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Summary findings and indicator proposals for the life cycle environmental performance, quality and value of EU office and residential buildings

Draft for public consultation

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1. Introduction

1.1 The background to this study

The European Commission's 2014 Communication on Resource Efficiency Opportunities in the Building Sector identified the need for a common EU approach to the assessment of the environmental performance of buildings. A study to develop this approach was initiated in 2015 by DG ENV and DG GROW, with the technical support of DG JRC-IPTS.

The output from the first stage in this study during 2015 was Working Paper 1 which brought together the findings of Work Package A and identified 'macro-objectives' for the life cycle environmental performance of buildings[1]. Working Paper 1 can be downloaded from the project website here:

http://susproc.jrc.ec.europa.eu/Efficient_Buildings/documents.html

Working Paper 2 has now been prepared which brings together the interim findings from Work Packages B and C. It provides an analysis of a range of evidence at building project level for how environmental improvements that contribute towards the six macro-objective areas have been measured.

The evidence brought together in Working Paper 2 has enabled the identification of a wide range of potential performance indicators under each of the macro-objectives. These findings have been used to formulate a first set of proposals for indicators. These proposals provide a technical basis for a public consultation and further dialogue with registered stakeholders.

The public consultation will take place during a 14 week period that will run from July through to the 7th October 2016. In support of the public consultation, a draft of Working Paper 2 will be made available for download from the project website here:

http://susproc.jrc.ec.europa.eu/Efficient_Buildings/documents.html

This summary document has been prepared as a further supporting document for the public consultation. It summarises the interim findings from Working Paper 2, as well outlining the first proposals for indicators which form the basis for the public consultation and further discussion with registered stakeholders.

1.2 The six macro-objectives that inform indicator identification

The starting point for development of the indicator framework has been the identification of a number of 'macro-objectives'. These establish the strategic focus and scope for the framework of indicators. The working definition of a macro-objective as defined by the Commission is:

> *An environmental, resource efficiency or functional performance aspect of significance to the life cycle environmental performance of buildings at EU level.*

In Working Paper 1, two types of macro-objectives were identified – those relating to '*life cycle environmental performance*' and those relating to *'quality, performance and value'*. Six of these macro-objectives have been taken forward in order to identify related performance indicators. All six of these macro-objectives will focus on action at the building level:

'Life cycle environmental performance' macro-objectives for buildings

1. **Greenhouse gas emissions from building life cycle energy use:** Minimise the total GHG emissions along a buildings life cycle, with a focus on building operational energy use emissions and embodied emissions.

[1] European Commission, *Identifying macro-objectives for the life cycle environmental performance and resource efficiency of EU buildings - Working Paper 1*, JRC-IPTS Science and Policy Report, December 2015

2. **Resource efficient material life cycles:** Optimise building design, engineering and form in order to support lean and circular flows, extend long-term material utility and reduce significant environmental impacts.
3. **Efficient use of water resources:** Make efficient use of water resources, particularly in areas of identified long-term or projected water stress.

'Quality, performance and value' macro-objectives for buildings

4. **Healthy and comfortable spaces:** Design, construction and renovation of buildings that protect human health by minimising the potential for occupier and worker exposure to health risks.
5. **Resilience to climate change:** The futureproofing of building thermal performance to projected changes in the urban microclimate, in order to protect occupier health and comfort.
6. **Optimised life cycle cost and value:** Optimisation of the life cycle cost and value of buildings, inclusive of acquisition, operation, maintenance, disposal and end of life.

A further set of up to ten macro-objectives were identified that may potentially be considered for the identification of performance indicators in the future.

1.3 Scope definition for the indicators

Following on from last year's stakeholder consultation process, which included a first working group meeting in Brussels followed by a formal written consultation with the working group members, it was decided to define a scope for the building types to which the indicators would be targeted. Moreover, in seeking to identify indicators and put them into context, reference should be made to recognisable building project stages and life cycle stages.

1.3.1 Building types and projects

Following feedback received from stakeholders during 2015 as described above, it was decided to narrow the scope of the study to focus on residential and office buildings. These were chosen because they represent the majority (86%) of the total floor area of the EU building stock. Of this total, residential property represents by far the majority of the total floor area of the EU building stock (75%). For each of these uses, the execution of new-build and renovation projects has therefore been considered during the initial process to identify indicators.

1.3.2 Building project stages

In order to ensure that the findings from the study are linked to the process of developing a building, typical project stages will be referred to throughout. Box 1.1 identifies a typical ordering of these stages, based on the RIBA (Royal Institute of British Architects) Plan of Work (2013)[2], and has been extended to address future refurbishment and end of life stages.

It is considered important to relate any findings to these stages in order to ensure there is a focus on the practical relevance of the indicators. In particular, this will help to identify at which stage in a project indicators may be more relevant, and which specific actors should be involved.

Box 1.1 Scope of building project stages to be considered

1. Strategic definition and brief

Includes: analysis of existing situation, design brief, performance objectives, feasibility study, master-planning, outline development appraisal

[2] RIBA, *Plan of work 2013*, https://www.ribaplanofwork.com/

Key phases: Existing building survey (for renovations)

2. Concept design

   Includes: concept, design development, preliminary technical studies and cost estimation

   Key phases: design team appointment

3. Developed and technical design

   Includes: technical drawings, construction details, technical studies, building/technical specifications, bill of quantities, cost estimation, employer's requirements, tendering procedure/bidding phase,

   Key phases: planning and building control permitting, bidding phase (including evaluation/commissioning), lead contractor appointment, environmental certifications

4. Construction

   Includes: demolition/site preparation works (may precede this stage), contract performance monitoring, as-built documentation, handover strategy

   Key phases: Commissioning, quality testing/inspection

5. Handover and close-out

   Includes: (preliminary and final) delivery, defects period, post-completion verification of environmental certifications

   Key phases: Commissioning, quality testing/inspection, building manual/training

6. In-use

   Includes: Occupation, operation, maintenance, repair, refurbishment

   Key phases: Post occupancy evaluation, performance monitoring, building life cycle management plan

7. Refurbishment

   Includes: See stages 1-5 (according to the scale of the works)

8. End-of-life

   Includes: tendering procedure/bidding phase, pre-demolition inventory check

   Key phases: Building disassembly, component and material reuse/recycling

Adapted from RIBA (2013)

1.3.3 Building life cycle stages

In order to ensure that the findings from this study are related to the life cycle of a building, the stages defined by CEN Technical Committee 350 will be referred to throughout. It is considered important to relate the use of indicators to these life cycle stages because this will help to identify at which stage they may be more relevant.

Figure 1.1 provides an overview of these stages, which comprise Product (A1-3), construction (A4-5), Use (B1-7) and end of life (C1-4). An additional 'module D' is also included within standards EN 15978 and EN 15804 for building and product life cycle assessment respectively, which allows for the net benefits of reuse, recycling and recovery to be accounted for.

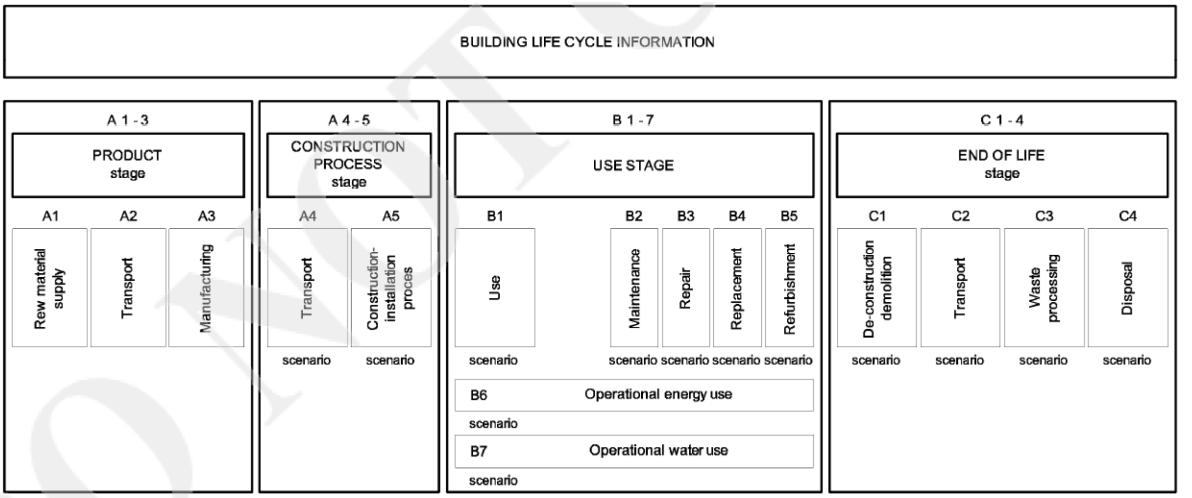


Figure 1.1 The scope of building life cycle stages to be considered

Source: CEN (2011)

1.4 The different types of evidence analysed

Options for the indicators have been identified based on a multi-layered evidence gathering exercise that is intended to be as comprehensive as possible for each macro-objective. This combines evidence gathered from:

- 'Field studies' (primary evidence)
  - Professional experience at project level of setting performance requirements and using indicators.
  - Technical research at building level to identify methods for measuring/monitoring performance.
- 'Cross-check' (primary and secondary evidence)
  - Public sector initiatives at national and regional level, including building permitting and planning requirements.
  - Assessment and reporting schemes: The operational experience from running and using major multi-criteria certification schemes and investor reporting tools currently being used across Europe.
  - Technical studies: The synthesis of experience and expertise from the building sector in one or several member states in order to propose or refine performance measurement tools, metrics and guidance.
  - Standards and harmonisation initiatives: Projects to support greater harmonisation and uptake of performance measurement and reporting tools.
  - Collaborative EU projects: The shared experience and outcomes from the sharing of share knowledge and experience related to performance improvement.

Evidence gathered from the detailed analysis of field studies has been used to understand how performance can be measured and monitored at project level. The information gathered from the field studies has then been supplemented by a range of 'cross-check' evidence that is specific to each macro-objective. This is intended to ensure that the findings from the field studies are analysed within the broader professional, regulatory and technical context.

More details of the methodology can be found in Chapter 2 of Working Paper 2.

2. Overview of the proposed framework and how it could work

This section provides an overview of the findings to have emerged from analysis of the options for indicators under each of the six macro-objectives. A range of indicators were identified in Working Paper 2 from which the first proposals presented in this document have been selected. This section also discusses the potential horizontal implications for development of the common EU framework.

For each macro-objective, the preferred options for headline and supporting indicators are presented. These are accompanied together with an outline of the fundamental rules that may need to be laid down in the calculation methodology, together with focus areas for guidance that have been identified at this stage in the study.

The horizontal findings to have emerged from this analysis are also brought together and briefly discussed. Opportunities and challenges that these findings may pose for development of the common EU framework of core indicators are identified.

2.1 Overview of the emerging indicator framework

In total fourteen indicators have been identified, of which ten could be considered to represent a 'basic' ambition level and four could considered to represent an 'advanced' ambition level, thereby supposing a higher level of expertise to use them. An overview of the indicator set identified is presented in Figure 2.1.

In addition to the indicators, it is proposed that two additional aspects are addressed alongside the indicators:

- Supporting aspects of performance that, based on best practice, are recommended for each indicator as focus areas for attention, and
- Methodological notes setting out, for example, the boundary and scope to be used for calculations.

These two points are elaborated on further in the more detailed description of the proposals in Chapter three of this document.

2.2 Horizontal themes relating to how the framework could work

In seeking to identify options for indicators, a number of 'horizontal' themes have emerged that are common across several indicators. These relate to how the framework could work as a whole. They are as follows:

1. <u>Encouraging professional development and life cycle thinking</u>: Relationships between indicators and differing ambition levels could be used to encourage professional development.
2. <u>Encouraging improved measurement of intensity of resource use</u>: Smarter indicators could be provided that experience shows provide an improved means of measuring the intensity of resource use.
3. <u>Building upon existing standards and methodological developments</u>: Whilst the existing standards and methods represent an important starting point, it may be necessary to set some minimum reporting 'rules' to improve comparability and encourage greater use.
4. <u>Data availability, quality and transparency</u>: In the case of both Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) data is fundamental to the comparability and meaningfulness of the results.
5. <u>The level at which indicators should be comparable</u>: Variations across the EU ranging from climate to valuation techniques can affect the comparability of results.

6. The potential to track performance along a project's life cycle: The ability to track performance from design through to occupation, with a focus on both technical performance and occupant satisfaction, is becoming increasing important.

Before introducing the first proposals for indicators, these horizontal themes are each briefly discussed, with a focus on their potential bearing on implementation of the framework of core indicators as a whole.

Theme 1: How the indicators could encourage professional development and life cycle thinking

A number of potential relationships can be identified between the individual indicators. In some cases indicators addressing the same performance aspect suppose different levels of professional expertise, as well as more or less comprehensive life cycle thinking, in order to use them.

These relationships could be used, or emphasised, in a number of ways in order to support the wider EU adoption of a life cycle approach. For example, they could be presented as a ladder of professional development:

- Macro-objective 2 indicators 2.2 to encourage a 'basic' entry level understanding of building and elemental service life, using already available project data.
- Macro-objective 1 indicators would then introduce an 'intermediate' entry level for life cycle assessment based on a single impact category (Global Warming Potential) and a defined scope. This would require greater expertise, more advanced tools and analysis.
- Macro-objective 2 indicator 2.1 ('full Life Cycle Assessment') would reflect an 'advanced' full life cycle approach adopted by the most advanced design teams.

A further possibility to encourage life cycle thinking is to highlight linkages between different indicators. For example, by encouraging design teams and clients to think about and make the links between building life cycle CO_2 emissions (indicator 1.2) and future deconstruction potential and material circularity (indicator 2.3).

Theme 2: How the indicators could encourage improved measurement of intensity of resource use

Experience from practitioners suggests that there would be value in promoting a 'graduated' approach to performance monitoring. Using this approach, design teams would be encouraged to start using a basic core indicator. They could then be offered, or encouraged to use, additional indicators that could support more accurate measurement of the intensity of resource use.

To take an example for one macro-objective, operational total primary energy consumption normalised to kWh per m^2 can mask significant variations in energy consumption. This can justify the use of other units of normalisation, as listed below:

- Basic indicator: kWh/m^2 floor space per annum
- Advanced 'smart' use intensity indicators:
  - office buildings: kWh/workspace unit per annum
  - residential buildings: kWh/bed space per annum or (for mortgage valuations) annualised energy cost in €/home

Figure 2.1 Overview of the first indicator proposals

'Life cycle environmental performance'

Macro-objective 1: Greenhouse Gas emissions from building life cycle energy use

1.1 Operational energy consumption

Total primary energy consumption
Indicator:
kWh/m^2

1.2 Life cycle Global Warming Potential

Operational and embodied GWP
Indicator:
kg CO_2eq/m^2

Macro-objective 2: Resource efficient material life cycles

2.1 Full Life Cycle Assessment

Cradle to grave LCA
Indicator:
Impact category results

2.2 Building service life planning

Service life
Indicator: Building and components (years)

2.3 Deconstruction and recyclability

Deconstruction and recyclability score
Indicator: Aggregated scope for listed building components

2.4 Construction & demolition waste

a.Demolition stage
b.Construction stage
Indicator: kg/100m^2 and % landfill diversion

Macro-objective 3: Efficient use of water resources

3.1 Operational water consumption

Total mains drinking water consumption
Indicator:
m^3/person/year

'Quality, performance and value'

Macro-objective 4: Healthy and comfortable spaces

4.1 Indoor air quality

Pollutant emissions
Quantitative reporting:
✓ CO_2
✓ Total VOCs
✓ Carcinogenic VOCs
✓ R-Value
✓ Formaldehyde
✓ Benzene
✓ Particulates (PM 2.5/10)

Qualitative reporting:
✓ Presence of mould

Macro-objective 5: Resillience to climate change

5.1 Thermal comfort

Overheating risk assessment
Indicator:
(Adaptive) degree hours

5.2a Additional cooling

Additional cooling primary energy consumption
Indicator: $kWh/m^2.yr$

Proxy indicator *(if 5.2a not feasible)*

5.2b Microclimate cooling

Green factor
Indicator: Sum weighted cooling effect for green features on/around buildings

Macro-objective 6: Optimised life cycle cost and value

6.1 Life Cycle Costing

a. Utility costs
Indicator:
€/yr/m^2 (30/50 yrs)

b. Acquisition and maintenance costs
Indicator:
€/yr/m^2 (30/50 yrs)

6.2 Creating value and managing risk

Value/risk factors
Indicator:
Reliability rating of indicator input data

Key to the colour coding: **'Advanced' core indicators** | **'Basic' core indicators**

Theme 3: Building upon existing standards and methodological developments

The importance of building upon existing standards, as well as prevailing thinking on methodologies, has emerged as a common theme across the range of evidence analysed. However, in order to promote wider and more consistent use of standards such as EN 15978 (building LCA) and ISO 15686-5 (building LCC), it may be necessary to set some common, minimum reporting 'rules'. The consensus from a number of sources of evidence is that this could include:

- A narrowed set of boundaries: Focussing on life cycle stages which evidence shows are more significant, or for which it would be of most immediate value for the target market *e.g. production stage for building products, operational costs for home buyers and property investors.*
- A more limited scope: By setting a specific cut-off or defining a set of building elements/components for which there is evidence that they are 'hot spots' for environmental impact *e.g. superstructure, substructure and external envelope for LCA.*
- Using defined scenarios: The fixing of some scenarios and related assumptions *e.g. minimum building service life for LCA, end of life routes for LCA, reference year for LCC.*

Theme 4: Data availability, quality and transparency

In the case of both LCA and LCC, the availability, quality and resolution of datasets can be problematic, as it can:

- Be a potential barrier to uptake because of the perceived gaps;
- Complicate use of the indicator by requiring further data collection;
- Create problems for the comparability and meaningfulness of results.

For a number of potential indicators and their associated methodologies, this theme raised a number of specific challenges for wider implementation across the EU:

- How users can be supported in member states where no databases or datasets are initially available;
- The basis on which generic or unverified data can be used, in order to encourage design teams/clients to 'get started'; and
- How variations in the quality of data, and the associated uncertainty, can be reflected in performance reporting.

In Section 3 these issues are further discussed in relaton to embodied CO_2.eq data (indicator proposal 1.2), building component costs and life spans (indicator proposal 2.2), and climate change projections for specific locations (indicator proposals 5.1/5.2).

Theme 5: The level at which the indicators should be comparable

There are many possible factors that can introduce variations in building performance across the EU. These can, for example, include climate, geology, construction culture, product manufacturing and property markets. This raises the question as to how meaningful it would be to be able to compare the performance of buildings across the EU.

In practice, performance comparisons tend to be more meaningful at a project level, in a local property market, or across a property portfolio. However, at a policy level or in the management of international portfolios there would be value at national or regional level. Comparability can therefore be approached in a number of ways:

- By supporting comparisons from the bottom up: A priority focus on comparisons at project level and in local property markets, followed by regional/national portfolio level;

- By supporting comparisons from the top down: A priority focus at the EU-level based on absolute performance, normalised to reference units of consumption or linked to policy targets/objectives.

A related decision is whether to contextualise reporting to reflect local conditions – for example, typical water consumption patterns, the local costs of building materials – or to make comparisons based on generic parameters.

Theme 6: The potential to track performance along a projects life cycle

There is an increasing focus by property investors, as well as design professionals, on how well occupied buildings perform compared to their design specifications. This has tended to focus on the potential for variance between performance variables established at the design stage and measured performance upon practical completion and during occupation - the so-called performance gap.

Addressing performance gaps creates a number of challenges when specifying indicators. For example, up until now, the focus of attention on addressing indoor air quality has tended to be on source control – the selection of building materials that emit less hazardous substances. But some of these emissions may be expensive and complex to measure in a completed building. For example, an 'R-value' for evaluation of health-related emissions, as used in Germany and Belgium, refers to emissions concentrations for nearly 100 individual substances.

In other cases, it may not be possible to establish very specific, simple indicators For example, in the case of dampness and mould, a rating systems based on expert inspections may be needed. In this case, inspections may not yield meaningful results until several years into occupation of a property.

Measuring real performance can also extend to involve the occupants themselves – the end-users of the building. This aspect is particularly important given the financial value of office productivity and healthy homes. Occupant surveys aim to understand whether occupants are satisfied with specific performance aspects, such as air quality and thermal comfort.

In some cases, the results of statistical models used at design stage to predict occupant satisfaction (for example, 'Predicted Mean Vote' for thermal comfort) have the potential to be compared with the findings from surveys. However, care needs to be taken to control for other influences on satisfaction of dissatisfaction with a home or office.

3. First proposals for the indicators by macro-objective

3.1 Macro-objective 1: Greenhouse gas emissions from building life cycle energy use

3.1.1 Key findings from the indicator scoping and evidence gathering

The findings relating to this macro-objective reflect the three distinct areas of focus that are described in the scope and definition in Working Paper 2 – operational energy efficiency, embodied life CO_2 emissions and the potential to minimise the gap between design and actual performance.

3.1.1.1 Operational energy use

In order to make the link between environmental performance and cost it is proposed to refer to the operational energy used by a building. This energy use can be reported on using *measurements* from metering, but can also be *calculated* at the design or as built stage.

Identifying a suitable core indicator

The recast Energy Performance of Buildings Directive (EPBD) establishes a unit of measurement (total primary energy kWh/m^2.yr), a scope of energy consumption aspects and is supported by a number of comprehensive EN standards that provide calculation rules and reporting formats (notably EN 15603 and EN 13790, to be superseded by EN 52000-1 and EN 52016).

The above referred to standards are intended to provide a tool for Member States to use, if they choose so, when implementing the Directive. In light of the local and climatic differences and the subsidiarity aspects intrinsic to buildings, the Directive does not impose a single calculation method to be used across the EU Member States.

The multi-criteria building assessment schemes and reporting tools examined in Working Papers 1 and 2 address both *calculated* primary energy consumption at design stage, and *measured* primary energy consumption during the use phase. EN 15603 and the standard that is intended to supersede it (prEN 52000-1) provide methodologies for addressing both these forms of reporting. Reporting on measured (metered) consumption requires disaggregation of regulated and unregulated ('non-EPB') energy consumption, with the regulated component being the main focus for minimum performance requirements in member states.

It is considered that an indicator that corresponds with the units, scope and functional unit of the EPBD Directive (i.e. total primary energy consumption) is likely to be the most readily and widely accepted – particularly with reference to National Calculation Methods across the EU. In line with the provisions of Article 11(9) of the Energy Performance of Buildings Directive, the Commission is currently developing an EU Voluntary Certification Scheme (EVCS) for non-residential buildings.

Following consultations with stakeholders and Member States, this EVCS scheme will be founded on the prEN 52000-1 standard as its default option for the calculation and rating of energy performance of buildings. The EVCS will be supported by a European Commission Implementing Regulation.

The reliability of data and input assumptions

The reliability of calculated energy consumption data is strongly influenced by the input assumptions, but also by the simulation used. The quality of building survey data and information on the construction details of existing buildings is also important for renovation projects. The EVCS will use dynamic simulation as the basis for energy assessment (hourly calculation intervals) and calculation of the non-renewable primary energy balance as the headline performance metric, to be calculated according to the pr52000-set of standards for the energy performance of buildings.

Taken together, the choice of hourly calculation intervals and dynamic simulation may represent a high ambition level for the core indicator set, considering that steady state (monthly calculation step) simulations are still the basis for National Calculation Methods (NCM) in several EU countries and that the scope for the core indicators includes residential buildings.

It may therefore be preferable to retain a broader focus on total primary energy use, which includes both non-renewable and renewable primary energy use, in order to ensure that the overall energy efficiency of a building is addressed and that renewable energy is also used efficiently. Other related performance indicators could be considered at a later point in time, once the market uptake of the EVCS has reached a certain level and experience is available.

The potential to use different measures of energy intensity

Performance in kWh (per year) can be normalised using a number of different functional units, some of which better reflect the resource intensity of a buildings use. Options identified from literature and benchmarking exercises include m^2 of useable floor space, per bed space, per workstation, or per full time employee.

Accounting the construction quality and commissioning

Certain indicators can also be used to monitor the quality of construction as executed and the commissioning process for services such as Heating, Ventilation and Air Conditioning (HVAC). The extent to which these two aspects are addressed can be a significant factor in explaining any deviation between design (calculated) and actual (measured) operational performance. Some countries, cities, refurbishment programmes and certification schemes set strict requirements for quality testing, such as thermal bridging and air pressure testing. This in turn may incentivise a greater focus on detailed design and construction quality to minimise any performance gap.

3.1.1.2 Embodied life cycle Global Warming Potential

The calculation of a 'carbon footprint' or life cycle Global Warming Potential (GWP) is a demanding task that, based on consistent feedback from a range of pilot studies and practitioners, still requires time and expertise. It is not currently standard practice, even on projects that have sought major multi-criteria building certifications, and there remain significant issues to address before there is an accessible and comparable basis for calculations to be carried out across the EU.

Working within the framework of EN 15978 and EN 15804

A number of national initiatives have reached the conclusion that although EN 15978 provides a solid methodological basis for calculations, wider adoption would require a more tightly defined, common set of rules to ensure that the standard is consistently applied.

The availability of data is an issue that requires particular attention. For example, in many cases generic life cycle inventory databases used for LCA may have to be used initially. This brings inherent problems with the quality and age of data, with comparative studies indicating a significant potential for variance in the results (generic data versus up to date primary data). A hierarchy of data quality has been suggested by some pilot studies as a way forward.

Reflecting both the availability of data, and those building elements and life cycle stages which account for the most significant embodied CO_2.eq emissions, a narrowing of the boundary and scope of embodied CO_2 calculations consistently emerges as a pragmatic way of focusing attention on those life cycle stages and parts of a building where the most significant scope for improvement exists. The main focus is generally on structures, followed also by elements such as foundations, floors and the external envelope.

Replacement of building components during the life span of a building is an additional area for consideration. There is evidence that for office buildings, internal fit-outs and the replacement of facades can also become hot spots. The inclusion of use stages B2-4 in embodied carbon calculation rules is therefore being considered in some EU countries, so as to encourage the consideration of more durable components and finishes.

Rules relating to the life cycle stages C and D

The end of life of a building (stage C), as well as module D benefits beyond the life cycle boundaries, are still hypothetical concepts for building design teams. However, under the current rules in EN 15978, if these stages are not included within the boundary, the life cycle embodied CO_2.eq emissions associated with some common building materials could be significantly over or underestimated.

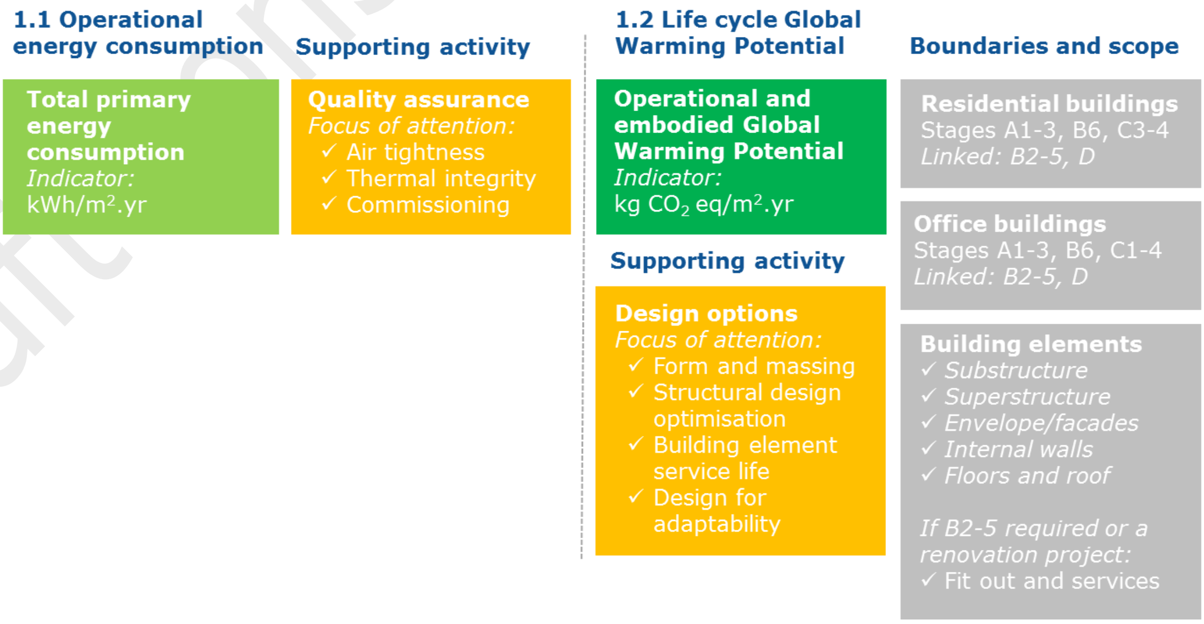
Two examples can be cited. In the case of timber, if the end of life stage is omitted, then embodied CO_2.eq along the life cycle may be underestimated because of potential emissions from landfilling. In the case of steel, optimistic assumptions for the claiming of Module D credits could result in an underestimation of life cycle embodied CO_2.eq emissions.

Both of these cited examples suggest that, based on the current practice for some multi-criteria certification schemes, there is the need to set some simple rules relating to the end of life stage. For example, the definition of end of life scenarios and improved verification of design for deconstruction and recyclability so as to ensure there is a level playing field for building materials. This situation may change for some building materials if, under a new draft mandate from DG GROW, the end of life and biogenic CO_2 rules from the European Commission's Product Environmental Footprint methodology are introduced into EN 15978.

3.1.2 First proposals for indicators

In this section, the proposed options for macro-objective 1 indicators are outlined. Two options are illustrated in Figure 3.1, which are based on a variation in the boundary and scope of indicator proposal 1.2, with potential links to indicator proposals associated with macro-objective 2 (indicator proposals 2.2 and 2.3). The proposals are specified further in Table 3.1.

Option 1: Defined life cycle boundaries and scope



Option 2: Whole life cycle boundary with defined scope

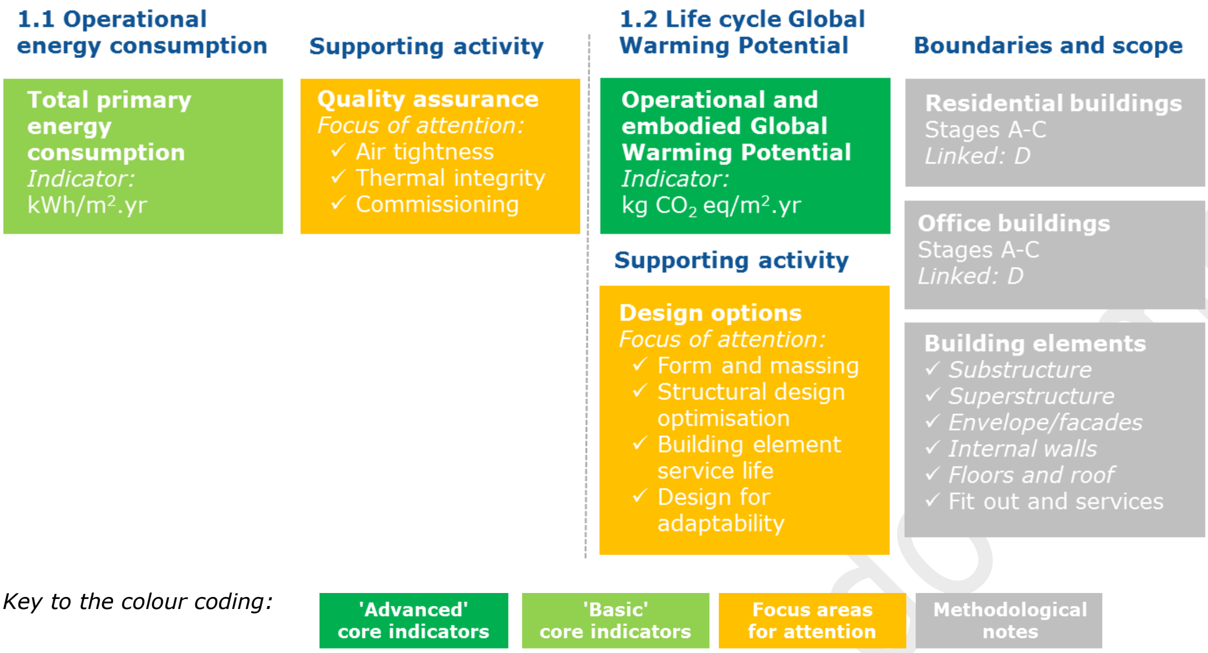


Figure 3.1 Structure of the proposed macro-objective 1 indicators

Table 3.1 Specification for the macro-objective 1 indicator proposals

Indicator	**Unit of measurement**	**Boundaries and scope**	**Sources**
1.1 Operational energy consumption			
Total primary energy consumption	kWh/m².yr	Calculation according to the scope of EN 15603 of the minimum EPBD regulated energy consumption scope – with heating (b) and cooling (c) consumption also identified separately. Calculated and measured consumption can both be reported, but shall be disaggregated and reported in accordance with EN 15603 and prEN 52000-1 (with reference to Annex B).	FS CC AR
Supporting focus of attention: Quality assurance of the building fabric and HVAC i. Air tightness ii. Thermal imaging iii. Commissioning	m³/h.m² at 50 Pa *and* variance Confirm thermal imaging study carried out Functional performance testing carried out	Air tightness testing for a sample of residential properties and compartments of an office building upon completion. Thermal imaging for a sample of residential properties or an office building. Functional performance testing of building services and management systems.	FS CC AR
1.2 Life cycle Global Warming Potential			
Operational and embodied Global Warming Potential	kg CO_2eq/m² .yr	*Option 1:Defined boundaries and scope* Calculation for the following life cycle stages according to EN 15978: - A1-3 Production - B6 Operational energy use - C3-4 End of life *The following additional stages shall be reported on if indicators 2.2 and 2.3 are used:*	FS CC AR

		- B2-4 Maintenance, repair and replacement - D Benefits beyond the system boundaries The calculation shall be for a defined list of 'hot spot' building elements, to include: - Substructure, - Superstructure, - External envelope/facade systems - Internal walls - Floors and roof - Fit out and services (for renovations)	
		Option 2:Whole life cycle with defined scope Calculation for all life cycle stages according to EN 15978. - A1-3 Production - B6 Operational energy use - C1-4 End of life *The following additional stages may be reported on if indicator 2.3 is used:* - D Benefits beyond the system boundaries The calculation shall be for a defined list of 'hot spot' building elements, to include: - Substructure, - Superstructure, - External envelope/facade systems - Internal walls - Floors and roof - Fit out and services (for renovations)	FS CC AR

Key to sources:

FS (Field study findings) CC (Cross Check evidence) AR (Assessment and Reporting scheme criteria)

3.1.3 Proposed calculation rules (where applicable)

3.1.3.1 Operational primary energy use (1 'basic' indicator)

- To ensure alignment with the proposed EVCS scheme and prEN 52000, the time frequency used for the calculation shall be reported.
- For measured energy consumption data, and in accordance with EN 13790 (prEN 52016), an assessment period of at least three years with similar patterns of occupation is recommended. If not, the appropriate adjustments shall be applied.
- Both calculated and measured primary energy consumption shall, in accordance with the current EN 15603 format, be disaggregated into the minimum scope of (regulated) delivered energy as set out in the EPBD (recast) and unregulated (non-EPB) energy consumption.
- It shall be reported whether *calculations* have been made based on standard or actual conditions of use.
- Additional normalisation options that may better measure intensity of energy use shall be offered to users. These could be used alongside the core indicator to improve the measurement of intensity of resource use e.g. per bedspace, per workstation, or per full time employee.
- For calculated total primary energy consumption, the generic residential appliance and office equipment electricity use data provided in the current EN 15603 Annex C could be used as a starting point.
- As a supporting activity, it is recommended that upon completion of a building (or for a sample of residential buildings/apartments), testing of the quality of the

finished building fabric according to EN13829 (fan pressurisation) and EN 13187 (thermal imaging) is carried out.

- Reference shall also be made to commissioning routines, such as functional performance testing, as a supporting activity.

3.1.3.2 Life cycle Global Warming Potential (1 'advanced' indicator)

- Calculation shall be carried out according to the boundaries and scope of EN 15978, but an option is proposed to reduce the boundary to a more limited number of life cycle stages and a defined minimum scope of building elements.
- Reporting could consist of both the calculated emissions for each life cycle stage, so as not to lose information, and an aggregated figure.
- The service life to be used for calculations shall be set at 50 years for both residential and office buildings. Reporting may also optionally be made for a longer time frame.
- In the reduced boundary and scope option, the scope of the life cycle stages shall focus on the production stage (cradle to gate) and operational energy use, with the exception of where building component service lives are reported on as part of proposed indicator 2.2, where the scope shall be extended into specific stages of Use.
- It is proposed to define EU end of life scenarios and that module D net benefits be subject to reporting on proposed indicator 2.3.
- The proportion of the embodied CO_2 data by source shall be reported. With reference to EN 15978/15804 it is proposed to refer to a simple hierarchy in order to reflect the different sources of data, their age and quality – for example:

  - Generic (default) EU or Life Cycle Inventory (LCI) data
  - Generic national data
  - Collective EPD or LCA primary data from national or private databases
  - Primary data from manufacturers for specific building products

3.1.4 Potential trade-offs, benefits and linkages

- Macro-objective 4: Airtightness and thermal bridges are linked with the ventilation rate and the potential prevalence of mould and moisture problems. A high level of airtightness increases the need for an adapted ventilation rate, whereas thermal bridges are an important cause of mould and moisture problems.

Macro-objective 1 consultation questions

- Which aspects of indicator proposal 1.1 should be aligned with the proposed EU Voluntary Certificate Scheme?
- Does indicator proposal 1.1 provide a strong enough incentive to design more efficient buildings?
- To what extent should the boundary and scope of reporting on indicator proposal 1.2 be defined in order to encourage reporting?

These questions can be answered using the online EU Survey tool

3.2 Macro-objective 2: Resource efficient material life cycles

3.2.1 Key findings from the indicator scoping and evidence gathering

The findings relating to this macro-objective reflect the four distinct areas of focus that are described in the scope and definition in Working Paper 2 – lean material flows. circular material flows, extended material utility and reducing significant environmental impacts.

3.2.1.1 Material efficiency and structural design optimisation (lean design)

There is a significant potential for building material efficiency by encouraging the comparison of different potential forms of housing and offices to deliver the same number of units or m^2 office space on the same site. The chosen form and massing can result in significant variations in building material use, as well as influencing the surface area to volume ratio and linked to this the thermal efficiency of a building.

Encouraging a focus on the structural design optimisation for all forms of material – steel, concrete, timber and structural insulation – could also yield significant material efficiency gains. This can be measured in terms of load bearing capacity or a utilisation ratio (compared with Eurocode requirements for example).

Trade-offs can however be identified, for example, when leaner concrete design requires higher cement content (e.g. post tensioned or high strength concrete) or where stronger/lighter steel has higher embodied primary energy or CO_2 eq. Different structural solutions should therefore not be compared on a mass basis for different types of structural materials. For comparisons of different structural materials proposed indicator 1.2 (life cycle embodied CO_2.eq) should be used instead.

For both housing and offices, design optimisation within proposed indicator 1.2 could be extended to include not only the building structure but also the building envelope, floors and partitioning, which could encourage reduction in waste through more efficient design/off-site construction processes.

3.2.1.2 Design for extended service life and adaptability (material utility)

The material inventory stored within building structures and envelopes is substantial and its utility should as far as possible be extended, either in situ or for the purpose of building element/component re-use (or recycling). Whilst the potential for future adaptability of buildings is highlighted in the literature as being an important consideration, there are few mature indicators currently in use.

EN 15643-3/EN 16309 provides some limited pointers as to measures that can be taken to increase adaptability. ISO 20887 Design for Disassembly and Adaptability of Buildings is under development by TC 59/SC17, initiated by proposals from Canada.

The state of the art are lists of between 7 and 15 adaptability aspects related to office building, floor plate and servicing multifunctionality (DGNB, BREEAM NL). These lists are based on scorings by property valuation systems and research on 'open buildings' in the Netherlands. A composite score can be derived which could form the basis for an indicator for office buildings. More work is needed to fully incorporate the concept of change of uses from office to residential and vice versa.

For office buildings or apartment blocks with an anticipated service life of >50-60 years, and particular those with structures that are not able (based on current technology) to be readily dismantled, it has been suggested that they should demonstrate their fitness for future adaptability, so as to prolong the lifespan of the structure and other major building elements.

The design life of the building envelope may warrant special consideration as it is exposed more than the structure to external environmental conditions, or in some cases they may be one and the same. Some multi-criteria certification schemes encourage reporting on the service lives of building, structures and certain defined components, in some cases linked to LCA or LCC calculations. Here again, it would be possible to consider linking reporting on embodied CO_2 eq to the service life of the façade or envelope *e.g. shorter life facades shall report on design for deconstruction*.

3.2.1.3 Design for deconstruction and circularity (circular flows and material utility)

Two different aspects of circular material flows related to buildings have been identified. The first relates to transforming primary input flows to reused or recycled materials. The second relates to the potential in the future for materials to be reused or recycled at the end of life of a building or its elements.

Recycled and reused input materials

The specification of building materials with recycled content can deliver improvements in environmental performance. There are, however, cases where the benefit of recycling of high weight materials such as aggregates can be cancelled out by processing and transport related impacts. Care therefore needs to be taken, and it is in general recommended that a life cycle approach is used to assessing the benefit of recycling.

Reuse is another case in point, because there may exist the potential to re-use substantial elements of an existing building – for example, the foundations and superstructure – as part of a remodelling exercise. Linked to this, there may be the potential to re-assess the thermal integrity, internal layouts and the use intensity of a building. This can be captured by a 'new build recovery' index which establishes a link between a building to (potentially) be demolished and the new building design – as encouraged by a number of multi-criteria assessment schemes.

In cases where reused building materials are brought from offsite, the potential balance between the environmental benefits and processing/transport impacts related to bringing the materials back into use requires further investigation. It is likely that in the case of short supply chains there would be a net benefit.

Design for deconstruction, disassembly and recyclability

Future consideration of the potential of a building for deconstruction and disassembly is a new and challenging concept for design teams and clients. There are currently no mature indicators to measure disassembly, but it is a concept that is already practiced for some building types e.g. light industrial buildings, in 'circular building' contracts in the Netherlands.

A number of major surveys of demolition contractors reviewed as part of this study indicate highlight two main aspects as being important to address:

- Improved consideration of a buildings deconstruction potential at the design and construction stage (ease of dismantling/separability of building elements are cited);
- The archiving of building inventory information from the design and construction stages (as-built drawings) so that it can then be referred to upon renovation, reuse or demolition.

As already noted for adaptability, ISO 20887 Design for Disassembly and Adaptability of Buildings is under development by TC 59/SC17, initiated by proposals from Canada. This is also intended to address disassembly.

The state of the art is a category scoring for ease of disassembly, scope of disassembly and viability of disassembly (DGNB International). A refinement of this approach takes into account both the potential for disassembly and the potential recyclability of building components and their constituent materials (DGNB Germany). This could form the basis for an indicator, with a scope defined in order to focus attention on hot spot building elements.

For office buildings or apartment blocks with an anticipated service life of <50-60 years, it has been suggested that the superstructure, envelope and/or façade should be designed for dismantling (i.e. whole potentially re-usable parts such as concrete panels, bricks, steel sections).

Uncertainty relating to end of life scenarios for building materials suggest that there may be value in establishing the disassembly potential of a building and key elements as a pre-requisite for the claiming of Module D benefits according to EN 15978/15804 (e.g. in the case of steel structures).

3.2.1.4 Construction and demolition waste minimisation (circular flows)

Waste can arise both from the demolition of existing buildings in order to clear a site, and from practices on site during the construction or renovation of buildings. The need to encourage clients and contractors to report on construction and demolition waste arisings appears to be particularly important in those EU countries where waste arisings are high and recovery rates currently low, and where there is not yet a construction culture that addresses this issue.

In order to achieve high-grade recycled material, the amount of unwanted constituents in material streams needs to be limited. This can be achieved by a selective demolition process or by a sorting process after the demolition.

A number of certification schemes specifically focus on rewarding the reuse of whole buildings, or major elements such as structures and foundations. This supposes evaluation of the extent to which a whole building's energy performance can be improved, but the re-use of hot spot elements within the building envelope such as structural systems could be encouraged by this approach.

Generally landfill diversion rates do not provide information about the type of recovery (reuse, recycling, energy recovery). The potential to incentivise and focus attention on the recycling of material may therefore not be achieved. Another important aspect is the quality of separated material streams and their recovery potential (e.g. separate recycling of the glass fraction versus including the glass in the mixed stony fraction).

Demolition waste is generally more difficult to recover/recycle/reuse than construction waste (e.g. bricks) – albeit depending on how waste is managed on a construction and demolition site. The two waste streams also tend to have a very different composition. Off-site manufacturing and prefabrication are techniques that can be used to reduce construction site waste, as well as supporting faster and more precise construction. However whilst they may reduce waste there may be trade-offs such as greater transport distances.

3.2.1.5 A whole life cycle perspective on significant environmental impacts

In the scope and definition of the macro-objective, reference was made to the potential to 'reduce significant environmental impacts' associated with building materials. Whilst individual improvement measures can be specified for building materials (e.g. sustainable sourcing of timber, substitution of portland cement in concrete), this could be problematic because – as was highlighted in Working Paper 1 - each major type of building material has a distinct environmental impact profile.

The state of the art methodology to evaluate the environmental impacts of different building materials is a full LCA. Based on the findings of the study to date, however, this is not currently a common practice in the market and supposes a high level of expertise. Moreover, the absence of a robust, agreed common EU weighting methodology for LCA Impact Categories means that using the results requires expert judgement, and these can in general therefore only be used for broad identification of hot spots within individual Impact Categories *e.g. global warming potential, resource depletion potential, ecotoxicity*.

A further related issue is that because each common building material has such distinct environmental impacts, a broad range of indicators would be required to capture all potentially significant impacts. The CEN/TC 350 standards EN 15804 and EN 15978 provide a limited number of midpoint Impact Categories compared to the European Commission's Product Environmental Footprint (PEF) method, or other more widely used methodologies such as CML or ReCiPe. Whilst the impact categories listed by the CEN/TC 350 LCA standards may be expanded in the future, they would not currently be able to support comparisons involving, for example, the relative sustainability of forestry management or the ecotoxicity of material production processes.

3.2.2 First proposals for indicators

In this section the proposed options for macro-objective 2 indicators are outlined. Figure 3.2 illustrates one 'advanced' indicator which is to be further defined (2.1) and three 'basic' indicators. The proposals are specified further in Table 3.2.

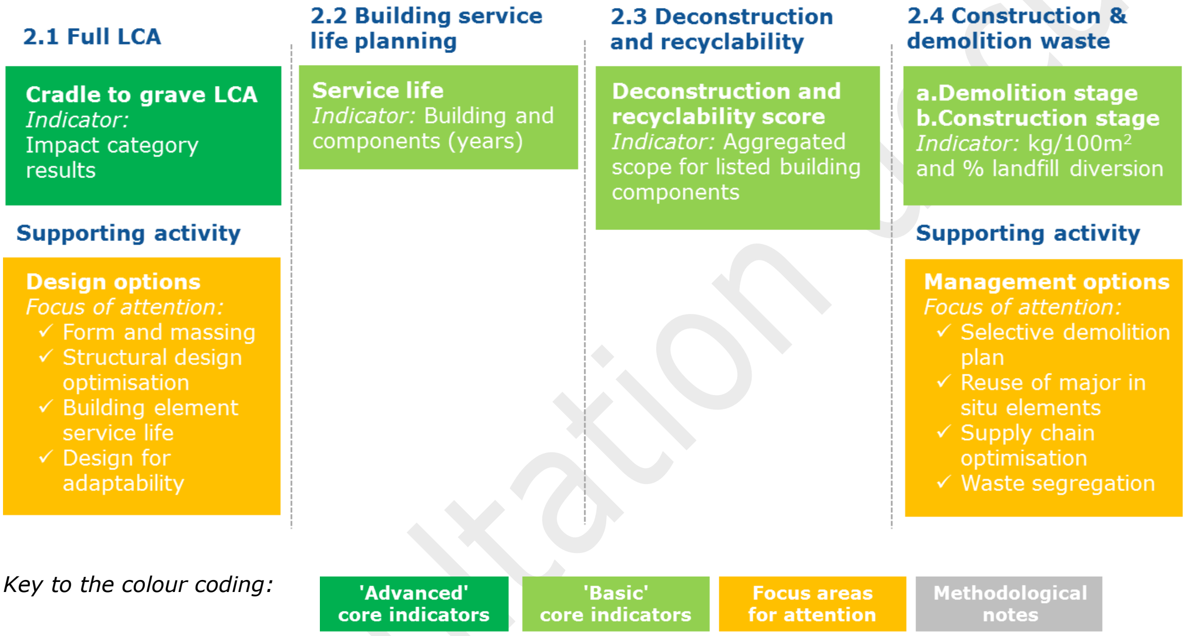


Figure 3.2 Structure of the proposed macro-objective 2 indicators

Table 3.2 Specification for the macro-objective 2 indicator proposals

Indicator	**Unit of measurement**	**Boundaries and scope**	**Sources**
Material efficiency and structural design optimisation *(focus areas for attention)*			
a. Building form and massing	*recommended as a design activity as part of 1.2 and 2.1*	Bill of Quantities for building substructure, superstructure and envelope	FS CC
b. Building structure comparison	*recommended as a design activity as part of 1.2 and 2.1*	Bill of Quantities for building substructure, superstructure and façade (if load bearing)	FS CC
2.1 Full LCA			
Cradle to grave LCA	Impact category results normalised to m^2	Cradle to gate LCA according to EN 15978 and with an expanded list of impact categories *(to be specified).*	FS CC AR

2.2 Building, element and component service life			
Service life reporting	Design service life of the building and specified building elements and components.	Inventory of service lives for specified major building elements and components. *To reflect the scope of indicators 1.2 and 6.1b*	AR CC
2.3 Design for deconstruction and recyclability			
Ease and scope for disassembly and recycling	Sum of category scores	Rating of the disassembly potential and recyclability of three main building aspects: - Building services - Non-load bearing components of the building shell - Load-bearing components of the building shell	AR CC
2.4 Construction and demolition waste minimisation			
Waste arisings a. Demolition b. Construction	*For each:* i. Tonnes per 100m² floor area ii. % diversion to recycling and re-use (excluding backfilling)	Reporting on total waste arisings and diversion rates from demolition sites (excluding excavations) and, following on from that, the construction site.	CC AR

Key to sources:

FS (Field study findings) CC (Cross Check evidence) AR (Assessment and Reporting scheme criteria)

3.2.3 Proposed calculation rules (*where applicable*)

3.2.3.1 Design for deconstruction and recyclability (1 'basic' indicator)

- Where external building elements have a design life <20 years, it is recommended to report on this indicator.
- Where the structural material life span is <50-60 years it is recommended to also report on this indicator.
- Where the structure's service life span >60 years and/or effective disassembly is not an option, it is recommended to examine as part of calculation of proposed indicator 1.2, scenarios for future design for adaptability (with guidance to be provided).

3.2.3.2 Construction and demolition waste (2 'basic' indicators)

- A monitoring and accounting system is required in order to report.
- Backfilling is to be specifically excluded from the landfill diversion options.
- The demolition of a building and the potential for elements or components of it to be used in the construction of a new building in the same location could be linked by using a 'New Build Recovery Index' *e.g. if the structure or other major elements are to be re-used in situ without demolition*.
- Where off site construction is used, any waste arising at the factory shall be within the scope of the calculation.

3.2.4 Potential trade-offs, benefits and linkages

- Macro-objective 1: Comparisons between different material options (including concrete mix designs, use of timber or polymer structures) should only be made using proposed indicators 1.2 or 2.1, so as to consider trade-offs and benefits (e.g. thermal mass, higher cement content).

- Macro-objective 1: Benefits from Module D of EN 15978 could be taken into account for specific building elements if design for deconstruction, disassembly and recyclability is reported on.
- Macro-objective 1: Offsite construction can reduce site waste as well as supporting higher quality, air tight construction.
- Macro-objective 1: Recycled content composed of high weight non-metallic minerals may incur transport CO_2 emissions which may offset embodied CO_2 reductions.
- Macro-objective 6: Links can be identified between the requirement to estimate the lifespan of the building and elements as a component of LCC calculations in macro-objective 6, and embodied life cycle CO_2 in macro-objective 1.

Macro-objective 2 consultation questions

- What form should reporting on a full LCA (indicator 2.1) take?
- Should a design for adaptability indicator be developed or is it sufficient to encourage consideration within indicator proposals 1.2 and 2.1?
- Does indicator proposal 2.2 have added value being reported as a separate indicator?
- Would 2.3 encourage design teams and contractors to focus on this issue at design and construction stage?
- Should the in situ reuse of large building elements such as structures in new or remodeled buildings be specifically encouraged by an indicator?
- Is a separate recycled content indicator for building materials needed if it can already be addressed within indicator proposals 1.2 and/or 2.1?
- Should indicator proposals 1.2 and 2.3 be linked to allow for potential net CO_2 benefits at the end of life of a building to be consistently accounted for?

These questions can be answered using the online EU Survey tool

3.3 Macro-objective 3: Efficient use of water resources

3.3.1 Key findings from the indicator scoping and evidence gathering

The findings relating to this macro-objective reflect the two distinct areas of focus that are described in the scope and definition in Working Paper 2 – operational water consumption and the potential to focus attention on areas of water scarcity.

3.3.1.1 Water consumption

The scope of improvement measures for water tends to be limited to water consumption in the use phase, although water consumption in the construction stage is (optionally) addressed in certain certification schemes.

Different units of measurement and calculation tools are used depending on the certification scheme – for example: % reduction compared to reference value; m^3/year (per building); m^3/person.year (per occupant). Each certification scheme has its own unit of measurement and calculation tool. Some have now been integrated into national building permitting, which is the case in the UK, for example.

In general, the calculation methods used fall into two broad categories:

1. Determine consumption based on reference performance data which is then linked to building occupant consumption patterns,
2. Determine consumption based on reference performance data or manufacturers performance data for sanitary fittings.

Outdoor water usage (e.g. irrigation) tends to be handled as a separate calculation – although for reporting tools, disaggregated metered consumption for all uses can be reported. Metering installation is a supporting criteria in all multi-criteria assessment schemes and is required in order to obtain data to participate in reporting schemes.

In some cases, certification schemes distinguish between uses where potable water (from the mains drinking water supply) is required and those where this supply could be substituted by lower quality grades of water. A link is then made to how these lower quality grade uses are serviced e.g. using rain water and/or grey water.

3.3.1.2 Identifying areas of water scarcity

In some cases, the stringency of requirements applied to water consumption is adjusted to reflect local water scarcity. For example, BREEAM refers to three precipitation zones, but this does not provide for significant differentiation across the EU.

The European Environment Agency (EEA) water exploitation index (WEI), which was established in 2014 as a headline EU resource efficiency indicator, is a possible way of identifying EU areas where the efficient use of water should be a priority. The WEI reports on water stress according to a three level scale (0 – 20% low stress, >20% = stress, >40% severe stress). It is understood that reporting on the WEI will shortly undergo a revision by the EEA.

Water scarcity is a relatively new LCA indicator, and like WEI is greatly dependent on the availability of regional/local data. The WULCA project, combining international experts on the subject under the auspices of UNEP/SETAC, has developed a new impact assessment model, called AWaRe. This indicator has some similarities to the WEI but is understood to be harmonised with ISO 14046 for water footprint assessments. This standard additionally provides for the calculation of embodied water use. Data quality and availability for (embodied) production stage water footprinting is currently understood to be limited and of variable quality.

3.3.2 First proposals for indicators

In this section the proposal for a macro-objective 3 indicator is outlined. One option is illustrated in Figure 3.3 with a proposed reference to additional areas of design stage attention. The proposals are specified further in Table 3.3.

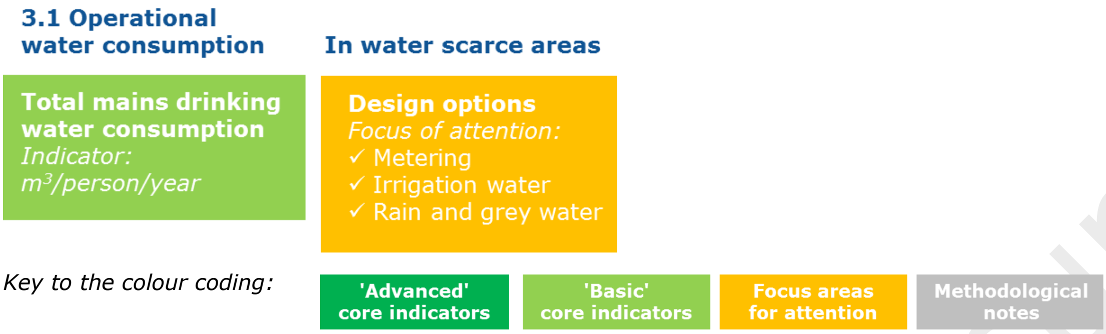


Figure 3.3 Structure of the proposed macro-objective 3 indicator

Table 3.3 Specification for the macro-objective 3 indicator proposal

Indicator	Unit of measurement	Boundaries and scope	Sources
3.1 Operational water consumption			
Total mains drinking water consumption (during use stage)	Residential and office buildings *m^3 per person per year*	Residential: All supplied water consumption, including sanitary appliances and external water use. Offices: All supplied water consumption, including the base building (common areas, servicing and external use) and tenant/occupier spaces	FS AR
Focus areas for attention *in water scarce areas*			
- Metering, - Irrigation water, - Rain and grey water	*Reductions or substitutions of mains water will be taken into account in 3.1*	Substitution of mains drinking water use by rain water or (recycled) grey water	AR

Key to sources:

FS (Field study findings) CC (Cross Check evidence) AR (Assessment and Reporting scheme criteria)

3.3.3 Proposed calculation rules (where applicable)

- The focus shall be on the consumption of drinking water supplied by the mains utility distribution network to the building.
- Reporting shall disclose whether the consumption figure is calculated or measured. In the case of the latter, metering shall reflect the scope of water consumption (to be defined).
- The methodologies for the two building types will reflect current certification practices, but with the unit of measurement harmonised to reflect an individual occupants annual usage.
- A methodology will be provided for residential buildings that is based on generic assumptions about the average water consumption of households in four zones of the EU.
- Primary data from sanitary equipment manufacturers shall be verified by third party certification or a product labelling scheme.

- A multiplying factor could be applied to the total consumption in order to adjust the generic performance of a fitting to typical occupant consumption patterns for that region of the EU *e.g. in Southern Europe the generic data might be multiplied by 1.26 because data suggests that water consumption is on average 26% higher than the overall EU average*. This is because there are significant variations in average water consumption across the EU. Adjusting the results in this way would mean that:
  - reporting betters reflect regional trends in water use;
  - that calculated and metered performance are better correlated, and;
  - would support users who wish to set meaningful benchmarks.
- In areas of water scarcity, additional areas to focus attention at design stage could be recommended. For example, these could encourage the substitution of potable mains water.

3.3.4 Identified trade-offs, benefits and linkages

- Macro-objective 1: less consumption of hot water has a positive effect on energy use as a result of domestic hot water production
- Macro-objective 5: Changes in the extent of irrigated areas and associated planting strategies of a site may interact with the micro-climate surrounding the building envelope

Macro-objective 3 consultation questions

- Is the proposed indicator sufficient to measure intensity of water use?
- What type of data do you consider appropriate to use for the water consumption of sanitary fittings?
- Should calculated residential water use be adjusted to reflect average consumption in that part of the EU *e.g. Southern Europe*.

These questions can be answered using the online EU Survey tool

3.4 Macro-objective 4: Healthy and comfortable spaces

3.4.1 Key findings from the indicator scoping and evidence gathering

The findings relating to this macro-objective reflect the two distinct areas of focus that are described in the scope and definition in Working Paper 2 – worker and occupant exposure to chemical hazards and biological hazards. This is also referred to in general as Indoor Air Quality.

3.4.1.1 Exposure to chemical hazards

A wide range of potential indoor air pollutants and hazardous substances have been identified. These include radon, NO_2, CO, Benzene, Formaldehydes, TVOC, particles, CO_2, heavy metals and asbestos. These pollutants have diverse sources, including human respiration (CO_2), interior finishings and furniture (e.g. TVOC and formaldehyde), insulation material (e.g. fibres) and polluted external air (e.g. benzene and particulates).

Health-based ventilation

Ventilation rates are important to obtain a good level of comfort within a building. In the case of insufficient ventilation, occupant health and well-being might be negatively affected, or pollutants emitted from indoor sources may accumulate. A sufficient ventilation rate that is adapted to the building, its indoor finishings and decoration, and its occupant density and behaviour, is necessary to extract indoor contaminants, control humidity and provide fresh air.

The EU funded HealthVent (Health based ventilation) project put forward an application strategy that could provide a useful framework for a composite set of EU indicators on indoor air quality [3]. The strategy places a priority on source control - including factors relating to a buildings location, materials specifications and maintenance - with adjustment of ventilation rates as a last resort to control indoor exposure – based on occupancy levels and the extent of source control. A minimum health-based ventilation rate is recommended, which forms the starting point for rates in EN 15251 (to be superseded by prEN 16798). A similar strategy was adopted by the Finnish Classification of the Indoor Environment, which is seen as a pioneer in this field.

EN pr16798, and EN 15251 before it, have established indoor comfort classes, ranging from class I to class IV, for Indoor Air Quality. These are intended to reflect an expected proportion of people that may be dissatisfied with the indoor air quality. Category II is a 'normal' level recommended for new buildings and renovations. Reflecting the HealthVent framework, the IAQ-comfort class ventilation rate in these standards is determined by reference to the level of pollutant emissions and, therefore the ability to remove both human emissions as well as emissions from materials used indoors.

Source control as a focus for attention

Annex C of EN 15251 and Annex A3 of prEN 16798 define an expected 'low' and 'very low' indoor pollution level. The scope includes emissions of total volatile organic compounds (TVOC), formaldehyde and carcinogenic VOCs, with an extension of the scope in EN 16798 to include R-Value. prEN 16798 also includes a new Annex A6 – WHO health-based criteria for indoor air. This provides WHO IAQ guideline levels for an expanded list of substances, including benzene, PAHs and particulate matter (PM 2,5 and 10). Annex C in EN 15251 and Annex A6 in prEN 16978 are informative only, having no linked requirements within the associated body of the standards. However, in prEN 16978 Annex A3 is now proposed as being normative within the standard.

[3] HealthVent, Project website hosted by the Technical University of Denmark, http://www.healthvent.byg.dtu.dk/

Selection of 'healthy' interior building materials is important and is generally considered as a priority over increasing ventilation rates: source control over source reduction. It is supported by three classes of measures:

- Imposed in product policy: e.g. Belgian regulation on VOC emissions from flooring products, the German AgBB and the French labelling for indoor construction products;
- Imposed in national building codes: D2 National Building Code of Finland, Ministry of the Environment, Department of Built Environment;
- Encouraged by voluntary product labels and building certifications: e.g. DGNB, LEED, EU Ecolabel, M1, Blue Angel and NaturePlus, etc.

Ongoing work, led by DG GROW, to agree a harmonised EU product VOC emissions class system could provide a scope and stable basis for classifying the performance of interior building materials. The harmonised approach looks likely to focus on establishing classes for total VOCs, Carcinogenic VOCs,an R-Value and formaldehyde. Supporting this approach, EU Lowest Concentration of Interest (LCI) values for hazardous substances have been established. LCI values form the basis for calculating the R-value used in a number of national product emissions schemes, and this aggregated value is currently the subject of discussion for inclusion in the harmonised EU product VOC emissions classes.

Determination of Indoor Air Quality (IAQ)

Although in situ post-completion IAQ testing is not yet commonly carried out across the EU, there is increasing awareness and demand in some countries such as Germany for example, where it is a mandatory requirement, post-completion but before occupation, as part of the DGNB assessment scheme.

The determination of indoor concentration levels for emissions can be performed using different analytical methods and techniques, and can be expressed in differing units. The use of standardised methods is recommended (e.g. the ISO-16000 series).

The most significant potential emissions sources are understood to relate to interior finishings, but there is not a clearly defined EU priority list. One field study highlights paints and varnishes, textile furnishings, floor coverings and fit-out materials incorporating particle board. Another possible approach is to prioritise by area of finish, although this would not reflect the potential for emissions. In each case, not only the material itself is likely to be relevant, but also chemicals used to install or fix the materials in place (*e.g. adhesives used to attached flooring or panels)*.

A further issue is whether in-situ IAQ testing should be carried out for an unoccupied building (post-completion) or post-occupation, when additional emissions sources may have been introduced, such as furniture. Post-completion is receiving growing attention, as opposed to post-occupation, when it becomes more difficult to identify source pollutants. Few field studies other than collaborative EU research projects and dedicated research projects provide results from the measurement of emissions post-completion. In the private sector, this is mainly because this type of testing has only recently been introduced into HQE and BREEAM assessments. However, as already noted, in the case of DGNB, it is now a mandatory requirement.

External sources of pollution

Some indoor air pollutants originate from external pollution, particularly in locations with high vehicular or industrial emissions. In general, studies suggest that benzene and PM 2,5 and 10,0 are of the most significance.

A focus on controlling external pollution may lead to decisions on where air intakes are placed, e.g. in courtyards/patios or away from pollution sources. EN 13779 additionally rates external air quality and indicates filtration levels. Field studies underline the effect of filtration of intake air, as well as the maintenance of air filters; the EU Healthvent project proposed a strategy for aligning required ventilation rate to 1) outdoor pollutant levels (WHO guidelines), and 2) initiatives for selecting low-emitting building materials.

3.4.1.2 Exposure to biological hazards

Humidity and condensation may also be important considerations as they can have significant implications for the health of occupants. Reviews of studies relating to homes suggested that around 17% of the EU population (approximately 80 million people) live in homes in which damp and associated mould growth may provoke respiratory or allergenic health effects.

Measurement of damp and mould is a relatively new area, and it appears that test methods to evaluate levels in-situ are relatively undeveloped for widespread use. Some Member States such as Finland have run extensive programmes to tackle problems in existing buildings, but these appear to have focused more on encouraging action through training and guidance. There is also increasing focus on damp in new properties, where increased air tightness coupled with poor ventilation can provoke problems.

Expert inspections and rating systems appear to be used in some member states and has been proposed as part of a harmonised Nordic standard. In at least one member state, damp and mould forms part of a hazard categorisation system for housing. Such systems can be used to diagnose building-related problems, such as thermal bridging and ventilation, prior to renovation and to monitor any recurrence post occupancy.

Building regulations in a number of member states seek to address the causal factors for damp and mould. For example, in Poland, there is a focus on the temperature of the inner surfaces of external walls, with reference to risk assessment of hygrothermal conditions according to ISO 13788. A thermal co-efficient level is specified to prevent condensation because of thermal bridging. In Sweden, buildings must be designed to avoid moisture conditions that can result in damage, smell or the appearance of mould. Maximum moisture conditions are laid down.

3.4.2 First proposals for indicators

In this section the proposed option for a macro-objective 4 indicator is outlined. One option is illustrated in Figure 3.4 with a proposed reference to additional focus areas for attention at design stage. The proposed reporting consists of a combination of quantitative and qualitative reporting on indoor air quality. The proposals are specified further in Table 3.4.

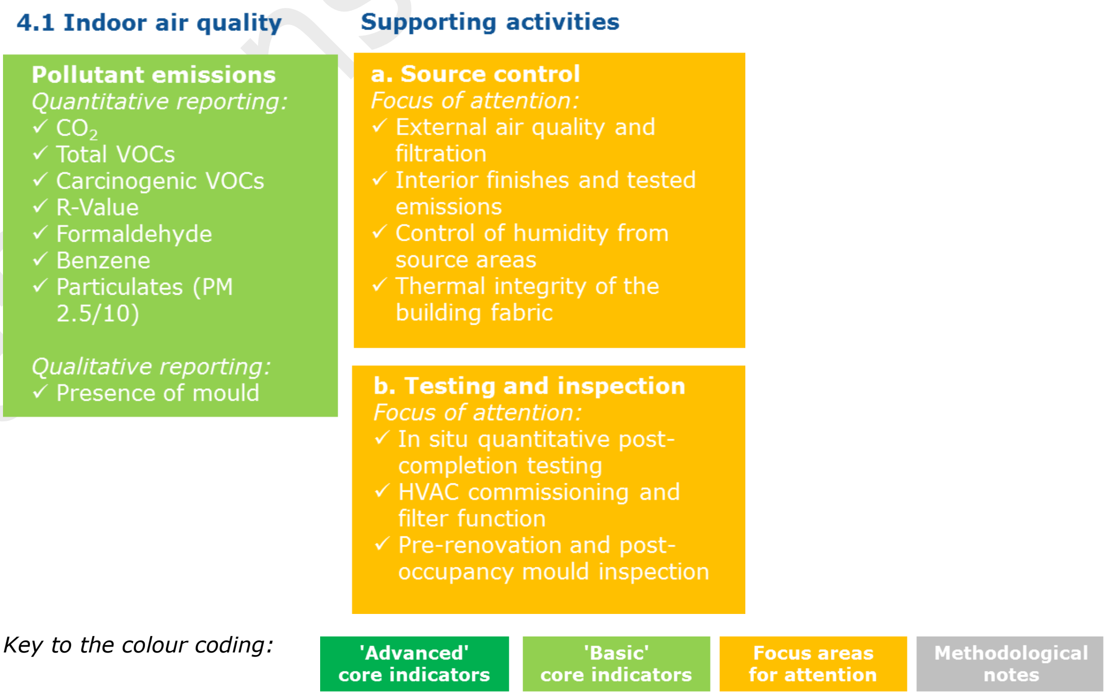


Figure 3.4 Structure of the proposed macro-objective 3 indicator

Table 3.4 Specification for the macro-objective 3 indicator proposal

Indicator	**Unit of measurement**	**Boundaries and scope**	**Sources**
4.1 Indoor air quality			
Reporting on specific pollutant levels and the presence of hazards	*Quantitative reporting:* ppm, µg/m^3 and R-Value *Qualitative reporting:* Damp/mould inspection classification	*Quantitative reporting:* - CO_2 - Total VOCs - Carcinogenic VOCs - R-Value - Formaldehyde - Benzene - Particulates (PM 2,5/10) *Qualitative reporting:* - Presence of mould	FS CC AR
Supporting activities			
a. Source control	Compliance with Category filter specification	Intake air classified into Outdoor Air (ODA) class according to WHO air quality guidelines. EN 13779 Table A.3 ODA classificaition and A.5 filter classes	FS CC
	µg/m^3 after 28 days *or* weighted score based on emissions classes	Product emissions testing results in accordance with CEN/TC 16516 for a specified list of interior finishes (incorporated within 4.1)	FS CC
b. Testing and inspection	ppm, µg/m^3 and R-Value	Post-completion (pre-occupancy) testing for 4.1 scope. *This could be carried out for a sample of office spaces or house/apartment types*	FS AR
	Classification system *or* Mould Severity Index	Pre-renovation inspection and post-occupancy (year 2/3) inspection of residential property to identify and diagnose: - areas with elevated humidity levels - severity of mould growth - localised thermal bridging and air gaps	FS CC

Key to sources:

FS (Field study findings) CC (Cross Check evidence) AR (Assessment and Reporting scheme criteria)

3.4.3 Potential trade-offs, benefits and linkages

- Macro-objective 1: Air tightness may reduce ventilation rates and could lead to a build-up of pollutants and humidity.
- Macro-objective 5: Green infrastructure can help to purify and clean air before it enters ventilation intakes.
- Macro-objective 6: Indoor air quality is cited as a factor that can improve worker productivity and the value of residential properties.

Macro-objective 4 consultation questions

- Do you agree with the proposed approach?
- Are the specific listed pollutants appropriate?
- How should the scope of building products, for which emissions testing results should be obtained, be defined?
- Is a qualitative inspection rating for damp/mould suitable?

These questions can be answered using the online EU Survey tool

3.5 Macro-objective 5: Resilience to climate change

3.5.1 Key findings from the indicator scoping and evidence gathering

The findings relating to this macro-objective reflect the two distinct areas of focus that are described in the scope and definition in Working Paper 2 – the thermal comfort of occupiers and the potential to moderate the urban microclimate around buildings.

3.5.1.1 The thermal comfort of building interiors

The indicators of thermal tolerance identified are similar to those used to measure/benchmark thermal comfort. As a result, various reference standards for thermal comfort (ASHRAE 55, EN ISO 15251/7730, CIBSE TM52) are also relevant for this aspect of the macro-objective. Care needs to be taken in selecting a reference standard. For example, comparisons with the actual performance of buildings against the outputs from predictive methodologies such as Predicted Mean Vote (PMV) have shown that they can be inaccurate by several degrees Celsius because they may over or under estimate discomfort levels.

The main difference that would be required for this macro-objective would be the use of predicted meteorological data sets to simulate future scenarios (e.g. UKCIP09, Meteonorm). There is therefore a dependency on these weather data files. However, care needs to be taken to specify the benchmark time series and future emissions scenario, as these can affect comparability. A more accessible option that has been used would be past heat wave weather data, such as 2003, but these were not consistent in their impact across the EU, and in their comparability with the 2030s and 2050s scenarios.

There are also differences between how people experience and adapt to thermal conditions in offices and residential buildings, as reflected in the different temperature thresholds laid down in EN 15251, and in the different approach to calculation methods for mechanically and naturally ventilated buildings. As a result, the methodologies vary, as is currently reflected in a number of standards – with calculation methods focusing on energy used (mechanically cooled buildings) and on how much time the interior is out of temperature range (naturally cooled buildings, including those with cooled structures).

Thermal comfort are a commonly complied criteria within multi-criteria assessment schemes for offices. However, the thermal comfort standards specified usually suppose the use of dynamic simulations, which are more complex to carry out and suppose greater cost and expertise. Although many member states already factor overheating into their National Calculation Methods (NCMs), as required by the Energy Performance of Building Directive (EPBD), not all are dynamic. Residential building NCMs and assessment scheme criteria tend to offer simplified summer overheating estimates as compliance options.

3.5.1.2 Moderation of the external microclimate

The presence of vegetation on buildings (e.g. green roofs) or between/within buildings (e.g. trees) can moderate external temperatures. The shading/cooling function of vegetation and soil can be factored into the (dynamic or steady-state) simulation of a buildings energy requirements, but input data does not appear to be readily available or robust (e.g. the shading effect of trees of different species and age) and it does not appear to be possible to do this in all NCMs – raising issues of comparability.

Various types of 'green factors' have been developed that act as a proxy for the benefits of green infrastructure (e.g. plant evapotranspiration, soil water retention) – as applied in Berlin, Malmö and Stockholm. The LEED multi-criteria assessment scheme also addresses this aspect, using both an area factor (in the non-residential and residential criteria) and consideration of the shading potential of vegetation after ten years growth (in the residential criteria). These factors apply weightings to the proportion of a building and its site that are not sealed surfaces and have green cover. However, the scientific basis for some of these weightings has been questioned. More robust weightings have therefore been developed for projects seeking to apply the green factor approach in other cities such as Southampton.

The use of a green factor raises a question as to what type of features would actually provide climate change resilience in 2030 or 2050. Green walls might not be maintained, but semi-mature trees could be considered a longer term feature. As already noted, the LEED residential criterion considers shading from vegetation after a growth period of ten years. If a green factor is used to provide future resilience it might therefore need to distinguish between the types of measures taken.

3.5.2 First proposals for indicators

In this section the proposed options for two macro-objective 5 indicators are outlined. The two options are illustrated in Figure 3.5, together with a proposed additional option for a proxy indicator in the case that external microclimate benefits cannot be accounted for within building energy simulations. The proposals are specified further in Table 3.5.

Given the level of overlap between the potential indicators with energy consumption and indoor comfort, it is proposed for discussion that the indicators for macro-objective 5 be moved so as to be reported on alongside the indicators for macro-objectives 1 and 4. However, stakeholders' views will be welcomed on whether it is desirable to retain a distinct macro-objective focusing on *'resilience to climate change'*.

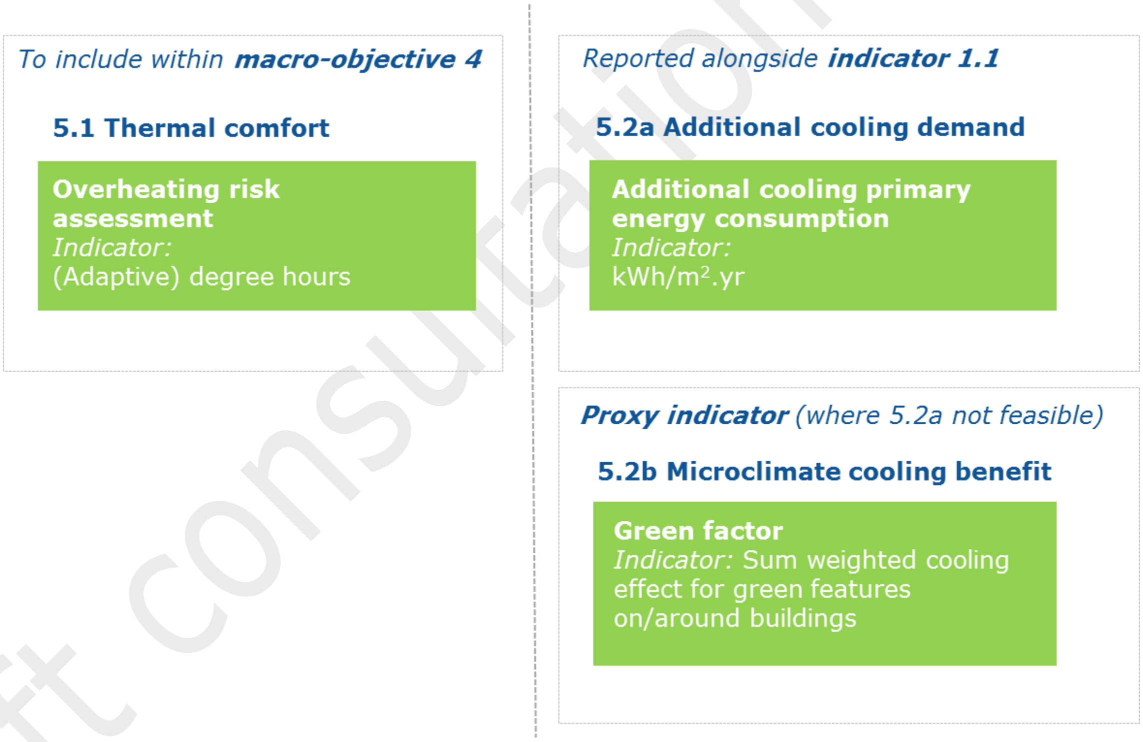


Figure 3.5 Structure of the proposed macro-objective 5 indicators

Table 3.5 Specification for the macro-objective 5 indicator proposals

Indicator	Unit of measurement	Boundaries and scope	Sources
5.1 Thermal comfort *to include within* ***indicator 4***			
Overheating risk assessment	(adaptive) degree hours	Variance in degree hours over baseline temperature in 2030s and 2050s compared to the present weather file.	AR
5.2a Additional cooling demand *Reported alongside* ***indicator 1.1***			
Additional cooling primary energy consumption	kWh/m^2	Calculated additional cooling energy in 2030s and 2050s compared to the present weather file in order to maintain a defined interior temperature.	FS CC AR
5.2b Microclimate cooling benefit ***Proxy indicator*** *(where 5.2a is not feasible)*			
Green factor	Sum of weighted cooling effect for green features on/around the building	A set of weightings would be used to favour spaces around, within and on the building that have deep soil, semi-mature trees and have the potential to have a significant Leaf Area Index by 2030/2050.	FS CC

Key to sources:

FS (Field study findings) CC (Cross Check evidence) AR (Assessment and Reporting scheme criteria)

3.5.3 Proposed calculation rules (where applicable)

- In each thermal comfort scenario, the modelled future performance of the building shall be compared with the building design submitted for compliance with local energy performance requirements.
- It should be possible for users to model using either steady state (e.g. EN 15603/prEN 52001) or dynamic simulations (e.g. EN 13790/prEN 52016), but in all cases, an adaptive approach shall be taken by relating internal to external temperatures.
- The weather files used shall be the medium emissions scenario for the 2030s and 2050s, using 1961-1990 as the baseline.
- The green factor shall be made available as a proxy indicator where there is no robust scope to account for the microclimate benefits of vegetation and soil in the National Calculation Method.
- The green factor shall be adjusted to reflect development density/site coverage, and the weightings should favour vegetation with the greatest future cooling capacity, together with deeper soil.

3.5.4 Potential trade-offs, benefits and linkages

- Macro-objective 1: Potential to reduce future energy use for cooling. Energy modelling will require consideration of the characteristics of specific building components and evaluation of overheating risk *e.g. thermal capacity, air tightness, solar shading, glazing*.

- Macro-objective 3: The choice of vegetation may affect the demand for irrigation water (as addressed by the multi-criteria scheme VERDE which has an irrigation estimator based on a vegetation listing for Spain).
- Macro-objective 4: Relative humidity and air velocity within a building may be affected.
- Macro-objective 6: Green spaces and views ('biophillia') have been demonstrated to enhance property values and can also contribute to wellbeing and productivity.

Macro-objective 5 consultation questions

- Should both thermal comfort and additional cooling energy demand be reported on?
- Do you agree with integrating these two main proposed indicators into reporting on macro-objectives 1 and 4?
- Would the proxy indicator for the microclimate cooling effect be a useful alternative to a building thermal simulation?

These questions can be answered using the online EU Survey tool

3.6 Macro-objective 6: Optimised life cycle cost and value

3.6.1 Key findings from the indicator scoping and evidence gathering

The findings relating to this macro-objective reflect the two distinct areas of focus that are described in the scope and definition in Working Paper 2 – the life cycle cost of buildings and the potential to capture the benefits of environmentally better performing buildings in appraisals of value and risk.

3.6.1.1 Life Cycle Costing

While Life Cycle Costing (LCC) offers a long term perspective on investment in buildings, but feedback suggests that it is still not a commonly applied methodology. In the case of at least one major certification scheme, feedback from practitioners suggests that LCC could be best promoted by limiting the scope to those building elements and components that clients tend to focus on in order to optimise value *e.g. HVAC, facades*. In another case, the provision of reference parameters and data that all projects must use has led to greater uptake and comparability.

ISO 15686-5 currently serves as common reference standard, although EN 15643-4 and EN 16627 (both developed by CEN/TC 350) are European reference standards. For energy performance and costs, the EPBD 'cost optimal' methodology set out in Delegated Regulation (EU) No 244/2012 also provides a simplified LCC methodology for energy costs that has been used by member states.

In a similar way to LCA, attention must be paid to the age, quality and certainty of cost data used to carry out an LCC. There are different cost classification systems and databases in use. These include generic cost yardsticks available at international level, those published at national level (e.g. RICS BCIS, UK) and those compiled by cost consultants based on recent market prices.

The value of LCC calculations will depend on the user's market outlook. Net Present Value, for example, may be more appropriate for investment properties and supposes the setting of a discount rate (e.g. DGNB 5.5%, EPBD Cost Optimality 3.5% for public buildings). A family buying a home may be more interested in annual running costs. Social landlords or a residents association in an apartment block will have to manage cyclical and long term maintenance costs.

The assumptions used will have a significant bearing on the results. Factors such as the discount rate and building service life may benefit from being fixed, as is the case in a number of examples of LCC criteria specified by major certification schemes.

3.6.1.2 Property market valuation

A number of initiatives have sought to identify how reduced life cycle costs, reduced future risks/liabilities, as well as improved health and comfort aspects, can be factored into investment and property value appraisal methodologies.

Energy efficiency has been the first main focus of attention, with a range of international and EU projects addressing valuation methods e.g. UNEP, SB Alliance, Revalue and ImmoValue. However, data availability and quality of input assumptions related to EPCs have been cited as a significant issue. Energy assessment data can have a wide degree of variation from actual performance and valuers also need reliable databases on reference buildings (comparables). The outputs from LCC assessments for energy and water are in theory more directly useable than EPCs.

A broader focus of attention has been property risk assessments, which can include future costs and liabilities arising from, for example, *changes in legislation, 'acts of god', letting prospects, structural condition and adaptability*. International requirements for banks to conduct risk ratings, for example according to the EU TEGoVA (European Group of Valuers' Associations) property rating system, result in a number of relevant factors now being taken into account when making such a rating.

Within such criteria, it is possible to identify those factors that may be influenced by an improved building. So whilst there is always an element of professional judgement in a valuation, there is also generally reference to a systematic underlying rating method. Here again, in the same way as for EPCs, it is understood that investors raise concerns about the quality and reliability of data and assumptions relating to the performance and risks associated with environmentally improved buildings. Some form of reliability rating is needed to improve a valuer's outlook on future costs and liabilities.

Investor reporting tools such as GRESB also ask users to report on '*risks and opportunities*'. These describe the extent to which environmental, quality and life cycle cost factors have been factored into due diligence for acquisitions.

Residential mortgages have also become a focus for attention. A number of studies in the UK having looked at how home energy costs can influence mortgage calculations. A property with lower running costs could influence the affordability of repayments or the potential to securitise more lending. This approach is understood to already be common practice in the USA.

3.6.2 First proposals for indicators

In this section the proposed options for two macro-objective 6 indicators are outlined. The two options are illustrated in Figure 3.6. The second indicator could be linked to a set of simplified ratings of the reliability of data and assumptions used to calculate other indicators in the common framework. The proposals are specified further in Table 3.6.

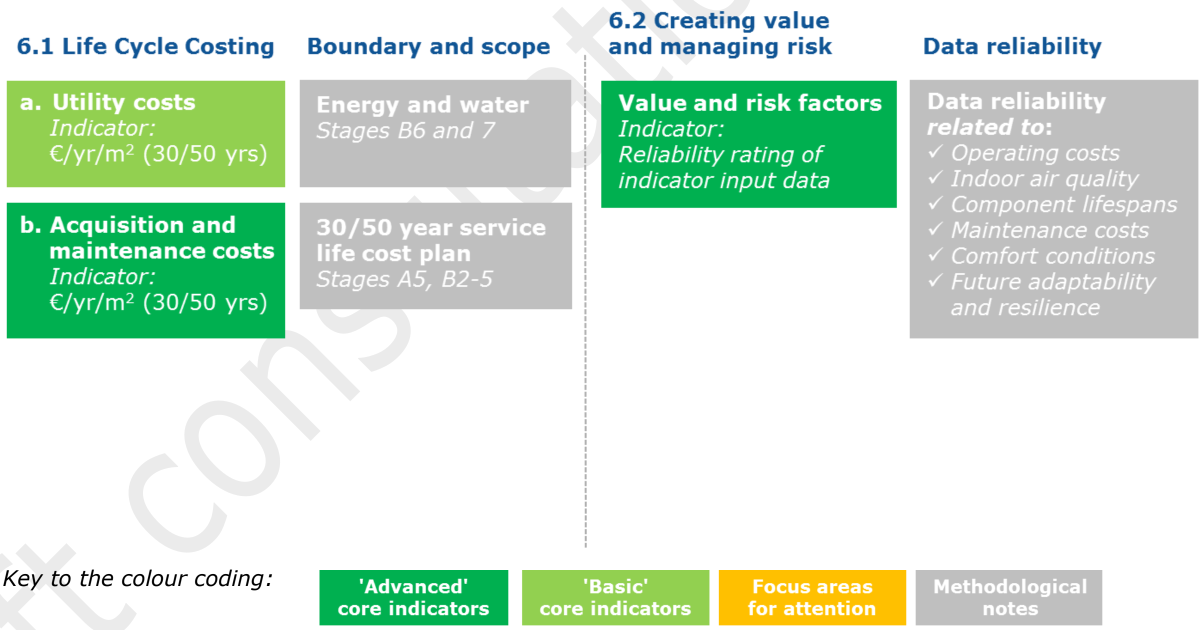


Figure 3.6 Structure of the macro-objective 6 indicator proposals

Table 3.6 Specification for the macro-objective 6 indicator proposals

Indicator	Unit of measurement	Boundaries and scope	Sources
6.1 Life Cycle Costing			
a. Long-term utility costs	€ per year normalised per m² over 30 years (offices and individual houses) and 50 years (apartment blocks)	Real energy and water costs with sensitivities applied. Greater certainty will be attributed to dynamic energy simulations, renovations based on detailed building surveys and quality assurance actions (see B1) B1 – B7: Use stage	FS CC
b. Long-term acquisition and maintenance costs	€ per year normalised per m² over 30 years (offices and individual houses) and 50 years (apartment blocks)	Outline cost plan for 30 year service life and inclusive of initial capital costs. The plan to be split into routine, cyclical and major repair schedules. A fixed minimum list of building elements to be specified for reporting. *Scope of life cycle stages:* A5: Construction stage (capital/acquisition costs for the asset) B1-B7: Use stage - Maintenance - Repair - Replacement	CC AR
6.2 Creating value and managing risk			
Value and risk factors	Reliability rating for the input data and assumptions for each indicator	Step 1 Identify those common framework indicators that are referred to in the TEGoVA valuation factors and which have been incorporated into the building's appraisal or risk rating, indicatively to include: – 1.1/3.1/6.1 Operating costs (energy and water) – 2.2 Building element/component lifespans – 4.1 Indoor air quality – 5.1/5.2 Present and future thermal comfort conditions and additional cooling requirements – 6.2 Long term maintenance costs Step 2 Carry out a simplified rating of the data and assumptions used for each of the identified common framework indicators. *An aggregation step could be added in order to give a headline rating.*	CC AR

Key to sources:

FS (Field study findings) CC (Cross Check evidence) AR (Assessment and Reporting scheme criteria)

3.6.3 Proposed calculation rules (where applicable)

- The European Commission's existing Energy Performance of Buildings Directive (EPBD) cost-optimal methodology could provide a simplified basis for making the energy calculations.
- Energy and water costs shall, furthermore, factor-in assumptions relating to inflation and uncertainty.
- Greater certainty/reliability could be attributed to operational energy cost projections that are supported by dynamic simulations, construction quality assurance actions and, in the case of renovations, a detailed building survey used as the basis for energy modelling (*see below*).
- The minimum calculation period for offices and individual residential properties shall be 30 years, with the latter reflecting a typical mortgage term. This could be extended to 50 years for apartment buildings.
- A base year or reference year shall be defined and reported on for all calculations.
- The minimum scope of building elements to be costed shall be defined for all users of the indicator, with a focus on those which are typically associated with the most significant life cycle costs over a 30 or 50 year term, as well as taking into account performance requirements (e.g. HVAC systems).
- Reporting shall identify the proportion of the life cycle building element, component and system costs that are based on generic and specific cost yardsticks.
- For those common framework indicators that align with TEGoVA valuation factors a simple reliability rating will be defined. This is proposed as consisting of a simple scale (for example, 1-5) which will rate the data and assumptions used to calculate the reported performance.

  For example, for proposed indicator 1.1: Operational primary energy, a calculated performance based on a detailed specification of the building's elements, the thermal performance of these elements and the design air tightness, supported by the results from a dynamic simulation, could achieve a high reliability rating.

3.6.4 Potential trade-offs, benefits and linkages

- There are interactions with macro-objectives 1 and 2, as these both require consideration of a buildings service life and maintenance/replacement cycles.
- Operational efficiencies identified in B1 and B3 require an LCC analysis in order to generate long-term cash flow savings that can be factored into property valuations.
- The other macro-objectives define a number of benefits and/or future risk factors that could then be factored into an appraisal of a property's value *i.e. lower operating costs (energy and water), longer element/component lifespans, future adaptability in the market, future resillience to increased cooling energy demand, reduced exposure to chemical/biological pollutants.*

Macro-objective 6 consultation questions

- Could the EPBD 'cost optimal' methodology be used as a simplified methodology for indicator proposal 6.1a?
- Is the focus for Life Cycle Costing on operational and acquisition/maintenance costs appropriate?
- Would a simple reliability rating based on a scoring of the input data and assumptions for each of the other indicators be useful to valuers?

These questions can be answered using the online EU Survey tool