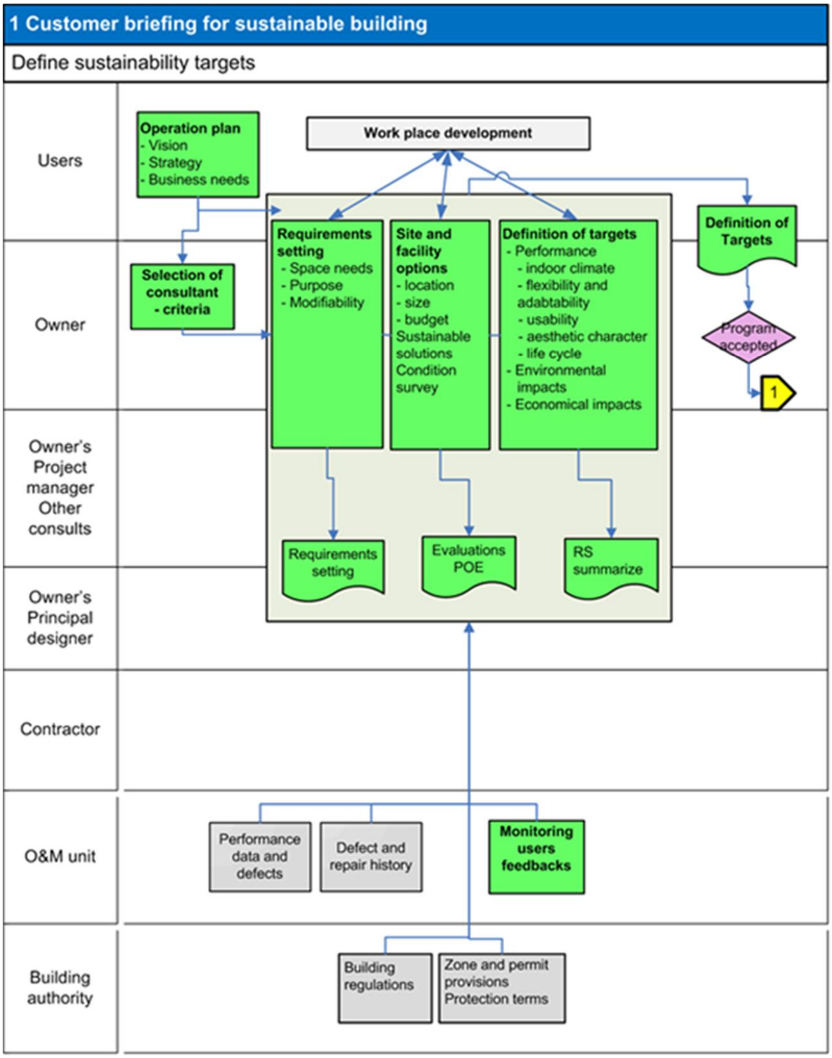
Operation plan - Vision - Strategy - Business needs	The operation plan is based on the business vision and strategy. Principles of sustainable development are written and interpreted in the organization's vision and strategy. These principles may be originally introduced as principal goals of social responsibility and then expressed as targets in the action plan.
Tasks/Actors involved	• Users (companies or individuals) or Owner (companies)
Sustainability Principles/Aspects that can be considered at this stage	**Background comments** • Normally at this stage the targets are not set with the help of indicators but with more general principles (e.g. we want the property to keep its value, we must be able to sell it for different kinds of users, etc.). • It's important to clarify what's behind the commissioning, if it's only certification or something else. If the objective is certification, a set of rules must be followed and documentation needs to be collected through the process. However, the sector caring about certification is a very limited one, mainly office and retail buildings. • Companies might have their own goals and roadmap e.g. to energy efficiency, carbon footprint, water, indoor environment as a whole (not divided into sub-indicators). **Recommendations** • **Companies should have clear goals and a clear strategy (principles) on how they are going to achieve those goals. Quantitative targets can be set for individual buildings and real estate portfolio. An owner or user may set quantitative targets for improved energy efficiency and carbon footprint at organization level or building stock owned. Companies would need to think about their future needs: what kind of buildings/space they need. In order to do that they should upgrade their business strategy and even their vision.** • **It's important that targeted decreased environmental impacts, improved building performance and life cycle economy/costs are described in such a way that the goals can be monitored.** • **Owner/User companies or organizations should have: 1) Clear understanding and definition of their current situation regarding these aspects. 2) An actual commitment to improve that situation and make a change and 3) Targets on how much they are going to improve those and when (it's very important to set a time schedule).** • **In relation to their building stock, the owner company should have a strategy about how much they are going to improve that stock and when (regarding environmental impacts mainly in relation to energy efficiency and carbon footprint; also water management when relevant).**

Core Indicators	This stage does not necessarily use building level indicators and corresponding units but the stated targets may refer to the overall activities or whole building stock. The decisions about the individual solutions and building specific choices and made later. However, the corresponding topics should also be used at this stage (water, waste, energy, GHGs, land, building's social performance).
Sustainability Assessment Tools available	
Assessment method(s)	To study the current values for energy, GHGs, water etc. basic data must first be collected with the help of monitoring, inquires and when necessary with estimation. Primary data (use of electricity, use of district heat, transportation etc.) is then interpreted to primary energy, GHGs etc. with the help of databases (LCI databases etc. relevant in that country or region) that explain environmental impacts of energy carriers, transportation etc.
Background information and data	• Good real built examples. Showing the users different solutions in the form of real building examples so they can understand what kind of choices they have and what kind of results can be produced. • The conditions should be adapted to the local context from the very beginning. • Background data needed in order to create a good understanding about the current situation: • Monitoring information about indoor environment and consumption of heating and cooling energy, electricity and water • Post occupancy evaluation data • Relevant CF data for electricity, heating energy etc.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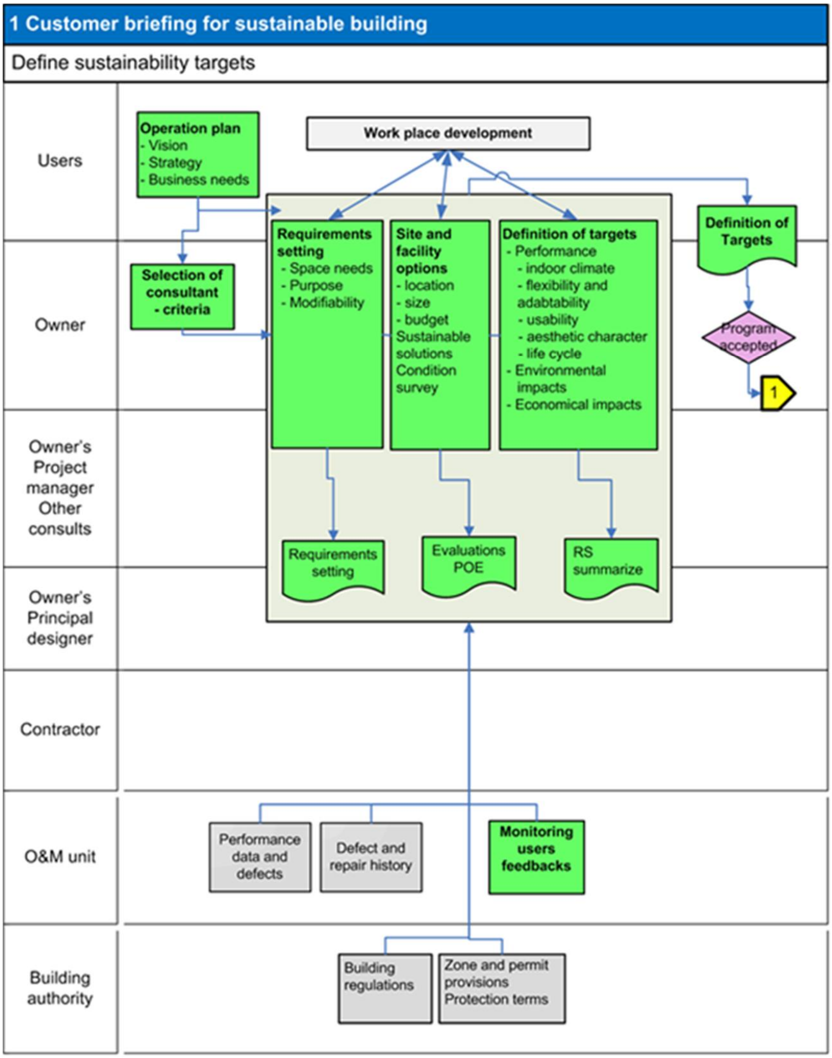
Selection of consultant - Criteria	The selection of criteria includes the consideration of sustainable building references and the management of sustainable building methods.
Tasks/Actors involved	• Owner
Sustainability Principles/Aspects that can be considered at this stage	**Background comments** • Selecting a consultant means selecting either internally or externally for programming in order to clarify the needs and targets for the intended case/project (not necessarily means a new building). **Recommendations** • **The most important criteria for the selection of the consultant are their competence to use sustainability indicators and relevant assessment methods.** • **Other important criteria for the selection of the consultant are their competence to manage complex projects and handle collaborative teamwork.** • **The use of sustainable building references or concept references (database needed) by the consultant to explain the clients what they should be aiming at can be very helpful, and in that case relevant SuPerBuildings Core Indicators should be used as a framework for the assessment of those references.**
Core Indicators	This stage does not set targets in terms of individual indicators.
Sustainability Assessment Tools available	
Assessment method(s)	Competence evaluation matrix, interview frames.
Background information and data	The consultant should be able to describe the reference buildings with indicators. Essential indicators may be for example NRE and CFP and relevant indicators of social performance (building performance such as indicators of indoor environment). Assessment methods are described in D4.2.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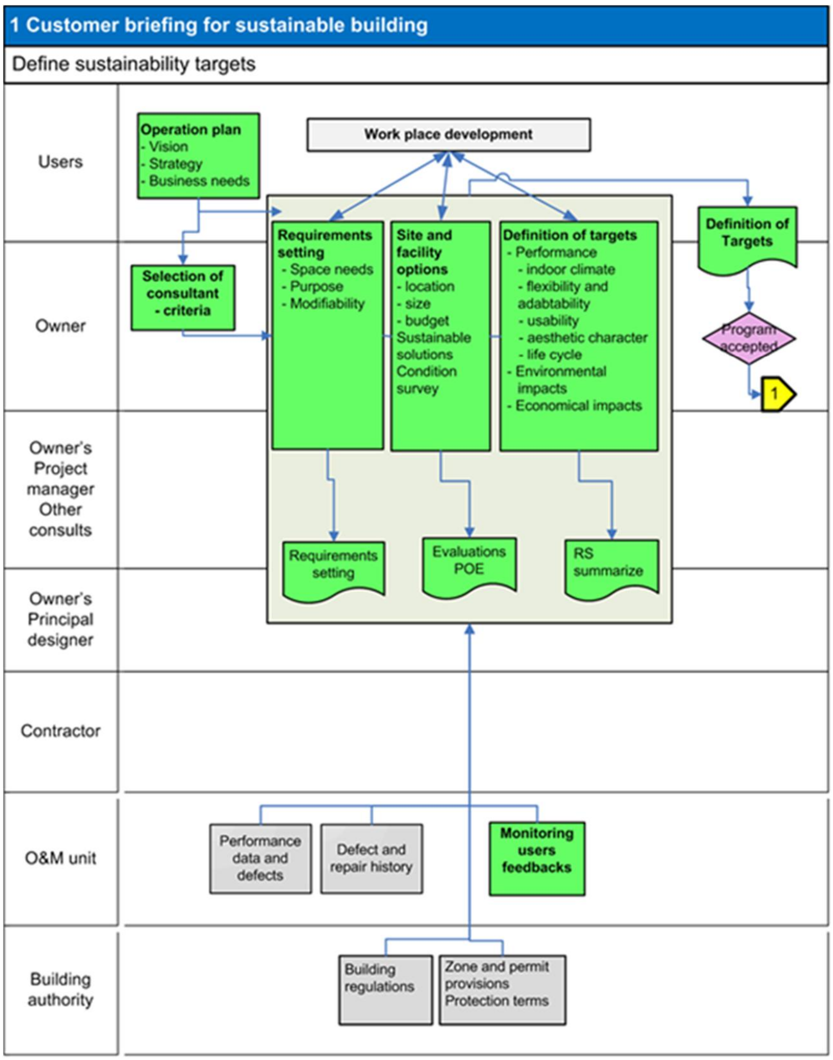
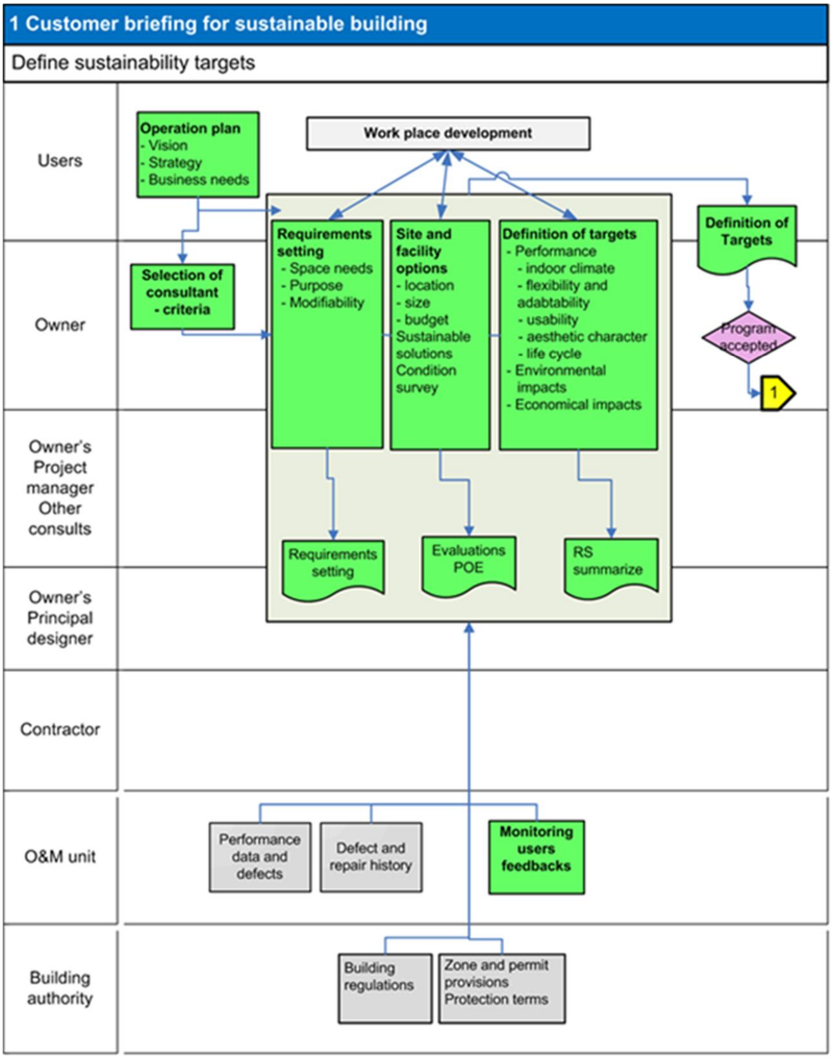
Requirements setting - Space needs - Purpose - Adaptability - Access	The customer briefing aims at the description of the owner's and users' need for the spaces and the building. This stage describes the coming needs based on activities and explains the basic solutions for fulfilling the needs. The background material for the customer briefing includes the organization's vision about future activities, the strategy and the action plan. The stage results in the creation of the customer briefing document.
Tasks/Actors involved	• Users • Owner • Owner's project manager • Owner's principal designer
Sustainability Principles/Aspects that can be considered at this stage	**Background comments** • Here it's possible to set targets for the functionalities we want the building to have. Study the trade offs between needs and sustainability targets. • The main difficulty at this stage is to know clearly what is possible in the scope of the budget, so affordability is a decisive parameter. • It might be useful if, as regards to the users, we establish certain typologies of users (a person sitting in an office, a company that rents a building, etc.) to define what kind of targets they have. • At this stage it should be possible to list which are the customer's needs and combine that with the customer's targets. The approach to sustainability is at a quite rough and general level. **Recommendations** • **The starting point should be the consideration of sustainability goals presented in the operation plan and fitness for purpose (fulfils users' needs – compare ISO 21929 definition for sustainable building). Needs can be explained with the help of relevant social performance indicators and essential issues that affect life cycle economy, and life cycle energy use and GHGs of the building. The former includes aspects of adaptability, access, indoor environment, accessibility, safety, and usability. The latter include space efficiency, utilization rate and access.** • **Customer briefing should also be able to define what are the (possible) specific sustainability aspects that are emphasized in the customer's strategy and should also be considered when different alternatives are dealt with.**
Core Indicators	This stage does not necessarily set quantitative targets in terms of individual indicators.

Sustainability Assessment Tools available	There are no tools available but a structured outline and tool would help to systematically identify and record the customer needs.
Assessment method(s)	
Background information and data	Operation plan.



Site and facility options - Location - Size - Budget	The first estimates about the sustainability of the different alternatives are done at this stage. The area and volume of spaces, the performance of the building and the access to services (e.g. access to public transportation to pedestrian and bicycle ways) have an essential impact for example on the carbon footprint of the organization. In addition to the preliminary budget assessments, also preliminary carbon footprint assessments are considered in the comparison of the basic alternatives. Either the selected consultant is able to carry out preliminary sustainability assessments or the process uses external assessment services. The principal options considered are a) the acquisition of a new lot and a new building, b) the acquisition of an existing building (and its refurbishment when needed), and c) the development of the organization's activities with the help of which it may be possible to adapt oneself to the existing spaces. The result of this stage is the formulation of a document describing the assessment results for the alternative options.
Tasks/Actors involved	The following expertise is represented at this stage: the development of the organization's activities, searching of spaces and sustainable building assessment. • Users • Owner • Owner's project manager • Owner's principal designer
Sustainability Principles/Aspects that can be considered at this stage	**Recommendations** • **The primary options are roughly assessed and compared regarding the chosen sustainability aspects stated in customer briefing. In every case, the primary options are roughly assessed and compared in terms of life cycle costs, energy, GHGs and the specifically addressed aspects of building performance (for instance adaptability, accessibility, access, safety, indoor environment, usability, aesthetic quality).** • **The existing information about the company's facilities is analyzed in relation to its value condition, social performance. Some additional evaluations should also be conducted if needed (post-occupancy evaluation, user satisfaction questionnaires and/or interviews).** • **Different companies have different needs for different types of spaces. So the first question to consider is acquisition (is it really necessary?). Clarify what kind of requirements customers really have; which ones are essential and which ones are not.**

Core Indicators	At this state first quantitative assessment should be made regarding investment costs, life cycle costs, energy and GHGs. The social performance of alternatives should also be assessed but qualitatively. Relevant indicators are primary energy, GHGs and also other environmental indicators that are addressed in customer briefing. Relevant social performance indicators are those addressed in customer briefing. (Please, see table of indicators in Annex 1)
Sustainability Assessment Tools available	Simple environmental assessment tools for buildings should be developed further to support the preliminary assessment of life cycle costs, primary energy and GHGs of options (new building, renovation, different locations). Structured approach should be developed which supports the qualitative assessment of social performance.
Assessment method(s)	LCC comparisons, Value analysis, Condition survey methods.
Background information and data	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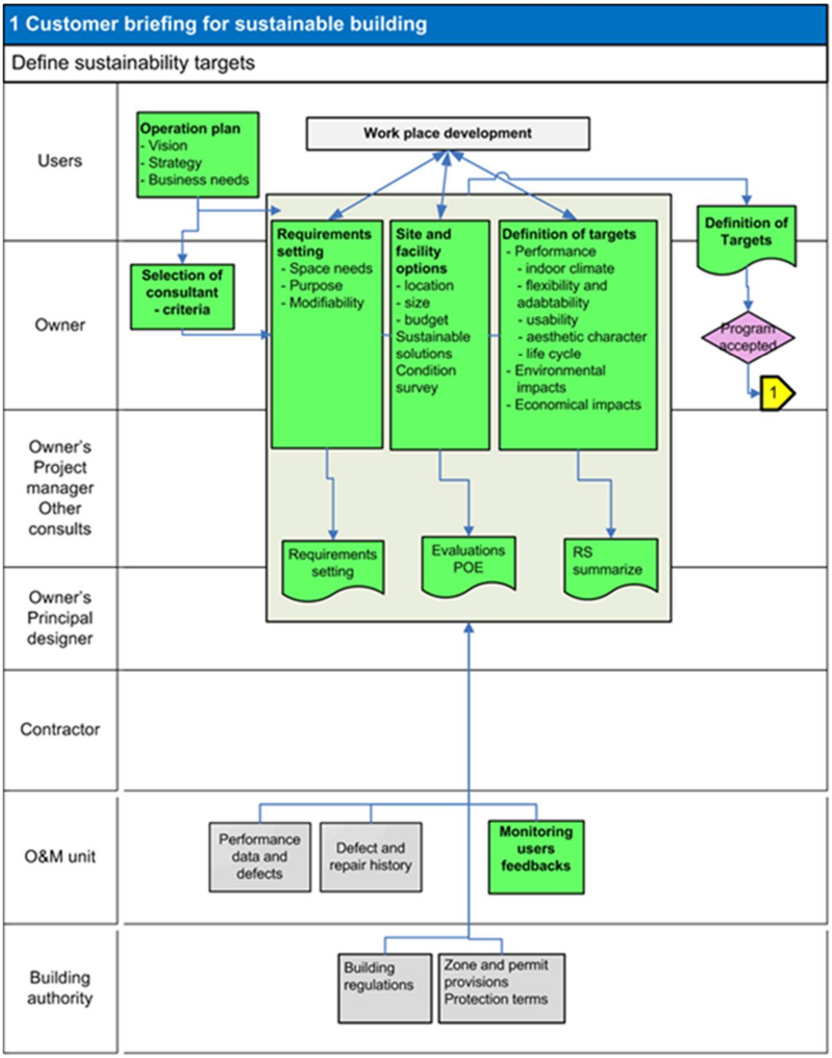
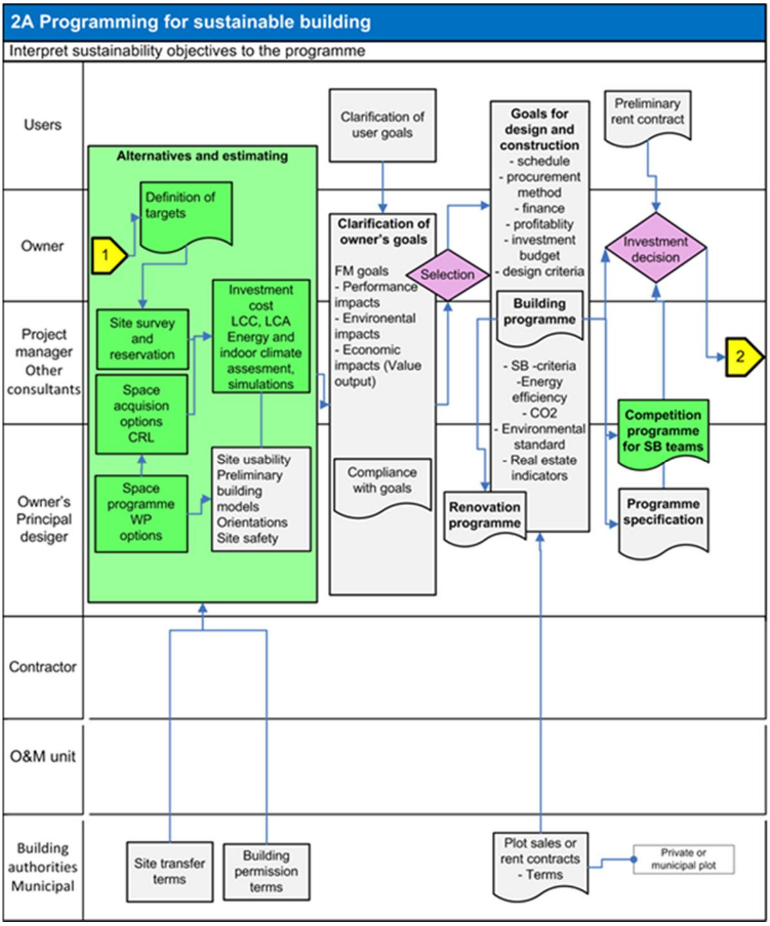
Zone and permit provisions
Protection terms

Definition of targets - Performance - Environmental impacts - Economic impacts	Owner, project manager and principal designer, in collaboration with a representative of the users, set such targets for spaces that correspond to the user purpose and user needs. The life cycle targets are adequately high level targets to which the organization is able to commit. When the owner accepts the targets and makes a positive decision, this stage ends up in the formulation of the target definition document.
Tasks/Actors involved	• Users • Owner • Owner's project manager • Owner's principal designer
Sustainability Principles/Aspects that can be considered at this stage	**Background comments** • The targets are outlined into the following parts: 1) social performance, 2) environmental impact and 3) economic impact. Social performance is divided into the following elements: access, indoor environment, safety, adaptability, usability, accessibility, aesthetic quality and cultural heritage, maintainability and service life. **Recommendations** • **Targets for the new building or renovated building are set precisely, quantitatively when possible. When qualitative targets are set, those are defined with adequate details so that monitoring is possible. SuPerBuildings Core Indicators and other relevant indicators (depending on what is defined in customer briefing) can be used. ALL CAN BE USED AT THIS STAGE.** • **The targets should be realistic and refer to seriously intended achievements.** • **Urban level indicators like Density and Access to basic services should also be considered at this stage.**
Core Indicators	Indicators are necessary in this sub-phase. (Please, see table of indicators in Annex 1)
Sustainability Assessment Tools available	At this stage, target setting tools are very important. PROMISE, BREEAM, LEED, etc. should be further developed so that better support quantitative or qualitative and classified target setting. **Recommendations** • **It is very important to use a specific structure (e.g. from the assessment tool itself, showing not only text description, but indicators and metrics) instead of just describing what we are aiming at.**
Assessment method(s)	At this stage assessment is not done.

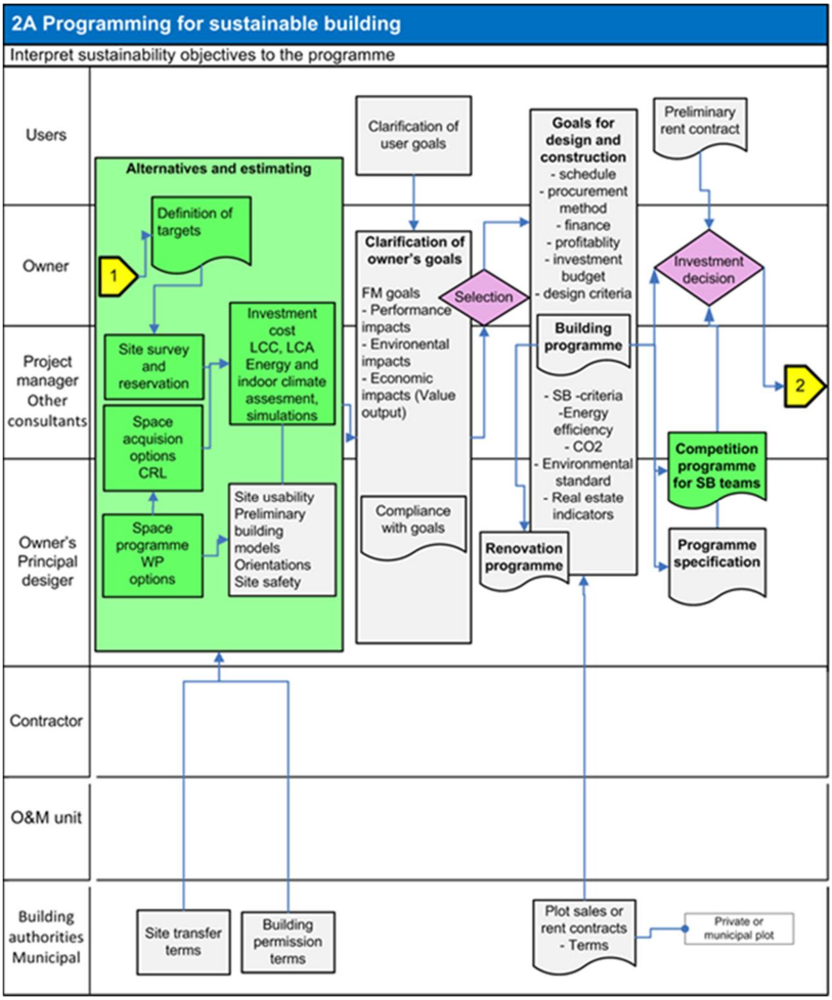
Background information and data	• Information about the organization's present and typical values (for the indicators in question). • Information about benchmarks regarding the indicators in question.



Monitoring users feed-back	Monitoring users' feedback supports the customer briefing, comparison of primary options and target setting.
Tasks/Actors involved	• O&M unit
Sustainability Princi-ples/Aspects that can be considered at this stage	**Background comments** • Information based on user surveys, rather than indicators and/or benchmarks are needed here. However, some com-mon baseline/structure should be used to collect the infor-mation. Comparison to other similar buildings could be con-sidered also. • It's important to learn from mistakes in order to be aware of the best options. **Recommendations** • **The structured process as described in the previous step (Definition of targets) should be used here for monitoring users' feedback. If the structure used has been SuPer-Buildings Core Indicators, the same set should be used for monitoring.**
Core Indicators	When monitoring users' feedback, essential indicators are espe-cially those that deal with social performance (indoor environ-ment, accessibility, access etc.). (Please, see table of indicators in Annex 1)
Sustainability Assess-ment Tools available	• In addition to users' feedback also Building Automation Re-ports should be made use of. This reporting should be devel-oped in such a way that it supports the monitoring of SB as-pects. A link should be created between those issues moni-tored and building level indicators (primary energy use, GHGs, water and waste). • Also, checking lists for facility management should be devel-oped and made use of. How to deal with "building as built" da-ta. Interviews with facility management professionals can be very useful.
Assessment method(s)	Structured approaches and methods for asking users feedback so that the same outline as target setting could be used should be developed.
Background information and data	• Post-occupancy evaluations. • Facility feedback. • Databases (LCI databases, etc., relevant in that country or region) that explain environmental impacts on energy carriers, transportation, etc.


2A Programming for sustainable building
Interpret sustainability objectives to the programme
Users
Owner
Project manager Other consultants
Owner's Principal desiger
Contractor
O&M unit
Building authorities Municipal
Alternatives and estimating
Definition of targets
1
Site survey and reservation
Investment cost LCC, LCA Energy and indoor climate assesment, simulations
Space acquision options CRL
Space programme WP options
Site usability Preliminary building models Orientations Site safety
Clarification of user goals
Clarification of owner's goals
FM goals
- Performance impacts
- Environental impacts
- Economic impacts (Value output)
Selection
Compliance with goals
Goals for design and construction
- schedule
- procurement method
- finance
- profitablity
- investment budget
- design criteria
Building programme
- SB -criteria
-Energy efficiency
- CO2
- Environmental standard
- Real estate indicators
Renovation programme
Preliminary rent contract
Investment decision
2
Competition programme for SB teams
Programme specification
Site transfer terms
Building permission terms
Plot sales or rent contracts
- Terms
Private or municipal plot

Definition of targets	Customer requirements form a guideline for the whole programming process. Programming consultant controls the process by documented customer requirements. If later solutions don't meet the requirements, it's necessary either to correct plans or to document adjusted goals as new goals for the next process phases.
Alternatives and estimating - Site survey and reservation - Space programme - Space acquisitions options - Investment cost - Simulations	The choice of the site is not neutral from a sustainability point of view. One or several sites may be possible and it's very important to perform a multi-criteria analysis of the site(s), identifying local opportunities, constraints and risks, studying the urban context and social needs, etc. The choice of the site should consider the result of this kind of analysis. The programme should rely on this site analysis and give appropriate orientations and requirements in order to limit the identified constraints, manage the risks and take advantage of the opportunities of the chosen site. Space programme, alternatives for acquisition, cost estimates and simulations, and specified goals (facility management, opportunities and limitations of design solutions and other clarifications) and comparison between goals and requirements are essential part of sustainable programming. Finally, a reasoned choice can be made out of the most potential alternatives in order to start the design. The result of programming is a programme statement and a conclusion of the remaining options.
Competition programme for SB teams	The outcome is to produce a competition programme (set of rules) that defines a number of key sustainability criteria (and possibly sub-criteria) to be fulfilled by the design proposals and according to which those will be assessed by an expert jury.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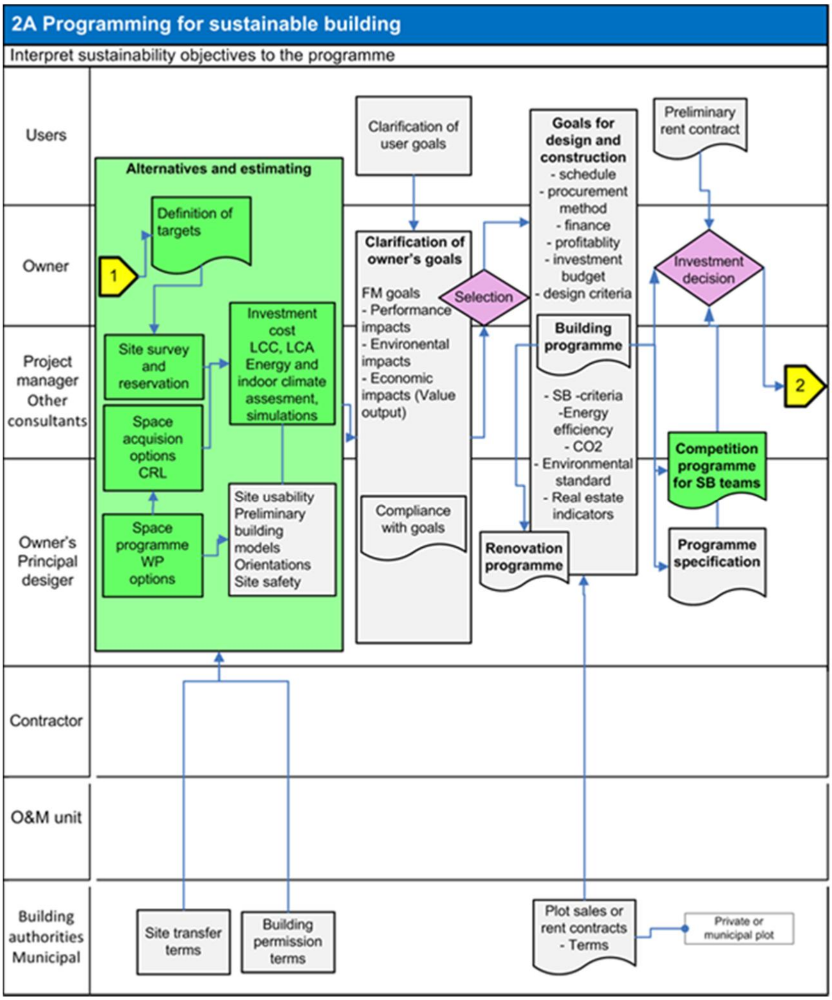
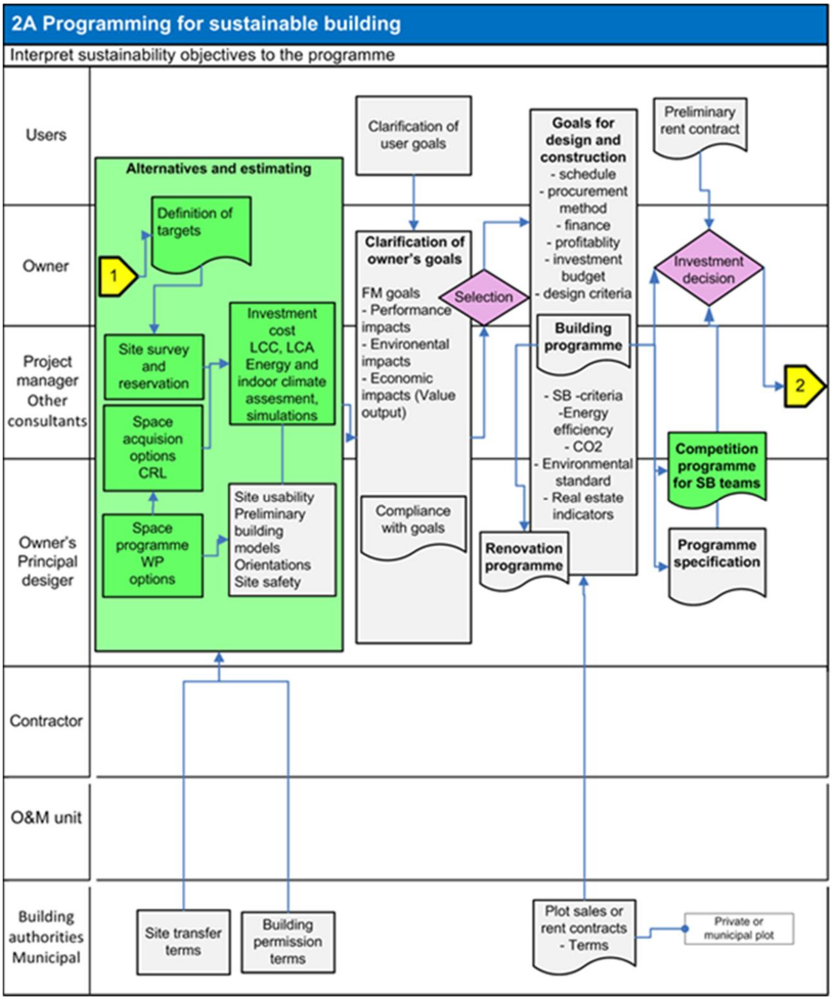
Definition of targets	Customer requirements form a guideline for the whole programming process. Programming consultant controls the process by documented customer requirements. If later solutions don't meet the requirements, it's necessary either to correct plans or to document adjusted goals as new goals for the next process phases.
Tasks/Actors involved	• Users • Owner • Project manager, other consultants • Owner's principal designer • O&M
Sustainability Principles/Aspects that can be considered at this stage	**Background comments** • The targets at this stage are more focused because we are already dealing with a specific site, specific city regulations, etc. Feasibility studies on different aspects can be useful at this stage in order to set the limits for the targets. The team needs to be experienced enough. **Recommendations** • **Sustainability aspects that need to be considered follow the more general targets set in phase 1_5. Targets should be set with the help of core environmental indicators (at least NRE, CFP and Water) and others coming from phase 1_5. Targets should also be set with the help of building level indicators for all relevant aspects of social performance and economical aspects. (Please, see table of indicators in Annex 1)** • **When setting targets also the assessment method (principles of assessment) should be addressed.** • **Maintanability and reparability should be considered already at this stage as a general target.**
Core Indicators	Core environmental indicators and building level indicators are needed to set targets. (Please, see table of indicators in Annex 1)
Sustainability Assessment Tools available	
Assessment method(s)	

Background information and data	• Information about the organization's present and typical values (for the indicators in question). • Information about benchmark's regarding the indicators in question. Detailed target setting needs information about relevant benchmarks. Benchmarks should be developed for different types of buildings and regions regarding core sustainable building indicators. Some information about benchmarks is available in D5.1 and D5.2.



Alternatives and estimating - Space programme - Acquisition options - Cost estimates - Simulations?	Space programme, alternatives for acquisition, cost estimates and simulations, and specified goals (facility management, opportunities and limitations of design solutions and other clarifications) and comparison between goals and results are essential part of sustainable programming. Finally, a reasoned choice can be made out of the most potential alternatives in order to start the design. The result of programming is a programme statement and a conclusion of the remaining options.
Tasks/Actors involved	• Users • Owner • Project manager, other consultants • Owner's principal designer • Municipal authorities
Sustainability Principles/Aspects that can be considered at this stage	**Background comments** • Regarding the use of indicators/benchmarks we can consider the range of options and for each option an idea of costs, environmental impacts, indoor climate, etc. • Different options are assessed against space-efficiency which has an important impact in relation to sustainability because if affects carbon footprint, energy efficiency and users satisfaction. The assessment should cover the aspects with regard to which the targets were set. **Recommendations** • **Sustainable design requirements for building plots should be given by municipalities.**
Core Indicators	Core environmental indicators, building performance without detailed indicators, and other indicators like life cycle costs, historical value or architectural quality might be used to compare the different options. (Please, see table of indicators in Annex 1)
Sustainability Assessment Tools available	There is a need to develop tools which support preliminary assessment of alternatives. At this stage there is no detailed data about the design.
Assessment method(s)	Basic principles for the assessment of indicators are described in D4.2.
Background information and data	As a possible database, a collection of previous buildings for which the economic parameters are described in detail. There aren't these databases at present, or maybe only in relation to certain aspects like energy and water consumption, rent level or space prices.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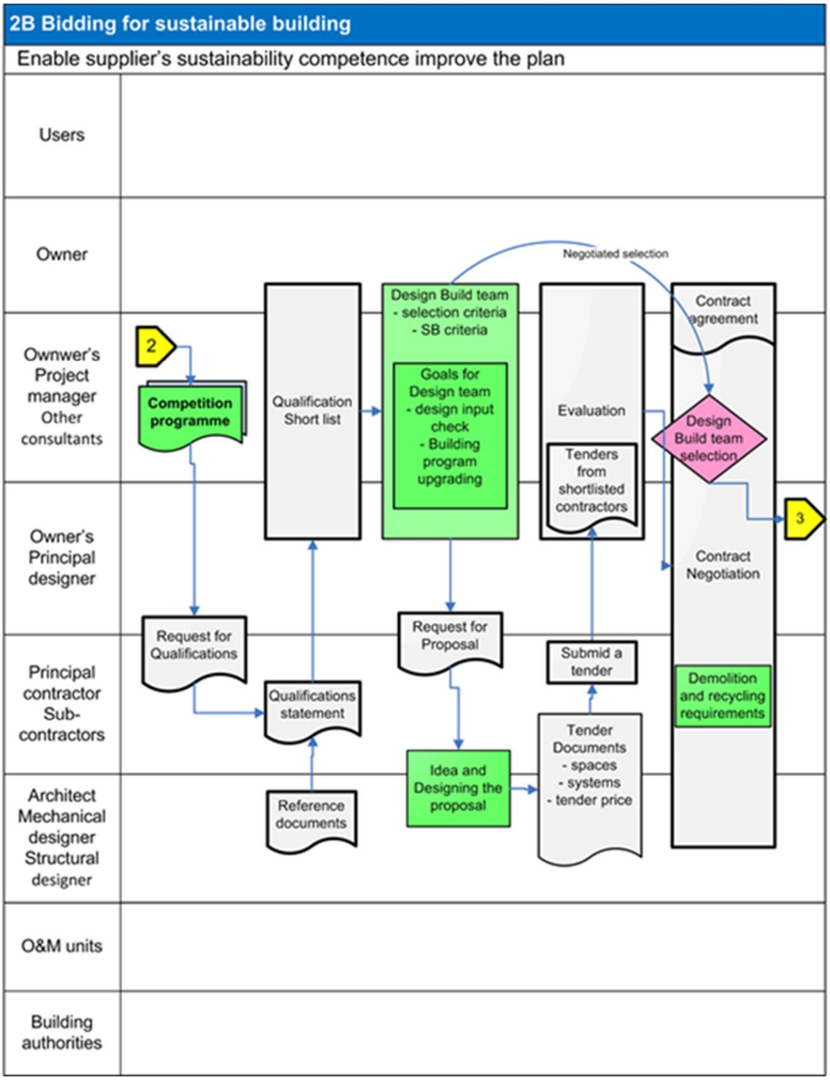
Competition programme for SB teams	The outcome is to produce a competition programme (set of rules) that defines a number of key sustainability criteria (and possibly sub-criteria) to be fulfilled by the design proposals and according to which those will be assessed by an expert jury.
Tasks/Actors involved	• Owner • Project manager, other consultants • Owner's principal designer
Sustainability Princi-ples/Aspects that can be considered at this stage	**Background and comments** • The jury needs to be explained in detail the criteria and sub-criteria defined in the programme and how those will be as-sessed when rating the proposals (normally through some kind of "weighting" tool). • The competition process and the results of the assessment should be well documented and accessible if necessary. **Recommendations** • **Certain core indicators should be used: energy, CF, LCC, essential performance. (Please, see table of indicators in Annex 1)** • **If other indicators, such as use of locally produced mate-rials or use of certified wood are used, ensure that indica-tors are not overlapping.** • **The risk or having a too technical definition of a number of requirements is that the design team will be very lim-ited in their task and then afterwards there will be too much attention on those instead of on the overall con-cept.** • **The meaning of national laws and standards is also con-sidered at this point.**
Core Indicators	• To achieve comparable assessment results, assessment methods and system boundaries must be defined. Please, see further instructions in SuPerBuildings Deliverable 4.2 about issues that affect the comparability of results. • Core indicators should be used. (Please, see table of indica-tors in Annex 1)
Sustainability Assess-ment Tools available	
Assessment method(s)	
Background information and data	The background information is supposed to have been used already.


2B Bidding for sustainable building
Enable supplier's sustainability competence improve the plan
Users
Owner
Ownwer's Project manager Other consultants
Owner's Principal designer
Principal contractor Sub-contractors
Architect Mechanical designer Structural designer
O&M units
Building authorities
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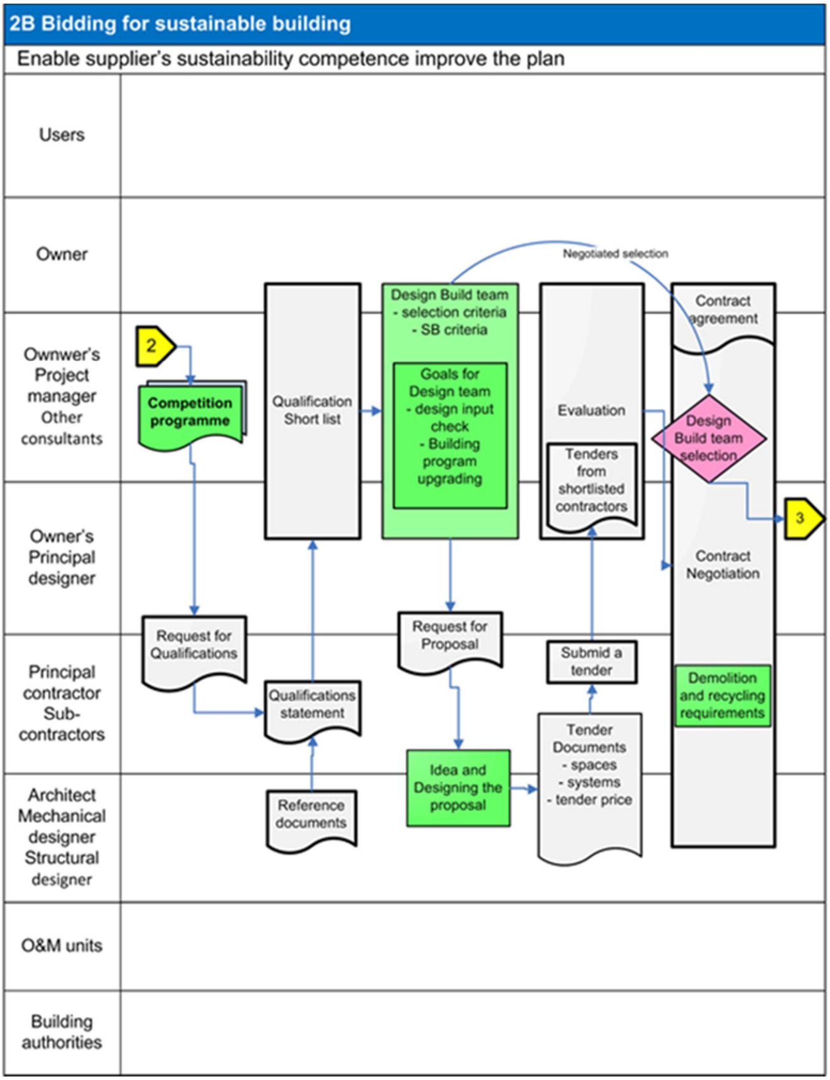
Competition programme
Qualification Short list
Design Build team - selection criteria - SB criteria
Goals for Design team - design input check - Building program upgrading
Negotiated selection
Evaluation
Tenders from shortlisted contractors
Contract agreement
Design Build team selection
3
Contract Negotiation
Request for Qualifications
Qualifications statement
Reference documents
Request for Proposal
Idea and Designing the proposal
Submit a tender
Tender Documents - spaces - systems - tender price
Demolition and recycling requirements

Competition programme	The competition programme (coming from 2A) should state what the client wants. This results in a document from which the rest of the process continues.
Designing the proposal	At this stage the higher level sustainability targets (CFP, GHG, etc.) of the building begin to turn into more detailed design selections by the design team.
Design Build team selection criteria	Design Build team selection criteria are defined on the basis of programme goals. Criteria are requirements of sustainable building knowledge and references described with the help of metrics regarding sustainability issues (considering both design values as well as operational values). The starting point is performance thinking, where the owner presents performance goals including environmental and economic viewpoints without limiting design solutions. Note: Selection of the appropriate delivery system depends on the competence of the client and the project nature. When the client has the competence (e.g. earlier experience on similar projects), the sustainable solution could be designed by the client (Design Bid Build or Construction Management).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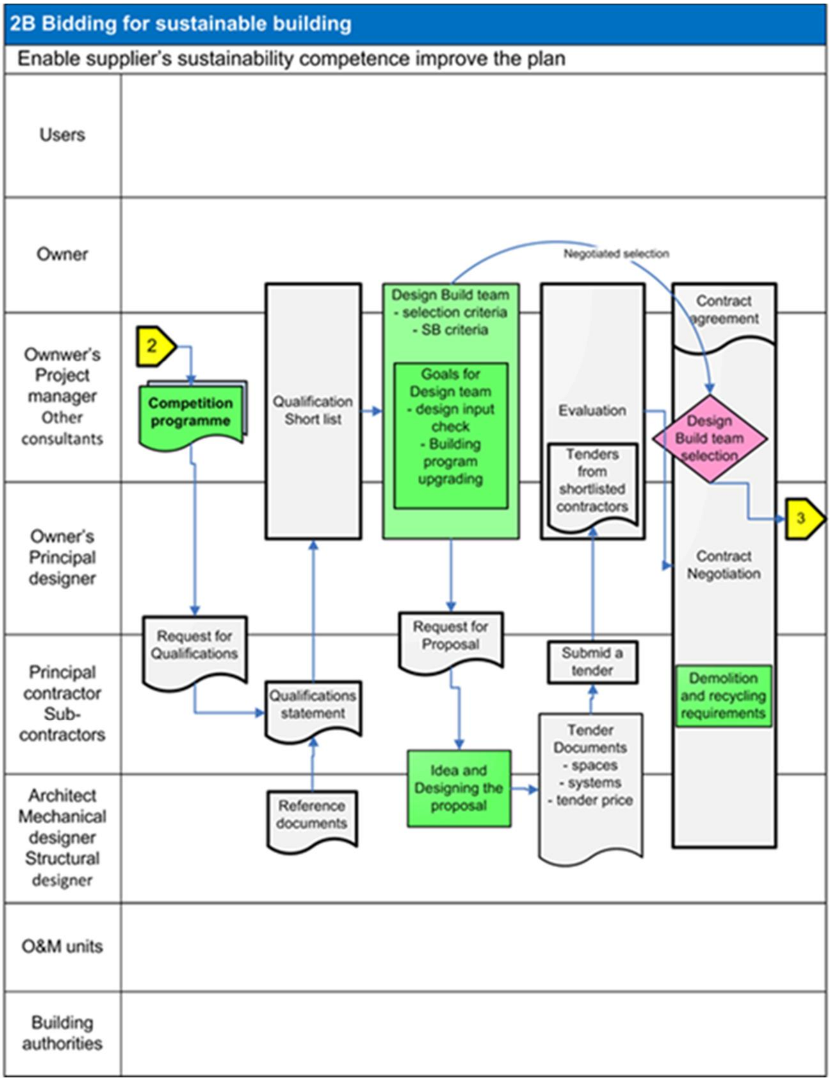
Competition programme	The competition programme (coming from 2A) should state what the client wants. This results in a document from which the rest of the process continues.
Tasks/Actors involved	• Owner • Project manager • Other consultants
Sustainability Principles/Aspects that can be considered at this stage	**Background and comments** • The indicators described are meant for the request for proposals, design of the proposals and evaluation of the proposals. • The indicators mentioned here are performance targets. No need to deal how different criteria are weighted at this stage. • Use national benchmarks for e.g. energy in use can be complemented with additional indicators, e.g. CO_2 emissions. • Regarding target setting for energy, the process should be a two-step one: first minimize demand and then decide how to produce the energy needed with renewables. Possible indicators: Space heating demand. Share of renewable energy. Space cooling demand. Share of renewable energy. Electricity use of the building (lighting, HVAC services, etc.). Appliances are excluded. Share of renewable energy. Hot water heating energy demand. Share of renewable energy. Peak load demand. Water consumption. Overall carbon footprint of materials. Total carbon footprint. • Since LCC is a comparison method and life cycle costs include investment costs and use costs, the target could be maximum LCC. • Building performance. The target should correspond to the needs of the users and the purpose of the building. Space efficiency should be dealt with at the same time. Indoor environment (CO_2 levels, temperature, humidity, acoustics, visual comfort, draft, etc.) with classification. • Some other indicators that could be important: aesthetic quality, flexibility, safety. For these, qualitative assessment methods may also be used. **Recommendations** • **All these targets should be as quantitative as possible and in addition the principles of the assessment method should be defined, e.g. energy hourly based done simulations.** • **Define transparent valuation for the indicator set that will be used in the selection process.**

	• **Define principles of assessment.** • **The same indicators proposed for 2A should be used here as well and possible also later on.**
Core Indicators	• The competition programme (coming from 2A) should state what the client wants. This results in a document from which the rest of the process continues. • Same indicators proposed for 2A. (Please, see table of indicators in Annex 1)
Sustainability Assessment Tools available	Using a certain tool for target setting makes it easier for comparability.
Assessment method(s)	
Background information and data	Might be useful to give some examples of buildings in relation to the indicators proposed.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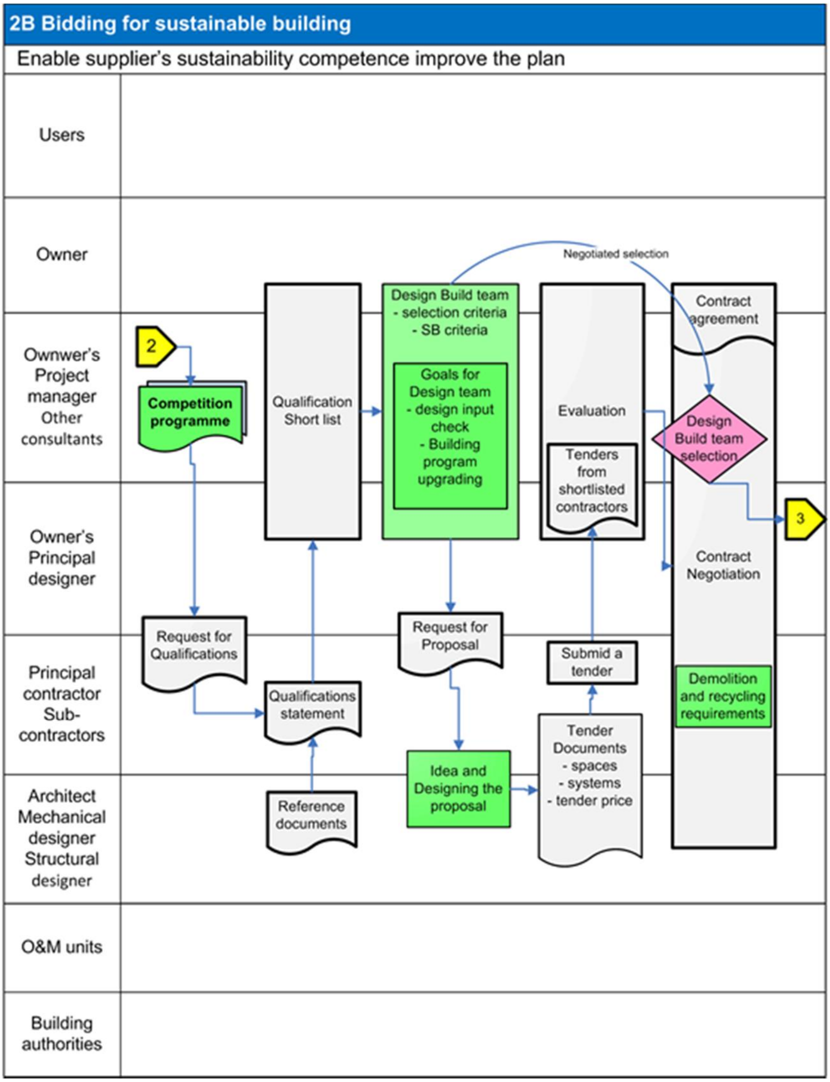
Designing the proposal	At this stage the higher level sustainability targets (CFP, GHG etc.) of the building begin to turn into more detailed design selections by the design team.
Tasks/Actors involved	• Architect • Principal contractor & special contractors • Mechanical designer • Structural designer • O&M unit
Sustainability Principles/Aspects that can be considered at this stage	**Background comments** • The idea is to optimize the design regarding the given targets/indicators. The important thing here is to be able to use those methods that make it possible. • Because of the nature of the complicated inter-connections between the physical systems in the building, the overall integrated modelling and simulation of the sustainability aspects is needed and should be used whenever possible. • The selected sustainability modelling tool or group of tools will make a bridge between higher level sustainability targets and detailed design selections. The use of Building Information Model during the design process is recommended to ensure the design data consistency. • The design selections must be documented in detail to ensure the transparency. This documentation is a natural and more detailed extension to the owners program. **Recommendations** • **Principal designer together with the whole team has to take care that the design as a whole fulfils the targets set.** • **Design should contain also the monitoring plan.** • **More tools for assessment during the design phase using simplified input are needed. These tools should benefit from structural design tools through BIM.**
Core Indicators	The design options are assessed in terms of those indicators given in the competition programme and with the help of those methods and assessment principles also described in it.
Sustainability Assessment Tools available	• Different kinds of tools for the assessment and simulations of buildings such as for example IDA-ICE for energy simulations, other tools for the simulation of acoustics, lighting, etc. • Environmental assessment software for the environmental assessment.
Assessment method(s)	
Background information and data	EPDs, environmental data for energy carriers.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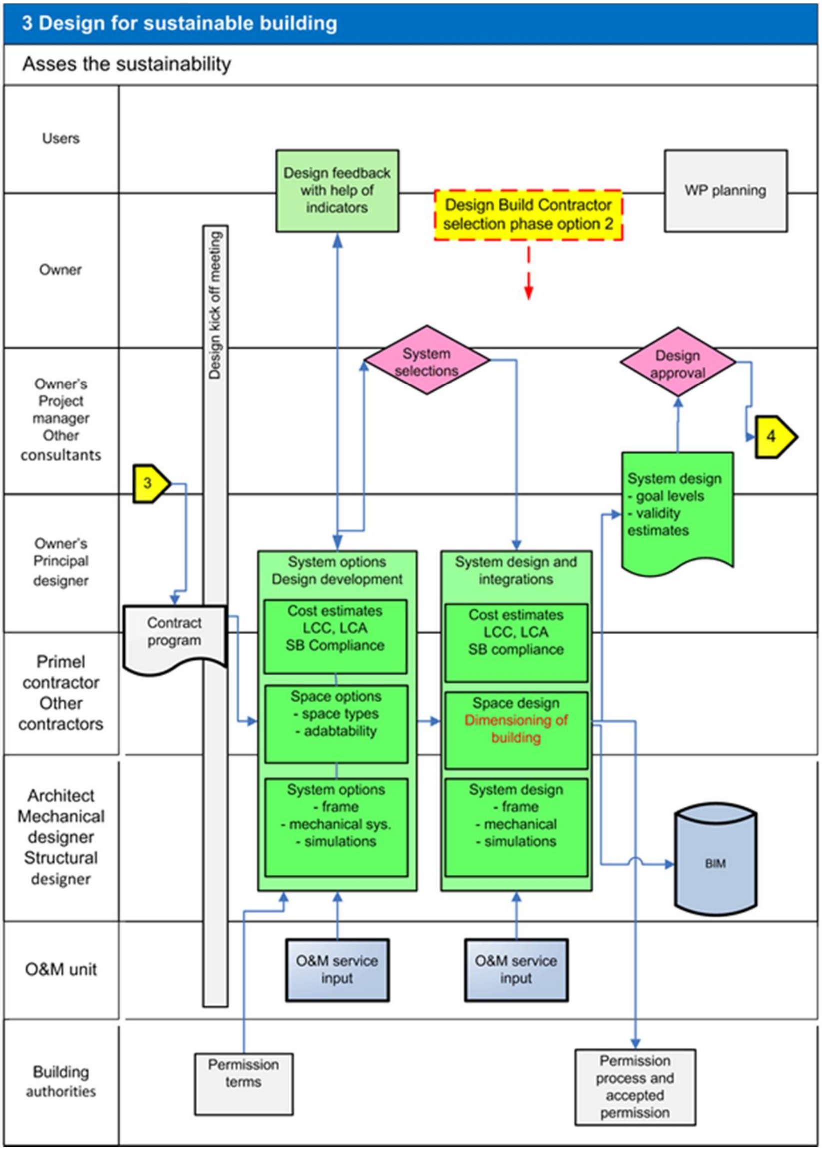
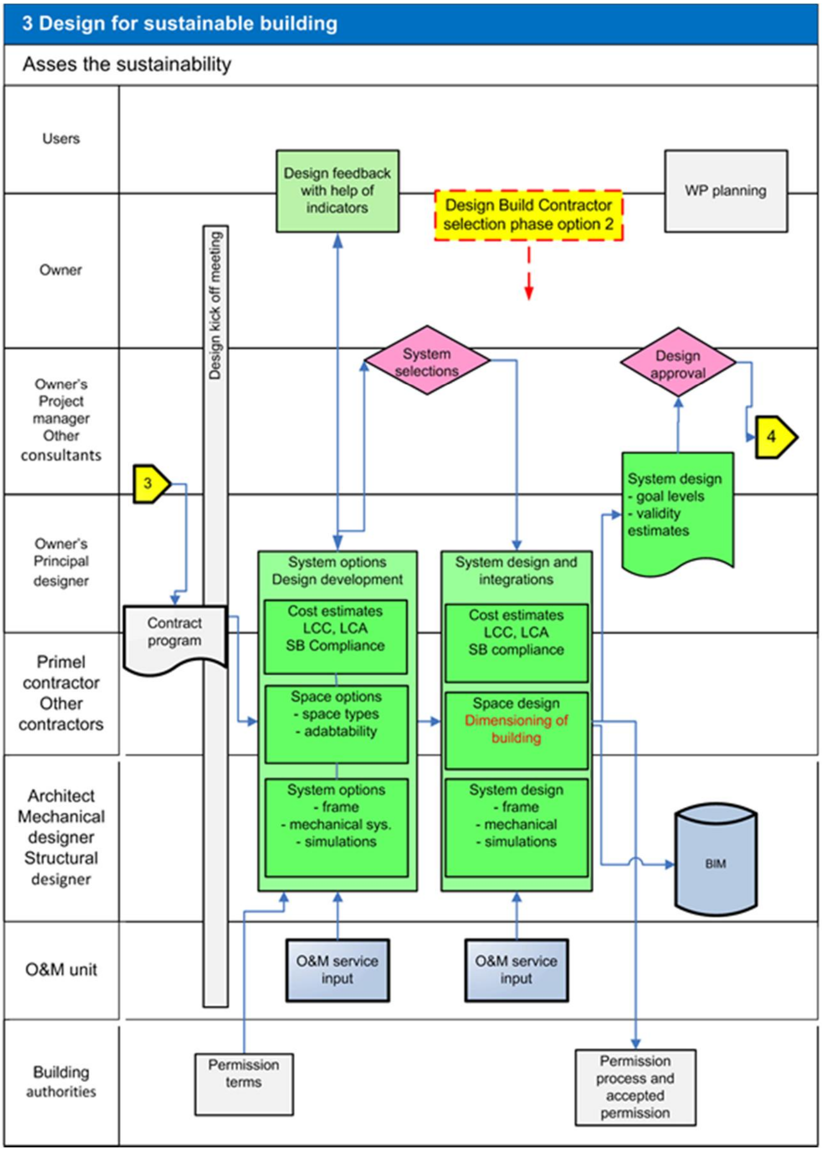
Design Build team selection criteria	Design Build team selection criteria are defined on the basis of programme goals. Criteria are requirements of sustainable building knowledge and references described with the help of metrics regarding sustainability issues (considering both design values as well as operational values). The starting point is performance thinking, where the owner presents performance goals including environmental and economic viewpoints without limiting design solutions. Note: Selection of the appropriate delivery system depends on the competence of the client and the project nature. When the client has the competence (e.g. earlier experience on similar projects), the sustainable solution could be designed by the client (Design Bid Build or Construction Management).
Tasks/Actors involved	• Owner • Owner's Project Manager and other consultants • Owner's Principal Designer
Sustainability Principles/Aspects that can be considered at this stage	**Recommendations** • **The specification of the selection criteria should be as clear as possible since the design teams will tailor their proposals according to these and they will be evaluated against them.**
Core Indicators	Sustainability aspects and indicators must be in accordance with the set targets.
Sustainability Assessment Tools available	
Assessment method(s)	A weighted selection table.
Background information and data	


3 Design for sustainable building
Asses the sustainability
Users
Owner
Owner's Project manager Other consultants
Owner's Principal designer
Primel contractor Other contractors
Architect Mechanical designer Structural designer
O&M unit
Building authorities
Design kick off meeting
Design feedback with help of indicators
Design Build Contractor selection phase option 2
WP planning
System selections
Design approval
3
4
System design - goal levels - validity estimates
Contract program
System options Design development
Cost estimates LCC, LCA SB Compliance
Space options - space types - adabtability
System options - frame - mechanical sys. - simulations
System design and integrations
Cost estimates LCC, LCA SB compliance
Space design Dimensioning of building
System design - frame - mechanical - simulations
BIM
O&M service input
O&M service input
Permission terms
Permission process and accepted permission

System options and design development	The system options are described in terms of space, structure/envelope components and equipment, and they are assessed in terms of main building performance aspects, as well as environmental, social and economic impacts. The adoption of an integrated design approach is recommended.
System design and integrations	The next design level is building system design, where collaborative design and planning are essential and all design expertise is needed. The adoption of an integrated design approach together with the use of a BIM reinforces the global quality, optimization, coherence, reliability and cost-effectiveness of the building project. The design is assessed and controlled by performance-based results with the help of sustainability indicators. Users participate in providing feedback on plans and/or 3D models.
Result	The result is system-level design solutions, predicted sustainable performances (in principle, in line with initial goals) and validity estimates.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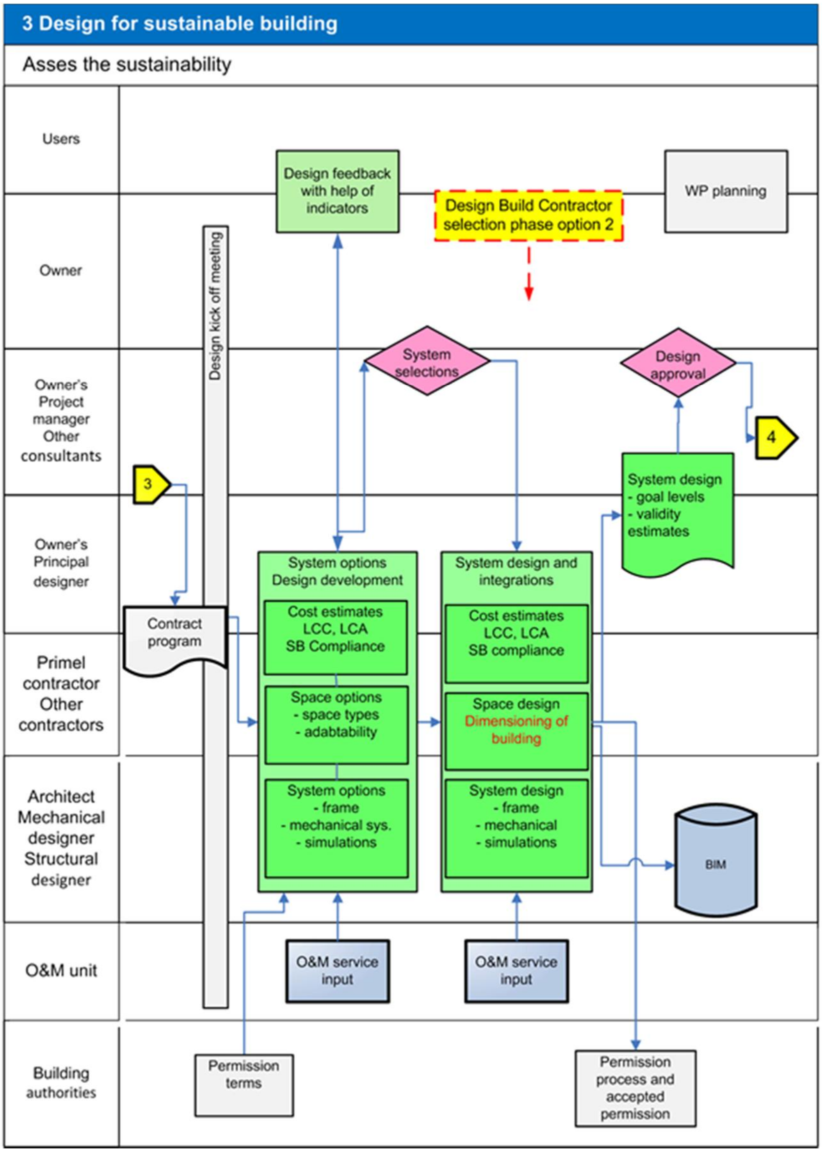
Permission process and accepted permission

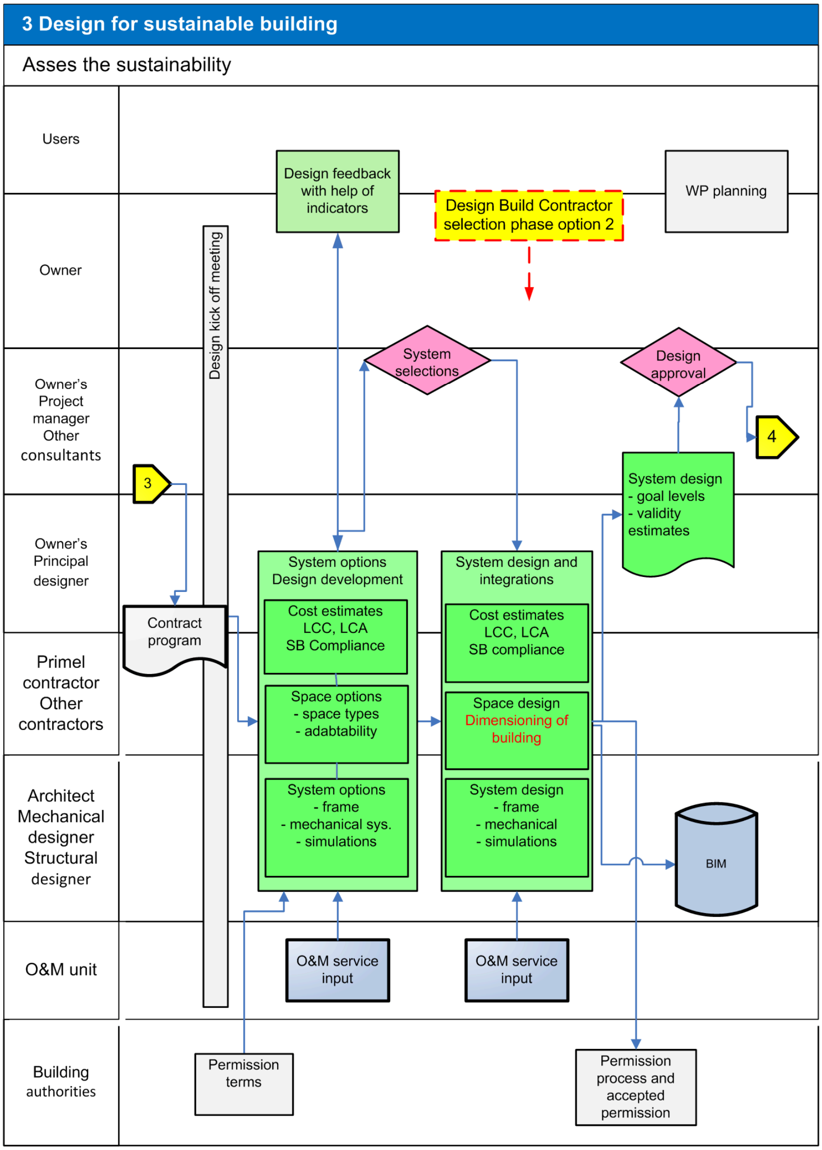
System options and design development	The system options are described in terms of space, structure/envelope components and equipment, and they are assessed in terms of main building performance aspects, as well as environmental, social and economic impacts. The adoption of an integrated design approach is recommended.
Tasks/Actors involved	• Users • Owner • Owner's Project Manager and other consultants • Owner's Principal Designer • Prime contractor, other contractors • Architect, Mechanical designer, Structural designer, Energy and Environmental designer • O&M operators • Building authorities • Neighbours
Sustainability Principles/Aspects that can be considered at this stage	**Background and comments** • Considering what kind of technical specifications are needed for the final integration of sustainability goals is important here. • Subcontractors are important in this part because we are considering different system options. They might be asked to provide supplementary information for the sustainability assessment. This step makes somehow a difference in relation to the "traditional" process. • This might include a certain pre-selection of options among the ones available. **Recommendations** • **It might be useful to have a shortlist of information (e.g. carbon footprint, energy performance, etc.) that should be asked from the system supplier/subcontractor. This might be in itself a condition for the selection of suppliers.**
Core Indicators	Most of the core indicators are relevant here. (Please, see table of indicators in Annex 1)
Sustainability Assessment Tools available	• LCI and LCC comparisons. • It is preferable to use design tools that can communicate with a BIM (through IFC language).
Assessment method(s)	Calculation, simulation, either simplified or detailed, with default values when precise data are not available yet (e.g. EPDs of construction products).

Background information and data	• Plans, descriptive documents, quantity survey, databases, using default values if needed. When dealing with different project options, a BIM able to manage "versioning" is preferable. • Products and building characteristics (nature, quantities, properties…) included in the BIM.



System design and integrations	The next design level is building system design, where collaborative design and planning are essential and all design expertise is needed. The adoption of an integrated design approach together with the use of a BIM reinforces the global quality, optimization, coherence, reliability and cost-effectiveness of the building project. The design is assessed and controlled by performance-based results with the help of sustainability indicators. Users participate in providing feedback on plans and/or 3D models.
Tasks/Actors involved	• Users • Owner • Owner's Project Manager and other consultants • Owner's Principal Designer • Prime contractor, other contractors • Architect, Mechanical designer, Structural designer, Energy and Environmental designer • O&M operators • Building authorities • Neighbours
Sustainability Principles/Aspects that can be considered at this stage	**Background and comments** • Design specifications should be given with the help of measurable and clear indicators (transfer of upper level targets to product level is important). The selection of the real products should fulfil these criteria (like CF, service life, embodied energy, care and maintenance). The technical characteristics should be extended to environmental and other life cycle characteristics. **Recommendations** • **Integration of data exchange between building simulation tools and sustainability assessment tools. BIM can be useful for this purpose (everybody involved can rely on the information stored in the BIM for their calculations).** • **The detailed technical specifications have to be developed in order to respect the upper level indicators. Clarification of what type of information should be included in the technical specifications.** • **Keep integrated design continuously in mind.** • **Having an independent commissioning professional/team to check the design might be important to recognize defects at design phase and to verify the compatibility between sustainability targets.**
Core Indicators	All the core indicators are relevant here. (Please, see table of indicators in Annex 1)

Sustainability Assessment Tools available	• Simulation tools. • Examples of LCA-oriented tools: Elodie, LEGEP, DGNB, Ilmari, etc. • LCC tools. • Design reviews.
Assessment method(s)	The default values are replaced by real values representing the technical choices made. **Recommendations** • **Simulate realistic scenarios (patterns of use and users behavior) instead of conventional scenarios.** • **For LCA-based indicators, apply appropriate standards (EN 15804 and EN 15978) and refer to guidance documents (as EeBGuide, ILCD Handbook, LoReLCA, etc.).**
Background information and data	• Plans, descriptive documents, quantity survey, databases, using default values if needed. • Products and building characteristics (nature, quantities, properties…) included in the BIM.


3 Design for sustainable building
Asses the sustainability
Users
Owner
Owner's Project manager Other consultants
Owner's Principal designer
Primel contractor Other contractors
Architect Mechanical designer Structural designer
O&M unit
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Design kick off meeting
Design feedback with help of indicators
Design Build Contractor selection phase option 2
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System selections
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Contract program
System options Design development
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Space options
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System options
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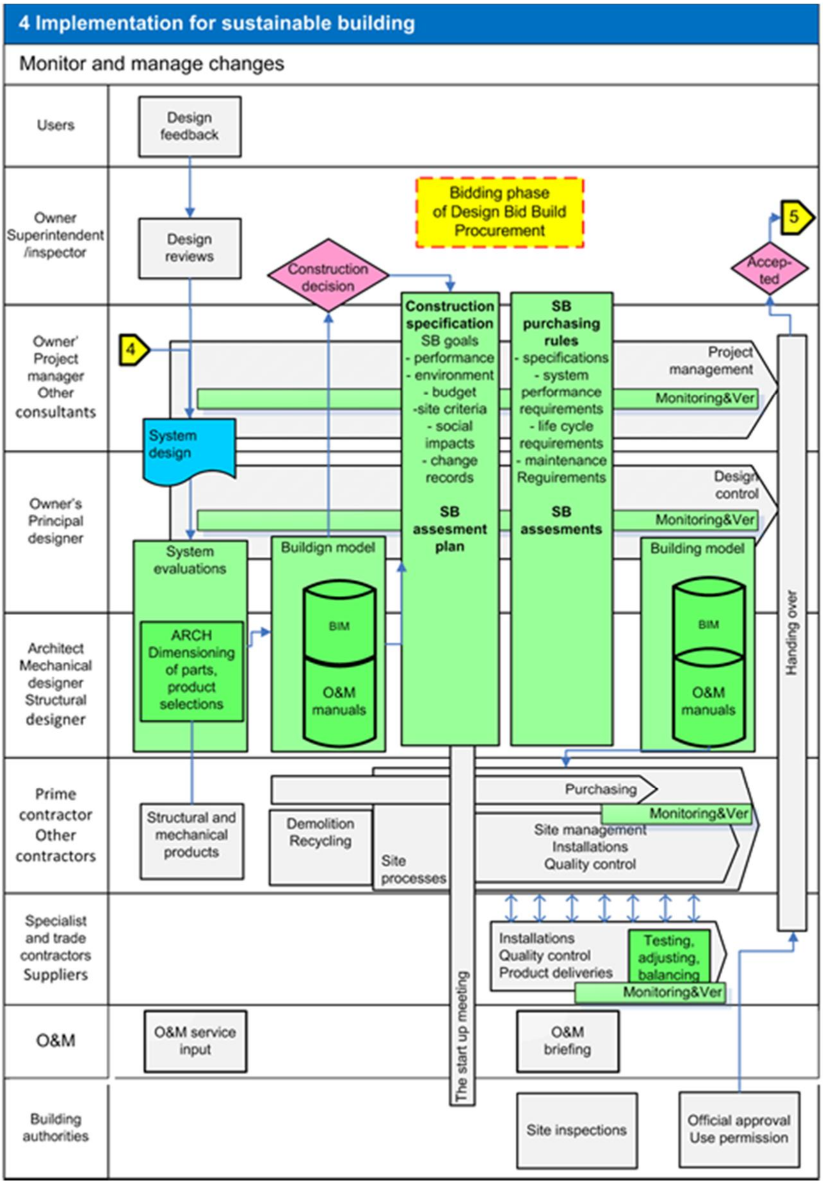
System design and integrations
Cost estimates LCC, LCA SB compliance
Space design
Dimensioning of building
System design
- frame
- mechanical
- simulations
BIM
O&M service input
O&M service input
Permission terms
Permission process and accepted permission

Result	The result is system-level design solutions, predicted sustainable performances (in principle, in line with initial goals) and validity estimates.
Tasks/Actors involved	• Users • Owner • Owner's Project Manager and other consultants • Owner's Principal Designer • Prime contractor, other contractors • Architect, Mechanical designer, Structural designer, Energy and Environmental designer • O&M operators • Building authorities • Neighbours
Sustainability Princi-ples/Aspects that can be considered at this stage	**Recommendations** • **Design should include alternative options if certain sustainability targets conflict with costs.** • **It should be possible to improve the initial targets if better alternatives are discovered during the process.** • **System-level design solutions should be described in terms of those sustainability indicators used in target setting. In addition, assessment methods should be de-scribed. Some methods may have been prescribed by the client brief and some assessment methods may be free to choose and in that case they have to be explained and justified.** • **Impartial commissioning professional/team should check the plan for the client.**
Core Indicators	The same building level indicators must be considered through the whole process. Product level indicators are not building level sustainability indicators: e.g. air tightness of the envelope (prod-uct level indicator) significantly affects the energy performance of a building (building level indicator).
Sustainability Assess-ment Tools available	• Simulation tools. • Examples of LCA-oriented tools: Elodie, LEGEP, DGNB, Ilmari, etc.
Assessment method(s)	The assessments done should be documented (scope, bounda-ries, assumptions, scenarios, data quality, uncertainties, most influent parameters, etc.) and the results analyzed. **Recommendations** • **When several options are assessed, the results should be compared, considering possible variations in the "func-tional equivalent".**

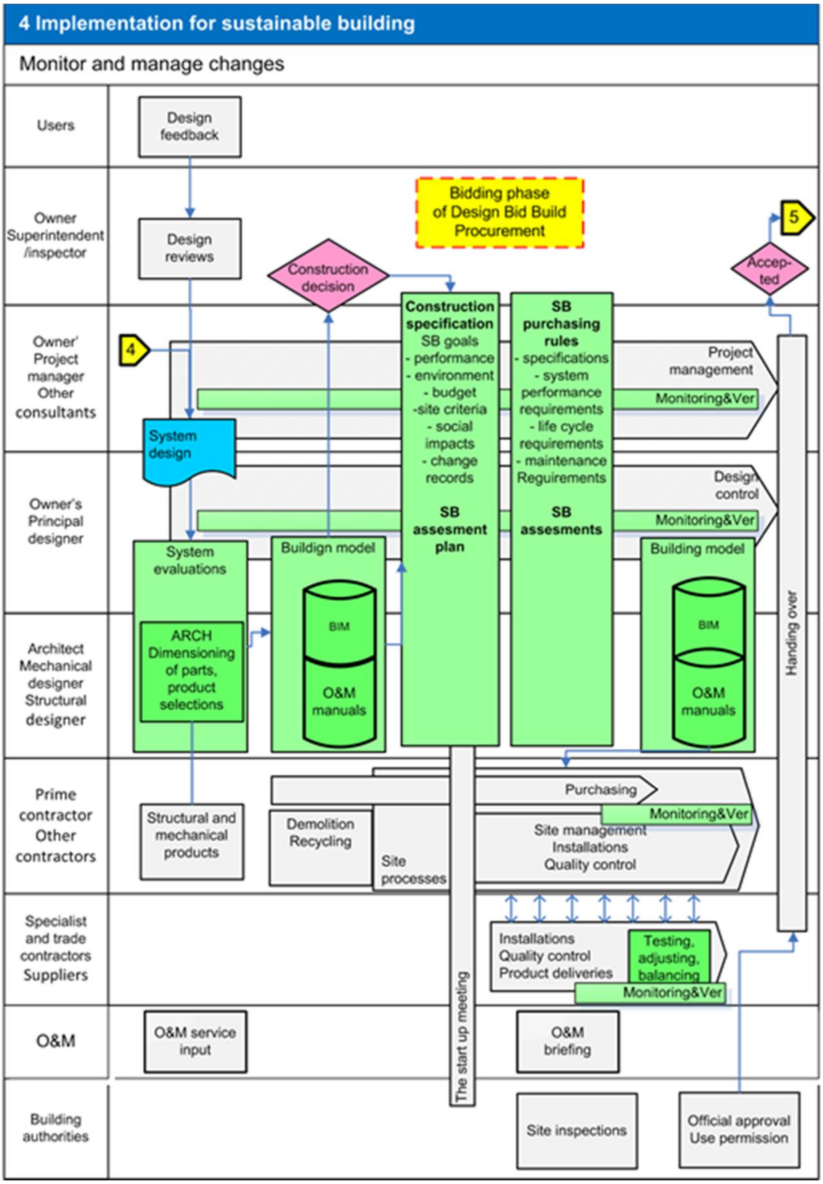
Background information and data	Data quality has to be documented.



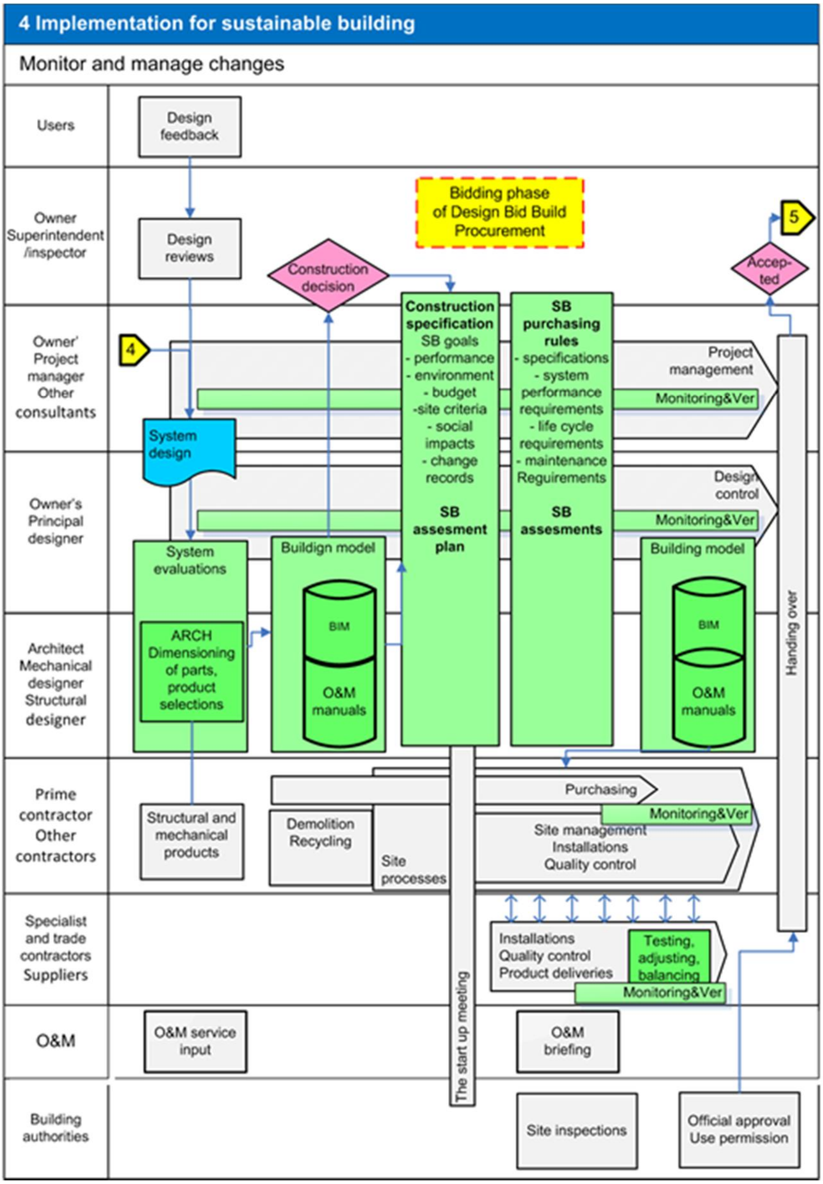
Dimensioning and selection of products	After the system level design, the design goes on by dimensioning, calculations and the selection of products. The selections are based on the assessment results of the alternatives. Design-Build and Design-Build-Operate procurement and delivery models have best supported the process of sustainable building. In those cases the significance of owner's supervising in detailed design and in implementing of targets is diminished during the process. It is essential that the fulfillment of targets can be verified from the final outcome. It has to be possible to distinguish the influence of users when the final result is assessed.
Drawings and specifications of systems and the building	Detailed design results in the creation of the design (building model, BIM), its assessment result and the construction specification. The approval of the design and the building decision, and the milestones of these decisions depend on the procurement model.
Construction specification	The construction specification describes the solutions that fulfill the targets and thus completes the design. At the same time, this is an updated document of the building programme and it includes the possible (well reasoned) changes of targets that have been made during the preliminary design. The construction specification states the site specific environmental and social targets in addition to the performance targets and environmental and economic targets of the building. Specifications are essential information source in addition to the drawings for all subcontractors and material suppliers.
Purchasing rules	Specific criteria are defined for actors and for purchasing. The criteria cover also the maintenance stage. The criteria cover the functionality of systems, service life, care and maintenance, and environmental impacts based on assessments. The building level targets on interpreted and concretised with regard to actors and purchasing on different levels. Service life requirements, care and maintenance requirements and environmental and economic requirements are derived from the system level performance requirements.
Monitoring and verification of performance	5A. The realization of targets is monitored continuously. When needed the changes of targets are written to the construction specification (which includes the description of targets). The targets are kept updated all the time and the continuous understanding of the targets is ensured. 5B. At this stage the building is adjusted to correspond to the user needs. Users' training is also started.

Building model and reference documents

This stage results in the completion of the building and its model. In addition, the guidelines and instruction of care and maintenance are created as an outcome. The instruction includes the target levels of performance. Operation and maintenance manuals will be completed in collaboration by designers and contractors.



Dimensioning and selection of products	After the system level design, the design goes on by dimensioning, calculations and the selection of products. The selections are based on the assessment results of the alternatives. Design-Build and Design-Build-Operate procurement and delivery models have best supported the process of sustainable building. In those cases the significance of owner's supervising in detailed design and in implementing of targets is diminished during the process. It is essential that the fulfillment of targets can be verified from the final outcome. It has to be possible to distinguish the influence of users when the final result is assessed.
Tasks/Actors involved	• Users • Owner • Owner's Project Manager and other consultants • Owner's Principal Designer • Prime contractor, other contractors • Architect, Mechanical designer, Structural designer • O&M unit • Building authorities
Sustainability Principles/Aspects that can be considered at this stage	**Recommendations** • **Upper level indicators should be translated into product level technical specifications (e.g. space heating demand, electricity use and acoustic conditions should be considered when dealing with product level issues such as heat recovery efficiency, specific heat consumption of fans and noise level of the air handling unit.** • **At this stage the design should define product level requirements in order not to destroy building requirements (e.g. performance requirements, this is particularly important when changes are proposed as to make sure that the original requirements are met).**
Core Indicators	Product level indicators are not building level sustainability indicators. E.g. the air tightness of the envelope (product level indicator) significantly affects the energy performance of a building (building level indicator).
Sustainability Assessment Tools available	
Assessment method(s)	
Background information and data	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O&M service input
O&M briefing
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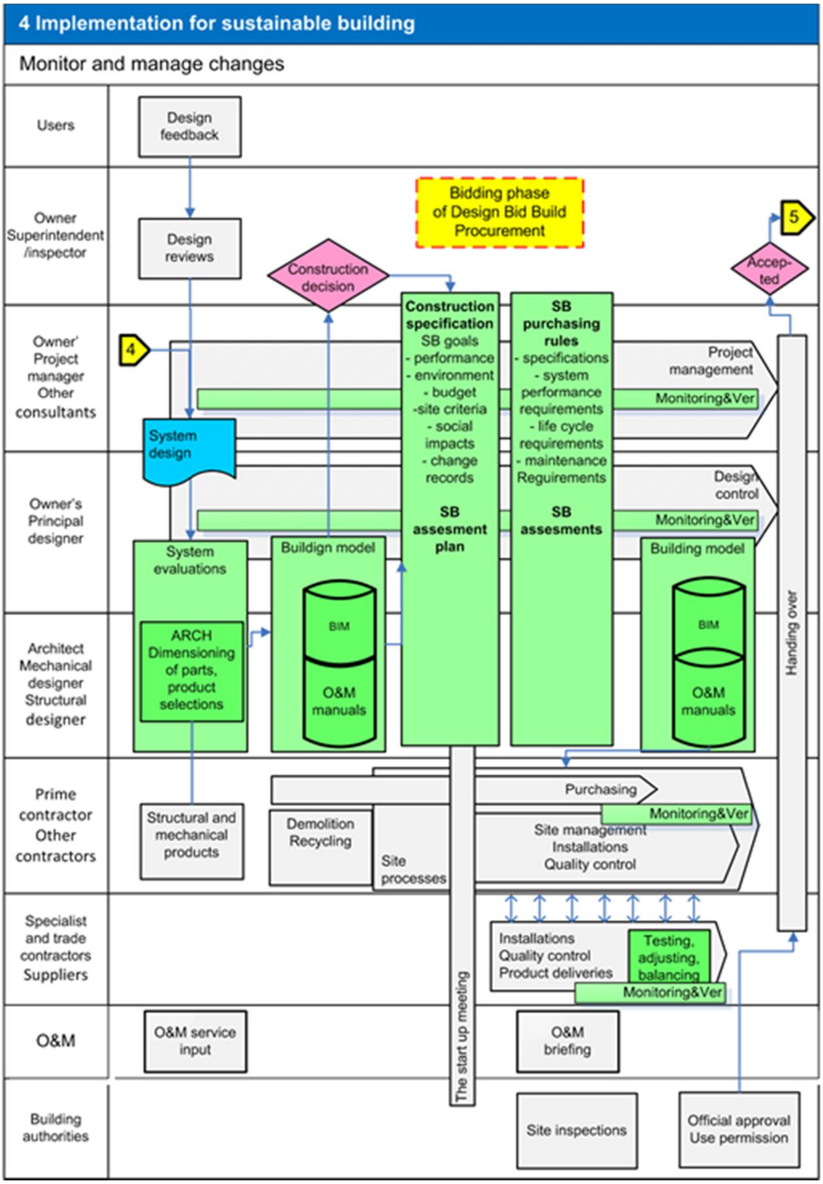
Drawings and specifications of systems and the building	Detailed design results in the creation of the design (building model, BIM), its assessment result and the construction specification. The approval of the design and the building decision, and the milestones of these decisions depend on the procurement model.
Tasks/Actors involved	• either Owner and Owner's Designer or • Main Contractor and Main Contractor's Designer (depending on the project delivery system)
Sustainability Principles/Aspects that can be considered at this stage	**Recommendations** • **Sustainability review should be part of the total review and it should be done with the same indicators used for target setting (e.g. energy and indoor simulation with the help of BIMs)** • **Define indicators, assessment methods and checkpoints for monitoring.**
Core Indicators	
Sustainability Assessment Tools available	At this stage a detailed assessment of the design has been carried out with performance indicators. It is an iterative process. For this check-in simulation and calculation methods are needed. Building authorities will check for regulatory aspects but sustainability aspects often are not included in those.
Assessment method(s)	Energy efficiency simulation with the help of BIMs, Green House Gases assessment with the help of BIMs and product data on the basis of energy performance data and energy data. **Recommendation** • **Sustainability review should be done with the help of same indicators and corresponding assessment methods (e.g. energy efficiency simulation and Green House Gases assessment).**
Background information and data	Environmental data for products (EPDs) and energy.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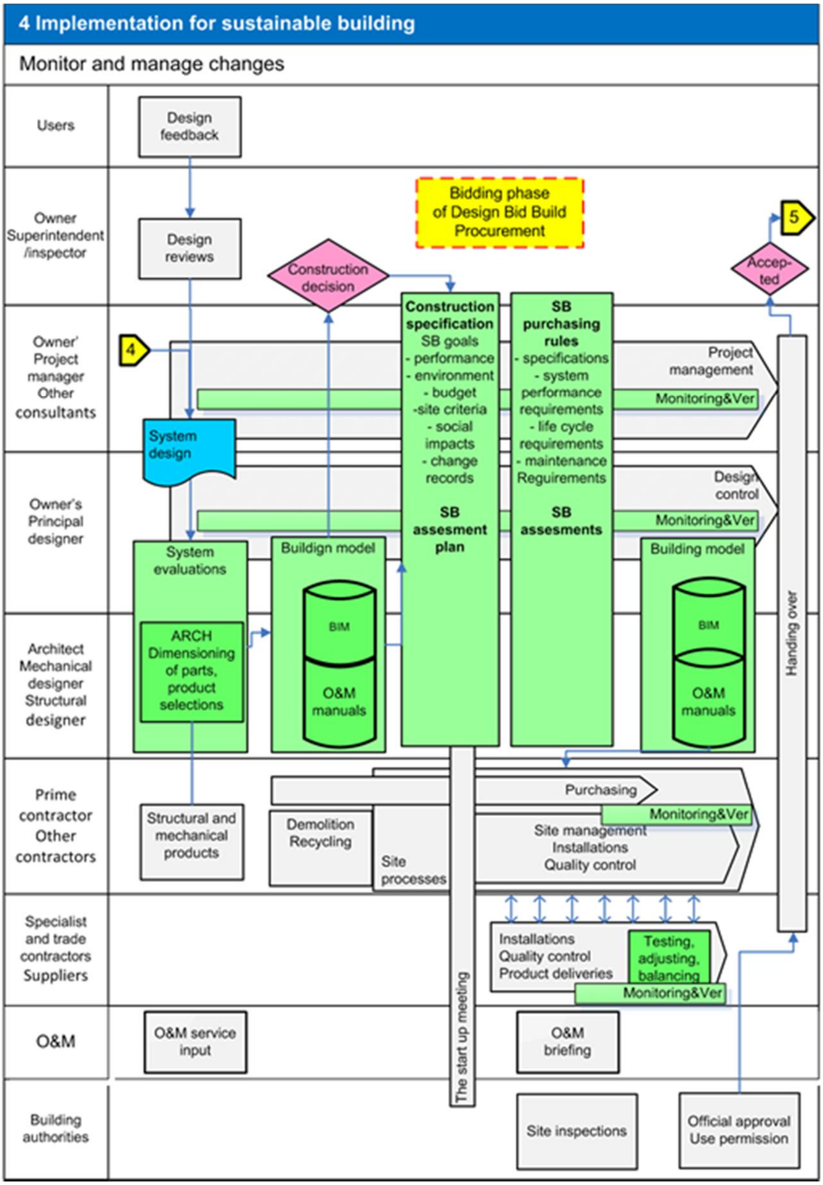
Construction specification	The construction specification describes the solutions that fulfill the targets and thus completes the design. At the same time, this is an updated document of the building programme and it includes the possible (well reasoned) changes of targets that have been made during the preliminary design. The construction specification states the site specific environmental and social targets in addition to the performance targets and environmental and economic targets of the building. Specifications are essential information source in addition to the drawings for all subcontractors and material suppliers.
Tasks/Actors involved	• Architect and other designers • Main contractor
Sustainability Principles/Aspects that can be considered at this stage	**Recommendations** • **In addition to these upper level (well reason) targets the work programme should include system level translated targets (e.g. construction check lists). This is particularly important since a big part of the work might be done by subcontractors.** • **At this phase the sustainability can still be increased through the proposed improvements to the client.**
Core Indicators	Indicators are building level indicators and relevant performance requirements for lower level systems.
Sustainability Assessment Tools available	• Suppliers (including contractors and manufacturers) may have their own catalogues with reliable sustainability data. **Recommendation** • **The model describing the building should include also the description of the sustainability with the help of the original indicators.**
Assessment method(s)	
Background information and data	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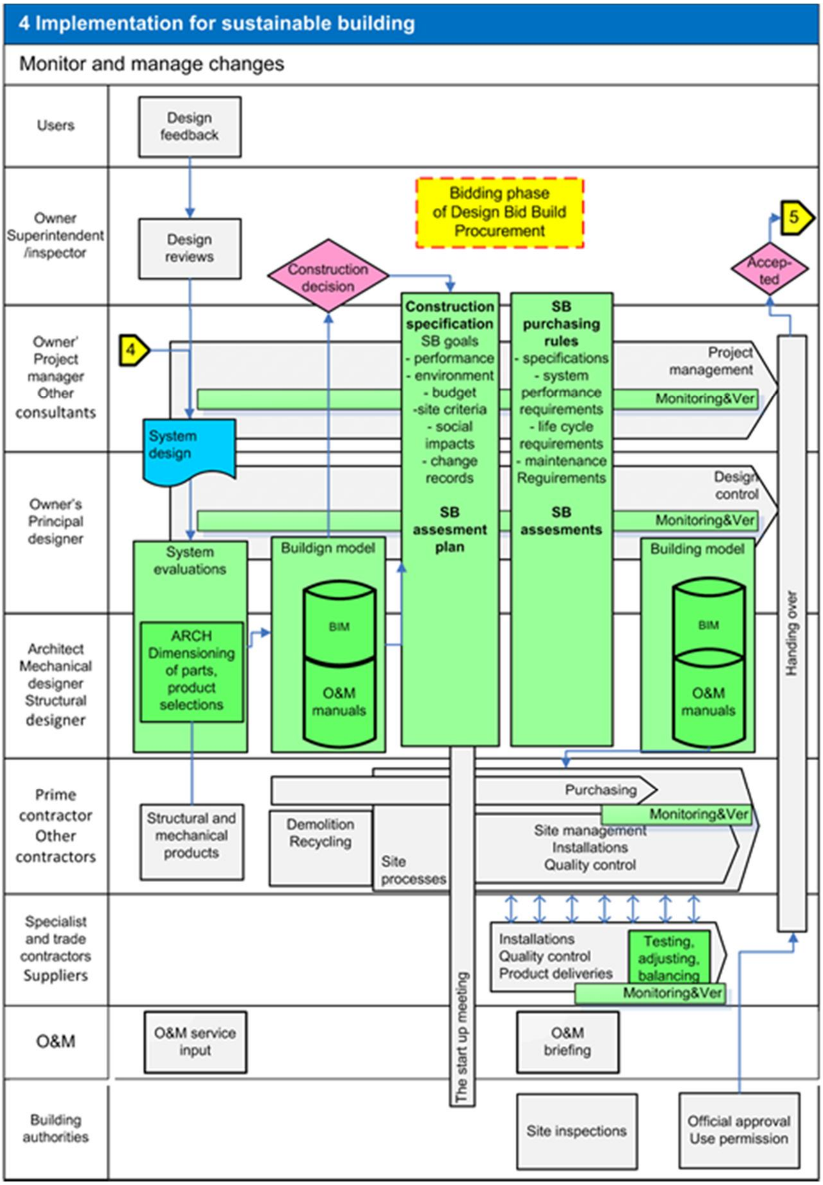
Purchasing rules	Specific criteria are defined for actors and for purchasing. The criteria cover also the maintenance stage. The criteria cover the functionality of systems, service life, care and maintenance, and environmental impacts based on assessments. The building level targets on interpreted and concretised with regard to actors and purchasing on different levels. Service life requirements, care and maintenance requirements and environmental and economic requirements are derived from the system level performance requirements.
Tasks/Actors involved	• Owner's Project Manager and other consultants • Owner's Principal Designer • Prime contractor, other contractors (procurement unit, maintenance competence) • Architect, Mechanical designer, Structural designer
Sustainability Principles/Aspects that can be considered at this stage	**Recommendation** • **Purchasing rules should be based on the system and product level values interpreted from building level targets.** • **All purchasing units should take responsibility for providing material and product certificates for the maintenance database.**
Core Indicators	
Sustainability Assessment Tools available	
Assessment method(s)	
Background information and data	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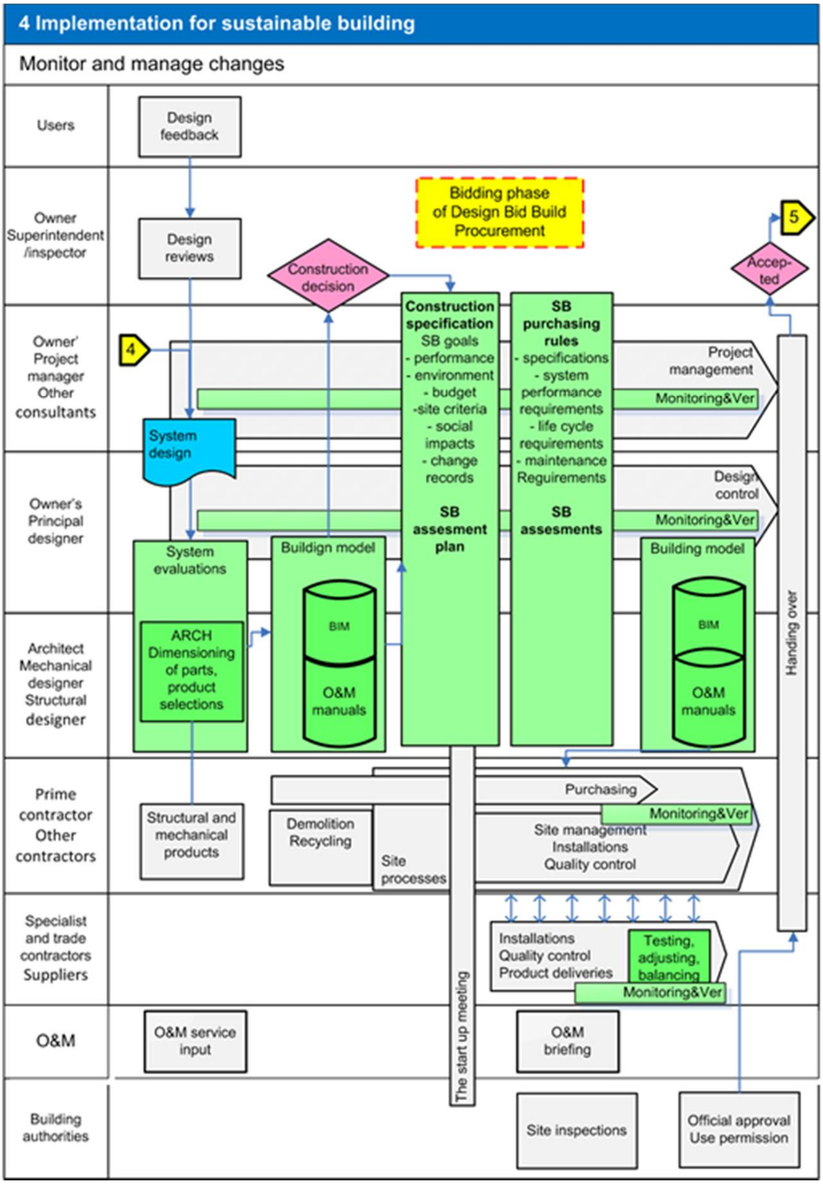
Monitoring and verification of performance	5A. The realization of targets is monitored continuously. When needed the changes of targets are written to the construction specification (which includes the description of targets). The targets are kept updated all the time and the continuous understanding of the targets is ensured. 5B. At this stage the building is adjusted to correspond to the user needs. Users' training is also started.
Tasks/Actors involved	• Users • Owner • Owner's Project Manager and other consultants • Owner's Principal Designer • Prime contractor, other contractors • Architect, Mechanical designer, Structural designer • O&M unit • Building authorities • Insurance companies (depending on the country)
Sustainability Principles/Aspects that can be considered at this stage	**Recommendations** • **Municipalities' additional site inspections would be useful.** • **It should be checked that all installations are completed according to the targets, and that all mechanical systems meet the stated performance requirements.**
Core Indicators	Same indicators with the help of which the targets were set. (Please, see table of indicators in Annex 1)
Sustainability Assessment Tools available	
Assessment method(s)	Life Cycle Commissioning.
Background information and data	Monitoring and verification documents, TAB (Testing, Adjusting and Balancing) documents, etc.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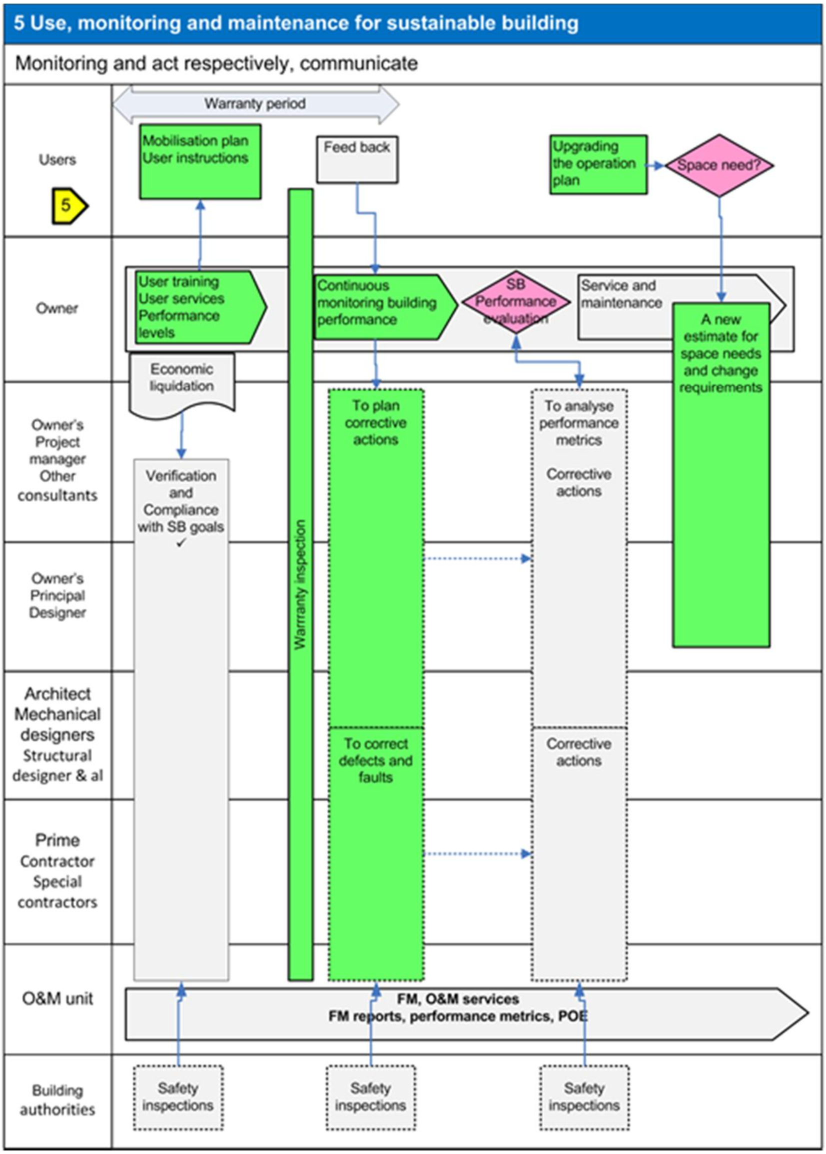
Building model and reference documents	This stage results in the completion of the building and its model. In addition, the guidelines and instruction of care and maintenance are created as an outcome. The instruction includes the target levels of performance. Operation and maintenance manuals will be completed in collaboration by designers and contractors.
Tasks/Actors involved	• Prime contractor, other contractors • Architect, Mechanical designer, Structural designer • O&M unit
Sustainability Principles/Aspects that can be considered at this stage	**Recommendations** • **The as built model should be described with the help of all indicators that were used in design. Both building level and system level results should be given. In addition, the information about used assessment methods should be saved.**
Core Indicators	Same Performance indicators as used in Design phase. (Please, see table of indicators in Annex 1)
Sustainability Assessment Tools available	BIM based sustainability assessment applications (the simulations must be based on the as built model).
Assessment method(s)	
Background information and data	It's important to keep the targeted performance levels updated. The way the information is communicated needs to be target group specific. E.g. for the tenants maybe the performance in use, for maintenance companies maybe service life and maintenance information.


5 Use, monitoring and maintenance for sustainable building
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User training User services Performance levels
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A new estimate for space needs and change requirements
Economic liquidation
Owner's Project manager Other consultants
Verification and Compliance with SB goals ✓
Warranty inspection
To plan corrective actions
To analyse performance metrics
Corrective actions
Owner's Principal Designer
Architect Mechanical designers Structural designer & al
To correct defects and faults
Corrective actions
Prime Contractor Special contractors
O&M unit
FM, O&M services
FM reports, performance metrics, POE
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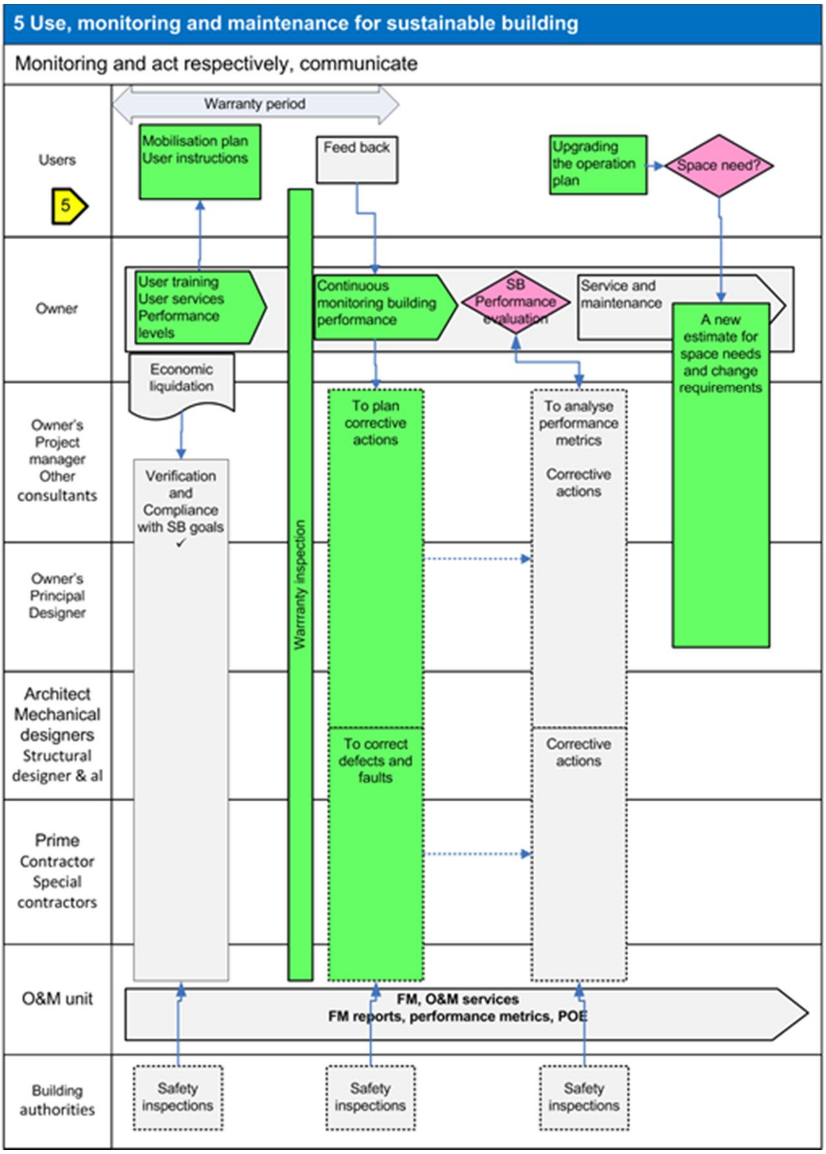
Safety inspections

Training	User and Facility Management personnel training is the first task (may have started in 4.5 already). User training ensures that the users know how to operate the building to ensure that the performance target will be met over lifetime. Online monitoring and communicating to users may influence in sustainable user behavior. Training also ensures that Facility Management personnel know performance targets and user impacts on property performance.
Warranty inspection	Warranty inspection and corrective actions consists of several inspections and analyses (process). All performance deviations and defects should be documented. When all corrective actions are completed the final warranty inspection will be performed.
Continuous monitoring	Performance targets and measured values are monitored and building performance is controlled to meet owners' and users' needs and the target level of sustainable construction. User feedback is collected at the same time.
Corrective actions	If necessary, analysis and corrective actions will be done (building is not meeting its present use either due to non-performance or changed use needs). However, if use needs change, new targets need to be set. Condition surveys or cause analysis are needed before corrective actions, if quality of indoor climate is weak. Problems can be seen also in user feedback.
Upgrading the operation plan and a new space need	When owners' operation plan has been changed a lot, a new space acquisition process will be started again by a new sustainable briefing. Experiences from the previous space acquisition will be used in the next acquisition process aimed at continuous improvement.



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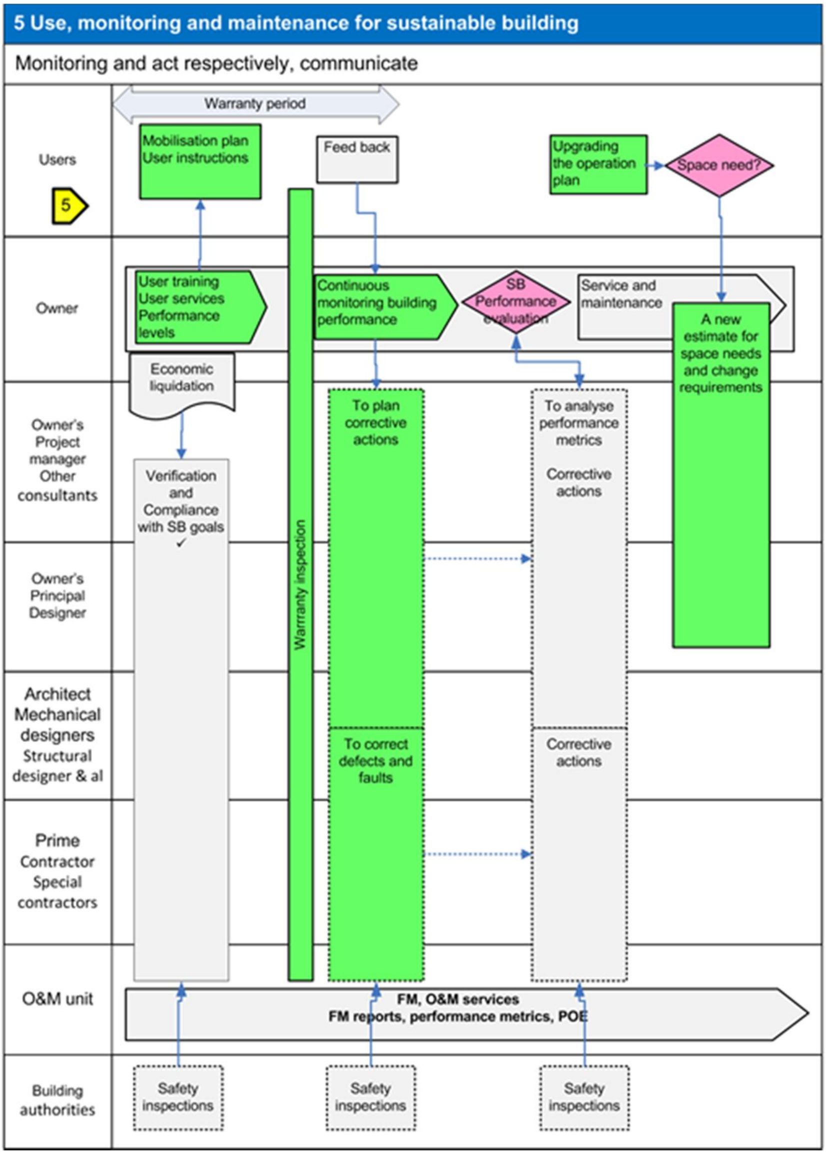
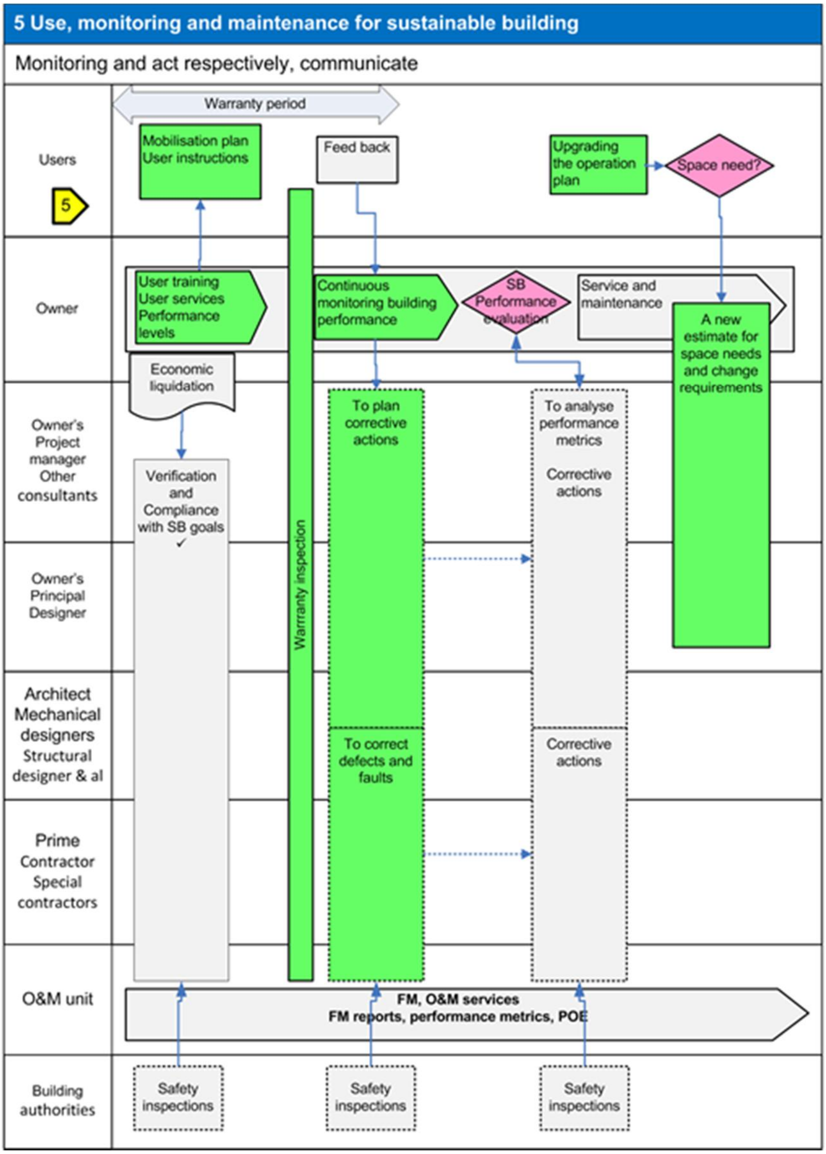
Training	User and Facility Management personnel training is the first task (may have started in 4.5 already). User training ensures that the users know how to operate the building to ensure that the performance target will be met over lifetime. Online monitoring and communicating to users may influence in sustainable user behavior. Training also ensures that Facility Management personnel know performance targets and user impacts on property performance.
Tasks/Actors involved	• Users • Owner • Prime contractor, other contractors • O&M personnel
Sustainability Principles/Aspects that can be considered at this stage	**Background and comments** • Some aspects can be checked at the hand over phase (technical characteristics of envelope e.g. insulation or heating components) but other aspects can be monitored only after 1-2 years (e.g. energy and water consumption). **Recommendations** • **After 3 years in operation the building should perform as simulated with the help of sustainability indicators. If not, it should be analyzed if the deviation comes from different use than estimated or because of deviation in the performance of the building systems.** • **In addition to technical targets also life cycle targets should be checked on the basis of the production model. Realization of audit.** • **Ensure that the Facility Management Personnel knows the performance targets set for the building. They should also understand the connection of the monitored values (like the consumption of electricity) with the final targets.** • **The Facility Management Personnel should also understand the impact of user behaviour on the building's performance and they should be able to give further instructions and training for the users of the building.** • **A system with the help of which the users would be able to follow the building performance might be useful in order to support users to understand the impact of user behaviour.**
Core Indicators	Performance indicators are needed here. (Please, see table of indicators in Annex 1)
Sustainability Assessment Tools available	Life Cycle Commissioning.

Assessment method(s)

Background information and data



Warranty inspection	Warranty inspection and corrective actions consists of several inspections and analyses (process). All performance deviations and defects should be documented. When all corrective actions are completed the final warranty inspection will be performed.
Tasks/Actors involved	• Users • Owner • Architect and other designers • Prime contractor, other contractors
Sustainability Principles/Aspects that can be considered at this stage	**Recommendations** • **The building should perform as simulated with the help of sustainability indicators. If not, it should be analyzed if the deviation comes from different use than estimated or because of deviation in the performance of the building systems. Some aspects as energy efficiency can only be monitored reliably after 3 years of operation.** • **In case of observed construction or design defects the sustainability targets should be revisited.**
Core Indicators	
Sustainability Assessment Tools available	
Assessment method(s)	
Background information and data	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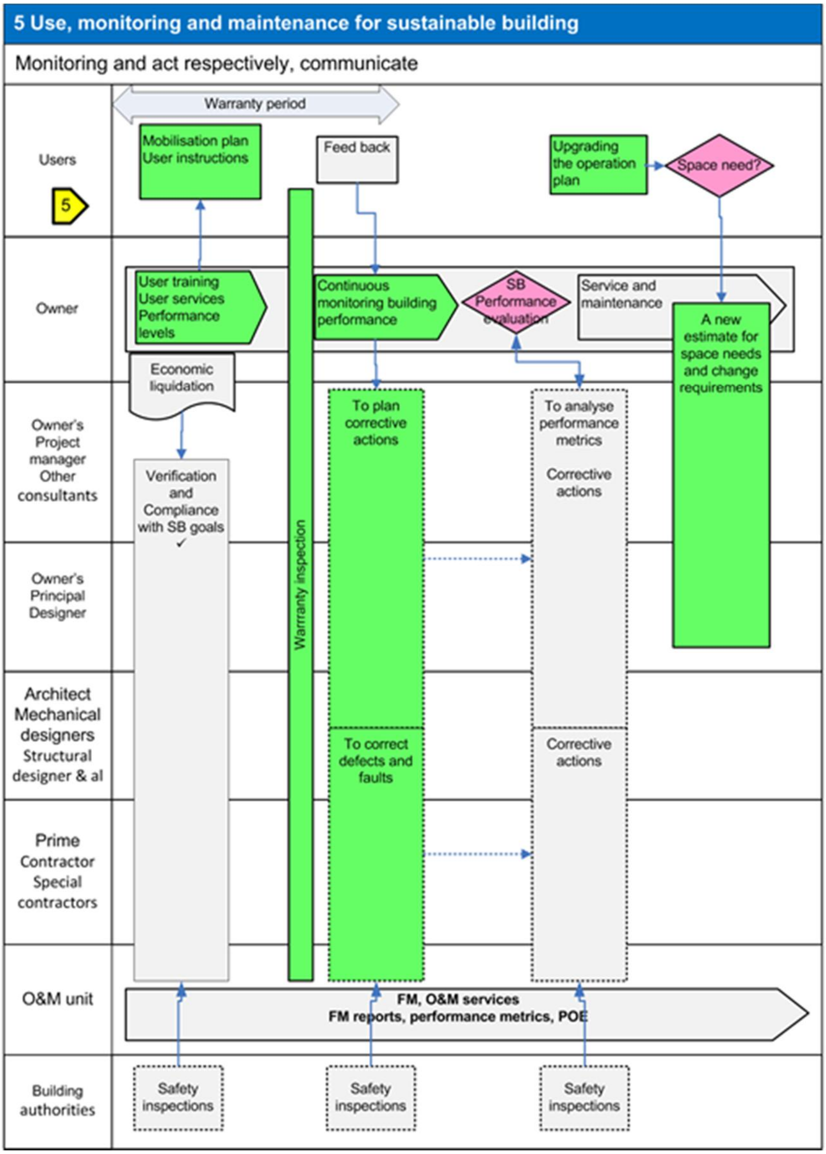
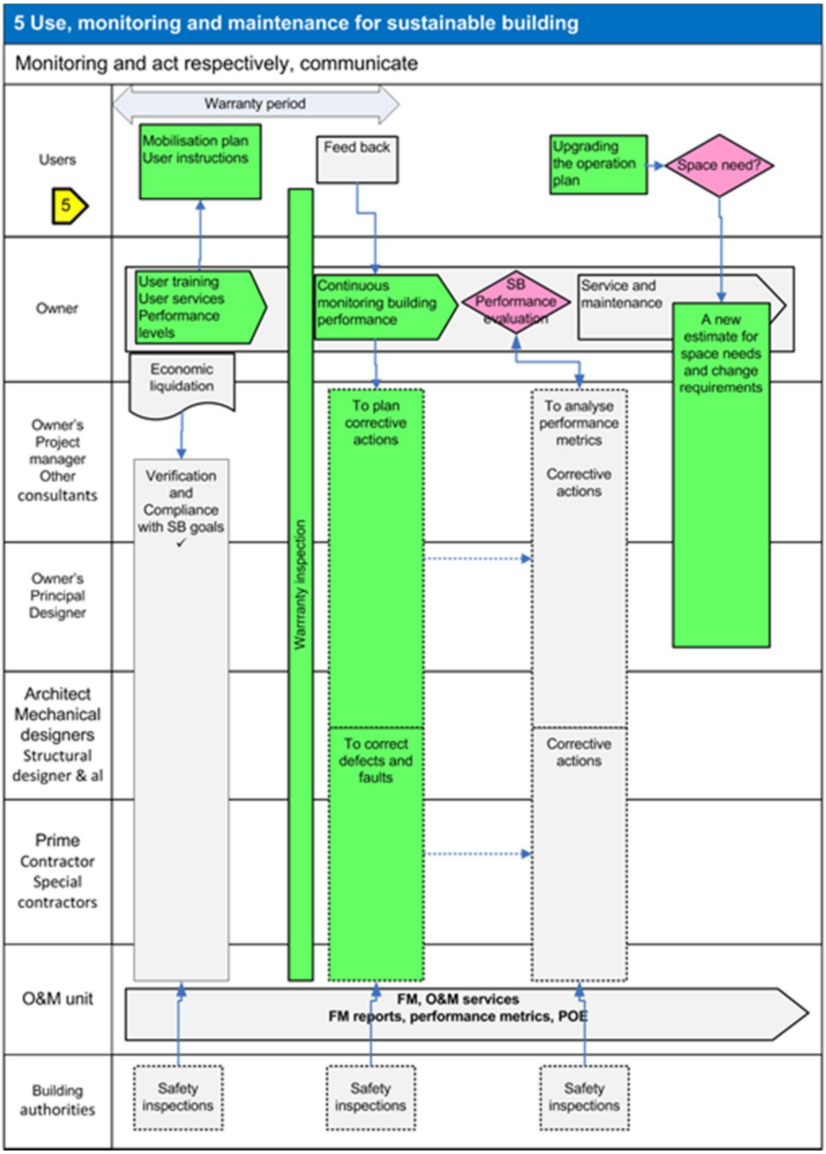
Continuous monitoring	Performance targets and measured values are monitored and building performance is controlled to meet owners' and users' needs and the target level of sustainable construction. User feedback is collected at the same time.
Tasks/Actors involved	• Users • Owner • O&M unit • Service providers for benchmarking and assessment • Developers of certification systems
Sustainability Principles/Aspects that can be considered at this stage	**Background and comments** • Reporting can provide more or less information about sustainability depending on how it is planned. **Recommen** • **Monitoring should be linked with relevant benchmarks (not only with the targets but also with similar building types).**
Core Indicators	The same building level indicators must be considered through the whole process. There should be an understanding between the parameters monitored and the indicators with the help of which the targets were set.
Sustainability Assessment Tools available	Web services. Reports from Building Automation Systems are tools in continuous monitoring. It's possible to develop features of automation systems to support continuous monitoring and linkage with the sustainability indicators.
Assessment method(s)	
Background information and data	


5 Use, monitoring and maintenance for sustainable building
Monitoring and act respectively, communicate
Warranty period
Users
5
Mobilisation plan User instructions
Feed back
Upgrading the operation plan
Space need?
Owner
User training User services Performance levels
Warranty inspection
Continuous monitoring building performance
SB Performance evaluation
Service and maintenance
A new estimate for space needs and change requirements
Economic liquidation
Owner's Project manager Other consultants
Verification and Compliance with SB goals ✓
To plan corrective actions
To analyse performance metrics
Corrective actions
Owner's Principal Designer
Architect Mechanical designers Structural designer & al
To correct defects and faults
Corrective actions
Prime Contractor Special contractors
O&M unit
FM, O&M services
FM reports, performance metrics, POE
Building authorities
Safety inspections
Safety inspections
Safety inspections

Corrective actions	If necessary, analysis and corrective actions will be done (building is not meeting its present use either due to non performance or changed use needs). However, if use needs change, new targets need to be set. Condition surveys or cause analysis are needed before corrective actions, if quality of indoor climate is weak. Problems can be seen also in user feedback.
Tasks/Actors involved	• Users • Owner • Owner's Project Manager and other consultants • Owner's Principal Designer • Prime contractor, other contractors • Architect, Mechanical designer, Structural designer • O&M unit • Building authorities
Sustainability Principles/Aspects that can be considered at this stage	**Recommendations** • **During the life cycle of a facility, when assessing its sustainability different alternatives can be considered like refurbishment renewal through partial demolition complementary construction**
Core Indicators	
Sustainability Assessment Tools available	
Assessment method(s)	
Background information and data	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Owner's Principal Designer
Architect Mechanical designers Structural designer & al
To correct defects and faults
Corrective actions
Prime Contractor Special contractors
O&M unit
FM, O&M services
FM reports, performance metrics, POE
Building authorities
Safety inspections
Safety inspections
Safety inspections

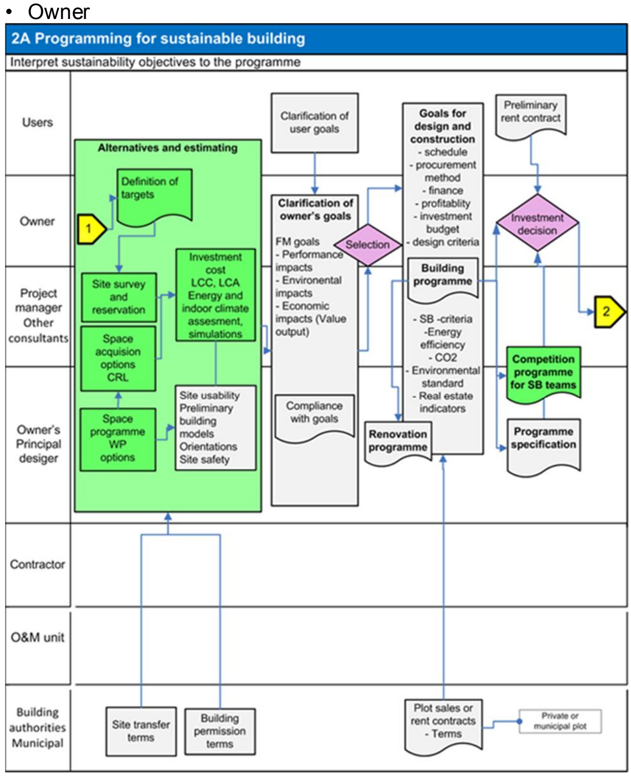
Upgrading the operation plan and a new space need

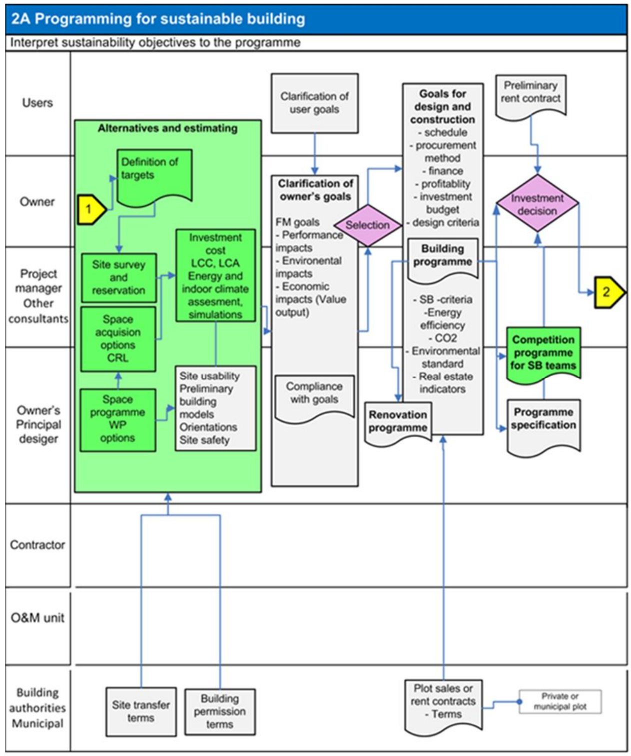
When owners' operation plan has been changed a lot, a new space acquisition process will be started again by a new sustainable briefing.

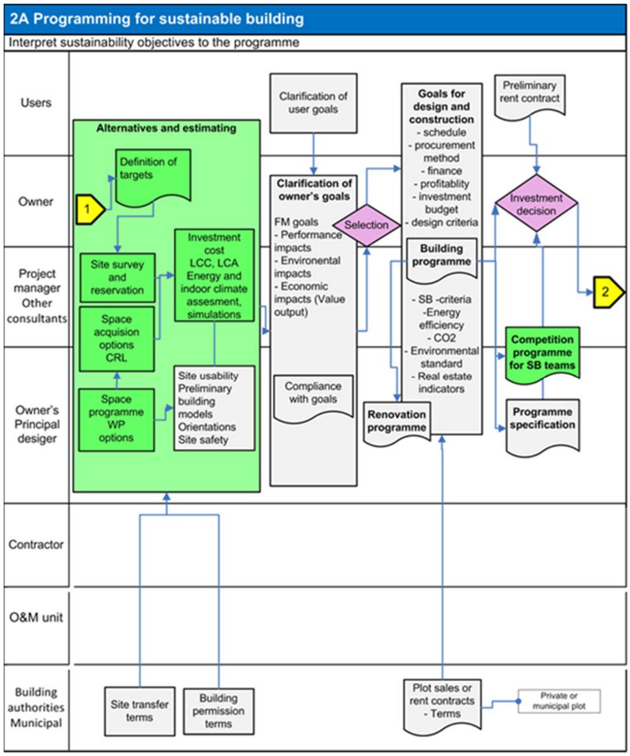
Experiences from the previous spaces and space acquisition will be used in the next acquisition process aimed at continuous improvement.

Tasks/Actors involved

- Users
- Owner




2A Programming for sustainable building
Interpret sustainability objectives to the programme
Users
Owner
Project manager Other consultants
Owner's Principal desiger
Contractor
O&M unit
Building authorities Municipal
Alternatives and estimating
Definition of targets
Site survey and reservation
Investment cost LCC, LCA Energy and indoor climate assesment, simulations
Space acquision options CRL
Site usability Preliminary building models Orientations Site safety
Space programme WP options
Clarification of user goals
Clarification of owner's goals
FM goals - Performance impacts - Environental impacts - Economic impacts (Value output)
Selection
Compliance with goals
Goals for design and construction - schedule - procurement method - finance - profitablity - investment budget - design criteria
Building programme
- SB -criteria -Energy efficiency - CO2 - Environmental standard - Real estate indicators
Renovation programme
Preliminary rent contract
Investment decision
Competition programme for SB teams
Programme specification
Site transfer terms
Building permission terms
Plot sales or rent contracts - Terms
Private or municipal plot
1
2



Sustainability Principles/Aspects
that can be considered at this stage

Recommendations

- **Review the actual space needs and the associated ways of working and living and improved processes.**
- **Identify potential future changes (adaptability in design, extension, division, adaptability in use)**

Core Indicators

Sustainability Assessment Tools available

Assessment method(s)

Quantified measures, user surveys.

Background information and data

8.4 References

Häkkinen, T., Nykänen, V. "Sustainable building process". Paper presented at SB11 Helsinki World Sustainable Building Conference, Helsinki, Finland, 18–21 October 2011. Published in the conference's proceedings.

8.5 SuPerBuildings' selected indicators (Annex for Chapter 8)

The goal of the SuPerBuildings project was not to develop a uniform assessment system with a defined list of indicators. On the contrary, the aim was to support the further development of existing systems. In this context, the discussion focused on indicators for which there are still methodological issues (e.g. land use) or on indicators that are missing at the moment (e.g. in the field of economics). Therefore, the indicators that are analyzed in the report are not considered as a core list of indicators, but as a list of discussed and processed indicators. It is recommended by SuPerBuildings when selecting indicators for assessment systems to be guided by the state of international and European standards.

1. Rational use of water
1.1. Embodied water use
1.2. Operational water use
1.3. Wastewater production
2. Consumption of non-renewable primary energy
2.1. Embodied energy in the life cycle of construction products
2.2. Energy consumed during the operation phase due to the building itself
2.3. Energy consumed during the operation phase due to activity-related equipment
2.4. Energy linked to transportation of persons due to the location/urban context of the building
2.5. Energy embodied in water-related services during the operation phase
3. Land use
3.1. Soil sealing
3.2. Change of land use
4. Potential impact on climate change/Global warming potential/Carbon footprint
4.1. Greenhouse gases including at least CO_2, CH_4 and N_2O
4.2. Greenhouse gases covered by IPCC Guidelines
5. Construction and demolition waste generation
5.1. Non-hazardous waste to disposal
5.2. Hazardous waste to disposal
5.3. Nuclear waste to disposal

6. Water pollution due to material leaching
7. Indoor thermal environment – Hygro-thermal comfort
7.1. PMV (Predicted Mean Vote)
7.2. PPD (Percentage of People Dissastisfied)
7.3. Operative temperature
7.4. Air temperature
7.5. Relative Humidity (RH)
7.6. Air velocity
8. Visual comfort
8.1. Illuminance
8.2. Daylight factor
9. Indoor air quality
9.1. Several pollutants are considered. The different pollutants are considered and assessed independently from each other
10. Cultural heritage – Monument or monumental value/Historical value
11. Architectural quality – Aesthetic quality
11.1. Architectural quality in the design stage
11.2. Architectural quality in the tender stage
11.3. "Educated" decision making
11.4. Public art in/on/around buildings
12. Life cycle costs
12.1. Capital cost
12.2. Costs in the operational phase
12.3. Maintenance costs
12.4. End of life costs
13. Long term stability of value
13.1. Options for easy adaptation to change of use
13.2. Ability to meet future legislative requirements
13.3. Ability to adapt to climate change
13.4. Certain physical characteristics that have been proven to remain in demand over decades
13.5. Financial risk indicators
14. Integrated design in the planning process

9. Recommendations about the use of indicators in Building Information Modelling

9.1 Introduction

SuPerBuildings has tried to increase the usability and mobilization of sustainable building benchmarking systems considering that the primary reason for promoting the use of these systems is the desire to promote sustainable building stock and sustainable built environment.

The premise is that the principles of sustainable performance of buildings and the knowledge about the desired performance levels should be known in all stages of building projects. In order to achieve significant impacts, building maintenance and refurbishment are extremely important stages to be considered. Effective tools should support sustainable building and consideration of different aspects of sustainable performance.

The objective of this task is to make recommendations concerning the integration of sustainable building assessment and benchmarking systems with the different stages of Building Information Models.

In the first part of this chapter, the notion of BIM and the underlying concepts (integration, interoperability) are introduced before a presentation of the IFC language, its object oriented structure and its mechanisms to attached properties and objects via the use of relationships.

20 indicators (resulting from work carried out in previous workpackages) are examined against the Industry Foundation Classes which is the open language used to exchange and retrieve data from the BIM. The correspondences between these indicators and the IFC concepts are identified when existing.

9.2 Recommendations for the integration of sustainable building assessment and benchmarking systems with the BIM

9.2.1 The notion of BIM

There are several definitions for the notion of BIM. The Acronym BIM is sometimes turned into “Build-ing Information Model” or “Building Information Modelling”, one representing more the concept and the other the approach.

On Wikipedia, the following definition is given to BIM:

“Building information modelling covers geometry, spatial relationships, light analysis, geographic information, quantities and properties of building components (for example manufacturers' details). BIM can be used to demonstrate the entire building life cycle, including the processes of construction and facility operation. Quantities and shared properties of materials can be extracted easily. Scopes of work can be isolated and defined. Systems, assemblies and sequences can be shown in a relative scale with the entire facility or group of facilities. Dynamic information of the building, such as sensor measurements and control signals from the building systems, can also be incorporated within BIM to support analysis of building operation and maintenance.”

This definition presents several facets of the notion of BIM, among others, the most important ones are:

- It covers the whole life cycle of a building project
- It creates a single information node that simplifies updates and synchronisation mechanism among ac-tors of the same construction project.
- It is a structured collection of building and construction objects including physical components, spaces, processes, actors involved, and relationships between these objects. All of these objects may be enriched by shared or specific properties. As a con-sequence, quantities or values stored in these proper-ties can be extracted and reused as the source of in-formation to perform calculations, analysis or simulations.

9.2.2 Advantages from a sustainable assessment point of view

For the user side, relying on a BIM centred approach several benefits presents several benefits from a sustainable assessment point of view. Among others, the following ones can be mentioned:

- BIM contains the data of a building that can be analysed from different environmental analysis point of views with different analysis tools (even if the data only was general geometries, quantities and qualities).
- BIM can include data about the environmental properties of the building parts and building products. That could be used as part of the analysis.

This kind of data would typically be produced by the manufacturer of a specific product or material. The data is entered to the BIM by the designer when specific products are chosen during the design process. (Some of the products may only be decided during construction in some practices…)

– The results of the analyses could be inserted back to a BIM and stored there. They would be compactly available for decision making in a single source. Problematic in this approach is data updating and version management. When something in the model is changed the environmental metric (=stored analysis result) and the other content of the model are no more coherent.

The concept of BIM is easy to understand but hard to turn into tangible reality in a current working environment as there is a strong need for an interoperable exchange format, rich enough to allow ALL users / stakeholders working simultaneously around the same digital model to enrich and retrieve data from the same single model.

BuildingSMART International (neutral, international and non for profit organisation coordinating technical and standardisation work around the BIM) is supporting the notion of OPEN BIM and thus promoting the use of a unique exchange language to dialogue with the BIM. This language is the IFC.

9.2.3 IFC4, the open language

The building sector's Industry Foundation Classes IFC represent an open specification for Building In-formation Modeling BIM data that is exchanged and shared among the various participants in a building construction or facility management project. IFC's are the international openBIM standard.

The IFCs were originally developed to describe building components in an objectified way (Liebich, 2010). Since the beginning a lot of improvement has been made but the integration of sustain-able/environmental notions is quite new as it has been done in the last release. In this latest version (IFC4) several enhancements have been done. Nevertheless, all notion related to Sustainability are not already taken into account. Now the IFC counts approximately 800 entities.

Based on STEP principles, the IFC data model is an object oriented model that separates the object identification and the associated properties, including potential different geometric representations and materials association. The following EXPRESS-G diagram (see Figure below) presents the backbone of the IFC data model:

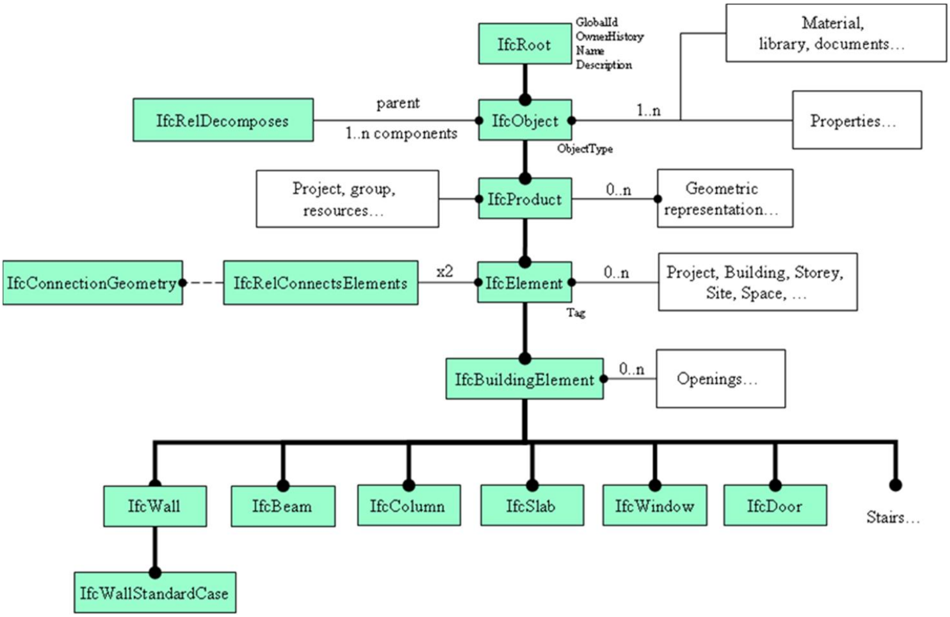


Figure 26. Backbone of the IFC data model (EXPRESS-G diagram).

9.2.4 The "Property Sets" and "Quantity Sets" mechanisms

Property Sets

In the IFC4 documentation, a Property set is presented as ""any specialization of object can be related to multiple property set occurrences. A property set contains multiple property occurrences. The data type of property occurrence are single value, enumerated value, bounded value, table value, reference value, list value, and combination of property occurrences. "

There is a high demand from manufacturers for solutions allowing better integration of their product libraries in application tools (such as design tools), and supporting automated information exchange and sharing. Several initiatives have been launched to improve the situation by developing semantic links between product libraries and product data models, as well as infrastructures to better support access to product information from design or procurement tools. Generally speaking this raises the problem of convergence between classifications and product modelling.

In the construction domain, for instance, IFC-based implementation of product libraries have good prospect for meeting the industry requirements. Indeed, while IFC classes represent generic categories of element (e.g. wall, beam, space) with very few attributes associated with a class to transfer information relevant to a manufacturer, IFCs incorporate a mechanism called Property Sets (PSets) which allow information publishers to dynamically allocate new properties to an object they wish to describe. Since there are numerous alphanumeric attribute definitions depending on discipline, life-cycle stage, building regulation and region, there will never be a complete set of internationally standardized attributes. Therefore, IFC defined property sets intent to standardize a basic set of properties, whereas other property sets can be regionally defined, or agreed upon in projects. The current drawback, however, is that there is no specification of the semantics of PSet information outside that published in the IFC distribution (PSD – Property Set Definition – Schema for the definition of property sets and properties).

As an example, below is the list of properties defined in the PSet attached to the common entity IfcBoilerType:

- PressureRating
- OperatingMode
- Material
- HeatTransferSurfaceArea
- NominalPartLoadRatio
- WaterInletTemperatureRange
- WaterStorageCapacity
- IsWaterStorageHeater
- Weight
- PartialLoadEfficiencyCurves
- NominalEfficiency
- HeatOutput
- OutletTemperatureRange
- NominalEnergyConsumption

It is important to stress the assets of such mechanism. IFC objects can have properties attached to them. The IFC model differentiates between attributes that are directly attached to the object as attribute of the entity, and properties, group in a property set and assigned to the object by a relationship. The latter is the more flexible way to extent applicable properties.

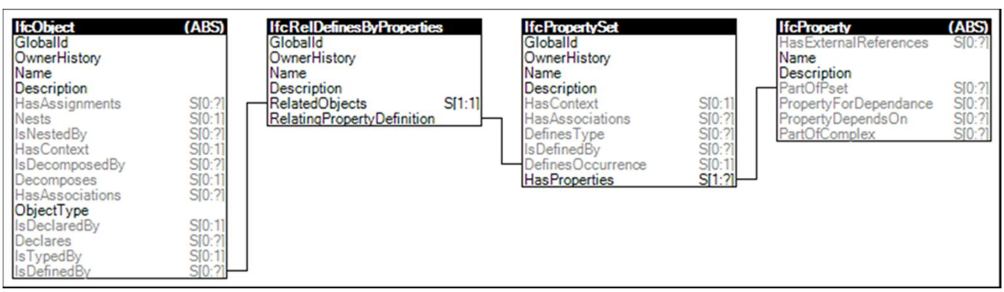


Figure 27. Linking mechanism between an IfcObject and a Property Sets.

Furthermore these properties may be specific to particular regions, projects or process. The IFC schema supports storing and transmitting these properties in named sets (so called “IfcPropertySet”). Therefore, a property set is a collection of properties that can be declared outside of the IFC schema but that can as-signed to all objects defined within the IFC schema.

In the case of a BIM way of working and a process lead approach, It is worth defining well-suited property sets commonly agreed by parties as the right structure to convey the domain specific information between BIM and this specific activity.

In the current version IFC4, there are more than 400 property sets already defined.

Quantity Sets

A quantity set contains multiple quantity occurrences. The data type of quantity occurrence values are count, length, area, volume, weight, time, or a combination of quantities. Each quantity is defined by its name, value, and optionally a description and a formula.

The quantity set is expressed by instances of IfcElementQuantity, where the Name attribute determines the common designator of the quantity set. This specification contains a number of predefined quantity sets, a template definition is provided for each of them in the documentation.

The name of the template has to be used as the value of the Name attribute. The MethodOfMeasurement attribute specifies the method, by which the values of the individual quantities are calculated. For the quantity set templates included in this specification, the value of MethodOfMeasurement shall be "BaseQuantities". There are currently 91 quantity sets defined in the IFC4.

The figure below illustrates an instance diagram.

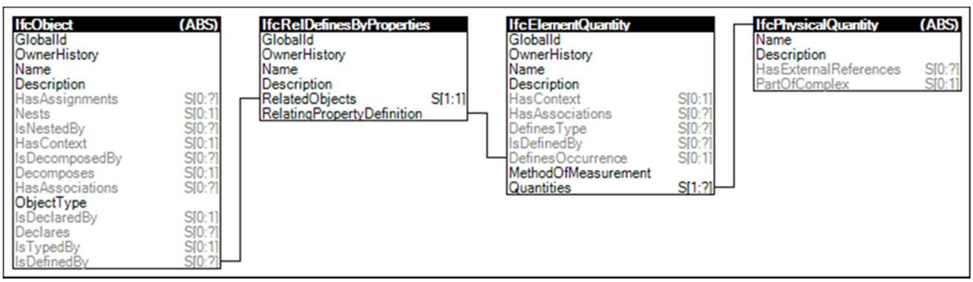


Figure 28. Linking mechanism between an IfcObject and a Quantity Set.

9.2.5 Environmental Property Sets and their connections with building elements

In the scope of this deliverable it is worth mentioning two propertysets that have just been introduced in this recent version of the IFC.

The first one is the property set “Pset_EnvironmentalImpactIndicators” which official definition is “Environmental impact indicators are related to a given “functional unit” (ISO 14040 concept). An Example of functional unit is a "Double glazing window with PVC frame" and the unit to consider is "one square meter of opening elements filled by this product”. Indicators values are valid for the whole life cycle or only a specific phase (see LifeCyclePhase property). Values of all the indicators are expressed per year according to the expected service life. The first five properties capture the characteristics of the functional unit. The following properties are related to environmental indicators. There is a consensus agreement international for the five one. Last ones are not yet fully and formally agreed at the international level”.

The second one is the property set “Pset_EnvironmentalImpactValues” which official definition is “the following properties capture envi-ronmental impact values of an element. They corre-spond to the indicators defined into Pset_EnvironmentalImpactIndicators. Environmental impact values are obtained multiplying indicator value per unit by the relevant quantity of the element”.

These two property sets are strongly interrelated as the first one is dedicated to the definition of the considered indicator(s) along with its unit(s) and validity domain(s). The table below details the different properties of the two property sets.

Table 40. List of properties for the two environmental property sets.

Pset_EnvironmentalImpactIndicators	Pset_EnvironmentalImpactValues
• EutrophicationPerUnit • WaterConsumptionPerUnit • PhotochemicalOzoneFormationPer-Unit • NonRenewableEnergyConsumption-PerUnit • ExpectedServiceLife • RadioactiveWastePerUnit • Unit • NonHazardousWastePerUnit • LifeCyclePhase • RenewableEnergyConsumptionPer-Unit • Reference • ResourceDepletionPerUnit • StratosphericOzoneLayerDestruc-tionPerUnit • HazardousWastePerUnit • ClimateChangePerUnit • AtmosphericAcidificationPerUnit • TotalPrimaryEnergyConsumption-PerUnit • InertWastePerUnit • FunctionalUnitReference	• AtmosphericAcidification • NonRenewableEnergyConsump-tion • InertWaste • PhotochemicalOzoneFormation • RadioactiveWaste • NonHazardousWaste • ResourceDepletion • WaterConsumption • RenewableEnergyConsumption • StratosphericOzoneLayerDestruc-tion • HazardousWaste • ClimateChange • Eutrophication • TotalPrimaryEnergyConsumption

They are commonly attached to the notion of IfcElement which is an abstract concept in the IFC ontology.

9.2.6 The IfcElement

An IfcElement is a generalization of all components that make up an AEC product. Those elements can be logically contained by a spatial structure element that constitutes a certain level within a project structure hierarchy (site, building, storey or space).

In other words, there is a hierarchy of concepts and if we consider the IfcElement as the root (which is not the case in the full IFC ontology), the structure can be derived as illustrated below.

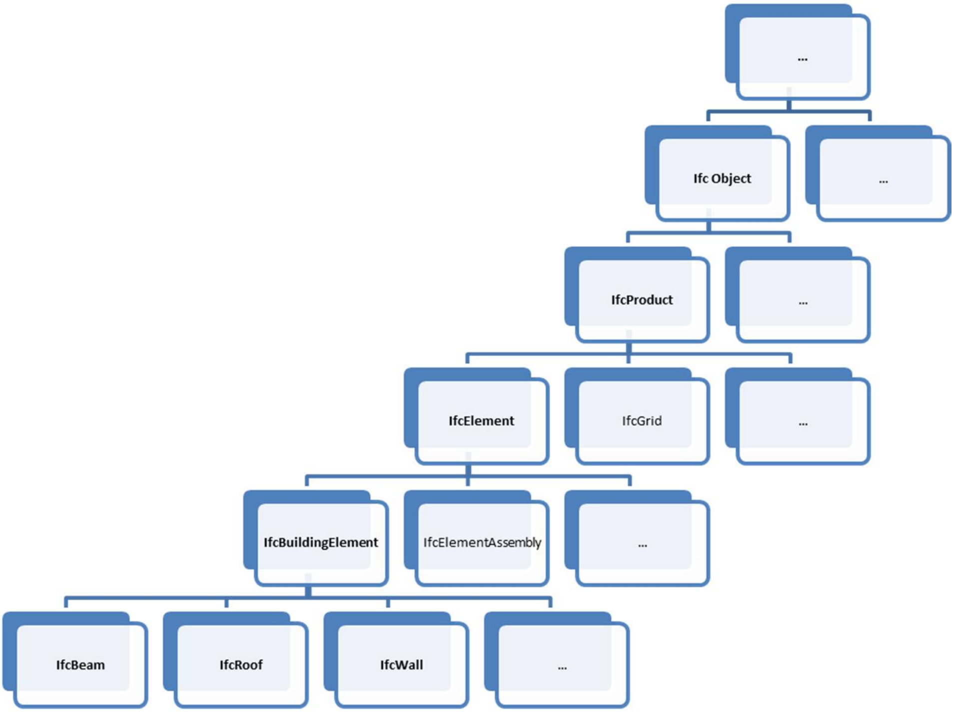


Figure 29. Taxonomy of concepts below the IfcObject.

At the lower level of the figure above are represented various concepts that are directly refering to building component (or building elements). All these objects that can be described as « child objects » in the current representation are inheriting from their « fathers » their different properties. Therefore, it is possible to « attach » the property sets available at the IfcElement or IfcObject level to an « IfcBeam », an « IfcWall » or similar.

9.2.7 Connection between IfcElement and the Environmental property sets

In the documentation, the connection between an IfcElement and a property set is illustrated as follow:

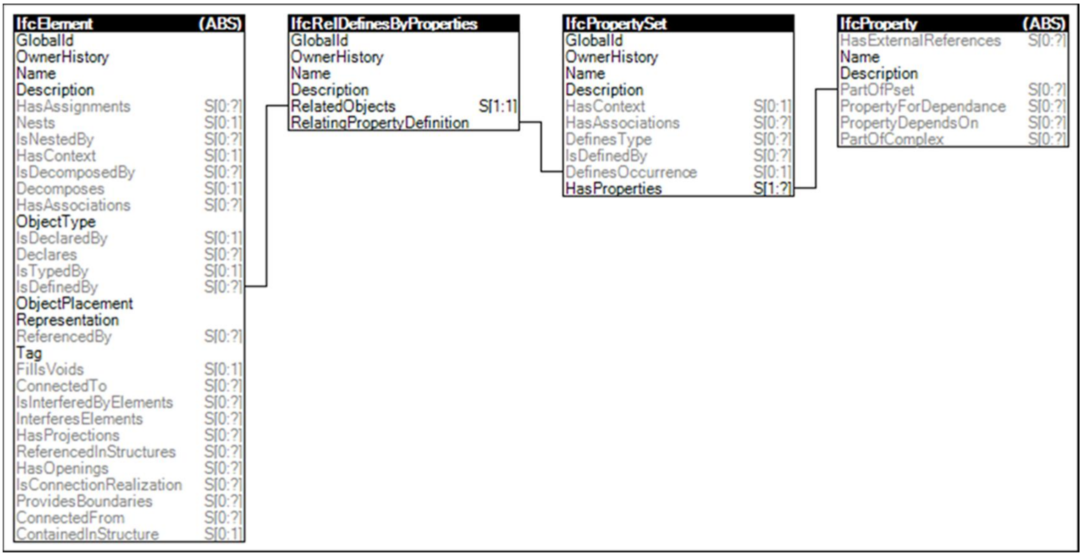


Figure 30. definition of the IfcElement concept and its connection with property sets.

The only property sets allowed to be attached to the IfcElement are :

- Pset_Condition
- **Pset_EnvironmentalImpactIndicators**
- **Pset_EnvironmentalImpactValues**
- Pset_ManufacturerOccurrence
- Pset_ManufacturerTypeInformation
- Pset_PackingInstructions
- Pset_ServiceLife
- Pset_Warranty

9.2.8 Link between building elements, quantities and materials

• IfcMaterial

The different elements listed below the concept of IfcBuildingElement like IfcWall, IfcDoor, IfcBeam, etc… are related to the concept of material (named « IfcMaterial ») which allows to express what the considered element is made of.

IfcMaterial is the basic entity for material designation and definition; this includes identification by name and classification (via reference to an external classification), as well as association of material properties (isotropic or anisotropic) defined by (subtypes of) IfcMaterialProperties.

• The different Qto_xxxBaseQuantities

As introduced earlier, there are several quantity sets specifically defined to express the quantities that are common to the definition of all occurrences of a sub-element of IfcBuildingElement.

For instance, there are the following correspondences:

Table 41. Examples of IfcBuildingElements and their corresponding quantity sets.

Sub element of IfcBuildingElement	Corresponding Quantity Sets
IfcBeam	Qto_BeamBaseQuantities
IfcChimney	IfcQto_ChimneyBaseQuantities
IfcColumn	Qto_ColumnBaseQuantities
IfcDoor	Qto_DoorBaseQuantities
IfcRoof	Qto_RoofBaseQuantities
IfcSlab	Qto_SlabBaseQuantities
IfcWall	Qto_WallBaseQuantities
IfcWindows	Qto_WindowBaseQuantities

These sets are provided in order to define in an accurate and non-ambiguous way the meanings of the values attached to each of these building elements.

• Example of the « Qto_WallBaseQuantities »

The table below illustrates how these Qtos are structured in order to define with a contextual and accurate semantic meaning the different quantities that are usually attached to the mentioned building elements.

Table 42. List of the properties of the Qto_WallBaseQuantities.

Property	Definition
Length	Total nominal length of the wall along the wall center line (even if different to the wall path).
Width	Total nominal width (or thickness) of the wall measured perpendicular to the wall path. It should only be provided, if it is constant along the wall path
Height	Total nominal height of the wall. It should only be provided, if it is constant along the wall path.
GrossFootprintArea	Area of the wall as viewed by a ground floor view, not taking any wall modifications (like recesses) into account. It is also referred to as the foot print of the wall.
NetFootprintArea	Area of the wall as viewed by a ground floor view, taking all wall modifications (like recesses) into account. It is also referred to as the foot print of the wall.
GrossSideArea	Area of the wall as viewed by an elevation view of the middle plane of the wall. It does not take into account any wall modifications (such as openings).
NetSideArea	Area of the wall as viewed by an elevation view of the middle plane. It does take into account all wall modifications (such as openings).
GrossVolume	Volume of the wall, without taking into account the openings and the connection geometry
NetVolume	Volume of the wall, after subtracting the openings and after considering the connection geometry.
GrossWeight	Total gross weight of the wall, without add-on parts, not taking into account possible processing features (cut-out's, etc.) or openings and recesses.
NetWeight	Total net weight of the wall, without add-on parts, taking into account possible processing features (cut-out's, etc.) or openings and recesses.

9.2.9 Binding sustainable indicators with existing IFC concepts or properties

The previous chapter describes the IFC relevant concepts and their inter-relation with each-others. The aim of this chapter is now to identify or to propose a link between the Sustainable Indicators as they are defined in the deliverable D4.2 and the most appropriate IFC element to support it making thus available a bi-directional exchange with the BIM.

9.2.9.1 Selection of relevant indicators

Nearly 20 key indicators have been either selected, or improved or developed, and documented through a structured format by SuPerBuildings project. They cover the 3 pillars of sustain-able development, but not all the related issues. Some are of particular interest and include added-value because they have been newly developed, as land use, cultural heritage, aesthetic quality, long term stability of economic value.

All these indicators were documented and the main activity in this task was to identify the relationships these indicators may have with existing IFC objects in order to facilitate the integration of these sustainable indicators with the BIM and thus ease the adoption of the sustainable assessment method promoted by the project. The result of this study is presented in the next chapter.

9.2.9.2 Sustainable indicators and corresponding IFC objects

In the table below, the example of the Environmental indicators is given. For each of these indicators, the corresponding IFC property set and element is indicated when existing.

Table 43. List of SuPerBuildings environmental indicators and corresponding IFC structures.

Issue	Pset & Related property	Comment / definition attached to the property	IFC related element
Consumption of non-renewable primary energy	Pset_EnvironmentalImpactIndicators/NonRenewableEnergyConsumptionPerUnit	Quantity of non-renewable energy used as defined in ISO21930:2007	IfcEnergyMeasure
• Embodied Water use • Operational water use • Wastewater production	Pset_EnvironmentalImpactIndicators/ WaterConsumptionPerUnit	Quantity of water used	IfcVolumeMeasure
Soil sealing Change of land use	Pset_SiteCommon/SiteCoverageRatio	The ratio of the utilization, TotalArea / BuildableArea, expressed as a maximal value	IfcAreaMeasure
Global warming potential	Pset_EnvironmentalImpactIndicators/ ClimateChangePerUnit	Quantity of greenhouse gases emitted calculated in equivalent CO2	IfcMassMeasure
Protection of atmosphere (other pollutants)	Pset_EnvironmentalImpactIndicators/ • PhotochemicalOzoneFormationPerUnit • StratosphericOzoneLayerDestructionPerUnit • AtmosphericAcidificationPerUnit	• Quantity of gases creating the photochemical ozone calculated in equivalent ethylene • Quantity of gases destroying the stratospheric ozone layer calculated in equivalent CFC-R11 • Quantity of gases responsible for the atmospheric acidification calculated in equivalent SO2	IfcMassMeasure

Issue	Pset & Related property	Comment / definition attached to the property	IFC related element
Construction and demolition waste generation • Non-hazardous waste to disposal • Hazardous waste to diposal • Nuclear waste to disposal • Solid waste separation	Pset_EnvironmentalImpactIndicators/ • NonHazardousWastePerUnit • HazardousWastePerUnit • RadioactiveWastePerUnit	• Quantity of non hazardous waste generated • Quantity of hazardous waste generated • Quantity of radioactive waste generated	IfcMassMeasure

Table 44. List of SuPerBuildings Societal indicators and corresponding IFC structures.

Issue	Pset & Related property	Comment / definition attached to the property	IFC related element
Concentration of various polluant			
Thermal comfort • PMV • PPD • Operative temperature • Air Temperature • Relative humidity • Air velocity	Pset_SpaceThermalRequirements • NaturalVentilation • NaturalVentilationRate • SpaceTemperature • MechanicalVentilationRate • SpaceHumidity	Properties related to the comfort requirements for thermal and other thermal related performance properties of spaces. This includes the required design temperature, humidity, ventilation, and air conditioning.	IfcThermodynamicTemperatureMeasure IfcRatioMeasure IfcCountMeasure
Illuminance Daylight factor	Pset_SpaceLightingRequirements Illuminance	Properties related to the lighting requirements that apply to the occurrences of IfcSpace or IfcZone. This includes the required artificial lighting, illuminance, etc.	IfcIlluminanceMeasure

Table 45. List of SuPerBuildings Economic indicators and corresponding IFC structures.

Issue	Pset & Related property	Comment / definition attached to the property	IFC related element
Life cycle cost • Capital cost • Cost in the operational phase			IfcCostItem
LongTerm stability of value			

The table represented above summarise the current situation. It shows clearly that, in its recent update (IFC4), the IFC have made a significant step forward in the integration of sustainable indicators into the BIM. The consequences are important. It shows clearly the ability of the IFC to evolve and take into account new domains. The BIM centred approach coupled with this integrating capabilities of the IFC as a common open language multiply the interest for the integration of the nD digital mock-ups in the use of sustainable building rating and benchmarking systems in different stages of building process, and in Multi-Discipline and Multi-Stakeholder environments.

The property set mechanism demonstrates its ability to provide a semantic layer above the IFC elements. For instance, in the table 5 above, the same IFC element "IfcMassMeasure" is used four times to store four different notions (Quantity of greenhouse gases emitted calculated in equivalent CO2, Quantity of gases creating the photochemical ozone calculated in equivalent ethylene, Quantity of gases destroying the stratospheric ozone layer calculated in equivalent CFC-R11, Quantity of gases responsible for the atmospheric acidification calculated in equivalent CO2). It is only because the property set has a well-defined and documented structure that the knowledge attached to the four occurrence of this "IfcMassMeasure" element differs. The property set mechanism seems therefore the most appropriate way to translate the proposed ontology into an IFC compliant structure.

9.2.9.3 IFC elements addressed in a sustainable assessment

Actually, most of BIM/CAD tools propose export function to IFC. The resulting IFC exported files then contain IFC objects with their properties that can be used for SBA. The table below is taken from a report about for the Sustainable Building Alliance (Huovila 2011). It shows a list of different devices and appliances that are concerned by different indicators and it makes the link from these devices to the corresponding IFC object, expressing thus the ability of the IFC language to support the representation of various objects that are concerned by sustainable assessments.

Table 46. List of Building Elements to be taken into account in indicator calculation.

List of Building Elements to be taken into account in indicator calculation	GWP	Energy Consumption	Water Consumption	Waste* derived from energy provision	**IFC Entities**	**IFC PSET**
Roof					IfcRoof	Pset_RoofCommon
Load bearing structure					IfcBuildingElements	
Exterior and basement walls including windows					IfcWall	Pset_WallCommon
Internal Walls					IfcWall	Pset_WallCommon
Floor Slabs					IfcSlab	Pset_SlabCommon
Foundation					IfcSlab	Pset_SlabCommon
Floor Finishes/Coverings					IfcCovering	Pset_CoveringFlooring
Refrigeration/Coolants					IfcDistributionElement	
Decorative wall finishes/coatings (e.g. wallpaper, paints)						
Doors					IfcDoor	
Heating/Cooling/Lighting Equipment and any power generating equipment (e.g. wind turbines/PV/solar heating)					IfcDistributionElement	
Internal Transport (Lifts, Escalators)					Building equipement	
Water and Sewerage systems					IfcDistributionElement	
Electrical distribution systems					IfcDistributionElement	

List of Building Elements to be taken into account in indicator calculation	GWP	Energy Consumption	Water Consumption	Waste* derived from energy provision	**IFC Entities**	**IFC PSET**
Urinals					IfcDistributionElement	
WCs					IfcDistributionElement	
Taps (internal and external)					IfcDistributionElement	
Baths					IfcDistributionElement	
Showers					IfcDistributionElement	
Thermal zone					IfcSpace, IfcZone	

Table 47. List of Building Services and Appliances to be taken into account in indicator calculation.

List of Building Services and Appliances to be taken into account in indicator calculation	GWP	Energy Consumption	Water Consumption	Waste* derived from energy provision	**IFC Entities**
Heating				*	IfcDistributionElement
Cooling or air conditioning				*	IfcDistributionElement
Ventilation				*	IfcDistributionElement
Heating for provision of domestic hot water				*	IfcDistributionElement
Lighting				*	IfcDistributionElement
Internal transports (e.g. lifts, escalators)				*	Building system
Computers and IT equipment				*	*IfcElectricalDomain*
Refrigerators				*	*IfcElectricalDomain*
Washing machines				*	*IfcElectricalDomain*
Dishwashers				*	*IfcElectricalDomain*
Dryers				*	*IfcElectricalDomain*
Other ‘small power’ devices				*	*IfcElectricalDomain*
Urinals					*IfcFlow Terminal*
WCs					*IfcFlow Terminal*
Taps (internal and external)					*IfcFlow Terminal*
Baths					*IfcFlow Terminal*
Showers					*IfcFlow Terminal*
Greywater/rainwater systems					*IfcFlow Terminal*
Water softeners (where present)					*IfcFlow Terminal*
Waste disposal units (where present)					*IfcFurnishingElement*

These two tables show that most of the needs in term of structural, 3D, Appliances information in order to calculate either GWP, Energy Consumption, Water Consumption or Waste are already present in the BIM.

Sustainable analysis tools require the input of geometry to define the simulation model. This is mostly done by either importing the geometry or manually rebuilding it. Importing and exporting of building geometry is error-prone and tedious, especially as geometry models established in CAD-software are often not suitable as simulation models. The main asset of the BIM is to facilitate the reuse of existing data without retyping them. Even the environmental data produced by manufacturers (EPDs on construction products) are now available via the BIM (Chevalier 2010).

9.2.9.4 Gaps between the indicators and their support in IFC

There is room for enhancement. Among others, one of the main assets of the BIM is to provide a unique repository of data along the whole life cycle of a construction project. In order to facilitate the understanding among the various actors, the exchange model and corresponding language (IFC) is structured and documented to ensure a semantic continuity about the information exchanged and stored at the various phases.

Three levels of trust for this semantic continuity can be defined:

- Level 0: There is not support from the IFC language and thus the is not guarantee at all that other actors or software platforms will be able to reuse it
- Level 1: There is a support from the IFC language. But there is no dedicated specific object or property to explicitly qualify the value of the indicator. The best example for that are the different notions of costs. There are few IFC entities dedicated to the cost and the notion of “cost per phase” can be determined and its value stored thanks to the IfcCostItem but this specific meaning cannot be explicitly defined in current version. It relies for the moment on a possible agreement among concerned actors.
- Level 2: There is a direct and explicit support from the IFC.

The tables below recap for all indicators the quality of capacity of the IFC to support it.

Table 48. List of SuPerBuildings Environmental indicators and corresponding IFC structures.

Issue	IFC related element	Quality of the IFC support	Comment
Consumption of non-renewable primary energy	IfcEnergyMeasure	**Level 2**	There is a direct support with the dedicated Property Set
• Embodied Water use	IfcVolumeMeasure	**Level 1**	There is a support of the Water use via the WaterConsumption-PerUnit property. The notion of Embodied Water is not explicit.
• Operational water use	IfcVolumeMeasure	**Level 2**	Direct support with the dedicated Property Set
• Wastewater pro-duction	IfcVolumeMeasure	**Level 2**	There is a direct support with the dedicated Property Set
Soil sealing	IfcAreaMeasure	**Level 2**	Direct support with the dedicated Property Set
Change of land use		**Level 0**	No support
Global warming potential	IfcMassMeasure	**Level 2**	Direct support with the dedicated Property Set
Protection of atmos-phere (other pollutants)	IfcMassMeasure	**Level 2**	Direct support with the dedicated Property Set Pset_EnvironmentalImpactIndicators/ • PhotochemicalOzoneFor-mationPerUnit • StratosphericOzoneLayerDe-structionPerUnit • AtmosphericAcidificationPerUnit
Construction and demolition waste generation • Non-hazardous waste to disposal • Hazardous waste to diposal • Nuclear waste to disposal • Solid waste sepa-ration	IfcMassMeasure	**Level 2**	Direct support with the dedicated Property Set Pset_EnvironmentalImpactIndicators/ • NonHazardousWastePerUnit • HazardousWastePerUnit • RadioactiveWastePerUnit

Table 49. List of SuPerBuildings Societal indicators and corresponding IFC structures.

Issue	IFC related element	Quality of the IFC support	Comment
Concentration of various pollutant		Level 0	
Thermal comfort • PMV • PPD • Operative temperature • Air Temperature • Relative humidity • Air velocity	IfcThermodynamicTemperatureMeasure IfcRatioMeasure IfcCountMeasure	Level 2	Direct support with the dedicated Property Set Pset_SpaceThermalRequirements • NaturalVentilation • NaturalVentilationRate • SpaceTemperature • MechanicalVentilationRate • SpaceHumidity
Illuminance	IfcIlluminanceMeasure	Level 2	Direct support with the dedicated Property Set Pset_SpaceLightingRequirements/ Illuminance
Daylight factor		Level 0	

Table 50. List of SuPerBuildings Economic indicators and corresponding IFC structures.

Issue	IFC related element	Quality of the IFC support	Comment
Life cycle cost • Capital cost • Cost in the operational phase	IfcCostItem	Level 1	There is a support of the notion of Cost, via the IfcCost item and there possibilities to qualify this cost item via the "IfcCostValue" which is an enumeration of cost categories. But only the "whole life" category sounds related to the needs expressed here. The rest is not mentioned
LongTerm stability of value		Level 0	

It appears that:

- For the Environmental indicators 10 (among the12 studied) have a direct equivalent in IFC, one has an indirect support and one is not supported;
- For the Societal indicators 7 (among the 9 studied) have a direct equivalent in IFC and 2 are not supported;

- For the Economic indicators none (among 2) have a direct equivalent in IFC, one has an indirect support and one is not supported.

9.2.9.5 Example of the corresponding ontology

The Ifc model is a taxonomy of objects starting from a single main object called IfcRoot. Under this root concept, IFC objects are sorted into a tree by level of specialisations. At each level there are possible relationship to attached information (other Ifc concepts or properties) in order to define the composition, the size, the weight, etc… of each considered object.

Each need of exchange make use of a subset of the whole model for its specific purpose. This subset is called a Model View Definition.

For the specific need of Sustainable Assessment, several IFC objects, properties, quantities have been addressed. The figure below shows the structure and dependencies between these elements.

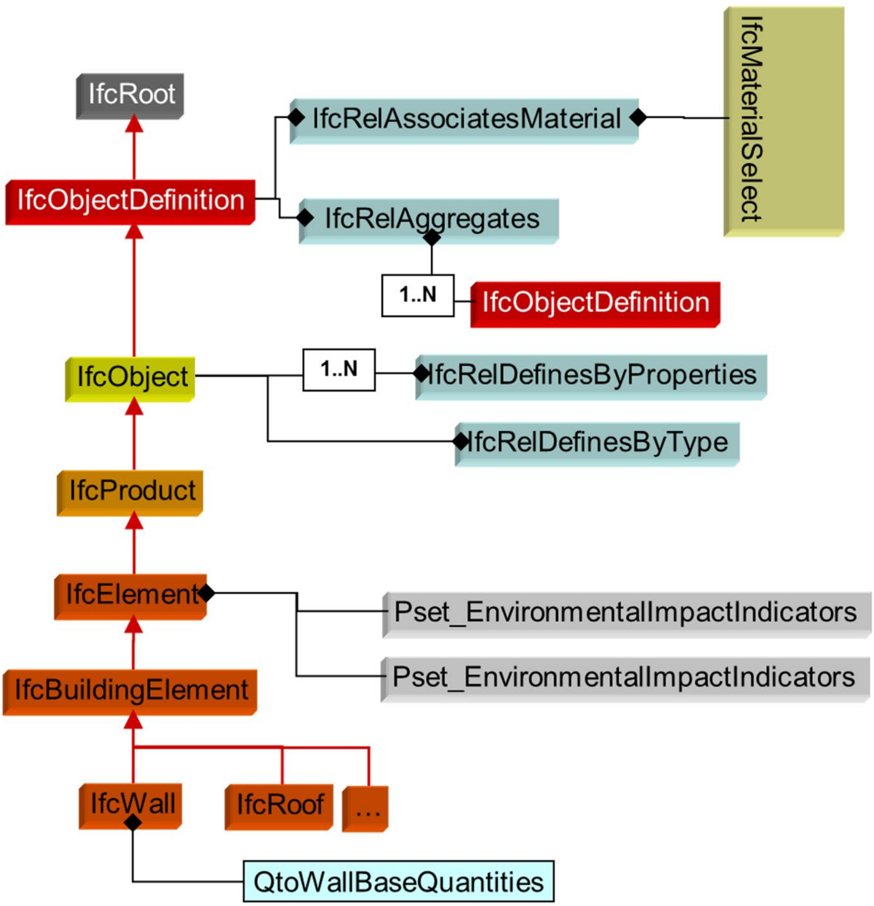


Figure 31. Simplified representation of the subset structure addressed by Sustainable Assessment.

9.3 How the integration to BIM should happen

9.3.1 The need for process formalisation

Actually, to use Building Information Modelling effectively and for benefit to be unlocked, the level of understanding among partners involved in the same construction process and project needs significant improvement. For this to happen, there must be a common understanding of the building processes and of the information that is needed for and results from their execution.

In order to do that, these practices have to be turned into shared/agreed processes. The first step is to define the different processes that are relevant in the sustainable building assessment across life cycle building.

The aim is to have a set of processes described in a uniform way, to be used for sustainable assessment. Actors, sequence of actions, type of data and checks on data should become visible to support the sustainable building assessment practices.

There are several tools and approaches providing method for formalising exchange and processes among partners. IDM (Information Delivery Manual) is one of these solutions that allows the formal and accurate description of processes among actors and tools interacting around a BIM.

The IDM will target both BIM users and solution providers. For BIM users, it will provide a simple to understand, plain language description of building construction processes, the requirements for information to be provided to enable the process to be carried out successfully, additional information that may need to be provided by the user and the expected end results of the process. For BIM solution providers, it will identify and describe the detailed functional breakdown of the process and the IFC capabilities needing to be supported for each functional part in terms of the entities, attributes, property sets and properties required.

9.3.2 IDM the BuildingSmart recommendation for process formalisation

IDM captures (and progressively integrates) business process whilst at the same time providing detailed specifications of the information that a user fulfilling a particular role would need to provide at a particular point within a project. To further support the user information exchange requirements specification, IDM also proposes a set of modular model functions that can be reused in the development of support for further user requirements. IDM is a guideline, a method for formalising exchange and processes among partners. Therefore, there should be one Interchange Manual per process, which can be seen and considered as the expression of formal requirements for the described process.

From a pragmatic point of view, IDM starts with a high level graphical description of the process. This part is called the “Process Map”. The formalism used to translate the process into a drawing (the so called “Process Map”) is based on a standard, the BPMN. OMG is maintaining the BPM Notation (Business Process Modelling Notation). The BPMN is the recommended notation for the first part of the IDM methodology (ISO/DIS 29481-1). The goal of BPMN is to provide a standard notation that is readily understandable by all business stakeholders. BPMN is intended to serve as common language to bridge the communication gap that frequently occurs between business process design and implementation by providing a notation that is intuitive to business users yet able to represent complex process semantics.

The second part focus on the description of the exchange (data flow) among the different identified sub-processes. This part has some recommendation in terms of formalism but no specific standard support it. It is recommended that the description of the exchange should be done using natural language in order to be elaborated in conjunction with non technical users.

Third and last part of the IDM is the functional part. This is the most technical one. After the high level analysis of the process (PM) and the description "in natural language" of different exchanges, it is then time to indicate what will be the basic technical elements that will support the data flow, keeping the semantics of the exchange. This part will also identify the common basic blocks that are used at different places all along the process.

It is also very important to stress the fact that BuildingSMART it not promoting "yet another standard". The approach chosen, is to rely on validated and trustable standards tailored for the needs of the Construction Sector.

9.3.2.1 Process Maps

A process map describes the flow of activities for a particular business process.

It enables the understanding of the configuration and the relationships among of activities that make the whole process work. It also describes the actors involved (according to the roles they are playing in the process), the information required, consumed and produced by these actors.

A process map may capture one or more "events" at which a requirement for the exchange of information is specified.

Process models in general are a great tool to help spot processing gaps and inefficiencies. The benefit of a swim lane process model is that it allows the user to quickly and easily plot and trace processes and, in particular, the interconnections between different process steps. These interconnections, especially when linked to a transfer in responsibility, are the causes for many process problems.

The swim lane technique maps processes linearly as a series of tasks. Lines and arrows between tasks represent the flow of information, goods or work-in-progress. Swim lanes organize process steps by themes, thematically related activities are arranged in one swim lane.

Swim lanes comprise activities bundled according to their thematical cohesion, and are used for the clear demarcation of relationships within the process.

The lanes do not reflect organizational units. It does not matter which organization is responsible for a process step to place it into a certain swim lane. Since the lanes do not reflect organizational units, they are resistant to changes in organization and provide a good foundation for a generic process model.

Below is an example of a process map describing the process of "Energy Analysis" during the design phase. It shows three different levels of details from one simplified high level view (provided with no specific swim-lane) to detailed maps at level 2 and level 3.

At level 2, the task number 2 of the first high level map is decomposed into several subtasks that are placed in different lanes according to the actors concerned by these subtasks.

For level 3, the same approach is applied and the task 2.5 is decomposed in one process with several sub-tasks.

It is worth mentioning that the notation used to represent these Process Maps relies on BPMN (Business Process Model and Notation) which is a standard maintained by the OMG (Object Management Group).

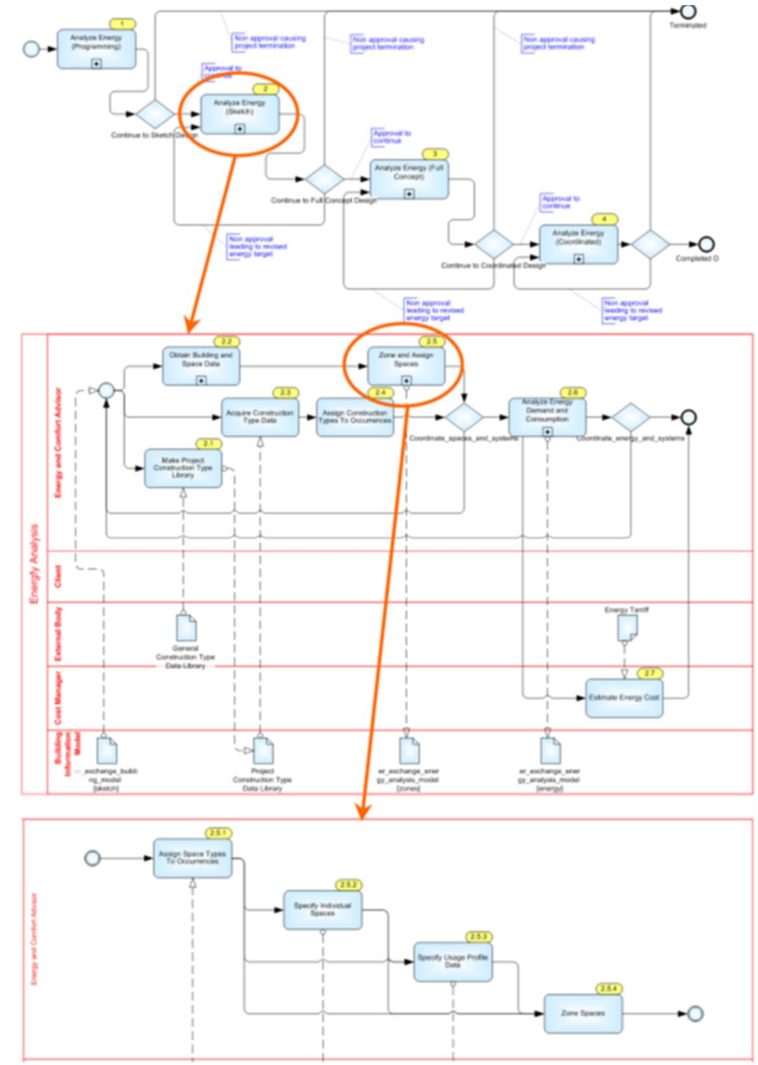


Figure 32. The IDM multiple level process map syntax.(Note: The example is from the IDM for energy analysis, by Jeffrey Wix, AEC3 Ltd.).

9.3.2.2 Exchange requirements

An Exchange Requirement (ER) can be seen as the description of the information that needs to be exchanged between the sub tasks (or events) of the process described by the Process Map.

An ER supports a particular business requirement at a particular stage of a project. It provides a description of the information in non-technical terms. They are general statements of requirement and they are expressed in natural language, which means the statements expressed are not specific to any IFC solution at that stage.

9.3.2.3 Functional parts

A description of the technical actions within the process mainly targeted towards the SW implementers. This again leads to the specific IFC capabilities supporting the actions and prescribed values of attributes where appropriate. The FP can be supported by an IFC schema view for the process (in EXPRESS, ifcXML and other formats). For solution providers, descriptions of IFC capabilities will also be developed for reusable 'functional parts' which are commonly occurring sets of data that may be used by any number of processes/ER's. FP gives the background for answering the questions of what data that is needed in a specific case for generating Model View Definition. On the basis of this, SW will certify to provide content that is captured using the model view definition format.

9.3.3 Relevance for Sustainable Assessment

The case studies of the project[103] show very interesting results that are addressing BIM issue and collaborative work especially those carried out by Fraunhofer IAO and Werner Sobek (WS), which addressed the topics of integrated design and information management systems.

There is a mandatory need to ensure the quality all along the whole process and among the list of key issues for the successful implementation of integrated design; one is of particular interest with respect to the BIM and the formalisation of process via the IDM.

The need for a better communication is identified as a crucial point especially the need for a “clear and well-defined communication structure”. The BIM is seen as essential as a supporting tool for integrated design.

This chapter has shown the assets of the BIM and the possibilities offered by the IFC to carry not only information but well-structured knowledge that can be reused and processed.

But again the formalisation of the different sub-processes that are under the “integrated design” overall process will lead to the production of one Interchange Manual per sub-process and thus to the harmonisation of practices and lead also to a common sharing of the underlying IFC ontology that is implemented in order to support the various information exchanged.

[103] see D7.3 in http://cic.vtt.fi/superbuildings/ and Appendix A

This formal description will also ease the work of software developers that will be able to provide with solutions compliant with the processes described.

Formalising the way information is described / supported by IFC will also disambiguate some of the situations listed in previous tables. A typical example is when the direct support is not ensured between the indicator and an IFC object. This situation may lead to different implementation of the support and thus break the overall interoperability by giving room to errors and misinterpretation.

If this choice is well documented and easy to understand by other parties because of the use of a common method to describe common implementation then it provides more guarantee to have this semantic continuity coupled with the technical interoperability all along the overall process. But this is only feasible because of the use of a common language (IFC) and a common method to describe the exchange processes (IDM and more specifically the FP aspects of IDM which is the more technical part making the link between the process data and IFC).

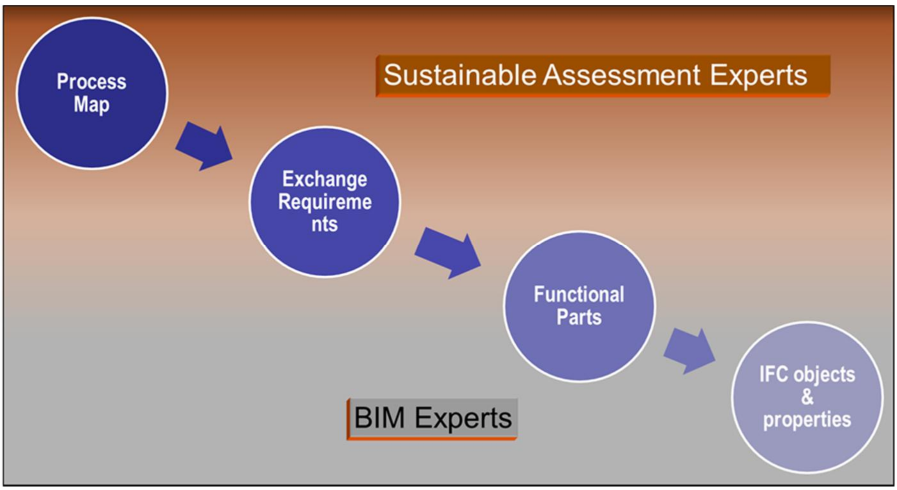


Figure 33. The IDM process. From high level process to technical implementation.

This last figure illustrates also that this formalisation process needs to be applied the collaboration at least of one Sustainable assessment experts who knows well the current practices and BIM experts who are able to identify in the model the appropriate objects and mechanism to support the exchange.

9.4 Conclusion

The sustainable indicators that have been developed by the consortium in the WP4 have been checked against their potential integration to BIM.

This means to answer three questions:

- Does the BIM be able to provide the needed input information in order to calculate the value of the indicators?
- Does the BIM be rich enough to have already concepts well suited to support the indicators (definitions and corresponding values)?
- Is-it enough to ensure consistency of information?

The answers to these questions have been given through the work presented in this document. As a conclusion it worth to recap the main outcomes this study has carried out.

The BIM is an approach, a concept. It represents more a way of working based on integrated exchange via ICT solutions.

In order to allow such exchanges, a specific open standardized language has been developed. It is the Industry Foundation Classes. This language supports the description of building projects and count approximately 800 entities. Al the construction elements that are needed to determine the value of the indicators are already present in the IFC.

In its recent update (IFC4) this language has been greatly enriched especially with regards to sustainable assessment. The section 2 of this chapter 2 shows that most of the indicators are already supported by the IFC4. There are still some gaps as some indicators are not supported and some others are weakly supported.

Among the 23 selected indicators, it appears that:

- For the Environmental indicators 10 (among the12 studied) have a direct equivalent in IFC, one has an indirect support and one is not supported;
- For the Societal indicators 7 (among the 9 studied) have a direct equivalent in IFC and 2 are not supported;
- For the Economic indicators none (among 2) have a direct equivalent in IFC, one has an indirect support and one is not supported.

But it is not enough to ensure the consistency of the information among the various exchanges and over the phases of a construction project. There is also a need for a formalised description of the assessment processes. In order to perform such task and in order to keep the link with the BIM and the IFC, a dedicated methodology has been developed by the BuildingSmart association. This method based on the production of interchange manuals is called IDM (Information Delivery Manual.

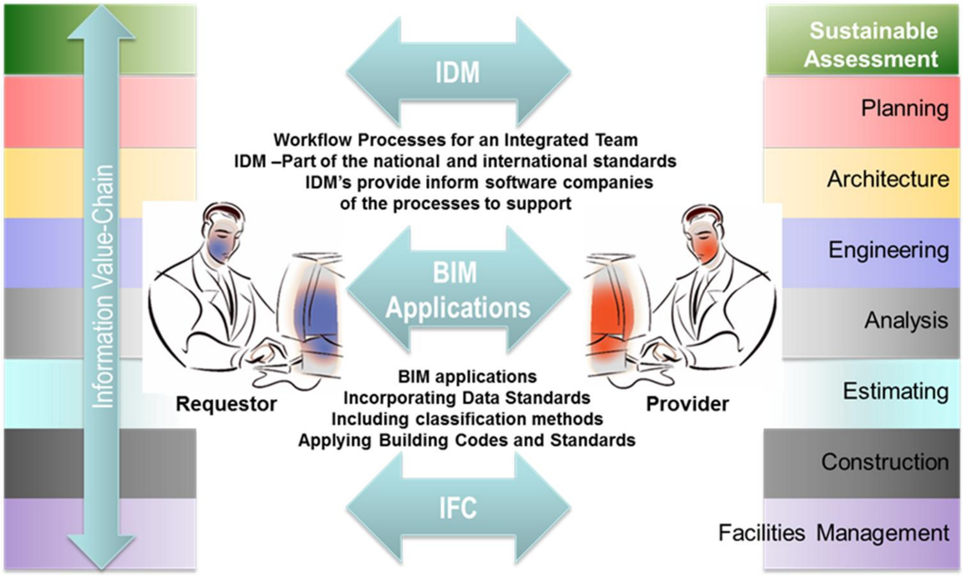


Figure 34. Developing the BIM Value-Chain (Courtesy: Dianne Davis, AEC Infosystems).

The combined use of IFC4 and IDM provides the right tools to ensure the technical and semantic integration of SuPerBuildings indicators to the BIM.

10. Integration sustainable building benchmarking methods with steering mechanisms

10.1 Introduction

Voluntary national Sustainable Building systems are in use in some European countries. However, the desired effect on the advance of sustainable building has been moderately low. The big number of different systems also hinders the acceptance and mobilization of the systems in Europe.

SuPerBuildings project sought information and theoretically assessed what is the potential impact of the common use of sustainable building assessment and benchmarking systems in Europe. The work modelled different scenarios about the usage of SB assessment and benchmarking systems and evaluated the potential of these systems when used in building steering considering different steering mechanisms and when used voluntarily in different stages of building process, especially in target setting, design, construction and building maintenance. On the basis of the results, the work analysed the need of different kinds of information management systems and tools in order to effectively make use of the sustainable building assessment and benchmarking systems.

The premise of the work was that the principles of sustainable performance of buildings and the knowledge about the desired performance levels should be known in all stages of building projects. Effective tools should support sustainable building and consideration of different aspects of sustainable performance.

The work used as a starting point the definition given by the EN 15643-1 Sustainability of construction works – Sustainability assessment of buildings – Part 1: General framework (Introduction):

- The sustainability assessment is quantified to assess the environmental, social and economic performance of buildings using quantitative and qualitative indicators, both of which are measured without value judgements.

– The sustainability assessment of buildings uses different types of information. The results of a sustainability assessment of the building provide information on the different type of indicators, the related building scenarios and on the life cycle stages included in the assessment.

The work used the following ideal framework for the assessment systems:

Areas of protection (issues of concern) define those issues that a) are important for sustainable development and 2) are relevant for building sector because buildings have an essential impact on these areas of protection.

Sustainability aspects of performance of buildings define those aspects of buildings that have impacts on these areas of protection.

Sustainability indicators together with measurement methods enable the quantitative and qualitative assessment and comparison of these aspects of performance.

Benchmarks provide information about the typical levels of results of measurement for buildings with regard to different indicators. For example benchmarking of energy use of buildings provides information about typical/ average/ambitious/poor levels of energy use. Benchmarking may be limited in such a way that it is relevant only in limited areas like for example information that is only regionally relevant.

This Chapter discusses and assesses the possibility to make use of sustainable building assessment and benchmarking systems as instruments of steering. The discussion is based on the concept that sustainable building assessment can be based on be can individual indicators or systems of indicators. Both individual indicators and systems can be used in such a way that only the assessment itself is important or also including benchmarking applied.

10.1.1 Indicators

Sustainable building assessment and benchmarking systems include indicators and measurement methods the purpose of which is to provide quantitative or otherwise comparable information about the performance aspects of buildings that have a potential impact on the issues of concern of sustainable development.

Different kinds of methods are needed for the assessment of different performance aspects of buildings. Environmental life-cycle assessment based indicators enable quantitative assessment and the expression of the result with single figures. Also life cycle cost assessment results can be expressed with a single value that shows the estimated life cycle costs. In principle, these kinds of indicators can be made use of in different stages of steering. The basic requirement is that such unambiguous measurement methods are available which define the measurement processes, functional units and data quality requirements with adequate accuracy so that comparable and reliable results can be achieved.

In order to be able to use these kinds of indicators and calculation results in regulation and in decision making we also need information and understanding about the normal levels of assessment results for different kinds of buildings in different regions. This knowledge enables to define benchmarks for performance and to define required levels of performance.

Indicators can be systemized with regard to the character of the assessment process. In principle we can speak of quantitative, descriptive and qualitative indicators on the bases of their assessment process.

Some performance aspects of buildings that affect the issues of concern of sustainable development cannot be directly and quantitatively measured. However, for example indoor conditions and air quality can be divided into measurable sub-aspects as shown in Chapter 5. In addition, many of the performance aspects of buildings that are important from the view point of relevant issues of concern can be descriptively dealt with so that different levels of performance can be addressed. This enables the comparison of buildings with qualitative indicators. For example different levels of access, accessibility and flexibility can be described with criteria such as the availability of elevators, minimum dimensions, maximum inclinations and level differences, adequate notations, light and contrast.

The advantage of the descriptive indicators is that a functional unit is not explicitly needed and the benchmarking is built-in to the description of the levels.

The third group of performance aspects is formed of such aspects that cannot be dealt with a straight quantitative assessment method or with a limited number of measurable sub-aspects or with the help of relatively simple descriptive classification but for the management of which complicated simulation methods are needed. Simulation methods are available for example for structural safety and fire safety. Simulation methods are also available for the assessment of indoor conditions in design phase (measurement with the help of sub-aspects can only take place in use phase).

The fourth group of performance aspects of buildings that may also be relevant for sustainable buildings is formed of such performance aspects with regard to which no measurement or simulations methods are available. For example in ISO 21929, aesthetic quality of building is included to those performance aspects of buildings that are relevant for sustainable buildings but no measurement method is addressed. The document says that "the indicator is a qualitative indicator". The assessment in the design phase and in-use phase should be executed and established as objectively as possible. The size, importance and architectural and social relevance of the building or the development should be taken into account when defining the assessment procedure and complexity. In some cases being in accordance with local building and urban planning regulations may be sufficient. In some cases processes such as expert assessment, architectural competitions or stakeholder commissions may be required." This was further discussed within SuPerBuildings and key findings are presented in Chapter 5.

Recommendations for the use and assessment of qualitative indicators are given in ISO 21929 (Annex 2): Approaches that can be considered when developing qualitative indicators:

- Define influencing parameters / aspects regarding the issue
- Establish the sensitivity of these parameters relative to each other
- Define if some sub-calculations are possible for each parameter of groups of parameters
- Organize the parameters into a structured list
- Define an assessment or measurement method for each element of the list (calculation, description, enquiry, yes/no answers, etc.)
- Establish rules of normalization (through scales or points) and aggregation (after weighting the
- different elements according to their relative influence)
- Define a final scale (e.g., from 0 to 5) or several classes (e.g., A to G) in order to get a final result or
- score, which will be the numerical value of the indicator
- Define certain points as crucial ones or as mandatory pre-requisites, leading to the given class or scale level (possibly the worst one) if related requirements are not met, whatever the other sub-assessment may be.

Regardless of which approach(es) is considered, it is important to ensure the transparency of this process, and to justify its validity.

In addition to indicators and aspects of (environmental, economic or social) performance, we can also speak about process indicators. These are not used for the direct characterization of the building under scrutiny but those try to indirectly indicate the building by characterizing some part of the building process seen essential regarding sustainable buildings.

This Chapter deals with the possibilities and potentials of both assessment and benchmarking systems as well as single indicators in the context of steering of sustainable building and construction. The focus is on indicators that can be numerically estimated with measurement or calculation methods or assessed with the help of descriptive performance levels.

The possibility to use sustainability indicators and sustainable building assessment methods in the context of steering was assessed in such a way that an outline is first used for the instruments of steering, and the suitability, problematic issues and advantages of the methods and single indicators are assessed with regard to these different instruments.

The potential of the methods was assessed so that rough estimates were done in terms of the potential impact of the use of these methods on the selected issues of concern. The work also assessed the potential from the view point of easiness of implementation, availability of needed background information, methods etc., needs of education, tools etc.

10.1.2 Instruments of steering

An effective steering instrument can be defined as follows:

a) has an impact on its focus area (energy efficiency, management of pollution...)
b) has support from the citizens
c) is feasible because tools needed in assessment and verification are available and accessible for all who need those
d) is feasible because guidelines and instructions needed are clear; municipalities and other authorities need clear instructions for implementation
e) has support from different stakeholder groups; it takes into consideration different building types and different types of owners. Owners are provided with required basic information, possibility to benchmark own facility with others and information how to improve the situation.

This definition explains the effectiveness both directly on the bases of this impact on the issues that are wanted to be regulated and indirectly on the bases of the readiness and willingness. This indirect efficiency is important because also in the case of regulations the true impact may be significantly weakened if there is no good support and if tools are not available.

This work focuses on the possibilities to make use of sustainability indicators in the context of such steering instruments as regulations, mandatory labelling programmes and voluntary certificates. However, the premise of this work is also that the framework of sustainable building could potentially formulate an overall framework for the steering of building and construction. In a desirable scenario where we share a common understanding about the issues of concern of sustainable development relevant to building, and also have a common understanding about the performance aspects that impact on these issues, the logical conclusion would be to base the principles expressed in building act on this understanding. This kind of approach is already written to the Finnish building act although we cannot distinguish the framework of sustainable building. It says that

> The objective of this Act is to ensure that the use of land and water areas and building activities on them create preconditions for a favourable living environment and promote ecologically, economically, socially and culturally sustainable development.

> The objective of building guidance is to promote: the creation of a good living environment that is socially functional and aesthetically harmonious, safe and pleasant and serves the needs of its users; building based on approaches

which have sustainable and economical life-cycle properties and are socially and economically viable, and create and maintain cultural values; the planned and continuous care and maintenance of the built environment and building stock.

In planning, special attention shall be paid to the following: appropriate regional and community structure of the region; ecological sustainability of land use; environmentally and economically sustainable arrangement of transport and technical services; sustainable use of water and extractable land resources; operating conditions for the region's businesses; protection of landscape, natural values, and cultural heritage; and sufficient availability of areas suitable for recreation.

The instruments of steering are here outlined in accordance with the UNEP report (Köppel et al. 2007). However, an additional group – municipal steering – is included to the list. In addition, the definitions of two groups – Economic and market based instruments and Support and information – are slightly changed. The outline of the steering instruments is shown in Table.

Table 51. Outline of policy steering and municipal steering instruments.

	Instrument	Description
A	Control and regulatory instruments, Normative	Regulations and guidelines as part of building codes, Procurement regulations', Performance obligations and quotas (e.g. energy efficiency, fire safety); Appliance standards (e.g. standards that define a minimum energy efficiency level); Standards that define methods for mandatory issues (e.g. measurement method for energy performance)
B	Control and regulatory instruments, Informative	Mandatory audits; Mandatory labelling and certification programmes; Utility demand side management programmes
C	Economic and market-based instruments	Performance based contracting (e.g. energy, carbon footprint): Cooperative procurement; Use of voluntary certificate schemes, Branding
D	Fiscal instruments and incentives	Taxation; Tax exemption/reductions; Public benefit charges; Capital subsidies grants; Subsidized loans
E	Support and information	Support for the development of voluntary certification and labelling; Public leadership programmes; awareness raising education; Information campaigns; Detailed billing and disclosure programmes
F	Municipal steering, Steering actions in city planning and land use	Terms for release and tenancy rights of registered plots, Urban renewal programmes; Increased recompense of permitted building volume; District level exceptional decision on permission

10.2 Background – current European policies and instruments of policy steering

10.2.1 Policies

The implementation of the principles of sustainable development is a fundamental goal of EU policies. The European Council of June 2006 adopted a comprehensive renewed Sustainable Development Strategy for an enlarged EU (EU 2006[104]). The renewed strategy recognises the need to gradually change the current unsustainable consumption and production patterns and move towards a better integrated approach in policy-making. The overall aim of the renewed EU Sustainable Development Strategy is to identify and develop actions, which enable the EU to achieve continuous improvement of quality of life both for current and for future generations, through the creation of sustainable communities. Sustainable communities should be able to manage and use resources efficiently and to make use of the innovation potential of the economy, ensuring prosperity, environmental protection and social cohesion.

Sustainable Industrial Policy Action Plan (2008) presents the strategy of the Commission to support an integrated approach in the EU, and internationally, to further sustainable consumption and production and promote its sustainable industrial policy. The Action Plan states that to implement this policy, consistent and reliable data and methods are required to assess the overall environmental performance of products, their market penetration and to monitor progress.

The construction sector is one of Europe’s largest industries and of major strategic importance as it provides the built environment, on which all other industries and sectors of the economy depend. As stated in the Lead Market Initiative/Sustainable Construction "The construction market accounts for 10% of GDP and 7% of the workforce. Buildings account for 42% of total EU final energy consumption and produce about 35% of all greenhouse emissions. More than 50% of all materials extracted from earth are transformed into construction materials and products. The wide-ranging market area of sustainable construction embraces environmental concerns (e.g. efficient electrical appliances and heating installations), user health (e.g. indoor air quality) and convenience issues (e.g. independence in old age). It encompasses developing sustainable solutions for residential and non-residential buildings and infrastructure."

The Lead Market Initiative (LMI) for Europe was launched by the European Commission following the EU's 2006 Broad based innovation strategy. The importance of the initiative is based on the problem that while Europe plays a leading role in terms of its science and the provision of science and technology graduates,

[104] EU 2006. Europe, European Commission, Environment, Policies, sustainable development. http://ec.europa.eu/environment/eussd/

it seems less successful in converting science-based findings into commercially valuable innovations. Public authorities can promote the quick take-up of innovations by implementing a number of 'instruments' or policy initiatives. These may include legislation, public procurement, standardisation, labelling and certification, and complementary instruments including business and innovation support services, training and communication, financial support and incentives (COM 2007[105]). Six markets were identified for the initial stage of the initiative including sustainable construction.

The communication “Towards a Thematic Strategy on Urban Environment” (COM 2004[106]) explains the priority theme Sustainable Construction by stating that “buildings and the built environment are the defining elements of the urban environment. They give a town and city its character and landmarks that create a sense of place and identity, and can make towns and cities attractive places where people like to live and work.”

As stated in the Thematic Strategy on the sustainable use of natural resources (COM 2005[107]) "European economies depend on natural resources, including raw materials such as minerals, biomass and biological resources; environmental media such as air, water and soil; flow resources such as wind, geothermal, tidal and solar energy; and space (land area). Whether the resources are used to make products or as sinks that absorb emissions (soil, air and water), they are crucial to the functioning of the economy and to our quality of life." The sustainable use of resources, involving sustainable production and consumption is highly important for the EU and globally.

Life cycle approach is emphasised in EU policies and legislation. Integrated product policy (IPP) (COM 2003[108], state report 2009[109]) has a clear role to play in contributing to sustainable development. All products and services have environmental impacts during their production, use and disposal. It is important to ensure that environmental impacts are addressed throughout the life-cycle and at the

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105 COM(2007) 860 final. A lead market initiative for Europe. Communication from the Commission to the council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions.

106 COM(2004) 60 final. Towards a thematic strategy on the urban environment. Communication from the Commission to the council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Brussels, 11.02.2004.

107 COM(2005) Commission of the European Communities. Brussels, 21.12.2005. COM(2005) 670 final. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Thematic Strategy on the sustainable use of natural resources.

108 COM(2003) Communication on Integrated Product Policy. COM(2003)302. Communication from the Commission to the Council and the European Parliament. Integrated Product Policy. Building on Environmental Life-Cycle Thinking. Commission of the European Communities. Brussels, 18.6.2003.

109 On the State of Implementation of Integrated Product Policy, COM 2009, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0693:FIN:EN:PDF

point of life-cycle where they will best and most cost-effectively reduce the overall environmental impacts and resource use.

10.2.2 Construction product regulation

The new construction product regulation is prepared and the first decisions were made in January 2011. The reasons for the development of the regulation are based on the understanding that the removal of technical barriers in the field of construction may only be achieved by the establishment of harmonised technical specifications for the purposes of assessing the performance of construction products. It says that

> When assessing the performance of a construction product, account should also be taken of the health and safety aspects related to its use during its entire life cycle.
>
> Threshold levels … should be generally recognised values for the essential characteristics of the construction product in question … and should ensure a high level of protection…
>
> Where applicable, the declaration of performance should be accompanied by information on the content of hazardous substances in the construction product in order to improve the possibilities for sustainable construction and to facilitate the development of environmentally-friendly products....
>
> The basic requirement for construction works on sustainable use of natural resources should notably take into account the recyclability of construction works, their materials and parts after demolition, the durability of construction works and the use of environmentally compatible raw and secondary materials in construction works.
>
> For the assessment of the sustainable use of resources and of the impact of construction works on the environment Environmental Product Declarations should be used when available.

Regarding building sustainability assessment methods, the specific mention to life cycle environmental quality in BWR 3 in relation to hygiene, health and safety, and the new BWR 7, dealing with sustainable use of natural resources, are of particular importance (see the list of basic requirements given in the end of this section).

The new meaning of BWR 3 will mean the need for consideration and measurement of dangerous substances during the different phases of the building life cycle. Some of the issues will overlap with other European regulations such as the chemicals classification regulation REACH, the Waste Framework regulations, Hazardous Waste and Landfill Directives. The CEN TC 351 set of standards which is being developed will set some assessment methods to help cover this BWR 3 in the use phase.

The BWR 7 is generally considered by the industry as a first and important step to incorporate sustainability into building products. However, there is obviously a need for standardization to assess this BWR, task that is on-going by the CEN TC 350. These newly developed standards will have to find a way to interact and deal with existing initiatives that assess sustainability of products, such as Environmental Labels and Declarations (type I eco-labels, type II self declarations, type II Environmental Product Declarations).

The regulation gives the following basic requirements for construction products.

> Construction works as a whole and in their separate parts must be fit for their intended use, taking into account in particular the health and safety of persons involved throughout the life cycle of the works. Subject to normal maintenance, construction works must satisfy these basic requirements for construction works for an economically reasonable working life.
>
> 1. Mechanical resistance and stability
> 2. Safety in case of fire
> 3. Hygiene, health and the environment
> 4. Safety and accessibility in use
> 5. Protection against noise
> 6. Energy economy and heat retention
> 7. Sustainable use of natural resources
>
> Regarding Hygiene, health and environment it is said: The construction works must be designed and built in such a way that they will, throughout their life cycle, not be a threat to the hygiene or health and safety of their workers, occupants or neighbours, nor have an exceedingly high impact, over their entire life cycle, on the environmental quality or on the climate, during their construction, use and demolition, in particular as a result of any of the following:
>
> a) the giving-off of toxic gas
> b) the emissions of dangerous substances, volatile organic compounds (VOC), greenhouse gases or dangerous particles into indoor or outdoor air
> c) the emission of dangerous radiation
> d) the release of dangerous substances into ground water, marine waters, surface waters or soil
> e) the release of dangerous substances into drinking water or substances which have an otherwise negative impact on drinking water
> f) faulty discharge of waste water, emission of flue gases or faulty disposal of solid or liquid waste
> g) dampness in parts of the construction works or on surfaces within the construction works.

Regarding energy economy it is said that the construction works and their heating, cooling, lighting and ventilation installations must be designed and built in such a way that the amount of energy they require in use shall be low, when account is taken of the occupants and of the climatic conditions of the location. Construction works must also be energy-efficient, using as little energy as possible during their construction and dismantling.

Regarding sustainable use of natural resources it is said that the construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:

a) re-use or recyclability of the construction works, their materials and parts after demolition
b) durability of the construction works
c) use of environmentally compatible raw and secondary materials in the construction works.

10.2.3 Energy performance directive

The Directive on energy performance of buildings (2002/91/EC) is the main legislative instrument at EU level to achieve energy performance in buildings. Under this Directive, the Member States must apply minimum requirements as regards the energy performance of new and existing buildings, ensure the certification of their energy performance and require the regular inspection of boilers and air conditioning systems in buildings. On 18 May 2010 a recast [Directive 2010/31/EU 2010] of The Directive on energy performance of buildings (2002/91/EC) was adopted in order to strengthen the energy performance requirements and to clarify and streamline some of its provisions.

The recast energy performance directive sets a target for all new buildings to be ‘nearly zero-energy buildings’ by 2020. The directive also deals with existing buildings undergoing a major renovation.

“Nearly zero-energy building" means a building that has a very high energy performance (as determined in accordance with Annex I). The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced onsite or nearby.

The provisions of the Directive cover energy used for space and hot water heating, cooling, ventilation, and lighting for new and existing residential and non-residential buildings.

This Directive lays down requirements as regards:

a) the common general framework for a methodology for calculating the integrated energy performance of buildings and building units

b) the application of minimum requirements to the energy performance of new buildings and new building units
c) the application of minimum requirements to the energy performance of:
   - existing buildings, building units and building elements that are subject to major renovation
   - building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are retrofitted or replaced and
   - technical building systems whenever they are installed, replaced or upgraded
d) national plans for increasing the number of nearly zero- energy buildings
e) energy certification of buildings or building units
f) regular inspection of heating and air-conditioning systems in buildings; and
g) independent control systems for energy performance certificates and inspection reports.

The introduction of the recast directive states that

- The energy performance of buildings should be calculated on the basis of a methodology, which may be differentiated at national and regional level. That includes, in addition to thermal characteristics, other factors that play an increasingly important role such as heating and air-conditioning installations, application of energy from renewable sources, passive heating and cooling elements, shading, indoor air-quality, adequate natural light and design of the building. The methodology for calculating energy performance should be based not only on the season in which heating is required, but should cover the annual energy performance of a building.
- In order to provide the Commission with adequate information, Member States should draw up lists of existing and proposed measures, including those of a financial nature, other than those required by this Directive, which promote the objectives of this Directive. The existing and proposed measures listed by Member States may include, in particular, measures that aim to reduce existing legal and market barriers and encourage investments and/or other activities to increase the energy efficiency of new and existing buildings, thus potentially contributing to reducing energy poverty. Such measures could include, but should not be limited to, free or subsidised technical assistance and advice, direct subsidies, subsidised loan schemes or low interest loans, grant schemes and loan guarantee schemes. The public authorities and other institutions which provide those measures of a financial nature could link the application of such measures to the indicated energy performance and the recommendations from energy performance certificates.

Comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements

The European Commission has established a comparative methodology framework for calculating **cost-optimal levels** of minimum energy performance requirements for buildings and building elements (Regulation No 244/2012). The methodology will formulate a common basis for different kind of national and international calculations concerning cost-efficiency of energy efficient solutions with following framework

- definition of reference buildings
- definition of packages of energy performance measures
- definition of technical solutions for each packages
- calculation of energy performance for each package
- calculation of investment and life cycle costs for each package
- calculating of economic optimum (life cycle cost in relation to energy performance)

All of the member states are under obligation to execute calculations for the national minimum energy performance requirements using the regulation 244/2012 methodology framework.

For the purpose of adapting the comparative methodology framework to national circumstances, Member States should determine the estimated economic lifecycle of a building and/or building element, the appropriate cost for energy carriers, products, systems, maintenance, operational and labour costs, primary energy conversion factors, and the energy price developments on this point to be assumed for fuels used in their national context for energy used in buildings, taking into account the information provided by the Commission. Member States should also establish the discount rate to be used in both macroeconomic and financial calculations after having undertaken a sensitivity analysis for at least two interest rates for each calculation. To ensure a common approach to the application of the comparative methodology framework by the Member States, it is appropriate for the Commission to establish the key framework conditions needed for net present value calculations such as the starting year for calculations, the cost categories to be considered and the calculation period to be used.

10.3 Background – efficiency and needs of steering instruments on the basis of literature

The following summary is based on the study of literature. It is important to note that the referred articles do not study the possibilities to make use of sustainable building assessment systems in the steering of sustainable building, but try to find out and make conclusions about the general possibilities to support either sustainable building or certain aspects of sustainable building with different steering instruments. Many of the studies focus on energy-efficiency Research on steering instruments seldom recommend a single method but often a combination of methods is recommended. In spite of this, the results are presented with the help of the same outline of instruments as presented in Section Introduction. In addition, a specific instrument 'Programmes and strategies' is added.

10.3.1 Efficiency of alternative steering instruments

10.3.1.1 Programmes and strategies

Circo (2007) has studied the role of the government in promoting sustainable building projects. He claims that sustainable standards have not yet found their place within the realm of land use regulation. In the United States, most land use control devices are normally adopted, implemented, and enforced at the local level, where they are subject to local political debates and variations. Municipalities alone cannot bring about a green building revolution. He emphasizes the role of the state policy makers to establish a strategy and ensure the perspective and consistency.

Also Dohrmann et al. (2009) emphasises the significance of large programmes and strategies as an effective instrument to promote sustainable building. When searching for state-wide potential for improved energy-efficiency, the programme planners should be able to identify market segments with a high potential to lead and realize such change. Large owners and developers should be targets for such programme planners and implementers. Dohrmann et al. (2009) also point out that refurbishment should be considered as a separate market from new construction when making state-wide programmes for energy-efficient building: "the remodelling and renovation market is different from new construction, is of significant size, but is also more difficult to influence than the new construction market."

10.3.1.2 Normative regulations and appliance standards

Köppel and Ürge-Vorsatz (2007) studied which instruments can achieve high energy savings and GHG emission reduction, which are especially cost-effective and which factors enable or enhance the effectiveness of these policies. They collected several case studies on the basis of which they concluded that regulatory and control instruments such as building codes and appliance standards are the most effective and cost-effective category of instruments if enforcement can be secured. They explain that regulatory instruments seem to be the most effective as they can overcome some of the most important barriers, for example reduce the transaction costs since they eliminate the need to search for information and negotiation. The fragmentised nature of the sector and the high number of actors involved (Femenias 2005) may also lead to a situation where regulations are considered as the only possible way to proceed.

When focusing only on energy-efficiency and GHG emissions reductions, the policy instruments that affect the supply size also have an effect as addressed by Atkinson et al. (2009).

It is important to notice that in order to be effective normative requirements – for example for energy-efficiency or reduced GHG emissions – need to be accompanied by powerful and reliable tools that designer can use within design and with the help of which the compliance with the requirements can be shown. Ambrose and Miller (2005) claim that tools such as LCADesign in Australia provide an example of the type of systems that designers could utilise to aid their design process, meet energy and environmental regulations and provide the public with buildings that are more comfortable to live and work in while reducing their impact on the environment. The tools also enable the regulatory bodies to look forward into the future and develop codes that build on the existing codes to strengthen their environmental emphasis, knowing that effective methods exist for helping ensure compliance.

Köppel and Ürge-Vorsatz (2007) strongly recommend an integrated framework. Especially for developing countries effective results can be achieved through combining regulatory instruments, such as standards and mandatory audits in certain buildings, capacity building, training and information campaigns as well as demonstration projects coupled with incentives. On the bases of their case studies, the highest GHG emission reductions were achieved with the help of appliance standards (that define a minimum energy efficiency level), building codes, demand side management programmes, tax exemptions and labelling.

The practices of sustainable housing projects in the UK basically formulate a modern way of making use of a sustainable building assessment and benchmarking system in steering. Social housing projects have to achieve the score 3 when assessed with the Code for Sustainable Homes[110]. The Code is voluntary for privately built housing. The UK government seeks for a situation where all housing associations integrate sustainability into their procurement and development approaches. Essa and Fortune (2008) assess that this policy has important implications for all organisations involved in new social housing building projects. The Code is an environmental assessment method for new homes based upon BRE Global's Ecohomes and contains mandatory performance levels in 7 key areas:

- Energy efficiency/CO_2
- Water efficiency
- Surface water management
- Site waste management

[110] Code for Sustainable Homes http://www.breeam.org/page.jsp?id=86

- Household waste management
- Use of materials
- Lifetime homes (applies to Code Level 6 only).

The Code for Sustainable Homes gives new homes a Code rating from one to six, with six being the most sustainable[111]. Homes are rated by accredited assessors, based on a scoring of a variety of different sustainability features. Within the Code, standards may be compulsory or voluntary. To reach level 3 of the Code for Sustainable Homes, for example, developers must reach the following minimum standards:

- Achieve 25 per cent reduction in carbon emissions from energy use in the home, compared to a similar home built to the building regulations
- Install water saving measures like low flow taps with the aim of achieving a maximum usage of 105 litres per day
- Ensure effective surface water management around the home
- Ensuring construction waste is properly disposed of, and that the wider environmental impact of the construction materials is reduced.

Beyond reaching these minimum standards, to hit Level 3, the builder also has to attain a score by choosing from a range of voluntary measures, such as by providing:

- More energy efficient lighting
- Cycle storage
- A home office
- Recycling facilities
- Enhanced home security
- Enhanced sound insulation.

The UK government publishes statistics[112] that show the number of Code for Sustainable Homes dwellings that have been certified to the standards set out in the Code Technical Guide, and the average energy efficiency (SAP ratings) of new homes which are based on the national Energy Performance Certificate register. According to these statistics (2010):

- There were 12,876 post construction stage certificates and 36,099 design stage certificates issued up to and including September 2010.

[111] Code for Sustainable Homes, Communities and Local Government, Dec 2006
[112] Statistics on the Code for Sustainable Homes and Energy Performance of Buildings, 19 November 2010, http://www.communities.gov.uk/publications/corporate/statistics/codesustainablesapq32010

- 11 per cent of homes with post construction certificates and 22 per cent of those with design stage certificates have been built for the private sector. 89 per cent of homes with post construction certificates and 78 per cent of those with design stage certificates have been built for the public sector.
- Between April 2007 and September 2010, 31,469 dwellings at the design stage received a three star rating and 287 dwellings received a six star rating.
- Between April 2007 and September 2010, 11,361 dwellings at post-construction stage received a three star rating and 19 dwellings received a six star rating.
- The majority of the certificates issued since April 2007 at design stage (87 per cent) and at post construction stage (88 per cent) have been awarded at Code level 3.
- The average energy efficiency (SAP) rating of new homes in England was 79.3 and in Wales 79.4 for the quarter ending September 2010.

When applying normative regulations, the nature of existing building stock as an objective of normative regulations differs significantly from that of new buildings. Strict regulations about the mandatory improvement in energy performance or other aspects of performance may easily lead to economic and social problems when part of the owners may not be economically capable for such improvements. Sunikka (2006) claims that further research is needed for the issue “sanctions for non-compliance”.

10.3.1.3 Fiscal instruments and incentives

Such fiscal instruments as subsidies, grants and tax exemptions can lead to high savings energy and environmental impacts, but subsidies are less cost-effective to society. However, financial incentives can be helpful especially to stimulate the market for new energy-efficient production. Economical instruments such as energy performance contracting may also have a high potential.

Subsidies are the most widely used instrument employed the EU member states when supporting the use of renewable energy sources for heating and cooling of buildings. The main reason is that they encourage the adoption of specific technologies that are usually capital intensive by reducing in a straightforward manner the high costs of investment. The size of the subsidy is easily fixed as a percentage of the total cost of the investment and subsidies allow authorities to discriminate between not only the technologies promoted, but also the type of beneficiaries. In the case of private beneficiaries, subsidies also allow authorities to provide different benefits depending upon whether the beneficiary is a household or a business. The type of subsidized technology is conditioned by the local availability of primary energy sources. For this reason, the most widely supported technologies are those that use solar energy. However, subsidies have the disadvantage of being closely linked to budgetary resources and therefore to budgetary constraints. However, the subsidies could lead to increased equipment costs because manufacturers tend to raise prices in anticipation of the discounts granted to customers. For these reasons, it would be desirable to progressively reduce the use of subsidies by looking for alternative ways to cut down costs or to seek alternative forms of finance. In contrast, the use of tax deductions has the advantage of being an ex-post incentive due to investors being able to receive financial compensation after they have carried out the installation of equipment. In this last case, the compensation procedures are faster and simpler. This type of instrument is appropriate, especially in those cases where investment costs are relatively high. The implementation of incentives through income and corporate taxes seems to be the most appropriate way to encourage uptake because the household and service sectors are the most important in the overall use of energy for heating and cooling, making them therefore the main beneficiaries of the tax deduction. Occasionally, these tax incentives might also be used to reduce taxes on property. Nevertheless, being an ex-post incentive, such tax deductions do not lower the hurdle of the initial upfront payment and therefore do not help low-income households (Cansido et al. 2011).

Köppel and Ürge-Vorsatz (2007) also suggest combinations of instruments in order to reinforce the impact. For example the following combinations may be especially advantageous:

- standards, labelling and fiscal incentives
- regulatory instruments and information programmes
- public leadership programmes and energy performance contracting in public sector.

Sunikka (2006) suggests the combination of economic incentives and mandatory certificates as a good instrument to improve the energy efficiency of the existing building stock. Pitt et al. (2009) ranked the importance of different topics as drivers and barriers for sustainable building. According to this study fiscal incentives and regulations help to drive SB. Such financial implications are consistent with “affordability” being the biggest barrier highlighted.

New financial solutions should be developed and made available for energy-efficient refurbishment and renovation. Rönty and Paiho 2012 have assessed the effectiveness of subsidies form the view point of Finland’s situation. They conclude that the impact of current solutions is very limited when looking from the view point of giving support and stimulation for environmental and energy-efficient renovation. The long-term perspective of supporting activities should be developed. When the types of subsidies and related percentages vary from year to year, this hinders both the development of renovation services and the planning of renovation projects.

10.3.1.4 Voluntary instruments

The effectiveness of voluntary instruments such as voluntary labelling and agreements depends on the context and on the effectiveness of accompanying policy instruments. Information instruments such as awareness raising campaigns are only moderately effective alone, but can successfully reinforce other instruments (Köppel and Ürge-Vorsatz 2007).

Circo (2007) points out that although much emphasis has been put to the recent growth of "the green building movement", the statistics offer quite modest numbers about the high level certification.

Pe´rez-Lombard et al. (2009) point out that energy certification schemes for buildings emerged in the early 1990s as an essential method for improving energy efficiency, minimising energy consumption and enabling greater transparency with regard to the use of energy in buildings. However, their definitions confuse building sector stakeholders. A multiplicity of terms and concepts such as energy performance, energy efficiency, energy ratings, benchmarking, labelling, etc., have emerged with sometimes overlapping meanings. They say that the words energy rating should only be used for the assessment of the energy performance, both for new and existing buildings, in standard or actual conditions. Energy benchmarking tools provide a comparative appraisal of the energy performance of an existing building within a comparison scenario. Assigning classes or labels implies a step forward: defining a scale based on a labelling index. The definition of the scale is more a political issue than a technical one, with the overall aim of reducing the energy consumption.

In order to increase the impacts of voluntary sustainable building there is a need to involve the investment, lending and insurance industries. This on the other hand requires that new decision support instruments and information systems are developed (Lorenz and Lützkendorf (2008). There is a need to understand and explain the linkage between property value and issues of sustainable development. Lorenz and Lützkendorf (2008) claim that the isolated analysis of financial variables and their transformation into a one-sided understanding of the economic value of property has lead to an artificial separation of economic, environmental, cultural and social elements of property value. Systems are needed which enable the information flows in such a way that the knowledge of the benefits of sustainable building can be accounted in highly influential processes of valuation, investment counselling and risk analyses. It would be important to seek for an integration of the traditional methods and tools for valuation, risk analysis and cost estimation and sustainable building assessment and benchmarking tools, because this would support the remarkably more powerful use of the voluntary systems.

The true impact of the voluntary systems of sustainable building also depends on the possibilities to integrate these systems to the right phases of building projects and thus also on the availability of relevant tools. When voluntary sustainable building assessment and benchmarking systems are only used for branding of specific buildings, the general impact may remain low. The impact can be improved if there is a possibility to make use of these tools in target setting and design processes (Häkkinen and Belloni 2011). This – however – requires the availability of powerful tools. In spite of big efforts, the building professionals still lack effective methods and tools, with the help of which it is possible to a) consider SB aspects in all stages of design, b) compare alternative solutions and buildings. It is necessary to develop methods and tools in terms of objectiveness, quality of information, and reliability of results. However, it is also of utmost importance to develop the usability of tools and the mobilisations of tools. BIM and BIM based tools may have an important role in the sustainability management of buildings. To achieve this it is necessary to describe processes and develop methods with the help of which it is possible to collect, share and use environmental information during design, construction and operation.

The effectiveness of voluntary sustainable building assessment and benchmarking systems is questioned by some researchers. Ding (2007) claims that little or no concern has been given to the importance of selecting more environmentally friendly designs during the project appraisal stage; the stage when environmental matters are best incorporated. Lamborn et al. (2006) say that the inclusion of rating tools in a more integrated way, where sustainable building is considered at every stage of design and construction rather than being a separate component, would be needed in order to improve the impact in terms of reduced harmful emissions and consumption of natural resources.

While most governments in Europe have found it necessary to subsidise and regulate the processes of urban renewal, it has not been the case with regard to improving the environmental performance and energy efficiency of existing housing. Up till now the policy approach in the EU Member States can be characterised by a market-led approach, which presumes that energy-efficient improvements will increase the property values. Also the energy certificates of the energy performance of Building directive has relied very much on the environmental conscience of private owners. However, as the pressure towards effective reduction of the consumption of non-renewable energy and emissions of GHG increase and as it is clear that the existing building stock has a decisive role, the governments are seeking more effective instruments to improve the energy performance of existing buildings.

Minna Sunikka (2006) claims that it is apparent that market players only consider environmental improvements “if there are no extra costs” or “if they are feasible”. Despite rising energy prices, the net value of the investment is negative. According to Sunikka, the economic obstacles indicate that only limited use is being made of tax benefits, advantageous loans and other incentives. "What is needed therefore is a policy that consists of compulsory requirements on the one hand and cooperation between the government and the market on the other. This has a better chance of being effective than the current policy, which is merely resulting in half-heartedness."[113]

10.3.1.5 Municipal support

Kadarpeta (2009) have studied the quality of instruments for successful energy neutral housing developments. He states that while there is a need for demanding building regulations, these need to be complemented with strong financial support in terms of renewable heat incentives, feed in tariffs and tax/stamp duty rebates in order to promote energy neutral housing developments in communities. An energy-neutral housing community is defined as a residential area where the net total energy used in all housing related processes and activities is generated within the district or community using renewable energy sources. The typical features include the production of heat and electrical energy required by a home from decentralized renewable energy sources within or surrounding the community. Municipalities should regulate energy neutral requirements effectively through their land allocation plans. The active participation of the municipality in all the phases of the project is necessary to ensure success in energy neutral development projects. Energy neutral ambitions should be propagated to local citizens during the planning stages and prospective customers should be involved in all the project phases. Good collaboration with technology and material manufacturers is necessary to provide technical support and reduce financial burden for project developers.

Local governments play an important role in the implementation of environmental and energy-efficiency policies. Sunikka (2006) suggests that special attention should be paid to assistance, access to loans and the facilitation of implementation.

10.4 Assessment of the SB steering mechanisms in selected EU member states by SuPerBuildings

10.4.1 Introduction

The project made an inquiry among the project group in order to assess the existing Sustainable Building steering mechanisms in the SuPerBuildings partner countries. The aim was

- to summarise the information about the instruments in use
- to collect proposals from the SuPerBuildings partners about interesting and effective steering mechanisms.

[113] http://www.otb.tudelft.nl/live/pagina.jsp?id=c4ed44eb-bf48-4675-9315-7a1b8ab57e57&lang=en

The questionnaire sent to all SuPerBuildings partners included the following outline of the steering mechanisms:

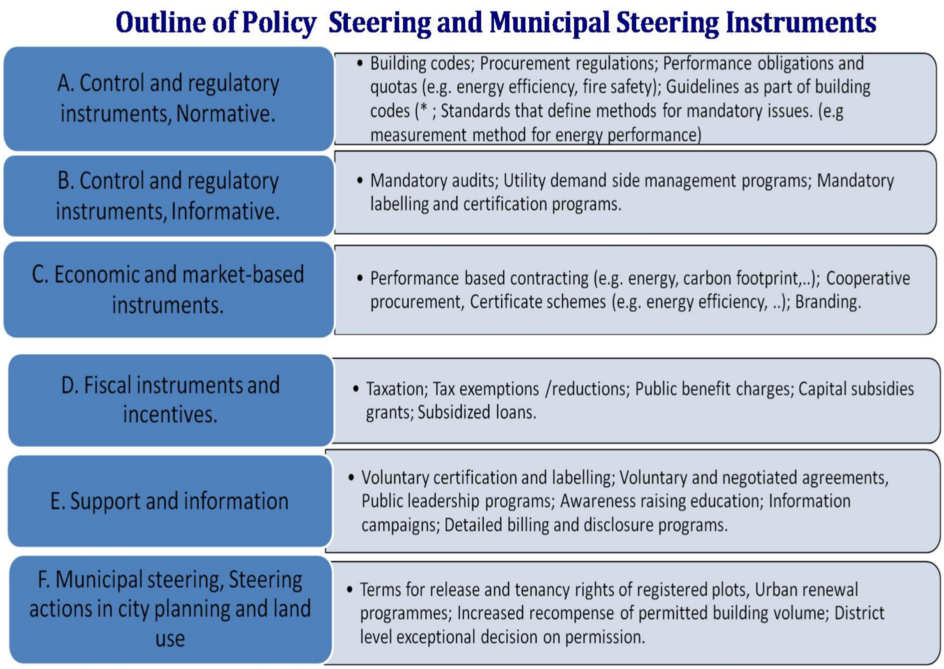

Figure 35. Outline of steering instruments.

NOTE: Voluntary systems of support and information are included here into the informative steering mechanisms because the public bodies may support the establishment of those or the up take of those with the help of education. In addition public organisations in the real estate markets (municipalities and organisations that take care of building, maintenance and letting of state owned properties) can be fore-runners in the use of these kinds of voluntary systems.

The partners were asked to give information about the following issues:

- integration of SB assessment or benchmarking systems or individual indicators (energy performance, carbon footprint, indoor environment) with steering
- scenarios how SB assessment systems could be used in steering.

Appendix D presents the outcomes of the survey.

10.4.2 Discussion based on the survey

New instruments were recognised in almost each steering categories. Many of the present examples and ideas are combinations of two instruments or categories. This supports the common notion that steering instruments are seldom used alone. Few frequently used policy packages have shown to be especially effective in case studies of energy efficiency (see also Köppel et al. 2007).

1. Public leadership programs combined with the support of energy performance contracting
2. Appliance standards and building code with labeling
3. Financial incentives and labeling

European countries are in different phases of development towards sustainable building. The use of effective policy steering instruments can support the implementation of new processes, systems and tools into practices of real estate and construction businesses.

Integration of assessment systems and tools into steering instruments is today's practice in some of European countries. Different types of interventions are chosen when requirering the use of assessment systems. These may cause strong changes to processes, if assessment systems are implemented as total systems in order to promote sustainable building. Implementation in terms of individual indicators and corresponding tools (e.g. assessment of energy efficiency or carbon footprint or indoor performance), will bring minor changes to processes and may be easier from the commitment point of view. On the other hand the use of assessment systems can be required at first as a required process with no limits of performance. On the other hand systems can be introduced to stakeholders with mandatory quantitative or performance based target metrics. The first option may be easier to implement in practice and can also be seen as a strategy to achieve the second option. The ways of interventions are closely related to the national cultures of construction regulations and steering.

Lesson learned in The Netherlands

In the Netherlands the GPR assessment system is used by real estate companies as part of business practices and by National Government and municipalities on their policy level. National Government has integrated the use of the assessment system in their sustainable purchasing policy (GPR score 7 needed for new office construction projects).

From 1 January 2013 a LCA-based calculation of the environmental impacts of the materials in the building is mandatory when applying for a building permit for new residential and office buildings in Netherlands. The calculation has to be conducted according to a national harmonized assessment method and it has to make use of the National Environmental Database, which comprises LCA profiles for different kinds of building products. No performance standard for the environmental impacts has been set yet but this may happen in the future, based on the submitted calculation results for different building projects.

Some municipalities have set a standard for sustainability score (e.g. GPR score 7 is minimum standard for new building projects within municipality) and a standard for tendering of public building projects. They allow reduction on tendering price when GPR score is high and also give subvention when GPR score is high. Assessment systems are also used as prescribed criterion in building design competitions or for building awards.

Lessons from GPR use by municipalities:

- Stakeholder support is vital as legal obligation is not possible.
- Organize workshops on Sustainable Building and GPR introduction.
- Set standards for new buildings and give good example with public buildings.
- Organize a follow-up check after construction to prevent lowering of ambition.

Lessons from GPR use by real estate companies:

- Consent from property owner is bottleneck for active improvement policy.
- Evaluation of housing stock meets with practical difficulties (no access to houses -> high uncertainty in GPR score).
- High turn-over rate (no ownership of complete building).

Lessons learned in Spain

There are increasing requests from various regional and local authorities to use different indicators and performance levels in planning and tendering stages considering various aspects – water, materials, energy or waste. The impact of these requests is yet to be evaluated thoroughly, but it has already had an effect on awareness and education.

For example in Catalonia, the “Eco-efficiency Decree” included specific requests to include environmental labelling of some of the building products, and therefore there has been an increased interest in environmental labelling. A list of all the products labelled can now be found in a web-site for public access (http://es.csostenible.net/productes/productos/).

In the Basque Country, there has also been a large interest on building sustainability assessment, triggered by the request for application of sustainability guides on public building sector projects. Although the request does not specifically set any limits for compliance (some municipalities do have more specific requests for some issues such as energy), the use of the guides has led to a situation where many professionals, and in particular architectural offices, study and consider to a greater extend the issues involved in sustainability assessment. This can be considered as a first good step towards the development of future mandatory evaluation methodologies for building sustainability assessment.

Lessons learned in Finland

In real estate business the assessment systems have been used as means of branding. Assessment is required by international investors and systems like LEED are often used. It seems that localised assessment systems of small countries do not have enough importance to reinforce the brand in international real estate business. The Finnish system, PromisE is used as guideline for setting environmental targets for investment projects. The system is used by some municipalities and public building owners.

In the area of refurbishment and retrofit of housing it is especially challenging to define effective steering instruments (supported by assessment systems). Here the decision making must also consider the community level social development.

General recommendations can be listed as follows:

- Requirement approaches on the use of assessment system can vary.
  - To set target limits to specific indicators
  - Only require the use of assessment system
- Set target limits individually for the performance of different types of buildings.
- Provide case based information and supervision throughout the practical planning and building process.
- Support service and market based development.
- Specify which target groups are most important.
- Develop strategy on how to support the needed research.

In UK the BREEAM system has been used for a long time, that it seems to be integrated as part of practices. The discussion is no more about integration of assessment systems to policy steering instruments, nor setting specific limit values. The discussions are already more focused on the required targets levels of the systems.

All countries have regulations on better energy efficiency. However, in the view point of sustainability as target this approach is too narrow.

Also it is important to realize that any intervention to today's ways and practices are changes that need to be implemented with the help of good understanding of stakeholders business perspectives. The commitment level is stronger if changes also support present or near future business strategies or scenarios of the main stakeholders.

Support and information for decision making during the life time procurement

"Instruments for decision support will have to bridge the gap between economic, environmental, social and cultural measures and components of property value and help to establish the necessary feedback-mechanisms that incentivize and drive change in the property industry. This requires a synergy we have not seen so far; i.e. an integration of the traditional methods and tools for valuation, risk analysis and cost estimation with the methods and tools developed by the sustainable building community for assessing and communicating the contribution of buildings to sustainable development." (Lützkendorf)

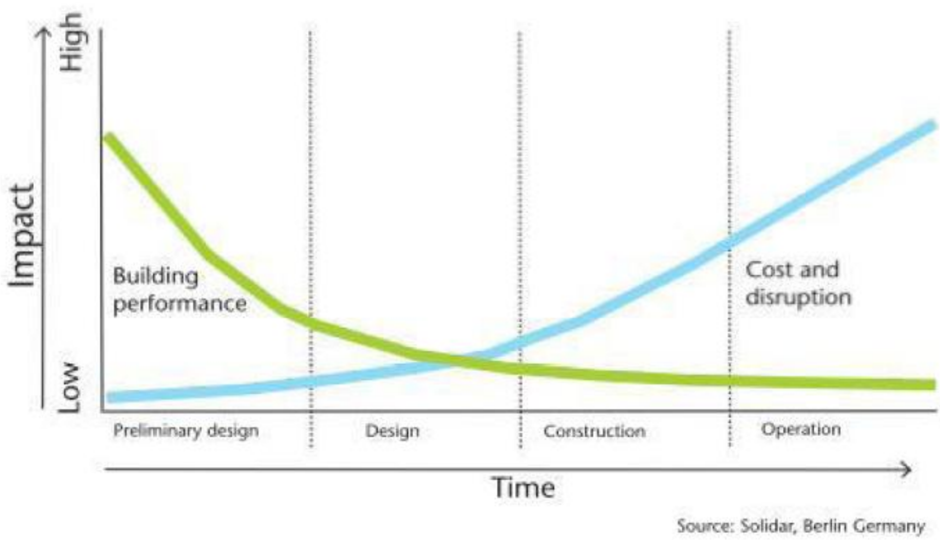

Figure 36. Princcipal presentation Impact-time relationship of different stages of building projects.

Today a building project with its many decisions points is strongly based on an effective information process. The earlier one receives good information on building performance (with advanced use of assessment systems and tools), the better one can influence the value creation and steer the project towards customer's goals and reach in a controlled way the target requirements of the project. Here the customer can be understood widely as client, end-user, another stakeholder of the value chain during procurement, or community or society.

Building related information on its sustainable performance is needed along the life cycle. In today's practices this information is very fragmented and do not provide enough feed-back information for decision making during interventions, e. g.

for planning, designing ,construction and refurbishment activities, neither good information for operation and maintenance related decisions.

In general, assessment methods can be understood as a technology and knowledge management tool (Kajikawa, Inoue). Their supportive functions have many specific aspects, for example:

1. Comprehensiveness. Assessment system provides a way of structuring sustainability related information on either organisational behaviour, person's behaviour, on one property, a neighbourhood or larger district. In case of property level assessment the systems usually integrates different functions of buildings with multi-criteria. They include environmental aspects, social aspects, economical aspects and the future requirements. Therefore, assessment systems for sustainable building can be used as a comprehensive framework integrating knowledge from different disciplines.
2. Function as design guideline. Assessment systems are increasingly used as design guidelines and checklists (in absence of better alternatives). The method is valid for decision support especially during early design
3. Signalling during life cycle. System used as a self-assessing system to encourage building owners and end-users to aspire to higher levels of sustainable performance. The most effective for signalling, in order to make wanted changes in behaviour happen, are quantitative assessments and value estimations with rapid feedback to end-customers.
4. Communication and ability to enhance dialogue among a range of stakeholders broader then design team. Assessment systems facilitate communication between stakeholders as the focus shifts to addressing sustainability and changing the culture of the building industry.
5. Property valuing: as it is becoming evident that a property's economic value also depends on the building's capability to create and protect environmental, social and cultural values, the assessment system can function as one valuing tool to provide either quantitative or qualitative values for property's worth in use.

Assessment systems when used in the connection with expert judgement can provide needed performance and value related information as feed-back in decision points and in many steering levels during the life time of a property. The number of steering levels supported by the use of assessment systems was studied in the survey. The requirement for better information and information for decision making was studied as a mapping exercise by linking the use of assessment systems with steering levels.

Decisions supported by information technology

Different actors fulfil different roles and have different standpoints and goals. They therefore need different kinds of information in different formats tailored to the requirements of specific decision making problems accompanying the life of buildings (Lorenz and Lützkendorf 2008).

The functionality of object based modelling technologies like BIM can serve different kind of information needs. Modelling of process level use- cases for needed information management and data exchanges is the first step when starting to develop supportive information technology.

Interesting examples on using BIM in the level of process steering, can be found in Singapore.

- Steering level: Building permit process
  BIM based design proposals make it possible to check the building information model against rules. This is the practice in Singapore building permit office. The rules for assessment are based on requirements in the Building Code.
- Steering level: Cost-analyses of design proposal:
  Whole life costing using design BIM tool integrated with a decision support tool giving instant feed-back to design team and property owner. The content of feed-back in the fuzzy-rule based system was partly based on assessment system (BCA) and partly on rules build up with several experts judgements. (Bee 2010)

Special challenges in retrofit projects

We face a challenge of reasoning behind our decisions in different steering levels. For example the authorities need reliable examples of adaptation of the Building Code in different types of buildings especially in refurbishment and retrofit project.

Supportive guidance and consultation steering are considered very effective steering instruments for planning in network context (Roininen 2009). Figure 3 shows a framework, that explains the nature of steering instruments. The Framework defines consultation steering as strongest in its governance capabilities and closest to practical usage. It can be seen at least as effective for refurbishment and retrofit projects as in planning.

In order to support the capability of planning authorities and building permit authorities to provide more supportive guidance and consultation in the future, there is a need for good ICT-tools. For example an IT-database including examples of sustainable adaptation cases of the building code in variety of building cases.

In the course of time new kind of BIM and IT-services easily provide a large amount of examples how decisions can be reasoned.

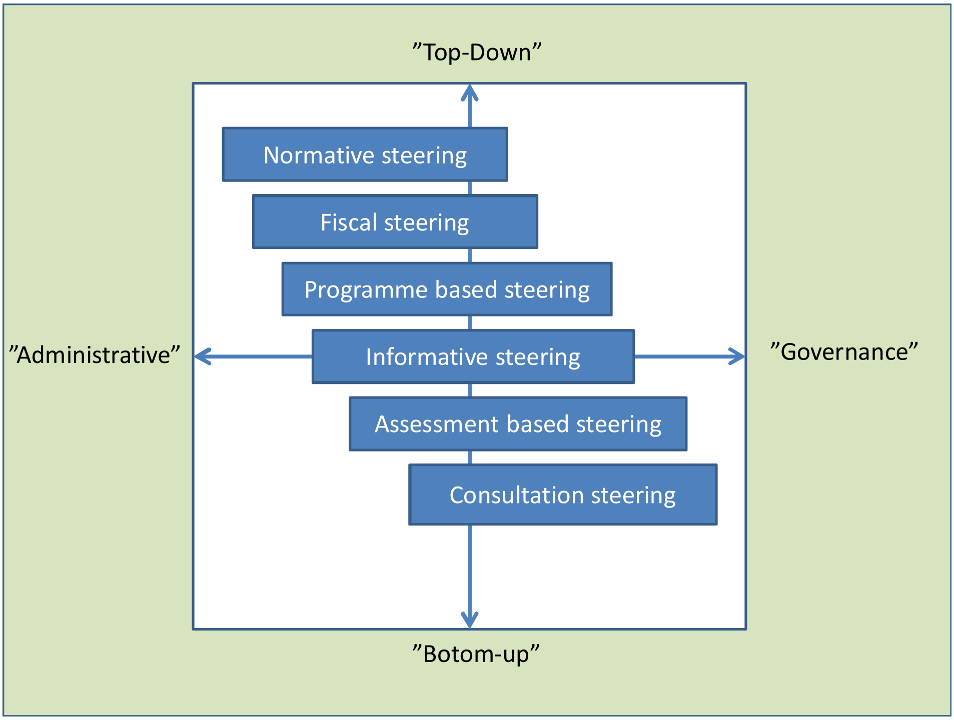

Figure 37. Framework of the ways of steering (Roininen 2009) shows them related to approaches (Top-down/Bottom-up) and related to types of steering (Administrative/ Governance).

10.5 Potentials of sustainable building assessment systems in connection with instruments of steering

10.5.1 Introduction

This chapter discusses the potentials and barriers of sustainable building assessment systems especially from the viewpoint of the following issues:

- Impact of its focus area
- Support from the citizens and building owners
- Availability of tools and guidelines.

However, the potential of making use of sustainable building assessment systems in the context of municipal steering is discussed separately in Chapter 9 on the basis of Dutch experience and case studies.

10.5.2 The adoption of the common outline of building performance to the European basic requirements, national building acts and building regulations

Section 3.2 explains that this report defines systems of sustainability assessment as systems which outline issues of concern (atmosphere, land, health etc.), address the performance aspects that impact on these issues of concern, and finally gives quantitative and qualitative indicators together with assessment methods which are able to measure the performance aspects.

On the basis of the current versions of ISO and CEN documents, the aspects of building recognised as aspects that have an impact on the issues of concern, actually are a) aspects of building performance (like accessibility, indoor conditions, indoor air quality, etc.) and b) direct environmental performance aspects (like release of green house gases).

When the list of performance aspects included into the systems of sustainability assessment of buildings tends to cover all central performance aspects of building, we can question whether we need to take these as specific sustainability aspects. We approach a situation where sustainability of buildings is defined as a requirement of overall quality.

The following table compares the aspects of building performance that are covered by the current version of the ISO DIN 21929 and the basic requirements.

It seems reasonable to conclude that one way of making use of the sustainable building assessment systems could be that the same outline of the aspects of building performance was used in building regulations and buildings acts as in the sustainability assessment systems of buildings. In a situation like this, the building acts would give basic principles, building regulations and codes would give minimum requirements and guidelines and sustainability assessment systems would give indicators and methods for assessment and benchmarking so that all these instruments used the same outline for the aspects of building performance. At the same time it would also mean that those aspects recognised as essential aspects of building having an impact to the issues of concern of sustainable development, would also be recognised as aspects that we need to consider in all buildings.

The achievement of this situation would still require a lot of discussions in order to achieve a common understanding of the performance aspects and basic principles. On the other hand the achievement of this situation would enable and possibly promote the use of sustainable building aspects in all levels of decision making.

Table 52. Comparison of the performance aspects covered by ISO draft and the basic requirements covered by the present version of CPR.

Sustainability aspects of buildings according to ISO DIN 21929	Basic requirements according to CPR
Emissions to air	Hygiene, health and the environment/ Emissions to air
Use of non-renewable resources	Sustainable use of natural resources Energy economy and heat retention
Fresh water consumption	
Waste generation	
Land use	
Access to services	
Accessibility	
Indoor conditions and air quality	Hygiene, health and the environment/ emissions to indoor air Protection against noise
Adaptability	
Costs	
Maintainability	
Safety	Mechanical resistance and stability Safety and accessibility in use Safety in case of fire
Serviceability	
Aesthetic quality	

10.5.3 Normative regulations

Individual performance aspects of buildings that are essential for issues of concern of sustainable development can of course be considered in national building codes. This is already the case as shown in Chapter 6. The following table outlines issues that have an effect on the efficiency of this kind of steering.

Table 53. Issues that affect the efficiency of the instrument Normative Regulations.

Impact on its focus area	Based on its normative character, the instrument affects directly on its focus area Is relatively easy to direct on new building but significantly more difficult to focus on existing building stock The true impact depends on the selection of the required levels of performance
Support from the citizens and building owners	The implementation requires certain common understanding about the need of the requirement; significant and fast changes are difficult New regulations are typically – and sometimes very strongly – resisted by those who are the initial payers of the changes
Availability of tools and guidelines	The implementation is not possible before the availability of needed tools and guidelines is ensured. Weaknesses in the availability of tools and guidelines may cause differences and regional or other inequity in realization

10.5.4 Mandatory information required by regulations

The control and regulatory instruments, the character of which is informative, include mandatory audits, mandatory labelling and certification programmes.

Both individual sustainability indicators as well as systems of sustainability indicators can obviously be used in this kind of regulation. At present – on the basis of the energy performance directive – energy performance certificates are required in the EU.

According to the Energy Performance of Buildings Directive (EPBD) (2002/91/EC), four main elements define the requirements that have been integrated into national legislation:

- Establishment of a methodology for an integrated calculation of the overall energy performance of buildings
- Definition of minimum energy efficiency requirements per member state based on this methodology
- Energy efficiency certification of new and existing buildings
- Regular inspection of heating and air conditioning systems.

The requirement of certification can naturally be extended to cover the information about the release of green house gases and other harmful emissions and use of natural resources. However, this increases the requirements of the methodologies, information and tools that should be available in order to enable the certification.
As the standardisation processes carried out by ISO and CEN are proceeding we have good reasons to believe that we will reasonably soon have commonly agreed

basic rules for the assessment of environmental impacts of buildings and building products.

The biggest barriers concern the extensive availability of environmental information of materials, products and sources of energy. One specific barrier is also the difficulty to develop reasonable and commonly agreed rules for the assessment of the environmental impact of electricity especially in countries where the demand significantly varies because of seasonal differences.

The extension of the mandatory certification to other aspects that those that can be quantitatively measured is improbable. The users of the information given in certificates should be able to trust the comparability of information. The less possible it is to formulate clear rules for the assessment (calculation), the less reasonable it is to extend certifications into these areas.

The following table outlines issues that have an effect on the efficiency of this kind of steering

Table 54. Issues that affect the efficiency of the instrument Mandatory information.

Impact on its focus area	The intended impact is to arise demand with help of information that enables comparisons The true impact depends on the extend of the focus area (all buildings/limited groups of buildings) It is easier to direct both to new and existing buildings than normative regulations The impact may be significant if the focus area is wide
Support from the citizens and building owners	Requires certain level of common understanding and support from the citizens and owners. If there is low support, the danger for attempts for circumvention of rules also increases Wide support depends also on the availability of the needed tools and on the foreseen costs of the required measurements (assessment and possible verifications)
Availability of tools and guidelines	The efficient implementation requires good availability of all information, methods, tools and guidelines that are needed in measurement, assessment and verification of results. It is not possible before the availability of needed tools and guidelines is ensured. Weaknesses in the availability of tools significantly impairs the implementation

10.5.5 Economical and market-based instruments

The economical and market-based instruments of steering include performance based contracting, cooperative procurement, use of voluntary certificate schemes (e.g. energy efficiency) and branding.

Market-based instruments for steering of sustainable building are available and in use in a number of countries. These include the eleven building evaluation tools that were analysed within SuPerBuildings and reported in D2.1.

A framework including the indicators and rules for benchmarking are needed. In principle, this should be based – as explained in Section 3 – on the understanding of essential issues of concern of sustainable development, relevance of those with regard to buildings, aspects of building performance that affect these issues of concern, development of assessment methods and indicators for these aspects, good understanding about the true and present performance of buildings with regards to these indicators and finally reasonable selection of performance levels and principles of weighting.

The following table outlines issues that have an effect on the efficiency of this kind of steering.

Table 55. Issues that affect the efficiency of the instrument Market based certification schemes.

Impact on its focus area	The use of the instrument may become extensive if the marketing of the scheme is successful and if the relevant actors believe on the branding The true impact of focus areas (like energy saving, savings in GHGs, improved accessibility and access and thus improved equity of different user groups) depends on several issues: - the selection of right performance levels and weighting criteria needs good understanding of local conditions. If this is missing and the chosen criteria are too easy, the impact remains insignificant or even negative - a wide system with a number of different level indicators may enable "playing" – users are not interested in ambitious development but on easy credits. - Well-recognized and valued voluntary systems which include locally relevant and adequately demanding criteria may be very effective in their focus area. - the impact improves as the systems support target setting and design in addition to labelling - it has been argued that significant extra potential could be achieved if the consideration of the systems and certification results were integrated to the decision making processes of investors and insurance companies.
Support from the citizens and building owners	The development and launching a successful system needs support from a certain group of stakeholders but initially a wide consensus is not needed
Availability of tools and guidelines	The assessment methods and certification methods are usually built into the schemes Successful stimulation of sustainable design requires the availability of information, assessment and simulation methods etc. needed in design for good environmental etc. performance

10.5.6 Fiscal instruments and incentives

Fiscal instruments and incentives include measures of taxation, tax exemptions and reductions, public benefit charges, capital subsidies grants and subsidized loans.

At present these kinds of instruments are used in a number of countries especially in order to promote the use of renewable energies and to promote improved energy-efficiency. It is also relatively typical that fiscal instruments and incentives are tried to use so that separate issues are pursued at the same time; for example, policy makers may seek at the same time for improved energy efficiency of existing building stock and stimulation for building during economical recession.

The use of the instrument requires good understanding of the market in order to be able to foresee the direct and also possible indirect impacts. Because of this, the focus area cannot be wide.

the following table outlines issues that have an effect on the efficiency of this kind of steering.

Table 56. Issues that affect the efficiency of the instrument Fiscal measures and incentives.

Impact on its focus area	There are a number of issues that affect the true impact of the instrument on its focus area: - A right timing is important. It is important that the market is ready for the intended activities (like renovations that save energy) for example in terms of the availability of needed skills and capacity - The level of tax reduction / incentive etc has to be right in order to be attractive but on the other hand it shall not be too high in order not to cause injustice for those who cannot make use of the instrument (for example because the instrument is directed only for small houses / multilevel buildings/owners ...) - Correctly timed and directed instrument may have an important effect and stimulation on the targeted limited focus area
Support from the citizens and building owners	As a policy measure it requires certain level of common agreement. Big resistance may be caused if the instruments is seen to favour too strongly a limited group The political and general support depends also on the foreseen net costs of the planned methods for the budget of the state and/or cities
Availability of tools and guidelines	When receiving the benefit (taxation or incentive) is linked to the requirement of providing certain information, the necessary assessment methods and tools should be available

10.5.7 Support and information

Support may include support for the development of assessment tools, awareness raising education about the use and benefits and information campaigns.

The development of sustainable building assessment methods and tools have taken place probably mainly withprivate funding. However, the development of basic principles and indicators has also received a lot of support both on national and European level. An example of this kind of support is this project SuPerBuildings the aim of which is to develop and select sustainability indicators for buildings, develop understanding about performance levels considering new and existing buildings, different building types and different national and local requirements, develop methods for the assessment and benchmarking of sustainable buildings, and make recommendations for the effective use of benchmarking systems as instruments of steering and in different stages of building projects. Earlier projects funded by the Framework Programmes that have developed sustainability indicators for buildings include PERFECTION, LENSE AND CRISP and TISSUE and STATUS which developed sustainability indicators for built environment.

The final impact of this kind of support is extremely difficult to assess. However, it is obvious that there is a wide acceptance and awareness about the sustainable assessment and benchmarking systems of buildings.

10.5.8 Support by building authorities on city level

This section discusses the potentials of the use of sustainable building assessment systems in connection with municipal steering on the bases of Dutch experiences and case studies.

Aims and boundaries of sustainable building policy on city level

As outlined in chapter 6 a number of instruments for SB policy steering may be available on a city level:

- Terms for release and tenancy rights of registered plots (a)
- Urban renewal programmes (b)

in case of city infill projects:

- Increased recompense of permitted building volume (c)
- District level exceptional decision on building permission (d)

in planning process:

- Use of assessment tools for evaluation of alternative concepts/plans (e)
- Planning obligation for design and construction (f)
- Focus on important planning issues(g)
- Building permit process: supervision of setting the goal for SB -level.

An advantage from steering on city level is that city authorities generally are in close contact with building plans and building parties, so that they can have an effective input to steer building plans in direction of higher sustainability standards. An instrument for SB evaluation that can be used for performance-based policy steering can be a very effective tool for city authorities.

On the other hand the scope of regulatory power on city level may be limited by national regulations and national authorities, to prevent inequality of legal rights between citizens in different places. This scope of city regulatory powers may vary from country to country.

The potentials are here discussed on the basis of the experiences in the Netherlands where extensive experience exists with the use of SB policy steering by city authorities.

The Dutch national building code sets the minimum standard for all new buildings, including a minimum energy performance. Many municipalities aim to improve the building quality above this minimum level and reduce the (carbon) footprint of the built environment in their city. However, in The Netherlands the legal system does not allow municipalities to impose higher standards on a proposed building project than the rules which are laid down in the national building code. This limits the scope for a specific building regulation on city level. For this reason policy development is mainly based on stakeholder involvement, preferably in an early stage of the building process.

In the past SB policy in the Netherlands made use of a national checklist of sustainable building measures that could be applied. Building parties could score which measures they had applied. Although this method had been developed by the Building Research Centre (SBR) and had been approved by the (building) industry, the opposition against it grew over time, for a number of reasons. Objections were that the number of measures applied was only weakly related to the actual reduction in environmental impact, some materials with a high impact were missing, architects felt obstructed in their design and it was difficult to check if the number of measures agreed on had really been taken in actual building.

A solution was found in a performance-based methodology: to agree upon a minimum performance regarding both building quality and reduction of the environmental footprint. The new performance-based policy distinguishes itself on the following issues from the former approach:

- Lists of required measures are replaced by performance-based agreements
- Municipalities and private parties together make clear and verifiable agreements (ambitions)
- The sustainability score of different designs or projects can be compared (benchmarking)
- The introduction of a generic policy for all building projects is considered as a first step towards reaching a sustainable city. The generic policy may comprise of the following approaches:
- Set a standard for the sustainability score, e.g. a minimum standard for new building projects within the municipality or a minimum standard for urban expansion plans;
- Set a standard for tendering of public building projects (allow reduction on tendering price or give subvention when a high sustainability score is realised);

– A certain sustainability score as a prescribed criterion in building design competitions or for building awards.

Different tools can be used for the performance-based SB policy. Here two examples are mentioned:

GPR Building

GPR Building is a software tool, which can be used to assess both the environmental impact and the design quality of new and existing buildings.

Essential in the GPR methodology, is the dual approach of environmental impact on the one hand and building quality on the other. A building is only considered to be sustainable if it has a high performance on both energy and materials and it will fulfil its function for a long time, to the satisfaction of the user and with a minimum impact on the occupants health. This therefore implies a high-quality building in the broadest sense of the term. A building is rated on five indicators on a scale of 1 (worst) to 10 (best). The key performance indicators are: Energy, Environment (assessing the environmental impact), Health, User quality, and Long term value (assessing the building quality). When assessed, the building performance is rated per indicator, but the main indicators are not aggregated into one overall score. Thus, policy makers can focus on the topics which are most relevant to a specific situation: in school buildings, for instance, the focus is often on energy, environment and health, whereas in residential buildings all indicators will be equally important.

GPR Urban planning

The municipalities of Groningen and Tilburg initiated the development of the software tool GPR Urban Planning. They felt the need for a tool that they could use to assess and monitor sustainability scores on a district level. GPR Urban planning rates a district on five indicators on a scale of 1 (worst) to 10 (best). The key performance indicators are: Energy, Surroundings (including use of space, nature, water and buildings and infrastructure), Health, User quality (including mobility, functionality and perceived value) and Long term value. It can be used for either restructuring plans of existing districts or for urban expansion plans. One of the strengths of the tool is that it contributes to communication between different departments in a municipality that work on urban planning.

Implementation issues for sustainable building policy in municipalities

As sustainable building policy presently cannot be enforced on the building industry and building developers a good implementation of the proposed policy by the municipal authorities is necessary. This chapter describes some important issues regarding the implementation, again based on the experiences in The Netherlands.

In the first place a good sustainable building policy contains an ultimate goal and measurable intermediate targets to achieve the goal. This way the progress of the policy can be monitored.

Stakeholder support is vital as mandatory building regulation on city level is not possible, in the Dutch context. Stakeholders in sustainable building include: project developers, social housing agencies, building industry and architect association. Several municipal departments, like the building and monuments department, project development and spatial development are also considered as stakeholders. From the start of the project, stakeholders have to be involved.

The alderman for environment is very important in implementation of sustainable building policy. He has to stimulate the administrative machinery to do their best to carry out the sustainable building policy. He also has to generate time and finances to realise sustainable building ambitions. Furthermore, he has to promote the policy to his fellow aldermen.

Basic knowledge of sustainable building among stakeholders is necessary for implementation of the policy. Knowledge can be enlarged by organizing workshops. Experience of the sustainable building process can be gained by carrying out pilot projects.

For a good long term effect of sustainable building policy choose an easy-to-use and reliable sustainable building tool. If a tool is too complicated or it takes too much time to use it, it will deter stakeholders.

Good examples of sustainable building with public buildings can motivate other parties to also realise sustainable buildings. Especially when it is shown that it is not complicated to do so. Sufficient monitoring of the sustainability in building projects (including a follow up check after construction) demonstrates the dedication of the municipality to their sustainable building policy. This may urge stakeholders in the building process to realise the ambitions that they agreed upon.

Communication of obtained results may contribute to the enthusiasm of stakeholders. They can distinguish themselves as supporters of sustainable building, which can contribute to marketing of their projects.

Finally, financial support for sustainable building projects can increase the enthusiasm of private parties to realise sustainable buildings.

Potential impacts of municipal policy based on sustainable building tools

The potential impact of municipal policy based on sustainable building tools for different market segments is described below:

- New residential: Municipal policy can contribute effectively to sustainability in this market segment.

- Existing residential: The impact in this market segment is not very high. When voluntary agreements are made for existing residential buildings, social housing agencies for instance can take sustainable building into account in renovation projects. Private persons might be stimulated to improve their dwellings by financial support of municipalities.
- New offices: Municipal policy can contribute effectively to sustainability in this market segment, especially when the municipality is involved in development of the project.
- Existing offices: The impact in this market segment is low since the municipality is generally not involved in renovation of existing offices.
- Public buildings: When municipalities set a good example, sustainability in this market segment will improve significantly.
- Other market segments: For new buildings in other segments municipal policy can contribute to sustainability in the same way as for new offices. For existing buildings this is much harder, as for existing offices.

The described approach of municipal policy also has limitations. One of the major limitations is that the policy is based on voluntary agreements between municipalities and private parties. The success of the policy depends on the willingness of these parties to contribute to sustainable building.

Another thing that can be a limitation of the approach is the implementation of the policy within the municipality. Enthusiasm of politicians as well as the administrative machinery to contribute to sustainable building and to carry out the policy is very important. If this is missing, the impact of the policy is limited.

10.6 Recommendations

The target of the work was to formulate recommendations for the usage of sustainable building assessment and benchmarking systems as an instrument in sustainable building steering. The work started by making use of the results of earlier results of the project concerning the barriers and drivers for sustainable building, surveys, and process studies. The process description enabled to study roles and tasks in the sustainable design and construction process opening viewpoints on the different levels of steering levels

The work considers all alternatives of steering. This Chapter presents the final conclusions given as recommendations for the use of sustainability indicators in steering processes.

The recommendations are outlined as follows:

1. Comprehensive understanding about the goal
2. New standards for planning and design
3. Wider scope for regulatory instruments
4. Development of municipal support and building supervising processes

5. Development of substantiation processes in performance based procurement
6. Further economical support for the refurbishment of existing buildings

10.6.1 Comprehensive understanding about the goal

Discussion

The definition of sustainable building covers the essential performance aspects considering environmental, economical and environmental aspects. For example ISO 21929 defines sustainable building with the help of issues of concern, aspects of buildings that affect these issues, and indicators with which the aspects can be assessed. ISO 21929 defines 14 core aspects of buildings which are emissions to air, use of non-renewable resources, fresh water consumption, waste generation, land use change, access to services, accessibility, indoor conditions and air quality, adaptability, costs, maintainability, safety, serviceability and aesthetic quality.

If European countries gradually agree that these aspects actually represent the essential performance aspects of buildings, we may gradually also come to the point where the same structuring could be used in the highest level of steering.

In a situation like this, the building acts would give basic principles, building regulations and codes would give minimum requirements and guidelines and sustainability assessment systems would give indicators and methods for assessment and benchmarking by using the same outline for the aspects of building performance. At the same time it would also mean that those aspects recognised as essential aspects of building having an impact to the issues of concern of sustainable development, would also be recognised as aspects that we need to consider in all buildings.

The achievement of this situation would still require a lot of discussions in order to achieve a common understanding of the performance aspects and basic principles. On the other hand the achievement of this situation would enable and possibly promote the use of sustainable building aspects in all levels of decision making.

Recommendation

On the highest level of steering (meaning building laws and regulations) a comprehensive understanding about sustainable building could be adopted as a general outline and basic requirement for the overall quality of buildings.

10.6.2 Specific guideline, tools and standards for planning and early design

Discussion

It has been shown that often the most important decisions regarding sustainable building are done in planning and in early stages of design. Such fundamental decisions as whether to build a new building or renovate, location, and functions and volume have very significant impact on the final solutions environmental, economic and social impacts. The decisions and selection concerning the energy concept and energy supply solutions are essential. The utilization of distributed solutions and renewable energy remarkable affect the sustainability impacts. In addition, important architectural choices – such as size, shape and orientation, and the main construction materials of the building – are done in the preliminary design phase.

The current standards (developed by CEN TC 350) support the assessment and comparison of buildings but those give less support for the early stages of sustainable building. Quantitative indicators following a life cycle approach are the primary indicators for the assessment of the environmental impact of buildings and products. However, those are not easy to use in preliminary stages of planning and design, where limited information is available. Although the assessment is possible by modelling and creating alternative solutions, the problem is that needed resources for time consuming tasks are not available.

SuPerBuildings (see D6.1) recommends that already in the stage of programming environmental targets should be set with the help of core indicators (at least NRE, CFP and Water). Targets should also be set for all relevant aspects of social performance and economical aspects with the help of building level indicators. At the same time the assessment methods should be addressed. In the bidding stage principal designer together with the whole team should take care that the design as a whole fulfils the targets set.

More tools are needed for the design phase. Tools that use simplified input are needed for early stages of design. To ensure the quality of the tools and comparability of the results, guidelines and standards are needed at the same time. Standards that outline issues that have a significant effect on the assessment result would make it easier to state requirements for the simplified assessment. Thus these standards would also support the comparison of assessment results.

Early stages of design might also benefit from guidelines and standards that characterize the process, list issues to be considered and outlines tasks of design for sustainable buildings.

Recommendation

It is recommended that a new standardization process would be started in order to develop guidelines and standards that support the design for sustainable building. These standards should especially support the early design. The needed guidelines and standards are of two main types. On the other hand such guidelines, standards and/or tools would be useful that support the quality management of tools which work on with the help of simplified inputs. The standards should support the characterization of these tools especially in terms of data quality and coverage of assessment.

Guidelines are also needed for client’s brief. To enable requirement setting guidelines are needed for benchmark development.

10.6.3 Wider scope for energy regulatory instruments

Discussion

The domain of control and regulatory steering instruments of sustainable building has much focused on the regulation of energy performance of buildings.

The Directive on energy performance of buildings (2002/91/EC and its recast 2010/31/EU2010) is the main legislative instrument at EU level to achieve energy performance in buildings. Under this Directive, the Member States must apply minimum requirements as regards the energy performance of new and existing buildings, ensure the certification of their energy performance and require the regular inspection of boilers and air conditioning systems in buildings. The recast energy performance directive sets a target for all new buildings to be 'nearly zero-energy buildings' by 2020. The provisions of the Directive cover energy used for space and hot water heating, cooling, ventilation, and lighting for new and existing residential and non-residential buildings. The primary energy consumption is taken into account with the help of chosen primary energy factors which vary from country to country (see D5.1).

The complexity of the effect of energy supply technologies and solutions would require the further development of assessment methods. In order to consider the overall impacts of distributed energy supply methods and the impacts of electricity, district heat, district cooling, combined heat and power and tri-generation in terms primary energy and other environmental impacts, calculation methods and rules should be developed. The current building-level assessment methods provide both dynamic and simplified solutions for the simulation of building's energy performance, but methodological development should be done to enable planning and design for sustainable urban districts. In addition, methodological development should be done to consider life-cycle perspective. This includes also methodological rules for the consideration of the future scenarios for energy supply.

SuPerBuildings' analyses (D4.2 and Ruuska et al. 2012) show that materials have a significant effect on building's overall energy consumption and greenhouse gas emissions. To enable the consideration of embodied energy and embodied CO_2e, product related information should be made available. EN 15804 (Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products) gives guidance and rules for the calculation of embodied energy and GHGs on life-cycle basis. However, comprehensive availability of environmental product declarations – as the standard sets a basis for a voluntary method – may take very much time.

Recommendation

The scope of the energy regulatory steering should be widened to cover life cycle based GHGs in addition to primary energy. In addition, building materials should be taken into account when GHGs are assessed.

An improved assessment method which considers the complexity of energy supply technologies should be developed to support the measurement and the comparability of assessment results.

The first step towards the comprehensive consideration of aspects that significantly affect the total energy use and total greenhouse gases could be the establishment of national methodologies for the assessment and the requirement about mandatory information.

In addition, there is a need for better coordination of regulations given on different levels.

10.6.4 Development of municipal support and building supervising processes

Discussion

Informative steering and support is needed in order to accelerate the refurbishment and retrofitting of existing building stock towards sustainable buildings. The ability of planning authorities and building permit authorities to provide more supportive guidance and consultation for designers and builders in building projects would probably facilitate the finding and utilization of better refurbishment and retrofitting solutions. More support is needed in order to accelerate the use of advanced solutions beneficial from the view point of energy performance and overall sustainability. This is especially important in the current situation where a huge number of existing buildings should be renovated all over Europe and much new information about sustainable refurbishment concepts is needed.

On the other hand, the building authorities – considering their role in the process – want to avoid a situation where their give guidelines or recommendations about the use of specific solutions. Thus the availability of recognized standards and design guidelines is emphasized at the same time.

The most effective steering model from the view point of customers is consultation steering (fig.). It is not used too much because it is quite resource consuming. To overcome this problem, new service models could be developed for building supervising agencies. Service models could create added value especially to district and neighbourhood level urban infill project.

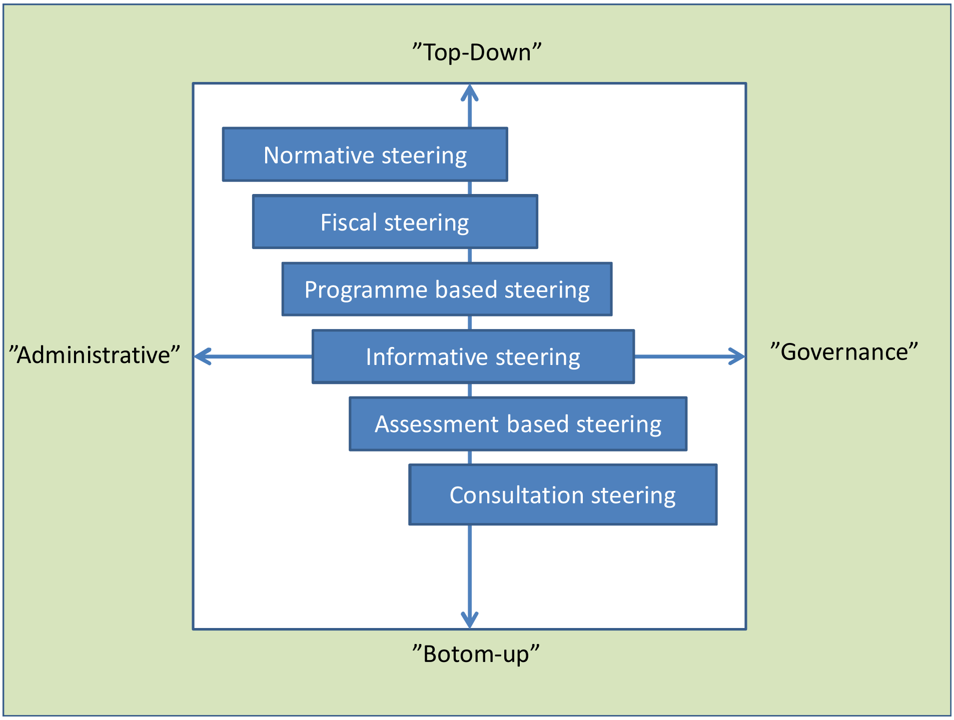

Figure 38. Steering models of building authorities (Roininen, 2009) shows steering models related to approaches (Top-down versus Bottom-up) and related to behavioural types of steering (Administrative versus Governance).

Recommendation

Such process indicators and guidelines should be developed which help local building authorities and building supervisors to give support and instructions for sustainable building planning and design. Guidelines are needed for consultation / cooperative steering; guidelines are needed for processes that help local building authorities to address different kinds of effective methods and tools for the design process and to follow performance based approach. These methods and tools should then support designers to consider sustainability aspects along the whole design process. Good examples of successive processes are available in some countries (see section 10.5).

The following is recommended:

The development of new kind of service models for building authorities that would help to add the use of consultation steering is recommended. This model could include different forms such as council sub-committees, task forces, steering groups, expert panels etc, that give input to policy process. In addition, contracted experts and consultants that bring their expertise to assessment process could be a part of new service models.

10.6.5 Development of procurement and verification processes

Discussion

In order to reach high level sustainable building, professional co-creation and innovation is needed. The use of policy steering instruments (fig.) should support this aim. Each level is needed to reach the total performance; and each level has level-specific instruments and methods.

Figure 39. Levels of steering form a hierarchy. Each level is needed for reaching the total effect /quality / performance.

The use of performance based procurement model is a natural choice in sustainable building where the target performance is assessed with the help of a verification process. The definition of required verification is as important as specifying the design / construction criteria. A new type of contract for public private partnership is needed. In sustainable building processes requirements are set for the final result on the bases of sustainability requirements. Clear rules are needed for the process. The process description should explain how SB indicators are used in the setting and verification of requirements. These kinds of processes should especially be developed for public procurement.

The description of the intended verification processes should be included in the Request for Proposals (RFP). Any requirement on the performance of a project element should be followed by the criteria and methods for verification. Here SB indicators can be used, qualitative, measurable as well as process related indicators.

When performance specifications are included, a series of submittals will probably be necessary, gradually more detailed as design and construction progress. The appropriate type of verification depends on: (1) the type of the requirement, (2) difficulty of verification, and (3) timing.

A verification plan should be carefully developed in order to identify project stages at which information is required for decisions and what kind of deliverables should be available. The congruence of the intended systems with the owner's criteria has to be shown.

The different levels of verification can be presented as a list which shows the scale of compliance from lowest to highest:

1. A simple statement by the design-builder that the design will comply (e.g. incorporated into a contract as a promise).
2. Manufacturer's product literature stating compliance.
3. Manufacturer's warranty.
4. Testing of similar products with certification that products of the same type will be used on the project (design proven by testing a mock-up).
5. Documentation of performance of products installed in actual projects and use of the same products in the project (design proven by the use).
6. The design engineer's stamp or seal on design (when engineering principles are well accepted).
7. The engineer's design calculations (simulations) (usually submitted for the project record).
8. Field testing of actual construction ranging from testing of samples taken from construction to testing in place.
9. Obvious compliance (if obvious by visual inspection or comparison, no substantiation is necessary).

If performance is critical to the success of the project, more verification of certain types would be recommended earlier in the project and multiple types of methods would be used. The cost of preparing verification should, however, be considered while over verification may also cause difficulties for the process. Typically, performance specifications make reference to industry standards, which is helpful by enabling inclusion of standard test methods to ensure that performance requirements are met objectively (Lahdenperä 2001).

Recommendations

The development of guidelines / standards for SB indicator based verification process is recommended. This would ease the operative implementation of the use of SB indicators in project level steering. SB-indicator based procurement and verification process should be adapted especially to performance based procurement models.

10.6.6 Further economic support for the sustainable refurbishment of existing buildings

Discussion

The building sector offers the largest single potential for energy efficiency in Europe and existing buildings have here an important role. Improving energy efficiency is regarded by the European Commission (EC) as a key element in the Community energy policy. It is described by the Commission as the most effective way to improve security of energy supply, reduce carbon emissions, increase competitiveness and stimulate the development of markets for new energy-efficient technologies. EC reports that the household sector has been estimated to represent 27% of the energy savings potential by the year 2020 (COM 2006).

The recast of the EPBD (2010) requires that when buildings undergo major renovation, the energy performance of the building or the renovated part thereof must be upgraded in order to meet minimum energy performance requirements as far as this is technically, functionally and economically feasible.

Recent research has shown (Tuominen et al. 2012) that the most commonly reported problem that hinders the energy-performance renovation of existing building stock is a lack of effect on property prices. The new EPBD based regulations will improve the availability of information and may thus decrease the meaning of this problem. However, in order to accelerate renovations the effective implementation of fiscal instruments and incentives is important.

With regard to the use of renewable energy sources for heating and cooling, subsidies are the most widely used instrument employed by the member states of the EU (Cansino et al.2011). They provide a straightforward manner to compensate often high costs of investment. However, subsidies have the disadvantage of being closely linked to budgetary resources and therefore to budgetary constraints. Moreover, the subsidies could lead to increased equipment costs because manufacturers may tend to raise prices in anticipation of the discounts granted to customers. The use of tax deductions enable to receive financial compensation after the installation of equipment, which makes the compensation procedures simpler. This type of instrument may be very appropriate, especially in those cases where investment costs are relatively high. Nevertheless, being an ex-post incentive, such tax deductions do not lower the initial upfront payment and therefore do not help low-income households. The current financial solutions have also been criticized; the long-term perspective of supporting activities should be developed. If the types of subsidies and related percentages vary from year to year, this hinders both the development of renovation services and the planning of renovation projects (Rönty and Paiho 2012).

Recommendation

Article 11 of the newest version of the Energy Performance of Buildings Directive (EPBD) stipulates that residential buildings must have an Energy Performance Certificate (EPC) when they are sold, rented out or constructed. The EPC includes a label rating of the energy efficiency of the dwelling and recommendations of cost-effective energy saving measures. The success of the EPC depends to a large extent on the conditions in member states. However, to accelerate the energy-efficient renovation of the existing building stock, a further development of financial support for the sustainable and energy-efficient renovation is recommended.

These incentives or fiscal measures should be described in such a way that those consider life cycle impacts and consider a wide SB scope; while the improvement of the energy performance and the use of renewable energy is required it is also important to maintain and improve indoor environment and other essential performance aspects.

SuPerBuildings also encourages insurance companies and banks to apply SB performance aspects in their taxation and interest rate policies. At present there are much better possibilities to consider comprehensive approach in voluntary processes. There are also much improved possibilities to explain the benefits of SBs.

10.7 Summary

The starting point of the work was that the principal reason for the common efforts to promote the use of SBA methods is the desire to promote sustainable building in Europe. It is believed that by making use of sustainable building assessment and benchmarking methods both on voluntary basis and as instruments of normative and economic steering, it will be possible to promote sustainable building and accelerate the adoption of sustainable building practices.

Sustainability assessment systems of buildings are defined as systems which outline issues of concern (atmosphere, land, health etc.), address the performance aspects that impact on these issues of concern, and finally give quantitative and qualitative indicators together with assessment methods which are able to measure the performance aspects. Indicators can be systemized with regard to the character of the assessment process. In principle we can speak of quantitative, descriptive and qualitative indicators on the bases of their assessment process.

In order to be able to use these kinds of indicators and calculation results in regulation and in decision making we also need information and understanding about the normal levels of assessment results for different kinds of buildings in different regions. This knowledge enables to define benchmarks for performance and to define required levels of performance. In addition, different kinds of methods are needed for the assessment of different performance aspects of buildings. The basic requirement is that such unambiguous measurement methods are available which define the measurement processes, functional units and data quality requirements with adequate accuracy so that comparable and reliable results can be achieved.

This chapter defines that an effective steering mechanism a) has an impact on its focus area, b) has support from the citizens and building owners, c) is feasible because tools needed in assessment and verification are available and accessible for all who need those and because guidelines and instructions needed are clear. The report deals with the following types of instruments of steering: 1) Normative control and regulatory instruments, 2) Informative control and regulatory instruments 3) Economic and market-based instruments, 4) Fiscal instruments and incentives, 5) Support and information, 6) Municipal steering (steering actions in city planning and land use).

The following list shortly summarises the assessed impact of the use of SB assessment systems in the connection of different steering instruments:

- Normative regulatory instruments: Based on its normative character, the instrument affects directly on its focus area; is relatively easy to implement for new building but significantly more difficult to implement for existing building stock; the true impact depends on the selection of the required levels of performance.
- Mandatory information: The intended impact is to raise demand through information that enables comparisons; the impact depends on the extent of the focus area (all buildings/limited groups of buildings); it is easier to direct both to new and existing buildings than normative regulations; the impact may be significant if the focus area is wide.
- Voluntary certification schemes: The use of the instrument may become extensive if the marketing of the scheme is successful and if the relevant actors believe on the branding; the true impact of focus areas (like energy saving, savings in GHGs, improved accessibility and access and thus improved equity of different user groups) depends on several issues: the selection of right performance levels and weighting criteria needs good understanding of local conditions. If this is missing and the chosen criteria are too easy, the impact remains insignificant or even negative, a wide system with a number of different indicators may enable "playing" – users are not interested in ambitious development but on easy credits. Well-recognized and valued voluntary system which includes locally relevant

and adequately demanding criteria may be effective in its focus area. The impact improves as the systems support target setting and design in addition to labelling. Also, more potential could be achieved if the certification results were integrated to the decision making processes of investors and insurance companies.

- Incentives and taxation: A right timing is important: the market must be ready for the intended activities (like renovations that save energy) for example in terms of the availability of needed skills and capacity. The level of tax reduction/incentive etc has to be right in order to be attractive but on the other hand it shall not be too high in order not to course injustice for those who cannot make use of the instrument (for example because the instrument is directed only for small houses/ multilevel ings/owners ...). Correctly timed and directed instrument may have an important effect and stimulation on the targeted limited focus area.
- Municipal policy: The impact is different in different market segments. Municipal policy can contribute effectively to sustainability in the market segment of new residential buildings; the impact in the segment of existing residential buildings is not very high. However, when voluntary agreements are made for existing residential buildings, social housing agencies for instance can take sustainable building into account in renovation projects. Private persons might be stimulated to improve their dwellings by financial support of municipalities.

When considering new policies and policy instruments it is important to assess the position of different stakeholders with regard to such policies and instruments. A good support from relevant stakeholders contributes to the effectiveness of policy instruments.

Indicators of sustainable design and construction SB assessment systems are mature enough and should be actively be brought to guide all life cycle phases of buildings. The following recommendations were formulated:

- Comprehensive understanding about the goal
- New standards for planning and design
- Wider scope for regulatory instruments
- Development of municipal support and building supervising processes
- Development of substantiation processes in performance based procurement
- Further economical support for the refurbishment of existing buildings.

11. SuPerBuildings summary and future prospects

The Lead Market Initiative is the European policy for 6 important sectors that are supported by actions to lower barriers to bring new products or services onto the market. The policy instruments deal with regulation, public procurement, standardisation and supporting activities. Sustainable construction is one of these lead markets in the EU. To reinforce the integration and implementation of the principles of sustainable development in the construction and real estate industry, manageable principles, methods and tools for the sustainability assessment and benchmarks are needed.

It is estimated that the demand for results of a sustainability assessment of buildings will grow even more in the coming years. Both voluntary processes as well as policy steering and municipal steering instruments need sustainability assessment methods and indicators.

Possible reasons for an increased need for assessment results and assessment tools are seen in:

- the concern about greenhouse gases and the knowledge about construction sector's potential in the reduction of GHGs may lead to the further development of regulatory and fiscal instruments
- the intention of the public sector to become a role model, leading to an integration of sustainability aspects into the procurement process
- the intention of cities to search for significant savings in energy consumption and GHGs, which may lead the increased consideration of sustainability aspects in building supervising processes
- an integration of sustainability aspects into the analysis and management of large building stocks (portfolio analysis and portfolio management concerning both private and public owners and developers), leading to a demand for different system variants for the use phase (sustainability assessment – in use)
- an integration of sustainability aspects into the risk analysis and valuation, leading to a demand for disaggregated assessment results

- the integration of sustainability aspects into the establishment of conditions for the financing and insurance of buildings leads to a demand from banks and insurance companies
- companies want to integrate information on the sustainability of their corporate offices and building stocks into the sustainability report and need information
- sustainable property funds give emphasis on a positive sustainability assessment as a condition for the purchase of objects
- an integration of sustainability aspects into planning and architectural competitions, leading to the question of suitability of rating systems for early stages of planning
- an integration into the planning process, which must lead to a development of new approaches
- sustainable buildings increase the user satisfaction and productivity.

The role of a sustainable construction sector has been assessed to be crucial for reaching the EU's long term 80–95% greenhouse gas emission reduction objective. According to the Roadmap for moving to a competitive low carbon economy in 2050 (COM (2011) 112[114]) the cost-efficient contribution of the buildings sector would be around 40 to 50% reduction in 2030 and around 90% in 2050. As the potential of the construction is seen big and there is a strong willingness to make it realize effective steering instruments will be needed. These will probably be used on all levels of steering. Especially regarding control and regulatory instruments as well as fiscal instruments and incentives, precise indicators and assessments methods are required. The more the focus is on GHGs the more clearly the methods have to measure it directly and comprehensively.

To significantly speed the renovation rate of existing building stock, both mandatory and voluntary steering processes will be needed. As the owners of big portfolios face the need to accelerate renovation processes that improve the energy performance and reduce the GHGs of the stock, they will need comprehensive methods with the help of which essential aspects – including environmental, economical and social aspects – can be simultaneously considered.

There is a further development of assessment methods and principles in two directions. On the one hand there is finally the transition from systems that focus mainly on the issues of environment and health protection to systems that take into account the issues of sustainability in their full breadth and depth. At the same time, a transition from predominantly qualitative assessment systems to predominantly quantitative assessment systems takes place. Concurrently, the state of the international and particularly European standardization has been evolved.

From the view point of effective steering mechanisms it is of utmost importance that the guidelines are clear and the tools needed in assessment and verification

[114] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0112:FIN:en:PDF

of results are available and accessible for all who need those in different stages of building processes. The adoption of further sustainability aspects to be part of control, regulatory and fiscal instruments and subsidies emphasizes the need of quantitative assessment methods and indicators and their accurate description on the basis of commonly agreed principles.

Regarding existing rating systems the further development of assessment systems has among others the following consequences:

- there is a great action over the introduction and testing of indicators related to the social and economic dimension of sustainability
- there is a great need for action in the field of integration of quantitative assessment procedures (including life cycle assessment and life cycle costing). At the same time, the need for LCAs results in a need for databases with LCA data for building products. The data must reflect the state of standardization in the EU.

Often the most important decisions regarding sustainable building are done in planning districts and in early stages of design. Such fundamental decisions as new building / renovation, location, main functions and volume have very significant impact on the environmental, economical and social impacts. The early decisions concerning the energy concept and energy supply solutions are essential. Important architectural choices – such as size, shape and orientation, and the main construction materials of the building – are done in the preliminary design phase.

In the past, the sustainability assessment was mostly used for marketing purposes. Now the situation has changed. The definition of project objectives and the process of planning are increasingly guided by the sustainability content.

This has changed the course of the sustainability assessment. Now this is predominantly applied as early as during the planning phase. No longer is in the foreground the examination of sustainability at the end of the planning but the "optimization" of sustainability during the planning. Particularly, when using sustainability assessments for supporting the planning and design process the relationships and interdependencies between the assessment criteria (which also represent planning goals) must be identified and considered in order to find the "optimal" solutions. To just examine the assessment criteria independently without considering the trade-offs and different effects among them, which is usually the case in the final assessment of sustainability, is not enough.

Often, assessment criteria have been evolved to assess technical features and characteristics in the direction of building performance assessment. The impact of technical characteristics and properties cannot always be assigned to one dimension of sustainability, as there are multiple effects. The solution of the methodological problem of a transition from a "double counting" to an assessment of multiple effects," will be seen as an important task for the coming years.

The current standards (developed by CEN TC 350) support the assessment and comparison of buildings but those give less support for the early stages of sustainable building. Regarding environmental assessment quantitative indicators following a life cycle approach are the primary indicators for the assessment of the environmental impact of buildings and products. However, those are not easy to use in preliminary stages of planning and design, where limited information is available.

More tools are needed for the design phase. Also tools that use simplified input are needed for early stages of design. To ensure the quality of the tools and comparability of the results, new standards may be needed at the same time.

Early stages of design might also benefit from guidelines and standards that characterize the process, list issues to be considered and outlines tasks of design for sustainable buildings.

The willingness to consider the sustainability aspects from the beginning of building and renovation projects also emphasizes the need for knowledge about benchmarks. Targets should be set for all relevant aspects of social performance and economical aspects with building level indicators.

Minimum requirements on the nature and scope of assessment criteria have been developed as well as calculation methods and rules. Although the current standards support the assessment and comparison of buildings, the standards, however, provide no information on benchmarks. There is a great need for the further setting-up and development (tightening) of benchmarks. As SuPerBuildings project has shown there is a lot of – especially local – understanding about the typical and best performance values of different building regarding certain sustainability indicators. However, much work is still needed to improve understanding of benchmarks and also to develop good processes for the determination of benchmarks

SuPerBuildings project has developed new understanding about core sustainability indicators with having the focus on the validity of indicators and assessment methods of indicators to provide comparable results. SuPerBuildings project has developed recommendations for the further development of existing sustainability assessment methods and tools. These enable the existing tools, while maintaining their independence, to improve their content. For this purpose the top down approach was developed, where the assessment criteria are derived from the areas of protection and the protection goals.

The project has also described and given recommendations for the use of indicators in different stages of building processes, together with building information models and in the connection of different steering instruments. The project brings this knowledge and recommendations for policy makers, local building authorities, sustainable building practitioners and tool developers for the further development of practical methods and tools that will be powerful when used in target setting, design, portfolio management, and municipal and other steering processes.

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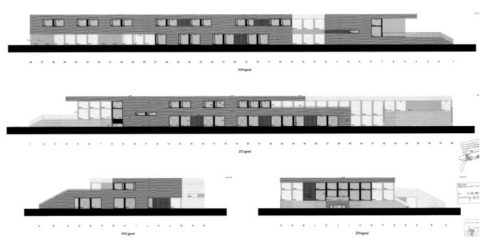
Appendix A: Case studies

Institution	Main field of expertise	Specific objectives	Selected case studies	
Fraunhofer **IAO** Institute for Industrial engineering, Germany	Data base services and information management tools	• Study role and needs of information management tools as enablers of common use of SBA	**ZVE-Center for Virtual Engineering** • Research and Office Building • 3600m2 • (planned) completion: end of 2011 • Supported by latest standards of information management tools and methods • DGNB certified	 Architect: Asplan (Kaiserlautern) in cooperation with UN Studio (Amsterdam)
Werner Sobek (**WS**) Stuttgart GmbH , Germany)	Integrated design	• Give recommendations on the planning of integrated design in certification schemes • Study the applicability of the SBA criteria in the different stages of the building process	**D10** • Residential building • 150m2 • Completed in 2010 • Triple Zero® concept [115] • Successful example of integral planning	 Architect: Werner Sobek, Stuttgart/Germany
YIT Kiinteistötekniikka Oy (Finland)	Building services (HVAC) – energy management	• Study the possibilities of using information received by means of Building Automation Systems (BAS) for the assessment of environmental indicators • In the long run use this information for the comparison and benchmarking of YIT buildings around Europe as well as target setting for new buildings	**2 sets of in-use students housing buildings:** Set A (5 buildings): • 15423 m^2 • Completed in 2010 Set B (11 buildings) • 17638 m^2 • Completed in 1977-1978	

[115] Zero Energy Building: Energy generated from regenerative sources on top and inside the building is at least equal to the entire primary energy requirements of the building.
Zero Emission Building: The building avoids CO_2 emissions as well as burning processes inside the building or on the property.
Zero Waste Building: No waste is produced when the building gets converted or deconstructed. At the end of their life cycle all building elements can be fully recycled without any components needed to be burnt or sent to a disposal site

VINCI Construction France	General contractor	• Test the **use** of a comprehensive set of sustainability indicators **in real building projects** • pilot the use of sustainability indicators from the viewpoint of **target setting and monitoring**	**Ensta Campus** • new students housing • 2275m^2 • Planned date of completion : end of 2011 • the building is also a pilot site for OXYGEN assessment versus HQE certification	 Architect: Hubert GODET
W/E consultants	consultancy firm for municipalites (policy making)	contribute to a better understanding of: • **CO_2 footprints** (embodied vs operational) • Methodological issues related to **land use** indicators • Use of CO_2 footprint and land use indicators in the context of **municipal policy**	**Sport en jeugdcluster Engelen** • Municipality of ‘s Hertogenbosch sport and youth center • 2200m2 • Completed in 2011 • SBA with GPR building	 Architect: Kuin en Kuin
		• Methodological issues related to renovation and depreciation of building parts	**Appollo house** • Renovation of an office building • 14.000 m^2 • Planned date of completion: end of 2011	

CASE STUDIES

One of the attention points in the development of Sustainabile Building Assessment (SBA) and benchmarking systems is the usability by different construction professionals, in different stages of the building process and for different types of buildings. Therefore, in order to confront the SuPerBuildings research work with these different perspectives, pilot test cases were carried out within the project by industrial members and SME’s of the consortium.

The general objective of those test cases was to test the results from and make recommendations to other parts of the work: WP4 (indicators and measuring methods for Sustainable building assessment) and WP5 (benchmarking). But apart from those general objectives, each of the pilots also approached their selected test case(s) with specific objectives related to their respective domain of expertise:

- **IAO**: Institute for Industrial Engineering (Germany): data base services and information management tools for SBA
- **YIT** Kiinteistötekniikka Oy (Finland): Energy management
- **VINCI** Construction France : Target setting and monitoring in construction projects
- Werner Sobek (**WS**) Stuttgart GmbH&Co (Germany): integrated design
- **W/E consultants** (Netherlands): Consultation for local governments (policy implementation).

In order to get a better inside on the background of the formulated recommendations, those test cases are briefly presented in the next section.
The general conclusions and recommendations derived from the case studies are then summarized by topic in the following sections:

- Sustainable building indicators
- The process of sustainable building assessment
- Comparability and benchmarking of sustainable building assessment results.

Pilot test cases were carried out, within the project consortium, by different members of the stakeholdersgroup (industry members and SMEs of the consortium), who each approach the test case from their own views and perspectives. A short overview of those case studies is presented in the table below

FEEDBACK ON SUSTAINABLE BUILDING INDICATORS

General remarks on indicator evaluation

As each member approached the test case from his own views and perspectives and with specific objectives, the methods and procedures for testing and evaluating the indicators developed within SuPerBuildings project were very different for the six case studies. The following sections give a short overview on the general approach of each case study as well as some general recommendations concerning usability, availability of data. of SBA indicators and how those can influence the performance of the building.

IAO's test case focused on the investigation of the potential of information management tools and other innovative solutions within SBA. Such tools like 3D modelling and VR (virtual reality) systems are considered to be very useful communication instruments between the different construction parties (e.g. architects, technical planners etc.) and the building users during the planning phase. In addition, the visual impression of the object and its surroundings can help to detect and eliminate planning mistakes before the construction of the building starts, leading to savings in costs and resources and higher user satisfaction.

In general the software solutions used in the case study already provide most of the data needed for indicator evaluation. Nevertheless improvements can be done, especially with regard to the collection of data. Indeed, the study recommends the establishment of a comprehensive database on building materials, components and technical equipment, containing information on embodied energy, embodied water use, embodied greenhouse gases and contained pollutants that is accessible for all relevant construction partners. Such a database would enable a faster and more precise building lifecycle assessment.

The main objective of YIT's test case was studying the possibilities of using information received by means of Building Automation Systems (BAS) for the assessment of environmental indicators, it therefore focused on indicators related to the operational phase of the building: energy use, water use, thermal comfort.

This case study underlines that: "when discussing about sustainability indicators, two main aspects have to be taken into account: What kind of knowledge do they provide and how can this knowledge be used for maximum benefit?" Also, in order to achieve sustainability targets the engagement of users is very important. Now, energy management systems that provide easy-to-understand and easy-to-use data and information on a building's energy (or water) consumption can support the engagement of users and can even influence user behaviour by making performance and consumption values easily available and apparent. Moreover, also basic knowledge on sustainable buildings in general can be communicated by means of such tools in order to educate users.

The purpose of the case study of VINCI Construction France was to test the use of a comprehensive set of sustainability indicators in a real building project. The author suggests the use of 12 indicators, divided into six impact and six anthropogenic indicators. Generally, the indicators identified in the case study correspond to the indicators assessed in SuPerBuildings, but some additional indicators were proposed as well.

In the case study of Werner Sobek (WS), the evaluation of sustainability indicators has been carried out with regard to integrated design, giving recommendations and applied examples for implementing integrated design in certification schemes. For this reason, the evaluation of indicators was qualitative and not quantitative. In order to enable a clear understanding of the processes related to the optimisation and assessment of a certain indicators, each indicator has been described as a pure process, whereas a process is defined as the transformation of input elements into output elements. The output of the indicator sums up all information that has to be submitted in order to prove the fulfilment of a certain requirement. The input is the information required in order to produce the output. Tools allow the transformation of inputs into outputs. In order to allow for a correct interpretation of the indicator results, the boundary conditions have to be clear.

With regard to the indicators further developed in SuPerBuildings, their usability was generally considered as good by WS. Nevertheless, the case study underlines that when evaluating the usability and applicability of sustainability indicators, the function and the size of the building, which has to be assessed, have to be taken into account, because these parameters influence time and effort that can be spent on assessment (e.g. in the case study D10 some calculations have not been carried out because of economical resources). Moreover, the importance of including a monitoring phase for the indicators related to the operational phase is highlighted, as well as the necessity to include a user survey for comfort indicators (indeed user perception cannot be measured as such, although it provides useful information for the optimisation of technical equipments).

Finally, in order to simplify the SBA process as well as to improve the performance of the building, WS suggests specifying in the indicator descriptions, which professions should be involved in the process and when the processing of the indicator should start.

The case studies carried out by W/E Consultants uses a different approach for the evaluation of the LCA based indicators (e.g. CO_2 emission). The author suggests the aggregation of nine environmental impact categories into one single indicator: the shadow price, which is depreciated over the expected life time according to the type of the building. The shadow price is a way to evaluate and weight emissions and environmental impacts. In addition, the resulting CO_2 emissions both from embodied and operational energy consumption are provided. As CO_2 emissions are very high on the political agenda, shadow price and CO_2 emissions (compared to a more extensive number of LCA indicators) are considered as a good set of output parameters for practical purposes (user friendly tools for building professionals). Land use is also seen as a relevant indicator, seen the fact that the Netherlands are so densely populated; however, it has not received much attention yet in the process of designing individual buildings.

Finally those test cases show that SBA can be useful not only to determine the environmental performance of a building after construction or renovation, but also within the decision making process.

Suggestions on additional indicators

Besides the sustainability indicators which have been selected and enhanced in the SuPerBuildings project, most of the case studies identified and suggested the introduction of additional indicators in order to assess the sustainability of buildings. Following section gives a brief overview of supplementary indicators.

The case study carried out by IAO points out an additional indicator regarding the “social acceptance” of large scale public constructions. This indicator would specifically help determining the general public support and acceptance in relation to these kinds of projects, which might eventually harbour potential for conflict.

VINCIs alternative approach of sustainability assessment offers a different point of view. 12 sustainability indicators, categorised in 6 impact and 6 anthropogenic indicators, are included in the general assessment method used in the case study. The six impact indicators (energy, water, natural resources, waste, GWP and eco-toxicity) measure the environmental impacts of a building in a multi-scale approach and correspond to the indicators selected in WP4.2 of the SuPerBuildings project. The six anthropogenic indicators evaluate the building quality referring to final user demands. Three of these indicators, namely human toxicity, thermal discomfort and operation costs, correspond in general with Chapter 5. The three additional anthropogenic indicators include aspects of spatial comfort, flexibility and amenities. Spatial comfort describes the available area per resident. The flexibility indicator assesses the rate of flexibility of the building, regarding its structure and use. The assessment of the flexibility indicator could be quite hard "since it depends on the possible financial investment in order to change the use and structure of the building". The indicator "amenities" expresses the proximity of public services, hospitals, stores, leisure facilities and community centres within a defined perimeter (e.g. 5 km) of the building.

The case study of Werner Sobek (WS) strongly supports the introduction of integral planning as supplementary indicator in order to ensure that integrated design is efficiently implemented in the project. Key aspects of integral planning include a preliminary phase for the development of the concept and the target setting, the improvement of the cooperation between the team members and a monitoring phase based on measurements, feedback of the users and adjustments that are done according to the results of the monitoring. Requirements and key success factors can be read in following section addressing the topics of integrated design and information management systems.

The two case studies of W/E Consultants suggest the introduction of an indicator which is called "shadow price". Basically, the shadow price is used determining environmental impacts of building materials. 9 different impact categories, namely abiotic depletion, global warming, ozone layer depletion, photochemical oxidation, human toxicity, ecological toxicity water, ecological toxicity terrestrial, acidification and eutrophication are evaluated and combined in one single impact indicator. According to the author the approach allows the comparison of scores on different sustainability topics. With regard to the interpretation of the assessment result, it has to be considered that the aggregated result strongly depends on the weighting of the separate indicators. The process of sustainable building assessment

This chapter mainly addresses the process of sustainable building assessment or more specifically recommendations and conclusions on the embedment of SBA in different phases of the building process, mainly from the viewpoint of integrated design, information management systems and monitoring.

Integrated design

The case study of Werner Sobek (WS) gives recommendations on the SBA process from the viewpoint of integrated design / integral planning. As mentioned before , integrated design is suggested as a supplementary indicator for SBA, because it includes all phases relevant for a comprehensive building assessment as well as all relevant actors of the building process.

Breaking down the process of integrated design, **Error! Reference source not found.**the case study presents recommendations concerning a successful integral design. Project members include architects, MEP engineers, (future/potential) residents and a sustainability consultant[116].

Moreover, the study points out several aspects to be considered for an integrated design.

First, during a preliminary phase the baseline concept should be developed based on regulations, benchmarks, standards and experiences. After that, improvements to this baseline can be proposed. As an example, at the earliest planning stage, the energy consumption of a building can be estimated using benchmarks and a baseline energy strategy can be determined. Based on this baseline, a set of options for a more energy efficient strategy can also be defined.. The two main goals of the preliminary phase according to the author are as follows. First, it allows that the sustainability targets are clearly understood and shared by all stakeholders involved in the project. Second, this approach may help to find the most suitable options and to integrate them as early as possible into the design. Although the development of several concepts and the involvement of a sustainability consultant from the earliest phase require more time and effort, it may save considerable resources and money in the operational phase.

Another aspect to be considered is the implementation of a monitoring phase and the so called post-occupancy evaluation during the operation of the building. Measuring the effective consumptions would provide a target-performance comparison and show potential optimisations and adjustments. Therefore, the monitoring concept should be developed in the design phase.

Moreover, for the fulfilment of the indicators related to the human comfort the involvement of users is necessary as the individual perception of users concerning quality standards cannot be measured. Therefore, in order to optimize the performance of the technical system during the operation phase as well as to improve the comfort of the users the author suggests to conduct the physical measurement in combination with the evaluation of the human perception, for example through interviews or surveys.

[116] Person responsible for guiding the planning team in the right direction and for the fulfilment of the sustainability criteria of the certification system. Actually, this task is often fulfilled by the certification assessor; however, it would better be a separate professional as the former is normally not involved from the earliest stage of the planning and is not always present in the planning meeting.

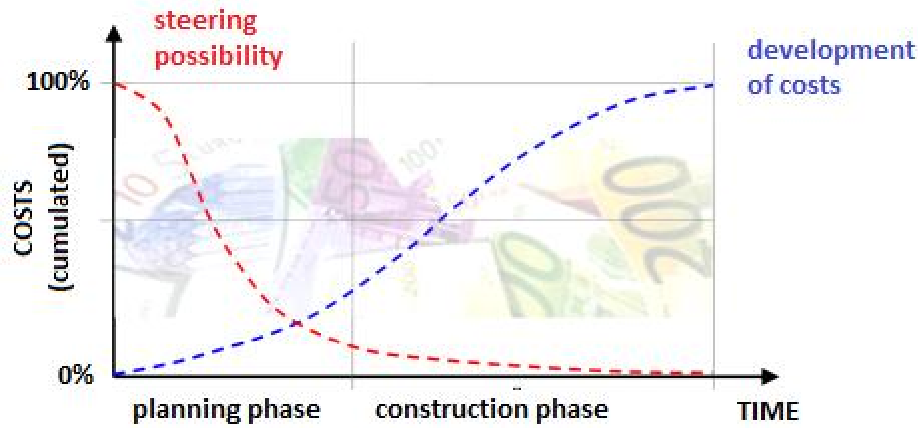


Figure 1. Possibility of steering of quality and costs within a building project (source: own representation based on Hageneder 2011, p. 27).

The key message of the study concerning the **integration of integral planning** (including the certification and monitoring process) **from the earliest stage of the project** is supported by Figure 5 that demonstrates the development of the building costs in connection to the contract period. In the early planning phase of a project, the possibility to influence and steer the project is considerably high. The more the project advances the bigger is the impact of amendments on the development of costs. In relation to the certification process, starting the process at the very beginning of the planning phase would help to define goals and main strategies. Additionally, the performance of the building can be improved by integrating sustainability issues in the design. Finally, required documentation regarding SBA can be managed more easily.

Nevertheless, the question how detailed and comprehensive the planning and assessment process should be, has to be decided with regard to the size, structure and function of the building (e.g. single/multi-storey building, multifunctional building, etc.), because certain calculations and simulations within a life cycle oriented building process require a great deal of time and/or costs.

Information management systems

The case study carried out by **IAO** focused on the use of information management systems in order to assess sustainability indicators. Several tools have been examined with regard to their use within SBA; the following section sums up the major findings:

3D modelling and VR systems are helpful communication devices for stakeholders involved in the construction of a building (e.g. architects, technical planning team, future residents, etc.). The systems provide visual (or even immersive) insight into construction objects and its surroundings. Hence occurring planning mistakes can be discovered in time and fixed before the building is constructed. As a result, waste is avoided and costs are saved, in addition to an increased customer satisfaction.

Such parametric 3D modelling tools can also be integrated in **Building Information Models** (BIM). "*A BIM is a software tool, which enables the creation and usage of consistent, coordinated, computable information concerning a building project during its design, construction and building operation and management*". [1, p.23] The model covers the entire lifecycle of a building and contains information on geometry, spatial relationships and its location as well as information on building components. In the course of the IAO case study expert interviews have been carried out, which as a result suggest not only the **connection of 3D modeling and VR systems with BIMs**, but also the enhancement of the BIM with **comprehensive databases on building materials**, components and technical equipments. Indeed, the connection and pooling of databases would simplify and accelerate the work flow within the project.WS also points out that the integration of EPD data into the databases of simulation software would be helpful for the evaluation of lca-based indicators (e.g. embodied water and energy use).

Considering that most construction companies are small and medium-sized companies with limited resources, **services on 3D modeling and the use of BIMs**, including comprehensive databases could be developed and offered to construction enterprises. In addition, these services could also be offered to future building owners and users in order to allow for a realistic impression of the building before it is constructed. Such building modeling services can also be provided to sustainability auditors in order to improve and fasten the process of assessment.

Moreover, as information management systems rely on comprehensive databases and a good communication structure; standardized, up-to-date technologies and information are required. However, the construction sector is considered to have no distinct **standards for workflows, communication, information as well as data exchange and formatting**. Processes are run for each building project individually, making standardized data collection and comparability difficult. The study describes the so called *"struggle of the construction industry (mostly consisting of small and medium sized companies with limited personal and financial resources) to modernise itself with help of innovative technology and process operations"*. The aim to establish high-level standardization processes has to be a priority. Possible solutions for standardization include:

- The definition and standardization of interfaces concerning data transmission and data formatting
- Frontloading (i.e. bringing together all relevant partners as early as possible)
- The set up of communication principles between the stakeholders.

The case study of **YIT** identifies the possibilities to use the information received by a **Building Automation System** (BAS) for the assessment of environmental indicators of buildings. The BAS monitors and records hourly consumption data relating to heating, electricity, domestic water and hot water. Main problems in the course of the assessment arise from incomplete monitoring and reporting systems, redundant amount of general data and a lack of precise and specific consumption data. Moreover, the more work is needed in the collection of the needed data, the less realistic is the use of an environmental indicator.

Therefore, the study suggests the use of monitoring systems, which should help to avoid unnecessary efforts with data collection and processing. Moreover, additional sensors and meters can provide a deeper understanding of the building's performance and for example also help to detect water leakage quickly and thus save costs and resources. Finally, the author suggests the use of easy-to-understand energy management systems which can positively influence the behaviour of residents

Comparability and benchmarking of sustainable building assessment results

This chapter focuses on findings and recommendations with regard to the comparability of sustainability assessment indicators as well as requirements for performance benchmarking in general. This section is primarily based on the case study of YIT, giving valuable recommendations on specific aspects of comparability of indicators and benchmarking (importance of knowledge on contributing factors, selection of reference units, use of relative indicators etc). In addition, the chapter highlights two possibilities of presenting the results of the sustainable building assessment, developed in the light of principles that allow for meaningful benchmarking (one gained from the YIT case study, the other one based on the VINCI test case).

Contributing factors and functional equivalent

One of **YIT**s main goals has been showing the possibility to use information gained by means of BAS (Building Automation Systems) for the assessment of environmental indicators. In the long term YIT aims for developing methods for using similar data gained from BAS installed in buildings all around Europe in order to compare and benchmark buildings easily. In the case study at hand, YIT uses the so called internal RAMI building monitoring system which is mainly used for monitoring and maintaining purposes.

As one of the key findings YIT stated, that for the interpretation of indicators, knowledge about the contributing factors (e.g. influence of user habits, regulatory framework, technical building setup and operation) is necessary, otherwise the interpretation of results as well as comparison is not meaningful. Also the contradictive results of the case study revealed that there is a lack of knowledge about the formation of the collected indicators: Indeed, the study examined two blocks of buildings of very different age (constructed respectively in 1977/78 and 1993), and curiously the buildings of the younger group showed a remarkably higher heating energy demand than the older ones. This might be a result of inefficient or incorrectly scaled and maintained heating systems or unreasonable user habits, but there may also be other reasons like for example changes of the regulatory framework over time. Over the years, the general floor height has raised which of course influences the results of energy consumption indicators referring to the area of the building as reference unit. Also building-integrated technical services have not only been improved, but also their operating practices have changed. Thus it is possible that older buildings with only natural ventilation might need less heating power than better insulated newer buildings with forced ventilation.

In light of that, the definition of a functional equivalent of buildings (e.g. residential, commercial etc.) is recommended, including information on geometrical features, use of building-integrated technical systems, user habits or extensive renovations. Moreover, in order to establish a benchmarking system, common accepted definitions of sustainability and performance assessment are required.

Reference units

The test case carried out by YIT also highlighted the importance of the reference units with regard to the interpretation of assessment results.

The reference unit of energy consumption indicators usually is [kWh/m²*a]. Within real estate, the area of a building is one of the most important reference values, but the methods for calculating gross and net areas of buildings differ from country to country. In order to allow for a meaningful indicator creation, calculation methods have to be cleared.

Furthermore, differences in actual height of the floor or volume of the building strongly affect per area indicators. Two buildings with the same area, but different floor height (volume) consume a different amount of energy, as the actual volume of the building is heated and not its area. Whereas the reference unit [kWh/m²*a] represents more the operational efficiency of energy use, considering the question whether the available area is efficiently used, the reference unit [kWh/m³*a] represents more the absolute value of heating consumption. As a consequence, it is advisable to use both reference units for energy consumption indicators.

With regard to water consumption indicators, the reference unit [m³/person] is considered to be useful. Nevertheless, with regard to the interpretation of the indicator difficulties may occur if the number of persons is not known. Furthermore, people of different age, income, education or occupation might have different habits that influence the indicator results (see also the importance of knowledge on contributing factors in chapter 0**Error! Reference source not found.**).

In case of water, YIT also states that monitoring of water consumption is essential within building energy management systems, based on both cold and warm water meters. At the same time it is important, that values are available upon request – also historical data for comparison and perspective. Such actions can help to detect leakages quickly and thus save costs and resources, as even small leakages can lead to the loss of large amounts of water over time.

Relative indicators

For the purpose of monitoring and benchmarking YIT suggests to supplement the measurement of quantitative indicators (e.g. energy consumption in [kWh/m^2*a] and/or [kWh/m^3*a], water consumption given in [m^3/person] etc.) with additional markers/meters that show for example the deviation of measured values from the national standard or average. Presuming that the relative indicators presented in the RAMI system, which was used for the YIT case study, are optimally configured it would be possible to compare different building performances despite differences in age, condition, building-integrated technical systems or other characteristics regarding the regulatory environment at the time of construction. Of course this means previously agreed understanding of the optimum levels, but would allow to discard complicated analysis of the building and its components.

In the YIT case study, the indicators concerning indoor air quality / thermal comfort were measured and presented as such relative indicators. In the RAMI system they are expressed as percentage deviation from preset optimum levels of e.g. indoor temperature or CO_2 concentration in more sophisticated cases. If the measured value differs from the normative one more than the allowed deviation, the performance assessment of the indicator is lowered. In doing so, the meter does not present the exact value of e.g. temperature, but it shows the quality of performance to stay within the allowed limits that are based on the Finnish indoor air quality classification.

Presentation of results

The building signature – VINCI

In order to allow comparisons of different buildings, **VINCI** introduces a radar profile as one possible solution. The radar profile is based on the concept of “building signature”, which summarizes the results of the quantitative assessment of the economic, environmental and social indicators (see chapter 0), aiming to compare them with a regional average. Accordingly, this would allow the comparison of different types of building as well as different local conditions. In the radar chart the blue radius represents the regional reference; every result within this radius implies a better performance of the indicator assessed. Moreover, this building rating method is also designed to be periodically updated, in order to enable the positioning of the building in a time scale.

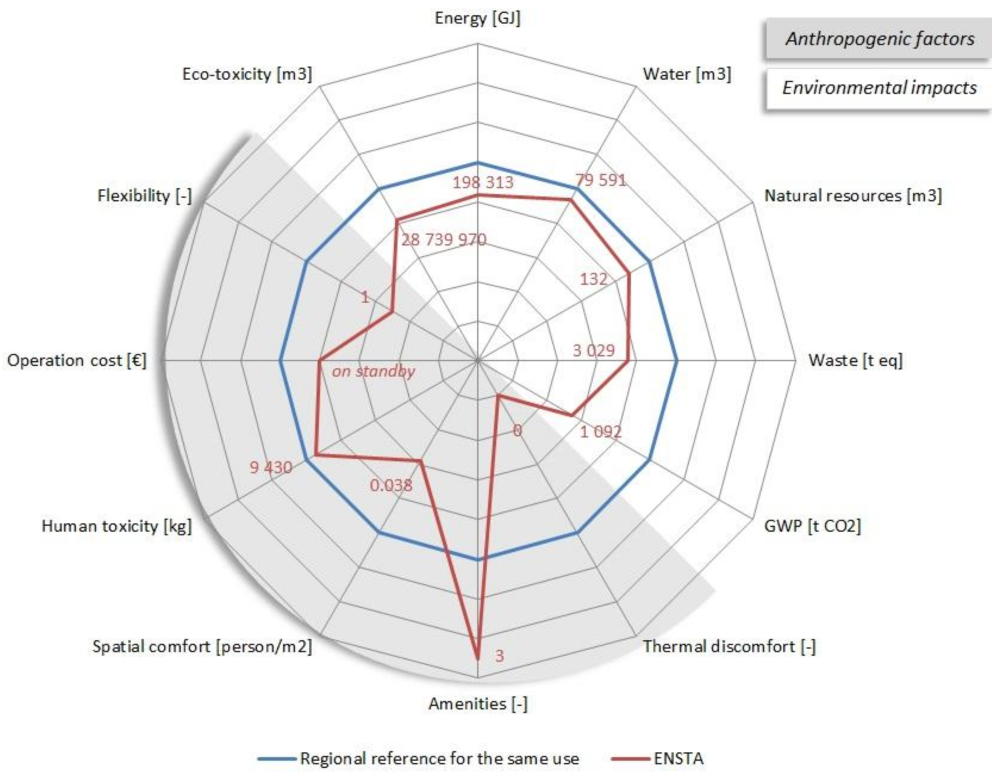
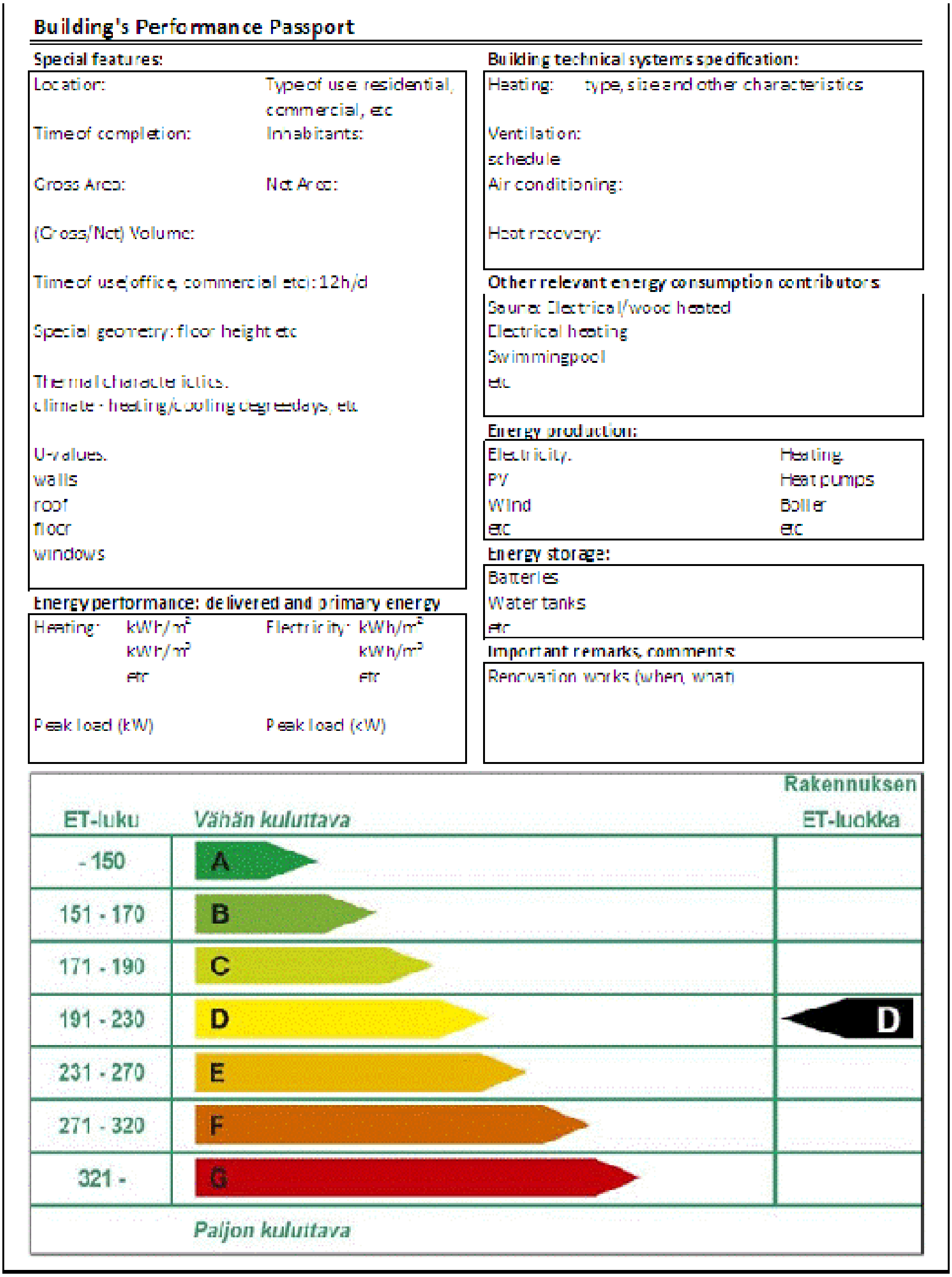


Figure 2. Radar profile representing 12 environmental impacts (source: VINCI Construction France).

Building's Performance Passport – YIT

Taking into account the challenges with regard to the lack of knowledge on contributing factors, the selection of reference units etc., YIT suggests the so called "BPP – Building's Performance Passport" (shown in Figure 7). BPP would include basic quantitative indicators supplemented with thorough descriptive information of core contributors which affect the consumption and total performance. Information about contributors should be gathered onto a single page and presented together with quantitative indicators and thus allow for a meaningful benchmarking.



Building's Performance Passport

Special features:

Location: | Type of use: residential, commercial, etc

Time of completion: | Inhabitants:

Gross Area: | Net Area:

(Gross/Net) Volume:

Time of use(office, commercial etc): 12h/d

Special geometry: floor height etc

Thermal characteristics:
climate - heating/cooling degreedays, etc

U-values:
walls
roof
floor
windows

Energy performance: delivered and primary energy

Heating: kWh/m² | Electricity: kWh/m²
kWh/m² | kWh/m²
etc | etc

Peak load (kW) | Peak load (kW)

Building technical systems specification:

Heating: type, size and other characteristics

Ventilation:
schedule
Air conditioning:

Heat recovery:

Other relevant energy consumption contributors

Sauna: Electrical/wood heated
Electrical heating
Swimmingpool
etc

Energy production:

Electricity: | Heating:
PV | Heat pumps
Wind | Boiler
etc | etc

Energy storage:

Batteries
Water tanks
etc

Important remarks, comments:

Renovation works (when, what)

ET-luku	Vähän kuluttava	Rakennuksen ET-luokka
- 150	A	
151 - 170	B	
171 - 190	C	
191 - 230	D	D
231 - 270	E	
271 - 320	F	
321 -	G	
	Paljon kuluttava	

Figure 3. Example of Buildings Performance Pass (source: YIT).

Conclusion

The case studies show the usability of the indicators developed within SuPerBuildings, but also provide valuable feedback on how to enhance SBA process, benchmarking and comparability of results.

The case study on information management systems concludes that the needed information management systems for SBA are already available; however, the linkage and connection of those tools could be enhanced. Indeed, as shown also by the case study on integrated design, industry wide standards for workflows, communication, information and data exchange, as well as data formatting would improve the SB assessment and construction process.

Amongst others, the evaluation of life cycle based environmental indicators (embodied water, energy and CO_2) would be greatly facilitated by the availabilty of one comprehensive database with EPD's of materials, components and technical equipment. Especially if such database is included in existing simulation software and BIM.

Several case studies also underline the importance of the planning phase. Indeed, the earlier sustainability targets are set and the sustainability assessor joins the building team, the more efficient the SBA process and the easier targets can be met without additional costs. Moreover, case studies point out the importance of the iterative process during the design phase and how SBA can support the decision making process not only in construction but also in renovation projects.

Another important aspect indicated by the case studies is the implementation of a monitoring phase (to be planned during the design phase) and a post-occupancy evaluation during the operation of the building. Indeed, this provides target-performance comparison, shows potential optimisations and adjustment of technical systems and therefore makes it possible to improve user comfort.

Moreover, as indicated by one of the case studies the results from monitoring systems can be used to calculate environmental indicators and therefore for the benchmarking of buildings across Europe. Also, the use of easy-to-understand monitoring systems can positively influence the behaviour of residents and therefore reduce energy and water use. Indeed as pointed out by different case studies, user behaviour is a determining factor for the real performance of buildings.

Finally, regarding benchmarking and comparability of results, solutions mentioned by some case studies in order to improve the comparison of different types of buildings as well as different local conditions are:

- The use of relative values (expression of results as a % deviation from a target value),
- a Building Performance Pass which gives additional information on contributing factors affecting the performance of the building,
- or the use of a so-called building signature which represents the outcome of 6 user and 6 impact related indicators in a radar profile, together with a regional reference level.

Appendix B: An overview of sustainability indicators included in different assessment methods

An overview of the sustainability indicators included in different assessment methods. A coloured cell indicates that the issue is covered by a tool. Consequently, columns with a lot of blank cells indicate that the issue is not commonly covered by existing tools, and columns which are almost completely coloured indicate that the issue is well covered and could eventually be considered as a core indicator.

Table 1. Environmental issues and indicators within the existing national building evaluation tools.[117]

ENVIRONMENTAL INDICATORS	CONSEQUENTIAL INDICATORS															
	land use and ecology					construction phase		materials		primary energy consumption (operational)						
METHODS	minimise land consump- tion	re-use of land	ecological value of the site	mitigate impact on site ecology	enhancing site ecology	limit impact on environment	limit impact on neighbour- hood	rational use	source materials with low impact	heating	domestic hot water	lighting	internal transport	renewable energies	ventilation
BREEAM & CSH															
BNB/DGNB															
promisE															
HQE															
Valideo															
CASBEE															
LEED															
Sbtool CZ															
klima:aktiv Gebaüdestandard															
TQB															
GPR Gebouw															

[117] Correction to the table Tables 1, 2 and 3:GPR Building does NOT evaluate:
- Minimise land use, LCI indicator: land use

GPR Building DOES include
- Rational use of materials, Source Materials with low impacts , Environ- mental management

Table 2. Environmental issues and indicators within the existing national building evaluation tools.

ENVIRONMENTAL INDICATORS	CONSEQUENTIAL INDICATORS					LCA INDICATORS									LCI INDICATORS			
	water			waste	management and risk	LCA indicators									LCI indicators			
METHODS	minimise surface runoff	minimise water consumption	limit onsite water pollution	waste production during use phase	environmental management and geophysical risk	global warming potential	ozone depletion potential	photo-chemical ozone creation potential	acidifica-tion potential	eutrophica-tion potential	abiotic depletion	biotic depletion	human toxicity	eco-toxicity	land use	depletion of resources	water consump-tion	waste
BREEAM & CSH	■	■	■	■	■	■	■											
BNB/DGNB		■			■	■	■	■	■	■								
promisE		■		■	■													
HQE	■	■	■	■	■	■	■		■									
Valideo	■	■	■	■														
CASBEE	■	■	■	■	■	■												
LEED	■	■	■	■														
Sbtool CZ		■		■	■	■			■	■								
klima:aktiv Gebaüdestandard		■		■		■	■	■	■	■	■	■	■	■				
TQB		■		■	■	■	■	■	■	■	■	■	■	■				
GPR Gebouw		■	■			■	■	■	■	■	■	■	■	■	■	■		

Table 3. Overview of available economic issues.

ECONOMIC INDICATORS	value management			whole life costs	asset value		maintenance	local and regional impacts	
METHODS	service life	planning and preparation	manage-ment	reduce whole life costing	building adaptability	improve building user productivity	ease of maintenance	changes in economic system	housing affordability or commercial viability
BREEAM & CSH									
BNB/DGNB									
promisE									
HQE									
Valideo									
CASBEE									
LEED									
Sbtool CZ									
klima:aktiv Gebaüdestandard									
TQB									
GPR Gebouw									

Table 4. Overview of available social issues.

SOCIAL INDICATORS	comfort and health						safety and security		user wellbeing		accessibility		
METHODS	visual comfort	thermal comfort	acoustic comfort	vibrations	indoor air quality	water quality	building safety assessment	building security	conside-ration of user's needs	quality of the building as a place to live and work	ability of users with physical impair-ments to use the facility	access to green and open spaces	access to public services and amenities
BREEAM & CSH	■	■	■		■	■	■			■	■	■	■
BNB/DGNB	■	■	■		■		■		■	■	■	■	■
promisE	■				■								■
HQE	■	■	■		■	■	■			■	■	■	■
Valideo	■	■	■		■	■		■	■	■	■	■	■
CASBEE	■	■	■		■			■		■	■		
LEED	■	■	■		■								■
Sbtool CZ	■	■	■		■			■			■	■	■
klima:aktiv Gebaüdestandard		■			■						■		■
TQB	■	■	■		■	■	■	■		■	■	■	■
GPR Gebouw	■	■	■		■						■	■	■

Appendix C: Collected energy data

Type of data received from Partners:
The table below provides an overview of the type of data received, i.e. a mix of primary energy figures and final energy figures, plus some examples of LCA results. In order to make some tentative comparisons, those figures where used where the most figures of the same unit were available.

	house new	house exist	office new	office exist
Austria	annual E final	annual E final	annual E final	annual E final
	annual E prim.			
Belgium	annual E prim .	annual E prim	*(not known)*	annual E prim
Czeck Republic	2x annual E prim.			
	annual LC E prim,			
Finland	annual E final	annual E final	annual E final	annual E final
France	annual E prim.	annual E final	annual E prim,	annual E final
	annual LC E prim (?)	annual E prim	annual E prim with embod.	annual E prim
Germany	annual E prim	annual E final	annual E prim	annual E final
Spain	annual E final	annual E final	annual E final	annual E final

colour key	annual final Energy
	annual primary Energy
	other/ none

Performance Values Received and Juxtaposed

Hous-ing exist.	Primary Energy		Final Energy				
	Begium	**France**	**Austria**	**Finland**	**France**	**Germany**	**Spain**
unit	kWh or MJ	kWhpe/(m².year) primary energy – does not take into account specific user energy con-sumption (plug-in appliances)	kWhfe/(m².year) (m2 – gross floor space; heating demand of the building, defined by OIB RL6, 2007))	kWh/gross-m²/year – delivered ener-gy, takes into account speci-fic user energy consumption (plug-in appli-ances) and heating, overall gross floor area 265 milj.m2	kWhfe/m²/year – final energy, takes into account specific user energy consumption (plug-in appli-ances)	kWhfe/ m2,	kWhfe/ (m².year)
OPERATIONAL ENERGY USE	91000 MJ 270 kWh/m²	250	190	230	203	212	129
Heating	200 kWh/m² 100-120-150 kWh/m² 50% of energy use	210	x	135	132		55
Hot water	3800 kWh 35 kWh/m² 10% of energy use	40		45	23	212	60
Cooling A/C				50	34.5 + 13.2 for cooking		14
Ventila-tion	0 kWh/m²	8					
HVAC control and auto-mation							
Lifts / escala-tors / fire, security and com-muni-cation							
Lighting							

Housing exist.	**Primary Energy**		**Final Energy**				
	Begium	**France**	**Austria**	**Finland**	**France**	**Germany**	**Spain**
Use/user specific electr. consumption (plug-in appliances)	35 kWh/m² 3000-3300 kWh – 40% of energy use						
Describe with text exactly what building type the value refers to	existing houses in Belgium (Flanders) – all types	Existing non-residential building stock (statistics)	publication from "Wien Energie	Existing housing stock (single family, row-houses, apartment buildings).	lower value for blocks of flats, higher value for detached single family/ duplex houses		
type of perfor-for-mance value – enter 'X'							
statistical value – deg. day adjusted	x					x	
statistical value – unadjusted	x						
calculated value			x				
political target							

Hous-ing exist.	Primary Energy		Final Energy				
	Begium	France	Austria	Finland	France	Germany	Spain
factors influ-encing the values							
Climate	determines heating demand		x				
Loca-tion (geo-graph-ical, altitude, urban or not)	different regions in Belgium with different dwelling types and distribu-tion						
Type of building			x			(different sta-tistical values based on diff-erent house-hold sizes – 175 f. blocks of flats, 195 f. single family dwellings)	
Age of building	older dwell-ings are less insulated and thus have higher heating demand					(not captured)	
Source of value (please specify)	study on environmental impact of dwellings in Belgium + set up of user pro-files for energy use (average and best case) statistics on total energy use of house-holds in Bel-gium with di-fference bet-ween different energy sour-ces (all recal-	INSEE	Austrian building directive OIB RL6 "energy and thermal insulation"; April 2007	Energy statis-tics for 2009, Statistics of Finland	Energy building statistics for 2007 ("Les chiffres clefs du bâtiments 2009", CEREN)	VDI 3807 statistics 1992	Estrategia Ahorro y Eficiencia Energética España 2004-2012 Sector Edificación (Ministerio de Economía) , Potential Ener-gy Savings and CO_2 Emis-sions Re-duction from Spain's exist-

Housing exist.		**Primary Energy**			**Final Energy**				
		Begium	**France**		**Austria**	**Finland**	**France**	**Germany**	**Spain**
		culated to MJ and kWh) statistical data available from different sources							ing residential buildings in 2020. WWF
General Comments		collection of available statistical data on energy use in dwellings in Belgium or its regions			publication from "Wien Energie	benchmark values are based on the energy statistics of Finland, share of sub-uses (household electricity, DHW) are expert estimations by VTT, operational DE other (=heating +hot water) sources (150 kWh/m2) is divided as follows: DH 69 kWh/m2,a, light fuel oil 34 kWh_oil/m2,a and wood 47 kWh_wood/m2, a. Values proportional to overall gross floor area (265 milj.m2) of the housing stock. Fuels calculated with lower heating values. District heating as energy on building site. Electric heating included in DE Electricity.		values are old, but still comparable to values quoted (on one-off basis) in literature, El. value likely to have increased, due to greater use of electronic devices	

Housing NEW	Primary Energy						Final Energy			
	Austria	Belgium (regs)	Belgium (stats)	CR (passive)	France (regs)	Germany	Spain	Austria	Czech R low E house	Finland
unit	kWhfe/(m².year) (m2 - gross floor space; heating demand of the building, defined by OIB RL6, 2007))	kWh/m²	kWh/m²/y	kWhpe/(m²year)	kWhpe/(m².year) - Primary energy, net area, does not take into ac-count specific user energy con-sumption (plug-in appliances)	kWh_{pe}/(m².year)	kWhfe/(m².year)	kWhfe/(m².year) (m2 - gross floor space; heating demand of the building, defined by OIB RL6, 2007))	kWhfe/(m²year)	kWh/net-m²/year – de-livered energy, takes into ac-count specific user energy consumption (plug-in applian-ces) and DH
OPERATIONAL ENERGY USE	100	130	170	60	50	70	49	66.5	50	129
Heating	x	60 -15 - 25	60-120	60	22.8	x	23.8			55
Hot water	x	x	25		12.8	x	18			35
Cooling A/C		x					7.2			
Ventilation		x			4					
HVAC control and automation					3.3					
Lifts / escalators / fire, security and communication										39
Lighting					7					
Use/user specific electr. consumption (plug-in appliances)			25							
Describe with text exactly what building type the value refers to.		all newly-built dwellings - EPB legislation - evaluation tools Referentieel Duurzame Woning + Valideo	all new dwellings		BBC-Effinergy label houses and office buil-dings - It will cor-respond to the future Standard regulatory "RT2012"					

Housing NEW	Primary Energy						Final Energy			
	Austria	Belgium (regs)	Belgium (stats)	CR (passive)	France (regs)	Germany	Spain	Austria	Czech R low E house	Finland
type of values										
statistical value - deg. day adjusted			x							
statistical value - unadjusted			x		x					
calculated value	x	x				x	x	x		x
political target		x		x					x	
factors influencing the value										
Climate	x	energy demand depends on climate conditions	energy demand depends on climate conditions		Differents climates in France,		x	x		
Location (geographical, altitude, urban or not)		regulation limits depend on region			Performance targets are not the same acording to climat and altitude		x			
Type of building	x	all dwelling types					x	x		
Age of building		here, new buildings are envisaged	here, new buildings are envisaged				x			
Source of value (please specify)	Klima:active	EPB legislation + Referentieel Duurzame Woning + Valideo Referentieel	statistical data - Isoterra - PHHP - study on representative dwellings in Brussels Capital Region		observatoire BBC effinergie	typical value for current building regs. Stated in various sources e.g. "Das dena-Gütesiegel Effizienzhaus – Regelheft mit Stand vom 01.07.2010"	Spanish Building Regullations (Escala Calificación Energética Edificios de Nueva Construcción)	The figure of 66,5 kWhpe/(m².year) refers to the Austrian building directive "energy and thermal insulation" (OIB RL6).		National Building Code D3 Rakennusten energiatehokkuus 2012

Housing NEW	Primary Energy						Final Energy			
	Austria	Belgium (regs)	Belgium (stats)	CR (passive)	France (regs)	Germany	Spain	Austria	Czech R low E house	Finland
General Comments			statistical data on energy use within newly-built dwellings are collected and presented here				The benchmark is in practice calculated for each single building, for the parand the certification is based on a reference buildingBorderline between categories A and B for a typical building in Madrid.	This means that all residential buildings in Austria have to cover this standard. As for the requirements in funding schemes are higher, the average energy performance of new residential buildings in Austria is a bit better. At the moment, the OIB RL6 is beeing adapted. The new OIB RL6 will include higher benchmarks.		The benchmark values are based on the maximum allowed energy use for the building using district heating system, according to the building code 2012

<table>
<tr><th rowspan="2">Office exist .</th><th colspan="2">Primary Energy</th><th colspan="5">Final Energy</th></tr>
<tr><th>Belgium</th><th>France</th><th>Austria</th><th>Finland</th><th>France</th><th>Germany</th><th>Spain</th></tr>
<tr><td>unit</td><td>kWh/m²</td><td>kWhpe/(m².year) primary energy – does not take into account spe-cific user energy con-sumption (plug-in appliances)</td><td>kWh/m²a gross floor area</td><td>kWh/gross-m²/year – de-livered ener-gy, takes into account specific user energy con-sumption (plug-in appliances) and DH</td><td>kWhfe/(m².year) final energy, does take into account user specific electric energy used by appliances</td><td>kWhfe/ m2</td><td>kWhfe/ m2</td></tr>
<tr><td>OPERATIONAL ENERGY USE</td><td>218</td><td>225</td><td>241</td><td>204</td><td>211</td><td>135</td><td>170</td></tr>
<tr><td>Heating</td><td rowspan="2">133.5</td><td>196</td><td>x</td><td>123</td><td rowspan="2">126</td><td rowspan="2">135</td><td>47</td></tr>
<tr><td>Hot water</td><td>29</td><td></td><td>7</td><td>7</td></tr>
<tr><td>Cooling A/C</td><td>26</td><td></td><td></td><td rowspan="6">74</td><td rowspan="6">85</td><td rowspan="6">105</td><td>45</td></tr>
<tr><td>Ventilation</td><td>6</td><td></td><td></td><td></td></tr>
<tr><td>HVAC control and automa-tion</td><td>8</td><td></td><td></td><td></td></tr>
<tr><td>Lifts / escalators / fire, security and communi-cation systems</td><td>4.5</td><td></td><td></td><td></td></tr>
<tr><td>Lighting</td><td>17</td><td></td><td></td><td>71</td></tr>
<tr><td>Use/user specific electr. consump-tion (plug-in applianc-es)</td><td>23</td><td></td><td></td><td></td></tr>
<tr><td>Describe with text exactly what building type the value refers to</td><td>number of representative offices in the Brussels Capital Region</td><td></td><td>The figure of 30,0 kWhfe/(m3.year) refers to the Austrian building directive "energy and thermal insulation" (OIB RL6). This means that all existing office buildings in Austria have to cover this</td><td>Existing office stock. Typical District heating office. Data obtained and compiled from several sour-ces: Kuntaliitto kulutus-tilasto 2009, Korhonen A, Pihala H, Ranne A Ko-titalouksien ja toi-mistotilojen laite-sähkön käytön te-</td><td>Existing non-residential building stock (statistics)</td><td></td><td></td></tr>
</table>

Office exist .	Primary Energy		Final Energy				
	Belgium	France	Austria	Finland	France	Germany	Spain
			standard after renovation. The figure only contains the heating energy demand.	hostaminen. Työtehoseuran julkaisuja 384. Helsinki 2002, Statistics of Finland, Aalto Kirsi-Marja: RAKENNUSTEN LÄMMITYSENERGIAN LASKENTAMALLI Kehityshankkeen esiselvitys Opinnäytetyö Mikkelin AMK Ympäristöteknologian koulutusohjelma 2009 and authors expert opinion			
factors influencing the values							
Climate	climate determines heating demand						
Location (geographical, altitude, urban or not)	Brussels capital region						
Type of building	difference between public and private buildings						
Age of building	age determines insulation degree and thus heating demand						
Source of value (please specify)	study on representative dwellings and offices in the Brussels Capital Region	INSEE	The figure of 30,0 kWhfe/(m3.year) refers to the Austrian build-ing directive "energy and thermal insulation" (OIB RL6). This means that all existing office buildings in Austria have to cover this standard. The figure only con-tains the heating energy demand.	Energy statistics for 2009, Statistics of Finland, Kuntaliitto, the energy use by building type for the service buildings is not very well known in Finland, data may contain some inaccuracies	Energy building statistics for 2007 ("Les chiffres clefs du bâtiments 2009", CEREN)	BMVBS: Bekanntmachung für Regeln und der Vergleichswerte im Nichtwohngebäude bestand 2009, offices with ac,	WWF Guia Ahorro y Eficiencia Energética en Oficinas (2008), DATAMINE project , Spanish Input (Intelligent Energy Europe Programme, 2009)

Office exist .		Primary Energy			Final Energy				
		Belgium	France		Austria	Finland	France	Germany	Spain
General Com-ments						The share of sub-uses (electricity, DHW, space heating) are expert-estimations by VTT	relatively old values, probably still stands for existing buildings, but+ electric values do not sufficient-ly account for IT	these values are used as medium value for Energy Performance Certificates for offices with ac (consumption based), the heating value is similar to that from a stu-dy dating back to the 1990ies which is quoted in the re-putable en-gineering guide VDI 3807.	

Offices NEW	Primary Energy		Final Energy		
	France	Germany	Austria	Finland	Spain
unit	kWhpe/(m².year) primary energy- does not take into account specific user energy consumption (plug-in aplliances)	kWhpe/(m².year)	kWhfe/(m3.year) (m3 – gross volume; heating demand of the building, defined by OIB RL6, 2007))	kWh/net-m²/year – delivered energy, takes into account specific user energy consumption (plug-in ap-pliances) and DH	???
OPERATIONAL ENERGY USE	50	100	22.75	150	96.5
Heating	12	40	22.75	79	29
Hot water				6	5
Cooling A/C	11	0		65	24
Ventilation	8	30			
HVAC control and automation	5				
Lifts / escalators / fire, security and communi-cation systems					
Lighting	14	30			39
Use/user specific electr. consump-tion (plug-in appli-ances)					
Describe with text exactly what building type the value refers to	BBC-Effinergy label houses and office buildings – It will correspond to the futur Standard regulatory "RT2012"		The figure of 22,75 kWhfe/(m3.year) refers to the Austrian building directive "energy and thermal insulation" (OIB RL6). This means that all new office buildings in Austria have to cover this stan-dard. The figure only contains the heating energy demand.	values are represen-tative for typical new office building, source: National Building Code D3 2012. The unit for the specific values is "net heated area". Hea-ting energy (DE other) district heating, which is the most common heating source for the new office buildings in Finland	WWF Guia Ahorro y Eficiencia Energéti-ca en Oficinas (2008), ECOFYS Report Energy Savings in Spanish Buildings – 2005

Offices NEW		Primary Energy			Final Energy		
		France	Germany		Austria	Finland	Spain
type of performance value – enter 'X'							
statistical value – deg. day adjusted							
statistical value – unadjusted		x					
calculated value			x		x	x	
political target							
factors influencing the values							
Climate					x		
Location (geographical, altitude, urban or not)							
Type of building					ratio of surface and volume		
Age of building							
Source of value (please specify)		observatoire BBC effinergie	ENOB (EnOB-Monitoring)		Austrian building directive OIB RL6 "energy and thermal insulation"; April 2007	National Building Code D3 Rakennusten energiatehokkuus 2012	WWF Guia Ahorro y Eficiencia Energética en Oficinas (2008), ECOFYS Report Energy Savings in Spanish Buildings,2005
General Comments			EnOB is a research initiative for energy-optimised buildings, predominantly offices. – the value can be seen as a general target for new building, however this is not a mandatory value (flexible benchmark calculation based on reference building for building regs)			The benchmark values are based on the maximum allowed energy use for the building using district heating system, according to the building code 2012	

Appendix D: Summary of the responses from SuPerBuildings partners

The project made an inquiry among the project group in order to assess the existing Sustainable Building steering mechanisms in the SuPerBuildings partner countries. The aim was

- to summarise the information about the instruments in use
- to collect proposals from the SuPerBuildings partners about interesting and effective steering mechanisms.

The questionnaire sent to all SuPerBuildings partners included the following outline of the steering mechanisms:

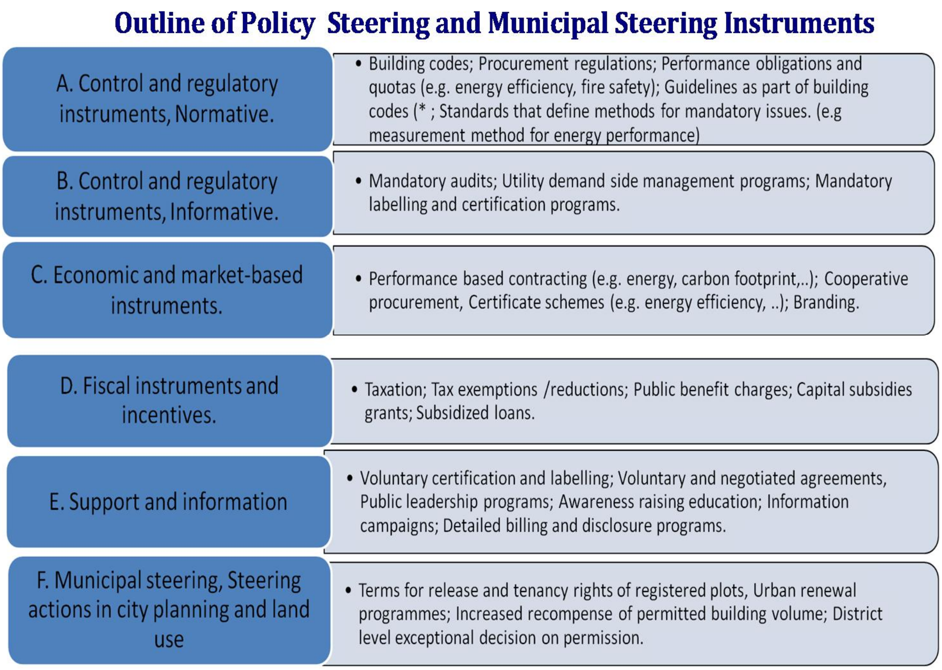


Figure 1. Outline of steering instruments.

NOTE: Voluntary systems of support and information are included here into the informative steering mechanisms because the public bodies may support the establishment of those or the up take of those with the help of education. In addition public organisations in the real estate markets (municipalities and organisations that take care of building, maintenance and letting of state owned properties) can be fore-runners in the use of these kinds of voluntary systems.

The partners were asked to give information about the following issues:

- integration of SB assessment or benchmarking systems or individual indicators (energy performance, carbon footprint, indoor environment) with steering
- scenarios how SB assessment systems could be used in steering.

The following text summarises the responses.
The abbreviation used in the lettering is as follows:

[A/b-3] => lettering of today's example, instrument A, category b – example from country number 3.

[>A/b+B/a-5] => lettering of future idea, combination of instrument A, category b and instrument B, category a – idea from country number 5.

Country numbers: 1 = Czech Republic, 2 = Germany, 3 = Belgium, 4 = Spain, 5 = The Netherlands, 6 = Austria, 7 = Finland, 8 = UK.

Policy instruments A: Control and regulatory instruments, Normative

Instruments related to this category are:

- Building act (a)
- Building code (b)
- Guidelines as part of building codes (c)
- Procurement regulations (d)
- Performance obligations and quotas (e) e.g. energy efficiency, fire safety, ...
- Standards that define methods for mandatory issues (f), e.g. measurement method for energy performance, ...
- Appliance standards (g)
- Material standards (h).

Exemplars of today's practices and future ideas (instrument A) are given in the following:

In Belgium there are standards for many building sustainability issues: e.g. visual comfort, acoustical comfort, security, safety, … Architects often refer to those standards when writing building specifications. Also some of them are made compulsory for buildings that are accessible to the public (e.g. schools, public buildings, restaurants, …). For example, there are min. requirements for accessibility (for disabled persons) of public buildings. [A/b-3]

The Walloon region wants to provide general building specifications that architects and public bodies can use as a basis for the redaction of specific building *specifications. The government specifically asked the body that is in charge of the redaction to integrate themes as waste management, energy, accessibility for disabled people, safety and security, and health into those specifications. [>A/e-3]*

Set minimum score that has to be reached in order to get a building permit. [>A/e + A/a-3]

The Spanish Acts (LOE) "express aim is to regulate basic aspects of the construction process, setting out the obligations and responsibilities of all those involved in the process, as well as the necessary guarantees for it proper implementation, in order to safeguard the quality of buildings via compliance with these basic requirements and to ensure the adequate protection of users' interests". [A/a-4]

The Spanish Technical Building Code (TBC) is the normative framework that establishes the safety and habitability requirements of buildings set out in the Building Act (LOE). To promote innovation and technological development, the TBC has adopted the most modern international approach to building norms: Performance-Based Codes or objectives. [A/b + A/e-4].

> The use of these new regulations based on performance calls for the configuration of a more flexible environment, easily updated in accordance with the development of techniques and the demands of society, and based on the experience of traditional norms.

Although at the moment the "basic requirements" do not explicitly include sustainability, with the new Construction Products Regulation a new Basic Work Requirement about sustainable use of natural resources, the building act should be expanded to explicitly mention sustainability of all the building phases. [>A/a-4]

The technical building code can be expanded to include evaluation methods and requirements for the things not yet included, such as sustainability of materials, water usage, waste. [>A/b,e-4]

All public authorities are obliged to achieve a certain sustainability level for their office space as part of the Sustainable Purchasing Policy. If a public authority (national and local) wants to construct or renovate a building for its own use, it has to meet a certain standard for sustainability. GPR building is one of the two tools that can be used for this evaluation. [A/d+B/a-5]

For rental or purchase of office space a standard has to be met with respect to energy label (minimally C). [A/e-5]

Set a mandatory standard for environmental impact scores of new buildings in the Building Code. [>A/b+B/a-5]

The Finnish Land Use and Building Act says that "The objective of this Act is to ensure that the use of land and water areas and building activities on them create preconditions for a favorable living environment and promote ecologically, economically, socially and culturally sustainable development." "The objective of building guidance is to promote: the creation of a good living environment that is socially functional and aesthetically harmonious, safe and pleasant and serves the needs of its users; building based on approaches which have sustainable and economical life-cycle properties and are socially and economically viable, and create and maintain cultural values; the planned and continuous care and maintenance of the built environment and building stock." "In planning, special attention shall be paid to the following: appropriate regional and community structure of the region; ecological sustainability of land use; environmentally and economically sustainable arrangement of transport and technical services; sustainable use of water and extractable land resources; operating conditions for the region's businesses; protection of landscape, natural values, and cultural heritage; and sufficient availability of areas suitable for recreation." [A/a-7]

In addition to building act and decrees, the building code gives specific regulations and guidelines for sustainable building. The Finnish Building Code includes regulations and guidance about: accessibility, energy performance, quality of indoor climate and acoustics, maintainability, and safety in use. [A/b-7]

By outlining the performance-based building codes in accordance with the sustainable building aspects/indicators. Thus the building codes – consisting of regulations and guidelines – would give guidelines and minimum level requirements for each aspect. If the approach of the current ISO 21292 draft was followed, the aspects would be as follows: Access to services, Aesthetic quality, Land Use, Accessibility, Emissions to air, Use of non-renewable resources, Fresh water consumption, Waste generation, Indoor conditions and air quality, Safety, Serviceability, Adaptability, Costs, Maintainability. [>A/c+E/d-7]

Government in England through the Office of Government Commerce requirements has set targets against BREEAM for new build and refurbishment projects. [A /b+c +B-8]

Building Act regulations where the following (in generic terms) are to be addressed by Building Regs: conservation of fuel and power, preventing waste, undue consumption, misuse or contamination of water, protection or enhancement of the environment, facilitating sustainable development, or furthering the prevention or detection of crime. [A/a-8]

Several regulations have been developed in regards to planning and infrastructure, for example: Local Development Frameworks and Development Plans (numerous), Planning and Compulsory Purchase Act 2004 (Planning Policy Statements (PPS) (various), Planning Policy Guidance Notes (PPG) (various), Regional Spatial Strategies (various), Strategic Environmental Assessment Directive 2001/42/EC. [A/a+b-8]

Policy instruments B: Control and regulatory instruments, Informative

Instruments related to this category are:

- Mandatory audits (a)
- Utility demand side management programs (b)
- Mandatory sustainable building assessment as professional analyse (c)
- Mandatory use of labelling system and certification programs (d)

Examples of today's practices and future ideas (instrument B):

SBToolCZ for public buildings [>B/d]

SBToolCZ – environmental part for public buildings [>B/d-1]

Set of environmental criteria for tendering [>B/e-1 or E/b-1]

Implementation of total system into architectural competitions [>B/a-1 or E/b-1]

Building Certification: Based on CO_2 emissions [B/c-4]

Mandatory "sustainable building assessment method should be introduced, following CEN TC 350 guidelines. [>B/a-4]

It is planned that an LCA evaluation of material impacts becomes mandatory under the new Building Code. Each new building or major renovation plan will have to submit an evaluation of material impacts based on a harmonized methodology. There is no limit value for the impacts. GPR Building is one the instruments that is recognized for this evaluation. [B/a-5]

Make sustainable building assessment mandatory for all public buildings. [>B/a-5]

The law about mandatory energy certificates was established in Finland in 2008. Correspondingly it could be required that all new buildings and refurbished buildings should be certificated with help of set of sustainability indicators (including a set of mandatory indicators). [>B/d-7]

CSH assessment is voluntary for England. From 1 of May 2008, a minimum of Code Level 3 is required for all new housing promoted or supported by the Welsh Assembly Government or their sponsored bodies and from 2nd June 2008, Code Level 3 is required for all new self-contained social housing in Northern Ireland. The Code does not apply in Scotland. [B/a-8]

The Welsh Assembly Government requires a BREEAM Excellent rating or a minimum of Code for Sustainable Homes (CSH) Level 3 together with 10% recycled content as a core condition of funding, with the aspiration of zero carbon for all new buildings in Wales by 2011. There are some exceptions for smaller schemes, and the standard is not required for refurbishment, alterations and extensions, although these schemes still have to be designed to energy efficient standards. The planning system in Wales also now requires as mandatory a minimum of CSH Level 3 and a reduction of 31% in carbon emissions above 2006 Building Regulations for residential buildings, and BREEAM Very Good for buildings above 1000 m^2. [B/a-8]

Policy instrument C: Economic and market-based instruments.

Instruments related to this category are:

- Performance based contracting (a) e.g. energy, carbon footprint, ...
- Cooperative procurement (b)
- Certificate schemes (c) e.g. energy efficiency, ...
- Branding (d)
- Valuing property (e)

Exemplars of today's practices and future ideas (instrument C):

Total performance based contracting [>C/a-1]

The sustainability assessment systems in Germany (BNB and DGNB) for offices. These are almost identical, since they started off as one. BNB is the government scheme; DGNB is a private sector scheme. Both are only in place since 2009 and hence it is not yet clear how they may relate to the types of drivers you are looking at. DGNB is developing system variations for other building types e.g. shopping centres. BNB has one system variation for operational and maintenance of office buildings

- BNB assessments are obligatory for all new federal government buildings (procurement rule) [C/b-2B]
- DGNB – (privately developed German system) – set as procurement standard by some commercial organisations [C/b-2A]

BNB assessments, in Germany, may also in future be adopted by regional governments as procurement rule [>C/b-2A]

The sustainability assessment system under development by government in Germany. Pilot phase has only just finished – this is very new and still in development. There is no official name yet. SA-Housing is being developed with the view to setting it as standard for publicly supported housing projects [>C/b-2A]

Also GPR (used in the Netherlands) is used to evaluate building projects that want to qualify for the ""Building Quality Award"" of the city. [C/d-5]

Bouwfonds REIM a real estate management company uses GPR as part of their risk management policy. 25 non-residential (existing) buildings have been assessed and improvement options to realize a certain ambition level have been described (by W/E). These improvements are new part of the discussions for building portfolio management. [C/e+E/a-5]

- In a similar way Bouwfonds REIM plans to assess their portfolio of residential buildings. As a first round 9 residential complexes (with existing buildings) will be assessed and improvement options to achieve a certain level will be described."

Policy instrument D: Fiscal instruments and incentives.

Instruments related to this category are:

- Taxation (a)
- Tax exemptions /reductions (b)
- Public benefit charges (c)
- Capital subsidies grants (d)
- Subsidized loans (e)
- Funding for development (f).

Exemplars of today's practices and future ideas (instrument D):

The Brussels region developed a sustainable building evaluation method (incl. Energy, materials, water efficiency, health and comfort) and gives large subsidies to construction or /renovation projects who obtain a very good score according to that evaluation method (application is voluntary). Information on selected exemplary buildings is then made publically available (website+ publications+ organised visits of the buildings). The government also gives support to the projects applying and does a 3-year follow up of selected buildings in order to gain a better inside on what they should promote. This initiative has a very important impact on the number of exemplary projects initiated during the past years in Brussels (as financial incentives are high, many buildings apply and thus make extra efforts to obtain a good score). [D/d-3 and E/e-3]

Give construction/renovation subsidies based on global sustainability score of the project [>D/d-3]

Funding systems for developing Environmental Product Declarations of construction products. Also for the implementation of Eco-Design strategies UNE 150.301 (future ISO 14006), which has been particularly successful in Architectural offices. Eg. ERAIKAL programme in the Basque Country. [D/f +E/a-4]

Give tax reductions for investments in buildings with a certain sustainability score [>D/b+C/f-5]

"Housing Subsidies": Austria has a quite distinctive system for housing subsidies. Although the housing subsidies are regulated differently in each of the federal states of Austria, the subsidies are quite high everywhere. They are bound to criteria of sustainable buildings, especially as heat energy demand is regarded. [D/d+A/e-6]

“Agreement art.15a between the federal government and the federal states about measurements in the building sector to reduce the emission of green house gases.” This guideline defines performance quotas for new and renovated buildings that have to be reached to get housing subsidies. There are also included performance quotas for public buildings. [D/d+A/e-6]

Incentives could and should be provided for the management of buildings in operations incentivising them to minimise environmental impacts. [>D-8]

Refurbishment of existing stock has not been a major priority of UK governments in the past, this area could have more support. Incentivising home owners to comply with sustainability requirements if refurbishment above certain threshold in terms of scope of works and/or cost. [>D /d-8]

Policy instrument E: Support, information and voluntary action

Instruments related to this category are:

- Voluntary certification and labelling (a)
- Voluntary and negotiated agreements (b)
- Public leadership programs (c)
- Awareness raising education (d)
- Information campaigns (e)
- Detailed billing and disclosure programs (f)
- Information campaigns (g).

Exemplars of today’s practices and future ideas (instrument E):

"Deutsches Gütesiegel Nachhaltiges Bauen" (DGNB) is a German voluntary certification system for sustainable buildings. It is for planning and assessing buildings and provides certificates in the categories gold, silver and bronze. It was developed in cooperation with the German Federal Ministry of Transport, Construction and Urban Affairs (BMVBS) and is based on an integrated planning in the early concept phase of a sustainable building project. 6 aspects are covered: ecological, economical, social & cultural as well as technical, procession and location aspects. It is a voluntary certification system and needs an independent auditor who is accompanying the building owner along all stages. The building owner gets a pre-certificate and is responsible for achieving all defined requirements according to the DGNB criteria (60 criteria). Therefore the advantage of the certificate is mainly for marketing purposes and value creation. [E/a-2A]

Voluntary certification can only be successful if the incentives are appropriate for the building owners and the benefit for certification exceeds the effort. That means in case of marketing purposes the clients itself need to have a clear overview of all advantages they will get for buying a certificated building. Besides, e.g. less energy costs (further taxation incentives) could be a measure to promote sustainable buildings. [>E/e-2A]

DGNB – standards are also used by some organisations as part of due diligence/ corporate social responsibility processes. [E/a-2A]

BNB module for operation and maintenance is supposed to be rolled out across the offices of the federal government. [>E/a-2A]

The Flanders region developed a sustainable building evaluation method for office buildings. This method is now used for all new governmental buildings. The method itself is also publically available (to encourage other builders to pay more attention to sustainability. It is however **a self-evaluation guide**, so there is no possibility to get an independent certificate). They also documented some exemplary buildings for all themes of the method on their website (e.g. example of building that is exemplary in terms of mobility, one that is exemplary in terms of material use, ...) in order to show how high scores can be achieved in practice. [E/a-3]

Some social housing companies also developed their own evaluation schemes and it is used through all phases of the building process (especially for design and tendering). [E/a-3]

In the Basque Country, Sustainable Building Guides (for housing, commercial, public administration, industrial buildings, and urban areas) have been developed over the last 5 years. The guides are publicly available and various workshops have been organized to promote the use of the guides. Assessing building projects with the Guides has been made mandatory in public building and social housing tender documents, and they have been used and published as demonstration projects. [E/d+ E/e-4]

The City of Maastricht uses GPR Building to stimulate sustainable building within its territory. This is done on basis of voluntary agreement with housing associations and property developers active in the city. For new buildings, the aim is now to achieve a minimum GPR score of 7 on each of the five indicators. The policy applies to all new buildings in Maastricht. For existing buildings, the aim is to apply the methodology to all projects, in order to obtain more knowledge on sustainability levels of the existing building stock and the retrofitting potential. The same applies for monumental buildings. Targets for municipal buildings are higher, to set a good example: new municipal buildings should obtain a minimum GPR score of 7,5 on each indicator, whereas existing buildings which are to be refurbished should be improved by 2 points on each indicator as compared to the original building. [E/a+b-5]

The city of Rotterdam uses GPR Building as an information tool for new housing construction. Market parties get free access to GPR to evaluate their construction plans. There is no minimum standard set. [E/a-5]

Make voluntary agreements between public authorities (municipalities) and building parties (property developers, housing associations) to achieve a certain ambition level based on an SB assessment system. See example of Maastricht. [>E/a+b-5]

"klima:aktiv Building Standard": klima:aktiv is an initiative by the Federal Ministry of Agriculture, Forestry, Environment and Water Management. The core element of the klima:aktiv initiative is the **klima:aktiv building standard**, which defines criteria for sustainable buildings. The criteria are subdivided into 4 categories, named "Design and Execution", "Energy and Supply", "Materials and Construction", "Comfort and Indoor Air Quality". To declare a building as a "klima:aktiv house" or "klima:aktiv passive house", it has to reach at least 700 respectively 900 points of a total of 1.000 points. [E/a+b-6]

"TQB – Total Quality Building": TQB is a comprehensive certification scheme for sustainable buildings. The responsible body is the Austrian Society for Sustainable Buildings, which was founded in 2009. The sustainability criteria are grouped into 5 categories: site and facilities, economic efficiency and technical quality, energy and water, health and comfort and resource efficiency. [E/a-6]

"Service packages for sustainable municipalities": There exist service packages for municipalities to guide them towards sustainable buildings and sustainable city planning. [E/e+F/f-6]

There is a voluntary scheme for environmental rating of buildings (PromisE). The development of the system was supported by public financing. The scheme is used in the requirement setting and marketing processes (however, the use of the system is relatively little). [E/a-7]

The Homes and Communities Agency was formed on 1st December 2008 bringing English Partnerships and the Housing Corporation together referred to by the HCA as 'the single conversation". In 2007, the Housing Corporation prescribed a minimum standard of Code for Sustainable Homes Level 3 in their Design and Quality Standards. English Partnerships also set Code for Sustainable Homes level 3 as the minimum standard for new build housing and a BREEAM Very Good rating for non domestic buildings in their quality standards. [E/a-8]

Policy instrument F: Municipal steering, Steering actions in city planning and land use

Instruments related to this category are:

- Terms for release and tenancy rights of registered plots (a)
- Urban renewal programmes (b)
- In city infill projects:
  - Increased recompense of permitted building volume (c)
  - District level exceptional decision on building permission (d)
- In planning process:
  - Use of assessment tools for valuation of alternative concepts/plans (e)
  - Planning obligation for design and construction (f)
  - Focus on important planning issues(g)
  - Building permit process: supervision of setting the goal for sb-level (h)

Exemplars of today's practices and future ideas (instrument F):

SB Tool CZ [F/e-1]

SA-Housing may in future be used for setting standards for new developments (as planning obligations) – this is very much feared by the housing industry. [>F/f-2A]

Local, municipal, or regional regulations to include sustainable building criteria. San Sebastian **ordinance** on energy efficiency and environmental quality of buildings. Durango municipality (also in Basque Country) developed in 2008 an ordinance for environmental design of residential and office buildings. Require certain aspects (energy, water, waste, etc), and promote and even fund interventions. [F/g-4]

Catalonia decree on "Eco-efficiency" establishes certain requirements related to water, energy, waste and materials. Particularly interesting is the request to provide Environmental Labels (type I or type III) for at least a "group of products" eg. paint, insulation, etc. [F/g +B/c-4]

In the field of municipal steering and city planning more attention should be paid to the aspect of building categories (single family homes vs. multiple storey residential buildings) and land use planning on the whole. This could help to prohibit urban sprawl and all its effects (car traffic etc.). [>F/g-6]

The role of local authorities could be emphasized in building planning by taking a strong role in planning process. This could happen by defining sustainable building related requirements for local master plans and for lot use (for purchase and rental). The sustainable building indicators (/systems) could be made use/integrated by making use of these indicators in formulation of requirements for purchase/rental. [>F/a+E/b-7]

The role of local authorities could also be emphasized by acting as an active advisor for designers in the context of building permissions processes. The supervision process of building projects by local building authorities could use specific instruments that support sustainable building. These might be guides *for energy-efficient building, specific guides for quality assurance in sustainable building processes, recommendations for the improvements of energy-efficiency in refurbishment projects etc. Sustainability indicators (and systems) should be used as a framework for guidance for sustainable building. [>F/h+E/d-7]*

Local Authorities Incorporating Environmental standards (BREEAM included) as part of supplementary, planning guidance. [F/e-8]

Examples and ideas of integration of individual indicators with different steering instruments

Areas of systems 1: Energy efficiency

Integration of assessment systems with steering used, like:

- Benchmark systems used by forerunner stakeholders
- Energy Certificate, some countries also include carbon footprint calculations
- Guidelines in the building code manuals
- Energy performance regulations for existing building stock
- Targets to special building stock.

Examples:

The energy benchmarking system used by KfW (a state-owned bank that distributes grant funding). Their standards are very well known by the general public and real estate industry – hence influential. The standards refer to the percentage of difference of energy use compared to the requirements of building regulations. [D+E-2B]

The German "Energieeinsparverordnung" (ENEV) is a normative regulation for energy efficiency and less use of energy which integrates an energy assessment or calculation, leading to an energy pass (ENEV 2006). The energy pass gives information about the buildings energy balance (building quality with respect to energy consumption of a building, including the storefront as well as any in-house plants), its carbon footprint and suggestions where building-renovation/modernization is useful. For all new buildings an energy pass is mandatory, for the existing building stock, when buildings are sold or rented. [A-2A]

“OIB Guidline Nr. 6” (Guideline of the Austrian Institute for Building Technology): The guideline deals with energy efficiency and heat insulation in the building sector. It defines performance quotas for the final and the net energy demand of different building types. It also includes conversion factors for the translation of final energy to primary energy. There are also U-values defined for building elements that transfer heat (windows, outside walls etc.). [A-6]

The energy performance regulations should be effectively extended to cover existing building stock. For example the following kinds of regulations should be developed: During the next ten years (2012 – 2022) the energy-performance level of residential buildings should be improved by two steps and in minimum to the level C as defined in the context of extended energy auditing system. In formative and fiscal methods should be developed in order to support this change. [>B-7]

Carbon Emissions Reduction Target (CERT): is delivering cavity wall, loft insulation and low energy lighting at a significant rate. These particular measures will be delivered to the majority of homes that need them by around 2014-16.The Government, in setting an increased carbon saving target for the scheme, says energy suppliers will be required in effect to double their current efforts and that this should both increase activity in established markets, such as those for insulation, and also encourage new development in markets for microgeneration technologies. [A-8]

Grants are available for some microgeneration works. The Low Carbon Buildings Programme has seen £21.5 million committed to projects in buildings including homes, schools and businesses. About a third of it has gone to about 4,000 homes. The Government, via DEFRA and the Department for Business, Enterprise and Regulatory Reform, has also announced an “Environmental Transformation Fund” which will provide £370 million to support the development and spread of new technologies. Additional grants page: http://www.therenewableenergycentre.co.uk/grants/ [D-8]

Areas of systems 2: Carbon footprint

Integration of systems with steering used, like:

- Regulation on use of renewal Energies
- Municipal support as service of free carbon footprint calculation
- Declaration platform for building materials
- Mandatory energy certificates with information on carbon footprint
- Proactive service, where people will take on board energy efficiency measures thus reducing their carbon footprints.
- Planning methods in order to reduce new areas carbon footprint

Examples:

"The German ""Act on the Promotion of Renewable Energies in the Heat Sector"" (Erneuerbare-Energien-Wärmegesetz – EEWärmeG) of 2008 stipulates that owners of future buildings must cover part of their heat supply with renewable energies. This applies to residential and non-residential buildings for which a building application or construction notification was submitted after 1 January 2009.

The owner is free to choose which source of renewable energies is used. The important aspect is that a certain percentage of heat is generated this way. The percentage depends on the type of energy employed. If solar power is used, for example, it must cover at least 15 per cent of the heat demand. At least half of the heat must be generated by renewable energies if solid or liquid biomass, geothermal energy or ambient heat is used." [A-2A]

The Act was drawn up with the objective that every owner of a building should be able to find an individually tailored, cost-effective solution. In addition, the German government has further increased its comprehensive support programme, the market incentive programme for renewable energies, to supplement the Act. It assists building owners in getting a start on heat from renewable energies. [E-2A]

Financial Steering mechanisms in form of low-rate credits and subsidies effectively lead to private investments and therefore tax revenues. A possibility could be to connect the size of individual incentives with individual benchmarking system outcomes. The more sustainable the investment is, the more payment it gets. [D-2A]

A municipality in Belgium offers the service of free carbon footprint calculation for all companies on its site. The only condition is that companies commit to make efforts to reduce their emissions in the future.

The EPL-score (Energy Performance of Location) is a simple assessment instrument to evaluate urban expansion plans in terms of CO2 emission. This instrument is used very widely by municipalities in the Netherlands to set a certain ambition level for urban expansion or renewal. No mandatory standard can be set due to legal restrictions, so its use by developing parties is only on voluntary basis. Nonetheless it is considered to be a fairly successful approach. [E-5]

www.baubook.at: baubook is a declaration platform for building materials (besides that it includes a lot of other information concerning sustainable buildings). It contains a large number of products and reports specific values (e.g. primary energy demand non renewable, sometimes CO_2-emissions etc.). [E-6]

The mandatory energy certificates should also give corresponding information about the carbon footprint (emissions of green house gases). [>B-6]

The Department for Environment, Food and Rural Affairs (DEFRA), via the Energy Saving Trust, will also, by December 2008, launch a new Green Homes Service. Offers a home health check in terms of energy efficiency. Advice is then given covering areas such as energy saving, water saving, recycling and waste reduction, and green travel options. It is hoped that by offering this proactive service, more people will take on board energy efficiency measures thus reducing their carbon footprints. In addition to the advice on offer, the Green Homes Service also aims to connect people to companies providing discounted or free energy saving products such as insulation, and provide details of available grants for energy efficiency measures and renewable energy options. By offering all of this advice and information from one service, it was envisaged that more people would make greater steps in increasing their energy efficiency.

Planning should be linked to the sustainability of the area to be developed according to, for example, how much it would allow reducing the new areas carbon footprint. [F-8]

Area of systems 3: Indoor performance

Integration of systems with steering used, like:

- Regulations in guidelines and Acts
- Scheme that would help businesses to assess the indoor environmental performance of the buildings.
  - Design quality indicator-method
- Indoor environment performance based contracts
- Grants
- Development programs.

Examples:

“OIB Guidline Nr. 2” (Guideline of the Austrian Institute for Building Technology): The guideline deals with hygiene, health and environmental protection. It includes obligations concerning sanitation, exhaust fumes of fireplaces, protection of moisture, protection of harmful substances (especially emissions of building materials), illumination, ventilation etc. [A-6]

The Finnish Building Code includes regulations and guidance about quality of indoor climate and acoustics. [A-7]

Disability Discrimination Act 1995, Clean Air Act 1993, Control of Pollution Act 1974, Water fittings regulations (various). [A-8]

Develop a Scheme that would help businesses to assess the indoor environmental performance of the buildings. [>C-8]

The Design Quality Indicator is a method of evaluating the design and construction of new buildings and the refurbishment of existing buildings. Indoor performance is secured by Design in these cases. [E+C-8]

A Disabled Facilities Grant is a local council grant to help towards the cost of adapting your home to enable you to continue to live there. A grant is paid when the council considers that changes are necessary to meet your needs, and that the work is reasonable and practical. [D-8]

Decent Homes programme: improving substandard social housing, providing new kitchens, bathrooms and central heating systems to tenants, often in the most deprived parts of the country. [D-8].

	Series title and number **VTT Technology 72**

Title	**Sustainability and performance assessment and benchmarking of buildings** **Final report**
Author(s)	Tarja Häkkinen (Ed.)
Abstract	This report is presents and summarises the results of the European SuPerBuildings project. The project developed and selected sustainability indicators for buildings, develop understanding about performance levels considering new and existing buildings, different building types and different national and local requirements, developed methods for the assessment and benchmarking of sustainable buildings and made recommendations for the effective use of benchmarking systems as instruments of steering and in different stages of building projects.. The final report presents the main results of the project and makes references to the original project deliverables available on the project's web site: http://cic.vtt.fi/superbuildings/ The final reported has been edited by the project coordinator Dr Tarja Häkkinen. The main authors of the report are prof. Thomas Lützkendorf, Maria Balouktsi, Andrea Immendörfer, KIT-U, Syviane Nibel, Boris Bosdevigie, Alexeandra Lebert and Bruno Fies, CSTB, Dr Patxi Hernandez Iñarra, TECNALIA, Antonín Lupíšek and prof. Petr Hajek, CVUT, Susanne Supper, ÖGUT, Erik Alsema W/E, Laetitia Delem and Johan Van Dessel, CSTB, together with Tarja Häkkinen, Carmen Antuña, Tarja Mäkeläinen from VTT. The final report introduces the current SB assessment systems and discusses barrier and drivers for sustainable building. From the beginning, SuPerBuildings agreed not to add another sustainability system to the numerous existing ones. Instead, the principles for the design and development of assessment systems should be worked out, discussed and made publicly available. As the sustainability of buildings should always be assessed with the help of indicators, one of the key objectives of SuPerBuildings is to ensure "validity" for sustainability indicator systems. This determines the true possibility of an indicator system to give information about the sustainability of buildings. Project selected indicators for further development. Regarding these indicators the final report presents information about their validity, assessment methods, and performance levels. The final report also discusses the problematics and functional equivalent, and weighting and normalization criteria. Finally, the report gives recommendations for the use of indicators in different stages of building processes, in connection of building information models and in the connection of different steering instruments.
ISBN, ISSN	ISBN 978-951-38-7908-2 (URL: http://www.vtt.fi/publications/index.jsp) ISSN 2242-122X (URL: http://www.vtt.fi/publications/index.jsp)
Date	December 2012
Language	English
Pages	409 p. + app. 49 p.
Name of the project	EU_SUPERBUILDINGS
Keywords	Sustainable building, indicator, benchmark, assessment, performance
Publisher	VTT Technical Research Centre of Finland P.O. Box 1000, FI-02044 VTT, Finland, Tel. 020 722 111

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VTT TECHNOLOGY 72 Sustainability and performance assessment and benchmarking...

ISBN 978-951-38-7908-2 (URL: http://www.vtt.fi/publications/index.jsp)
ISSN-L 2242-1211
ISSN 2242-122X (verkkojulkaisu)